Speleology in the Third Millenium:
Sustainable Development of Karst Environments

SPELEO BRAZIL 2001

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PROCEEDINGS
(online)

13th International Congress of Speleology
4th Speleological Congress of Latin America and the Caribbean
26th Brazilian Congress of Speleology

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The event is being promoted by the International Union of Speleology (**UIS**), the Speleological Federation of Latin America and the Caribbean (**FEALC**), and the Brazilian Society of Speleology (**SBE**), although the latter alone will be responsible for the organization. The following organizing committee has been installed for this purpose:

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Apresentação

“Brasil?!!! Onde fica?”

Quando estávamos na cidade suíça de La Chaux-de-Fonds, a todo momento que ouvíamos essa pergunta, mais nos sentíamos encorajados a conquistar o direito de sediar e organizar o próximo Congresso Internacional de Espeleologia, que estávamos pleiteando e concorrendo com fortíssima candidata, a Austrália.

A vontade de mostrar ao mundo que temos um país maravilhoso, um povo hospitaleiro, capacitado e muito trabalhador foi coroada de êxito quando o resultado final nos deu a vitória e por sinal apertadíssima.

Não podemos deixar de dizer que a vitória também nos deixou por alguns momentos apreensivos pela responsabilidade que assumimos.

As fases preparatórias se seguiram com muito sucesso, quando as equipes de trabalho eram tomadas pelo desejo de compartilhar seu entusiasmo com o mundo espeleológico, se empenhando cada vez mais.

Também não faltaram períodos em que a responsabilidade pesasse demais sobre as costas de cada um de nós. As dificuldades foram muitas, mas a força renascia quando nos lembrávamos que a comunidade espeleológica mundial havia depositado sua confiança nos brasileiros, e que de forma alguma iríamos decepcioná-la.

Deixamos aqui nossa satisfação em receber todos os congressistas, tanto os brasileiros como também os estrangeiros, que participaram, contribuíram, e compartilharam de forma direta e indireta para o sucesso do SPELEOBRAZIL2001.

José Antonio Basso Scaleante
Presidente da SBE

Foreword

"Brazil? Where´s that?"

When we were in the Swiss city of La Chaux-de-Fonds, we constantly heard this question, but we were encouraged to try to win the right to organize and host the next International Congress of Speleology anyway, just as we were planning, even though we were competing with the very strong candidate of Australia.

Our desire for a chance to show the world that we have a wonderful country and very friendly people, who are both capable and hard-working, became reality when the final results were announced and we were the winners -- but just barely!

We must admit that this victory left us quite anxious for a while because of the responsability which we had taken on.

The initial planning phases went well, as the various teams were embued with the desire to share their enthusiasm with the speleological community, and one achievement led to another.

There may have been times when we felt the weight of that responsability. We faced numerous problems, but we recuperated our strength when we remembered that the international speleological community had entrusted us Brazilians with the congress, and we were not about to let them down.

We would like to register here our satisfaction in having been able to welcome all of you who participated in the congress, both Brazilians and foreigners. We would also like to thank everyone for their contributions, which helped, either directly or indirectly, to make a success of SPELEO BRAZIL 2001.

José Antonio Basso Scaleante
President of the SBE

Mensagem do Presidente da Comissão Organizadora

Prezados espeleólogos,

É com grande prazer que lhe envio essa publicação, que é produto do esforço de cerca de 500 participantes de 43 países e da colaboração de várias pessoas e instituições que fizeram do Speleo Brazil 2001 um evento de reconhecido sucesso. Lembrando, as atividades do congresso se concentraram no Centro de Convenções Nacional Ulysses Guimarães, ocupando todos os seus 2000 m2, distribuídos em 4 auditórios, 12 salas e o amplo saguão de entrada.
Nesse saguão foram montados a secretaria do congresso, grande parte das agências de serviços (banco, correio, viagens etc.), o stand central da SBE, a Speleo Art, o setor dos painéis científicos, a grande área da Speleo Fair e o Speleo Bar.

Programa Científico

O ineditismo e a alta qualidade dos 199 trabalhos científicos apresentados, incluindo 4 simpósios internacionais, reforçaram os significativos avanços da espeleologia mundial nos últimos 4 anos.
Foram divididos em seis sessões, de acordo com o tema:
Sessão 1 – Geociências em geral (63 trabalhos)
Sessão 2 – II Simpósio sobre arqueologia e paleontologia em cavernas (19 trabalhos)
Sessão 3 – Simpósio sobre bioespeleologia (16 trabalhos)
Sessão 4 – Técnicas e pesquisas espeleológicas e temas espeleológicas e temas especiais (47 trabalhos)
Sessão 5 – Simpósio sobre espeleo-mergulho (14 trabalhos)
Sessão 6 – Simpósio sobre proteção e manejo de cavernas turísticas (40 trabalhos)

Também foram apresentados mais de 30 painéis sobre os mais variados temas. A UIS premiou o painel considerado melhor pela audiência.
O programa científico foi ainda enriquecido pela apresentação de belas imagens de vídeos e diapositivos, destacando-se entre elas a projeção de imagens inéditas de cavernas em 3D produzidas por Andy Eavis.
Durante o evento foram igualmente lançado três livros sobre cavernas no Brasil: Espeleo Turismo: Planejamento e Manejo de Cavernas, de Ricardo Marra; 10 anos de GEEP Açungui, do GEEP Açungui, e a reedição revisada e atualizada de Cavernas, O Fascinante Brasil Subterrâneo de Clayton Ferreira Lino.

SpeleoArt

Além dos trabalhos científicos, um dos destaques do Congresso foi a Speleo Art, que reuniu fotografias, pinturas, escultura, poesias e instalações com os temas relacionados com as cavernas, produzidas por 30 artistas entre brasileiros e estrangeiros. As mais de 90 obras de arte foram apreciadas por cerca de 900 visitantes. Os melhores trabalhos foram avaliados e receberam premiação.

SpeleoMídia

Outro evento marcante no congresso foi o festival de vídeo Speleo Mídia, que trouxe para Brasília a produção de vídeos sobre cavernas dos 4 cantos do Mundo. Dentre os inscritos foram selecionados 19 vídeos inéditos que foram apresentados ao público em seções corridas ao longo de 2 dias do congresso. Na abertura do Festival, foram projetadas, pela primeira vez fora da América do Norte, as extraordinárias imagens subterrâneas do filme “Journey to Amazing Caves”, produzidas por Wes Skiles, originalmente no sistema Imax. No encerramento do Speleo Mídia, foram premiados os 3 melhores filmes (e 3 menções honrosas) escolhidas por júri de especialistas e 1 escolhido por júri popular.

SpeleoFair

No saguão reuniram-se diversos estandes de organizações governamentais, federações espeleológicas de vários países, empresas patrocinadoras e lojas de equipamentos espeleológicas. Os destaques da Speleo Fair ficaram com o estande do CECAV/IOBAMA (Centro de Estudos, Proteção e Manejo de Cavernas/IBAMA), construído na forma de uma caverna, e a exposição de fósseis pleistocênicos organizada pelo Museu de Ciências Naturais da PUC/MG.

Atividades Sociais

Também no saguão central se localizou o Speleo Bar, o ponto de encontro social do evento que incluía lanchonete, praça de convivência com projeção de vídeos e palco para apresentações culturais incluindo capoeira e músicas brasileiras.

Por sinal, como não poderia deixar de ocorrer em um congresso realizado no Brasil, as festas e atividades sociais também foram grandes momentos do evento. Entre eles a divertida gincana que reuniu 8 equipes internacionais que cumpriram vários desafios incluindo a montagem de quebra cabeças, produção de trabalhos artísticos, caça ao tesouro, pesquisa e competição de técnicas verticais (escaladas, rappel e tirolesa). À gincana se seguiu uma animada noitada de samba, suor e cerveja.
Outra noite foi realizada uma típica festa "Julina", na beira do lago, com fogueira, forró, caldos, quentão e vinho quente.
Assim se encerrou o dia de 18 de julho, que foi dedicado a visitas a Brasília e a várias cavernas na vizinhança. Os participantes certamente terão fotos fantásticas de mostrar e histórias divertidas para contar.
Na última noite do congresso um grande banquete reuniu cerca de 200 participantes em uma das mais famosas churrascarias de Brasília e não poderia ter sido melhor a festa, a comida e a confraternização para finalizar uma semana de intenso trabalho.

Atividades Institucionais

No entanto, o congresso foi mais do que ciência, diversão e arte. Não faltaram as importantes atividades institucionais das três organizações responsáveis pelo Speleo Brazil 2001: a UIS (União Internacional de Espeleologia), a FEALC (Federacion Espeleológica da América Latina e Caribe e a SBE (Sociedade Brasileira de Espeleologia). Todas realizaram suas Assembléias Gerais, com eleição de novas diretorias e definição de seus planos para os próximos anos e provação de diversas moções. A implementação desses planos será o desafio a ser vencido pela nova diretoria da SBE – agora presidida por José Antonio Scaleante, da equipe da FEALC – agora sob o comando de Abel Valle, de Porto Rico, e da diretoria recém eleita da UIS – agora presidida pelo colega brasileiro José Ayrton Labegalini.
Igual desafio terão também os colegas espeleólogos da Coréia e da Grécia na proporção da Expo Cave Korea 2002 e na organização para 2005 do 14o Congresso Internacional de Espeleologia, em Atenas.

Excursões de 1 dia

No dia 18 de julho não houve programação científica, de modo que os congressistas tiveram o dia livre para conhecer Brasília e as diversas cavernas do entorno. Além de city tours arquitetônico e cultural, foram organizadas pelos grupos de espeleologia de Brasília (EGB e GREGEO) 7 excursões: Gruta Escaroba (Formosa, GO), Gruta Tamboril (Unaí, GO), Gruta dos Ecos (Cacalzinho GO), Buraco das Araras (Formosa, GO), Gruta Jaboticaba (Formosa, GO), Gruta Primavera (Formosa, GO) e Buraco do Inferno (Padre Bernardo, GO).

Excursões pré e pós congresso

Além das atividades do evento central do Speleo Brazil 2001, foram organizadas várias excursões para cavernas brasileiras. Foram 6 excursões pré congresso e 5 pós congresso. No total, 92 congressistas participaram dessas atividades e tiveram oportunidade de apreciar algumas de nossas mais belas cavernas e sítios arqueológicos.
As excursões foram programadas de forma a permitir não apenas a visita a cavernas, mas também um contato direto com as comunidades visitadas, sua cultura e com algumas amostras da exuberante natureza brasileira. O intenso contato nessas excursões e o trocar de experiências levou à formação de novas amizades entre espeleólogos de todo o mundo. Talvez sejam esses contatos o maior e mais duradouro resultado do Speleo Brazil 2001.

Mais uma vez, agradecemos a todas as pessoas e instituições que asseguraram o sucesso do congresso, cuja qualidade técnica-científica pode ser constatada através dos trabalhos reunidos nestes anais.

Clayton Ferreira Lino

Message from the President of the Organizing Committee

Dear Fellow Speleologists,

It is with great pleasure that we are sending you this publication, which is the product of the efforts of some 500 participants from 43 countries and of the collaboration of the numerous individuals and institutions which made Speleo Brazil 2001 a recognized success. Just to remind you, all the activities of the congress took place in the National Convention Center Ulysses Guimarães, occupying the entire 2000 m2 of the center, including the 4 auditoriums, 12 other rooms, and the spacious atrium on the ground floor. In addition to the services such as banks, post office, travel agencies, and the Speleo Bar, the atrium housed the registration desk, the exhibition of SpeleoArt, and the poster display, as well as the various stands of the SpeleoFair.

Scientific Program

The high quality of the 199 scientific papers presented, including 4 international symposia, reinforced the significant advances of world speleology in the past four years. The scientific program was presented in six sessions, based on the theme:
Session 1 – Geological Sciences in General (63 papers)
Session 2 – Symposium on Archaeology and Paleontology in Caves (19 papers)
Session 3 – Symposium on Biospeleology (16 papers)
Session 4 – Speleological Research and Techniques and Miscellaneous Topics (47 papers)
Session 5 – Symposium on Cave Diving (14 papers)
Session 6 – Symposium on the Protection and Management of Caves (40 papers)

More than 30 posters on a wide variety of topics were also presented, with the UIS awarding a prize to the poster considered the bests by the viewing audience. This scientific program was enriched by various video and slide presentations, including the 3-D images of caves produced by Andy Eavis.
In addition to the scientific presentations, three new books about caves in Brazil, hot off the presses, were introduced, and were autographed by their authors: Espeleo Turismo: Planejamento e Manejo de Cavernas, by Ricardo Marra; 10 anos de GEEP Açungui, by GEEP Açungui, and the revised edition of Cavernas, O Fascinante Brasil Subterrâneo by Clayton Ferreira Lino.

SpeleoArt

In addition to the scientific program, one of the highlights of the congress was SpeleoArt. This exhibit presented some 90 works of art, including photographs, paintings, sculptures, and poems on topics related to caves, produced by 30 artists from brazil and abroad; the exhibition was visited by some 900 visitors. The are work judged to be the best received prizes.

SpeleoMedia

Another activity which was quite popular at the congress was the festival of videos of SpeleoMedia, which united original videos about caves coming from the four corners of the world. Nineteen of the films registered were selected and shown to the public continuously during two days of the congress. During the opening of the festival, the extraordinary underground images of the film "Journey to Amazing Caves", originally produced in IMAX by Wes Skiles, were shown for the first time outside North America. During the closing ceremony, the three best films (and three runners-up) selected by specialists in the area were awarded prizes, as well as that chosen as best by the general public.

SpeleoFair

The SpeleoFair provided visibility for various organizations, both public and private, including the sponsors of the event, the Brazilian Speleological Society (SBE), and various other speleological groups, as well as those offering speleological goods for sale. High points of the fair included the life-sized cave constructed by CECAVE (Center for the Study, Protection and Management of Caves/IBAMA) and the Pleistocene fossil display organized by the Natural Science Museum of the Catholic University of (PUC) of Minas Gerais.

Social Activities

At the far end of the atrium was the SpeleoBar, the social meeting point of the event, which included a screen for the projection of videos and a stage for cultural presentations (capoeira and traditional Brazilian music), as well as serving lunches and furnishing an area for informal gatherings and conversation.

As was to be expected in an event held in Brazil, the numerous parties and social activities were an integral part of the congress. Among these was the ginkhana, which involved the participation of eight international teams and presented various challenges, including the assembly of a puzzle, the preparation of an original work of art, a display of skill in SRT and related techniques, research, and a treasure hunt. This was followed by an animated session of samba, sweat and beer.

Another night was devoted to a typical “Festa Julina” on the shores of the Paranoá Lake, complete with a bonfire, dancing, and the typical soups and hot rum punch (quentão). This brought to an end the day of July 18, dedicated to tours of the city and visits to various of the caves in the vicinity. The participants are sure to have lovely pictures to show and intriguing stories to tell.

The final evening brought together approximately 200 participants in one of the mot famous barbecue houses of Brasilia – a fitting finale for the week of intensive scientific activities and the cementing of international friendships.

Institutional Activities

But the congress was more than science, entertainment, and art. There were also important institutional activities of the three organizations responsible for Speleo Brazil 2001: the International Union of Speleology (UIS), the Speleological Federation of Latin America and the Caribbean (FEALC), an the Brazilian Speleological Society (SBE). All held general assemblies and elected new officers, determined plans for the next few years, as well as passing various motions. These will be the challenges facing the new officers of the SBE, headed by José Antônio Scaleante, the new group of the FEALC, headed by Abel Valle (Puerto Rico), and the newly-elected team of the UIS, headed by our Brazilian colleague José Ayrton Labegalini. Similar challenges will face our colleagues in speleology of Korea and Greece in the preparation of Expo Cave Korea 2002 and the organization of the 14th International congress of Speleology in Athens in 2005.

One-Day Excursions

On July 18, no activities were planned at the conference center so that the participants could visit Brasilia and some of the caves in the vicinity. Seven options for visits to caves were organized by the speleological groups in Brasilia (EGB and GREGEO), with support provided by members of the fire department. The caves visited were the following: Gruta Escaroba (Formosa, GO), Gruta Tamboril (Unaí, GO), Gruta dos Ecos (Cacalzinho GO), Buraco das Araras (Formosa, GO), Gruta Jaboticaba (Formosa, GO), Gruta Primavera (Formosa, GO) and Buraco do Inferno (Padre Bernardo, GO).

Pré- and Post-Congress Activities

In addition to the main event, various excursions to Brazilian caves were organized. There were 6 pre-congress excursions and 5 post-congress ones, with a total of 92 participants having an opportunity to visit some of our most beautiful caves and archaeological sites.

The excursions were planned to allow not only the visiting of caves, but also direct contact with the people in the surrounding communities, as well as with their culture; numerous chances to appreciate the exuberant nature were also available.

The intense contact involved on these trips and the exchange of experiences led to the formation of new friendships between speleologists around the world. Perhaps in the long run these contacts will be the most lasting result of Speleo Brazil 2001.

Once again, we would like to thank all of those who guaranteed the success of the congress; its technical-scientific quality can be seen in the papers united in these proceedings.

Clayton Ferreira Lino

SUMÁRIO / SUMARY

Aplicación del Método de Predicción de las Direcciones Principales de Drenaje Subterráneo al Karst de la Región de Torotoro (Bolivia)

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3 - Ingeniera Geóloga por la Universidad de Sao Paulo. Brasil.

Resumen

Las investigaciones realizadas se han incardinado en la expedición Humajalanta 98, coordinada por Akakor, a quien agradecemos la logística recibida.

El estudio que presentamos abarca una región de 400 km^2 de extensión, correspondiente a los afloramientos calizos del cretácico superior, que conforman aquí los valles andinos del interior, entre los asentamientos nativos de Rodeo, Julo Grande e Inca Corral. Se han realizado 661 mediciones de planos extensionales, distribuidas en 4 estaciones: Humajalanta, Chiflonkhaka, Huayllas y Rodeo.

Los resultados obtenidos, que reflejan la anisotropía direccional del karst de la región, se han contrastado con las direcciones en las que se desarrollan las cavernas existentes, mediante la aplicación estadística de Kolmogorov. Se discute la aplicación de los resultados obtenidos al karst mixto (normal y termal) existente en la región.

1.- Introducción

Los trabajos de karstología que aquí se presentan, han sido realizados durante la "Expedición Humajalanta 98", organizada por Akakor Geographical Exploring, que nos suministró toda la logística que precisamos. Queremos agradecer desde aquí, a su presidente Lorenzo Epis, como máximo responsable de Akakor, y hacerlo extensivo a todos los demás miembros de la referida Sociedad Geográfica.

De los nativos de la región, queremos también agradecer su ayuda a Timoteo Jaillita, dirigente de la Comunidad Laguna, a Mario Jaldín, guardaparque de Torotoro y Amed Becerra, de la Federación Boliviana de Espeleología, también intérprete de Torotoro, intérprete de las lenguas aymara y quechua.

2.- Situación General

El área investigada se emplaza en el entorno de la localidad de Torotoro, provincia de Charcas, departamento de Potosí, Bolivia, en los terrenos calizos de la margen derecha del río Caine, donde se encuentran numerosas y excelentes improntas de dinosaurios.

Geológicamente, el karst se emplaza en los niveles mesozoicos (cretácico) representados por las calizas de la formación "El Molino", que yace sobre niveles calcareníticos, también karstificados, con un espesor total de más de 200 mts. Su estructura está representada por dos pliegues paralelos, sinclinal de Torotoro y anticlinal de Huayllas, de dirección NW (con cierre periclinal) - SE (donde los pliegues terminan suavizándose). (ERASO et al., 1998).

Geomorfológicamente e *hidrogeológicamente*, la región tiene dos estilos diferentes:

- Al NW de Torotoro una serie de cañones kársticos (El Garrapatal, Inca Corral, Laguna Mayu y Sucu Sumo), donde se emplaza un acuífero kárstico freático (con termalismo según fallas transcurrentes N30º-45º).
- Al SE de Torotoro un gran sinclinal (cuyos sedimentos miocenos confinan parcialmente un acuífero kárstico de carácter artesiano), que se cierra periclinalmente en la Comunidad Rodeo.

En la Figura 1 (ERASO et al., 1998) presentamos una cartografía esquemática de la región, de carácter geodésico-geólogo, donde también aparece la ubicación (GPS) de las estaciones de medida donde hemos aplicado nuestras investigaciones.

3.- Trabajos de Campo

El objetivo perseguido con estos trabajos, consiste en aplicar aquí, el "Método de Predicción de las Direcciones Principales de Drenaje Subterráneo en Regiones Kársticas" (ERASO, 1985/86), (ERASO & FERNANDEZ-RUBIO, 1990). Es decir, la cuantificación direccional de la anisotropía del macizo kárstico, en cuyos planos de debilidad estructural, (σ_1, σ_2), se establecen los conductos de drenaje y las galerías donde se desarrollan las cavernas.

La región de Torotoro, donde se emplaza entre otras, la caverna mayor de Bolivia (Humajalanta), supone un excelente ejemplo para contrastar nuestro Método de Predicción.

En la zona estudiada, se realizó la toma de datos $(N = 661)$, distribuidos en 13 Estaciones que se agrupan en 4 Zonas (ver Figura 1):

- Zona 1, *Sector Humajalanta* $(N = 210)$: Estación 1, Humajalanta Exterior $(N = 34)$; Estación 11, Humajalanta Interior $(N = 46)$; Estaciones 9 y 10, Laguna Mayu $(N = 46, N = 41)$; Estación 13, Tara Kkollu $(N = 43)$.
- Zona 2, *Sector Chijflon-Q'haq'ha* $(N = 192)$: Estación 2, Chijflon-Q'haq'ha $(N = 48)$; Estaciones 3 y 4, de Cañón Torotoro hacia estación 2 $(N = 38, N = 56)$; Estación 8, Huaq'ha-Senq'ha $(N = 50)$.
- Zona 3, *Sector Huayllas* $(N = 200)$: Estación 5, hacia cima Huayllas (2900 mts s.n.m.) $(N = 69)$; Estación 6, hacia cima Huayllas (3050 mts s.n.m.) $(N = 80)$; Estación 7, hacia cima Huayllas (3250 mts s.n.m.) $(N = 51)$.
- Zona 4, *Sector Rodeo* $(N = 59)$: Estación 12, Comunidad Rodeo $(N = 59)$;

4.- Tratamiento Informático. Predicción de las Direcciones Preferentes de los Conductos Kársticos

El tratamiento informático de los datos de campo, se ha realizado mediante la aplicación del Método de Predicción (ERASO, 1985/86), utilizando la Versión 4.0 (realizada por Mª del Carmen Domínguez), no publicada pero disponible vía e-mail.

Los resultados se condensan en la Figura 2, donde se observan comparativamente las correspondientes leyes de distribución, en probabilidad direccional de cada una de las Zonas 1, 2 y 3, que contienen varias estaciones de medida, y del Global, que con una población total de 661 planos extensionales (σ_1, σ_2), predicen las direcciones preferentes de drenaje según modas, en las que cada una de las cuales lleva cuantificada su probabilidad porcentual.

El desarrollo del tratamiento informático, que aquí no detallamos, se encuentra en las páginas 9 a 29 del informe entregado a Akakor (ERASO et al., 1998).

Las modas direccionales que predice el Método de Predicción, se encuentran en la Tabla 1, donde se compara el Global con las zonas 1, 2 y 3 de la región kárstica investigada.

De dicha tabla se desprende que las modas direccionales que predicen las direcciones principales de los conductos kársticos, son, para el karst de Torotoro (Bolivia), las siguientes:

a.- Una moda principal en la clase 4 (N45º-60º) con máximo modal según N48º, con una probabilidad asociada del 18'3%.

b.- Seis modas secundarias:

- según la clase 2, (N15º-30º), con máximo modal a N21º, con el 9'3% de probabilidad asociada,
- según la clase 11, (N150º-165º), con máximo modal a N162º, de 9'2% de probabilidad asociada,
- según la clase 1, (N0º-15º), con máximo modal a N12º, con el 9'0% de probabilidad asociada,

- según la clase 6, (N75º-90º), con máximo modal a N87º, con el 8'1% de probabilidad asociada,
- según la clase 10 (N135º-150º), con máximo modal a N141º, con el 7'5% de probabilidad asociada,
- según la clase 8, (N105º-120º), con máximo modal a N117º, de 6'2% de probabilidad asociada,

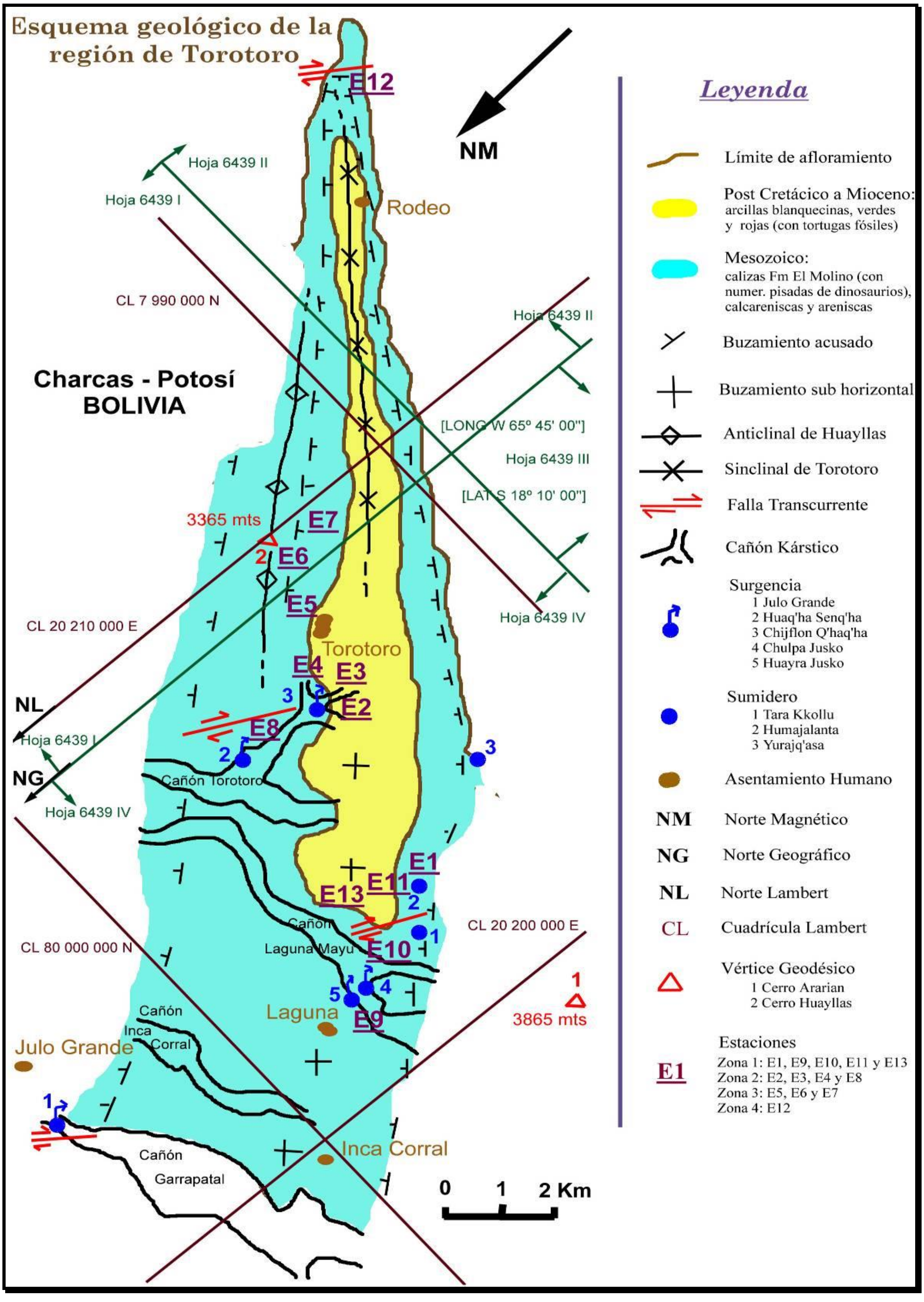
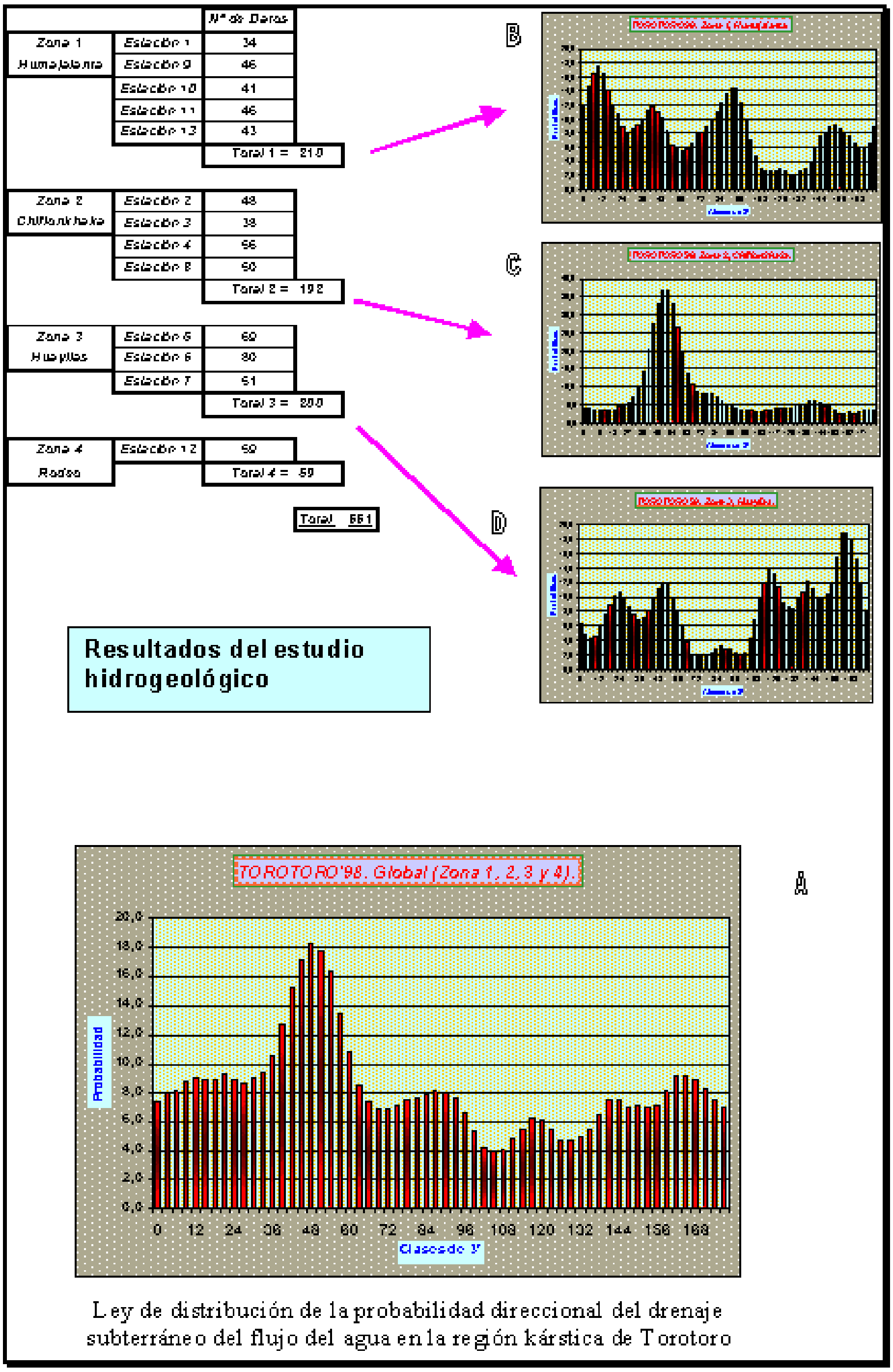


Figura1: Esquema geológico de la región de Torotoro



		Nº de Datos
Zona 1 Humajalanta	Estación 1	34
	Estación 9	46
	Estación 10	41
	Estación 11	46
	Estación 13	43
		Total 1 = 210
Zona 2 Chiflonkhaka	Estación 2	48
	Estación 3	38
	Estación 4	56
	Estación 8	50
		Total 2 = 192
Zona 3 Huaylias	Estación 5	69
	Estación 6	80
	Estación 7	51
		Total 3 = 200
Zona 4 Rodeo	Estación 12	59
		Total 4 = 59

Total 661

Resultados del estudio hidrogeológico

Ley de distribución de la probabilidad direccional del drenaje subterráneo del flujo del agua en la región kárstica de Torotoro

Figura 2: Función de distribución de los planos de debilidad de las diferentes Zonas y el Global

5.- Las Direcciones Reales de las Cavernas: Valores Topográficos Anteriores y Actuales (Expedición Humajalanta 98)

Los detalles de las topografías utilizadas, así como su análisis direccional y distribución por clases de 15º sobre norte magnético, vienen detalladas en las páginas 29 a 35 del informe entregado a Akakor (ERASO et al., 1998).

Los resultados, referidos a 4'3 km de topografía subterránea, se representan en la Tabla 2, donde se aprecian:

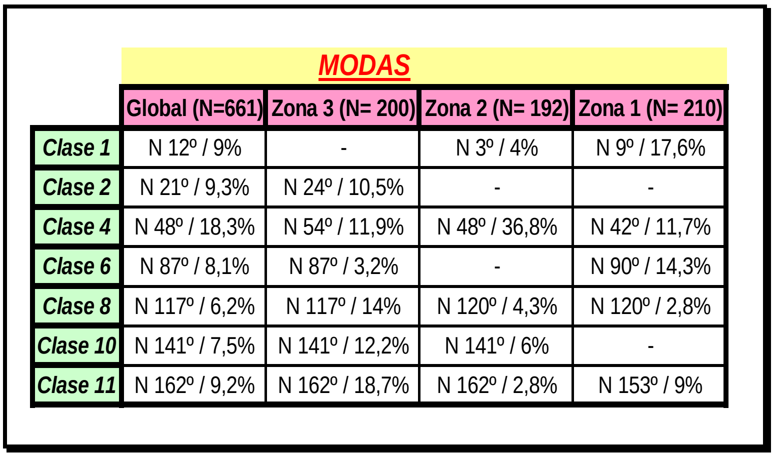
a.- Dos modas principales a ambos lados de la clase 4:

- según clase 5 (N60º- 75º) con 14'9% de probabilidad

- según clase 3 (N30º- 45º) con 10'6% de probabilidad

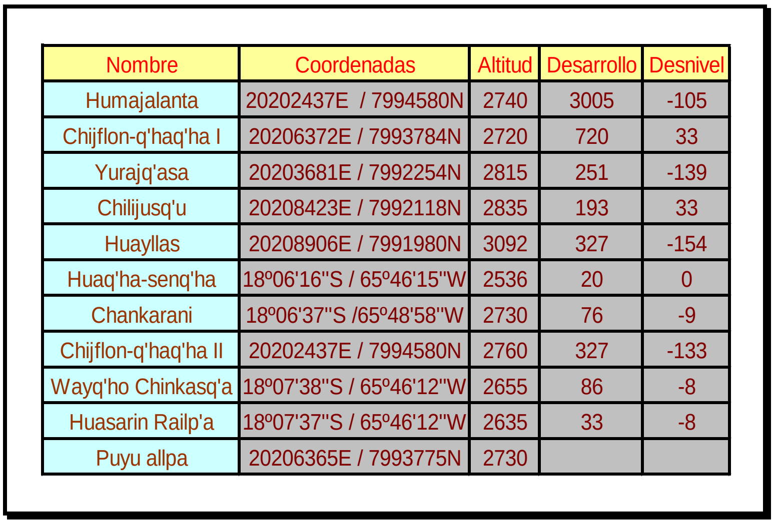
b- Y dos modas secundarias:

- según clase 9 (N120º- 135º) con 8'9% de probabilidad
- según clase 1 (N0º- 15º) con 8'6% de probabilidad



	MODAS			
	Global (N=661)	Zona 3 (N= 200)	Zona 2 (N= 192)	Zona 1 (N= 210)
Clase 1	N 12º / 9%	-	N 3º / 4%	N 9º / 17,6%
Clase 2	N 21º / 9,3%	N 24º / 10,5%	-	-
Clase 4	N 48º / 18,3%	N 54º / 11,9%	N 48º / 36,8%	N 42º / 11,7%
Clase 6	N 87º / 8,1%	N 87º / 3,2%	-	N 90º / 14,3%
Clase 8	N 117º / 6,2%	N 117º / 14%	N 120º / 4,3%	N 120º / 2,8%
Clase 10	N 141º / 7,5%	N 141º / 12,2%	N 141º / 6%	-
Clase 11	N 162º / 9,2%	N 162º / 18,7%	N 162º / 2,8%	N 153º / 9%

Tabla 1: Coincidencia o proximidades de modas de direcciones de drenaje entre las leyes de distribución



Nombre	Coordenadas	Altitud	Desarrollo	Desnivel
Humajalanta	20202437E / 7994580N	2740	3005	-105
Chijflon-q'haq'ha I	20206372E / 7993784N	2720	720	33
Yurajq'asa	20203681E / 7992254N	2815	251	-139
Chilijusq'u	20208423E / 7992118N	2835	193	33
Huayllas	20208906E / 7991980N	3092	327	-154
Huaq'ha-senq'ha	18º06'16"S / 65º46'15"W	2536	20	0
Chankarani	18º06'37"S /65º48'58"W	2730	76	-9
Chijflon-q'haq'ha II	20202437E / 7994580N	2760	327	-133
Wayq'ho Chinkasq'a	18º07'38"S / 65º46'12"W	2655	86	-8
Huasarin Railp'a	18º07'37"S / 65º46'12"W	2635	33	-8
Puyu allpa	20206365E / 7993775N	2730		

Tabla 2: Resultados topográficos obtenidos en exploración

6.- Contraste entre Predicción (Método) y Direcciones Reales (Topografía) de los Conductos Kársticos

Comparando la ley de distribución de las direcciones principales de drenaje - dada por el Método de Predicción - y las direcciones reales de conductos - según las topografías utilizadas -, hemos aplicado el test estadístico de Kolmogorov-Smirnov a la curva acumulada de cada una de ambas distribuciones consideradas, para conocer el error máximo entre predicción y realidad.

Los resultados encontrados, cuyo detalle se encuentra en las páginas 35 a 37 del informe entregado a Akakor (ERASO et al., 1998), los condensamos en la Tabla 3. El error máximo se encuentra en la clase 4 y su valor es $\varepsilon \leq 3'0\%$, es decir, muy pequeño. Siendo para la clase 9, del 2'2%, para la 10 del 1'4%, y menor del 1% para las otras clases, lo que a nuestro juicio demuestra la validez del Método de Predicción utilizado.

	Clase 1	Clase 2	Clase 3	Clase 4	Clase 5	Clase 6	Clase 7	Clase 8	Clase 9	Clase 10	Clase 11	Clase 12
Predicción	9,4	8,6	10,1	19,2	6,1	7,3	7,0	5,1	4,5	7,3	8,0	7,4
Cuevas	8,6	8,4	10,6	9,4	15,0	9,7	6,3	8,2	9,0	4,4	3,8	6,8
Acumul. Predi.	9,4	18,0	28,1	47,4	53,4	60,7	67,6	72,8	77,3	84,6	92,6	100,0
Acumul. Cuev.	8,6	17,0	27,6	36,9	51,9	61,6	67,9	76,0	85,0	89,4	93,2	100,0
Error	**0,2**	**0,3**	**0,2**	**3,0**	**0,4**	**0,3**	**0,1**	**0,9**	**2,2**	**1,4**	**0,2**	**0,0**

Tabla 3: Resultados del test de Kolmogorov-Smirnov al comparar la Predicción y los Conductos

7.- Conclusiones

Los errores máximos, según el test de Kolmogorov-Smirnov, entre la predicción dada por el Método, y las direcciones medidas en las topografías, de las cavernas existentes, son:

- Para la moda principal (clase 4), $\varepsilon \leq 3'0\%$
- Para las modas secundarias: Clase 1, $\varepsilon \leq 0'2\%$; Clase 2, $\varepsilon \leq 0'3\%$; Clase 6, $\varepsilon \leq 0'3\%$; Clase 8, $\varepsilon \leq 0'9\%$; Clase 10, $\varepsilon \leq 1'4\%$; Clase 11, $\varepsilon \leq 0'2\%$,

Es decir, lo suficientemente pequeños como para validar la bondad del Método de Predicción utilizado.

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Geophysical Benchmarking of Cave Cavities and Underground Water Horizons

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Summary

Seismic-electric effect method was applied in field to forecast subsurface cave dome cavities and to benchmark underground water horizons. A source of seismic waves were repeated blows of a heavy hammer or powerful signals of magnetostrictive installation. Main frequency used was 500 Hz. Passing layers the seismic wave caused electromagnetic fields on the boundary interfaces. Electric responses of these electromagnetic fields were measured on a surface by pair of grounded dipole antennas or by one pivot and a long wire antenna acting as a capacitive pickup. The arrival times of responses from a cave cavity and from a water horizon correspond to the time of seismic wave propagation from a source to the cavity or to the water interface correspondently. The method depths successfully investigated were between 2,5-25m. An advantage of our method in comparing with usual seismic ones is in a fact that signals registered from boundary interfaces are distinctly traced on a receiver to be available for a proper treatment.

Introduction

A seismic wave propagating in a fluid saturated medium can induce an electromagnetic field (PRIDE, 1994). Generally in a porous rock, adsorption of electrical charge to the surface of solid grains creates an excess of mobile ions of the opposite charge in the pore fluid. A seismic wave propagating in such rock displaces the ion-carrying fluid with respect to the solid matrix generating a streaming electrical current that results in a macroscopic charge separation inducing an electrical field. The value of the induced electrical field depends on the type of a saturation, porosity, permeability, chemical properties of the solid matrix and so on (BOULYTCHOV, 1997), (BOULYTCHOV & KOKSHAROV, 1999).

Field experiment

When a spherical incident P-wave crosses an interface between two mediums it creates a dipole charge separation due to imbalance of the streaming currents induced by the seismic wave on the opposite sides of the interface. The electrical dipole radiates an electromagnetic wave that can be detected by remote antennas on a surface. The SE conversion is numerically showed to occur at permeability or fluid chemistry contrasts (HAARTSEN & PRIDE, 1994). A source of seismic waves were blows of a heavy sledgehammer or repeated powerful impulses of magnetostrictive installation. The vertical ground motions were measured using an array of geophones. Main frequency used was 500 Hz. As a base the nonmetallic lucite plate was used for the source impact with the plate to avoid a high frequency electromagnetic pulse generated while the impact moment. To eliminate an undesirable current in the ground induced by an electric current flowing through the trigger cable at the moment of the source impact, the trigger cable was isolated from the ground and cut as short as possible. The horizontal electrical fields were measured on a surface by low noise preamplifiers connected to a pair of grounded dipole antennas represented by two stainless steel electrodes-stakes or by one pivot and a long insulated wire acting as a capacitive pickup. Exit signals were recorded by a data acquisition installation elaborated in our institute geoacoustics laboratory. In different experiments antenna lengths used were to be 2,4m or 4,8m, a spacing between the antennas was chosen to be 0,6m or 1,2m. The offset between the source and antennas measured to the electrode closest to the source ranged from 1,2m to 14,4m. The antennas measured the potential of the electrode closer to the source with respect to the electrode further away from the source. Two mutually perpendicular remote antennas were used for the coherent noise recording and were located at about 35m away from the seismic source. The first reason of the coherent noise may be an electrical current induced in the ground by remote power lines. Another one may be a telluric current induced by a time variation of the Earth’s magnetic field. Both noises usually dominate in recorded signal (trace A on fig. 1: signal/noise rate is about 0,01). But the noises are observed to be the same either close or far away from the seismic source. Thus to get a pure SE signal, the noises are possible to be subtracted from the electrical records. Two mutually perpendicular antennas are used because the telluric and the power line induced currents can change direction and amplitude (but not phase) with location due to ground resistivity variations. Traces B and C are the remote noise records. The coherent noise in each individual electrical trace was matched with a linear combination of traces B and C. The coefficients of the linear combination were estimated to obtain the best (least-squares) match. So, trace D was got as result of a linear combination of traces B and C subtracting from the trace A. The cutoff frequency of the low pass filter in the Fourier domain was set to be 1500 Hz. It was made to avoid a smearing in the first breaks in the electrical traces what was due to an influence of high frequencies of power line harmonics. To evaluate an influence of remaining coherent harmonics of power line induced noise, the phases, frequencies, amplitudes of these harmonics were estimated by a least-squares fit in the time domain (BUTLER & RUSSEL, 1993). The corresponding sinusoids got wasn't too significant in our experiments. Thus the trace E is a result of the trace D magnified by 100 and of consequent use of the low pass filtering. The signal-noise ratio in trace E is 100. Such procedure was applied to deduce pure SE traces suitable for a further treatment. Experiments were carried out on Seminsky range plateaus of Altai mountains. Vertical cross-sections of the subsurface at the experimental site (fig.2) were derived from SE measurements and seismic refraction observations and verified by hydrogeological data.

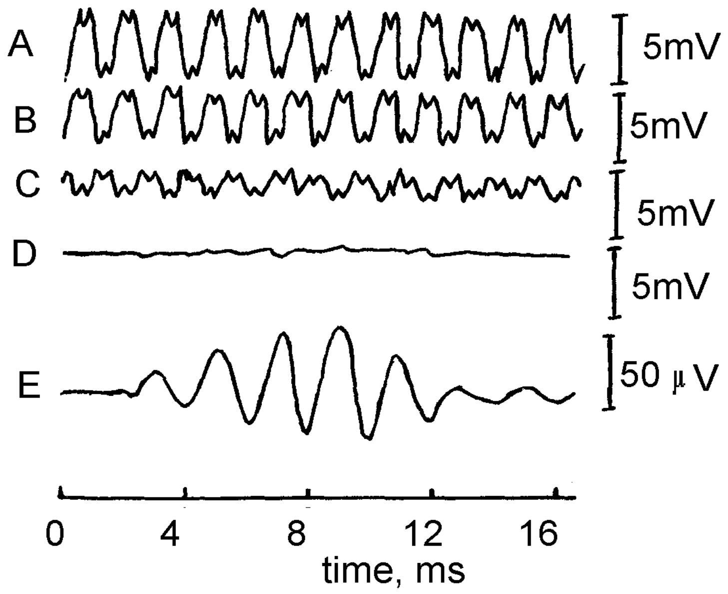

Fig.1 Noise reduction in the electric data.
Trace A - electric signal recorded by antennas; traces B and C - remote noise records; trace D - result of linear combination of traces B and C subtracting from the trace A; trace E - result of trace D magnified by 100 and of the use of low pass filtering.

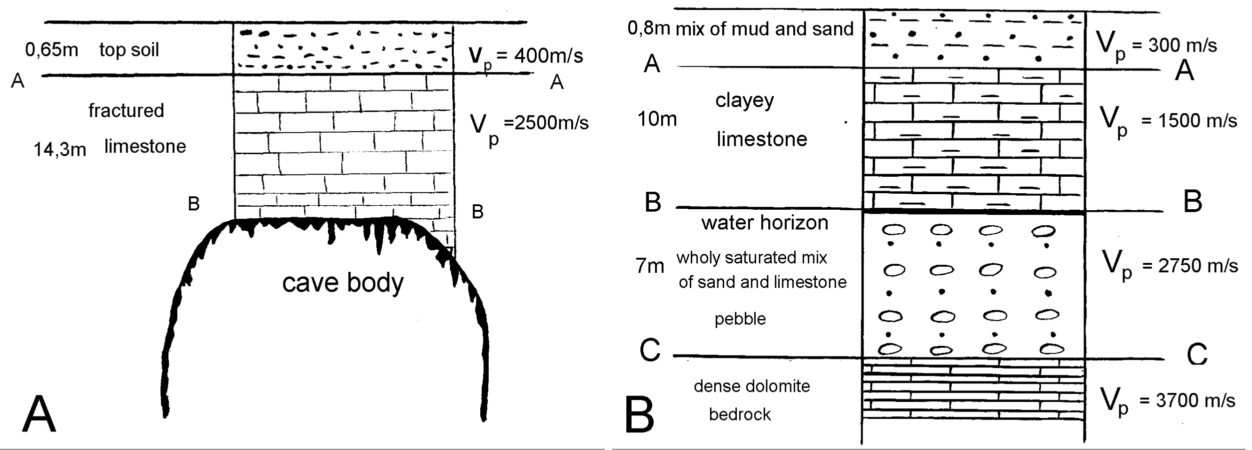

Fig.2 Samples of investigated vertical cross-sections (not to scale) of the subsurface at the experimental site: A - with a cave dome, B - with a water horizon.

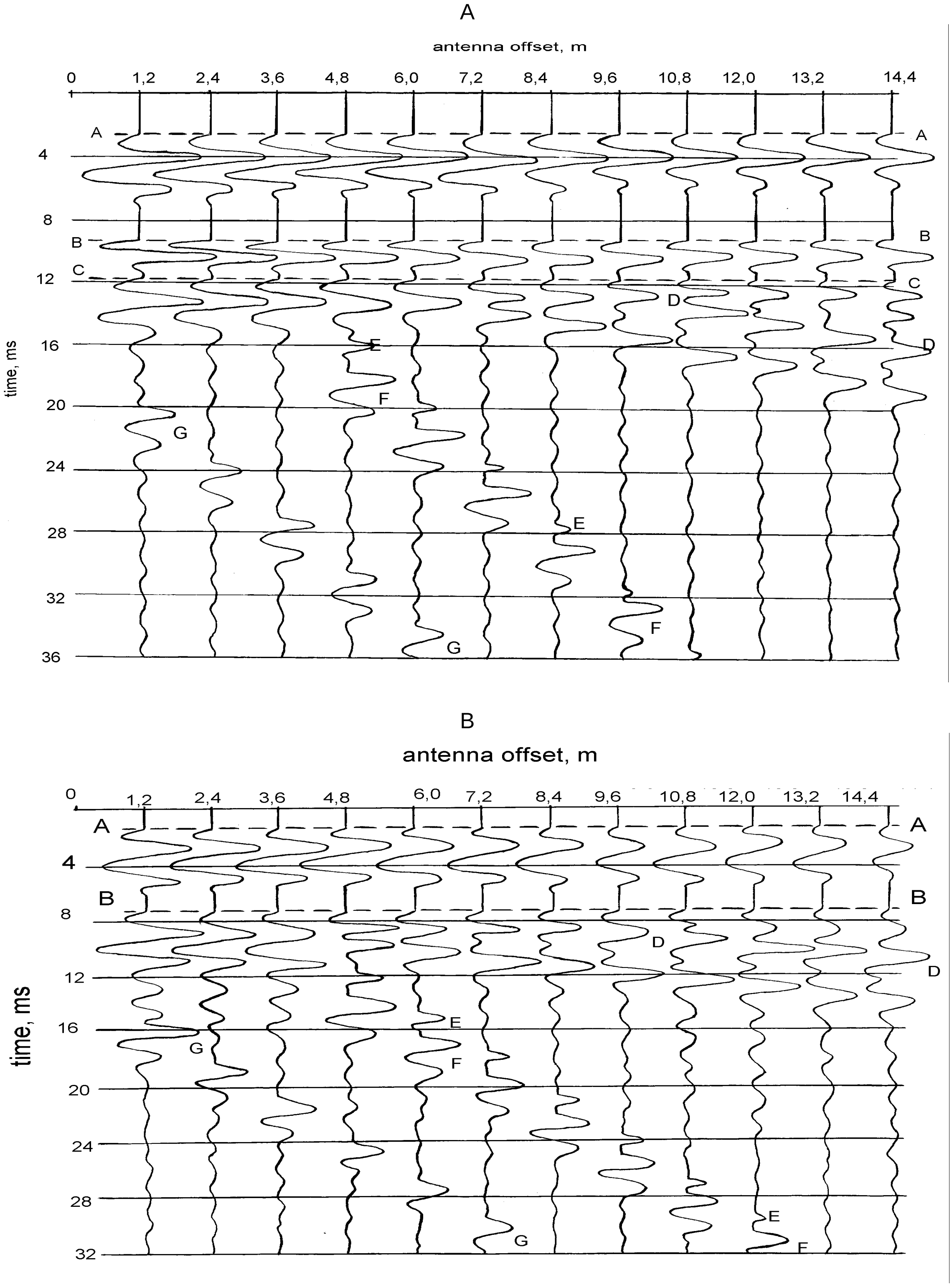

Fig.3 SE data observed in the field: A - with a cave dome, B - with a water horizon. Event A-A - SE response from the first boundary between layers, event B-B - SE response from the cave dome in case A and from the water horizon in case B, event C-C - SE response from a bedrock in case B, event D-D – SE response of head wave travelling along A-A interface, event EE – SE response of guided wave propagating along a day surface, event F-F – SE response of reflected wave from A-A interface, event G-G – SE response of reflected wave from B-B interface

Results of the Field Measurements

The negative electrical pulses arriving simultaneously at all antennas can be seen on samples of SE data (fig.3) observed in the field with 2,4m antennas and 0,6m spacing between the antennas. The amplitudes of the pulses are strongest at the antenna closest to the source and decrease further away from the source, thus the pulses originated directly below the source. Since the arrival times of these pulses occur to be the same at all antennas, the pulses traveled with electromagnetic wave velocity. At last the arrival times of the pulses-responses from any boundary interface are exactly equal to the times of seismic wave propagation from a source to correspondent boundary interface. Therefore these pulses are concluded to be caused by electromagnetic waves radiated from the interfaces at the time when the incident P-waves cross its. Particularly the event A-A (fig.3, A) is identified to be the SE response from the top soil and limestone boundary. The event B-B appears to be the SE response from the cave dome. The event A-A (fig.3, B) is found to be the SE response from the first boundary between top layer and clayey limestone. The event B-B occurs to be the SE response from a water horizon of a water bearing layer, and finally the event C-C is revealed to be the SE response from the interface between the water bearing layer and dense dolomite bedrock. Several regular waves were registered accurately as well. Waves D-D are estimated to be the SE response of head wave travelling along A-A interface. Its velocity can be easy evaluated from the field records (fig.3). It's equal to P-wave velocity beneath A-A interface. E-E wave may correspond upon its arrival time to the SE response of guided surface wave. F-F wave is calculated to be SE response of reflected wave from A-A interface. Its evaluation may give P-wave velocity above A-A interface. G-G wave is estimated to be SE response of reflected wave from B-B interface. It may give P-wave velocity value above B-B horizon. All evaluations of mentioned above waves may represent a thorough information about subsurface cross-section in order to calculate the depth locations of stratigraphic horizons. Thus for described samples of cross-sections the properly registered SE responses can allow to benchmark the dome cave emptiness and underground water horizons.

Conclusion

In comparing with observations made by other researchers (MIKHAILOV et al., 1997), (WOLFE & GERSHNZON, 1996) where the signals registered from the second frontier were too weak and not evident, in our experiments we succeeded to get perfect and clear SE signals from the second and the third boundary interfaces. It was made owe to a stronger source use and by means of fitted higher seismic wave frequencies as well due to a proper registering device used. The results obtained appear to be promissory for shallow subsurface investigations and perspective for a mapping of stratigraphic boundaries in general geology particularly in geomorfology, archaeology, gidrogeology and of course speleology.

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Phreatic Overgrowths on Speleothems as Indicators of Sea Level Fluctuations Between 150-60 ka in Coastal Caves of Mallorca (Balears, Spain)

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Abstract

Phreatic Overgrowths on Speleothems (POS) form around pre-existing supports at the surface of brackish pools located in littoral caves along the coast of Mallorca (Balearic Islands, Western Mediterranean). Sampled POS alignments, occurring both above and below present sea level and recording past sea stands at the corresponding elevations, have been dated by U-series method. As the most outstanding results of this dating programme, a detailed Western Mediterranean eustatic curve for the period 150-60 ka BP is presented. The periods of high and low sea stands recorded in Mallorca have been preceded and followed by rapid sea level changes, more than 18 metres in magnitude which happened during temporal intervals less than 10 ka. The deduced minimum rates of sea level shift are about 1.5 m/ka, with average values of about 4 m/ka.

Resumen

Espectaculares recubrimientos freáticos sobre espeleotemas (Phreatic Overgrowths on Speleothems, POS) se han formado en la superficie de los lagos salobres que ocupan muchas cuevas costeras de Mallorca (Islas Baleares, Mediterráneo Occidental), creciendo sobre cualquier soporte adecuado, como estalagmitas, estalactitas y coladas parietales. Se han datado, mediante el método de las series de Uranio, muestras de bandas de recubrimiento (POS) localizadas tanto por encima como por debajo del actual nivel freático, en asociación con antiguos niveles del mar. El resultado más destacable del programa de dataciones efectuado, que aquí se presenta, ha consistido en la obtención de una curva detallada de las oscilaciones eustáticas del nivel marino para el intervalo 150-60 ka BP. Las estabilizaciones del mar registradas en las cuevas de Mallorca, tanto las que se encuentran sobre el nivel actual como las que se observan varios metros por debajo del mismo, aparecen insertas dentro de una pauta general de rápidos cambios de nivel del mar, de más de 18 metros de magnitud, que se produjeron en breves intervalos de tiempo, inferiores a 10 ka. Las tasas mínimas de fluctuación del nivel del mar se sitúan en torno a 1,5 m/ka, con un valor medio de 4 m/ka.

Phreatic Overgrowths on Speleothems (POS) in the Coastal Caves of Mallorca

Phreatic Overgrowths on Speleothems (POS) are a common feature in the coastal endokarst of Mallorca (Balearic Islands, Western Mediterranean). POS form around pre-existing supports at the surface of the brackish pools frequently found in many littoral caves in Mallorca. The vast majority of caves located along the southern and eastern coastline of the island are partially drowned by phreatic waters, whose peculiar chemistry allows for oversaturation and subsequent precipitation of carbonates in the close proximity of the water table. The position of today's sea level determines the presence and the current water-plane elevation of these underground brackish pools, the surfaces of which respond to minor fluctuations such as tides. Consequently, eustatic variations control the elevation of the POS-coatings whose growth takes place mainly during sea level stands.

Most of the POS-coatings develop on different types of previously formed vadose speleothems, thus adopting bulky shapes. Sometimes they are belt-like speleothems formed around stalagmites and columns.

In many cases, especially when the POS affect the tip of partially submerged stalactites, the former straw morphology can be modified substantially giving rise to some rather flask-like appearances (Figure 1). The bands of subaqueous coatings, marked by such POS alignments on the walls of the caves, permit an easy and accurate identification of high sea paleolevels (GINÉS & GINÉS, 1974; GINÉS *et al*., 1981a). Furthermore, POS alignments are also found by scuba diving below the water table, in the submerged parts of several caves (GRACIA, *et al*., 1998). Obviously, the main interest of these carbonate precipitates is that they record ancient positive and/or negative stabilisation of the sea, as indicated by means of the strictly horizontal alignments of the POS that can be recognised inside the caves (Figure 2).

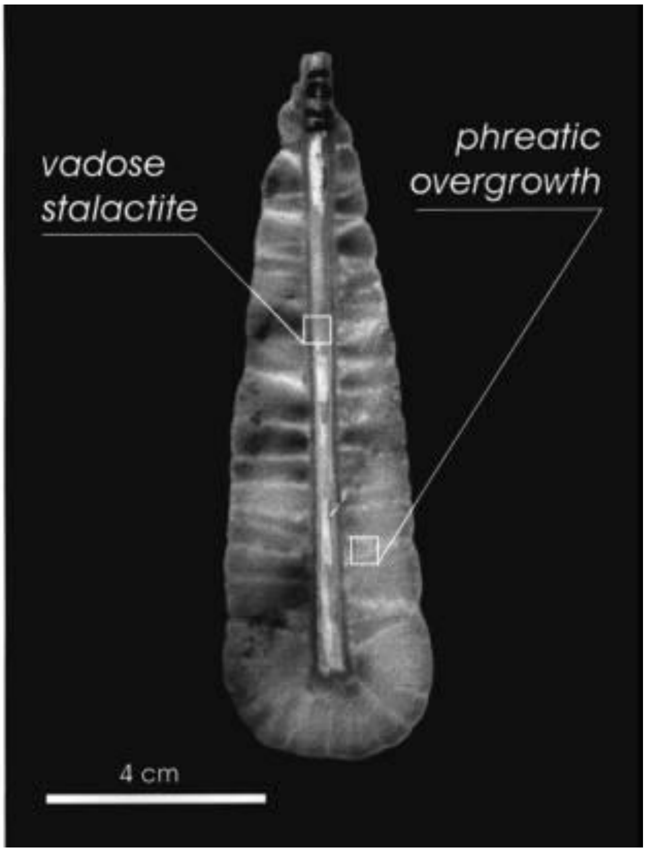

Figure 1: Delicate stalactite coated by an aragonite POS (Phreatic Overgrowth on Speleothem) collected at the surface of a brackish cave pool (Cova des Pas de Vallgornera, southern Mallorca)

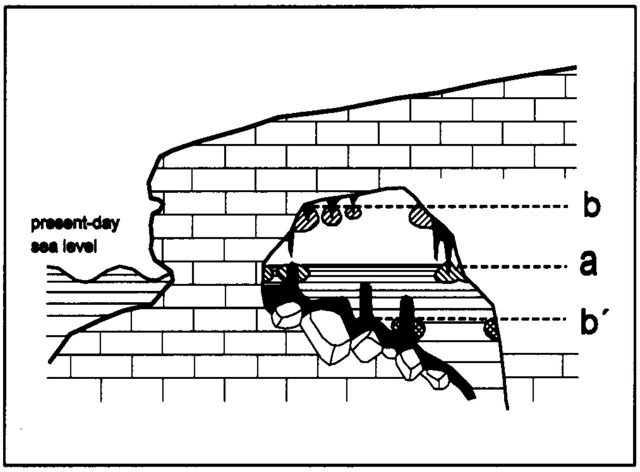

Figure 2: Sketch of a karstic littoral cave containing POS paleolevels.
a: POS alignment to the current water table; b: POS paleolevel located above present sea level; b': submerged POS paleolevel.

Although there is still much that needs to be understood about the geochemistry of coastal karst, it appears that these phreatic overgrowths on speleothems originate preferentially within the range of daily fluctuations of the ground water table (POMAR *et al*., 1979). Generally, coastal POS from Majorcan caves are roughly similar to other subaqueous speleothems but their morphology, texture and mineralogy show a remarkable diversity (POMAR *et al*., 1976; GINÉS *et al*., 1981b). Calcite, low Mg-calcite, high Mg-calcite and aragonite mineralogy is present. On the other hand, depending on their external appearance and textural patterns, they can be classified into several groups: smoothed, globular, coralloidal, branching and macrocrystalline (GINÉS, 2000). Such differences call for additional research on the ancient hydrological and climatic controls involved in this particular geochemical environment.

In Mallorca, a great number of phreatic-crystallisation paleolevels have been observed between the current sea level and +40 metres. GINÉS & GINÉS (1974) have considered the possibility of correlating these deposits altimetrically with Middle and Upper Pleistocene shorelines as identified by means of the stratigraphic and paleontological study of the Pleistocene beach deposits (BUTZER, 1975; CUERDA, 1975). These authors suggested that the POS situated 30 metres above present sea level should date back at least to OIS 9.

Since 1981, several dating programmes of Majorcan POS located above the present sea level were realised (GINÉS *et al*., 1999). The analysis carried out using the Uranium series method confirmed the previously established chronological model, with regard to altimetric correlation between POS paleolevels and Pleistocene beach deposits. The results of the dating programmes show ages that range from present-day to more than 350 ka, the limit of this method. The overgrowths less than 250 ka old are well correlated with the climatic events that involve a sea level similar to, or slightly higher, than the present one (OIS 1, 5 and 7, which correspond to warm periods). The samples which are more than 300 ka old (paleolevels higher than 30 m a.s.l.) have to be assigned tentatively at least to OIS 9 or 11.

In 1994 the study of POS was extended to new caves and new samples. Until now, 16 coastal caves have been investigated and 51 samples have been dated. Some of them were also analysed for O and C isotopic composition in order to collect information about past climate changes (VESICA *et al*., 2000). However, research dealing with submerged POS alignments had not been started until very recently (1999 and 2000 sampling campaigns). In spite of the difficult sampling, POS located below the current water table represent a very promising field of research, because they bring new information on the regressive marine fluctuations associated with the cold pulsations that affected sea level in the past. In fact most of the benchmarks of the eustatic curve for the last interglacial, that follows, correspond to data yielded by submerged POS.

An eustatic curve for the last interglacial obtained from U-series dating of POS

U-series dating of phreatic overgrowths on speleothems (POS) are a good tool in order to improve the knowledge of Pleistocene sea level change, as has been demonstrated in the case of Mallorca by a widespread background of available publications (HENNIG *et al*., 1981; POMAR *et al*., 1987; GINÉS & GINÉS, 1989; TUCCIMEI *et al*., 1997; GINÉS *et al.*, 1999; TUCCIMEI *et al*., 2000a; VESICA *et al*., 2000).

Near the coastline, owing to the easy porosity-connections with the sea, phreatic waters flooded the caves in accordance with contemporaneous sea level. Such brackish karst waters precipitated POS close to their surface as a consequence of enhanced CO_2 outgassing. As explained before, the occurrence of this kind of speleothems, both above and below the current sea level, gives evidence of the height attained by the top of the brackish pools that occupied the lower part of the caves during the rises and falls of the sea. For this reason, POS alignments are excellent indicators of coastal paleo-watertables when located above the current sea level (GINÉS & GINÉS, 1974; GINÉS *et al*., 1981a) and, on the other hand, become rather unique evidence in the case of the paleo-watertables recorded below it.

U-series dating of POS collected at different depths below present sea level provides new information about poorly known aspects of the sea level history in the Western Mediterranean. Conventional marine level records (fossil beaches, abrasion platforms and other geomorphological data) do not give precise data about regressive events, except in the case of coasts affected by severe uplift. In tectonically stable coasts, remnants of previous coastlines formed during low stand periods have been submerged and consequently it is very difficult to study them. But in the coastal karstic caves, besides the technical problems regarding the observation and collection of submerged POS, these kinds of crystallisations represent excellent records of the changes in sea level without being disturbed by other successive coastal dynamic processes.

After the data obtained by means of U-series dating on 22 POS samples (12 of them submerged POS) collected in 9 coastal caves of Mallorca (Figure 3), it is now possible to attempt the reconstruction of an eustatic curve for the last interglacial, valid for the Western Mediterranean basin. As documented in the general reports of the campaigns (GINÉS & GINÉS, 1989; GINÉS *et al*., 1999; TUCCIMEI *et al*., 2000a), the sampling programme was not formerly restricted to the last interglacial. However, in fact the most exciting findings became concentrated around stages 4 and 5 of the oxygen isotope record.

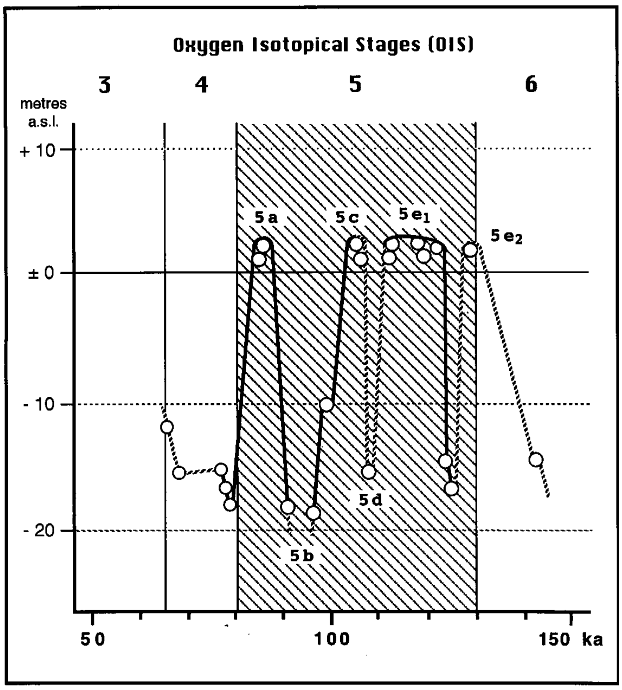

Figure 3: Location map of the caves containing POS whose sampling has documented the last interglacial sea level curve presented here. - BA: Cova de na Barxa, Capdepera; DI: Cova del Dimoni, Manacor; PI: Coves del Pirata, Manacor; FA: Cova de Cala Falcó, Manacor; VB: Cova de Cala Varques B, Manacor; GL: Cova de sa Gleda, Manacor; SE: Cova des Serral, Manacor; PS: Cova den Passol, Felanitx; CS: Cova des Drac de Cala Santanyí, Santanyí.

Obviously, one remarkable feature shown by the collected data corresponds to the information gathered about the sea level stands that occurred at negative elevations (GINÉS, 2000; TUCCIMEI *et al*., 2000a), because no other evidence was previously found on such paleolevels in Mallorca. If chronological data for submerged POS are integrated with those relative to analogous crystallisations located above present sea level, a detailed eustatic curve for the last interglacial can be reconstructed (Figure 4). Even if affected by small recent tectonic activity, littoral areas of eastern and southern Mallorca can be considered substantially stable, being documented a maximum of 1 metre tilting for the time span studied (TUCCIMEI *et al*., 1997). Furthermore, average errors of the U-series dating method for the time range between 60 and 150 ka are about 3%. Thus, the accuracy of the data obtained seems to provide a good estimate of the magnitude of marine level fluctuations as well as of the rapid changes in elevation produced during OIS 4 and 5 in accordance with minor climatic variations.

What emerges from the curve plotted after our research (Figure 4) is that sea level fluctuations during the time range between 60 and 150 ka seem to occur in accordance with the following pattern: periods of sea stands, large enough to produce the formation of POS at a certain elevation (at least 1-2 ka long), alternating with rapid sea level changes, more than 18 metres in temporal intervals shorter than 10 ka. The minimum rates of sea level changes deduced on the basis of the eustatic curve here presented are about 1.5 m/ka, with average values of 4 m/ka. High sea level stands as reported after our research for the substages 5a, 5c and 5e are in good agreement with previously published data by HILLAIRE-MARCEL *et al*. (1996) and ROSE *et al*. (1999).

POS: a Useful Method to Determine Pleistocene Sea Level and Climatic Changes

The new data, obtained from the sampled-POS chronologically associated with the last interglacial sea level pulsations, emphasises the suitability of further studies on this kind of speleothems with regards to Quaternary research. U-series dating, stable isotope investigations, fluid inclusions analysis and mineralogical studies, coupled with accurate altimetric identification of paleo-watertables, can improve our knowledge on Pleistocene sea level shifts and involved climate changes, as demonstrated in the case of Mallorca.

During the last two years, POS studies have successfully extended to similar coastal-cave features from the Alghero area (eastern coast of Sardinia, Italy). The high correlation found with some preliminary results provided by Sardinian samples (TUCCIMEI *et al*., 2000b) suggests that more coastal karst areas around the world should be the subject of detailed survey with respect to POS-related topics.

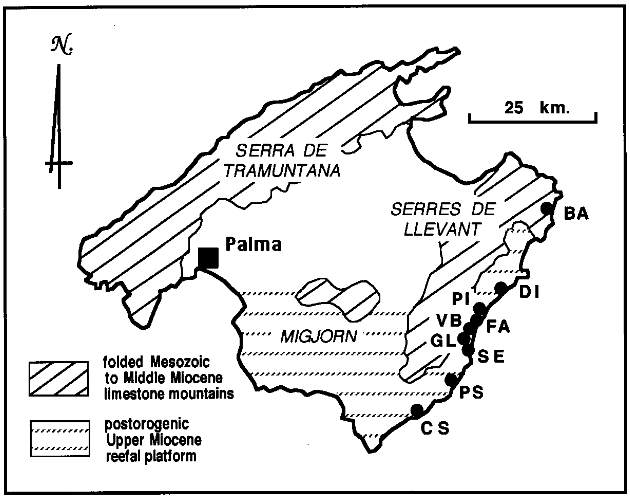

Figure 4: Last interglacial eustatic curve deduced from Th/U dating of POS from coastal caves of Mallorca. Unbroken lines represent sea level fluctuations documented by means of more than one dating.

Acknowledgements

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The Subsoil Solution Features and Distribution of Soil CO2 in Stone Forest Region, Lunan, Yunnan, China

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Abstract

The stone forest in Lunan is one of there unique karst landscape in China, Also in the world, that is Lunan stone forest, tower karst presented by Guilin karst and fengcong depression especially in Dahua county, Guangx. It is obviously that the stone forest is composed by the features formed by subsoil solution and reformed by the rainwater after the subsoil features exposed. The subsoil solutional features may occur in any part on the stone columns. Some features such as solutional troughs and through caves appear near the top of columnes The subsoil solution features of limestone, are the main components of Lunan stone forest landscape. The study results show that the CO_2 concentration distribution of soil and weathering materials is strongly influenced by the different vegetation, geomorphologic structure and soil properties in the directions of the vertical and horizontal and. Also the CO_2 concentration in the contact zone between soil and weathered materials and limestone has been studied. The relation of depth of subsoil solution features with subsoil air CO_2 has been discussed. Also the CO_2 seasonal variations in different soil and weathered basalts have been measured in the different ecological system and geo-environment. Some conclusions may be drew: (1) the soil CO_2 content is increased with soil depth from 0-80cm below the surface and decreased with depth below 100 cm generally, the maximum concentration appears in the section of 40-80 cm depth of soil in the karst blocks, but in the weathered basalt, the CO_2 content peak occurs from the depth of 80 cm to 120 cm; the high CO_2 concentration were recorded in the late Spring and Summer, lower in the Winter. (2) the subsoil solution features mainly developed in the depth of 0.4—0.7 m below the ground surface, it is well coincided with the soil air CO_2 distribution; (3) the order of influence intensity of vegetation on the soil CO_2 concentration are: vigorous lawn > cypress forest > scattered grassland > pine forest > shrub > the cultivated land without vegetation; (4) solution capacity of soil water in the dissolutional gully system is 80% higher than the water in solutional gully without soil; (5) the potential solution capacity of soil water in the dynamic equilibrium with soil CO_2 against limestone is estimated in the range of from 73.242 mg/l to 202.275 mg/l in the period from April to June, 1999, estimated with the means of carbonate dynamic equivalence. At the same time, the solution capacity of ground water in basal weathered materials is higher than that of soil water according to the CO_2 concentration measurenent.

Calcite Biomineralisation in the Caves of Nullarbor Plains, Australia

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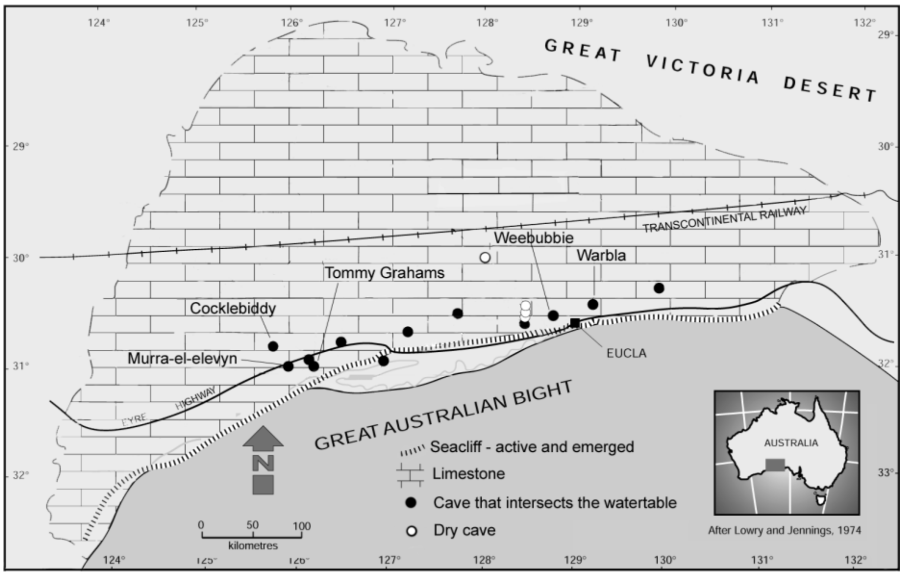
In caves under the Nullarbor Plain, divers report extensive mantles of a biological material. The mantles are gelatinous and transparent and only can be seen because of the microcrystalline calcite associated with them. They cover the roof and walls of the partially and totally water filled passages to the limits of exploration.

The nature of these mantles was investigated using electron microscopy and DNA analysis. The microcrystalline calcite was examined using electron microscope techniques, X-ray diffraction, Fourier transform infrared spectroscopy, Raman spectroscopy and thermogravimetric analysis. The cave water was analysed for major ions and trace metals and modelled using geochemical modelling software.

Water analysis revealed high levels of sulfate and nitrate together with significant nitrite. The community structure showed a high proportion of novel phylotypes as well a high abundance of Nitrospira relatives. The unusual community, the nitrite in the water, and the apparent absence of aquatic macrofauna, means these microbial structures may represent biochemically novel, chemoautotrophic communities dependent on nitrite oxidation.

The waters were slightly saturated with respect to calcite, suggesting the microbial mantles play a role in calcite nucleation and crystal growth. The calcite crystals were predominately spindle shaped with curved {hk.0} faces lying parallel to the c-axis. Calcite precipitated under conditions designed to mimic the inorganic solution chemistry of the cave revealed a different morphology to that observed in the cave samples. These differences suggest that the formation and growth of the microcrystalline cave calcite is influenced by the microbial mantles.

The Nullarbor region of Australia is the worlds largest contiguous karst system (Figure 1), with an area in excess of 200 000 km^2. The area is an extensive plain of Eocene and Miocene limestones across which the annual rainfall ranges from 150 – 200 mm (GILLIESON & SPATE, 1992).



After Lowry and Jennings, 1974

Figure 1 – The Nullarbor region showing cave locations

A number of extensive caves have been discovered in the area,including the largest chamber and longest underwater passage in Australia. The entrance to these caves is typically through dolines, formed as the result of collapse of a portion of the cave roof. A number of caves in this area intersect the Nullarbor aquifer, an extensive saline groundwater body that forms a watertable 100 m below the surface.

The length of the underwater cave passages (up to several kilometres) and the water clarity makes the region attractive to cave divers. Divers penetrating submerged passages of the caves have reported the widespread presence of dense 'mantles' of biological material associated with 'snowfields' of microcrystals. Morphologically similar microbial mantles have been reported from many Nullarbor caves and are generally found throughout the underwater sections, including remote chambers.

Samples were collected from Cocklebiddy (31º 57'S, 125º 54'E), Murra-el-Elevyn (32°02'S, 126°02'E), Tommy Grahams (32º 05'S, 126º 11'E) and Weebubbie (31°39'S, 128°46'E) Caves, Western Australia and Warbla Cave (31°31'S, 129°07'E), South Australia in May and June 1999 and May 2000.

Figure 2 - Phil Prust collecting water samples from the Nullarbor caves. The microbial mantles can be seen extending from the wall. (Photo Peter Rogers)

Microbial Mantles

The mantles take the form of hanging "sheets" or "tongues", with a mucoid consistency and up to 1 m in length (Figure 3). Suspended within the mantles are dense accumulations of crystals giving the mantles a semi-opaque white appearance. In near-entrance passages of the caves the curtains may have a red brown colour from dirt and dust knocked into the lakes. Limestone above the growths is usually irregularly pitted to depths of 3-5 mm. The floor beneath the curtains often comprises dense snowfields of material that apparently originates from the mantles above.

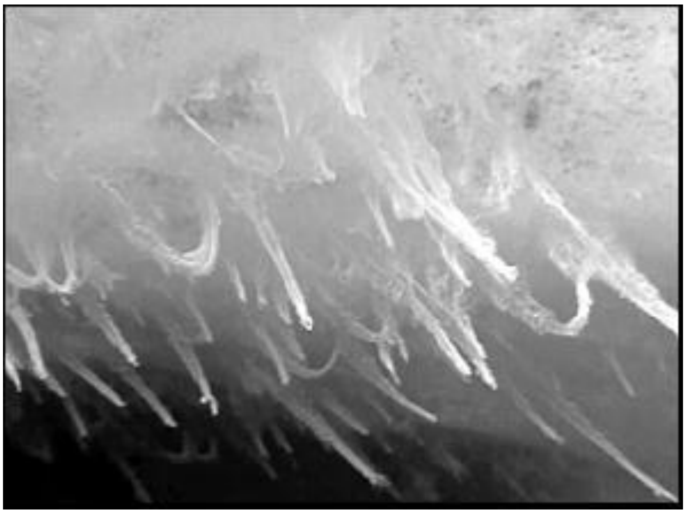


Figure 3 – The microbial mantles (photo P Bouler)

Observations under the light microscope show the biomass is primarily composed of densely packed, unbranched filaments together with spherical, rod and spiral shaped cells.

DNA analysis of the biomass revealed the phylotypic structure of the Weebubbie cave community had many features that suggest it represents a distinctive microbial community. These include a high relative abundance of *Nitrospira* relatives and a high proportion of phylogenetically novel sequences. Of the 36 phylotypes identified in Weebubbie Cave, 12 could not be identified to subdivision level. Furthermore, only two of the novel phylotypes showed any relationship to previously described environmental clones (HOLMES et al., 2001).

The relatively high proportion of novel phylotypes (subdivision or division) is strong evidence for the unusual nature of this community. Together with the absence, or low abundance, of typical terrestrial bacteria such as *Actinobacteridae*, *Acidobacteria*, α-*Proteobacteria*, and *Verrucomicrobia* this suggests the gene library represents a bacterial community which is remarkably different in structure from terrestrial communities. In this respect the community shows some parallels to the remarkable 'division-level' diversity reported for an American hot spring (HUGENHOLTZ et al., 1998).

The trophic structure of the Nullarbor cave community may also be distinctive. The Nullarbor caves contain a high standing microbial biomass, but little or no dissolved organic matter in the water. This implies that the community is primarily supported by chemoautotrophy. Previously reported chemoautotrophic cave ecosystems have been based on sulfur-oxidation and also support an enriched macrofauna (SARBU et al., 1996; AIROLDI et al., 1997; ANGERT et al., 1998; HOSE & PISAROWICZ, 1999).

On the basis of our phylogenetic survey nitrite oxidation is likely to play a significant role in the trophic structure of the Nullarbor cave community. Three phylotypes all show close relationship to one of the two described *Nitrospira* species. Although few *Nitrospira* cultures have been characterised, all known strains are obligate chemolithoautotrophs, which obtain their energy for growth from the oxidation of nitrite (EHRICH et al., 1995).

The remainder of the clones exhibited a high proportion of phylogenetically novel sequence types. The community structure, the presence of nitrite in the water, and the apparent absence of aquatic macrofauna, suggest these microbial structures may represent biochemically novel, chemoautotrophic communities dependent on nitrite oxidation.

Water Chemistry

The cave waters are saline, oxic and have a pH in the range of 7.5 – 7.85. Haloclines were observed in Cocklebiddy, Tommy Grahams and Warbla caves. Of note was the significant levels of nitrite 5-10 ppm and high nitrate levels (Table 1).

Table 1 Water chemistry of the caves investigated during this study

Cave	Tommy Grahams		Murra-el-elevyn	Cocklebiddy		Warbla		Weebubbie
Microbial community observed by divers	No		Yes	Above the halocline		Yes		Yes
Lake Temperature (oC)	23.1		23.7	18.8		22.4		18.9
Sample Depth	15 m	25 m	-5m	6 m	10 m	9 m	13 m	22 m
Conductivity mS/cm	17.2	37.7	14.3	14.2	21	n.d.	n.d.	23.3
SI_c	0.59	0.59	0.43	0.09	0.47	0.02	0.17	0.23
NO_3^-	150	170	180	900	210	30	30	100

n.d. = not determined

The saturation index for calcite (SIc) lies between 0 and 0.5 for the caves where the mantles have been observed. Under these conditions inorganic precipitation of calcite is unlikely due to activation barriers to nucleation and growth (WHITE, 1997). Microorganisms can alter their surrounding microenvironment and it is likely they are both acting as a nucleation source and influencing local supersaturation levels, resulting in calcite precipitation.

Calcite Biominerals

Crystals associated with these mantles were collected from the roof, walls and floor of the caves. Observations under the field emission scanning electron microscope showed the crystals were generally spindle-shaped with curved faces (X in Figure 4) defining the morphic form. Many of the crystals were morphologically polar; frequently one terminus was attached to the bacterial filament (T and F in Figure 4) whilst the other was truncated by three well-defined, symmetry-related faces. The crystals ranged in length from 1.5 microns to 11 microns. The crystals are calcite, confirmed by X-ray diffraction, thermogravimetric analysis, Fourier Transform infra-red spectroscopy and Raman spectroscopy (CONTOS et al., 2001).

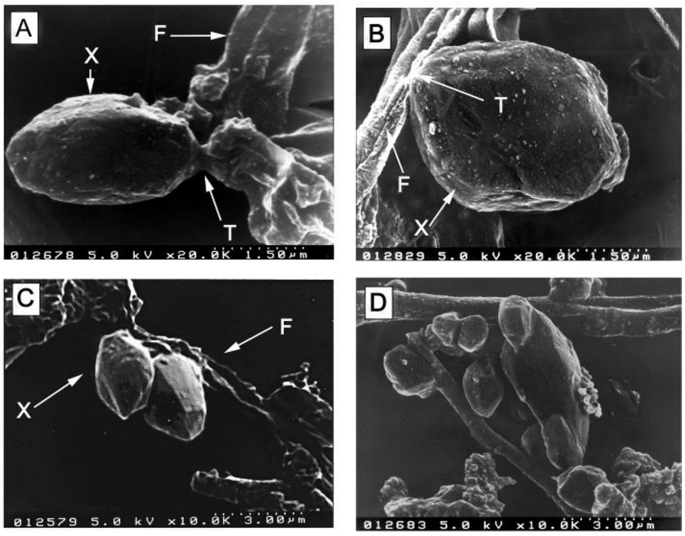


Figure 4 - SEM images of cave crystals

Inorganic Ions Influence on Calcite Morphology

To investigate the influence of the ions present in the caves waters on the calcite morphology a series of doped assays were carried out.

Calcium carbonate crystals were prepared in synthetic cave water. Carbon dioxide was bubbled through a continuously stirred mixture of AR grade calcium carbonate (2 g L^{-1}) and distilled deionised water for two hours. This solution, now saturated with respect to calcium carbonate, was filtered through a 0.22 micron filter to removed the undissolved calcium carbonate. The carbon dioxide was bubbled through the filtrate for a further half hour before the filtrated was poured into crystallisation dishes and left to stand (KITANO, 1962). Salts were added to the crystallisation dishes to mimic the cave water. The assays were repeated using 0.22 micron filtered cave water instead of the synthetic water. A control, with no salts added was prepared for each assay.

The cave shape is different to that expressed by synthetic calcite grown either with (Figure 6) or without (Figure 5) the influence of inorganic ions. In all the doped assays the synthetic calcite expressed negative {01.□} faces, which from a determination of the interfacial angles are most likely to be of {01.1} form (Figure 6).

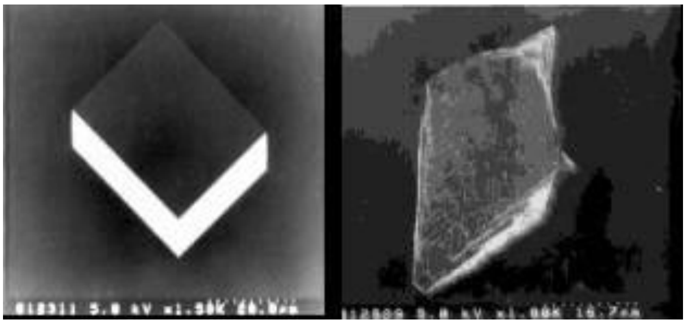


Figure 5 - SEM image of calcite grown without additives

Figure 6- SEM image of calcite grown under the influence of inorganic ions in cave water

Influence of Carboxyglutamic Acid

While the crystals collected from the caves did not bear a similarity to those gown under the influence of inorganic ions, these is a marked similarity between the morphology of the cave crystals and synthetic crystals grown in the presence of L-γ-carboxyglutamic acid and its chemical derivative, malonic acid (MANN et al., 1990). These crystals, also spindle shaped, expressed curved prismatic{hk.0} faces lying parallel to the c-axis and were truncated by smooth rhombohedral {10.4} faces (Figure 7).

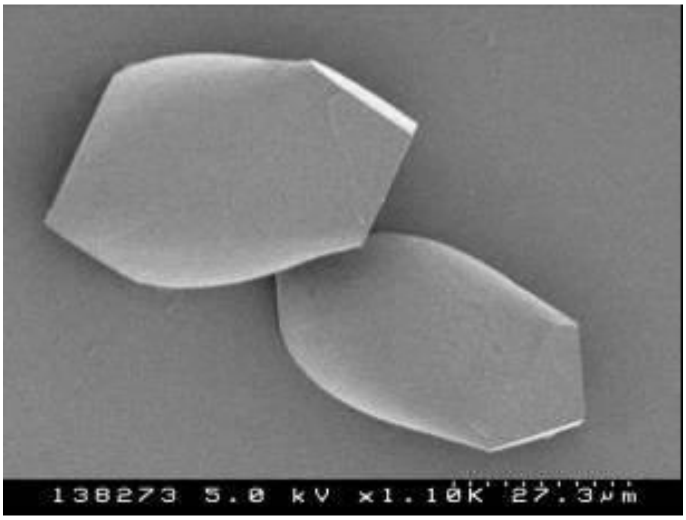


Figure 7 - SEM image of calcite grown under the influence of the α,ω-dicarboxylic acid, malonic acid

Growth perpendicular to the c-axis was inhibited by the adsorption of malonate onto the prismatic faces. A major characteristic of these faces is the orientation of the carbonate group with its C_{2v} axis perpendicular to the crystal surface. It is also noted that the distance between the carboxylate groups in the malonate is comparable with the distance between the carbonates in adjacent anion layers in the prismatic faces. Thus, it is suggested that these structural factors mediate the stereoselective adsorption of malonate onto the inorganic surface. The pseudo-curved appearance of the crystals suggests that adsorption is equal for all prismatic faces with the result that no one unique set is stabilised in the growth form.

The origin of the polarity in the growth form is less clear. One notes, however, that calcite crystals with a comparable crystallographic morphology are induced to form on ordered organic films *in vitro* (HEYWOOD & MANN, 1994)

Spindle-shaped calcite crystals, elongated along the c-axis, are a feature of the otoconia recovered from the inner-ear gravity devices of reptiles and mammals (ROSS & POTE 1989). These crystals are known to be formed in the presence of proteins containing γ-carboxyglutamic acid.

Conclusions

The microbial mantles found in the Nullarbor Caves have not been reported elsewhere. The microbial community shows remarkable division level diversity and a high proportion of phylogenetically novel sequence types. These microbial structures may represent biochemically novel chemoautotrophic communities.

With waters only slightly saturated with respect to calcite, the intimate association of the crystals with the bacterial filaments suggests inductive nucleation of the crystals on the cell walls of the bacterial filaments.

The cave crystals’ morphology is unusual and differs from the form expressed solely under influence of the inorganic ions in the cave water. The morphology of the cave precipitates is likely to arise from the interaction of the microbial community with the evolving crystals. The habit of the crystals recovered from the cave is similar to that known to occur in a number of biominerals.

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Hydrothermal Genesis of Metatyuyamunite, Ca(UO2)2(VO4)2•3-5H2O in the Valea Rea Cave, Romania

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Abstract

Metatyuyamunite, $Ca(UO_2)_2(VO_4)_2 \cdot 3\text{-}5H_2O$, a new mineral for Romania, occurs as canary yellow sub-millimeter-size plate-like crystals in Valea Rea Cave (Bihor Mountains). This unusual mineral has precipitated on, and in between delicate needle-like aragonite crystals. X-ray diffraction, optical and scanning microscope (including EDS), and luminescence were used to identify metatyuyamunite. The X-ray diffraction pattern can be indexed with the orthorombic cell a = 10.77; b = 8.53; c = 17.62 of metatyuyamunite. From a genetic point of view it seems that tyuyamunite was first precipitated from hydrothermal solutions and in a later stage it dehydrated to metatyuyamunite.

Introduction

During the course of mineralogical sampling undertaken in Valea Rea Cave, an unidentified yellow mineral growing over a white crust was collected from a side passage. X-ray powder patterns indicate the presence of metatyuyamunite, a hydrated uranyl vanadate.

This is the first reported occurrence of metatyuyamunite in Romania. Furthermore, it is the third such occurrence in a cave environment worldwide. The two other known cave occurrences are Spider Cave (New Mexico, USA) (POLYAK & MOSCH, 1996) and Caverns of Sonora (Texas, USA) (ONAC et al., 2001). In the outside environment, metatyuyamunite is rather a common mineral, associated with uranium and vanadium deposits (LANGMUIR, 1997).

The presence of metatyuyamunite in Valea Rea Cave adds one more species to cave mineral association described by ONAC et al. (1995), GHERGARI et al. (1997), and GHERGARI & TAMAS (1999).

Geographic and Geological Setting

Valea Rea Cave is located on the upper part of Rea Valley, just below the top of Cârligati (Bihor Mts., Romania) (Fig. 1) (DAMM et al., 1996). Since its discovery on 1986, over 18 km of passages have been mapped to a total depth of 360 m. The main axis of the cave, the Colectorului (Collector) Gallery, is an active stream passage (20-25 l/s) approximately 3.5 km in length. Two other fossil galleries are located above the active one at 20 m and 50 to 70 m’s respectively. Typically, large chambers or labyrinth passages are to be found where all three galleries interconnect.

Due to a large variety of rocks that occur in the Valea Rea - Cornu Muntilor region, one can consider it a petrographic mosaic. All geological deposits occur as narrow stripes oriented NE-SW. Three compartments are evident starting from the north and going to the south (Fig. 2) (BLEAHU et al., 1985):

The North Compartment consists of andesites (bearing pyroxenes and hornblende) formed during the I^{st} cycle of banatitic eruptive activity (Maastrichtian – Paleogene) (STEFAN et al., 1988).

The Central Compartment includes a Permian to Triassic sedimentary formation belonging to the Upper Sebisel Member of the Finis - Ferice Nappe (BORDEA & BORDEA 1972; BALINTONI, 1997).

The geological succession begins with purplish-red color quartzite sandstone, conglomerates, and shales on Verrucano facies. Locally, within some of these horizons, important concentrations of uranium were found during mining prospecting.

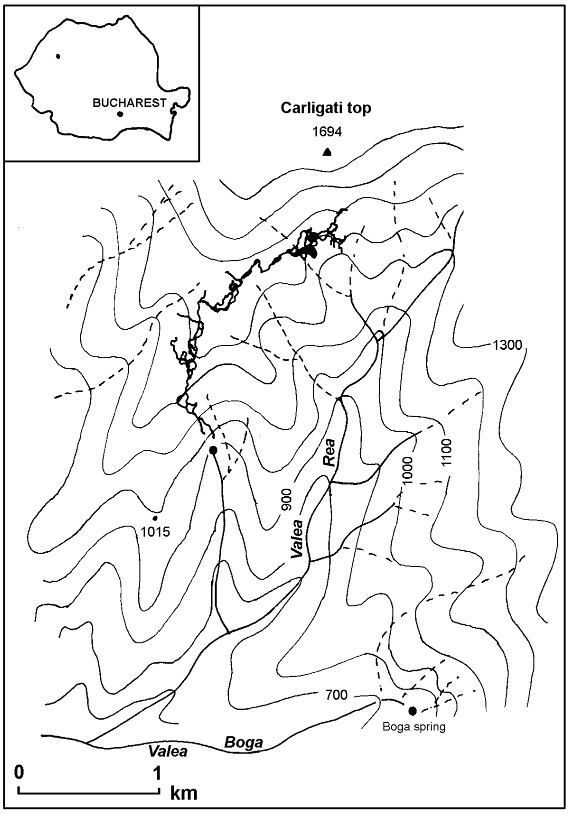


Fig. 1. Location of Valea Rea Cave

The unit above consists of white conglomerates and quartzite sandstone of Lower Triassic age, covered by a series of 600-m thick black dolomites (± chert), shales and limestone breccia. Valea Rea Cave is developed mainly within the dolomite horizon of Anisian (Middle Triassic) age.

The South Compartment consists mainly of granodiorite formed during the IInd cycle of the banatitic activity. Dykes of granites and microgranites having a SE-NW orientation cut through the sedimentary rocks.

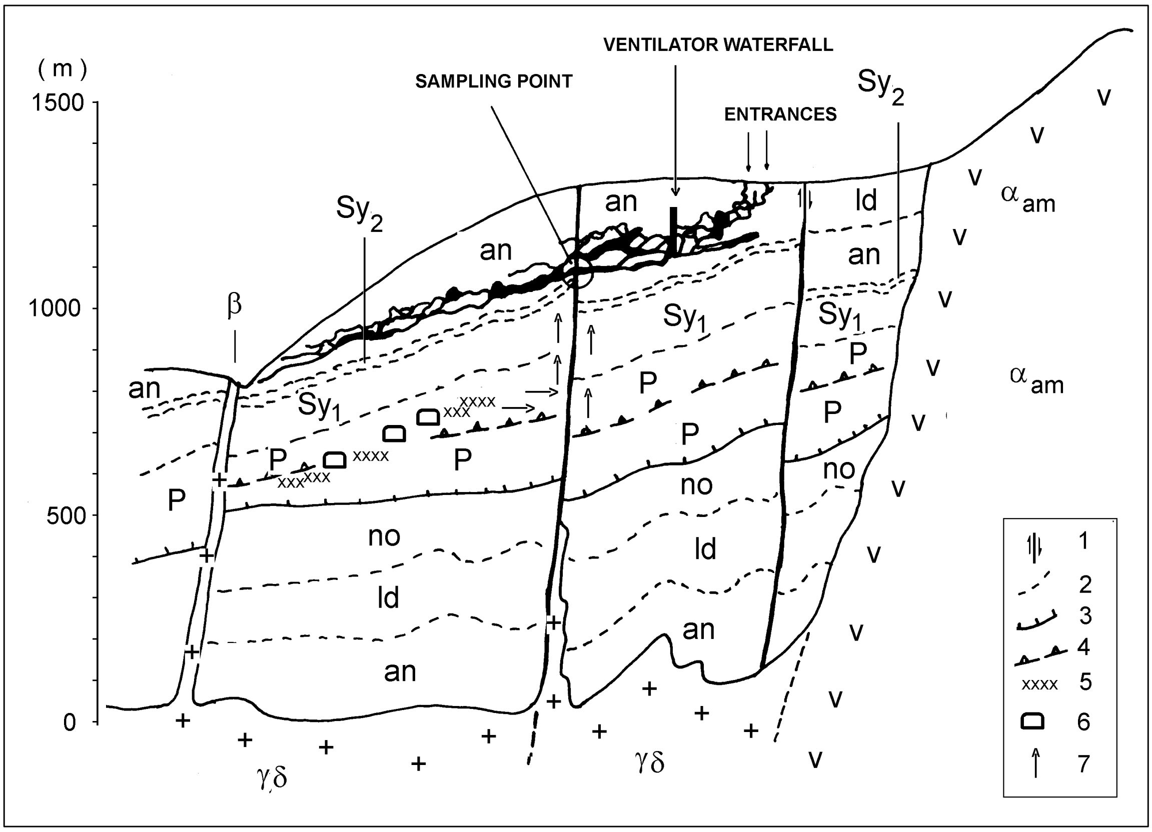
The metallogenesis in Bihor Mountains is associated with the IInd cycle, characterized by bodies of intrusive, hypabyssal and plutonic rocks. Mineralizations are of pyrometasomatic and hydrothermal origin. The main paragenesis assemblages are V-Ni-Co; Zr-Ti-Cr; Cu-Mn, and Pb-Zn. Uranium was originally concentrated syngenetically in a fluvial environment. At later stage, it was mobilized by hydrothermal solutions and redeposit along fault lines in organic rich gray sandstones of Permian age (MATYASI, 1998). Hydrothermal ore minerals build up mainly in veins and hydrometasomatic bodies; locally there are impregnation bodies or simple nests (STEFAN et al., 1988).

Geochemical studies of banatitic magmatites from the northern Apuseni Mountains show values of 3.4 to 6.6 ppm for uranium, while the vanadium content range between 6 and 170 ppm (exceptionally) (STEFAN et al., 1992). The uranium concentration recorded in the Permian rocks occurring just below the cave shows values up to 1% (MATYASI, 1998).

Occurrence of Metatyuyamunite

Metatyuyamunite forms yellow patches that cover white delicate crystals on both walls of a narrow-side passage (20 m in length), 300 m downstream from Ventilator Waterfall (in the upper third of the cave system) (Fig. 2). Each of these yellow patches is a few square centimeters, but altogether are spread over several square meters.

The cave temperature in the close vicinity of sample location is about 9°C whereas the relative humidity is 99-100%.



1: faults; 2: geologic boundaries; 3: nappe overthrusts; 4: reverse faults; 5: mineralization zones; 6: mining galleries;7: ascending geothermal solutions; □□□andesite;□□ : granodiorite; □ : basalt; P: permian; Sy_1: Lower Scitian; Sy_2: Upper Scitian; an: Anisian; ld: Ladinian; no: Norian.

Fig. 2. Geological cross-section along Valea Rea Cave showing the lithology, tectonic featuresand the cave network

Analytical Methods

X-ray Diffraction Data

The X-ray diffraction powder pattern for metatyuyamunite was obtained on a Scintag V Pad diffractometer, (Cu-Kα), using quartz as an internal standard. The scanning was continuous at a speed of 1° 2θ/min and a time constant of 2.5 seconds. The diffractometer was operated at 45 kV and 40 mA within the □□□range of 5 to 80°, and refined between 8 and 33°. □The X-ray pattern shows a number of lines, all well-marked and sharp. The strongest five lines 8.32 (90), 4.16 (40), 3.25 (55), 2.36 (26), 2.10 (40) are presented in Fig. 3. Since the X-ray diffraction pattern comprises only 8 lines, the indexing of these reflections may look uncertain, but nevertheless gave a clear orthorhombic cell having, a = 10.77, b = 8.53, c = 17.62. These values are close to those from ICDD file 8-287 and to those obtained by POLYAK & MOSCH (1996) or ONAC et al. (2001).

The X-ray diffraction pattern for the white crust on which metatyuyamunite was precipitated is almost identical to that of synthetic aragonite (ICDD file 5-453).

Optical and scanning electron microscope analyses

Observations made on a Stemi 2000-C (Zeiss) binocular (50x magnification) revealed that bladed crystals of metatyuyamunite (0.1-0.3 mm in size) are sprinkled over millimeter-size, transparent to translucent, colorless to white acicular crystals and radial aggregates of aragonite. Metatyuyamunite crystals have a canary yellow color and adamantine luster.

In thin section, metatyuyamunite is colorless to pale yellow; the extinction is parallel and shows perfect rectangular cleavage.

The scanning electron microscope (SEM) investigation was conducted on a Hitachi S-3500N device. The SEM images revealed euhedral to subhedral decimicron platy-like crystals of metatyuyamunite (Fig. 4) as well as acicular crystals of aragonite. Some of the aragonite crystals are twinned.

Several crystals of metatyuyamunite were examined by means of electron probe microanalysis using an energy dispersive spectroscopy (EDS) detector attached to the SEM. The semi-quantitative elemental analysis provided by EDS confirmed the presence in all samples of uranium (~67%), vanadium (~21%), calcium (~6.5%), and oxygen.

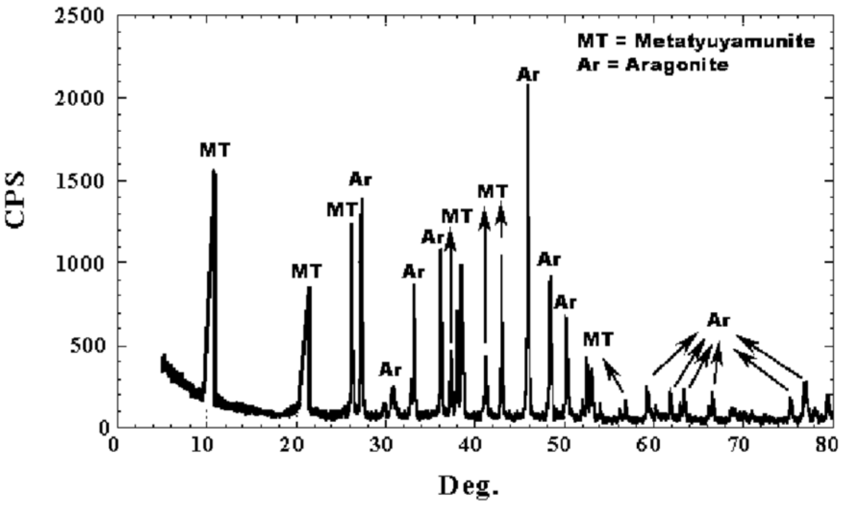


Fig. 3. X-ray diffraction pattern of metatyuyamunite

Luminescence

A Hitachi (model 4010) spectroflurophotometer was used to investigate the luminescence of the metatyuyamunite. Under short wave UV, the yellow crystals luminese bright green.

Measurements of the excitation and emission spectra show the characteristic emission of the uranyl ion (Fig. 5). The sharp lines at 504, 525, and 547 nm are characteristic of the uranyl ion and in good agreement with the results obtained on the Sonora specimen by ONAC et al. (2000). The broad band centered at 450 nm is not part of the uranyl spectrum and likely arises from fulvic acid and related organic compounds incorporated into the co-existing aragonite.

Results and Discussion

Hydrothermal solutions are responsible for the origin and development of Valea Rea Cave. Diagnostic features supporting this origin include exotic mineral deposits (celestine, barite, dickite, nacrite, quartz etc.), tree-form effluent chimneys, multi-story mazes, and highly corroded wall crusts (ONAC et al., 1995; GHERGARI et al., 1997).

*E*h, the concentration of vanadium, and the amount of carbon dioxide mostly control the geochemical behavior of uranium (LANGMUIR, 1978; MAYNARD, 1983). Carnotite and all other uranyl minerals are soluble at low CO_2 pressures similar to those found in a cave environment. The following features are sufficient for a general understanding of the behavior of uranium in natural waters: it is soluble under oxidizing conditions unless vanadium is present, and is insoluble under reducing conditions (DREVER, 1997).

We believe uranium and vanadium were mobilized by hydrothermal solutions moving upward through the Permian sandstones occurring below the cave. After development of cave and under subsequent vadose evolution of the cavity, uranium was transported as highly soluble uranyl carbonate complexes in neutral to alkaline, oxidizing waters. The presence of even small amounts of vanadium in solution led to immobilization of uranium as carnotite, tyuyamunite or other uranyl minerals. Uranium could also have been precipitated under reducing conditions, created by a reducing zone in the dolomite due to rich organic matter and/or sulfide minerals such as pyrite (LANGMUIR, 1997).

The problem in interpreting the presence of metatyuyamunite in Valea Rea Cave is whether it is primary or of secondary mineralization (i.e. formed by dehydration of tyuyamunite). STERN et al. (1956) determined the number of moles of water was a function of the partial pressure of water vapor. Plateaus on the dehydration curve were found at values of 5 and 8.5 moles of water per moles of $Ca(UO_2)_2(VO_4)_2$. Considering the wide range of water vapor partial pressure (relative humidity) recorded in cave environments the two minerals can theoretically co-exist. Our analytical investigation revealed only the presence of metatyuyamunite, which was successfully rehydrated to tyuyamunite by placing it in a moist atmosphere (the rehydrated mineral was confirmed by X-ray diffraction). Therefore, the problem mentioned above is still an open question.

Regarding the precipitation of the mineral association, the following succession is suggested. Either metatyuyamunite or tyuyamunite (dehydrated in one step to metatyuyamunite in a later stage) or both could have been precipitated where CO_2-rich groundwater equilibrated with cave atmospheric CO_2 levels. This succession would only occur after aragonite was first deposited as wall crust from a uranyl-rich carbonate complex. The presence of metatyuyamunite crystals, randomly disposed between or over aragonite crystals, may be evidence to support our theory.

The presence of uranium-vanadium compounds in Valea Rea Cave add new insight into the hydrothermal interpretation of its speleogenesis, regardless of which of the two minerals were precipitated first.

Acknowledgements

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Hydrogeological Investigations of the Lajeado-Bombas Karst System (South São Paulo State, Brazil) Based on Rhodamine-Wt Tracer Test

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Abstract

Qualitative tracer tests using fluorescent RWT are in development in order to establish the karst groundwater drainage basins of the Lajeado carbonatic area (on Mesoproterozoic limestones and dolomites), Betari river basin, a tributary of the Upper Ribeira River, Southern São Paulo State.

This research intends to identify the hidraulic conections between the sinkholes of the Roncador, Carniça, Grande, Sebastião Machado, Batalha, Fundo and Passoca creeks and the main springs of the karst system, as the Laboratório cave, Bairro da Serra lake, Bombas ressurgences, Jeremias and Córrego Seco cave ressurgences. Activated charcoal detectors are being used which are eluted in order to test the presence of RWT with a Turner Fluoremeter.

Preliminary results show that the Lajeado area has four main groundwater basins and one flow route which only is active during high water table stages.

Resumo

Testes qualitativos utilizando o traçador fluorescente RWT estão em andamento para determinar as principais bacias de drenagem da água subterrânea na área carbonática do Lajeado-Bombas (Proterozóico Superior), bacia do rio Betari, afluente do alto curso do rio Ribeira, sul de São Paulo.

O estudo pretende identificar as conexões hidráulicas dos sumidouros dos córregos Roncador, Carniça, Grande, Sebastião Machado, Batalha, Córrego Fundo e Passoca com os principais pontos de ressurgência da região, representados pela gruta do Laboratório, Lago do Bairro da Serra, ressurgência do córrego Bombas, ressurgência da gruta do Jeremias e Córrego Seco. A confirmação das conexões é obtida pela análise de captores de carvão ativado instalados nas ressurgências dos sistemas cársticos. Resultados preliminares dos testes de conexão permitiram a identificação de quatro bacias de drenagem da água subterrânea e uma rota de fluxo intermitente, ativa somente na época de N.A. alto (período de chuva).

Introdução

Os aqüíferos cársticos freqüentemente apresentam grandes reservas de água subterrânea, o que os tornam um importante alvo de estudos, já que a água potável é um recurso cada vez mais escasso em nosso planeta (BONACCI 1987).

Estes aquíferos apresentam características hidrológicas e hidrogeológicas peculiares, no qual a água flui através do maciço rochoso obedecendo uma rede de condutos que muitas vezes não segue as rotas do escoamento superficial como ocorre em outras litologias. No estudo destes aquíferos os traçadores são importantes ferramentas para demarcar as áreas de captação de ressurgências cársticas e definir as rotas do fluxo subterrâneo.

Neste trabalho o traçador fluorescente rhodamina-WT foi utilizado para identificar conexões entre sumidouros e ressurgências na área carbonática Lajeado-Bombas e demarcar as bacias de drenagem subterrânea.

Localização

A área cárstica do Lajeado-Bombas situa-se no Alto Vale do Rio Ribeira de Iguape, município de Iporanga, na região sul-sudeste do estado de São Paulo. A área engloba as localidades do Bairro da Serra, Sítio Novo, Lajeado e Bombas.

Segundo Karmann (1994), a área cárstica do Lajeado-Bombas apresenta 47 km2 de rochas carbonáticas continuamente expostas, constituindo uma das maiores áreas carbonáticas do alto Ribeira. Neste trabalho investigou-se a hidrologia do setor SW desta área, localizada na margem direita do rio Betari. Grande parte da área está situada nos limites do Parque Estadual Turístico do Alto Ribeira (PETAR).

Geologia

A região estudada está inserida na Faixa Dobrada Apiaí, em um conjunto de rochas supracrustais vulcano-sedimentares, de grau metamórfico fraco a médio, reunidas no Supergrupo Açungui de idade Mesoproterozóico a Neoproterozóico (CAMPANHA 1991), sobre os metacalcarenitos e metacalcilutitos impuros calcíticos e dolomíticos da Formação Bairro da Serra do Subgrupo Lajeado.

A região é caracterizada por dois domínios estruturais. O primeiro é representado por um sinclinal ligeiramente assimétrico com direção geral NE-SW do acamamento e mergulho entre 10 e 50º para SE e NW. O flanco sudeste deste sinclinal passa para uma estrutura homoclinal, com direções paralelas, porém com mergulhos altos, de até 80º, dominando para NW, caracterizando o segundo domínio estudado (KARMANN *op. cit*).

Trabalhos Anteriores

A região do Lajeado-Bombas sempre interessou os pesquisadores pelo seu grande potencial espeleológico e pela grande quantidade de sumidouros e ressurgências. Neste sentido diversos trabalhos foram realizados: KRONE (1904 *apud* SLAVEC 1976), SLAVEC (1976), COLLET (1977), CEU (1977 *apud* GPME 1998), ZILIO (1978), LE BRET (1995), SOUZA & KARMANN (1996), KARMANN (1994) e GPME (1998).

A primeira aplicação de traçadores na região é descrita por SLAVEC (1974), e tinha por objetivo verificar a conexão hidrológica do abismo do Sítio Novo e a ressurgência da gruta do Laboratório. A partir do resultado positivo, acreditava-se que o abismo fosse a única água que formava a ressurgência da gruta do Laboratório, sendo que o rio das Areias mudava de direção para a região das Bombas. Desta forma foi realizada uma coloração com a injeção de fluoresceína na gruta das Areias de Baixo, com captores de carvão ativado instalados na gruta do Laboratório e ressurgência das Bombas, porém com resultados negativos. Em 1975 o mesmo grupo realizou uma nova coloração com fluoresceína, comprovando a conexão entre a gruta das Areias e a gruta do Laboratório (GPME 1998).

Materiais e Métodos

Testes qualitativos tem como objetivo testar conexões hidráulicas entre pontos de entrada e saída de água do sistema. Baseiam-se na injeção de uma quantidade previamente calculada de traçador no sumidouro do sistema e no monitoramento das ressurgências com a utilização de captores de carvão ativado. Os captores possuem a função de registrar a passagem do traçador nos pontos de coleta, evitando o monitoramento constante desses pontos. Após a realização do teste, os captores são recolhidos e analisados em laboratório para verificar a passagem ou não do traçador, fornecendo informações qualitativas a respeito das conexões e rotas de fluxo do sistema. Neste estudo foi utilizado o traçador fluorescente rhodamina-WT com 39% de ingrediente ativo. Os captores foram confeccionados com uma tela de *nylon* de malha 0,4 mm, num formato retangular (14 x 4 cm) preenchidos com carvão ativado na granulometria de 1 a 2mm. Para a extração da rhodamina-WT dos captores de carvão, optou-se pela utilização do eluente composto por Etanol p.a.(96% ,v/v) e KOH p.a. (15% p/v em H2O), homogeneizados na proporção 1:1. Esta opção levou em conta a praticidade de manuseio do produto e o baixo custo. A solução obtida na extração foi analisada por um espectrofluorímetro Turner TD-700 no Laboratório de Geoquímica do Instituto de Geociências da Universidade de São Paulo. A presença de algas e sedimentos em suspensão, podem influenciar os valores de fluorescência e comprometer a interpretação dos resultados, conforme trabalhos de SMART (1976) e SMART e LAIDLAW (1977). Desta forma, antes da realização dos testes os pontos de coleta foram monitorados para obter-se valores de *background* da fluorescência no sistema.

Para evitar a sobreposição entre um teste e outro, após a realização de cada campanha foram instalados novos captores de carvão ativado no sistema. Estes foram analisados antes do início de um novo teste para verificar se a fluorescência retornou ao seu nível de base.

Pontos de Injeção e Monitoramento do Traçador

A definição dos pontos de injeção e monitoramento do traçador fluorescente, foi baseada nos trabalhos de LE BRET (1995), SLAVEC (1976), ZILIO (1978), KARMANN (1994), além do levantamento de Cavidades Naturais mantido e organizado pela SBE, no qual foram selecionadas somente as cavidades que apresentam atividade hidrológica. Foram indicadas para injeção da rhodamina-WT a Dolina das Areias I e II (SP-18/19), gruta do Córrego Fundo (SP-048), abismo da Passoca (SP-044), abismos Berta Leão I e II (SP-096/97) e abismo do Roncador (SP-099).

Outros pontos de injeção foram selecionados a partir da análise de fotografias aéreas. Os principais pontos localizam-se preferencialmente nos contatos entre rochas carbonáticas e unidades metapelíticas, sendo que o área das bacias de captação foi o guia na escolha dos pontos mais significativos. Foram escolhidos os sumidouros dos córregos Carniça, Grande, Sebastião Machado e Batalha.

Para a determinação dos pontos de monitoramento, foram selecionadas as principais ressurgências da região: gruta Laboratório (SP-016), Lago do Bairro da Serra, gruta do Córrego Seco (SP-49), ressurgência das Bombas e da gruta do Jeremias (SP-053).

Resultados Obtidos

Os testes realizados até o momento permitiram a identificação de conexões hidrológicas entre sumidouros e ressurgências da área estudada e a definição de quatro sistemas cársticos: Sistema Areias, Sistema Córrego Fundo, Sistema Bombas e Sistema Jeremias conforme mostra a Figura 01. Baseado na presença de bagres-cegos no Sistema Areias e Bombas, trabalhos antigos descreviam uma possível ligação do sistema Areias e o sistema Bombas (KRONE 1904 *apud* SLAVEC 1976). Os dados obtidos neste estudo não demonstraram conexão entre estes dois sistemas. No sistema Córrego Fundo foi comprovada a existência de uma rota de fluxo intermitente. Em condições de N.A. baixo (período de estiagem), as águas coletadas pela gruta do Córrego Fundo e abismo da Passoca, ressurgem no Lago do Bairro da Serra. Em períodos de N.A. alto (período de chuva), ocorre uma “fuga” do excesso de água deste sistema para a gruta do Córrego Seco.

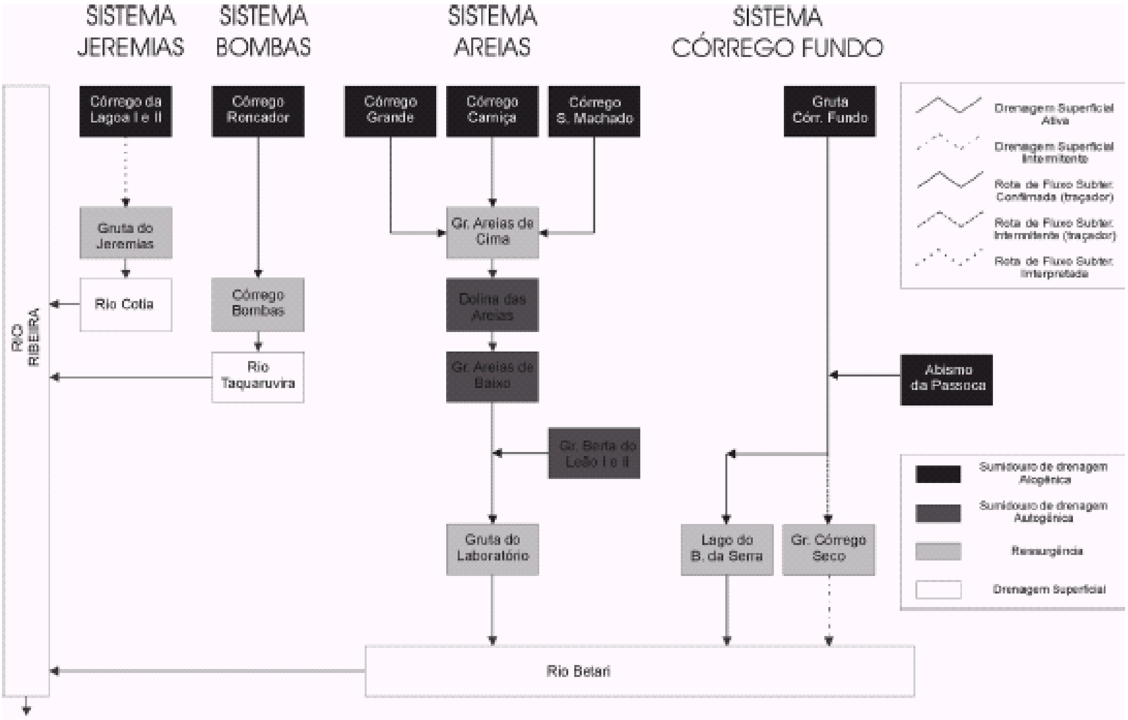

Figura 1 – Rotas de Fluxo identificadas na Faixa Lajeado/Bombas utilizando traçador fluorescente Rhodamina-WT

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Geologia Preliminar das Grutas: Toca da Boa Vista e Toca da Barriguda, Campo Formoso – Bahia – Brasil

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Abstract

The caves are developed at dolomite rocks of Una Group that was affected by two metamorphic events of Brazilian Cycle.

The method consisted of description and measures of observation points of planar and linear features like bedding, fractures and fold axis.

The results allow defining 3 lithofacies, with 3 characteristic subfacies, and defining a structural control to the development of the caves. Most part of conduits is controlled by vertical fractures and sometimes by folds axis. The fractures are parallel to the fold axis and have NNW-SSE and ENE-WSW directions. Evidence of refold is observed by existence of folded axis and dome and basin features. A zone of reverse fold were well defined, at the north part of TBV, by the occurrence of drags folds, tension gashes and fractured contacts of different lithofacies. This fault occurrence lead to the supposition that these caves are laterally controlled by inverses systems of faults.

Resumo

A proposta desse trabalho é apresentar os resultados dos estudos geológicos realizados nas principais cavidades da região de Lajes dos Negros, município de Campo Formoso/BA, realizado pela equipe da SEE, em janeiro de 1998.

A metodologia das atividades consistiu na execução do levantamento de dados geológicos estruturais e estratigráficos (litofaciológicos), com coleta de amostras para estudos petrográficos de laboratório, elaboração de croquis e cortes geoespeleológicos e tomada de fotografias ilustrativas das estruturas e litofácies observadas.

Os resultados obtidos permitiram melhorar o entendimento da gênese das cavidades estudadas e, também, o desenvolvimento de alvos ou metas para estudos posteriores.

Introdução

A área estudada encontra-se situada ao norte do estado da Bahia (Figura 1) e corresponde também ao norte do cráton São Francisco, assim denominado por ALMEIDA (1977).

2. Geologia Regional

2.1. Geomorfologia

O Distrito Lage dos Negros situa-se a NW da cidade de Campo Formoso (Figura 1) nos domínios da unidade geomorfológica dos planaltos cársticos da Chapada Diamantina, que se constitui de um conjunto de formas aplainadas e feições estruturais observadas nas rochas carbonáticas da Formação Salitre do Grupo Una (BARBOSA et. al. 1996).

Essa região, por possuir índice de precipitação pluviométrica anual oscilando entre 1792-759 mm/ano e cursos d'água incipientes, possui uma geomorfologia cárstica peculiar, onde predomina o carste encoberto denotados por pequenos dolinamentos com afloramentos lapiezados.

2.2 Hidrologia

A região encontra-se situada na bacia hidrográfica do rio Salitre, afluente do rio São Francisco. Essa bacia engloba as localidades de Campo Formoso, Brejão da Caatinga, Lage dos Negros e Vargem Grande. O seu curso, de direção SW-NE, é predominantemente intermitente com locais de percurso perene, principalmente, na sua extremidade NE. Vários afluentes do rio Salitre, que nascem no lado oeste das serras de Casa Nova e São Francisco, entre eles o riacho Salobro, unem-se ao rio Lage antes dele passar por Lage dos Negros. Já a leste da serra de São Francisco mais alguns riachos também alimentam o rio Lage aumentando um pouco mais sua vazão. A 12 km para leste o rio Lage muda de direção e passa a percorrer a direção SW-NE. Após 15 km, nessa direção, ele passa a se chamar rio Pacuí. O rio Pacuí, perene, possui uma média de 1,5 m de largura por 0,6 m de profundidade e uma vazão aproximada de 240 litros por segundo (BRUNETTO et. al. 1987). Esse rio é afluente do rio Salitre.

2.3. Estratigrafia

Na Região da Chapada Diamantina, o Supergrupo São Francisco (Proterozóico Superior) apresenta suas maiores áreas de ocorrência nas bacias de Irecê e Utinga, e é representado pelo Grupo Una que compreende duas formações: Formação Bebedouro (basal) e Formação Salitre (Figura 1).

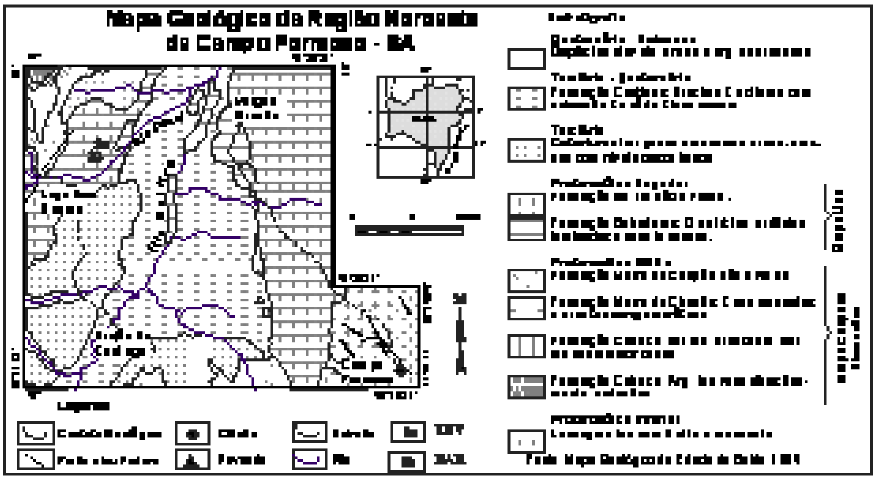


Figura 1 – Mapa geológico da região noroeste do Campo Formoso (BA) onde se encontram as grutas Toca da Boa Vista e Barriguda.

A divisão do Grupo Una, abaixo descrita do topo para a base, foi feita por DOMINGUEZ (1996): **Formação Salitre**: Unidade Jussara: Compreende calcarenitos finos a grossos, calcissiltitos e calcilutitos de coloração cinza-escuro a preta. Esta unidade foi depositada sob a ação de ondas e correntes, sujeito à ação de tempestades. Unidade Gabriel: Compreende intercalações de calcissiltitos, calcilutitos e calcarenitos finos de colorações rosa, creme e cinza. Provavelmente esta unidade foi depositada em zona litorânea (*shoreface*) sob a ação de ondas. Unidade Nova América: Compreende calcilutitos cinza-escuro de acamamento paralelo com espessura centimétrica. Estruturas arqueadas do tipo *tepee* e camadas brechadas com intraclastos tabulares são freqüentes. Esses calcilutitos ocorrem intimamente associados a calcarenitos finos a grossos. Esta unidade é o resultado da deposição em ambiente de perimarés protegidos, tais como lagunas e planícies de maré, freqüentemente expostos a condições subaéreas. Unidade Irecê: Compreende camadas de calcilutitos e calcarenitos finos a médios, de coloração cinza-escuro a negra, de espessura centimétrica, intercaladas com margas e siltitos. Esta unidade é o resultado da deposição em ambiente plataformal, com as camadas de calcarenitos representando deposição durante períodos de tempestade e as intercalações de margas e siltitos como resultado da deposição a partir de suspensão sob condições menos energéticas. **Formação Bebedouro**: Demarca o limite entre os supergrupos Espinhaço e São Francisco na Chapada Diamantina. Compreende diamictitos, ardósias laminadas com seixos pingados, arenitos grossos argilosos, localmente conglomerados com estratificação cruzada, e arenitos finos com laminações plano-paralelas. Esses sedimentos são interpretados como de origem glaciogênica.

2.4. Estrutural

O estado da Bahia pode ser separado em compartimentos geotectônicos, sendo que o local trabalhado (Rio Pacuí) pode ser considerado como pertencente aos domínios intracratônicos da Chapada Diamantina (CD, 18) e bacias de Irecê e Utinga (BIU, 19) sendo que os metassedimentos da Chapada Diamantina estão estruturados em formas de planaltos, suavemente dobrados em sinclinórios e anticlinórios. Nos sinclinórios encontram-se preservadas as seqüências carbonáticas do Proterozóico Superior constituindo as “bacias” de Irecê e Utinga (BARBOSA et al. 1996).

Segundo ROCHA (1996) os calcários do Supergrupo São Francisco, devido à sua plasticidade e resistência ao intemperismo, ocupam as regiões mais baixas, estruturadas por sinclinais em perfeita concordância com os sedimentos mais antigos do Supergrupo Espinhaço (sinclinal Irecê, Rio Salitre, Amauiú e Utinga). Estes grandes sinclinais e os anticlinais correspondentes podem representar o episódio D_1 mais antigo e abrangente que atingiu a cobertura Proterozóica sugerindo que a compressão principal (*stress*) foi originada no sentido E-W. Neste domínio (norte da Chapada Diamantina) é comum a superposição de dobras de eixos perpendiculares com interferência, aproximando-se de figuras do tipo domos e bacias e cisalhamentos intraestratais com deslocamentos de N para S. Nesta região, como em toda a Chapada Diamantina, é também comum a presença do cisalhamento transcorrente (dúcteis e rúpteis) com direções em torno de NNW (dextral) e NNE (sinistral), formando ângulos de 30º e 40º entre si. Estas estruturas transversais superpõem as estruturas longitudinais anteriores e podem ser consideradas como o segundo episódio D_2 da deformação que atingiu a cobertura. A disposição das estruturas, dos estratos, além dos deslocamentos indicados nos planos tectônicos sugerem que a compressão principal ocorreu aproximadamente no sentido N-S (*stress*).

3. Geologia das Grutas: Toca da Boa Vista (TBV) e Toca da Barriguda (BAR)

Esse estudo foi feito com base nos dados obtidos no campo (Figura 3), no estudo petrográfico das amostras coletadas e no tratamento estatístico dos elementos estruturais planares e lineares. Dessa forma foi possível realizar a caracterização litofasciológica e estrutural dessas cavidades.

Pontos descritos: TBV = 45, BAR = 20 (total = 65). Caminhamentos (em projeção linear horizontal): TBV = 6,15km, BAR = 3,62km. Fraturas medidas: TBV = 149, BAR = 43 (total = 192). Eixos de dobras: TBV = 33, BAR = 05 (total = 38).

3.1. Litofasciologia/Estratigrafia

Litofácies CSC: a litofácies calcário (C) - silexito (S) - calcário (C) caracteriza-se pelas intercalações de camadas decimétricas (máx. 0,8 m) de calcário cristalino com camadas centimétricas (máx. 0,2 m) de silexito. Os calcários apresentam cor rosa-acinzentado, textura microcristalina, estratificações e ondulações plano-paralelas, partições de aspecto “plaqueados”, e silicificações sendo portanto duros e compactos. Os silexitos são criptocristalinos, de cor cinza-rosada, compactos e muito duros (não riscam). Os níveis silexíticos quando alterados tornam-se porosos e apresentam estruturas concêntricas, sendo as últimas devido à alteração diferencial dos diversos níveis que o compõem. Esta litofácies CSC está relacionada ao “nível superior” das grutas, definido por AULER & MOURA (1990). Ela ocorre, tipicamente, nas entradas da Toca da Boa Vista (TBV) e Barriguda (BAR). Os contatos superiores e inferiores, dessa litofácies, com as litofácies vizinhas (SCS e CCH), são tipicamente transicionais.

Litofácies SCS: a litofácies silexito - calcário - silexito, que ocorre no ponto BAR-10 (estação topográfica B-79), mostra um predomínio das camadas de silexitos sobre as de calcários. Possui também nódulos lenticulares ligados e isolados de silexitos que, internamente, possuem estruturas concêntricas. A origem desses silexitos está ligada a fluxos residuais de soluções silicosas que percolaram o calcário durante a sua diagênese.

Litofácies CCH: a litofácies calcário cristalino homogêneo apresenta colorações em tons róseos: cinza rosado, rosa acinzentado, rosa claro a rosa médio. Sua textura é predominantemente cristalina média, podendo chegar a cristalina grossa. Apresenta-se, normalmente, homogêneo (CCH), compacto, sem estruturas e pode ser calcítico ou dolomítico. Às vezes, torna-se mais duro e silicoso caracterizando a litofácies calcário cristalino silicoso (CCS). Pode, também, apresentar-se muito fraturado, caracterizando a litofácies calcário cristalino homogêneo fraturado (CCHF) e, localmente, com estratificações cruzadas acanaladas de médio porte (litofácies CEX) e *hummockies*, que são estratificações cruzadas por ondulações de ondas originadas por tempestades. Comumente essas litofácies exibem estruturas estilolíticas. Essa litofácies posiciona-se inferiormente à litofácies CSC, com contato transicional (nível intermediário de AULER & MOURA 1990). O nível inferior das grutas TBV e BAR acha-se totalmente controlado por essa litofácies. Há um predomínio do processo de dissolução da rocha durante sua abertura, por isso os condutos encontrados nessa litofácies caracterizam-se por serem caoticamente labirínticos e arredondados, com marmitas, *pockets* e, também, feições de dissoluções residuais, como pilares e pendentes. O lapiezamento vertical e inclinado é muito comum na rocha fraturada (litofácies CCHF). Os locais de ocorrências típicas das litofácies descritas são: **CCH** = TBV, pontos G-04 (salão Telécio), G-08 a G-10 e BAR, pontos G-04 e G-18. **CCHF** = TBV, pontos G-11, G-22 e G-45. **CEX** = TBV, pontos G-12, G-13, G-14. BAR, pontos G-13 (*hummockies*), G-17 e G-19. **CCS** = BAR, pontos G-12 e G-16. O contato CSC (superior)/CCH (inferior) ocorre em grande parte do Novo Mundo e Boa Vista Clássica (TBV). Especificamente, ele pode ser observado nos pontos da TBV G-07, G-17 (Abismo do Sapo), G-20, G-23, G-30 (Conduto Oásis) e G-42.

3.2. Estrutural

Acamamento

O acamamento, das diversas litofácies, encontra-se essencialmente horizontalizado, localmente, no entanto, apresenta mergulhos das camadas devidos aos dobramentos superimpostos e nas proximidades de falhamentos. O diagrama de pólos (figura 2A) apresenta uma distribuição estatística em forma de “borboleta”, onde as asas dessa indicam as maiores concentrações de medidas, com máximos de 23,5%, nas posições 350/10 e 160/10. Essas concentrações indicam, então, mergulhos baixos do S_0 que ora cai para SSE e ora para NNW. A inclinação real do caimento do mergulho varia de 0^0 a 22^0. Os maiores desses valores estão associados a flancos de dobras. O acamamento pode apresentar-se ondulado (BVG 14) e em forma de suaves “domos e bacias” devidos a redobramentos (dobramentos superimpostos), como no ponto BVG 24. Eventualmente ocorrem, nas litofácies CSC e SCS, lentes e nódulos silicosos “rotacionados”, como por exemplo nos pontos BVG 26 e BVG 36.

Dobras

São comuns na litofácies CSC. As dobras observadas são cilíndricas e assimétricas, com vergências para SE e SSE. Localmente apresentam vergências para NW. Possuem dimensões que vão de centimétricas a decamétricas. São dos tipos suaves (comuns), abertas (abundantes) e apertadas (raras), segundo a classificação de DAVIS (1984). Algumas se encaixam na classificação de RAMSAY (1967), como dobras supratênues, classe 1A, com adelgaçamento da zona apical e espessamento dos flancos (BVG 07). Localmente ocorrem dobras de fluxo do tipo convolutas (BVG 01). As dobras centimétricas são do tipo “bengala” (BVG 01) e as maiores chegam a 40 m de comprimento de onda com 6 m de amplitude, como, por exemplo, no Salão da Dobra (BVG 30). Associadas aos fraturamentos ocorrem dobras de “acomodação” (BVG 27) e nas proximidades dos falhamentos ocorrem dobras parasíticas “de arrasto” (BVG 15). Os eixos desses dobramentos possuem mergulhos generalizados devidos aos dobramentos superimpostos. Essa superposição de dobramentos imprime um padrão de suaves “domos e bacias” no acamamento. Esse caso é bem visível no teto do salão do ponto BVG 24 (estação MK 09). Alguns tetos de condutos são controlados por esses eixos dos dobramentos, como, por exemplo, nos pontos BVG 23 e 34. O estereograma polar (figura 2B) desses eixos mostra uma concentração maior de medidas com caimento para NE. Observa-se, também, nesse digrama uma leve tendência desses valores alinharem-se em dois conjuntos que possuem direções NE-SW e NNW-SSE. Algumas ocorrências típicas dos dobramentos podem ser relacionadas: a) bengalas e convolutas (BVG 01); b) dobras suaves a abertas: (BVG 02, 14, 17 29 e 30, BAR 01, 05 e 06); c) dobramentos intraestratais assimétricos com vergência (BVG 18 (NW), 25 (SE), 33 (SE), 34 (SE), 39 (SSW) e BARG 06 (Salão Saleste)); d) dobras apertadas com rotação de blocos (BVG 36).

Juntas

As juntas encontradas e medidas são essencialmente verticais e constituem, de acordo com o diagrama de rosetas (figura 2C), três conjuntos, sendo dois maiores e um menor: 1) um maior de direção NNW; 2) outro maior de direção ENE; e, 3) um menor de direção NW-SE. Os dois primeiros conjuntos podem ser correlacionados às direções dos eixos de dobramentos, sendo, portanto, paralelas às direções desses eixos. O terceiro conjuntos eqüivale à bissetriz do ângulo reto formado pelos conjuntos 1 e 2. Os conjuntos 1 e 2, paralelos aos eixos e planos axiais dos dobramentos, podem ser considerados como sendo uma foliação plano axial incipiente (?), como observada no ponto BVG 28, onde as juntas estão orientadas segundo direções plano-axiais. Nas cavidades, as juntas estão lapiezadas, como nos pontos BVG 04 e 14, e outras formam pares cisalhantes conjugados, típicos, como nos pontos BVG 08, BARG 11 e 19. Alguns condutos mostram evidente controle estrutural, pelas juntas, como nos pontos BVG 27, BARG 07 e 20. No ponto BVG 12 (Salão dos Discos Voadores) ocorre uma grande fratura (150/90) associada a *tension gashes*. O ponto BVG 18 foi o que mais apresentou medida de juntas (17) e onde foi estimada uma densidade de 38 juntas por metro linear. O conduto do ponto BARG 17 está controlado por um sistema de 2 fraturas que possuem traços anastomosados no teto.

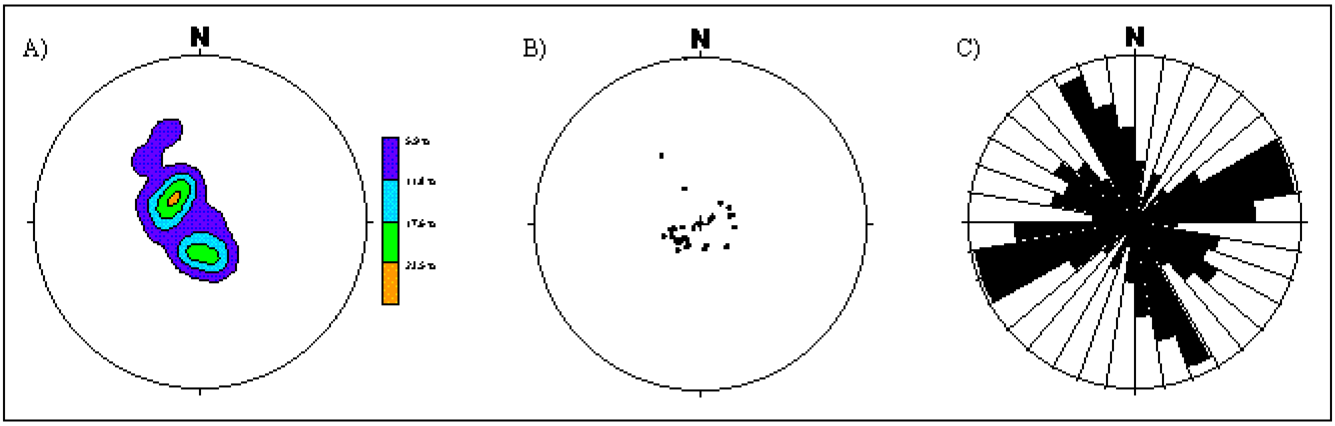
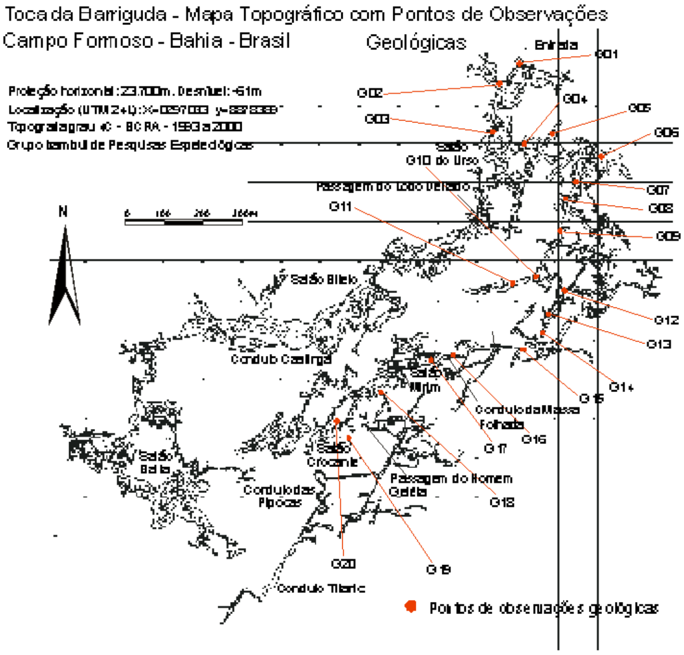


Figura 2 – Representações estereográficas das estruturas geológicas das grutas Toca da Boa Vista e Toca da Barriguda. A) acamamentos; B)eixos de dobras; e, C) juntas



Falhamentos

Evidências de falhamentos foram encontrados em diversos pontos das gutas TBV e BAR. Principalmente nas proximidades do chamado “inimigo Invisível”, o que nos leva a sugerir que o desenvolvimento lateral, dessas cavernas, está condicionado a falhamentos que as bordejam. Futuras investigações podem vir a confirmar que este “inimigo invisível” consiste de falhas, inversas, que limitam e controlam o desenvolvimento lateral dessas cavidades. As evidências mais claras de cisalhamentos foram observadas desde o ponto BVG 11 (litofácies CCHF) até o ponto BVG 15. São elas: a) intenso fraturamento (BVG 11); b) fraturas associadas a *tension gashes* (BVG 12); e, c) dobras de arrasto em contato litológico (BVG 15). A continuação desse falhamento ocorre no final do salão do Conduto Açungui (BVG 36), onde dobramentos assimétricos apertados associam-se à rotação de blocos e no ponto BVG 35 o redobramento mais intenso provocou falhamentos evidentes, também, pelo aumento significativo no conjunto de espeleotemas, nesse local. Outra região que, futuramente, merece ser mais investigada e que, provavelmente, encontra-se próxima a zona de falhamentos é a do Salão da Dobra, onde abaixo da grande dobra ocorrem níveis de silexito redobrados em formas caóticas.

Nos argilitos do Salão da Miragem (BVG 29) foram observados espelhos de falhas com a presença de *slickensides*.

Outras feições

Lineações minerais foram observadas com direções perpendiculares a *steps* em flancos de dobras, de dimensões métricas no ponto BARG 08, denominado de Salão das Duas Dobras.

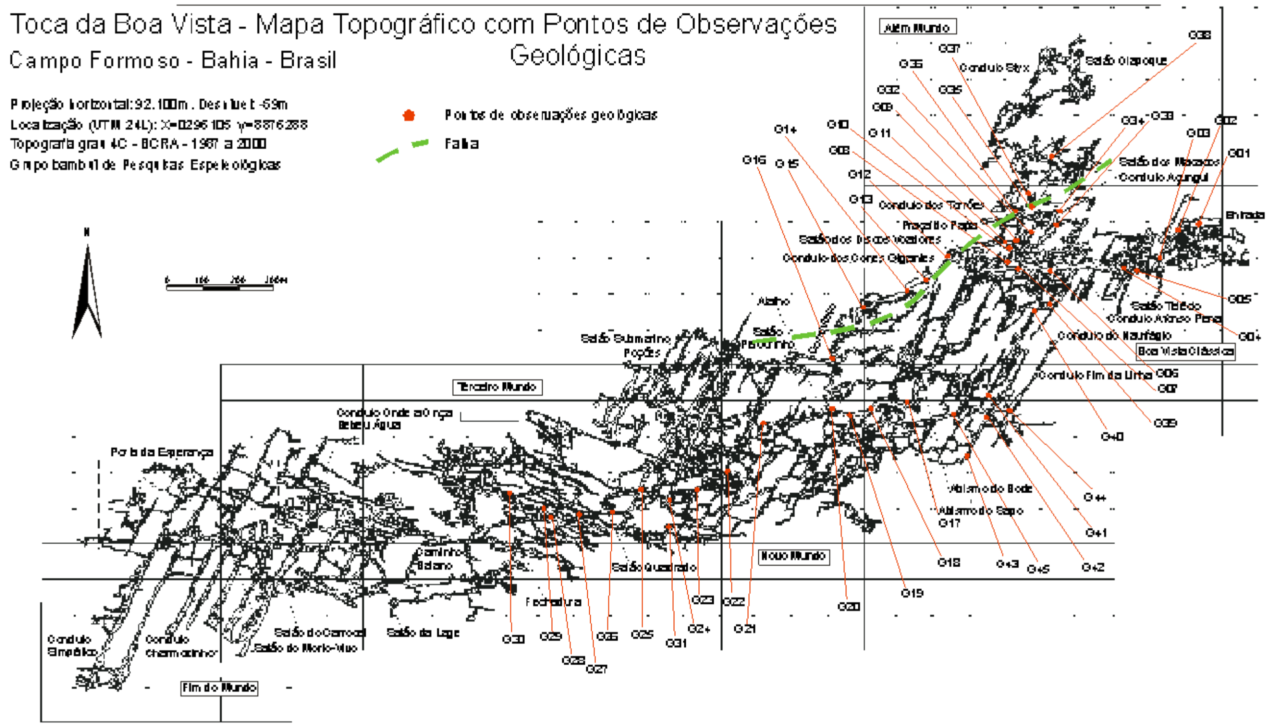


Figura 3 - ***Mapas topográficos da Toca da Boa Vista e Toca da Barriguda, Campo Formoso (BA) contendo os pontos onde foram realizadas observações sobre acamamento, juntas, dobras, falhamentos e outras feições geológicas, pela SEE em janeiro de 1998. Modificado de GBPE 2000.***

4. Considerações Gerais

As grutas Toca da Boa Vista e Barriguda desenvolvem-se em rochas carbonáticas, cujas litofácies principais são CCH, CSC e SCS. Essas litofácies podem ser correlacionadas às unidades Gabriel e Nova América, da Formação Salitre, Grupo Una, da seguinte maneira: litofácies CCH e subfácies, Unidade Gabriel; litofácies CSC e subfácies, Unidade Nova América.

Os elementos estruturais encontrados, como os eixos de dobras redobrados e feições do tipo domos e bacias, confirmam a estruturação regional proposta para a área (ROCHA 1996), onde os episódios de deformação, em número de dois, são: deformação com *strain* E-W (D1) e deformação com *strain* N-S (D2).

Os calcários podem ser, petrograficamente, classificados, de uma maneira geral, como calcários dolomíticos cristalinos.

AULER (2000) sugere um processo de desenvolvimento hipogênico dessas cavidades (TBV e BAR) com dissoluções por soluções ricas em H_2S, em rochas não fraturadas, e propõe uma classificação do tipo *SPONGEWORK*. Os dados estruturais apresentados neste trabalho, que estão de acordo com os dados regionais levantados por ROCHA (1996), evidenciam uma estruturação, pré-dissolução, encontradas nas rochas hospedeiras, com predominância de juntas verticais de direções aproximadas NS e EW. Assim acredita-se que a classificação mais correta para essas cavidades seria o padrão *NETWORK* (PALMER 1991), que explicaria, também, o tipo de planta baixa reticulado apresentado por elas.

Evidências de falhamentos foram encontradas na porção norte da TBV, Salão dos Discos Voadores e dos Cones Gigantes, como locais intensamente fraturados, *tension gashes* e dobras de arrasto. Essas evidências parecem indicar que essas cavidades são controladas, lateralmente, por zonas de falhas inversas.

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Radon Studies in Jenolan Tourist Caves, New South Wales, Australia

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Radon studies have been carried out for the past ten years at the Jenolan Tourist Caves, New South Wales, Australia. Extensive clastic sediment deposits found within the cave system have been identified as being the major radon source. By grab sampling it has been shown that radon levels within the caves vary over a wide range both diurnally and seasonally as well as varying spatially. A number of sites have been continuously monitored for radon and radon progeny in order to determine the average conversion factor necessary to determine radiation doses from radon measurements. Because of the different times that the cave guides and maintenance workers spend at various locations in the caves it is impossible to calculate the dose they would receive from their work place using the data accumulated from grab or continuous in-situ sampling. Thus, in order to fulfil its duty of care, the Jenolan Caves management has instituted a badge program that provides a measure of personal exposure of the cave guides and maintenance workers. The methods, results and conclusions of a one-year study at Jenolan Caves will be used to illustrate the paper.

The Jenolan Caves are 110 km west of Sydney (Figure 1). These caves are one of Australia's most spectacular and well-known natural resources, and lie within the Blue Mountains World Heritage Area. They have an international reputation for their varied, numerous, and colourful speleothems.

Figure 1 Location of Jenolan Caves

In 1991, Basden and James (Lyons 1992) measured high levels of radon in sections of the tourist caves at Jenolan. In some instances these levels exceeded 1000 Bq m^{-3}, the environmental safety level for radon in the workplace (NH&MRC and NOHSC 1995); above this level, affected areas must be ventilated. Radon is hazardous because it is a radioactive gas that decays via alpha particle emission into products that are themselves radioactive as well as short lived. As part of a more detailed survey, Solomon *et al*. (1995) concluded that the radon levels at Jenolan Caves were not hazardous to cave tourists but presented a possible health risk to cave workers.

Not wishing to ventilate the caves, yet needing to fulfil its duty of care to the cave guides and maintenance workers, the Jenolan Caves management supported a number of investigations into radon within the tourist caves. These studies proposed to determine the radon source, how it varies and what the variations depend upon, and whether there is a risk to cave workers at Jenolan Caves.

The source of radon within the caves at Jenolan was established as being the clastic sediments. These sediments are extensive and widely distributed throughout the caves and their associated passages.

Furthermore, it was realised that there was no way in which the radon emission from the sediments could be controlled that would not also harm the caves.

A second study of grab sample and continuous measurements established the spatial distribution and seasonal variation of radon within the northern section of the Jenolan tourist caves (Figure 2). Not only were radon levels found to exceed 1000 Bq m^{-3} at some sites, usually those deep in the caves, they exceed that value in all seasons. The northern Jenolan caves are entered from the Grand Arch and it is in their far reaches that radon levels of over ten times the allowable level have been measured. High radon levels are experienced in the areas of cave containing sediments or with sediment in the nearby passages.

The diurnal variation during summer at the same sites (Figure 3) was also measured. Moreover, it was found that radon levels varied from year to year dependent upon climatic conditions. In addition, continuous measurements showed that on most days radon levels peak in early afternoon, corresponding with the time of peak usage.

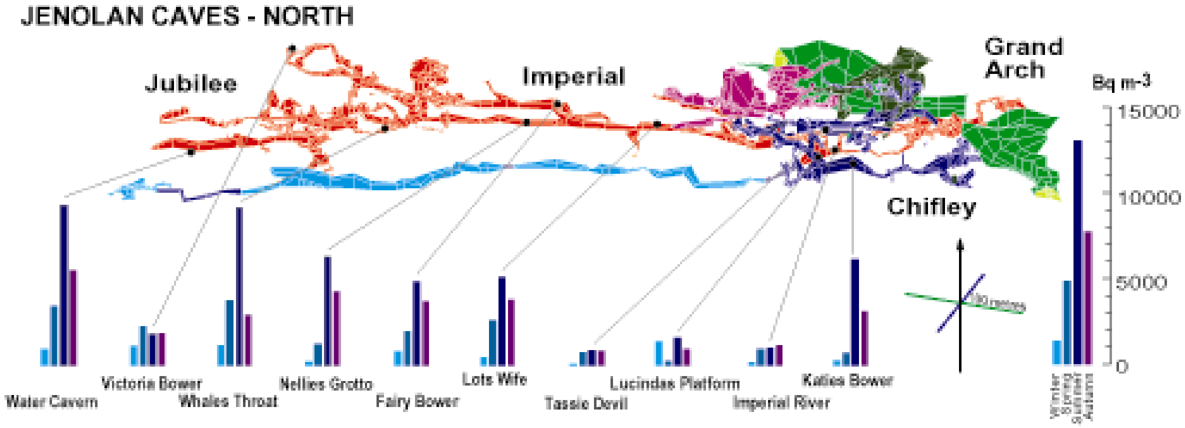

Figure 2 Distribution and Variation of Radon at Jenolan (N)

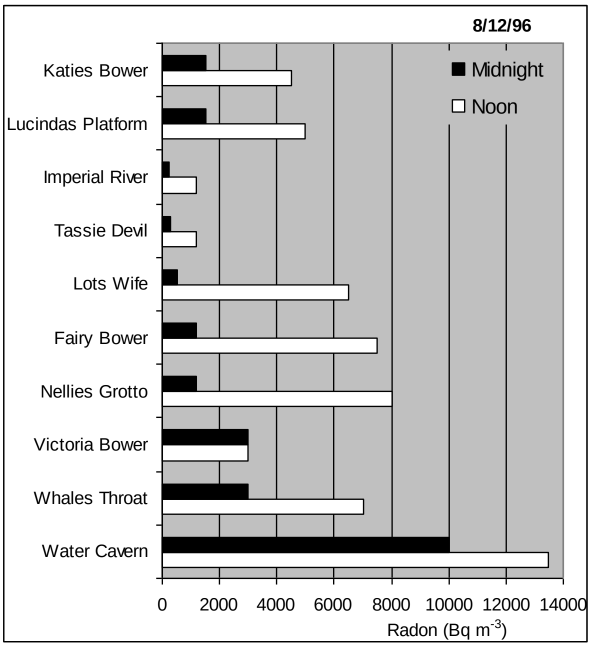

Figure 3 Diurnal variation of Radon

A contemporary study was aimed at determining whether to measure radon or its decay products (progeny) in order to assess the health risk at the caves due to exposure to radiation. Theoretically, the radon progeny should be measured as they present the greater health risk. Radon being an inert gas, is breathed into the lungs and out again. And, despite its short half-life of 3.8 days, the probability of it decaying whilst in the lungs is low. On the other hand, the progeny are chemically reactive, radioactive species of very short half-lives, in the order of minutes. If breathed in, there is a good possibility of reaction with the sensitive tissues of the respiratory tract and lungs, where they can become trapped, and where they can do the most damage. Furthermore, their own decay products are radioactive as well, and so enhance the hazard posed.

The progeny, however, may become attached to fine particles in the air, reducing their hazardous potential (Solomon *et al*. 1992, Solomon 2001). When attached to such particles, the progeny are referred to as "attached progeny". These fine particles and attached progeny are deposited in parts of the lung that have an effective cleaning mechanism, which can act to protect these sensitive tissues. The “unattached” progeny do not progress as far into the respiratory system. Although their momentum is the same, their speed of movement is much greater than that of the attached progeny, meaning they come into contact with the walls of the airways much earlier.

So, as an added complication, the hazard of the progeny depends on the proportion which are attached to particles. For instance, in an atmosphere with a given radon concentration and few fine particles, there will be a high proportion of unattached progeny, suggesting a significant hazard. But as unattached progeny interact with nearby surfaces more readily, the number of unattached progeny is reduced. This means, however, that there will be a lower total concentration of progeny in the air, but those that are there will be more hazardous.

Although the hazard is proportional to radon progeny concentration, measuring just the total concentration of progeny is an inaccurate measure of the hazard since the conversion factor varies according to the ventilation rate, fine particle size and concentration, as well as the detailed geometry of the immediate environment. In practice, it is usually more accurate and much simpler to estimate radiation exposure from radon concentration rather than from total radon progeny concentration.

In 1998, Zahorowski *et al* conducted an intensive 6 month survey of two chambers at Jenolan Caves, the results of which indicate that dose estimates based on the ICRP-65 convention (ICRP Publication 65, 1994) should be increased by 50% for these caves. The ICRP-65 convention was derived from radon and dose measurements from factories and homes. Caves, however, tend to have lower ventilation rates and lower particle concentrations than homes and this leads to a given radon concentration being more hazardous. Subsequent analysis by Zahorowski *et al* (1998) of a longer time series of data showed that a factor of 2 increase is necessary to allow for the special attributes of the cave atmosphere at Jenolan.

The conclusion reached at the end of these studies was that neither grab sampling nor continuous measurements of radon or its progeny were of use in establishing the level of health risk to an individual, particularly as these types of measurement are site-related. Consequently, such measurements cannot accurately estimate the exposure to an individual who moves between sites. Furthermore, any method of assessing the risk associated with exposure to radon-laden air is dependent upon the stability of the parameters under which the measurements are conducted. And, it has been shown at Jenolan that, over time, radon concentrations do not follow any predictable pattern. To overcome these problems, a reliable method of measuring personal exposure was needed.

There are two types of personal monitors: progeny monitors and radon badges. Radon progeny monitors are expensive - around US$10,000 per unit - and conspicuous. Although portable and computerised, they are also heavy, containing a large battery and air pump. The batteries need recharging on a daily basis and the on-board memory requires downloading to an external computer system for storage. They do have a considerable advantage in that the dose is immediately available but the reliability of that result depends upon the conversion factor utilised.

Radon badges are simpler and less expensive (~US$40) than progeny monitors, and require no power or computer back-up on-site. But, no instantaneous dose result is available, as the badge needs to be analysed in a laboratory.

Radon Badge Method

The personal radon monitors used at Jenolan consisted of a piece of TED[#] material in a permeable plastic container roughly 5 cm in diameter, conveniently and innocuously designed as a badge that clips onto clothing or a belt. These were provided to Jenolan Caves management by the Australian Radiation Protection and Nuclear Safety Agency (ARPNSA), who also analysed the TED material and produced the dosage reports. The guides and maintenance workers were required to wear the badges at all times at work, with a control kept in the Guides Office. Badges were kept in the same location as the control when not being

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[#] Track etch detectors (TEDs) are film-like materials that are sensitive to impacts by alpha particles, and thus can record the decay of radon by exposure to radon-laden air. The TED needs to be analysed in the laboratory as an etching process is used to bring out the impact craters which are then counted.

worn. The guides and maintenance workers also kept journal records of the hours spent per day underground. Together the radon exposure measured by the badge, and the recorded hours underground, were used to determine the dose accumulated by the cave workers in the caves.

It was decided that, to avoid over exposure of the TED material, the badges should be analysed every 3 months and on a seasonal basis, corresponding to the same periods of measurement used in previous studies (eg. Figure 2). After 2 three-month periods, corresponding to summer and autumn, it was decided that a six-month exposure time over winter and spring would not lead to over exposure of the TEDs. A total of 20 badges were used (19 cave workers and a control). Although complete records of radon exposure were obtained, ten of the time keeping journals were incomplete due to periods of leave and turnover of staff.

Results and Discussion

The results of the badge program at Jenolan, conducted over several years, are shown in Figures 4, 5 and 6. Figure 4 shows the radon exposure for cave workers for the year 1999. As can be seen, no individual received a total exposure greater than 14 mSv. The allowable exposure limit for a "radiation worker" is 20 mSv per year averaged over 5 years (Solomon *et al*. 1996). The same graph also illustrates the seasonal variations that occur in the exposure, and endorses that radon levels are highest during summer as shown in Figure 2. There are clearly anomalies in the records shown in Figure 4, such as that of badge 18, which may be explained by the worker concerned being deployed in regions at the end of the cave system where the radon level is continuously high (Figure 2). No attempt has been made to link recorded level of exposure to site within the cave system.

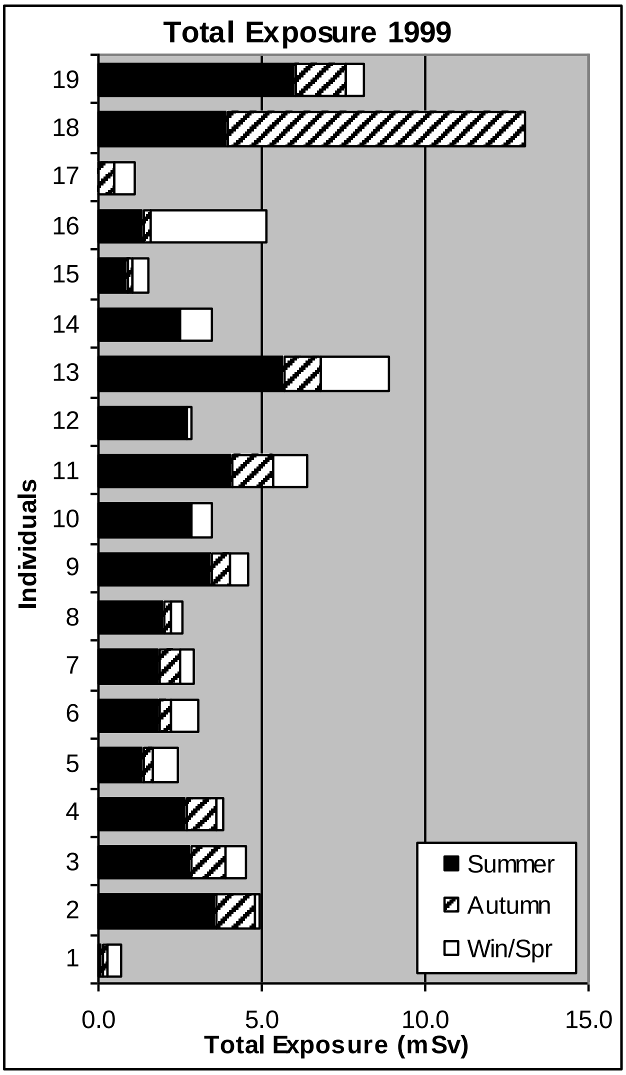

Figure 4 Measured Exposures by Badge Monitors

The management of the Jenolan Caves, after the publication of the Worksafe Report (Solomon *et al*. 1996) into occupational exposure to radon by cave workers, set a working limit of 1000 hours underground. Figure 5 extrapolates, for those cave workers where complete time keeping journals were available, the doses shown in Figure 4 to an estimated exposure for 1000 hours underground during 1999. The extrapolation was necessary because no cave worker at Jenolan Caves was underground for more than this time limit while at work. In this case, it is readily seen that no cave worker approached the limit set for a radiation worker (ie. 20 mSv), and only one individual exceeded half that limit.

Figure 6 shows the variation that can occur in exposure measurements between two consecutive years, proving that regular exposure measurements need to be taken. From the graph, the radon exposure measured during the 1999-2000 period was considerably lower than that of the 1998-1999 period. This corresponds to very different climatic conditions experienced in those two years at Jenolan, illustrating further the unpredictability of the radon levels from year to year as well as season to season.

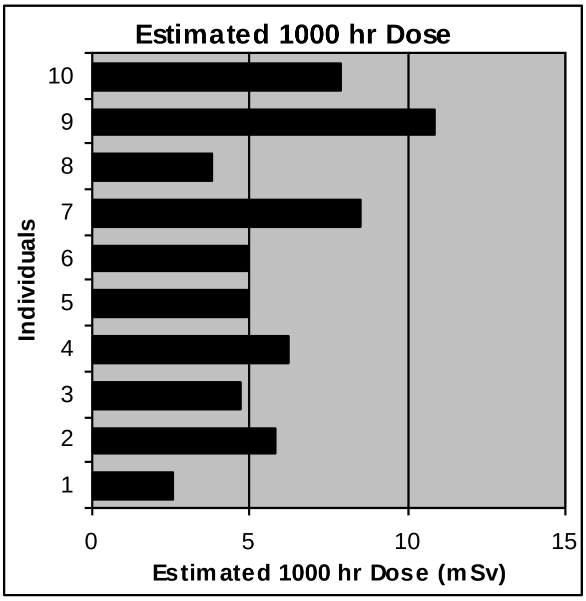

Figure 5 Estimated 1000 hour Exposure

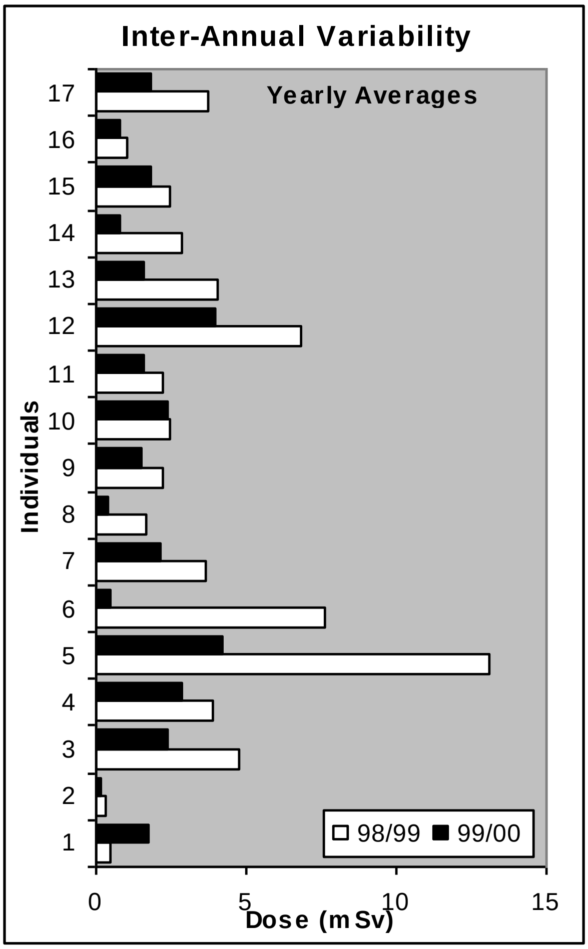

Figure 6 Yearly Variations in Dose Measurements

Conclusions

The studies of spatial, seasonal, diurnal and annual variation of radon at Jenolan Caves endorsed previous findings that there was no risk to tourists while also confirming that there could be a risk to cave workers. After careful consideration of a number of studies it was clear that the risk to cave workers could not be assessed from the site specific radon studies. Therefore, it was concluded that a badge program was needed to assess the risk to cave workers. Additional studies at Jenolan Caves led to the conclusion that it was preferable both scientifically and economically to use personal monitors that measured radon rather than radon progeny.

The badge program conducted at Jenolan Caves has successfully shown that, in the years 1998-2000, the health risk due to exposure to radon decay was not at a hazardous level. It confirmed that in environments such as caves the use of personal badges is necessary to properly assess any hazard due to radon. The badge program has shown that deployment of workers in the high radiation areas could conceivably lead to unacceptable doses. Although the badge program has only been in operation for 2 years, the results obtained indicate that the doses need to be monitored on a regular basis. Consequently, the management at Jenolan Caves has decided to continue the program.

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Quantitative Assessment of the Potential for Karst Features to Lead to Caves in a Topographically Subdued Karst Landscape

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Abstract

The environmental impacts of urban developments in topographically subdued karst areas are often difficult to predict. The small karst features typical of such areas are seldom visible on aerial photographs and topographic maps and are hard to find and assess in the field. Carefully designed grid searches are needed to find the features. At least some excavation is critical to accurately describe them. If local karst development is adequately understood, a model can be developed to quantitatively assess the descriptions of the karst features and accurately estimate their potential to lead to caves, which are the sites of highest hydrologic significance and environmental vulnerability. This information can be applied to guide urban development away from the most sensitive areas. However, we must keep the perspective that karst areas as a whole are vulnerable, and karst features represent only the most visible and sensitive features within a highly sensitive and permeable terrain.

Introduction

As urban areas increasingly encroach on karst terrains, there is greater need for the assessment of their likely impacts on water quality and quantity and on subterranean karst ecosystems. Dye tracing is one long-used and effective method of determining which wells and springs may receive contaminants from potential urban developments. Geophysical techniques can be used to determine the likely presence or absence of caves in certain locations. Doerfliger and Zwhalen (1997) developed the EPIK method to assess hydrologically vulnerable areas in karst spring drainage basins through the use of air photo interpretation, tracer tests, geophysical data, and geomorphological mapping. In 1999, Veni proposed an evaluation strategy using only geomorphic observations for karst areas where tracer and geophysical tests, that other assessment methods rely upon, are not available or not feasible within the scope of a particular study.

In the United States, Texas is one place where karst areas are primarily assessed by locating karst features and evaluating them solely on their morphology. Tracer and geophysical tests are rarely performed since they are not mandated by state water protection regulations, and few businesses or agencies will fund any research methods not required by law. The difficulties in assessing such areas is increased in Texas by the presence of a topographically subdued karst landscape, where high permeability features that often lead to hydrologically and biologically significant caves have little or no expression on the land surface. The purpose of this paper is to describe a quantitative method proven effective in studying such areas in Texas and which may prove useful elsewhere. Some specific aspects of this method will not directly apply to other karst areas, and will need adjustment according to the local hydrogeologic setting.

Collecting Field Data

Topographic maps and aerial photographs are of limited value in assessing subdued karst terrains. They should be examined, but karst features are generally too small or shallow to appear. Their primary value is in locating relatively large geologic features, like fractures, folds, and geologic contacts, and in reflecting the overall hydrologic setting.

Small karst features are best found by conducting an intensive grid search of the study area. Typically, a team of 3-5 people, spaced about 15 m apart, walks perpendicularly from a linear landmark (such as a road or fenceline) or along a compass direction to a defined destination. The outer edge of the transect is marked with biodegradable flagging (i.e. toilet paper), so that upon reaching the end of the transect, the team shifts to that side, uses the flagging as a guide, and walks back in the opposite direction searching the adjacent area. This technique discovers most karst features within an area, although some small features with little surface expression may still be missed. The 15-m-spacing could be changed if warranted by local conditions, but it is effective for most topographically subdued terrains. Wider spacing usually misses too many features, and narrower spacing significantly increases search costs for generally little additional information. Any discovered features are marked with metal tags and long strips of brightly colored plastic flagging tape; their identification numbers are then engraved on the tags and marked in waterproof ink on the tape. Each feature's location is marked on a topographic map and its Universal Transverse Mercator coordinates are recorded from a GPS unit, including the estimated position error.

Upon discovery, each feature is sketched and described on a form that requests the following information:

- Lithology
- fractures and attitude of bedding
- size and depth
- airflow
- cavernicolous fauna
- size of recharge area
- type of recharge (steam, floodplain, sheetflow, etc.)
- type and permeability of sediment fill
- feature type

The date, survey team, and other information are also recorded, and the feature is photographed. Once a karst feature is recorded, a reconnaissance excavation is often conducted. These excavations are critical in evaluations of topographically subdued karst areas. An average of 5-10 minutes of hand excavation can distinguish small but actual karst features from non-karst depressions such as old weathered stump holes, animal burrows, and latrine pits. A metal rod should also be used to probe into the soil of karst features in search of shallow voids and to quickly and further estimate the features' origins and permeabilities with minimal additional effort or disturbance. Excavations should not be conducted if a site seems likely to contain cultural or paleontologically significant materials, and should immediately cease if such materials are encountered and not resume until a specialist evaluates the site.

When open caves are found, they should be explored briefly, but sufficiently to describe their general character. Whenever possible, the caves should be revisited and surveyed, not only for their length, depth, and layout, but to include descriptions and measurements of hydrogeologic features including strata, fractures, flow features (including but not limited to scallops, pitting, ponding, and enlarged bedding planes and fractures), sediments, speleothems, bone distribution, water flow, air flow, air quality, and resolution features. If the scope of the study allows, dye tracing is generally encouraged. In some cases, certain karst features may be revisited and fully excavated to determine their significance. Those that open to caves should be surveyed as above.

Quantitatively Assessing Field Data

Veni's (1999) strategy for geomorphologically assessing karst areas requires gathering sufficient information on how karst features occur and are expressed in a particular area in order to accurately predict their significance. This is a critical first step prior to quantitatively assessing the significance of karst features, as described in this paper, especially in topographically subdued landscapes.

Figure 1 illustrates a spreadsheet used to quantitatively assess karst features in central Texas. It is divided into two primary sections: feature characteristics and feature type. Each feature's characteristics are tallied with point values commensurate with each characteristic's significance in demonstrating the permeability of a feature, and hence the feature's likelihood to be a hydrologically significant cave relative to either water quantity or sensitivity to groundwater contamination. The sum of these points is multiplied by a point value assigned to the feature type. Proper interpretation of the feature type is the key to accurately quantifying the features' significance. Figure 1 includes four examples:

- Karst features (KF) 1 and 2 are very small, capture minimal sheetwash, but appear to have permeable soils and are located in a favorable lithology. Their total feature characteristics points are equal. However, under "feature type," KF1 is identified as a solutionally formed sinkhole while KF2 is an epikarst feature. In the study area, sinkholes are highly permeable and hydrologically significant, but epikarst features are usually clay-filled, poorly permeable, and hydrologically less vulnerable. Therefore, the feature characteristics, multiplied by a high feature type number for KF1, rank it as a moderately permeable or significant feature. In contrast, KF2 is multiplied by a low feature type number and gets a relatively low rank.

- KF3 and KF4 have high and nearly equal scores for feature characteristics, yet KF3, an open cave, is ranked at zero significance while KF4, a small sinkhole similar to KF1, is ranked as highly permeable and significant. The reason is that KF3 is a paleospring, a hydrologically inactive conduit that once discharged water but now provides no recharge to the modern aquifer. Its feature characteristic points are multiplied by zero for that feature type.

The strategic importance of excavation in subdued karst areas is also evident in the quantitative assessments. KF1 may have been entirely overlooked, mistaken without excavation as a non-karst depression, and KF2 could have been recorded as a possibly significant sinkhole rather than a poorly permeable feature. KF4 could have been ranked equally with KF1, except that excavation revealed airflow and guiding fractures that suggest a much higher likelihood of the feature leading to a cave.

<table>
<tr><th></th><th colspan="23">Feature Characteristics</th><th colspan="15">Feature Type</th><th></th><th colspan="2">Results</th><th colspan="6">Recharge area (sq. m)</th></tr>
<tr><th></th><th></th><th></th><th colspan="4">Recharge type</th><th colspan="2">Size</th><th colspan="3">Fracture</th><th colspan="4">Lithology</th><th colspan="4">Sediment infill</th><th colspan="3">Topography</th><th></th><th colspan="2">Artificial</th><th colspan="5">Cave</th><th colspan="2">Sink</th><th colspan="4">Solution cavity</th><th colspan="2">Spring</th><th></th><th></th><th></th><th colspan="6">(only recharge features)</th></tr>
<tr><th>Feature name or number</th><th>Airflow (10)</th><th>Cave fauna (8)</th><th>None (0)</th><th>Sheetflow (1)</th><th>Channelized (5)</th><th>Streambed (9)</th><th>Length or width >2 m (3)</th><th>Depth >1 m (4)</th><th>Present (2)</th><th>Guides feature (4)</th><th>Regional trend (6)</th><th>Upper Glen Rose (3)</th><th>Basal Nodular (4)</th><th>Dolomitic (8)</th><th>Kirschberg (7)</th><th>None (10)</th><th>Loose (7)</th><th>Moderate (4)</th><th>Compact (1)</th><th>0-5° (8)</th><th>5-20° (3)</th><th>20-90° (1)</th><th>Feature characteristics total</th><th>Depression (2)</th><th>Well (10)</th><th>Paleospring (0)</th><th>Phreatic (8)</th><th>Spring (2)</th><th>Transitional (9)</th><th>Vadose (10)</th><th>Collapse (6)</th><th>Solutional (7)</th><th>Enlarged bedding plane (3)</th><th>Enlarged fracture (5)</th><th>Epikarst (2)</th><th>Honeycomb voids (2)</th><th>Paleospring (0)</th><th>Spring (0)</th><th>Total (0-720)</th><th>"None" (0), Low (1-150), Moderate (151-250), High (>250)</th><th>Significance (0-10)</th><th><10</th><th>10-100</th><th>100-1,000</th><th>1,000-10,000</th><th>10,000-100,000</th><th>>1,000,000 (>1 sq. km)</th></tr>
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Figure 1: Quantitative assessment spreadsheet for certain karst areas in Texas, USA, with example data and criteria.

Application of the Results

The particular values used in Figure 1 are not important for this paper. They would likely be different for other karst areas and even need to be adjusted when used in different karst areas within Texas. Other characteristics and feature types may need to be added for other karst settings. What is significant is that the results can be used to quantitatively identify areas where karst features are more likely to lead to caves of greater hydrological and biological vulnerability to groundwater contamination. Assessments such as this have been successfully used to guide the placement of highways and other urban developments to less environmentally sensitive routes through karst areas. Veni (1999) reported using this method to correctly assess 76 of 98 karst features that had no reconnaissance excavation, confirmed by complete excavation of the features, and 93 of 98 features that had reconnaissance excavations.

Karst areas are generally the most environmentally sensitive of terrains and among the most complex and least understood hydrologic and geomorphic systems. While the quantitative assessment method described here is effective at identifying karst features that are likely to lead to caves, use of this method alone will not prevent groundwater or ecosystem degradation. Data from several studies clearly demonstrate that in pollution risk assessments of karst aquifers, conduit development is of secondary importance to the type of land use in the recharge area due to high non-conduit permeabilities (e.g. Ogden et al., 1991). This assessment method only identifies the most sensitive features in highly sensitive terrains. Karst features with “low” sensitivity or permeability should not be considered as having no sensitivity to adverse impacts. They are low only relative to other karst features and may still be environmentally vulnerable.

Conclusions

Successful management of karst terrains in urban environments is best achieved by preserving the most vulnerable features and drainage basins in their natural state, coupled with minimizing pollutant loading of the aquifer. In topographically subdued areas, intensive and systematic searches are needed to locate karst features, and reconnaissance excavations are needed to properly assess them. Compilation and study of factors locally important to cave development can be used to develop accurate methods to quantitatively assess karst features. Once established, such methods can be used to identify areas of greater sensitivity to environmental impacts and to divert those impacts to less sensitive locations.

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Geoespeleologia das Cavernas do Inficionado - Minas Gerais, Brasil

[Geospeleological Study of Inficionado`s Caves - Minas Gerais, Brazil]

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Abstract

Caraça Range is located in the *Quadrilátero Ferrífero*, in *Minas Gerais* state, Brazil. The *Inficionado* Peak is the second largest altitude of the Range. The lithology of caverns is quartzite founded in the *Inficionado* Peak. In this lithology development the *Centenário* cave, the largest of the world. The *Centenário's* cave has 3.800 m (BCRA-4C) of labyrinthine passages, with a height difference of –481 m, considering its upper and lowermost parts. The caves development along fractures. The main factor of development of this caves are the mechanical erosion. Another caves are exploring, example is the *Bocaina* cave, with big possibilities, is between the 10 biggest cave's in quartzite of the world.

Resumo

A Serra do Caraça situa-se no Quadrilátero Ferrífero, no centro do estado de Minas Gerais, Brasil. O Pico do Inficionado (2.068m) é a segunda maior altitude da Serra do Caraça e sua litologia é caracterizada por quartzitos. Neste Pico e nos arredores encontram-se várias cavernas e abrigos, entre as quais se destaca a gruta do Centenário, a maior do mundo nesta litologia. Os condutos formam uma rede labiríntica quadrática atingindo a profundidade de – 481m de desnível e somando 3.790 m de projeção horizontal (4.700m de desenvolvimento linear). As cavernas exploradas desenvolveram-se através da erosão mecânica e estão condicionadas estruturalmente por falhas. Além desta cavidade já foram exploradas outras 6 cavernas. A gruta da Bocaina que está sendo explorada atualmente (1999-2001) já está entre as das 10 mais profundas cavernas em quartzito do mundo, tendo potencial para novas descobertas.

Introdução

A Serra do Caraça localiza-se no Quadrilátero Ferrífero, porção sudoeste (figura 1), constituindo-se das mais elevadas altitudes desta região, onde o modelado é sustentado por quartzitos. Dentre os picos mais elevados destacam-se o Pico do Sol com 2.072 m e o Pico do Inficionado com 2.068 m de altitude. As estruturas observadas no maciço do Inficionado devem-se ao controle estrutural, onde o relevo foi esculpido por uma rede de drenagem tributária do rio Doce. A rede de drenagem está condicionada por descontinuidades estruturais, tais como falhas, fraturas, acamamento e/ou xistosidade.

Nos quartzitos do Pico do Inficionado desenvolvem-se grandes abismos e cavidades (figura 2), caracterizando-o uma interessante feição morfológica. Ressalte-se que existem cavernas e abrigos em outros picos da região, assim como nos locais topograficamente menos elevados (figura 3).

O clima foi fator preponderante para o desenvolvimento das feições espeleológicas, sendo que em altitude têm-se um microclima próprio, bem mais úmido, frio e com amplitude térmica considerável, distinto do encontrado nos arredores.

Dentre as cavidades destaca-se a Gruta do Centenário, a maior do mundo em quartzito. Além desta cavidade foram exploradas as grutas do Centenário II e III, do Centum, do Bloco Suspenso, da Fumaça e da Bocaina. Em algumas cavidades foram observados pequenos espeleotemas de sílica amorfa (opala - α) indicando uma certa solubilidade.

Geologia

Em termos de situação geotectônica, o Quadrilátero Ferrífero localiza-se no sul do cráton de São Francisco (Arqueano) sendo posteriormente retrabalhado no ciclo Brasiliano (ALMEIDA, 1977). Afloram na região rochas pertencentes ao complexo granito-gnáissico de idade Arqueana e rochas supracrustais (Supergrupo Rio das Velhas e Minas) do Arqueano e Proterozóico.

Geologia Local e características das cavidades

No maciço do Inficionado observam-se rochas pertencentes ao Supergrupo Minas, Formação Moeda. Consistem de sericita-quartzo xistos e quartzo-sericita xistos de coloração branca, cinza, amarelada e avermelhada, coesos, granulação fina a média, foliação proeminente. Podem ser encontrados também níveis de microconglomerados suportados pela matriz com seixos de quartzo subarredondados e estruturas primárias como acamamento e estratificações cruzadas acanalada e tabular planar de pequeno e médio porte. A sericita ocorre em filmes intercalados com níveis quartzosos; localmente observam-se cianita associada a veios de quartzo, podendo apresentar-se nas cores preta ou azul. Em lâminas delgadas (RIBEIRO-RODRIGUES, 1992) observa-se clastos e porfiroclastos de quartzo com extinção ondulante, feições de dissolução por pressão e recristalização pós-deformacional. A deformação evidencia uma foliação oblíqua ao acamamento.

Quando da exploração das cavernas nota-se uma interessante diferença de resistência nos quartzitos. A parte superficial é dura, coesa, mostrando recristalização e textura sacaroidal. Na porção intermediária do abismo têm-se uma rocha friável com alto teor de umidade. Estas camadas de resistência variável alternam-se nos abismos dificultando a exploração. São camadas de espessura métrica a dezenas de metros. Os contatos são bruscos.

Estruturalmente nota-se a presença de dobras e falhas, e entre as falhas sigmóides (figura 4) de dezenas de metros. As falhas horizontais ou subhorizontais são falhas de cavalgamento que possibilitaram o aparecimento da Serra do Caraça através da repetição de camadas. As falhas horizontais marcam planos de desenvolvimento subhorizontais na caverna. Freqüentemente observam-se veios de quartzo com cianita associados a estas falhas. Às falhas verticais invariavelmente associam-se abismos.

A morfologia das cavidades é labiríntica quadrática com condicionamento estrutural. Os condutos principais possuem direção de 280º a 300° e os condutos secundários variam, direção norte-nordeste, direção 145°. Alguns destes condutos secundários formam rampas, caracterizando fraturas com mergulho aproximado de 70° a 80°, que interceptam os condutos principais em diversos níveis. O desenvolvimento é preferencialmente vertical.

As seções são retangulares verticais com larguras variando entre 0,30 metros ou menos a 10,0 metros nos salões, sendo a média em torno de 1,0 metro. As alturas das galerias chegam a dezenas de metros, sendo poucos os locais onde é possível observar o teto. Em alguns locais o teto é formado por blocos encaixados nas fendas.

A composição do piso pode variar, de rocha, blocos de quartzito, guano de andorinhão formando pilhas métricas e areia, esta última somente nas partes planas ou onde o córrego não corre mais

Na Gruta da Bocaina foi observado depósitos aluvionares, compostos de areia e seixos subangulosos de quartzo branco, tamanho entre 1,0 cm a 2,0 cm.

Os espeleotemas ocorrem nas paredes e tetos de condutos secos, sendo observados na Gruta do Centenário, na parte Clássica, no Conduto do Areião e no Salão do Abismo da Velozia. As formas lembram coralóides, couves-flores, cogumelos do tipo “orelha de pau” e pequenas estalactites. O espeleotema foi confirmado como sendo de OPALA (tipo A, de Jones e Segnit, 1971) através de difratometria de raios X.

A origem das cavernas parece associar-se ao alargamento de falhas e fraturas através de intemperismo. A presença de blocos suspensos nos abismos denotam o fenômeno de incasão. Foram exploradas as Grutas: Bloco Suspenso, Fumaça, Centum, Centenário II e III além da Gruta do Centenário e Gruta da Bocaina.

A Gruta do Centenário possui 3.790 m de desenvolvimento e um desnível total de –481 m, sendo que a entrada superior encontra-se a 2.051 m de altitude, quase no cume do Pico do Inficionado (figura 2).

A Gruta da Bocaina situa-se a sul do Pico do Inficionado, em uma fenda paralela à do Centenário e demais cavernas da região. A entrada caracteriza-se por um abismo com -116 metros de profundidade, onde existe um patamar a – 80 metros. Este patamar possui diversos blocos encaixados devido a presença de um estreitamento vertical na fenda.

As cavernas não se restringem ao Pico do Inficionado, podendo ser observadas também no Pico do Sol (Barrio e Prucha, comunicação verbal) e na Cascatona, corroborando a existência de uma província espeleológica em quartzito.

Geoespeleologia

A gênese das cavernas no maciço do Inficionado relacionam-se principalmente com o tectonismo e erosão mecânica. Os grandes movimentos tectônicos a que foram submetidas estas rochas originaram falhas e fraturas. Através dos séculos estas descontinuidades sofreram alargamento devido a erosão mecânica. Os agentes desta erosão ainda não foram delimitados, sendo que a contribuição de água é essencial. A dúvida persiste sobre a erosão oriunda de gelo e neve, devido à antiguidade das rochas.

Na erosão mecânica por água têm-se fragmentos de quartzo utilizando a água como meio de transporte. Neste trajeto os fragmentos colidem entre si e com as paredes, formando e/ou alargando os condutos. Como exemplo desta gênese pode-se citar os "tuboáguas" na Gruta do Centenário.

Está sendo avaliada a relação entre o pH e o início da erosão e/ou abrasão. A grande quantidade de guano de andorinhão deixa o meio onde o mesmo está depositado com pH ácido. Medidas preliminares (total de 15 medidas) nos depósitos de guano indicam pH variando de 3 a 7. O pH da água varia de 5 a 7. A matéria orgânica encontrada em superfície também deixa o pH localmente ácido.

Forte aliado do crescimento das cavernas são os desmoronamentos, ocasionados por diversos fatores, onde talvez o principal seja o intemperismo. A amplitude térmica no topo do Pico do Inficionado é elevada propiciando a variação do volume das rochas e consequente quebra. Geralmente as entradas das cavernas possuem diversos blocos evidenciando a incasão. Na gruta da Bocaina estes desmoronamentos formam níveis com blocos variando de dezenas de metros a poucos centímetros. Na Gruta do Bloco Suspenso é possível observar logo na entrada um grande bloco encaixado no conduto. O Conduto do Areião, na Gruta do Centenário, trata-se de uma pilha de sedimentos friáveis resultado do retrabalhamento dos depósitos de gravidade e material advindo da erosão ocorrida nas paredes do conduto. Neste conduto observa-se a maior concentração de espeleotemas justamente por este encontrar-se sem drenagem atualmente. Um fenômeno que vale a pena ser citado são as tempestades de raios que atingem o Pico e também propiciam a quebra das rochas e formação de blocos em superfície.

Geralmente as presenças da areia no piso, nas partes mais baixas das cavidades estão associadas ao "fechamento", isto é, as galerias ficam planas, o rio perde energia e não há mais intenso transporte de sedimentos. O afunilamento dos condutos impedindo a passagem é um fenômeno comum nas cavidades do Inficionado.

As cavernas estão condicionadas por falhas verticais ou subverticais e veios de quartzo que marcam falhamentos horizontais. O condicionamento estrutural vertical ou subvertical é caracterizado pela rede labiríntica quadrática na qual os condutos principais possuem direção noroeste-sudeste (280º-320º) e os condutos secundários possuem direção norte-nordeste. Os salões geralmente são a interseção destas descontinuidades. As falhas horizontais foram reconhecidas no exterior (figura 4) e no interior das cavernas. No interior das cavidades estas falhas são reconhecidas condicionando veios de quartzo associados a cianita em locais planos ou com pequena inclinação. O nível aproximado de –400m na Gruta do Centenário evidencia esta feição.

Considerações Finais

As feições mais características na Serra do Caraça são a litologia em quartzito, constante presença de grandes desníveis e abrigos, morfologia labiríntica quadrática, seções retangulares e condicionamento estrutural. Freqüentemente possuem drenagem ativa em seu interior, mostram fenômeno de incasão com presença de blocos encaixados nas fendas e predomínio de erosão mecânica.

A serra do Caraça apresenta importantes feições espeleológicas podendo ser considerada uma Província Espeleológica segundo definições de KARMANN e SÁNCHEZ (1979).

As explorações na Serra do Caraça estão apenas iniciando. Existem diversos abismos e cavernas, e a exploração, topografia e estudos irão requerer alguns anos.

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Luminescent Growth Banding and Stable Isotope Stratigraphy in a Stalagmite from Northern Norway: preliminary results for the period AD 1734 to 955 BC

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Abstract

Luminescent organic matter in a stalagmite from northern Norway is found to display characteristic patterns of annual and sub-annual bands for the period AD 1734 to 955 BC. The stable isotope stratigraphy, with a temporal resolution of 10 to 30 years/mm, shows large-scale fluctuations with time similar to the variation in annual band width. Preliminary results suggest that, in one annual layer, the main luminescent lamina is deposited in the spring in relation to flushing of organic matter from the soil zone during snowmelt, and that minor laminae (of lower intensity and thickness) are formed during the autumn. Moreover, this indicates a strong relation between summer soil zone conditions and stalagmite growth rate, thus information from studies of annual bands are expected to improve the understanding of stable isotopes in high latitude speleothems.

Introduction

Calcite speleothems provide a multitude of archives of paleoenvironmental change (see reviews by SCHWARCZ, 1986; GASCOYNE, 1993; LAURITZEN & LUNDBERG, 1999a) which can be accurately dated by the uranium series (^{238}U-^{234}U-^{230}Th) method (SCHWARCZ, 1986). In this work we report preliminary records of variation in annual luminescent growth banding and stable isotopes from the period from AD 1734 to 955 BC provided by the L-03 stalagmite from northern Norway.

Speleothem luminescence is mainly caused by organic, acidic compounds with aromatic or conjugated π-bonds derived from the overlying soil and trapped within the calcite (BAKER et al., 1993; SHOPOV et al., 1994). Mechanisms controlling speleothem growth rate are related to climate change, through precipitation, temperature, carbonate precipitation process, but also to local factors causing changes in percolation water flow route (BAKER et al., 1998; DREYBRODT, 1999).

Changes in $\delta^{18}O_c$ along the growth axis of a stalagmite may reflect changes in the ^{18}O content of the dripwater which, in turn, can reflect surface temperature. The $\delta^{13}C_c$ signal is related to changes in the source of carbon and/or the calcite precipitation process (GASCOYNE, 1992). In order to use $\delta^{18}O_c$ as a paleotemperature proxy it must verified that the speleothem calcite was deposited in isotopic equilibrium with its parent dripwater, a condition recognized by insignificant variation in $\delta^{18}O_c$ along a growth horizon, and where any slight changes in $\delta^{18}O_c$ does not correspond to changes in $\delta^{13}C_c$ (HENDY, 1971; SCHWARCZ, 1986). Such measurements are usually referred to as the "Hendy-test".

Site and Sample Description

The L-03 stalagmite was collected from Larshullet, a cave situated in the Rana area, approximately 20 km south of the Svartisen ice cap and the Arctic Circle, northern Norway (Figure 1; inset). The area is characterized by mean annual temperatures of +3 to +4 °C and mean annual atmospheric precipitation of about 1500 mm.

Only a centre section of the L-03 stalagmite exists after previous analyses (α-dating); this slice was again split in the centre yielding two opposite facing slices (Figure 1). The stalagmite is beige of colour, has visible banding, and measures 144 mm along the vertical growth axis. The apex area of the stalagmite display zones of less massive calcite with non-coalescing crystals and large amounts of fine grained detritus.

Methods

Six subsamples of 2 to 3 mm vertical thickness (grey areas, Figure 1), weighing 0.3 to 1.0 g, were dated by the TIMS uranium-series technique with tailored chemical and instrumental procedures (LAURITZEN & LUNDBERG, 1997; 1999), at the University of Bergen using a Finnigan MAT 262 mass spectrometer.

For the analysis of luminescent laminae, a polished sample slice (right slice, Figure 1) was investigated under microscope at 20x and 50x magnification. Overlapping images from top to base of the stalagmite were collected using a Zeiss Axiotech reflected light microscope with mercury vapour light source, and a black and white CCD camera, and continuously analysed using Image Pro Plus/Express image analysis software. The distances between observed luminescent laminae were measured between the centres of each of the laminae. The detritus rich zones forced us to place the traverse for image analysis to the far right side of the sample slice (broken vertical line, Figure 1).

A 0.5 mm dental drill was used to sample along the vertical growth axis at 0.5 mm intervals (right slice, side view, Figure 1). More than 270 subsamples of 88 to 100 μg were analyzed for stable oxygen and carbon isotopic composition. Subsamples were also measured at 1.5 to 10 mm intervals along three individual growth horizons (A-C) for the 'Hendy' tests. The analyses were done at the GMS Laboratory, University of Bergen, using a Finnigan MAT 251 mass spectrometer and an automatic on-line carbonate preparation device ('Kiel device'). Standard carbonate samples have an analytical reproducibility of ±0.06 and ±0.07 ‰, for δ^{13}C and δ^{18}O respectively. Results are reported as ‰ versus PDB, using the NIST (NBS) 19 standard as a reference.

Figure 1 The L-03 stalagmite. Sample slice viewed from the front; grey areas to the left indicate positions of TIMS dates, vertical broken line on right side gives position of traverse for luminescent laminae analysis. Sample slice (right part) viewed from the side; growth axis with mm scale is identical with traverse analysed for stable isotopes. Inset: map of Scandinavia, arrow indicates location of the sample site just south of the Arctic circle.

Figure 2 a) The distance between recorded laminae from the top surface (0 mm) to 110.6 mm below the top surface. b) The distance (=band width) between laminae with annual status.

Figure 3 Hendy-tests for the horizons A, B and C. $\delta^{18}O_c$ is plotted against distance from the growth axis (mm), and against $\delta^{13}C_c$. Minor variation in $\delta^{18}O_c$ is observed along the horizons and no obvious correlation is evident between $\delta^{18}O_c$ and $\delta^{13}C_c$.

Figure 4 Upper curve: Variation in $\delta^{18}O_c$ from base to top of the sample. Middle curve; variation in annual band thickness (grey curve - annual data, black curve – 29 yr running mean). Lower curve; variation in $\delta^{13}C_c$.

Lab. no.	**mm from base**	**mm from top** (luminesc. traverse.)	**^{238}U conc. (ppm)**	**^{232}Th conc. (ppm)**	**^{234}U/^{238}U**	**^{230}Th/^{234}U**	**^{230}Th/^{232}Th**	**^{234}U/^{232}Th**	**Age** (yr before AD 2000)
334	12-14	129.5	5.755 ±0.014	0.695	1.1132 ±0.0067	0.03297 ±0.00083	82.86 ±2.84	2513 ±107	3644 ±93
339	36-39	106.0	2.830 ±0.010	0.647	1.1152 ±0.0085	0.02692 ±0.00041	35.69 ±0.69	1326 ±33	2967 ±46
323	53-56	88.5	3.359 ±0.004	0.601	1.1111 ±0.0029	0.02296 ±0.00009	38.6 ±0.36	1683 ±17	2525 ±10
336	111-114	31.5	5.205 ±0.007	0.766	1.1172 ±0.0044	0.01146 ±0.00006	23.66 ±0.19	2065 ±19	1253 ±6
304	120-123	24.5	4.930 ±0.006	0.690	1.1259 ±0.0034	0.00983 ±0.00006	21.92 ±0.21	2229 ±25	1075 ±7
333	135-138	8.5	3.714 ±0.002	0.486	1.1260 ±0.0021	0.00647 ±0.00010	15.17 ±0.03	2345 ±58	705 ±12

Table 1 TIMS uranium-series dating results from sample L-03

Results

TIMS uranium-series dating

Table 1 shows the TIMS uranium-series dating results from the six subsamples with positions indicated as grey areas in Figure 1. The results show ^{238}U concentrations higher than 2.8 ppm, ^{232}Th concentrations lower than 0.8 ppm, and with ages in chronostratigraphic order. The growth period of the stalagmite commenced before 3600 yr ago (1600 BC), and terminated after 705 yr ago (AD 1295).

Characteristics of luminescence laminae

The L-03 speleothem sample is found to be continuously banded in the analysed interval, i.e. from 144 mm (top surface) to about 34 mm above sample base. Growth is also believed to have been continuous as no evidence of hiatuses are observed in microscope.

Figure 2a shows the variation in distance between observed laminae from the top surface to 110.6 mm below the top surface (i.e. 144 to ~34 mm above the sample base). A total of 3570 laminae were recorded in this interval. Two characteristic patterns of luminescence laminae are observed: 1) zones with closely spaced and highly intense luminescent laminae (< 20 μm between individual laminae), corresponding to white, visible bands in the speleothem calcite, and 2) zones with one high-intensity luminescent lamina followed by another low-intensity lamina, or in rare cases two, and then again a high-intensity lamina. The distances between these three features are typically 10 to 20 μm (high to low) and 30 to 50 μm (low to high).

The low-intensity laminae are believed to be subannual (seasonal), the high-intensity laminae represent the main annual organic depositional event (i.e. flushing of organics from the soil zone), and the distance between two high-intensity laminae represents the annual band thickness. Figure 2b shows the thickness of the interpreted 2690 annual bands from the top surface to ~ 34 mm above sample base (0 to 110.6 mm from top). To confirm the annual nature of the banding in Figure 2b, the difference in age between two dated positions (see Table 1) is compared with the number of laminae between the same positions:

Between 8.5 and 24.5 mm below the top surface a total of 491 luminescent laminae are recorded, 114 of these are considered to be subannual. The number of interpreted annual bands, 377, compares well with the difference in age of 370 ±14 yr from the TIMS dates. 231 laminae are observed between 24.5 and 31.5 mm below the top surface and 80 of these are interpreted to be seasonal laminae, giving 151 annual bands compared to the age difference from TIMS on 178 ±9 yr. Between 31.5 and 88.5 mm below the top surface a total of 1718 laminae are recorded, of which 530 are considered to be subannual, yielding 1188 bands of annual status compared with a TIMS age difference of 1272 ±12 yr. Between the 88.5 and 106.0 mm below the top surface, the total number of laminae is 562, of these 125 are subannual. The number of annual bands, 437, which compares very well with the 442 ±47 yr difference between the dates. The age of the topmost calcite is unknown, being impossible to date with the uranium-series method due to the very high content of ^{232}Th. However, between the top and 8.5 mm below the top surface 459 laminae are recorded, only 20 of these are convincingly of a subannual character, giving 439 annual bands in the topmost interval. By subtracting this from the topmost TIMS date an age of 266 yr B2K or AD 1734 is obtained for the top surface.

The top 20 mm has been counted twice and there is little uncertainty on the number of bands and their status in this upper interval. From the comparison with the TIMS dates, about one hundred bands seem to be missing between 31.5 and 88.5 mm below the top surface, and a recount is required. However, as a preliminary result, the comparison between the band counting and the TIMS dates are considered to be quite good.

If the annual growth rate is assumed to be constant, the distance between annual and subannual laminae may be used as an indicator of the duration of the seasons. For example, if the thickness of an annual band, as measured between lamina #1 and the overlying lamina #2, is 46 μm, the monthly growth rate is 3.8 μm. If then the distance between lamina #1 and lamina #1a (subannual status) is 12 μm, this can be taken as representing 3.2 months of growth. Each luminescent laminae is produced by hydrological "events" flushing organic material from the soil zone to the percolation zone. We therefore suggest that the main laminae or luminescent band is deposited in spring/early summer in relation to snowmelt (May-June), while the less intense, subannual laminae result from heavy autumn rainstorms.

Stable isotopes

Figure 3 shows the Hendy tests made at horizons A, B and C, 23.0, 86.0 and 116.5 mm above sample base respectively. The internal variation for each horizon is less than 0.3 ‰ for $\delta^{18}O_c$ and 0.2 ‰ for $\delta^{13}C_c$. The variation is considered to be insignificant and as no evident correlation is found between $\delta^{18}O_c$ and $\delta^{13}C_c$ the sample is considered to be deposited in isotopic (quasi-) equilibrium with its parent dripwater.

As the L-03 stalagmite ceased to grow hundreds of years ago, comparisons cannot be made between the stable isotope data and instrumental temperature records. A negative relationship between temperature and $\delta^{18}O_c$ is therefore assumed based on previous findings (e.g. LAURITZEN & LUNDBERG, 1999b), i.e. a decrease in the cave temperature is accompanied by enrichment in the $\delta^{18}O_c$ signal. The oxygen and carbon isotope measurements (Figure 4) are plotted on a calendar year timescale derived from the TIMS dates in Table 1, and on the interpreted annual bands between the upper TIMS date and the stalagmite surface. The temporal resolution is 10 to 14 yrs per measurement except between the upper TIMS date and the top surface were the resolution is 30 yr per measurement.

Conclusions

The L-03 stalagmite is shown to display annual luminescent banding. The variation in annual band thickness is believed to be related to climate through the biological activity in the soil zone. Further work on annual and sub-annual banding may improve our understanding of seasonal processes in the soil zone and how they affect the chemistry of the dripwater.

Moreover, a positive correlation is evident from the large scale trends of annual band thickness data, the stable oxygen isotopes, and to a lesser degree, the stable carbon isotopes. This relationship is expected to enhance the knowledge on all three proxies.

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Cenozoic History of the Moravian Karst Cave Systems, Czech Republic

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Abstract

The Moravian Karst (MK) is an example of a fluviokarst area, which is usually subdivided into three segments – each with a separate drainage pattern. Cave systems were formed by subsurface streams during the Cenozoic. These cave systems, the length of which exceeds 30 km, always consist of lower and upper cave levels. The lower levels are genetically linked with the bottom of the karst valley and were formed in the Early Miocene whereas large upper levels have been formed by subsurface rivers since the Late Miocene after blocking the springs of lower levels by sediments. The MK cave systems underwent several stages of cave sediment deposition and erosion. A reconstruction of hydrological processes during the Early, Middle and Late Pleistocene was based on radiometric and paleomagnetic datings of preserved cave deposits.

1. Introduction

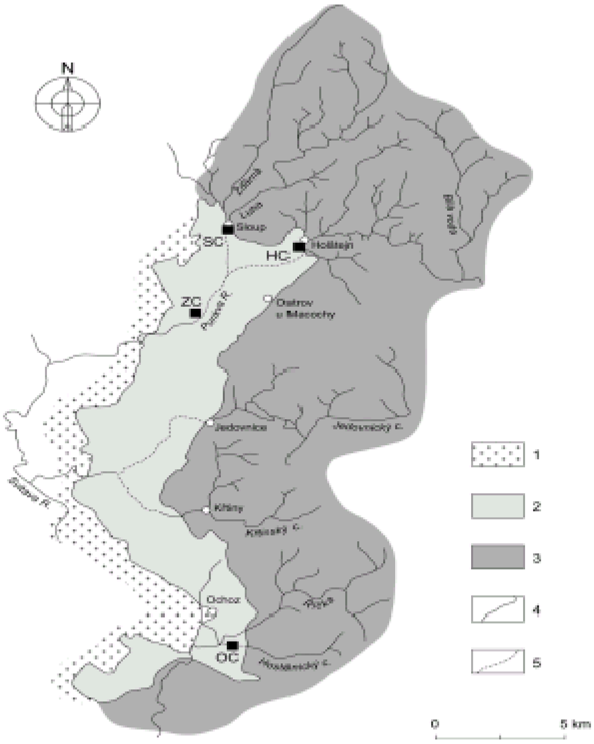
The MK is located in the eastern part of the Czech Republic.

Devonian limestones form a N-S-trending belt, 3–5 km wide and 25 km long. The karst area is surrounded by Lower Carboniferous nonkarstic sediments and Proterozoic granitoids (Fig. 1). The limestone surface is dissected by deep valleys, locally adopting the character of karst canyons dividing into the northern, central and southern segments. The streams flowing through cave systems spring N and E of the MK. Water passes through cave systems and re-appears on the surface at resurgences along the western margin of the karst area (see Fig.1). Each of the three segments of the MK is characterized by a separate drainage pattern. The 30 km long cave system is located in N segment of karst drained by the Punkva River. The large portion of this system is called the Amaterska Cave. The Rudicke propadani-Byci skala Cave with the length of 6 km was formed by the Jedovnicky Creek in the central segment. The Ochozska Cave is 1800 m long and was formed by the Hostenicky Creek in the S segment of the MK.All these large karst systems consist from lower active and upper flood cave levels. Flood passages are often filled with sequences of fluvial sediments intercalated by speleothem horizons.

2. Methods

The key sections in cave sediments were drawn at the scale 1:10.

Based on sedimentary structures the genesis of the individual sediment bodies was interpreted. The ages of the cave sediments were determined by several independent methods. Speleothems were dated using the 230Th/234U method (a-particle counting) in the Uranium-Series Laboratory of the Institute of Geological Sciences of the PAN in Warsaw and at the University of Bergen, Norway. In one case, the age of fluvial sediments was determined by measurement of 10Be and 26Al isotope contents in quartz pebbles. The dating was performed at Purdue University, Indiana, USA. Paleomagnetic record was measured in both detrital and chemogenic deposits for age determination by correlation with paleomagnetic record from sediments with established paleomagnetic time scale. Measurements of oriented samples of soft sediments and speleothems were performed in the paleomagnetic labs of the Institute of Geology AS CR in Praha, CZ and at Michigan Technological University, USA.



1 – Proterozoic granitoids; 2 – Devonian to Lower Carboniferous limestones; 3 – Lower Carboniferous shales, greywackes and conglomerates; 4 – surface reaches of streams; 5 – subsurface reaches of streams; caves with key sedimentary sections: SC – Sloupsko-sosuvska Cave; HC – Holstejnska Cave; ZC – Zazdena Cave; OC – Ochozska Cave

Fig. 1. Modern hydrography of the Moravian Karst

3. Key sedimentary sections in the cave systems of the Moravian Karst

3.1. Holstejnska Cave

The Holstejnska Cave is located near the N periphery of the MK, in a half-blind valley. This ponor cave is formed by a horizontal corridor, posing the upper level of a cave system. Its lower level is the Cave No. 68, lying 60 m deeper. The two levels are interconnected by vertical cavities filled with sediment. The Holstejnska Cave is a 40–50 m broad corridor filled with several sediment bodies of different ages. Local cavers excavated corridors in sediment fill of this cave more than 700 m long.

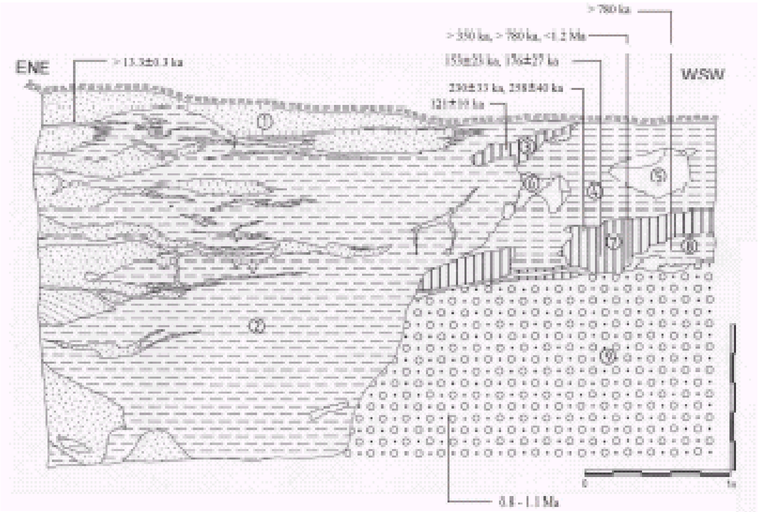
Key Section 1

Section is perpendicular to the flow direction of the subsurface stream and shows three sedimentary units (Fig. 2). The periods of fluvial activity were alternated by periods of speleothem deposition. Channels filled by youngest sediments (Unit C) are eroded into both older units.

Age of sediments

The oldest fluvial sandy gravel forming Unit A was transported into the cave within the period of 0.8 to 1.1 Ma, as evidenced by the ratios of 10Be and 26Al isotopes measured in quartz pebbles from these deposits (KADLEC et al., 2000a). Fluvial sandy silts preserved on the surface of this sandy gravel shows reverse paleomagnetic polarity, thereby indicating higher age of sediments than the Brunhes/Matuyama paleomagnetic boundary – i.e. 780 ka. Flowstone layer preserved in a relic on the surface of Unit A consists of two parts separated by a silt lamina. The lower part of the carbonate bed shows reverse paleomagnetic polarity (SROUBEK & DIEHL, 1995) and Th/U age exceeding the limits of this method, i.e. 350 ka (HERCMAN et al., 1997).

The 234U/ 238U isotope ratio in the carbonate, however, indicates age lower than 1.2 Ma. This means that the lower part of the flowstone layer and the underlying sandy silt are again older than the Brunhes/Matuyama paleomagnetic boundary. The age of the upper part of the flowstone layer as revealed by Th/U dating is 176 ±27 ka and 230 ±33 ka. Similar data were produced by older dating of flowstone from the upper part of this flowstone layer: 153 ±23 ka and 258 ±40 ka (Glazek et al., 1995). The above given results suggest that the hiatus in flowstone precipitation lasted ca. 500,000 years. The relic of a flowstone layer overlying Unit B was dated by the Th/U method at 121 ±10 ka. This means that fluvial clayey silt of Unit B was deposited in the penultimate glacial period between 153 ±23 and 121 ±10 ka. The latter date also gives the maximum age of the base of the fluvial Unit C (see Fig. 5). The end of the deposition of these youngest clayey silt, sand and sandy gravel is defined by the age of the flowstone layer with stalagmites overlying Unit C in the S part of the Holstejnska Cave. The base of the stalagmite was formed at 13.3 ±0.3 ka, while its apex at 4.7 ±1.1 ka (KADLEC et al., 2000b). The youngest fluvial Unit C, lying below the stalagmite, was therefore deposited in the Last Glacial.



1 – medium- to coarse-grained sand, horizontally stratified, locally cross-bedded; 2 – clayey silt ;3 – relic of flowstone layer ;Unit B (fluvial sediments): 4 – clayey silt with no bedding, occasionally contains lenses of sandy gravel; 5 – limestone block; 6 – calcareous concretion ; 7 – relic of flowstone layer ;Unit A (fluvial sediments): 8 – sandy silt ;9 – sandy gravel with weathered greywacke pebbles and cobbles often cemented with carbonate, no bedding

Fig. 2. Section 1, the Holstejnska Cave Unit C (fluvial sediments)

3.2. Sloupsko-sosuvska Cave

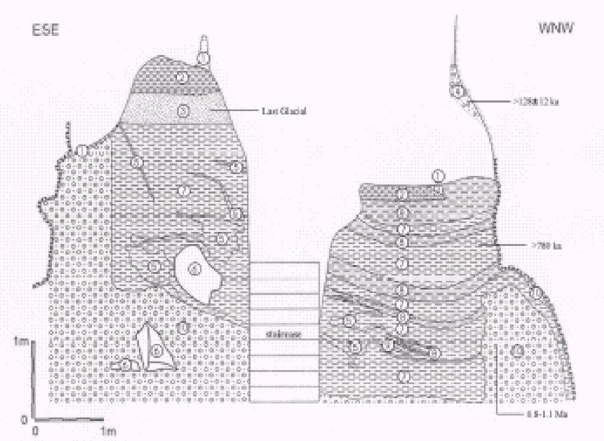
The Sloupsko-sosuvska Cave lies on the N periphery of the Moravian Karst, in a half-blind valley located 3 km W of the Holstejnska Cave (see Fig. 1). The cave system comprises the upper and the lower cave levels interconnected by several chasms up to 70 m deep. The length of the whole system exceeds 6 km. The modern stream disappears in the W part of the upper level, passes through vertical paths and re-appears at the lower level, then flows to the Amaterska Cave. Cave sediments of different ages are preserved at a number of locations at the upper level of the cave system.

Key Section 2

The section is oriented perpendicular to the flow direction of the subsurface stream. No speleothem are preserved in this section, instead stalagmite and thin crust at the top. In the oldest Unit A, the subsurface stream eroded a channel with steep banks filled with fine sediments of Unit B (Fig. 3).

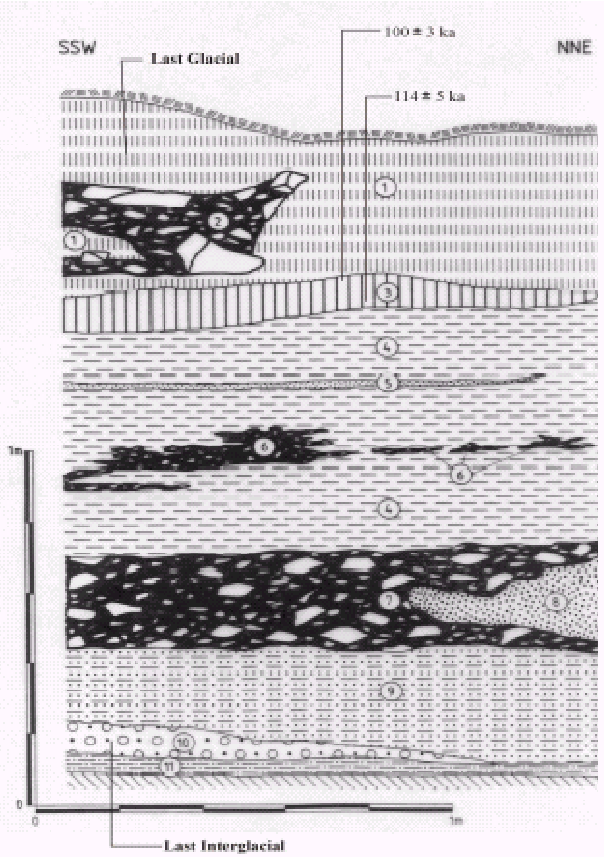
Age of sediments

Fine silt and sand (Unit B) filling the channel in gravel in Section 3 shows a reverse paleomagnetic polarity indicating the age older than 780 ka (SROUBEK & DIEHL, 1995). Lithology and intensity of weathering of pebbles in Unit A are comparable with those of the oldest fluvial sediments in the Holstejnska Cave (Unit A). Both units may therefore be of the same age, 0.8– 1.1 Ma. Their similar ages are also suggested by the equal rate of weathering of clay minerals at both localities (VÍT, 1996). The age of sandy gravel (Unit C) cemented to the cave walls above the section probably correspond with fillings exposed in the N part of the cave system, where a flowstone layer deposited on the sandy gravel was dated by the Th/U method. The flowstone originated in the last interglacial period at 128 ±12 ka to 112 ±9 ka. Therefore, underlying sandy gravel was deposited not later than in the Middle Pleistocene. The youngest sandy gravel in Section 2 (Unit D) was then deposited in the Last Glacial and overgrown by stalagmites of probably Holocene age.



1 – stalagmite; Unit D (fluvial sediments): 2 – sandy gravel; 3 – sand; Unit C (fluvial sediments): 4 – relics of sandy gravel cemented to limestone walls in the neighbourhood of the section; Unit B (fluvial sediments): 5 – clayey to sandy silt cemented with cabronate; 6 – limestone blocks; 7 – clayey to sandy silt; 8 – laminae of clayey silt and fine-grained sand; 9 – sand; Unit A (fluvial sediments): 10 – sandy gravel with strongly weathered greywacke pebbles and cobbles

Fig. 3. Section 2, the Sloupsko-sosuvska Cave



1 – infiltration laminated silts; 2 – limestone scree; 3 – flowstone horizon; fluvial sediments: 4 – clayey silt; 5, 8 – medium sand; 9, 11 – sandy silt; 10 – sandy gravel; 6,7 - limestone scree

Fig. 4. Section 3, the Zazdena Cave

3.3. Zazdena Cave

The Zazdena Cave located near the Macocha Chasm provides one of the largest exposures of cave sediments in the Moravian Karst. The exposure dates to 1938–1940 when a tunnel 350 m long was excavated in sediments filling a horizontal cave corridor.

Key Section 3

Layers of fluvial sandy gravel, sand and silt were deposited in the cave corridor. These deposits are covered by a flowstone horizon up to 20 cm thick. The infiltration laminated silts transported by meteoric waters, coming vertically through the cracks and karst chimneys, filled cave passage up to the ceiling.

Both fluvial and infiltration deposits are intercalated by the horizons of limestone scree transported from near karst chimney.

Age of sediments

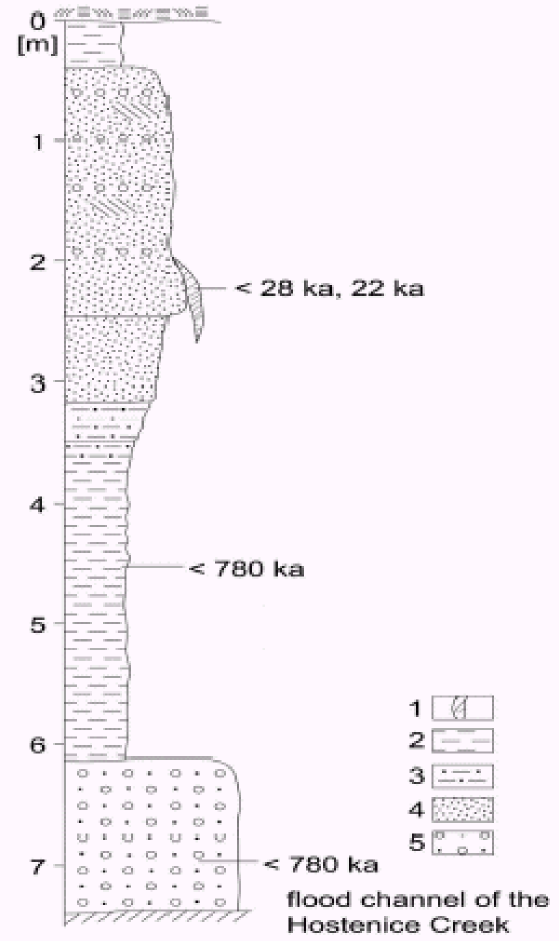
The Th/U dating has revealed that flowstone horizon was deposited at the beginning of the Last Glacial between 114 ±5 ka and 100 ±3 ka. Underlying fluvial sediments were deposited probably in the Last Interglacial. Laminated clayey silts underlying by flowstone were deposited during the Last Glacial.

3.4. Ochozska Cave

The section is located in a large flood corridor, which was originally filled with fluvial sediments up to the ceiling. The upper portion of 7 m thick sequence is exposed due to later erosion of subsurface stream. The lower portion of the sedimentary body was exposed by recently excavated 4 m deep test-pit.

Key Section 4

Lower portion of the section is formed by a gravel bar deposited on the limestone bottom of cave corridor. Due to collapse of cave mouth the corridor was filled by silts and sands deposited from stagnant or slowly flowing water (Fig. 5). Later the subsurface stream eroded a flood channel in this sedimentary sequence. Flowstone crusts were precipitated on the slopes of this channel.



Fluvial sediments: 1 – clayey silt; 2 – sandy silt; 3 – sand; 4 – sandy gravel

Fig. 5. Section 4 (the upper portion), the Ochozska Cave

Age of sediments

The paleomagnetic record was measured in 30 samples colected from clayey silts. All these samples reveal normal paleomagnetic orientation which mean that the age of deposits is most probably lower than 780 ka. The samples from the flowstone crust were dated by Th/U method. However, the carbonate is highly contaminated by detrital Th. Therefore, the results of datings have only approximative value. The flowstone is younger then 28 or 22 ka, respectively.

4. Discussion on History of the Moravian Karst Cave Systems

The early history of the MK cave systems is proposed on the basis of morphology of cave systems and half-blind valleys investigated by gravity and vertical electrical sounding survey (DVORAK, 1994; KADLEC 1996, 1997) because Tertiary cave deposits were excavated from cave passages and only Quaternary sequences are preserved.

In the **Paleogene**, surface streams in the Moravian Karst area formed shallow valleys. First horizontal cave systems originated at the levels of the bottoms of these oldest valleys.

The upper level of the Sloupsko-sosuvska and Holstejnska caves and many other care relics date back to this time (e.g., PANOS, 1963; HYPR, 1980). During the **Lower Miocene** Karpatian nappes were docked in the Carpathian Foredeep (SE of the MK).

Northwesterly nappe advance resulted in uplift of large areas at the E margin of the Bohemian Massif including the MK. The shallow valleys of Paleogene age were deepened due to river gradient changes. Tectonics movements and gradient changes of bottoms of surface valleys may have occurred at the contact between limestones and non-karstic sediments. With the tendency to reach graded profiles again, streams created in each segment of the MK cave system with ponors on the N or E periphery of karst. The lower levels of the Sloupsko-sosuvska and Holstejnska caves and lower active passages of the Amaterska, Rudicke propadani-Byci skala and Ochozska caves were formed. These systems were guiding water through the limestones to the SW, towards the base level formed by the local larger rivers. The resurgences of this cave systems were located at the bottoms of deep karst valleys formed during the Lower Miocene period of tectonic instability. In the early **Middle**

Miocene (during Lower Badenian), sea transgressed over the Moravian Karst and other areas on the E margin of the Bohemian Massif. The surface of the karst area was covered by marine sands and clays and all karst processes were interrupted.

It was a major event, dividing the Cenozoic history of the MK into two periods. In the period between the marine regression and the **end of the Miocene**, the MK was under the influence of erosion, slowly removing marine sediments from the surface. The marine transgression induced hydrographic changes, which influenced further development of cave systems during the Late Cenozoic. The former resurgence of the Punkva River near the bottom of the pre-Badenian valley remained permanently sealed beneath marine clays at a depth of almost 140 m below the present surface. The blockage of this resurgence from the Amaterska Cave caused the rise of the groundwater table.

Intensive flow at the level of the risen groundwater table caused the origin of a horizontal cave passage. The subsurface stream formed the large corridors of upper flood level of the Amateska Cave during the **Pliocene** and Early Pleistocene. The large flood passage in Ochozska Cave was formed in the same time period.

The Jedovnický Creek opened a completely new path into the pre-Badenian cave system draining the central segment of the MK. Newly formed passages in the Rudicke propadani-Byci skala cave have the character of high meandering corridors indicating rapid incision of subsurface stream, which tended to join the lower, pre-Badenian cave level.

Alternation of glacial and interglacial climate started in the **Early Pleistocene** resulted in changes in the behaviour of stream systems. In colder periods, the streams were characterized by higher discharge and also higher amounts of load. Large volumes of fluvial sediments might be responsible for blocking of caves draining ponor valleys. Water started to flow on the surface through karst canyons, and ponor valleys were gradually filled with fluvial sediments. Streams, which started to flow into the Holstejnska Cave and the upper level of the Sloupskososuvska Cave, opened vertical connections between the upper and lower levels in both systems, directing water to the Amaterska Cave. At the end of the Early Pleistocene (0.8–1.1 Ma), however, this path was closed, possibly as a result of an inhibition of flow of the subterranean stream in the Amaterska Cave due to, e.g., catastrophic choke. In such case, Holstejnska and Sloupsko-sosuvska ponor caves became filled with fluvial sandy gravel (Unit A). In the **Middle Pleistocene**, streams reentered the Holstejnska Cave and the Sloupsko-sosuvska Cave, partly eroding fluvial sediments deposited in the Early Pleistocene. After closure of this path for the subterranean stream in the latest Middle Pleistocene, the Holstejnska Cave and the Sloupsko-sosuvska Cave were filled with fluvial sediments (Unit B and Unit C, respectively). The end of detrital sedimentation in both caves is marked by a flowstone layer deposited in the Last Interglacial. Massive detrital sedimentation could be caused by the roof collapse of the Macocha Chasm, which blocked the flow of the Punkva River on the bottom of the chasm (KADLEC & BENES, 1996). The fluvial deposition in the Zazdena Cave was also induced by roof collapse in the near Macocha Chasm (KADLEC, 1994). Also the Ochozska Cave was filled with fluvial sediments deposited after the cave mouth collapse, which blocked the resurgence the Hostenicky Creek. It was the time when cave systems were blocked by sediments, and streams were flowing on the surface. In an attempt to reach a lower-positioned underground path, water created new connections to the lower drainage level along karstified faults and fissures. The last episode of fluvial erosion and accumulation took place in the caves during the **Late Pleistocene**. Subterranean streams produced channels in older fluvial accumulations, through which they flowed into chasms connecting upper and lower levels in ponor caves in the N segment of the MK. After repeated blockage of this path, channels and the whole cave corridors were partly or completely filled with the youngest fluvial sediments. The Zazdena Cave corridor was filled with laminated infiltration sediments up to the ceiling. In the Ochozska Cave the erosion of older fluvial sediments prevailed during the Last Glacial. In the **Holocene**, the active cave systems were dominated by stream erosion.

Abundant speleothem decorations were deposited in flood passages during the Holocene.

5. Conclusions

1. Subsurface rivers formed the MK cave systems with ponors on the N or E periphery and resurgences along the W periphery of karst area in the late Early Miocene, before the Badenian marine transgression.

2. Large flood corridors were formed during the Pliocene as a consequence of hydrographic change caused by transgression and marine sediment deposition.

3. Several periods of fluvial aggradation and erosion can be distinguished during the Pleistocene: in the late Early, late Mid and Late Pleistocene. Periods of fluvial deposition alternated with periods of speleothem deposition.

4 The deposition of fluvial sediments and the filling of cave corridors were usually controlled by local interruptions in the subterranean stream flow within the cave systems. Therefore, periods of aggradation in caves of the MK cannot be correlated with fluvial terraces of surface streams, the formation of which was controlled by climatic oscillations during the Pleistocene.

Acknowledgements

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Upward Growth of Bedding-plane Anastomoses

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Abstract

Bedding-plane anastomoses are erosional forms of micro-relief in caves and represent one of the earliest stages of speleogenesis. The paper describes their basic morphological characteristics and attempts to define their genesis, but the question that arises is: Why is the growth of bedding-plane anastomoses bound only to the upper, overlying bed, while the bed below remains almost intact? All authors who made research on bedding-plane anastomoses agree that these features are among the earliest solutional cavities in karst and that they form in phreatic conditions, with very slow laminar movement of water, which is not capable of transporting solid materials. When it comes to explanation of their upward growth, there is still no definite answer, but when reached, it will help to understand the processes which guide the development of the very first, tiniest conduits in limestone.

Introduction

Much has been told about the evolution of developed cave conduits, but some simple questions, like the one about the reason for upward growth of bedding-plane anastomoses, remained without definite solutions. The answer to this question lies within the understanding of the processes which direct the development of first karst conduits. Knowing how conduits behave at the earliest stages of their evolution, we might seek answers to more complex questions – why and how those conduits form, for instance.

Basic Morphological Characteristics

Bedding-plane anastomoses are braided tubes along limestone bedding planes. They are connected in networks which are visible in flat horizontal ceilings and collapsed boulders, while cross sections can be found in cave walls. Limestone bedding planes are subject to infiltration by water, which is the first phase, i.e. the necessary condition for the development of anastomoses. Their formation is more intense in those limestones which are not too much tectonically fractured, so the movement of groundwater is guided by bedding. Flowing between beds under phreatic conditions, the water dissolves the limestone, but the corrosion mostly affects the bed above the bedding plane, while the bed below remains almost intact. The direct proofs of development of anastomoses in bedding planes are profiles exposed in the cave walls. In that case, both beds are visible – below and above a bedding plane, with anastomoses formed in the upper bed, i.e. in the lower surface of the upper bed. In the first phases of development, bedding-plane anastomoses have rounded cross sections, which later in many cases become elongated (elliptical), although they may remain rounded and develop a so called "omega" shape. The size of the tubes is in most cases several centimetres to several tens of centimetres, but can, in certain cases, be measured in metres.

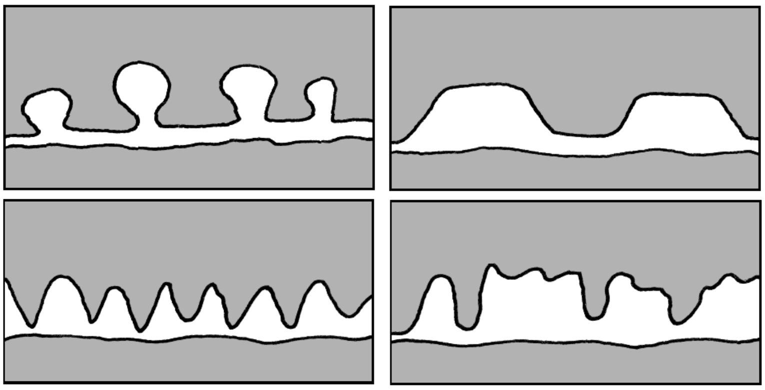

Figure 1: various cross sections of anastomoses

It is often the case that anastomoses form on several beds in a sequence, so every bed has a network of upward growing anastomoses on its lower surface. The result is to disrupt the stability of the beds and their eventual collapse. In this manner, great surfaces carved with anastomoses become visible. Collapsed material is in some cases washed away, or otherwise it remains on the place of collapse. This process can play an important role in cave passages development.

Hypotheses on Upward Growth

It is broadly accepted that bedding-plane anastomoses form under phreatic conditions, with very slow movement of water, in a laminar flow condition without capability to transport solid materials. However, when it comes to definition of the reason for their upward growth, there is no unique explanation, but several hypotheses.

According to BRETZ (1942), the reason for the upward growth of anastomoses lies in the existence of insoluble residue resulting from limestone dissolution. The residue settles to the bottom and protects the limestone below from solution (Fig. 2a). It cannot be washed away thanks to very slow movement of water, which is not capable of transporting solid materials. In this case, the development of bedding-plane anastomoses would have certain elements of paragenetic development. This theory seems to be convincing and logical, but it has not been proven experimentally or by calculation, so it still remains only an assumption.

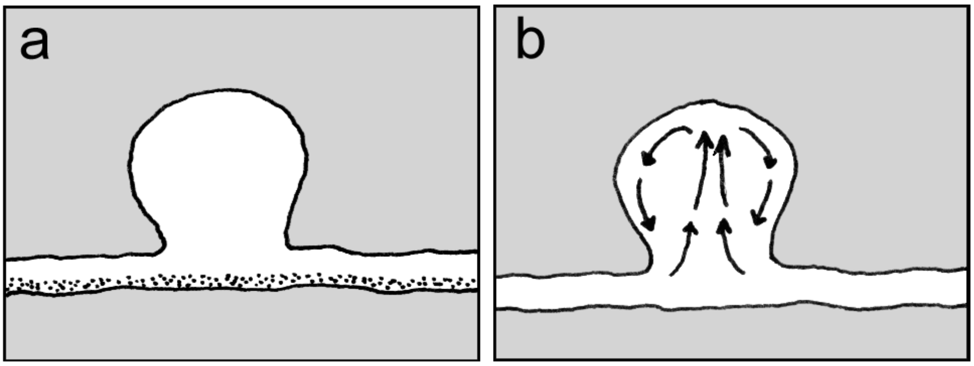

Figure 2: upward growth of anastomoses explained by: a) insoluble residue protecting the lower bed; b) natural convection of water

The most complex analysis of this karst phenomenon was given by EWERS (1966), who carried out numerous experiments with salt blocks – with precisely calculated values of hydraulic head, duration of the experiment, inflow of water and space between the blocks, anastomoses networks were formed on the lower surfaces of the upper blocks. Ewers does not give a general explanation for upward growth of anastomoses, but only the explanation which refers to his experiment – in salt blocks, it is caused by the solution gradient (more concentrated solution accumulates at the bottom and protects the lower bed).

CURL (1966), by defining the conditions in which natural convection of water occurs, suggested that it could be the reason for upward enlargement of anastomoses. Density differences of water cause its downward movement along the conduit walls and upward return movement in the central parts, which brings fresh solvent to the ceiling and upper walls (Fig. 2b).

One possible explanation was described by LOWE (1992), although he was not referring particularly to bedding-plane anastomoses, but to general genesis of primary karst conduits. The hypothesis relies to differences in solubility of beds (due to varying contents of calcium carbonate, grain size, type of carbonate cement, etc). Since sedimentary boundaries are characterized by the presence of micritic limestone below and sparry limestone above the boundary, then "...any water movement, acid generation and dissolution along the bounding bedding would be expected to exert much of their combined effect against the sparry bed above" (LOWE, 1992; p. 141).

Other Types of Anastomoses

Above-sediment anastomoses are, when compared to bedding-plane anastomoses, similar in appearance, but different in origin. They are formed as a consequence of filling of cave passages (entire passages or just overhangs) by sandy and clayey sediments (SLABE, 1995). Anastomoses are formed by the water that flow in phreatic conditions between the sediment fill and the ceiling. After the sediment fill is washed away, anastomoses, separated by roof pendants, are visible in the ceiling.

Apart from bedding-plane anastomoses, WHITE (1988) also mentions joint-plane anastomoses. Existence of this type of anastomoses is in contradiction with the last of the above mentioned upward growth hypotheses (solubility differences between beds). In the areas which are to a high extent tectonically fractured, these two types of anastomoses can both be present, and majority of joint-plane anastomoses are formed in steeply dipping joints. It is interesting to notice that almost in all cases anastomoses are developed with vertical longer axis, and are not perpendicular to bedding or joint planes.

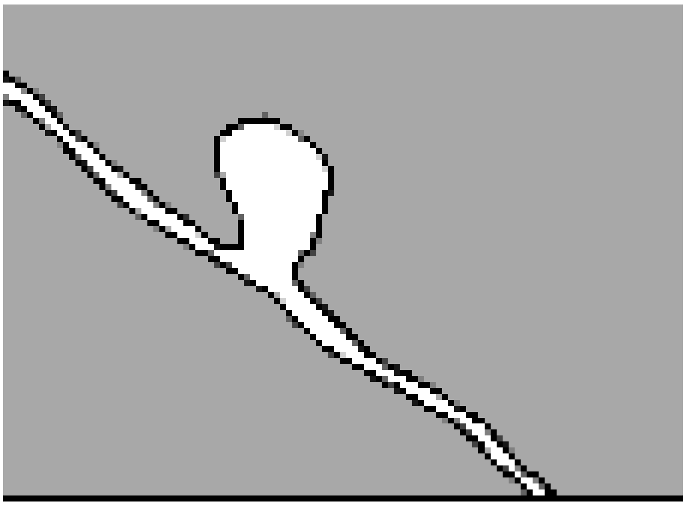

Figure 3: anastomoses in steeply dipping planes (bedding or joint)

It is usually considered that all bedding-plane anastomoses are antecedent, i.e. formed before cave passages developed. However, WHITE (1988) states that there are some evidence that in certain cases anastomoses can be younger than the cave passages in which they are visible (or formed contemporaneously), by water that penetrates into the bedding or joint planes, as a consequence of flooding of the passage (due to damming of the flow, increased hydrostatic pressure, etc).

Implications on Speleogenetic Studies and Suggestions for Further Research

If we accept that the bedding-plane anastomoses are among the earliest solutional openings in limestones, the need for their more detailed study becomes quite obvious. The cases in which anastomoses are direct reason of passage development (large enterable anastomoses which represent anastomotic maze cave passages, or collapse of several beds in sequence that occured due to formation of anastomoses and consequent disrupted stability) are not of such great importance as the understanding of the development mechanism itself.

Examination of the hypothesis on the influence of solubility differences between beds should be carried out with the help of thin sections analyses, experimental dissolution of compact samples (not powdered!), calcimetry, etc. Hypotheses on the impact of insoluble residue or natural convection of water require careful modeling and application of physics of fluids.

Besides the mechanism of development, the sequence of events is also to be researched. The cases in which anastomoses axes in inclined bedding or joint planes are perpendicular to planes have still not been reported in speleological literature (which, of course, does not mean that these cases do not exist). That would mean that formation of anastomoses took place only after the events of uplift or folding of limestones. Though, it must be expected that the different succession of events is also possible.

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Observations on the Karst Features in the Lingyuan and Leye Counties of Guangxi Province of Southern China

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Abstract

The scenery in Lingyun and Leye counties of Guangxi southern China constitute an area of classic karst. Masssive dolines, doline roups, cone karstand tower karst dating from the Pleistocene, features spectacularly in the landscape. The caves discovered on the expedition are mostly of phreatic origin, some active and some beautifully decorated fossil systems. This paper makes observations on the development of the karst scenery and considers difficulties encountered in the search for caves on the boundary of karst and Permian shales. Particular reference is made to the spectacular Dasheiwi doline, the second deepest doline in the world which has further potential for exploration and potential for tourist exploitation in the future. Pressure will be placed on its delicate ecosystem as a result. Reference is also briefly made to cave life found during the expedition.

Introduction

The Yorkshire Ramblers Club expedition to Guangxi 2000, took place during the month of October. This was 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 institutions.

The area involved in this expedition lies in the Western part of Guangxi province, the Lingyun and Leye Karst which is situated between the You and Hongshui rivers, some 300 kilometres west of Liuzhou. Access to these zones is allowed only after receiving special Government permits from the Ministry of Land and Resources and despite the relatively open attitude and economic tourist development in China, special permission had to be sought.

The Guangxi province of China is considered to be one of the most characteristic karst areas in Eastern Asia. This much eulogised scenery cannot fail to impress even the most seasoned traveller with karst towers and dolines of spectacular dimensions. This vast area is characterised by a sub-tropical climate with a karst peak forest at an altitude of from 150 metres to 2000 metres above sea level.

The expedition comprised of 17 individuals from Europe and one Cave Biologist from Tasmania. 8 Chinese members of the team joined us from the Karst Institute in Guillan. The expedition was split into 2 parts, first to explore the Lingyun region for 1½ weeks and for the remainder time, the Leye county area for a reconnaissance of an entirely new karst area.

Observations on Geology and Karst

The caves explored by the expedition lie inside limestone, the age of which can be dated between Devonian and Triassic, with a clear cut prevalence of Palaeozoic lithotypes. The karstification in China is closely linked to geologic-tectonic evolution and palaeogeography. The Palaeozoic era witnessed the greatest palaeo-karst development, affecting a large part of the limestone of China. Parts of this region revealed typical examples of palaeo karstification in middle Ordovician carbonate rock. The area was particularly affected by the Caledonian orogeny, the entire area in China being uplifted from the middle Ordovician to the middle carboniferous and subsequently became subject to typical shaping and denudation.

During this geological and tectonic evolution, an important role was played by orogenic movements in the Mesozoic era, which at the end of the Triassic and in the cretaceous, gave rise to an unconformity with two of the stratigraphic series absent due either to the lack of sediment deposition or to the removal of sediment through erosion.

From the upper Triassic to the lower Jurassic most of China had a humid, tropical-subtropical or humid-temperate climate that greatly favoured karst development. The karst of this period is to be seen in many zones in the area the expedition visited.

Studies on limestone moulding and the chronological classification of different types of karstic morphologies have shown that the diversification of the most important types of karst and the related structures began in the Pleistocene. From the middle Pleistocene on, the climate in Southern China became hot and humid and has remained so virtually to this day. This is why karstification underwent such constant development.

Karst areas take up to approximately 12% of the earths land surface and that is about 20 million km². China, whose carbonate area measure about 2.6 million km², has one of the largest karst areas in the world. The carbonate rock covers more than one third of the country and about half of it is concentrated in the Southern regions.

In the karst land of Lingyuan and to a lesser extent Leye county, the limestones are massively folded and separated by tight sink lines of Triassic shales and sandstones, numerous faults cut through these structures. In many respects, this topology reflects the geology, the sandstones and shale form long high ridges with thick soils and good terraces for farming in contrast to the limestone which presents a chaos of rugged features with thin soils, poor farming and water shortages. At thr boundary of the two Permian sandstones and shale sediment drain from surface streams into sink holes often causing massive infill and blockages in caves both active and fossil. Where dolines either reach down to base level with cave resurgences and sinkholes on opposite sides, or have sediment choked floors perched above cave streams. The karst towers are topographically made up of two types, the fengcong, peak cluster depression sub-system, and the fenglin or peak forest plain sub-system, which have different morphologies and an orderly configuration.

The fengcong is also called “cone karst” because its peaks usually have a conical shape. The base of the depression is marked by the presence of sinkholes and shafts. The height of the fengcongs from the depression floor to the top of the peaks ranges from 10s of metres to over 500 metres. One of the most important geomorphological features of the fengcong areas is the almost total absence of rivers and surface water courses, the water usually being assimilated into the substratam.

Although there are different theories about the regular distribution of karstic fenglin and fengcong recent studies have shown that the distribution of the peak cluster depressions and peak forest plains forms are mixed.

Example of Sites Visited

Towards the end of the second week of the expedition the team of 6 made a reconnaisance trip to the Leye area, 40 miles north of Lingyuan, a fairly isolated mining town situated in the cone karst limestone, boasting a number of very impressive dolines and doline groups. The Dashaiewi doline was visited first and is considered to be the second deepest doline in the world. A river system at the bottom was explored for over 1 kilometre to a confluence where it met another large river, the combined volumes of water making it very difficult to continue. Clearly, there is considerable potential between this sink and the resurgence 30 kilometres away in Beilong, where the river eventually joins the sizeable Hongshui River. This doline in particular may be the subject of tourist exploitation in years to come, if a way can be found to overcome its technically difficult access, concerns about the impact on its ecosystem would be considerable.

The expedition from a cave biology point of view collected over 300 specimens, 100 of which may be new species. An interesting new family of crustacea was also discovered. In total 17 kilometres of cave passage was explored and surveyed with 1153 man hours being spent over a period of 3 weeks in the field.

Conclusion and Acknowledgements

It is perhaps not unreasonable to be impressed by the Chinese understanding of karst given that their country has such as extensive abundance of limestone. In Lingyuan, particular problems were encountered in the exploration of caves on the karst/shale boundary where sediment infill was much in evidence and frustrated exploration of passage that would otherwise be of great dimensions. In Leye county conversely, the karst was rich in revealing open passage.

Considerable help was given to us by individuals from the Karst Institute at Guillin, in particular Professor Zhu whose knowledge and expertise, gave the expedition an opportunity to formulate an interpretation and understanding of the incredible scenery that abounds Lingyuan and Leye Counties.

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The Geological Investigation of the Limestone Caves in South Korea

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Abstract

The limestone caves in South Korea have been mostly developed within the Cambro-Ordovician carbonate rocks (the Joseon Supergroup), and there appears to be more than 1,000 caves in South Korea. The limestone caves in South Korea are distributed throughout the peninsula, however, most of them are concentrated in the eastern-central part of the peninsula.

Most of the caves have formed by the dissolution of groundwater along joints and bedding planes, and the strike and dip directions of the joints mostly dominate the development of the caves. So far known, the longest cave in South Korea is a Hwanseon Cave, which is about 10 km long. The deepest cave is the Yumundong Cave, which is ca 200 m deep.

The limestone caves in South Korea include a variety of speleothems such as soda straw, stalactite, stalagmite, column, curtain (and bacon sheet), cave coral, helictite (and heligmite), moonmilk, cave shield, cave bubble, cave raft, rimstone, shelfstone, cave pisolite, etc.. All the speleothems are composed of calcite or aragonite, or both. However, aragonite, calcite, gypsum, halite, hydromagnesite, huntite, and dolomite were reported within moonmilk. Textural examination reveals that the speleothems show a variety of microstructures. These are; 1) Normally oriented, isopachous fibrous texture, 2) Randomly oriented, fibrous texture, 3) Normally oriented, isopachous bladed texture, 4) Normally oriented, isopachous columnar texture, 5) Spherulitic fibrous texture, 6) Spherulitic columnar texture, 7) Equant texture, 8) Basket-weave texture, 9) Reel-like texture, and 10) Feathery texture. The difference in texture appears to result from the rate of crystal growth and the saturation state of fluids with respect to carbonate minerals (aragonite and calcite).

The speleothems, composed of aragonite, tend to show higher Sr compositions than calcitic ones, whereas Mg contents in aragonitic speleothems are lower. All the speleothems from different caves show distinctive Sr and Mg compositions, indication that the local supply of trace elements influenced on the trace element contents of the speleothems.

The oxygen isotopic compositions range from –9.4 to –4.0 per mil (vs. PDB). Considering the oxygen isotopic compositions of freshwater, the data suggest that the most of the speleothems formed in oxygen isotopic equilibrium except for some enriched aragonitic ones. The carbon isotopic values are highly variable from –10 to –5 per mil (vs. PDB), and these values are between the carbon isotopic compositions of the organic matter in overlying soil and the surrounding limestone. Using the simple mass balance equations, the influence by two end members is calculated.

Introduction

The geological research on limestone caves and the associated speleothems in South Korea has been carried out past 15 years. Recently, as the local government increased the interest in developing natural caves into show-caves, compiled scientific reports on limestone caves and lava tubes have been published (WOO *et al*., 1995; WOO *et al*., 1999; WOO *et al*., 2001; Woo *et al*., 2001). Among many areas of cave research, especially the mineralogy, texture, and chemical composition of speleothems and the origin of speleothems have been one of the main interest for the Korean cave geologists.

More than one thousand limestone caves are known in Korea, and most of them are concentrated in the eastern-central part of the Korean peninsula (Fig. 1), where the Paleozoic carbonate rocks are exposed. Also, lave tubes are abundant in the Jeju Island, which is a volcanic island and is located about 200 km south of the peninsula. Recently, WOO *et al*. (2000) reported the calcareous speleothems in the Dancheomul Cave (lava tube) in Jeju Island.

This paper deals with the general distribution and the genesis of the limestone caves in South Korea, and the recent result on the genesis of speleothems using textural, stable isotopic, and elemental data.

Geology of Carbonate Rocks

Most of the carbonate rocks in Korea are lower Paleozoic (Cambrian to Ordovician) in age, which is stratigraphically named as "the Joseon Supergroup". Except for the few locations, most of the limestone contain fossils such as trilobite, echinoderm, brachiopod, gastropod, etc., which indicate shallow marine environments. Also, non-skeletal components such as ooids and oncoids support this interpretation. Numerous sedimentary structures were reported; stromatolite, ripple mark, mud crack, bioturbation, microbial lamination, and birds' eye structure. Some limestone formations contain argillaceous material (i.e., clays), which hindered the development of the natural caves.

Characteristics of the Genesis of the Limestone Caves

The limestone caves in Korea show horizonal, vertical, and/or combined morphology, depending upon the strike and dip direction of the bedding planes and joints in carbonate rocks. Since the Korean peninsula is located along the Pacific margin, and the Sino-Korean plate collided with Asian continent, tectonic stress resulted in folding and folding of the carbonate rocks, which produced numerous directions of the joints and bedding planes in carbonate rocks. Therefore, most of the limestone caves in Korea have been developed along the joints and bedding planes. Both vadose and phreatic types of passages are present.

Mineralogy and Texture of Speleothems

Calcite and aragonite are dominant minerals comprising the speleothems in Korea. A single kind of speleothems can be composed of one mineral, or both minerals, probably depending upon the Mg/Ca ratio and/or saturation state with respect to carbonate minerals of the fluid from which the carbonate minerals precipitated. The higher state of saturation or the higher Mg/Ca ratio leads to aragonite precipitation. Based on the examination of the mineralogy of the speleothems in the several limestone caves, curtain (also bacon sheet), fried-egg stalagmite, cave shield, and rimstone are always composed of calcite whereas cave flower is always composed of aragonite. However, cave coral, stalactite, stalagmite, and flowstone are composed of calcite and/or aragonite. In some caves, moonmilk has been reported (WOO *et al*., 1999), and are composed of calcite, aragonite, dolomite, gypsum, huntite, and hydromagnesite. It is notable that the aragonite crystals show the shape of laths and the calcite crystals are anhedral in shape. Also, the hyrdomagnesite minerals show typical monoclinic plates.

Textural examination reveals that the speleothems show a variety of microstructures. Aragonitic textures are composed of; 1) Normally oriented, isopachous fibrous texture, 2) Randomly oriented, fibrous texture, 3) Normally oriented, isopachous columnar texture, 4) Spherulitic fibrous texture, and 5) Spherulitic columnar texture. Calicitic texture shows; 1) Normally oriented, isopachous fibrous texture, 2) Randomly oriented, fibrous texture, 3) Normally oriented, isopachous bladed texture, 4) Normally oriented, isopachous columnar texture, 5) Spherulitic fibrous texture, 6) Spherulitic columnar texture, 7) Equant texture, 8) Basket-weave texture, 9) Reel-like texture, and 10) Feathery texture. The difference in texture appears to result from the rate of crystal growth and the saturation state of fluids with respect to carbonate minerals (aragonite and calcite).

The evolution of one type of speleothems into the other is very common in the limestone cave, soda straw into stalactite, stalactite or stalagmite into cave coral, etc.. This results from the change in rate of water supply (WOO and WON, 1989).

Stable Isotopic and Elemental Results

The oxygen isotopic compositions range from –9.4 to –4.0 per mil (vs. PDB). Considering the oxygen isotopic compositions of freshwater (-10.7 to 9.3 per mil vs. SMOW), the data suggest that most of the speleothems formed in oxygen isotopic equilibrium except for some enriched aragonitic ones (CHOI, 2000). The carbon isotopic values are highly variable from –10 to –5 per mil (vs. PDB), and these values are between the carbon isotopic compositions of the organic matter in overlying soil and the surrounding limestone. 17 to 36% of the carbon in the speleothems was supplied from soil-derived carbon dioxide and 64 to 83% from the surrounding carbonate rocks.

The speleothems, composed of aragonite, tend to show higher Sr compositions than calcitic ones. Aragonitic speleothems show low Mg contents, whereas calcitic ones contain various Mg contents. All the speleothems from different caves show distinctive Sr and Mg compositions, indication that the local supply of trace elements influenced on the trace element contents of the speleothems.

Calcitization

The cave coral, stalactite, and flowstone in some limestone caves of Korea, which were originally composed of aragonite, were calcitized. The neomorphic calcite crystals contain reilic of the original aragonite crystals and growth laminae. The presence of these relics in neomorphic calcite as well as the similar Sr and Mg contents to the original aragonite suggests that the most the calcitization processes took place in a semi-closed diagenetic system via thin-film alteration front.

Summary

Limestone caves and lava tubes are present in Korea, and most limestone caves in Korea have been developed within the lower Paleozoic carbonate rocks.

Due to the tectonic movement of the Korean peninsula, the limestone caves in Korea have been formed along the strike and dip directions of the joints and bedding planes in carbonate rocks.

Most speleothems are composed of aragonite and/or calcite.

The calcitic speleothems show 10 types of microstructure, and and the aragonitic speleothems show 5 types.

Oxygen isotopes in aragonitic speleothems tend to be more enriched than calcitic ones, indicating that the aragonitic speleothems have been formed due to evaporation rather than degassing of carbon dioxide.

Some originally aragonitic speleothems have been replaced by calcite, due to the change of the chemical composition of cave water.

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Weathering of Cave Walls in Martinska Jama, SW Slovenia

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Abstract

Martinska Jama is a cave situated in karst area of Matarsko Podolje in the south-west part of Slovenia. The cave was formed in transition between Lower and Upper Cretaceous carbonate beds. In some parts of the cave limestone walls are extremely weathered specially in side passage Boeganov Rov. Limestone beds are weathered from few millimetres to some centimetres in depth, depend on freshness of breakdowns and presence of fissures. The weathered zone of carbonate rock is almost identical to parent rock in its mineral and chemical composition yet it is much more porous. It is very unusual that the weathered remain is not insoluble rest but purified calcite. Weathered zone of limestone bedrock has “spongy” like texture. The main reason of limestone weathering in this part of the cave is probably corrosive moisture which has it origin in percolation water from the surface above the cave.

Introduction

Weathering of the cave walls is characteristic in the caves formed in different karst type, different geographical position and in carbonate rocks of different origin and age. In Slovenia weathered zones of carbonate rocks were found in the caves of Alpine and Dinaric Karst areas, at different altitudes and in caves which have been formed in limestones and dolomites from Upper Triassic to Paleocene.

In article the weathering of limestone bedrock in Martinska Jama cave is represent. Cave Martinska Jama is located in karst area of Matarsko Podolje in SW Slovenia (Fig.1) at 565 m above sea level (y = 5425 555, x = 5045 305).

Fig. 1: Map of Slovenia showing the location of cave Martinska Jama.

Cave was formed in Cretaceous limestone – $K_{1,2}$ (ŠIKIĆ et al., 1972). Limestone beds dip toward NE with dip angle 20 – 30^0. The main tectonic structures in the area are in “Dinaric” NW-SE direction, well expressed are also N - S and in E -W directions.

Speleomorphology of the Cave

Cave lies on N slope of Veliki Mavrovec hill at foothills of Slavnik mountain. Entrance to the cave is open on SE slope of small collapse doline. The length of cave passages is 1004 m and the depth is 120 m. From the collapse doline cave is elongated in two directions (Fig. 2). Main part of the cave follows the geological structural elements, specially the main tectonic directions. First part of the cave follows N-S direction but the main part of the cave lies in NW-SE direction, only the last part of the cave follows the E-W direction. Freatic forms of cave channels are removed by breakdowns and weathering processes. Weathering of limestone is significant specially for small side passage Boeganov Rov, in smaller quantity was noticed was also in side passage Stranski Rov.

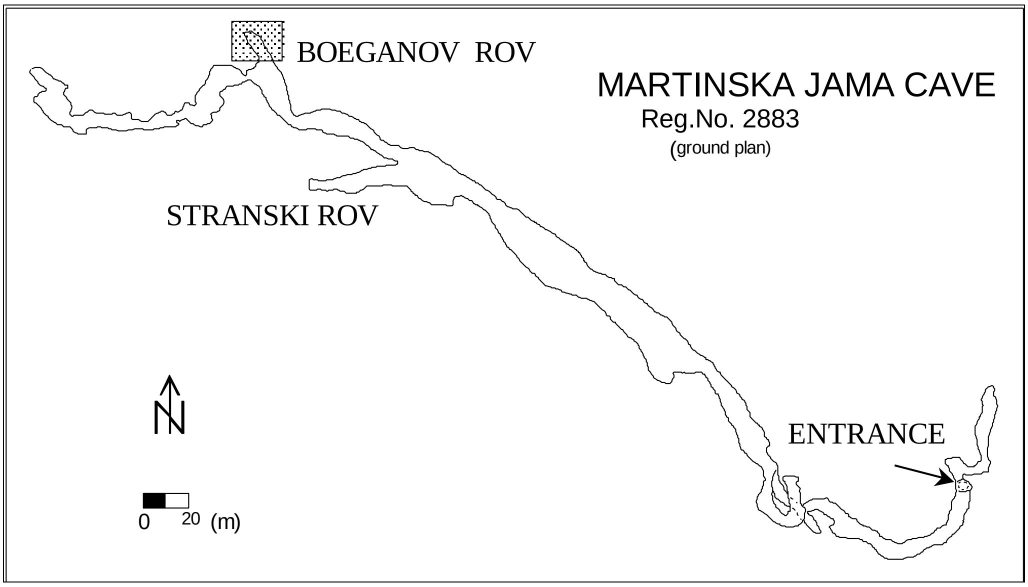

Fig. 2: Ground plan of Martinska Jama cave with marked passage Boeganov Rov.

Passage Boeganov Rov

Boeganov rov passage (Fig. 3) is interesting because its walls are completely weathered. At firs side it looks like they are covered by moon-milk precipitated from saturated water.

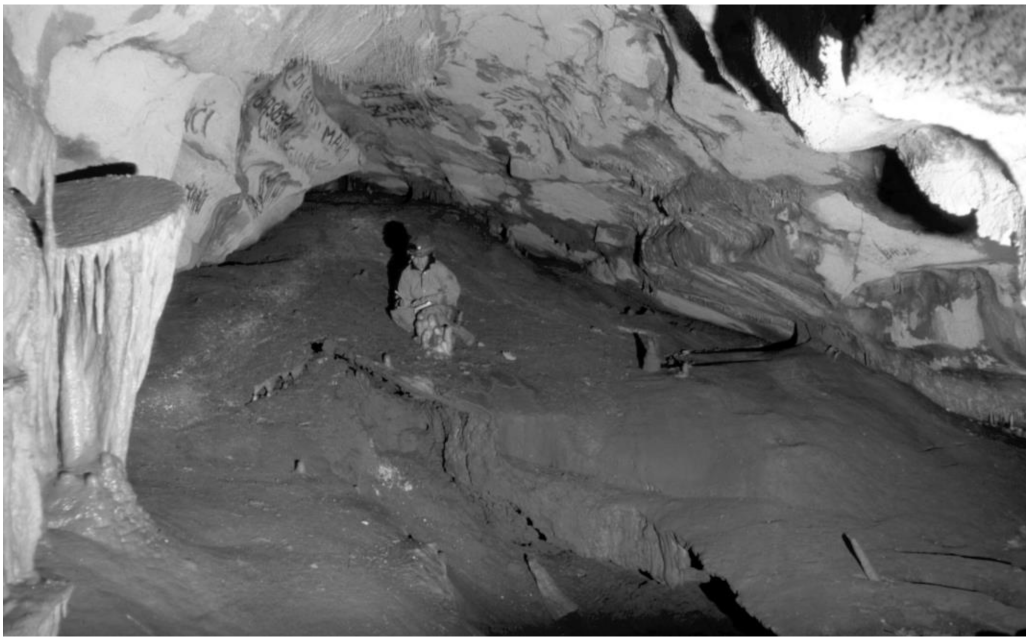

Fig. 3: Weathered walls of cave passage Boeganov Rov.

The passage is risen from the level of the main channel towards NW. Length of the passage is about 25 m. The entrance is almost closed by flowstone, inside the passage the small chamber is formed. The detailed ground plan is on Fig. 4. The walls of the chamber are not covered by flowstone, except of dripping water bound on the stronger fissures or bedding planes.

Temperature is almost constant during whole-year, it varies between 8,7 to $9,0^0$C. The air current was not perceived in the passage. In the passage there is no permanent water flow, wetness of the walls depends directly on atmospheric precipitation and intense percolation through fissures.

In Boeganov Rov passage limestone beds dip toward NE with dip angle 20^0 (dip 30/20). For water percolating is significant specially in one distinctive bedding plane which projects lower limestone bed into the cave at the W passage wall. The bedding plane was also tectonised the red clay is presented in it.

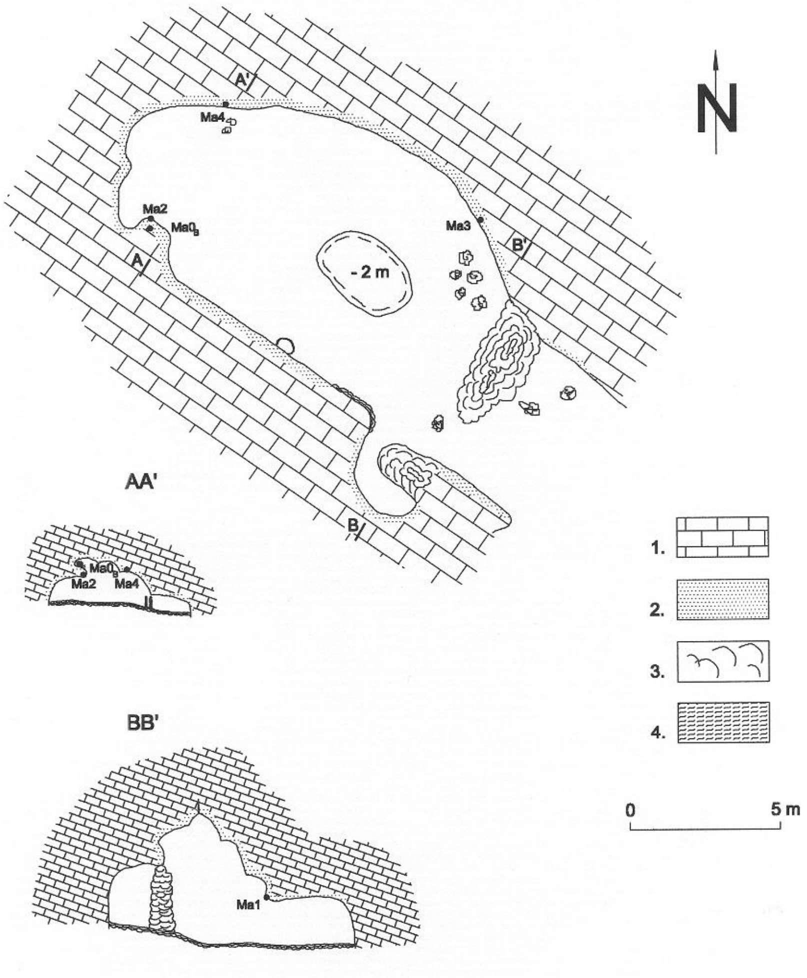

Fig. 4: Detailed ground plan of Boeganov Rov passage with two profiles: AA' and BB'. Legend: 1.- limestone, 2. - weathered zone, 3. - flowstone, 4. - fluvial deposits and marked locations of the samples, Ma0 – Ma4 - samples.

Along and under that particular bedding plane flowstone is precipitated because strong percolating of the water is presented. This water is also source for the wetness of the walls, specially were they are weathered. Porous weathered limestone acts like sponge, it sips the moisture. The moisture is aggressive at first, at each new cycle when new aggressive water reach the cave after rain at the surface. Aggressive moisture penetrates into limestone and at first dissolves contacts between the grains and small grains.

Sandyclay deposits are found on the passage floor and at rocky shelves on cave walls. Deposits have fluvial origin from non-carbonate Eocene flysch rocks. All cave walls are not in the contact with sediments now, but my be they were in the past.

Weathered Walls

Walls and the ceiling of Boeganov Rov passage are wholly weathered. Weathered limestone is white in colour and porous. It pass over to fresh one through some steps. Surface of limestone in the cave is soft and porous, separated grains of limestone are exposed and they create micro-roughness of the wall. Roughness of weathered limestone surface depends on its texture.

Fig. 5: Outstanding of calcite veins was formed by selective corrosion. Weathered limestone is porous and wet.

In some places the beginnings of "boxwork" (PALMER, 1981) is formed with outstanding of calcite veins (Fig. 5) and in the other places small rounded holes (Fig. 6) are presented. Surface of the limestone is weathered. Weathering penetrates into carbonate rock along open bedding planes, fissures, irregularities etc.. The weathered zone of limestone is from few millimetres to some centimetres thick. Thickness varies regarding to fresh breaks on the walls and to open fissures.

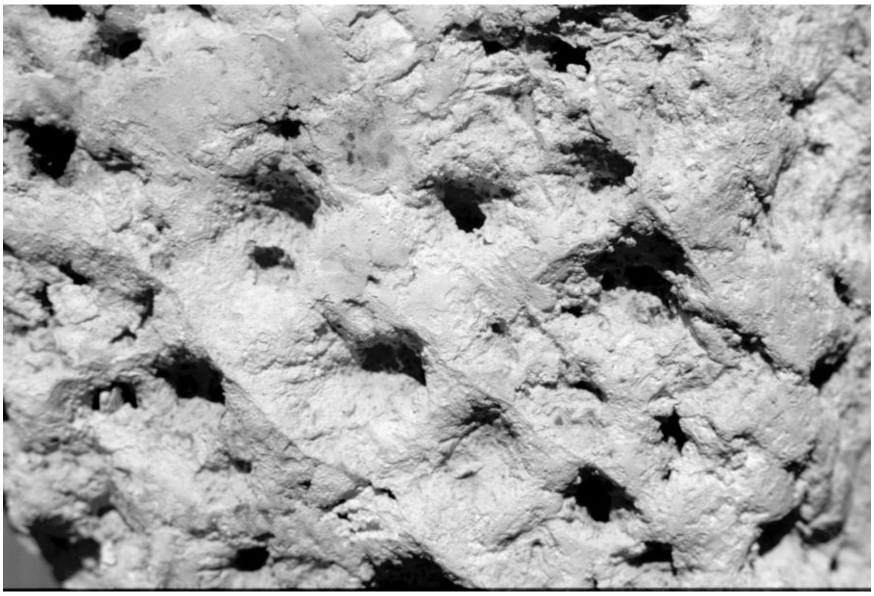

Fig. 6: Rounded holes on the weathered cave wall, diameters of lagers holes are about 1 cm.

Measurement of weathered limestone thickness was done by drilling (Fig. 7). The thicker measured weathered zone was 10 cm deep. Weathered limestone is porous and soft when is wet. When is wet is grey in colour, when is dry is white.

Percolating water also flows through open pores of weathered limestone, in the case when it becomes saturated calcite cement may be precipitated. In places where weathered limestone is cemented with fresh white or grey coloured cement, also sodastraw stalactites are formed. They are characteristic in places with stronger percolation of water through the open pores. Sodastrows are not bound on open fissures but they are dispersed on wider area of cave ceiling due to big porosity of weathered limestone.

Fig. 7: Measurement of weathered zone thickness was done by drilling.

Methods and Results

Samples were analysed by chemical, mineralogical and sedimentological methods.

Optically the thin sections, cross-sections, and SEM analyses of the samples were done. Chemical composition was defined by ACTALEB – Activation Laboratories LTD (Canada) with Total identification package of analyses (code 4E). Complexometry of samples were done on our Institute. EDS analyse under SEM was realised on J. Stefan Institute, Ljubljana. Mineralogical composition was determined by X-ray powder diffraction method on Department of Geology at Faculty of Natural Sciences and Engineering in Ljubljana. For the analyses samples were divided into: a. fresh part, b. discoloured part and c. wholly weathered part (Fig. 8).

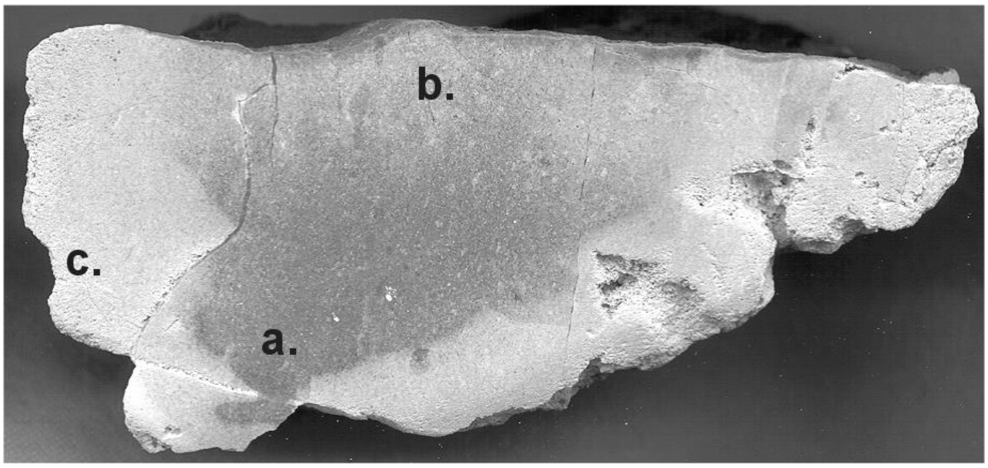

Fig. 8: Degrees of weathering in the sample Ma2. Legend: a.- fresh limestone, b.- discoloured limestone, c.- wholly weathered limestone.

Transition from fresh to weathered carbonate rock is seen in cross-sections of the samples which were scanned by computer scanner and also under SEM. Weathering is forced along the open fissures and interfered with calcite veins. The penetrating of weathering, that means dissolution, is not frontal but very much selective. Aggressive solution at first dissolves the contacts between the grains, small grains, defect grains etc..

Results of chemical analyses of sample Ma1 are presented in Fig. 9. Negative values indicate values under the detection limit.

	unit	**Ma1a**	**Ma1c**		unit	**Ma1a**	**Ma1c**
SiO_2	%	0,15	0,08	**Au**	ppb	92	24
Al_2O_3	%	0,06	0,04	**As**	ppm	-2	-2
Fe_2O_3	%	0,05	0,05	**Br**	ppm	1	1
MnO	%	0,002	0,002	**Co**	ppm	-1	-1
MgO	%	0,48	0,30	**Cr**	ppm	-2	3
CaO	%	55,76	55,93	**Cs**	ppm	-0,5	-0,5
Na_2O	%	0,20	0,15	**Hf**	ppm	-0,5	-0,5
K_2O	%	-0,01	0,10	**Ir**	ppb	-5	-5
TiO_2	%	-0,001	-0,001	**Mo**	ppm	-5	-5
P_2O_5	%	0,02	0,02	**Rb**	ppm	-20	-20
LOI	%	43,09	42,90	**Sb**	ppm	0,8	0,4
TOTAL	%	99,81	99,56	**Sc**	ppm	-0,1	0,3
Ba	ppm	2	2	**Se**	ppm	-3	-3
Sr	ppm	229	176	**Ta**	ppm	-1	-1
Y	ppm	2	3	**Th**	ppm	-0,5	-0,5
Zr	ppm	20	17	**U**	ppm	1,4	0,7
Be	ppm	-1	-1	**W**	ppm	-3	-3
V	ppm	13	10	**La**	ppm	0,3	1,1
Ag	ppm	0,4	0,6	**Ce**	ppm	-3	-3
Cd	ppm	-0,3	-0,3	**Nd**	ppm	-5	-5
Cu	ppm	2	2	**Sm**	ppm	-0,1	0,3
Ni	ppm	-1	-1	**Eu**	ppm	-0,1	-0,1
Pb	ppm	-3	-3	**Tb**	ppm	-0,5	-0,5
Zn	ppm	-1	-1	**Yb**	ppm	-0,1	-0,1
Bi	ppm	-2	-2	**Lu**	ppm	-0,5	-0,5

Fig. 9: Chemical composition of fresh and weathered part of the limestone sample Ma1. Ma1a - fresh part, Ma1c – weathered part.

In the weathered part of limestone the values of MgO, SiO_2, Al_2O_3 and Na_2O are lower, lower are also values of Sr, Zr, V, Au, Sb and U. The values of CaO, K_2O, Y, Ag, Cr, Sc, La and Sm are higher. In the fresh part of limestone sample Ma1 oxides present 99,81 % in weathered part they present 99,56 %.

Complexometry was done from samples Ma1, Ma2 and Ma3. Results are presented on Fig. 10.

Percent of CaO is higher in weathered parts than in fresh parts of limestone samples. It is also seen that content of MgO is lower in weathered part than in fresh part. In two weathered limestone samples the insoluble residue is higher, but in Ma2c there is no insoluble residue at all.

sample	CaO %	MgO %	calcite %	dolomite %	carbonate %	insoluble residue %	CaO/ MgO
Ma1a	55,13	0,8	96,31	3,69	100	0	68,91
Ma1c	55,24	0,6	97,07	2,77	99,84	0,16	92,07
Ma2a	55,12	0,8	96,31	3,69	100	0	68,9
Ma2c	55,18	0,73	96,68	3,32	100	0	75,59
Ma3c	54,12	0,61	94,1	2,77	97,87	2,13	88,72

Fig. 10: Complexometry results of limestone samples, a. - fresh part, c. – weathered part.

Qualitative EDS analyse on SEM was done two times in fresh part and two times in weathered part of limestone sample Ma2. At first out of windows 50 x 50 µm and the second time out of windows 100 x 100 µm. Typical measured spectra are presented on Fig. 11 and Fig. 12. The most characteristic result is that in weathered parts of limestone the amount of MgO is lower than in fresh part and that also the amount of Sr is lower in weathered part.

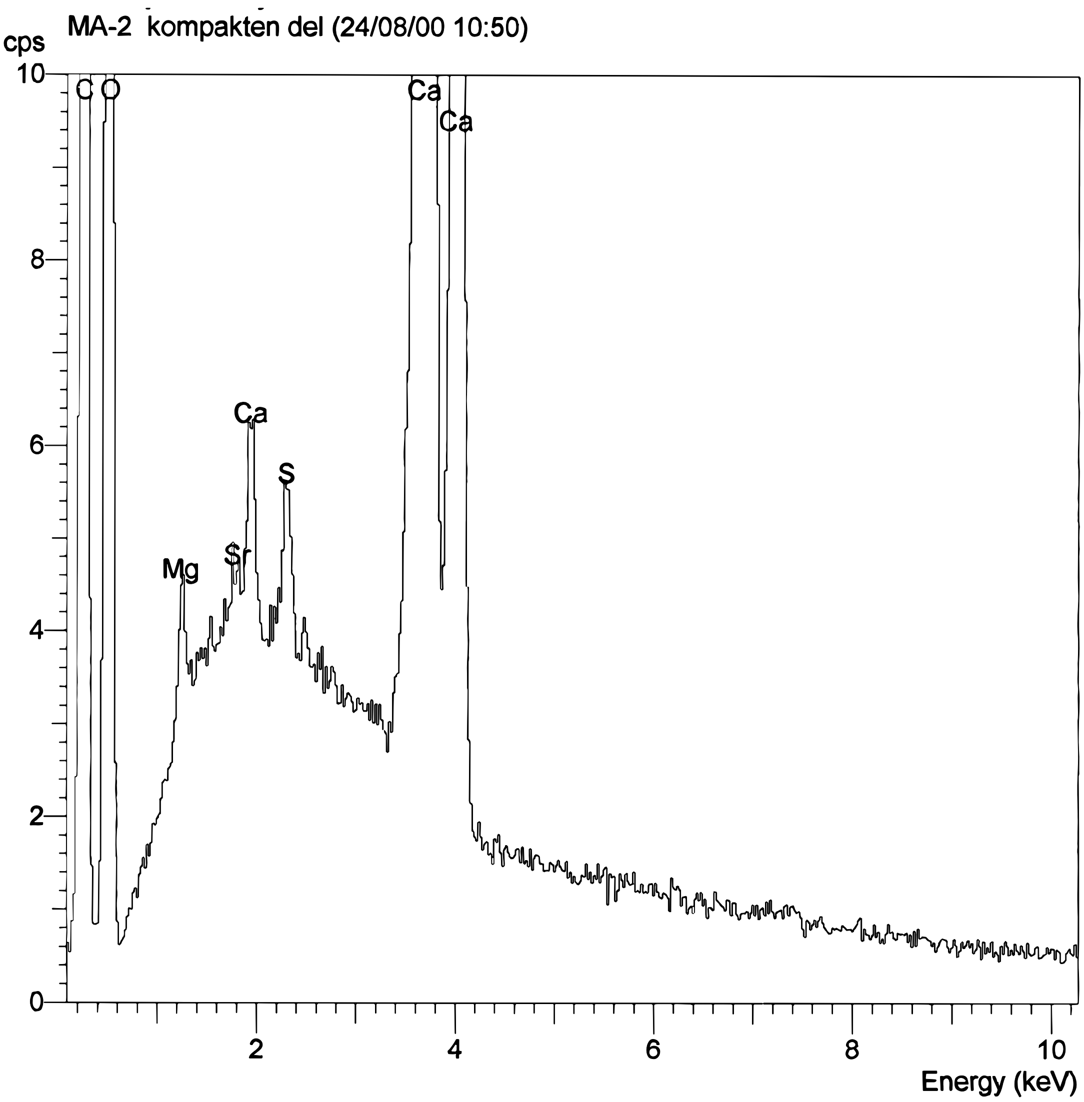

Fig. 11: Qualitative EDS analyse on SEM, measured spectrum of fresh part of limestone sample Ma2. Legend: Ca – calcium, C – carbon, O- oxygen, S – sulphur, Sr – strontium, Mg – magnesium.

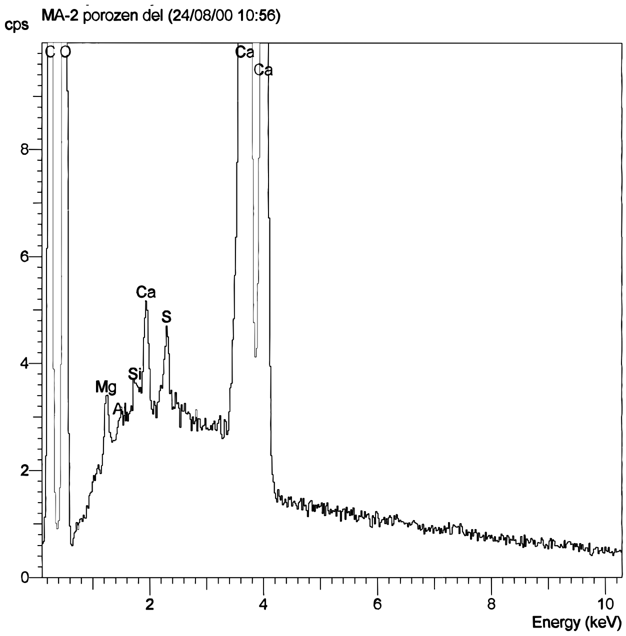

Fig. 12: Qualitative EDS analyse on SEM, measured spectrum of weathered part of limestone sample Ma2. Legend: Ca – calcium, C – carbon, O- oxygen, S – sulphur, Sr – strontium, Mg – magnesium.

Mineral composition of fresh and weathered samples of limestone is seen on Fig. 13. Fresh limestone, sample Ma2a, is composed 97 % of calcite, small amount of clay minerals and quartz. Weathered parts are even cleaner – 98 % of calcite, see Ma1b, Ma1c, Ma2b, Ma2c. But the difference is so small that from results we can't make any conclusions. Mineral composition of sandy deposit from the Boegan passage was also defined. It is composed 70 % of quartz, 15 % of mineral from illite/muscovite group and 15 % of goethite. It is clearly different in mineral composition like weathered limestone, so it can't be insoluble rest of limestone. Deposit has origin in weathered Eocene flysch of Brkini mountain, N of the cave.

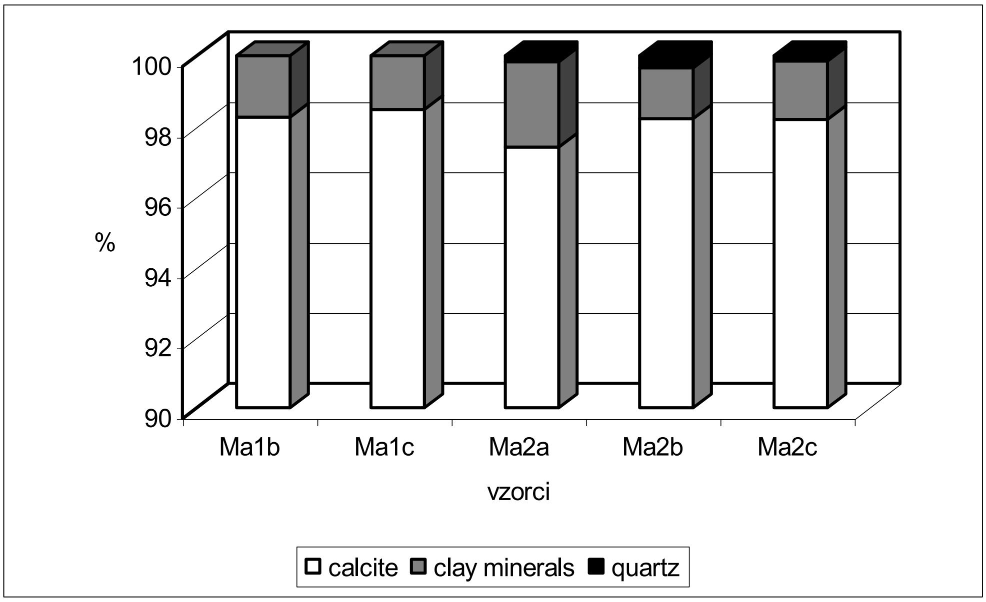

Fig. 13: Comparison between the mineral composition of fresh (a.), discoloured (b.) and wholly weathered (c.) limestone does not indicate any big difference.

Discussion

Weathering of limestone is part of limestone dissolution process, where dissolution is not complete and its rest is not non-soluble residue but very porous purified limestone.

The weathered part of limestone is almost identical to the parent rock in its mineral and chemical composition yet it is much more porous. In limestone different degree of weathering are seen. Weathered zones pass from wholly weathered limestone to fresh one through few steps of weathering. Fresh limestone at first becomes slightly discoloured and after weathering progresses becomes total discoloured (white) and porous. MgO and Sr are leached from calcite structure, so the calcite is purified during the weathering. In this case it is not going on the dissolution of the limestone and than precipitation of cleaner calcite crystals.

Weathered limestone is more and more porous and it has “spongy” like texture. Weathered limestone is wet the water is in it pores. If there is no source of the moisture the weathered wall of the cave becomes dry. The main reason of limestone weathering in this part of the cave is probably corrosive moisture (DAVIS & MOSCH, 1988) which has it origin in percolation water from the surface above the cave. Percolating water is strongly connected to the outside atmospheric precipitation so also the moistening is cyclic. Moisture is aggressive at first and it dissolves the limestone. Dissolution is selective and it stops when moisture becomes saturated or when its dry up. I have no evidence that the fluvial deposits in the passage have had any influence on the limestone weathering although the passage was once filled up by sediments. Probably the sediment was just one more agent to keep moisture on the cave walls.

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Unroofing of a Cave System – an Example from Classical Karst

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Abstract

Old caves are being exposed due to lowering and dissecting of a karst surface. The surface either uncovers or intersects them. In the first case the unroofed caves display the form of an oblong indentation and in the second a doline-like feature. Repeatedly intersected passage is shown as a series of described features. The most expressive are these features when the transport of sediments out of the caves is faster than the lowering of the nearby carbonate surface. A bigger cave system near Kozina indicates a diversity of exposing types. A smaller and already vacant passage was known before the earth works for motorway construction started. Other passages were filled up by fine-grained and gravel flysch deposits. Some of them have a thin roof other were roofless already. At the surface parts of a cave system are seen as a system of different indentations and doline-like features.

1. Introduction

Motorway construction reveals karstic relief and even frequently cuts deep into it, exposing a variety of interesting karstic phenomena and features of the development of the hollowed karstic aquifer and the formation of the karstic relief and composed epikarst. The construction of the last 50 km of motorway in the Karst has exposed over 300 caves; two thirds are filled with sediment and gravel and nearly one third are without ceilings (KNEZ & SLABE, 1999; KNEZ & ŠEBELA, 1994; KOGOVŠEK *et al*., 1997; MIHEVC, 1996; MIHEVC, 1999; MIHEVC & ZUPAN HAJNA, 1996; SLABE, 1996, 1997a, 1997b, 1998; ŠEBELA & MIHEVC, 1995; ŠEBELA *et al*., 1999). The latter were of special interest to us because they proved to be a more common karstic phenomena than was thought before they were exposed (Fig. 1). We also identified their characteristic forms (MIHEVC *et al*., 1998; KNEZ & SLABE, 2001, to be published).

This paper is an overview of experience gained in past years of research into this interesting karstic phenomenon. This includes current results, as motorway construction is ongoing and we are still performing karstological monitoring. We are of the opinion that more attention should be directed towards this karstic phenomenon even though it is not a new discovery. Our text focuses on cases in the Classic Karst, i.e. the Karst from which the name of all carbonate rock landscapes on which karstology has formed is derived (KRANJC *et al*., 1997, 1999).

The Classical Karst is a karstic plateau overlooking the boundaries of the north-western part of the Adriatic Sea. It is composed primarily of highly pure rudist Cretaceous and mostly foraminiferal Tertiary limestones, and in some places dolomites and clastits. The central part of the plateau is between 200 and 500 m above sea level. The 440 km^2 plateau was until recent times almost completely bare of plant cover, now is covering by forest. To the north-west it borders on the Vipava valley and to the south-east on the vast flysch area, where it rises to over 600 m above sea level. Its north-western boundaries are the Friuli lowlands and the Soča river; to the south-west lies the Adriatic Sea.

Our research did not uncover any traces of surface flows, which in the past was thought to explain the formation of the plateau surface. However, due to the karstification of carbonate rock the water level in the aquifer dropped to the present 200 m and more below the surface. Surface flows do not exist in the Karst. All karstic flows disappear underground in the area of contact between the flysch and the limestone bedrock. Of greater significance are the karstic aquifer and the sub-surface flows of water to the source of the Timavo river in Italy. The largest underground flow is the Reka river, which disappears underground in the Škocjan caves. From an environmental viewpoint the Karst is one of the most vulnerable natural systems in Slovenia.

2. Morphology of Relief Above Cave System

The relatively flat surface located between 520 and 530 m above sea level and with separate steep steps is segmented by dolinas and dolina-like landforms up to 10 m deep and 50 m in diameter, as well as oblong depressions up to 70 m long, 3 m deep (i.e. relatively shallow) and 5 m wide. Dolinas and dolina-like landforms with semicircular and oval cross-sections are separate or in pairs. We also observed the layout of dolinas in series parallel to the contour lines and 600 m in length. Cave passages appeared during motorway construction along the whole length of the series. The oblong depressions were located independently on the surface, some running from the dolinas and some connecting them. Real dolinas were filled with thick layers of soil or developed karren of a metre or more in depth. Removing the soil uncovered traces of water percolating at the perimeters of the karren and cracks through which surface water runs off on the bottom.

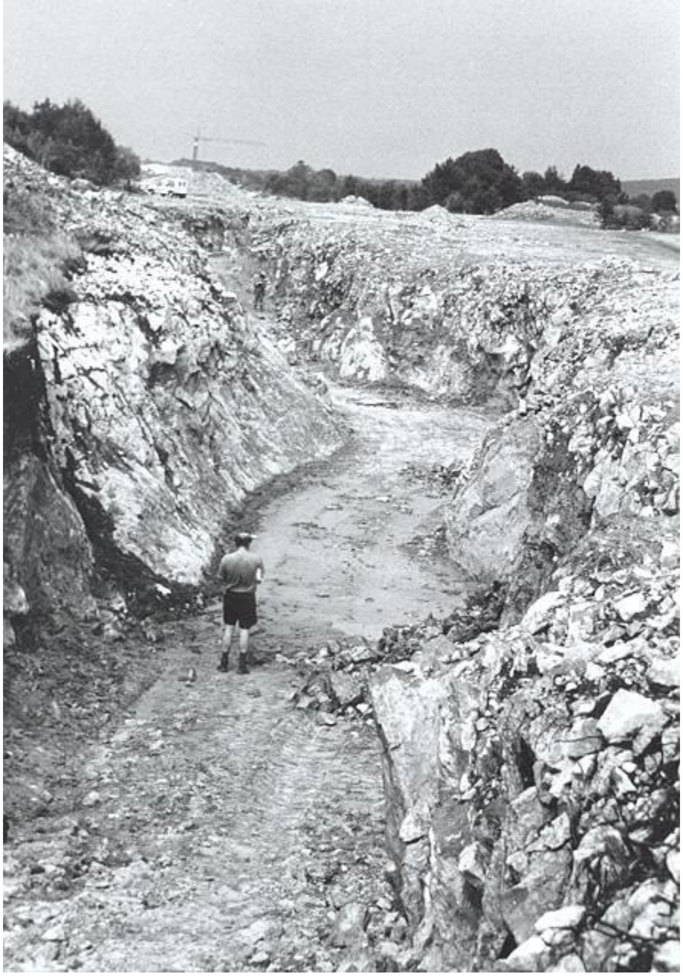

Figure 1. Unroofed cave.

3. Form of Cave System

The area under discussion contained a known, small and empty cave. Its bottom was covered with collapse rock and the lateral extension of the cave was filled with angular gravel.

We had predicted that unroofed caves would appear during the groundwork that bared the karstic surface; this was confirmed. Unroofed caves (Fig. 2) were individual dolina-like landforms that had developed in the middle of old passages, or oblong depressions as individual landforms on the karstic relief or intertwined with small dolinas. The dolinas were interrupted by preserved sections of the old ceiling. One characteristic of unroofed caves, which are in the majority and at the same time preserved as individual landforms, is the filling of the cave with sediments and flowstone. After the sediments and flowstone were removed from the caves, individual passages appeared. They were up to 5 m in diameter, while only the largest part of the cave, which on the surface gave the appearance of a landform similar to a shallow dolina, was up to 10 m in diameter. We concluded that the caves exposed by groundwork were below the 600-m-long series of dolinas and depressions of the same cave network. The enclosed drawing of part of the cave system being presented clearly shows how the dolinas cut through the network of cave passages. Individual passages opened in the cross-sectional direction during road bed construction, indicating that a thin passage ceiling was preserved.

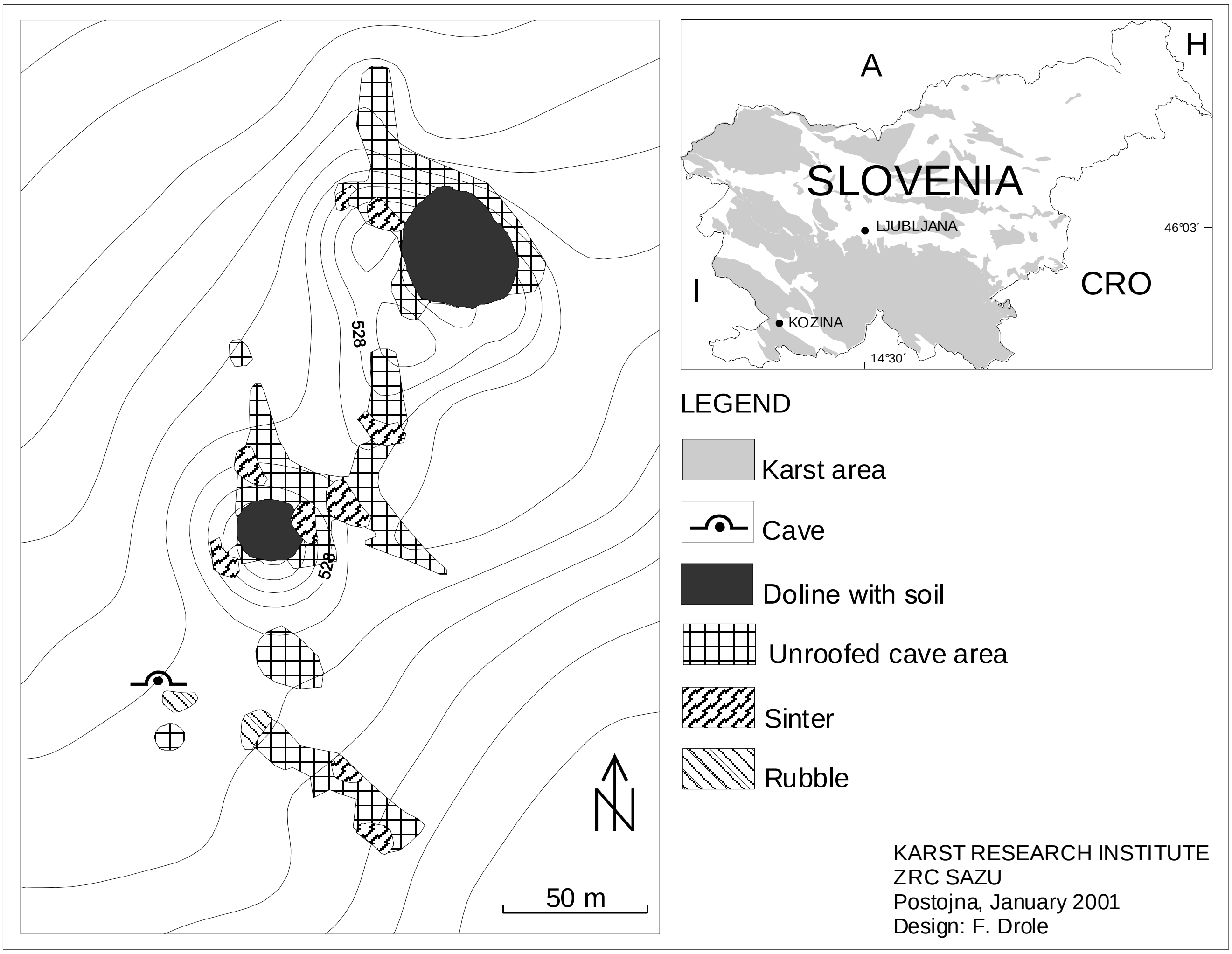

Figure 2. Part of the cave system at Kozina.

4. Sediments

The caves were filled primarily with sediments, flowstone and Pleistocene gravel. The filled space in the cave ensures better stability of the rock; this is why the ceiling in such passages can be thinner.

One third of the cave in the motorway construction area revealed a layer of yellow-brown sediment of flysch origin up to a few metres thick (Fig. 3). A fine-grainy sediment of sand size and fine gravel with separate layers of rubble were prevalent. Rubble stones with a diameter of over 10 cm were rare. The rubble and fine-grainy sediments are traces of underground water flows and floodwater in the caves. In addition to the yellow-brown sediment of flysch origin in the filled caves, we found a lateral dark red sediment which is younger and is the result of surface carbonate weathering. Both genetically different sediments are clearly delineated. They present the typical filling of underground passages. Soil was located above them in vertical fissures.

Stalagmites were rare among the flowstone whereas flowstone piles were more numerous. The flowstone was intensively white- to black-coloured, depending on the level of cations and oxides in the solution. Most of the observed flowstone was still compact; a smaller part disintegrated intensively into calcite debris on contact with atmospheric air. Paleogenetic limestone in this part of the Karst is thick-bedded and quite deformed, and is thus less resistant to weathering. During the Pleistocene Epoch it disintegrated into angular gravel; in some locations it covered areas of over 100 m^2 and in others it filled caves. We frequently found it over old flow sediments or filling space under sills. Due to Pleistocene material shifting, the angular gravel is often found mixed with loam, flysch sediments, finer sand and pieces of flowstone. The flowstone is sometimes found in its original location (stalagmites).

The filling type indirectly determines the speed at which the underground space empties and disintegrates.

Paleomagnetic research of the upper layers of yellow-brown sediment which fills the underground passages showed a normal magnetic turn, placing them in a period more recent than 0.73 Ma (ŠEBELA & SASOWSKY, 2000). The lower-lying sediments are much older. Paleomagnetic analyses performed by Šebela and Sasowsky showed a normal Gaussian curve (2.48-3.4 Ma) and Gilbert reverse period (3.8-5.9 Ma). BOSAK *et al*. (1998, 2000) also found a turn between the Brunches and Matuyama epochs. The latter data indicates the possibility that the cave formed before the Messina Age, characteristic of which is the lowering of the sea level and the development of karst in the Mediterranean area connected to it. After it was over, the cave filled with sediment.

Figure 3. Sediments in unroofed cave

5. Conclusion

The lowering of the karstic relief gradually exposed a large, horizontally and vertically branched-out cave network, mostly filled with sediment and gravel. A portion of the passages still have thin ceilings; others opened to the surface as they became unroofed caves. Larger horizontal passages opened as oblong depressions, their parts and steep passages cut by surface have dolina-like shapes. Dolinas cut through the cave network in a number of locations. Unroofed caves are a more discernible landform when located in the vicinity of dolinas or where water can rapidly remove the sediment from the cave. The exposure of the cave network is thus a significant surface karstic phenomena and part of the epikarst. The proportion of this phenomenon in the observed part of the karstic relief also demonstrates its significance.

The landforms of unroofed caves, which include dolina-like landforms, series of such landforms and oblong depression (KNEZ & SLABE, 2001, to be published), are the consequence of cave forms and the development of the relief above them. The relation between the speed of sediment removal from the cave and the lowering of the surrounding relief determines how discernible these landforms are.

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Sandstone Caves in Wisconsin

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Abstract

Sandstone caves account for about 30% of Wisconsin’s 250 recorded and mapped caves, yet they are consistently under-appreciated and underestimated. Most are formed in Cambrian aged sandstones in the southwestern part of the state, although others have developed in pre-Cambrian sandstones and by the collapse of Ordovician sandstones into cavities in underlying dolostones. Some of the caves have developed through stream meandering, waterfall undercutting or exterior erosion, but over 40 have formed through dissolution by groundwater, predominantly within the upper Jordan Sandstone where groundwater flow is focused downward through the overlying Oneota dolostone. The transitional Sunset Point member has recently been recognized as an important locus of speleogenesis. Although the longest sandstone cave is nearly 100m in length, most are much smaller, and a large number have not been recorded or mapped. Some are joint-controlled, while others are enlarged along bedding planes. Processes other than dissolution are involved in their development. Many of southwestern Wisconsin’s fragile rock formations may also actually be cave remnants. Some of the sandstone caves are significant sites of pre-European Native American artwork, including petroglyphs and pictographs.

Introduction

Over 77 or about 31% of the approximately 250 caves recorded and mapped in the U.S. state of Wisconsin are developed in sandstones. Despite this, these sandstone caves have received scant attention, except from recreational cavers, and little research into them has been conducted. To date, the most authoritative summary is that by CRONON (1970), whose efforts to stimulate increased attention appear largely to have fallen on deaf ears. Cronon provides a listing of the state’s known sandstone caves, grouping them into two broad classes: collapse caves and erosional caves. The former number at least ten and the latter at least 51, with an additional 16 unclassified. Of the erosional class caves, four are classified in a stream meander group, and at least four in an “exterior erosion” group, but the remaining 43 or more are attributed to ground water erosion, or speleogenesis.

Sandstone caves are not numerous in temperate areas, but they have been recorded in several locations (FORD & WILLIAMS, 1989; GILLIESON, 1996; JENNINGS, 1985; MIDDLETON & WALTHAM, 1986). Quartz sandstones are reasonably soluble in natural waters, especially under alkaline conditions (YOUNG & YOUNG, 1992), but insoluble residues often infill developing caves and dolines, with fissure and conduit flow being restricted.

Geological and Geomorphological Contexts

Wisconsin’s sandstone caves are formed within three geologic units. In the northern part of the state a few caves are developed in Precambrian sandstones, but these are not considered in detail here since they are few, small and produced primarily by processes other than dissolution. More significantly, caves in southwestern and central Wisconsin have developed in Paleozoic sandstones, particularly in the Cambrian aged Jordan Sandstone, which underlies the main carbonate cave host rock, the Early Ordovician dolostones of the Prairie du Chien Group, and in the Middle Ordovician St. Peter Sandstone, which overlies the Prairie du Chien Formation. Collapse caves are formed predominantly in the St. Peter Sandstone, and dissolutional caves in the Jordan Formation.

Depositional patterns during the Cambrian reflect the influence of the Wisconsin Arch and adjacent basins, with five rhythmic transgressional sequences of sandstones, dolostones and shales (PAULL & PAULL, 1977). The basal Upper Cambrian formation is the 100-250m thick shallow water Mount Simon Sandstone, which is overlain by the finer-grained impure sandstone of the Eau Claire Formation. Overlying this unconformably is the coarser, better-sorted sandstone of the Wonewoc Formation, which is up to 120m thick, and above this is the Tunnel City or Franconia Sandstone, which is 30-60m thick and lithologically similar to the Eau Claire. The dolostones of the St. Lawrence Formation cap this second transgressive cycle, which was followed by a period of erosion (PAULL & PAULL, 1977).

The Jordan Sandstone is the youngest of the sequence of Cambrian sandstones and is a clean, well-sorted, white, medium-grained, high-energy sandstone about six to 46 meters thick that was deposited during a third marine transgression onto the Wisconsin Arch (PAULL & PAULL, 1977). As the transgression continued, increasing marine depths favored carbonate deposition and the Jordan graded into the overlying Oneota dolostone, which is the youngest of the Prairie du Chien Group. Regional uplift at the end of the Early Ordovician was followed by two further transgressions, during the second of which the St. Peter Sandstone was deposited. The St. Peter is typically a white, massively bedded, medium-grained, well-sorted quartz sandstone, 12 to 107m thick, in places cross-bedded and in part of aeolian origin (PAULL & PAULL, 1977).

The sandstones are integral components of the northernmost of the three westward-dipping cuestas that dominate Wisconsin's western uplands (MARTIN, 1965). North of the Wisconsin River, the Jordan Sandstone typically forms 10m high laterally extensive vertical cliffs beneath a Prairie du Chien dolostone caprock; further south and west the St. Peter outcrops above the Prairie du Chien. Further north and east the older Cambrian sandstones outcrop, with the Tunnel City forming particularly extensive valley-side cliffs. Regional dip is slight, typically one or two degrees to the west or southwest. The landscape is fluvially dissected, with broad alluviated main valleys tributary to the Wisconsin and Mississippi Rivers flanked by narrow interfluvial ridges. Karst is a significant component of the upland landscape of southwestern Wisconsin's Driftless Area, with a wide array of dry valleys, sinkholes, caves and springs (DAY *et al*, 1989). Although dissolution of the dolostone is sluggish (DAY, 1984), the area was spared the ravages of Pleistocene glaciation (MICKELSON *et al*, 1982), which has allowed the persistence of the spatially restricted, essentially relict karst.

The Sandstone Caves

The only exhaustive discussion of the sandstone and sandstone-carbonate contact caves in Wisconsin has been by CRONON (1970, 1980), who has catalogued at least 77 individual examples, representing over 30% of Wisconsin's 250 recorded and mapped caves. The sandstone caves are consistently under-appreciated and underestimated in the cave and karst literature, perhaps because their speleologic pedigree is not appreciated, although they are well-known to recreational cavers. The caves occur in two distinct geological contexts, being formed both within the Cambrian sandstones, particularly the Jordan and the Tunnel City, and in the Ordovician St. Peter Sandstone.

Caves in the St. Peter Sandstone

The caves in the St. Peter Sandstone represent subjacent karst development, since they have developed essentially by the collapse of the sandstones into cavities in the underlying Prairie du Chien dolostones. Although not numerous, these are some of the most interesting caves in the state (CRONON, 1970).

The progression of cavity migration from the dolostone into the overlying sandstone is outlined by CRONON (1970:85) and results in a variety of sinkhole and cave morphologies with variable carbonate-sandstone ratios. Most of these caves are single rooms entered through sinkhole bases, and they are generally symmetrical, with circular plan profiles and ceilings arching upward toward the center. There is often a central pile of sand and sandstone rubble, and the floors typically slope downward toward one of the edges. At least 10 of these collapse caves are catalogued by CRONON (1970), and several more are known.

Several of southwestern Wisconsin's best-known caves, including Star Valley Cave and Viroqua City Cave, have exposures of the St. Peter Sandstone in their ceilings, and their sandy floors attest to gradual upward migration. In other cases, the upward migration has been such that the caves are now entirely within the overlying sandstone. Several pit caves occur in this category, including E-Pit, Jones Cave and Bridgeport Cave, which contains the largest cave room in Wisconsin.

Caves in the Jordan and Other Cambrian Sandstones

Some of the better-known and more accessible caves within the Cambrian sandstones have developed through stream meandering, waterfall undercutting or exterior erosion (MARTIN, 1965; CRONON, 1970), but at least 43 have formed through dissolution by groundwater, and are thus of true speleogenic origin. These occur throughout the Cambrian sandstone sequence where the sandstones have higher carbonate contents, such as in the upper Tunnel City and Jordan Formations. They occur particularly within the upper Jordan

Sandstone where groundwater flow is focused downward through the overlying fractured and karstified Oneota dolostone. The vertical continuity of the carbonate-clastic aquifer has been documented by the tracing of agricultural contaminant flushes to caves, springs and wells within both lithologies (REEDER, 1992; REEDER & DAY, 1993).

Some caves in the Cambrian sandstones are joint-controlled, with tall narrow passages, while others are enlarged into gently sloping "pancake" passages and rooms along bedding planes. Overall, their morphology and orientation is similar to that of regional carbonate caves (CRONON, 1970; DAY, 1986; DAY *et al.*, 1989; TERLAU & DAY, 1997). In particular, they slope generally downwards toward their entrances, indicating water egress (CRONON, 1970). One notable difference, however, is that the sandstone caves contain very little of the silt-clay sediment infill which characterizes the dolostone caves (DAY, 1988), presumably because the sediment has been retained within the latter rather than transported down into the underlying sandstones.

Notable caves in the Cambrian sandstones include Anderson's, Grunt and Hummel's Caves in Richland County (PETERSON, 1968). Although the longest cave in the Cambrian sandstones, Autograph Cave, in Juneau County, attains nearly 100m in length, most are much smaller, and a large number have not been recorded or mapped. For example, there are numerous small caves in the Jordan Sandstone cliffs flanking the Kickapoo River Valley north of Viola, but only one, Mount Nebo Cave, is catalogued by CRONON (1970).

The development of these caves involves processes additional to dissolution, notably granular disintegration, the mechanical flaking of interior wall and ceiling surfaces and the development of breakdown. Freeze-thaw may play an important role around entrances, where sand piles and vegetative debris accumulate, and cavities may be initiated or expanded by tree root growth or animal burrowing. Mass wasting of slopes, for example through rock toppling or rockfall (LYDEN, 2001) may further disrupt entrances.

Archaeological Significance

Several of the sandstone caves in southwestern Wisconsin have proven to be valuable archaeological sites yielding a variety of pre-European Native American artifacts, and a comprehensive survey is now underway to determine if other caves may provide additional evidence (G. HUPPERT, pers. comm., 2000). Much of Wisconsin's pre-European rock art is associated with sandstone caves and rockshelters in southwestern Wisconsin (SALZER, 1987a, 1997; BIRMINGHAM & GREEN, 1987; STILES-HANSON, 1987). In particular, Arnold Cave contains an impressive array of recently documented pictographs (G. HUPPERT, per. comm., 2000) and a famous petroglyph was discovered in the Gottschall Rock Shelter (SALZER, 1987b).

Natural bridges and other fragile rock formations

The absence of Pleistocene glaciation has permitted the development and persistence within the sandstones and dolostones of the Driftless Area of numerous fragile rock formations, some of which have at least a partial speleogenic origin. Two natural bridges occur in the Upper Cambrian Franconia or Tunnel City Sandstone, one at Pier Natural Bridge Park in Richland County, the other at Natural Bridge State Park in Sauk County. The former is essentially of fluvial origin, but the latter may have originated as a cave. Fragile rock formations in the St. Peter Sandstone include Elephant Trunk Rock, Monument Rock, Maiden Rock and the Three Chimneys, none of which have been the subject of detailed geomorphological study. Rock castellations in the Jordan Sandstone are numerous, especially at the tapering extremities of the interfluvial ridges, but these too have not been studied in detail.

One particularly striking rock formation is Five-Column Rock, in Vernon County (DAY & KUENY, 1999). The rock is formed at the transition from the Jordan Sandstone to the overlying Oneota dolostone, and has a basal sandstone plinth, a set of columns enclosing "windows", and a tabular dolostone summit, the entire structure being over 6m high. The morphology of the feature, its stratigraphic context and its juxtaposition to extant cave passage all point to a speleogenic origin, which may have broader significance for the development of similar features throughout the region. In particular, the columns are developed within the transition Sunset Point Member of the lower Prairie du Chien Group, which may represent a significant locus of speleogenesis adjacent to the sandstone-carbonate contact.

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The Minor Structure Analysis of the Akka Limestone, Iwate Prefecture, Northeast Japan

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Summary

In this paper we have used the statistical analysis as a tool for identifying the geological parameters controlling cavern-passageways orientation of Jurassic Akka Limestone, in Northern Kitakami massif, Northeast Japan.

The geological parameters, such as bedding plane, joint, fault and fold axis, were measured in the field, and plotted on equal-area, lower hemisphere stereographic diagrams.

The results of this study were based on the analysis a total of over 7200 data indicate that the geologic parameters will involved in the creation and the development of the caves in the Akka Limestone.

Introduction

The study area is one of the most interesting karst massif in Japan, because here is situated more than 100 caves, including the longest cave(Akka-do Cave ; more than 10km long) in Japan.

As is well-known, cavern passageways show more or less the same orientation as that of the geological minorstructure in the host limestone. The geological minor structure analysis of the Akka Limestone and associated rocks will help to understand the structural control involved in the creation and the development of the Akka Belt caves. Previously, several studies(MORI *et al*., 1966; KASHIMA, 1969) have been conducted throughout the Akka Limestone testing the geological minor structure controlling cavern passageways orientation.

It has been pointed out that Akka Limestone has been subject to intensive tectonic activity and recognized two excellent tectonic directions of nearly trending NW-SE and NE-SW of the Northeast area(SUGIMOTO *et al.,* 1973).

Since 1993, the authors have been doing the field investigation and the statistical analysis of a great many data of bedding plain, joint, fault and fold axis of the nine areas in the Akka Limestone(KASHIMA *et al*., 1994; KUWAHARA *et al.,* 1995:1996:1997:1998:1999 & 2000).

Geological Setting

The study area is located in the Akka Belt and is bounded by the Taro fault to the east and the Seki fault to the west, in the Northern Kitakami Massif, Northeast Honshu, Japan(Fig.1).

The Akka Belt is occupied by Mesozoic strata consisting of Late Triassic Kayamori Group and Trias-Jurassic Iwaizumi Group. The Iwaizumi Group is subdivided into three formations; named the Sawayamagawa Formation, the Akka Formation and the Takayashiki Formation.

Fig.1 Location and geological sketch of the study area(simplified from HASE G.S.O., 1981).
Abbreviation ; A:Cretaceous Granite, B:Akka Limestone & C:Akka Belt. 1:North-East area, 2:North-West area, 3:Yamane area, 4:Uchimagi area, 5:East area, 6:Shigawatari area, 7:Central area, 8:Ryusendo area & 9:South area.

The Akka Formation, which is exposed in about 4km miximum-wide and approximately 60km long trending in a northwest-southeast direction, made up largely of limestone(named Akka Limestone) and contains much intercalated basaltic rocks and chert. The Akka Formation is overlain by mainly of the alternation sandstone and slate of the Takayashiki Formation..

The Early Cretaceous(120-110 m.y.) granites occur as concordant intrusive masses to the Akka Belt and the limestone have been locally metamophosed to the marble.

The major caves of the study area are located in the Akka Limestone which varies in thickness from 500m in the North-East part to more than 1,000m in the Central part(SUGIMOTO, 1974).

Methods and Results

Geological minor structures; bedding plain, joint, fault and fold axis, were measured in the subdivided into nine areas on the basis regional categories of study area(1.North-East, 2.North-West, 3.Yamane, 4.Uchimagi, 5.East, 6.Shigawatari, 7.Central, 8.Ryusendo & 9.South) and the obtained data were plotted on each equal-area stereographic diagram(Schmidt's net) in serch for orientation of the major trend. The results were compared with limestone, clastic rocks and granite of the each areas in the Akka Belt as given Table 1. Fig.2 showing the relashionship of the major trends of bedding and joint in Akka Limestone in the each areas.

Table 1 Major trend data for bedding, joint and fault in the Akka Limestone of studied nine areas.

Fig.2 Equal-area stereographic plots of major trend of bedding(the left side) and joint(the right side) of the each areas in the Akka Limestone.

Conclusive Remarks

Accumulated data indicate that the NW trend corresponds to bedding plane whereas the NE trend represents joint and fault of the Akka Limestone. These trends are consistent with the cavern passageways, for examples; Uchimagi-do Cave cavern passageways in Uchimagi area are to show same orientation as that of joint(the main way) and bedding plane(the branch way), Shigawatari-do Cave cavern passageways in Shigawatari area are oriented along joint and fault.

An analysis of the geological minor structures for the Akka Limestone and associated rocks(clastic rocks and granite) shows the nearly same orientation. It can be explained as the result of genetical relation that these rocks have undergone the same stress environment.

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Palaeoclimate Data from New Zealand Speleothems

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Summary

The palaeomagnetic and magnetostratigraphic research represents the important tool for the deciphering of the age of cave infill process, when classical bio- and chronostratigraphic data are missing, which is a case of inner-cave facies, especially. Sedimentary fills of studied profiles were separated into individual sequences and cycles divided by numerous evidences of breaks in deposition (erosion features and/or precipitation features). Therefore, unconformities can hide a substantial geological time. The magnetostratigraphy of cave sediments brought surprisingly new data on age of the last cave filling, changing local theories for dating of speleogenetical processes: (a) Classical Karst (SLO): obtained magnetostratigraphic data older than Brunhes/Matuyama boundary clearly show the age of speleogenesis cannot be connected with Pleistocene climatic cycles. Fills of fossilised caves are clearly older than about 1.8 Ma. The speleogenesis was probably connected speleogenetical phase related to the Messinian crisis and the fossilization with post-Messinian sea-level rise in the Mediterranean region, and (b) speleogenesis of well-known Demänovská Cave System (Low Tatra Mts., SK) was much older than supposed earlier. Correlation of obtained magnetostratigraphic results, radiometric dating and river terraces of tributaries of the Váh River indicate definitively that there is no real correlation of cave levels and river terraces noted in numerous textbooks or river terraces of the Váh River are older than supposed earlier.

Introduction

The magnetostratigraphic research in caves both in Slovenia and Slovakia started in 1997-1998. It was provoked by the sterility of inner-cave facies and by limited use of absolute dating methods, like U-series and 14C. The age of speleogenesis in both regions have been connected traditionally with Pleistocene geomorphic cycles following the glacial/interglacial cycles. But preliminary data of HERCMAN et al. (1997) from Slovakia indicated substantially higher ages of the last cave fill than expected earlier. The palaeomagnetic and especially magnetostratigraphic method seemed to serve as useful tool to date processes in caves over the limits of common dating techniques. Here, we briefly summarise recent results and interpretations.

Laboratory Procedures

Laboratory procedures were combined in a way that enabled the derivation of the respective magnetic remanence components in different temperature intervals, during progressive thermal demagnetisation (TD) and demagnetisation by alternating field (AF), the determination of moduli and directions of remanent magnetisation. Oriented hand samples were collected in the field from individual beds. Laboratory specimens in the form of small cubes 20x20x20 mm were prepared in the field or from the hand samples to be measured on the spinner magnetometers JR-4 and JR-5. Laboratory specimens in their natural state were subjected to progressive thermal demagnetisation using the MAVACS (Magnetic Vacuum Control System) apparatus securing generation of a high magnetic vacuum in a medium of thermally demagnetised specimens. All of specimens were also demagnetised by the alternating field procedures, up to the field of 1,000 Oe. The apparatus Schonstedt GSD-1 was employed for alternation field demagnetisation. This procedure was more effective than thermal demagnetisation; consequently, it was applied to the whole set of specimens. The Kirschvink multi-component analysis of was carried out to separate respective remanent magnetisation components. The Fischer statistics of were employed for calculation of mean directions of the pertinent remanence components derived by the multi-component analysis (for more detail see BOSÁK et al., 2000a).

Slovenia

The detailed palaeomagnetic study of cave sediments within the Classical Karst (*sensu* KRANJC 1997) in the SW Slovenia has started in 1997. The opening of several profiles of cave sediments during the construction of highway near villages of Divača and Kozina provoked the study. Uncovered caves are often characterised by thinned or by completely missing roof. Occurrences of such caves are not limited to some areas, but they are typical for the whole territory of the Classical Karst (*cf.* lit. in BOSÁK et al., 200a). Totally 165 oriented laboratory samples have been investigated for palaeomagnetic properties.

Studied Sites

The accessible channels of the *Divaška jama* are situated between two collapsed dolines. The studied profile consisted of laminated clays and silty clays covered by flowstone layer and clays. The top of the profile shows normal magnetozone. The narrow normal subzone is in the long reverse magnetozone in the upper part of the cross-section. The middle and lower part of the profile show reverse palaeomagnetic directions. The *Trhlovca Cave* represents the continuation of the Divaška jama. The sedimentary profile has very complicated internal structure consisting of blocks separated by fissures. Sediments are especially clays and silty clays. The long normal magnetozone was interpreted from the top across middle part of the 4 m high cross-section. The lower part of the profile shows reverse magnetozone and narrow normal subzone. The *Divača profile*, discovered during highway construction, was 6 m high alternation of sands and clays in typical fluvial cycles. The lower part of the profiles was composed of laminated clays and silty clays. Two narrow normal magnetozones were detected in the lower part of reverse palaeomagnetic directions. The *Kozina profile*, discovered during highway construction, was 5 m high, 3 m were composed of clays, the upper part consists of collapsed roof. The top and lower part of the profile shows reverse magnetozone. There are two normal zones in the middle part of the profile. The *Črni Kal-Črnotiče profile* was situated in active quarry in a part of a huge passage with the diameter of about 10 m. The part of profile was composed of laminated silty-sandy (?)algal limestones intercalated by red clays of the terra rossa type. The long normal magnetozone was interpreted in the lower half of the log. The top part of the profile shows reverse palaeomagnetic direction interrupted by two normal polarised zones. No fossil remains were detected in all studied profiles, except some damaged pollen grains without stratigraphic importance in Kozina site (BOSÁK et al., 2000a, b).

Discussion

The comparison of obtained magnetostratigraphic results with the standard scales (CANDE & KENT 1995) indicate, that sediments of the Divaška Jama and Trhlovca Caves include Brunhes/Matuyama boundary and Jaramillo chron, i.e., they are substantially older than expected by GOSPODARIČ (1988). The age of the youngest sedimentary fill in both accessible caves is from at least 1.1 Ma to more than 350 ka old (spelothem dating in the Divaška Jama Cave;, cf. in BOSÁK et al., 1998)

Correlation of sediments from the Divača and Kozina profiles, which are nearly identical and Črnotiče Quarry with the standard scale was problematic as reverse polarised magnetozones can belong to Matuyama, Gauss or Gilbert chrons, i.e., from about 1.77 down to more than 5.23 Ma (BOSÁK et al., 2000a, b). If the age of the youngest fill is so old, therefore the speleogenesis itself has to be connected with the Messinian speleogenetical epoch (*sensu* PERNA, 1996) and the fossilization was than connected with rapid base level uplift after refilling of the Mediterranean basin by water (BOSÁK et al., 2000a, b).

Slovakia

The research started in 1998 to help to decipher the ages of fill of some caves, especially those open to public. Caves are developed in Mesozoic carbonate sequences belonging to different nappe levels of the West Carpathians in the Low Tatra Mts., High Tatra Mts., Slovenské rudohorie Mts. and Slovak Karst. Inner-cave facies were studied. Totally 95 oriented laboratory samples have been investigated for palaeomagnetic properties (PRUNER et al., 1999).

Studied Sites

The *Belianská Cave* (High Tatra Mts.) contains limited sedimentary profiles. The studied ones were about 1.5 m high composed of silts with rare intercalations of flowstones. Upper part was reverse polarised, the lower one showed normal polarization with one reversed sample. Five profiles of fluvial cave sediments (1 to 3 m thick) were studied in the 4th and 5th levels of the *Demänovská Cave of Freedom* (Low Tatra Mts.). Profiles were mostly composed of gravels, sands and silts/clays with some flowstone interlayers. Profiles at the 4th level showed normal polarisation, while profiles at the 5th level were reverse polarised. Two profiles in the *Demänovská Cave of Peace* were composed of sands and silts (about 0.5 m thick). All samples were normal polarised. The *Domica Cave* (Slovak Karst) was studied in two separate areas. Profiles, 0.5 to 1.5 m thick were composed of silts, sometimes slightly cemented, with some inter-layers of flowstones. All samples were normal polarised, except the single sample. The *Ochtinská Aragonite Cave* (Slovenské Rudohorie Mts.) yielded data only from one 0.7 m thick profile of clays with asbolane layers, covered by flowstone. The upper part of the profile showed normal polarisation, the rest reverse polarisation (PRUNER et al., 1999).

Discussion

Palaeomagnetic and magnetostratigraphic results from the Domica Cave, Ochtinská Aragonite Cave and Demänovská Cave of Peace brought no surprising data, because some of speleothems (flowstones) were already dated by the U-series method (cf. in PRUNER et al., 1999). Reverse polarised sample in the Domica Cave does not represent the Blake event, as data from cover flowstone are ca 131 ka. Boundary Brunhes/Matuyama was interpreted in the Ochtinská Aragonite Cave, because cover speleothem is ca 164 ka old. Nevertheless, the magnetostratigraphic data allow reconstruction of the evolution scheme of the cave more precisely.

Data from the Belianská Cave were surprising. The comparison with the standard scales (CANDE & KENT 1995) indicates, that the profile is older than 1.77 Ma. Sediments can be correlated possibly with the Matuyama/Gauss boundary at 2.58 Ma, or even with the older boundaries (e.g., at 6.15 Ma). The data allowed the definitoin of a new working hypothesis on the evolution of the cave, being formed by ascending warmer waters in connection with the uplift of High Tatra Mts. (study in preparation for the print).

Data from the Demänovská Cave System indicate the uncertainty in correlation of cave levels with river terraces of the Váh River (e.g., DROPPA 1966). Magnetostratigraphic interpretation of profiles proved the data of U-series dating of speleothems at the 4th level of the system. From the combination of data resulted, that the 4th cave level was dry already at about 700 ka (base of speleothem is ca 685 ka; e.g., HERCMAN et al., 1997), although previous correlation with river terraces assumed the age of speleogenesis to Mindel 2, i.e. to ca 330-500 ka (DROPPA, 1972). Data indicate that the speleogenetic process was substantially older than supposed earlier, which correlate well with data from Polish Tatra Mts. (GŁAZEK, 1989).

Theoretical Approach and Conclusions

The application of the magnetostratigraphy of cave sediments seemed to be an ideal tool for dating. It is generally known here that fossils can be found only in the upper parts of sedimentary fill, and the time range of numerical dating methods applicable in karst is short (ca 350 ka). Nevertheless, the magnetostratigraphy approach is facing numerous real problems, as exemplified especially on Slovenian sites. Sedimentary fills of profiles were separated into individual sequences and cycles divided by numerous evidences of breaks in deposition. Some of breaks were expressed by erosion and/or precipitation features. Some of magnetostratigraphic zones start on such unconformities. This proves that the whole cave systems could be several times completely filled and exhausted. Therefore, unconformities within sedimentary profiles can hide a substantial geological time. The velocity of deposition cannot be calculated in such profiles. The time duration of individual magnetozones cannot be calculated and the geometric character of obtained magnetostratigraphic picture cannot be compared with standard scales (BOSÁK et al., 2000b).

Therefore, the dating of cave sediments by the application of palaeomagnetic methods - magnetostratigraphy - represents a highly difficult and sometimes risky task, as the method is comparative in its principles and does not provide numerical outputs. Case studies indicate, that without the help of other dating methods, especially biostratigraphy, any correlation of obtained results cannot be explicit. Dynamic character of cave filling, exhumation and fossilisation is expressed by numerous unconformities within preserved sedimentary profiles. Therefore, the correlation of obtained arrangements of normal and reverse polarised magnetozones with standard palaeomagnetic scales can be finish only with difficulties and with a high degree of uncertainty. Such reality can be exemplified on examined logs both from the Classical Karst and from Slovakia, especially on profiles with complex magnetostratigraphic arrangements (Divača, Kozina, Črni Kal, Belianská Cave).

The obtained magnetostratigraphic data indicate substantially older age of cave filling processes than expected earlier: (1) shifting the possible start of the speleogenesis within the Classical Karst deeply below the Tertiary/Quaternary boundary, presumably to the Messinian speleogenetical epoch, and (2) changing the view on speleogenesis of some of Slovak caves and the state-of-the-art in the correlation of cave levels with river terraces; river terraces have to be older than earlier supposed.

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Figure 1 Measured magnetostratigraphic profiles in some of Slovenian (A) and Slovak caves (B) and their correlation with the magnetostratigraphic chart (after CANDE & KENT 1995) - A. Slovenia: 1 Črni Kal-Černotiče, 2 Kozina profile, 3 Divača profile, 4 Divaška Jama, 5 Trhlovca Cave; B. Slovakia 1-2 Belianská Cave, 3-7 Demänovská jaskyňa Slobody, 8-9 Demänovská jaskyňa Mieru, 10-13 Domica Cave, 14 Ochtinská Aragonite Cave

Non-Meteoric Speleogenesis: Evidence from Eastern Australia

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Abstract

Many caves in Palaeozoic limestones of eastern Australia have morphological, hydrological and mineralogical features indicating a non-meteoric, hydrothermal or artesian origin. Some caves decrease in volume with depth. Structurally guided cavities frequently terminate in blind ends. Cupolas, spongework, pockets and blades are common. Many caves intersect palaeokarst. Caves are often poorly related to the surrounding hydrology. Some caves and whole karsts lack streamsinks, springs or both. Cave streams postdate the main phase of excavation. Palaeokarst and less-soluble bedrock is altered, with pyrite and dolomite emplaced. These weather to form aragonite, huntite and gypsum. Etched walls, spar coatings and boxwork are common. Some caves contain remnants of iron-rich carbonate fills.

Introduction

Small impounded are common in the Palaeozoic fold belts of eastern Australia (Fig. 1).

The Palaeozoic limestones in which these karsts have developed have often undergone multiple periods of deformation and frequently have steep to vertical bedding. Despite their small size and impoundment by insoluble rocks, these karsts can be quite cavernous.

Many of the caves in the eastern Australian Palaeozoic karsts have morphological, hydrological and mineralogical features which suggest that they were either formed entirely or partly by water (most likely warm water) rising from below, rather than by sinking meteoric water. In addition many of the most cavernous bodies of limestone are closely associated with small hydrothermal ore deposits and some cavernous limestones have warm springs rising through them (OSBORNE, 1996). This paper reviews the features of the caves that are suggestive of speleogenesis by rising water.

Morphology

Eastern Australian caves have a distinctive morphology, while some of this can be accounted for by development in steeply-dipping limestone and by paragenesis (OSBORNE 1999a), conventional explanations have failed to account for many of their outstanding features.

Downward Narrowing Profiles

Many caves, such as the deep caves at Bungonia in New South Wales (Fig. 2) have a funnel-shaped profile, with cavities reducing in diameter with depth. It is very common for eastern Australian caves either to terminate blindly at depth, or to connect with small stream passages. The stream passages are usually smaller in cross-section the upper sections of the caves which they drain and have tortuous structurally-guided paths.

Downward narrowing of caves is observed in many eastern Australian karsts. It was previously explained as being due to higher water flows in the past. The enlarged midlevels of these caves, however consist of cupolas and blind halls (see below) and so could not result from fluvial action under wetter conditions in the past. Solution by upwelling water, rather than sinking meteoric water, could account for the upward enlargement of these caves.

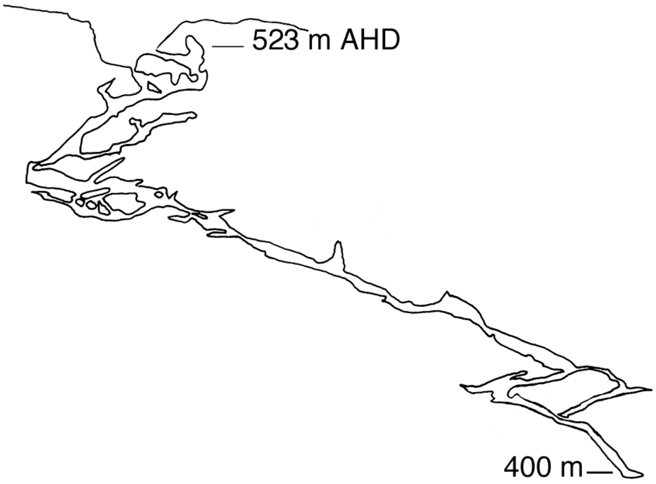


Fig. 1 *Fig. 2*

Fig 1. Karsts in Palaeozoic Limestones of Eastern Australia

Figure 2. Section of Grill Cave, Bungonia, A downward-narrowing cave after BAUER & BAUER (1998)

Hall and Narrows Caves

There are many relatively small network caves in eastern Australia. They generally consist of elongate north-south trending passages (halls) developed along the strike of the steeply dipping limestone, joined at right angles by short passages, which follow joints (narrows) (OSBORNE, 2001).

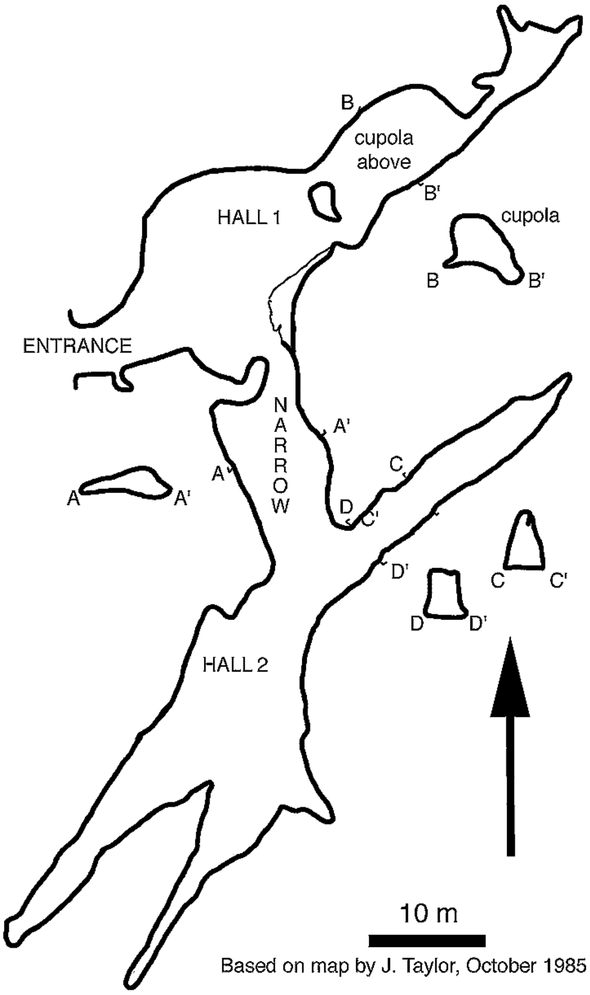
The key feature of these caves is that the halls terminate blindly in bedrock or mud plugs. Low velocity phreatic speleogens, such as roof pendants, wall and ceiling pockets and spongework are common, while scallops are rarely developed. Cupolas are often developed at the ends of halls (Fig. 3).

In some karst areas (eg. Bungonia) hall and narrows caves form groups aligned along strike. Adjacent caves often have halls developed at similar elevations in the rock. These have frequently been interpreted (OSBORNE, 1993) as representing sections of phreatic conduits along which water formerly flowed. This is not possible, since the halls have blind ends.

Downstream Narrowing Mazes

Exit Cave in Tasmania (Fig 1) is one of the most extensive caves in eastern Australia. It consists of over 40 km of network passages through which a major stream is captured underground. The captured stream flows through only some of the passages. And the trunk passage through which it flows becomes narrower downstream. There does not appear to be any lithological or structural impediment constricting this passage, rather it would appear that the passage width is unrelated to its situation in the course of the stream. This suggests that the stream was captured by the cave, rather than being responsible for its formation. BAKALOWICZ *et al*. (1978) noted that mazes of hydrothermal origin did not show a systematic increase in passage width downstream.

This particular observation is of limited application, since most network caves in eastern Australia, eg those at Cliefden (Fig. 1), do not contain active streams.



Based on map by J. Taylor, October 1985

Figure 3. Map of Yessabah Bat Cave A Hall & Narrows Cave

Cupolas

Large cupolas are common in these caves. At Jenolan Caves (Fig 1) cupolas up to 80 m high and 20 m in diameter are key features of the show caves. Some of the larger chambers at Jenolan are sets of coalesced cupolas, while other groups of cupolas are grouped in rising sets.

The apices of these cupolas are flat to gently-domed and they show no sign of penetration upwards into a guiding joint or bedding plane. The apex of the cupola is often modified by the development of rounded pockets and bellholes, which also lack a specific structural orientation.

In many complex caves such as at Jenolan, cupolas are isolated from active streamways. Where stream passages and cupolas do intersect, the pattern of cave development suggests that the streams intersected the cupolas by chance, rather than being part of the same developmental process.

“Nothephreatic” Caves

The term “nothephreatic” has been used in Australia (see JENNINGS, 1985) to describe caves that were excavated by diffuse flow under phreatic conditions. These caves are characterised by speleogens such as spongework, rock pendants, wall and ceiling pockets. Jennings cited Octinska Aragonite Cave in Slovakia and Wellington Caves (Fig. 1) as examples of this type of development.

Many caves in eastern Australia that lacked evidence for dynamic phreatic or fluvial development were characterised as “nothephreatic” (OSBORNE & BRANAGAN, 1988). These caves exhibit many of the morphological characteristics described in this paper. As a consequence their origin is currently under review.

Intersection of Palaeokarst

It is not uncommon for eastern Australian caves to intersect, or be guided in their development by, palaeokarst deposits. Good examples have been documented at eleven major cavernous karsts. Internationally this is not a commonly reported phenomenon (OSBORNE, 2000).

Some intersection of palaeokarst can be expected to result as a consequence of development being guided by vertical inception horizons, and from paragenesis (OSBORNE, 1999a).

These mechanisms do not, however account for the exposure of palaeokarst deposits in the walls of large solution chambers and cupolas at Jenolan, Timor and Wellington.

FORD (1995) noted that palaeokarst was more likely to be interested and control the development of caves formed by ascending waters that in the case of caves formed by descending meteoric waters. If this is so then the frequency of exposed palaeokarst deposits in eastern Australian caves is a strong indicator that non-meteoric processes played a role in their development.

Hydrological Evidence

Many eastern Australian caves appear to have little relationship with the hydrology of their surrounding environment. Isolated caves on the top of hills are common (at Timor and Wombeyan, Fig. 1). At other localities (Bungonia, Fig. 1) the springs draining complex cave systems are perched, for no obvious reason, almost 200 m above the present base level.

There are a significant number of caves, and some whole karsts, that lack permanent streamsinks or springs or both. Where springs, but not streamsinks are present these springs are simply returning vadose seepage water to the surface, rather than acting as a resurgence for a regional karst aquifer. The underground streams that feed these springs are underfit and apparently unrelated to the initial excavation of the caves through which they flow. Some caves located directly adjacent to swiftly flowing streams show no sign that a stream has ever flowed through them.

This isolation from both present (and postulated past) hydrological systems would be expected if the caves were excavated by rising non-meteoric waters than by descending meteoric water.

Mineralogical Evidence

Palaeokarst deposits and less-soluble units within the limestone bedrock exposed in the caves are frequently altered with the emplacement of pyrite and dolomite. Under vadose conditions, these minerals weather, producing aragonite, huntite, hydromagnesite and gypsum speleothems. Gypsum and hydromagnesite, developing in veins, are responsible for the development of breakdown zones directly adjacent to cupolas.

At Jenolan and Wyanbene the caves contain remnants of weathered ore bodies, and there is good field evidence that many caves have been, and/or are now in the process of being, exhumed by weathering and stoping of the ores. The remnants suggest that the unweathered ores were composed of ferroan dolomite, calcite and pyrite. The remaining remnants consist of calcite pseudomorphs after dolomite, iron oxides/hydroxides and limonite pseudomorphs after pyrite. The remnants either take the form of gossans or of slimy yellow mud. In part of Jenolan Caves there has been secondary enrichment of the weathered ore forming haematite nodules.

Some caves are party lined by coarse euhedral spar; others intersect crystal-lined cavities and expose crackle breccias. Reconnaissance isotope studies have shown that some of the spar linings have $\delta^{18}O$ PDB ranging from to –20 to –6 and a $\delta^{13}C$ ranging from –2 to +2, placing them in the deep-seated hydrothermal range of DUBLYANSKY (2000).

Cave walls are frequently deeply etched and/or altered. In many places (eg. Ribbon Cave at Jenolan) the wall surface is not composed of dense limestone, but of powdery micritised limestone centimetres deep. This is an alteration process, rather than a coating, as outlines of fossils in the bedrock are preserved in the micritised zones. At Bungonia Caves some limestone cave walls are silcified and basaltic dykes intersected by the caves have been bodily replaced by calcite, preserving their igneous texture.

The evidence suggests that two associations of low temperature (in the mineralogical sense) mineralisation were involved in cave excavation and filling: - An iron-carbonate association which micritised the cave walls, altered resistant bedrock and filled the caves with ferroan dolomite, calcite, ferroan calcite and pyrite.

A silica-clay association, which silicified cave walls and filled caves with kaolinite and illite.

Discussion

Many of the characteristics of caves developed in the Palaeozoic limestones of eastern Australia are not easily attributed to excavation by sinking meteoric water. Recently, I (OSBORNE, 1999) used evidence of the type described here to propose that at least two of the ten phases of cave development recognised at Jenolan Caves were caused by rising hydrothermal waters.

There is no evidence in the caves for water temperatures higher than 80 degrees. Where warm springs occur in the karsts today, the water temperatures are just below 30 degrees. The hypothesis I am currently testing is that there were one or more phases of excavation by warm (approx 30 degree) mineralised water which excavated cavities, altered wall rock and filled the cavities. In some instances iron-rich carbonates, dolomite and pyrite were deposited and in others silica and clays were deposited.

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Petrography of Lithified Cave Sediments

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Lithified cave sediments occur in palaeokarst deposits, relict caves and "caves without roofs". Lithification and diagenesis can transform the whole range of cave deposits into indurated rocks. These often contain fossils and are frequently misidentified as flowstone. In vadose conditions meniscus cement forms in coarse clastics. Water seeping through entrance facies emplaces spar and flushes out fines, forming pelletal and caliche-like textures. Speleothem recrystallises, losing depositional texture. In phreatic conditions acicular cements form, which change by neomorphism to blocky spar. Carbonate sands and muds, deposited in caves flooded by the sea, resemble marine limestones. Lithified lime muds from caves resemble marine mudstones.

Introduction

Petrographic study of indurated cave sediments is in its infancy. Increasing international interest in palaeokarst and "caves without roofs" has drawn attention to the need for further research in this area. Lithified cave sediments at Riversleigh and Wellington Caves contain some of Australia's most important Cainozoic vertebrate fossil deposits. Strongly lithified Permian, Carboniferous and Devonian palaeokarst sediments are recognized in many eastern Australian karsts. Workers often incorrectly identify resistant layers in ancient cave deposits as flowstone, not realising that a range of sediments deposited in caves, can, over time, become substantially indurated and that crystalline deposits, including flowstone, are changed by diagenetic processes.

A great variety of clastic and non-clastic sediments is deposited in caves, in both vadose and phreatic environments. Over time, these sediments are transformed into well-indurated rocks. Lithification and diagenesis in caves takes place under generally stable temperature and pressure conditions with highly variable water tables and abundant dissolved calcium carbonate.

Vadose Litihifcation and Diagenesis

In vadose conditions, crystalline deposits, such as speleothem, undergo significant recrystallisation involving extensive cannibalisation of small crystals and loss of depositional texture. Primary cavities are frequently filled with druse while secondary cavities may be formed and later filled with druse. Meniscus cement is deposited in coarse clastics with stable grains such as sands, frost-wedging breccias and bone breccias.

Vadose water seeping through poorly sorted entrance facies deposits will both deposit spar and flush out some of the fines. This process can result in pelletal and caliche-like textures and may, if continued over a significant period, replace much of the silt and clay with secondary spar.

Phreatic Lithification and Diagenesis

In phreatic conditions, acicular cements are frequently deposited in cave clastics. These often undergo neomorphic change to blocky spar. Marine carbonate sands and muds, deposited in caves flooded by the sea, frequently resemble normal limestones. Cave muds deposited in impounded karsts and then lithified, resemble carbonate-rich siltstones and mudstones. Lithified muds deposited in holokarsts are frequently difficult to distinguish from laminated marine mudstones.

Lithification of Entrance Facies

Entrance facies are generally poorly–sorted and frequently loosely packed. This loose packing allows vadose seepage waters to percolate through the matrix and deposit a complex range of cements including blocky spar, fibrous calcite and caliche-like cements.

Cement often surrounds peds within the matrix, producing a pelletal texture. OSBORNE (1978), following BRAIN (1958), described how percolating water not only deposited spar, but also carried away silt and clay from the matrix, resulting in friable silty diamictites being converted into dense rocks largely composed of calcite.

Lithification of Clastics

Lithified cave clastics resemble sedimentary rocks deposited in familiar fluvial environments. They preserve a range of textures and sedimentary structures. The feature common to most, but not all, lithified cave clastics is the overwhelming presence of carbonate cements.

Gravels

Gravels deposited in caves can be either well or poorly sorted. While in most cases the largest grains are allochthonous, in some cases as in the largest grains may be cave-derived limestone clasts and in others autochthonous grains such as pyrite, as in the *augenstein* of SEEMANN (1979).

A range of carbonate cements develop in gravels, including blocky spar, and plumose acicular forms. Often there is clear evidence of neomorphism, with zones showing inherited plumose texture going to extinction en masse.

While carbonate cements are common, ferruginous cements, either derived from weathering pyrite, or deposited by in-situ processes do occur, often in association with carbonate and manganiferous cements.

Sands

Of all lithified cave deposits, cave sandstones resemble most closely their surface equivalents. The grains in cave sandstones tend to be more angular and less spherical than those deposited by surface fluvial systems and carbonate cements, particularly coarse spar, tend to dominate.

The ease with which cave sandstones can be confused with surface materials makes the use of petrography essential when working with lithified sandstones from caves or suspected palaeokarst deposits. Quartz arenites and arenites composed of dolomite rhombs (not uncommon in hydrothermal palaeokarst) are easily confused in hand specimen.

Muds

Cave muds deposited in holokarsts and then lithified, resemble carbonate-rich siltstones and mudstones (see below).

Muds deposited in impounded karsts are composed of common weathering products from the surrounding non-carbonate environment, such as kaolinite, illite and quartz.

Due to their low permeability and small pore size, non-carbonate cave muds are less likely to be strongly lithified than coarser-grained allochthonous sediments. While some allochthonous cave muds can become strongly lithified, forming mudstones, there is now evidence that in some situation cave muds can survive for millions or even hundreds of millions of years in a soft, pliable hydrated state.

Breccias

Coarse, angular, fragmental deposits are common in caves. They do not all, however, have the same origin, and the term “breccia” is frequently misused in relation to cave deposits. Coarse-grained cave deposits in general, including: - diamictites, produced by slumping or rapid flood processes; conglomerates (organised and disorganised) from turbidite sequences and angular crystalline conglomerates (floe calcite) are frequently incorrectly described as cave breccias.

Three major groups of breccias can be recognised: -

Breakdown Breccias

Breakdown breccias are the best-known type of cave breccia. They consist of blocky fragments with great range of sizes (perhaps 10 mm- 10 m).

Breakdown piles continue to move after the fragments have separated from the bedrock, and clasts often continue to fragment due to crystal wedging while they are within the pile. Crushing, crystal wedging and gravity-deposited fines will contribute a small quantity of matrix to the breakdown pile.

Breakdown breccias can become lithified when fluvial sediments fill the pore spaces. Sandstone and conglomerate matrices are not uncommon in lithified karst breccias.

Breakdown breccias can also become lithified by precipitation of crystalline cements from groundwater or ore-bearing fluids. In these cases (see below) it is often difficult to determine if the brecciation is due to breakdown, or to the ore emplacement process itself.

Cold-Climate Breccias

These consist of relatively small (2-200 mm) angular, platy, fragments of limestone. They may have a silty matrix or an open-packed grain-supported fabric. Intergranular spaces are angular.

Lithification begins with the growth of vadose meniscus cement, and may continue with spar filling the intergranular spaces.

Hydrothermal Breccias (including crackle breccias)

Hydrothermal breccias are produced by the emplacement of hot, mineral bearing, fluids into karst rocks. There are two main types of hydrothermal breccias: crackle breccias and massive breccias, which resemble breakdown breccias.

Crackle breccias (QUINLAN, 1972) are breccias in which the bedrock clasts are separated, but retain a jigsaw puzzle fit, ie. the matrix appears to have been emplaced into the bedrock. In most crackle breccias that matrix is crystalline, and is frequently composed of coarse calcite spar. Crackle breccias may zone into massive breccias.

Massive hydrothermal breccias are very similar in structure to breakdown breccias, however they tend to fill the containing void completely. They form by a process similar to crackle breccias (BALWIERZ & DZULYNSKI, 1976), however there is much more matrix and large clasts can be rotated and displaced.

Bone-Bearing Sediments

Bone fragments occur in a variety of cave sediments, both as major and minor components. Where bone fragments are a relatively minor component of the sediment or rock, it makes sense to classify the rock on the basis of the texture and/or composition of the major components. Thus coarse-grained sediments and rocks that contain a few bone fragments should be regarded as gravels or conglomerates, with no particular emphasis in their naming being given to the bone component.

Caves do, however, contain sediments and rocks in which bone is a principal constituent or outstanding constituent. Because the bone component is frequently, but not always broken, bone-bearing cave sediments and rocks are frequently described as *bone breccias*. This usage is rather unfortunate as it groups together rocks whose only similarity is that they contain bones.

Three main groups of bone-bearing rocks are recognised.

Osseous Diamictites

Osseous diamictites are matrix-supported rocks containing gravel to cobble-sized bones and bone fragments. The matrix is usually composed of silt, clay or fine sand. The Pleistocene bone bearing “red earths”, reported from around the world, are examples of osseous diamictites.

While some deposits are both poorly sorted and lacking in structure, others have distinct bedding and aligned bones.

Osseous diamictites are generally vadose entrance facies deposits. The matrix, which often has an aeolian origin, is introduced into the caves by gravity and rain-wash, while the bones are frequently from victims of pit traps.

Clast-Supported Osseous Conglomerates

These rocks consist of small, closely packed bone fragments and teeth, which are initially cemented together by meniscus cement, forming quite strong, but highly porous rocks (the bone equivalent of a coquina).

Little or no mud is present and petrographically they resemble carbonate rocks classified as packstones by Dunham (1962).

Over time the pores become filled with equant spar or radial calcite, depending on the diagenetic environment.

The teeth and bone fragments are accumulations from the regurgitation pellets of birds (usually owls) or the guano of carnivorous bats. Little or no post-depositional transport of the fragments has occurred.

Osseous Sandstones (Osseous Arenites)

Osseous Sandstones (OSBORNE, 1982) are clast-supported, graded-bedded coarse sandstones and fine conglomerates. They occur in turbidite sequences, which were deposited in still, phreatic conditions when talus cones, rich in bone fragments, slumped into ponds producing turbidity currents.

These graded sands have a high primary porosity, and as a consequence become strongly cemented. The initial cement is often phosphate, or acicular carbonate, but later percolating water will often replace this with equant spar. As a consequence spar-cemented osseous sandstones are strong rocks, which can resemble quartz arenites to the naked eye, or be confused with bedrock.

The bone and tooth fragments in these rocks have a similar origin to those in clast-supported osseous conglomerates, but have been further fragmented and graded by transport.

Fresh Water (phreatic) Carbonates

Lithified carbonate muds, deposited in caves in holokarsts are frequently difficult to distinguish from laminated marine mudstones. While they lack obvious fossils, so do many marine mudstones.

In the absence of convincing field or microfossil evidence, chemical and isotopic analyses may be the only means of distinguishing between lithified fresh water carbonate cave muds and their marine counterparts.

Marine (phreatic) Carbonates

Marine carbonate sands and muds, deposited in caves flooded by the sea, frequently resemble normal limestones. JONES (1992) described graded-bedded limestones that were deposited in caves of the Cayman Islands during periods of elevated sea level in the Cainozoic as Caymanites. Similar graded-bedded sediments of Carboniferous age were recognised in eastern Australia by OSBORNE (1995).

It is only the outcrop and stratigraphic relationships of these rocks, not their petrography, which allows them to be recognised as lithified cave deposits.

Subaqueous (phreatic) Precipitation Deposits

A range of crystalline deposits form in the phreatic zone. These are similar to speleothem, in that they are largely composed of calcite, but tend to have a coarser initial crystal size, and more pronounced crystal form. Because they form under water, these deposits are more often seen as relicts, or in their lithified form as palaeokarst deposits, than in their active growth position.

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Niter and Sylvite from Jenolan Caves, New South Wales, Australia

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Niter deposits occur in two large natural bridges, the Grand Archway and the Devil's Coach House at Jenolan Caves, New South Wales. The likely source is urine from colonies of brush-tailed rock wallabies (*Petrogale penicillata*) that lived in the bridges until the late 1960s. Niter associated with sylvite is found in the "Dust Cave", an extremely dry section of the Grand Archway. The Grand Archway has an east-west orientation and strong dry cold wind flows though it in the winter, bringing temperatures below zero. Evaporation at low temperature is proposed to account for the deposition of sylvite, but not halite, in the Archway.

Introduction

Jenolan Caves in eastern New South Wales, Australia (Fig. 1) are developed in a narrow outcrop of steeply dipping Silurian Limestone.

The limestone is breached by two, adjacent, large bridges, the Devil's Coach House (oriented north-south) and the Grand Archway (oriented east-west) (Fig. 2).

MINGAYE (1898) described niter from the Devil's Coach House. HILL & FORTI (1997) cited this report. It has not proved possible to relocate the niter deposit described by MINGAYE, however, niter deposits have been found to be abundant in the Grand Archway.

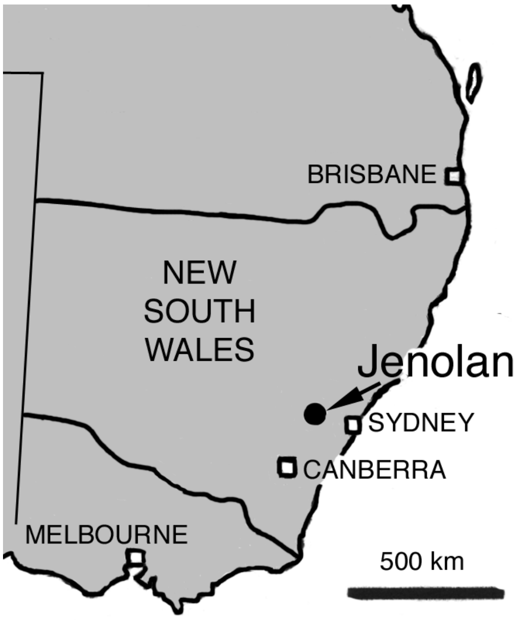

Figure 1 Location

The Grand Archway

The Grand Archway (Fig 2) is approximately 140 long. It is narrowest at its western end (15 m) and reaches a maximum width of 70 m about 90 m from its western entrance. At its western end the Archway has a flat paragenetic ceiling, 10m high, while at the eastern end the ceiling is modified by breakdown and slopes to the north at about 45 degrees.

Breakdown piles cover a terrace on the southern side, and occur in the eastern part of the northern side of the Archway. The breakdown is mantled by extensive deposits of fine grey-brown dust.

The interior of the Archway is dry. During the winter months (June, July, August), dry westerly winds blow straight through it. Snow and below zero temperatures are not uncommon at Jenolan in winter and icicles often grow from the ceiling at the western end of the Archway.

When the dust deposits in the Archway are moistened, efflorescences of niter grow. J.M. James (pers. comm.) reported the presence of niter and sylvite crystals in dust collected from the southwestern side of the Archway. White crusts of niter occur in crevices in breakdown and bedrock on the south side of the Archway.

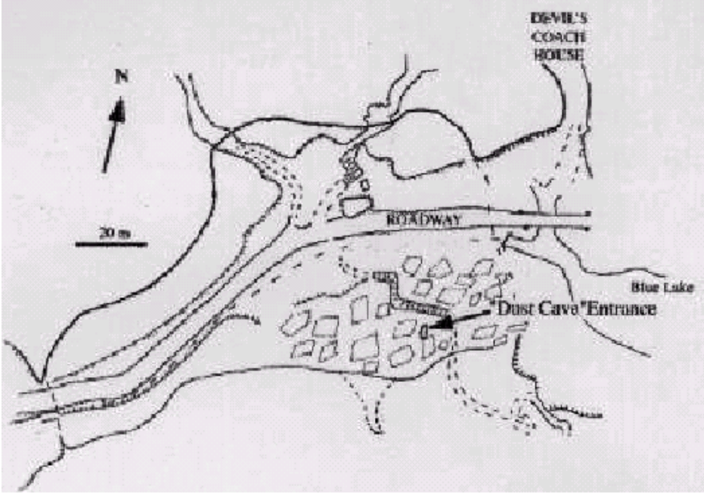

Figure 2 The GrandArchway

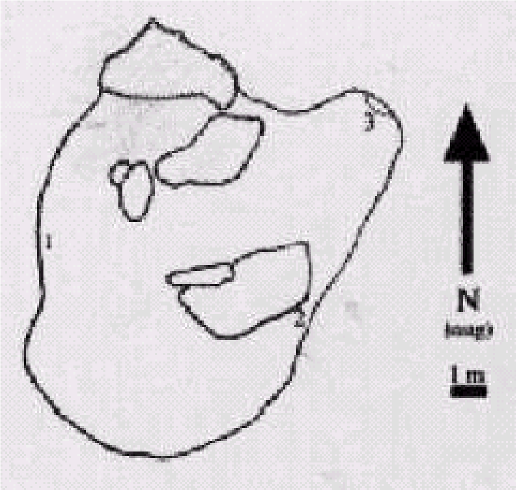

Figure 3. Dust Cave

"Dust Cave" Deposits

The "Dust Cave" is a cavity within the breakdown pile, high on the southern side of the Grand Archway. The cavity is approximately 9 m (NE-SW) by 7 m (NW-SE) (Fig. 3). The floor consists of fine dry dust. The walls consist of breakdown blocks, bedrock (limestone and lithified palaeokarst deposits) and poorly consolidated conglomerate cave fill.

Three significant white crusty deposits occur in the cave. Deposit #1, located on the eastern wall consists of white crusts with stalactitic projections growing along the beds of a laminated palaeokarst deposit (Fig 4). Deposits # 2 and 3 consist of crusts growing from the cave floor and from porous conglomeratic cave fills exposed in the cave walls.

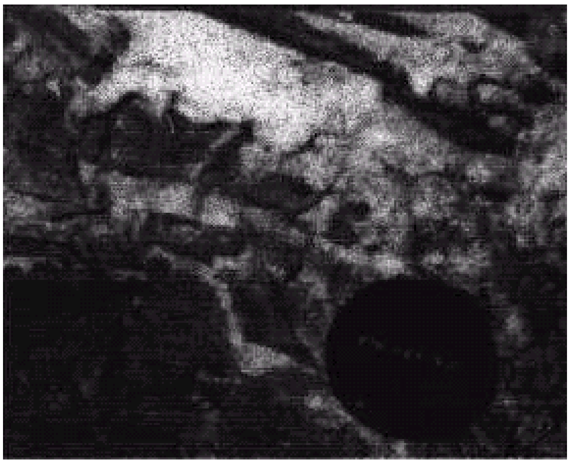

Figure 4

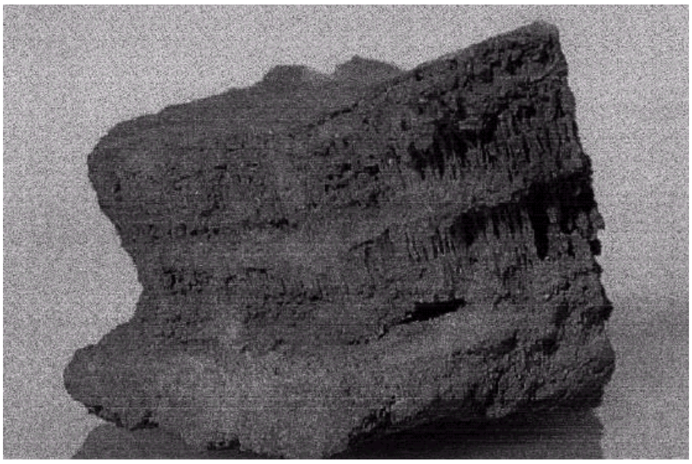

Figure 5

Figure 4. "Dust Cave " Deposit # Note stalactitic form of nitre (white) in top, left field. Lens cap is 55 mm in diameter.
Figure 5. Specimen D 52263 - Specimen is 50 mm high and 70 mm wide. The two distinct layers of columnar crystals that form upper 30 mm of ,the sample are separated by a fine grain crust. Note how the columnar niter crystals are separated by vertical

Mineralogy

Small samples of the deposits in “Dust Cave” were collected and examined using X-ray diffraction. Niter was identified in all three deposits and sylvite associated with the nitre in deposits 1 and 2.

Specimen D 52263

A sample of evaporitic crust (Australian Museum Mineralogy Collection # D 52263) was collected from the floor of Dust Cave at location # 2. The specimen was excavated from below a mound of fine dust. In form the specimen resembles “wedding cake” gypsum found in salt lakes. The specimen (Figure 5) is approximately 50 mm thick. The bottom 20mm is composed of cemented grey dust. Two layers of columnar niter crystals form the upper 30mm of the specimen; these are separated and capped by finer grained crust. As in “wedding cake” gypsum, significant open cavities occur between the columnar crystals.

X-ray diffraction showed that this specimen contained both niter and sylvite. In order to determine the location of the sylvite, a polished specimen was prepared and examined using SEM and Energy Dispersive X-ray Spectrometry. These showed (Figs 6 & 7) that the sylvite forms highly skeletal equant inclusions 0.3-3mm thick in the niter, sometimes as strings of separate inclusions aligned perpendicular to the horizontal surface of the crusts. Observed sylvite composition was variable, ranging from 5-15 % by volume.

The observations are consistent with the sylvite being deposited after the nitre and filling some of the vertical cavities between the columnar niter crystals.

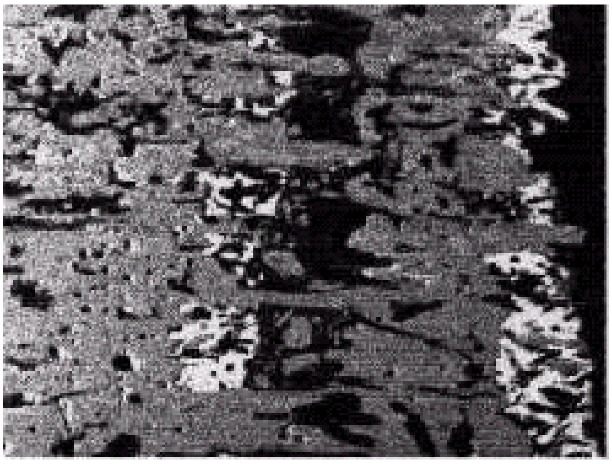

Figure 6

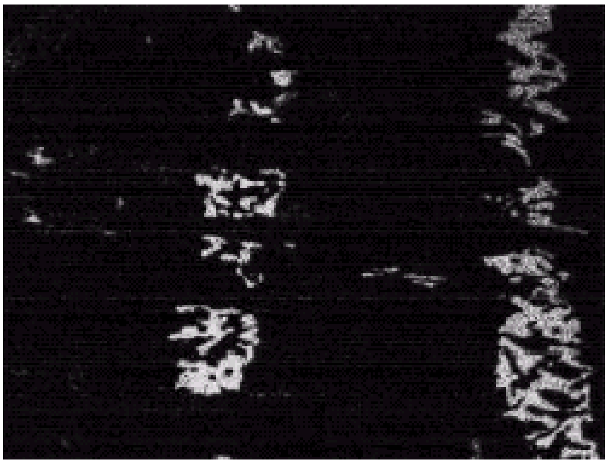

Figure 7

Figure 6. Backscatter Electron Image Specimen D 52263. Light grey = niter While = sylvite Image 4 mm high x 5mm wide.
Figure 7. Cl Ka- X ray Image Specimen D 52263 White = chlorine Image 4 mm high x 5mm wide

Paragenesis

Source of the Nitrate and Chloride

Niter deposits in caves have frequently been attributed to leaching from surface soils, volcanic ground water, bat guano piles and the action of nitrogen-fixing bacteria (HILL 1981a, 1981b, HILL & FORTI, 1997, LEWIS, 1992). These situations do not occur in the Grand Archway at Jenolan Caves. The Grand Archway was, however, until the late 1960s home to a breeding colony of the brush-tailed rock wallaby (*Petrogale penicillata*) and much of the dust in the cave is clearly derived from decaying rock wallaby faeces.

Deposition of Sylvite, but not Halite

In many of the occurrences of sylvite cited by HILL & FORTI (1997) sylvite occurs in association with the less soluble, and more common, chloride mineral halite. Since sodium is a common cation in organic waste, and sylvite is more soluble than halite, it might be anticipated that halite would occur in these deposits, with sylvite being deposited only in the final stages of the evaporative process.

Acknowledgments

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Australian Caves Without Roofs

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While “caves without roofs” have only recently been recognised in parts of Europe, they have been recognised in Australia since the 1870s. Some of Australia’s most significant Cainozoic vertebrate fossil deposits at Wellington and Wombeyan in New South Wales and at Riversliegh in Queensland occur in, or are closely related to, unroofed caves. Ongoing palaeontological work in the World Heritage Fossil Site at Riversleigh, karst documentation in northern New South Wales, karst mapping using differential GPS at Wellington and recent reconnaissance fieldwork has shown that these features are more common than was previously thought. Caves without roofs offer an opportunity for new insights into the development of Australia’s ancient landscapes.

Historical Reports

Geologists and vertebrate palaeontologists have recognised and speculated about unroofed limestone caves in Australia since the 1870s. THOMSON (1870) noted that bone breccia and stalagmite bases were exposed on the surface at Wellington Caves in central New South Wales (Fig. 1) and concluded that: - “what is now the surface of the ground has formerly been the floor of a cave”.

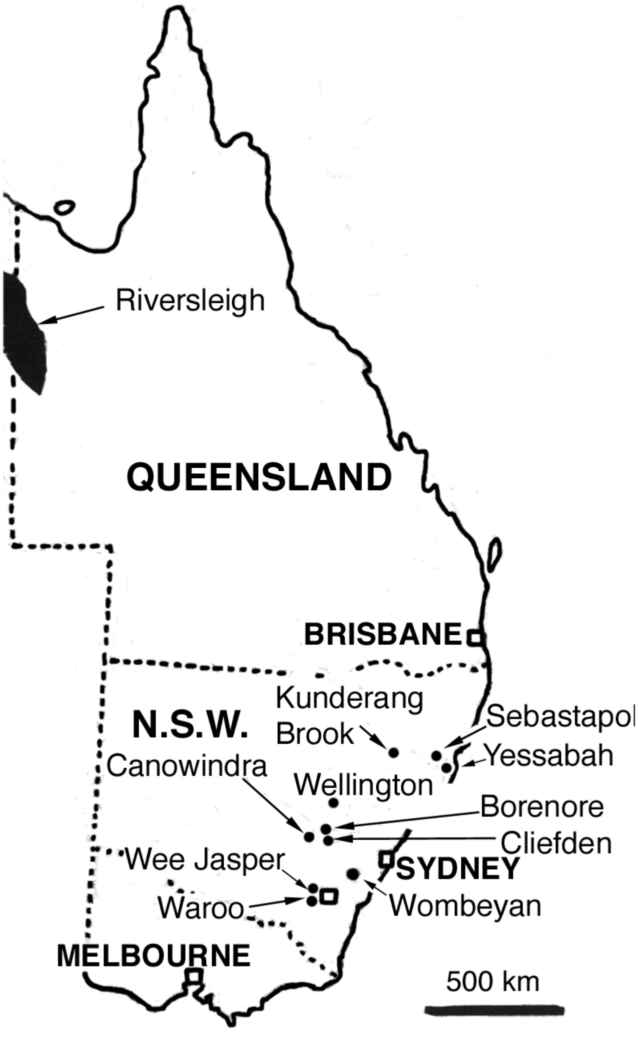

Figure 1. Eastern Australia

Wellington Caves was the location where marsupial fossils were first discovered in Australia in 1830.

In the early part of the 20th century Wellington Caves was disturbed by phosphate mining. As well as mining underground through filled caves the miners exhumed some filled unroofed caves (Fig. 2)

Another significant vertebrate fossil site, described as an unroofed cave, is the “Broom Breccia” deposit at Wombeyan Caves, New South Wales. This deposit yielded the remains of the Mountain Pygmy Possum, *Burramys parvus*, thought to be extinct until the discovery of a live specimen in 1966. BROOM (1896) considered that the: -“…deposit is evidently the remains of the floor of a cave, the whole roof and sides have long been weathered away.”

Recent Observations

Unroofed caves received little further attention until vertebrate palaeontologists, working at Riversleigh in northwest Queensland (Fig.1) on Cainozoic vertebrate fossils in Cambrian and Tertiary limestones during the 1980’s, recognised that some of their richest sites were unroofed caves (ARCHER et al, 1991).

Unroofed caves came to light during detailed karst mapping at Wellington Caves using differential GPS techniques in 1999 and 2000 (OSBORNE, 2001). Soil patches within massive limestone outcrops, which had previously not been mapped, were found to have a similar shape to the plans of structurally guided phreatic caves developed in the underlying rock. The mapping also revealed cave-shaped depressions with limestone walls 0.3 m to 0.5 m high and a smaller number of cave-shaped depressions with obvious walls, some curving, 1 m or more deep.

While there has yet to be detailed study of any of these features, reconnaissance fieldwork and checking through photographs suggests that caves without roofs occur in a number of Australian karsts. Caves without roofs occur at Borenore, Cliefden, Canowindra, Wee Jasper and Waroo (Fig. 1).

These karsts and developed in folded Ordovician to Early Devonian limestones, located in river valleys or gently undulating landscapes in the Western Slopes of New South Wales.

At Wombeyan Caves, where the Broom Breccia occurs, marble is exposed in topographic basin surrounded by steep hills of volcanic rocks. Streams have incised valleys into the floor of the basin, resulting in an incised plateau landscape of residual ridges. The Broom Breccia site is located high on one of these ridges. It consists of a circular depression in dense marble, approximately 2 m in diameter and 0.5 m deep (Fig. 3). Well-cemented bone breccia forms the base and coats the sides of the depression. While there is much further work to be done at this site it appears that the site is the intersection of a tube-like cave passage, rather than the “floor of a cave”.

Figure 2

Figure 3

Figure 2 Excavated cave Without Roof at Wellington Caves

Figure 3. The Broom Breccia Site, Wombeyan Caves - The breccia is located in the bottom of the depression directly in front of the man second from the right

In a quite different geological and topographic setting, unroofed caves occur at Kunderang Brook, Mt Sebastapol and Yessabah in gently-dipping Permian limestones exposed in deeply incised valleys and residual hills on the coastal plain of northeastern New South Wales (Fig 1).

There are many quite complex surface solution features developed in these karsts in addition to those that are clearly unroofed caves. These include pits, pinnacles and a range of complex depressions that have been greatly modified by the development of karren. It is possible that some of these features are remnants of interstratal caves from which the upper confining bed has been removed.

Discussion

Caves without roofs appear to be more common in areas of lower relief and on plateau surfaces where surface lowering is the principal mechanism of erosion, than in areas of high relief where valley incision dominates.

It is possible that 19th century geologists and palaeontologists were able to recognise unroofed caves because they were isolated from concepts of karst geomorphology that were developing at the time in Europe. Modern study of caves without roofs is just beginning in Australia; we have to make up for over 100 years of inaction.

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Espeleogênese de Cavernas Areníticas: algumas considerações aplicadas à Província Espeleológica da Serra de Itaqueri, Estado de São Paulo, BRASIL

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Resumo

A origem e evolução das cavernas de arenito (ou areníticas) são condicionadas pelo padrão estrutural, geomorfológico, estratigráfico e climático da área de ocorrência. Nesse trabalho é apresentado um modelo espeleogenético para as feições endocársticas das cavernas da porção centro-ocidental da Depressão Periférica Paulista em transição com as Cuestas Basálticas, na região denominada Serra de Itaqueri, podendo esse modelo ser assumido também para outras cavernas areníticas, tais como as da Serra do Padre e Serra de São Pedro. Este trabalho ressalta a importância do regime tectônico como principal condicionante na evolução dessas cavidades e inova por relacionar os processos de abatimento de blocos e arenização como conseqüência do tipo de falha associado, segundo o modelo de Riedel.

Palavras-chaves: espeleogênese, cavernas areníticas, geologia estrutural

Abstract

Speleogenesis of Sandstone Caves: some considerations applied to the Serra de Itaqueri Speleological Province, São Paulo State, BRAZIL

The origin and evolution of sandstone caves are a function of structural patterns, geomorphology, stratigraphy and climate of the region. In this paper is presented a new speleogenetic model for the endocarstic features of the center-western portion of the “Depressão Periférica Paulista” transitioning to the “Cuestas Basálticas” domain, in the region named Serra de Itaqueri, a model assumed to others near sandstone caves, like the ones at Serra do Padre and Serra de São Pedro. This paper emphasizes the importance of the tectonic regime as main condition to its evolution model and innovate relating the blocks falling and arenisation process to the fault type associated, according the Riedel’s model.

Keywords: speleogenesis, sandstone caves, structural geology

Resumen

Espeleogenesis de Cuevas de Arenita: algunas consideraciones genéticas aplicadas a la Provincia Espeleológica de la Sierra de Itaqueri, Estado de São Paulo, BRASIL

El origen y evolución de las cuevas de arenita son condicionados por el padrón estructural, geomorfológico, estratigráfico y climático de la área en ocurrencia. En este artículo presentamos un modelo espeleogenético de las fecciones endocarsticas de las cuevas de la porción centro-occidental de la “Depressão Periférica Paulista” en transición con las “Cuestas Basálticas”, en la región denominada Sierra de Itaqueri, pudiendo este modelo ser asumido también para otras cuevas areníticas, tales como las de la Serra do Padre y la Serra de São Pedro. Este artículo aún resalta la importancia del régimen tectónico como principal condicionante en la evolución de estas cuevas, e innova por relacionar los procesos de queda de bloques y arenización con el tipo de fallas asociados, siguiendo el modelo de Riedel.

Palabras llaves: espeleogenesis, cuevas areníticas, geología estructural

Introdução

Em geral as cavernas mais conhecidas do mundo encontram-se em formações calcárias. As cavernas, abismos e fendas em rochas siliciclásticas, no entanto são mais raras. Neste trabalho será enfocada a origem das cavernas de arenito da região das Cuestas Basálticas, mais precisamente na Serra Cuscuzeiro, Santana, Itaqueri e São Pedro, entre os municípios de Analândia e São Pedro no Estado de São Paulo, Brasil.

A origem das cavernas de arenito é bastante complexa. Neste trabalho, com base em dados estruturais, geomorfológicos e estratigráficos propomos um modelo de espeleogênese para as “feições endocársticas” da região.

A área estudada localiza-se na porção centro-ocidental da **Depressão Periférica Paulista** em transição com as **Cuestas Basálticas**, drenada pela bacia do Rio Corumbataí, afluente de primeira ordem do Rio Piracicaba.

Aspectos Fisiográficos

O clima da região é caracterizado por invernos secos e verões quentes, com cerca de 80% da precipitação pluviométrica anual concentrada nos meses de outubro a março e temperatura média anual de 19ºC. Os ventos dominantes apresentam componente direcional proveniente dos quadrantes sul e sudeste.

A região estudada encontra-se em sua maior parte na Bacia do Rio Corumbataí e limita-se ao sul com a Bacia do Rio Piracicaba. Os elementos da rede de drenagem da cuesta, são em sua maioria dendríticos a subdendríticos e em algum casos retangulares, com rios predominantemente obseqüentes e subseqüentes, i.e., rios que correm no fronte da cuesta e na frente do fronte da cuestas, respectivamente.

A área de vegetação natural em todo o Estado de São Paulo é muito reduzida, comumente com ausência de mata ciliar no médio e baixo cursos dos rios da Bacia do Rio Corumbataí, ocupado geralmente pelo cultivo de cana ou pastagens, sendo alguns remanescentes de mata ciliar encontrados ao longo do Rio Cabeça, Rio Passa Cinco e no alto curso do Ribeirão Claro (ZAINE, M.F., 1996), além de drenagens de menor porte. A região estudada encontra-se na zona de transição entre uma *mata mesófila* – formação florestal estacional latifoliada subcaducifólia tropical pluvial – e o *cerrado* – formação não-florestal herbáceo-lenhosa, herbáceo-arbustiva, com árvores perenefólias (BRASIL, 1977), somente preservados parcialmente em alguns bolsões e nas encostas, apesar do íngreme fronte das cuestas quase sempre apresentarem-se desprovidos de vegetação e expondo as rochas subjacentes.

Em ordem de grandeza decrescente por área, quanto ao uso e ocupação desse solo, temos, segundo KÖFFLER (1993 *apud* ZAINE, M.F., 1996): pastagem, cultura de cana-de-açúcar, silvicultura, mata, fruticultura, cerrado, cultura anual, ocupação urbana e outros. No alto das cuestas, próximo à cornija observa-se o reflorestamento de espécies vegetais exóticas como o eucalipto e no reverso amplo cultivo de cana-de-açúcar. Nos fronte da cuesta, área de mais difícil acesso, preserva-se ainda a mata original, mas modificada por ação antrópica, dado o potencial turístico da região.

O relevo é de cuestas, constituído de planaltos sustentados por maciços básicos, representados por morros testemunhos isolados, topos aplainados a arredondados, vertentes com perfis retilíneos e escarpas festonadas, tal como é descrito o relevo da região. A cuesta possui uma assimetria com camadas com mergulho inferior a 30°, dividido em reverso (porção menos íngreme, concordante às camadas) e fronte (porção mais íngreme), formada pela cornija e tálus, apresentando interrupção pela erosão ortoclinal.

A região de ocorrência das cavernas possui grande importância nesse contexto todo pois encontra-se nos arenitos que compõem zona de recarga do “Megaqüífero Guarani” (ROCHA, 1996) e deve ser preservada para manutenção da qualidade da água, utilizada para o abastecimento de milhões de pessoas, além de possuir uma vasta rede de drenagem superficial com cachoeiras na faixa de cabeceiras, junto ao fronte das cuestas, de especial interesse para o turismo ambiental.

Arcabouço Geológico

A geologia da área, compondo o Mesozóico da Bacia Sedimentar do Paraná, é representada basicamente, da base para o topo, pelas formações Pirambóia, Botucatu e Serra Geral, que compõem o Grupo São Bento, evidenciando uma sedimentação exclusivamente continental, em clima árido a semi árido, encerrada por amplo vulcanismo basáltico, durante o Mesozóico.

- ***Formação Pirambóia***: compõe um pacote de espessos corpos de arenito esbranquiçado, amarelado e avermelhado, de granulometria fina a média, com finas intercalações de siltito e argilito, e, localmente, com níveis conglomeráticos. Apresenta estratificações cruzadas de grande e médio porte. Regionalmente aflora nas regiões de Rio Claro, Ipeúna, Corumbataí, Charqueada e São Pedro, compondo uma larga faixa que acompanha o sopé das serras. Atinge na região cerca de 150 metros. Foi depositada em ambiente fluvial, apresentando por vezes influência eólica (SOARES, 1973 *apud* ZAINE, M.F., 1996), inclusive com o desenvolvimento de interdunas (BRIGHETTI & CAETANO-CHANG, 1992).

- ***Formação Botucatu***: é constituída por um pacote de arenitos avermelhados a rosados, bimodais, de granulometria fina a média, com alto arredondamento e esfericidade, foscos e friáveis ou localmente muito silicificados, geralmente com uma película ferruginosa (óxido e/ou hidróxidos de ferro) envolvendo os grãos. Mais raramente ocorrem arenitos argilosos e níveis conglomeráticos (RICCOMINI, 1995). Estrutura marcante nesta unidade são estratificações plano-paralelas e cruzadas (tangencial e subordinadamente acanaladas), de médio e grande porte, atingindo mais de 15 m de altura na área, representando paleodunas de um ambiente desértico e, subordinadamente, uma sedimentação flúvio-torrencial e lacustrina. A Formação Botucatu possui uma espessura máxima de 320 m e uma espessura média aproximada de 250 m, resultante de uma deposição em ambiente desértico (SGARBI, 1996). Na região suas exposições situam-se nas serras de Santana, Itaqueri, Cuscuzeiro, São Pedro e morros testemunhos, acima da cota de 800 metros, com espessuras médias de 50 a 70 metros.

- ***Formação Serra Geral***: compreende a maior província vulcânica continental conhecida, formada principalmente por basaltos toleíticos e andesitos basálticos. Esses derrames freqüentemente possuem intercalações de camadas de arenitos denominados "intertrapianos", de espessura centi- a decamétrica. Na região, os basaltos da Formação Serra Geral afloram na faixa das cuestas das serras da região, entre os municípios de Analândia e São Pedro, onde se encontra a maior concentração das cavernas areníticas estudadas, por vezes, intercalados com arenitos interderrames. Na Serra de Itaqueri, especificamente, é difícil a caracterização do basalto, já muito alterado e em grande parte erodido, muitas vezes considerado como inexistente, mas que efetivamente provocou uma silicificação diferencial no "Arenito Botucatu" durante o magmatismo. É típico na área de estudo a ocorrência de pequenos seixos, blocos e matacões com vestígios de "acebolamento" (esfoliação esferoidal), indicando alto grau de alteração por intemperismo físico (dilatação térmica). No topo dos derrames é comumente encontrado basaltos com textura amigdaloidal e vesicular. Nesses basaltos encontram-se ainda cristais de quartzo subhédricos em geodos e calcedônia.

Segundo FÚLFARO *et al*. (1982) a evolução geológica da Bacia do Paraná a partir do Permiano pode ser assim sintetizada:

a) Partindo-se do Permiano médio/superior a bacia adquire um caráter intracratônico de sinéclise, claramente definido durante o Permiano médio/superior, mantendo-o até o Triássico inferior;

b) No período juro-cretácico, no Brasil Meridional, tem-se um amplo soerguimento, gerador de intenso vulcanismo de caráter básico na área da bacia, tendo como trilha (veículo) de extravasamento das lavas as zonas falhadas e mais fracas dos antigos aulacógenos de seu embasamento. A retração da área deste soerguimento crustal controla assim processos de instalação de bacias marginais costeiras (e.g., bacias de Campos e Santos) por subsidência e a reativação e sedimentação (Grupo Bauru) no interior continental. Os limites sucessivos deste movimento de retração da área dômica são controlados pelos alinhamentos NE-SW. A fase rifte das bacias costeiras desta idade provoca levantamentos na margem continental, desenvolvendo sistemas de falhamento escalonado, tanto na direção das bacias marginais como para o interior continental, gerando, segundo os autores, estruturas como as de Piratininga, Agudos, Artêmis, Anhembi, etc.;

c) Contemporaneamente à tectônica descrita tem-se o início da sedimentação do Cretáceo superior na área setentrional da bacia. As zonas dos alinhamentos NW-SE compartimentam a Bacia do Paraná, controlando as áreas máximas de sedimentação até o Terciário, quando tem-se uma nova reativação e compartimentação da bacia; e por fim

d) O rifte do embasamento, principalmente no início da sedimentação, reativação paleozóica e a intensa influência rifte na sua evolução mesozóica permitem classificar a Bacia do Paraná como intracontinental cratônica, tipo 2-A (complexa), segundo a classificação de KLEMME (1980 *apud* FÚLFARO *et al.*, 1982), à semelhança das bacias do oeste siberiano.

Geologia Estrutural

A Bacia do Paraná possui um arcabouço estrutural e evolução que refletem as grandes estruturas do seu embasamento, sendo que a partir destes grandes traços, que compõem linhas de fraqueza, são condicionadas as respostas às atividades tectônicas impostas, tanto na geração e favorecimento de falhamentos, como também na sedimentação.

Regionalmente, segundo SOARES (1974), a Bacia do Paraná possui três compartimentos definidos como homoclinais sub-horizontais com mergulhos tendendo para direções convergentes.

SOARES (1974) classifica em cinco os tipos de estruturas básicas que ocorrem na região: falhas isoladas, sistemas isolados de falhas, *horst* e *graben*, domos e flexuras (periclinais), formas estas freqüentemente associadas. As **falhas isoladas** aparecem com bastante freqüência, mas são de pequena expressão na estruturação regional. Apresentam rejeitos inferiores a 20 metros e encontram-se comumente associadas a diques de diabásio, intrudidos após o falhamento. As **falhas inversas**, depois identificadas dentro da Gruta do Fazendão (RICCOMINI *et al*., 1996), são geradas por esforços compressivos, com dobras de arrasto, microdobras e plano com inclinação aproximada de 60 graus. As **falhas normais** estão ligadas a esforços tracionais associados ao rifteamento da bacia e delineiam na região o sistema de falhas Rio das Pedras-Piracicaba-Ipeúna. As **estruturas dômicas** encontram-se limitadas por falhamentos, apresentando amplitudes de levantamento superior a 200 metros, com mergulhos podendo atingir cerca de 6 graus. Também são reconhecidos na área grandes **alinhamentos tectônicos**, conhecidos por alinhamento Tietê, Guapiara e Paranapanema. Os **arcos**, assim como os alinhamentos, são reflexos das instabilidades tectônicas do embasamento cristalino, sobre o qual assenta-se a bacia, representando reativação de antigas zonas de fraqueza do Pré-Cambriano ao longo do tempo geológico.

A Bacia do Paraná é marcada por um padrão de feições lineares em forma de "X", dividido em 3 direções principais: NW-SE, NE-SW e E-W, predominando a primeira orientação (ZALÁN *et al.*, 1987), compondo zonas estruturais com maior mobilidade tectônica em comparação à áreas adjacentes, controlando a sedimentação durante a evolução da bacia (HASUI *et al.*, 1989 *apud* ZAINE, J.E., 1994). Bastante evidente é a estruturação do Rio Corumbataí NNE-SSW, retomada várias vezes em segmentos curtos de seu curso nas zonas de mudanças do traçado (PENTEADO, 1968). Segundo BJÖRNBERG (1965) a direção do Rio Tietê e do sistema de diques da Bacia do Paraná é N70E-N10E-N50W. FREITAS (1955) afirma que as direções preferenciais na Bacia do Paraná são WSW-ENE (pré-basáltica); NNW-SSE (falhas normais) e NNW-SSE e ENE-WSW (pós-cretácica). Para PENTEADO (1968) os sistemas de falhas NE-SW e NNW-SSE podem ser reativações de antigas falhas.

A geomorfologia da região é controlada fortemente por estas zonas de fraqueza, definidas pelos alinhamentos estruturais, controlando a sua drenagem e as áreas de rebordo das cuestas arenito-basálticas.

Manifestações neotectônicas, com falhamentos eminentemente transcorrentes, foram atribuídas ao Neogeno-Quaternário por HASUI (1990 *apud* ZAINE, J.E., 1994) e FACINCANI *et al.* (1994 *apud* ZAINE, J.E., 1994).

A área de ocorrência da maioria das cavernas tratadas neste trabalho coincide com o Alinhamento Estrutural Rio Moji-Guaçu (BRANDT NETO *et al*., 1981). Este alinhamento engloba as intrusões de Jaboticabal, Ipanema, Varnhagem e Salto de Pirapora e demarca a borda nordeste da "Bacia Bauru" e, nas proximidades de seu cruzamento com o Alinhamento Estrutural do Rio Tietê (COIMBRA *et al*., 1977), este alinhamento é sítio dos altos estruturais de Pitanga, Artêmis, Pau D'Alho e Gibóia.

O Alinhamento do Rio Tietê coincide, na área de ocorrência do embasamento cristalino, com a Zona de Cisalhamento de Itu, corroborando com a idéia de que estes alinhamentos são reativações de caráter rúptil na Bacia do Paraná. A região onde se situam as cavernas de arenito nas cuestas basálticas é afetada por falhas transcorrentes e normais. As falhas de caráter normal foram interpretadas como resposta ao regime distensivo da época da abertura continental (*c*. 126 Ma) (FACINCANI, 1996; RICCOMINI *et al*., 1996; HASUI *et al*., 1995).

São descritas, na Gruta do Fazendão (SP-170) falhas transcorrentes dextrais ao longo de seu desenvolvimento principal (VERÍSSIMO & SPOLADORE, 1994). Nesta caverna ainda se observam estruturas sin-sedimentares de liquefação induzidas por abalos sísmicos, associadas à falhas de empurrão, dobramentos convolutos e falhas transcorrentes conjugadas dextrais e sinistrais, respectivamente de direção NE e NW, relacionadas à um eixo de tensão máxima ($\sigma 1$) de orientação E-W horizontal (RICCOMINI *et al*., 1996).

Espeleogênese

Na região entre Analândia e São Pedro são encontradas cavernas em profusão, sendo poucas mapeadas e cadastradas e menos ainda estudadas sob o ponto de vista espeleógico geral e genético. As cavernas de arenito vêm de longa data sendo estudadas por espeleólogos de todo o mundo, mas ainda é discreta a participação das cavernas brasileiras neste cenário. Na região há alguns trabalhos, fazendo-se menção à Ebehard WERNICK (1976), Guy COLLET (1980, 1982a e b), César U. V. VERÍSSIMO e Ângelo SPOLADORE (1994) e SPOLADORE e outros (1994) e RIBEIRO e outros (1994 e 1997).

As grutas de arenito têm seu início na ação erosiva do escoamento das águas superficiais meteóricas (*run-off*) ao longo das paredes, provocando remoção de grãos das paredes do arenito que originam buracos ou tafonis, evoluindo então para depressões, tocas e até abrigos.

Para haver a evolução desses abrigos para formar grutas há que se observar alguns fatores considerados essenciais por GALAN & LAGARDE (1988 *apud* CORRÊA NETO *et al*., 1997) e atendidos pelas características regionais: *1.* um grande desnível entre o lençol freático e o nível de base local, proporcionado pela cuesta; *2.* presença de fraturas profundas, dado pelo intenso sistema de fraturamento; e *3.* clima chuvoso, fator este atendido pela distribuição anual de chuva.

Além do escoamento superficial e os fatores já expostos a rocha contém ainda planos de fraqueza (junta ou falha) e descontinuidades sedimentares que geram uma anisotropia no qual, pela infiltração de água, tem-se contínua remoção física e química do quartzo já observados por outros autores (MARTINI, 1987 *apud* CORRÊA NETO *et al*., 1997; CORRÊA NETO & CORRÊA, 1994; CRUIKSHANK & AYDIN, 1995; WRAY, 1997), formando pequenos condutos ou cavernícolas por erosão interna (*pipping*), um fenômeno observado principalmente na Toca do Pipping no Município de São Pedro (RIBEIRO *et al.*, 1999). O início do *pipping* se dá por um processo de dissolução inicial ao longo do limite entre grãos, denominado de arenização (*arenisation*) (SZCERBAN & URBANI, 1974 e MARTINI, 1979, *apud* VERÍSSIMO & SPOLADORE, 1994), processo esse favorecido pelas descontinuidades. O alto grau de arredondamento e esfericidade dos grãos de quartzo das areias do Grupo São Bento, principalmente a Formação Botucatu, aumenta a superfície de contato do quartzo com a água, acelerando esse processo de dissolução e remoção de grãos.

Com a evolução dos condutos (*pipes*) dá-se intenso processo de coalescência desses canalículos e os dutos próximos unem-se por alargamento de seu diâmetro, tornando-se um canal preferencial para escoamento da água subterrânea, dado que forma uma zona de mais baixa pressão que passa a desenvolver corredores quando acessíveis.

O desenvolvimento da cavidade dá-se também por um alargamento ao longo de descontinuidades da rocha (RICCOMINI *et al*., 1996). Estas descontinuidades são constituídas principalmente por falhas, juntas e planos de *set* das estratificações plano-paralelas e cruzadas de grande e médio porte e outras estruturas sedimentares, além de heterogeneidades de silicificação da rocha. O encontro de duas descontinuidades pode deixar o arenito mais poroso, facilitando a sua solubilização e corrosão e a remoção de seus grãos.

Com isso pode-se afirmar que as cavernas são controladas, principalmente, pela estruturação tectônica local e regional e subordinadamente pelas estruturas sedimentares. Neste caso tomou-se como exemplo de controle regional a disposição da maioria das cavernas segundo alinhamento da estruturação regional e o padrão de fraturamento da área. Como controle local temos a disposição das falhas rúpteis pós-sedimentares ao longo da Gruta do Fazendão, obedecendo ao padrão de fraturamento de Riedel.

A densidade, orientação e penetratividade do sistema de fraturamento é que determina as dimensões da caverna e o padrão de distribuição de seus condutos, assim como o tipo, orientação e dimensão das estruturas sedimentares presentes. As galerias possuem maior desenvolvimento quando as descontinuidades estruturais (fraturas) são aproximadamente paralelas à direção de mergulho das estruturas sedimentares, como é o caso do principal corredor de entrada e do Salão da Baleia da Gruta do Fazendão, já que atinge um desenvolvimento horizontal aproximado de 200 metros. Também parece haver um mergulho ótimo das estruturas sedimentares para promover a formação de grandes cavidades (CORRÊA NETO & CORRÊA, 1994), com ângulo entre 20° e 40°, como é evidente no Salão do Saco da Gruta do Fazendão.

O abatimento de blocos, comum em cavernas em arenito, originados da queda de material do teto dos salões e galerias é ocasionado pelo intenso fraturamento da rocha, formando depósitos de gravidade, com blocos variando de dimensões centi- a decamétricas. O processo de remoção mecânica de grãos (*pipping*) forma depósitos caracterizados como de aluvião no chão das cavernas, resultado direto da desagregação de grãos das paredes e condutos.

PAKISER (1960 *apud* BJÖRNBERG, 1965) anota que iniciado o deslocamento de blocos em falhas de rejeito direcional, em arranjo paralelo, estes produzirão compressões e distensões locais nas extremidades, e que no caso das cavernas da área de estudo tem fundamental papel como processo responsável pelo abatimento de blocos na região de distensão e pelo *pipping* nas regiões de cisalhamento.

O corredor principal da Gruta do Fazendão está controlado por uma falha transcorrente de caráter dextral, tal como já observado por VERÍSSIMO e SPOLADORE, 1994, sendo parte do Salão da Baleia, também controlada por esta falha e por uma outra mais adiante, definindo um binário completo. Tal como observados nesse trabalho em trabalho de campo, os corredores internos e o “gostosinho”, obedecem a fraturas T (tração), sintéticas X e R e antitéticas R’ de Riedel. As fraturas T condicionam também a queda dos blocos da caverna, que pode ser observado próximo ao Salão da Baleia e o corredor principal da entrada.

A Gruta do Paredão, situada na frente da Gruta do Fazendão, foi originada pela mesma falha principal da Gruta do Fazendão. Seguindo-se para o outro lado da colina, encontra-se a Toca do Ninho, também controlada pela mesma falha, o que parece ser uma constante na gênese das cavernas da área.

As principais cavernas da área se desenvolvem em 3 sentidos preferenciais, sendo NNE, NW e WNW. Abaixo se segue a lista de algumas cavernas e orientações de seu desenvolvimento longitudinal:

NNE ➔ Gruta do Fazendão, Gruta do Paredão, Abrigo do Roncador, Abrigo da Glória, Abrigo Santo Urbano e Toca do Ninho;

NW ➔ Gruta da Boca do Sapo e Abrigo do Rochedo;

WNW ➔ Toca da Chuva e Abrigo do Bauru.

As cavernas que possuem controle NNE (Fazendão, Paredão Toca do Ninho e Abrigo da Glória) cortam o relevo da cuesta e não obedecem a um sistema de drenagem como as outras, nos levando a acreditar que possuem idade mais recente, corroborando com a idade do tectonismo Cretáceo-Terciário estipulada por PENTEADO (1968), posterior a formação da cuesta. PENTEADO (1976) descreve falhas normais nos ribeirões da Lapa e Cantagalo, no fronte norte da Serra de Itaqueri, seccionando pedimentos rochosos esculpidos na última fase de pedimentação e pediplanação relacionadas a evento tectônico do Pleistoceno médio.

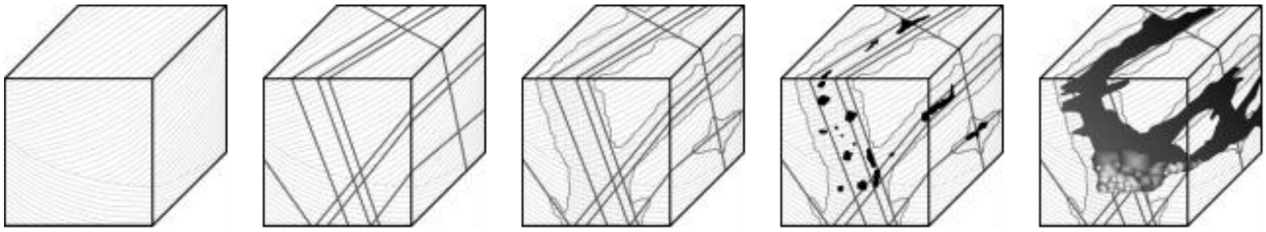
Nas paredes das galerias das cavernas é comum encontrar espeleotemas de calcedônia que se precipitaram a partir da exsudação de soluções capilares saturadas em sílica, tal como descrito por ROMERO & LIMA (1989 *apud* CORRÊA NETO *et al*., 1997) em cavernas de quartzito.

Diversos autores (MARTINI, 1987 *apud* CORRÊA NETO *et al*., 1997; CORRÊA NETO & CORRÊA, 1994; WRAY, 1997) relatam processos de dissolução e precipitação de sílica, que pode ser o processo de formação dos espeleotemas de estalactites e “couve-flor” de dimensões centimétricas existentes mais evidentemente na Gruta do Paredão.

Outras formações podem ser observadas nas cavernas da região, tais como *spots* de redução, manchas de descoloração ao longo de fraturas e estratificações, crostas ferruginosas e crostas silicosas na forma de couve-flor, já descritas por WERNICK (1976), além de cúpulas de corrosão (MARTINS, 1985 *apud* VERÍSSIMO & SPOLADORE, 1994) e estruturas de dissolução diferencial tipo “caixa de ovos” (PINHEIROS, 1987 *apud* VERÍSSIMO & SPOLADORE, 1994).

Observa-se na área diversos impactos antrópicos sobre o meio natural próximo às cavernas, entre eles: *alteração da rede hídrica e de sedimentos*, efeitos diretos do desmatamento nas áreas circunvizinhas à caverna e mata ciliar das drenagens, reflorestamento com espécies exóticas (como o eucalipto) no cimo das encostas e uso impróprio do terreno; *problemas de estabilidade/subsidência*, causado pelo uso agropastoril e movimentação rodoviária sobre as cavernas; *empobrecimento e erosão dos solos*, pelo emprego de técnicas agrícolas inadequadas e de monocultura; *poluição* e *destruição paisagística*, de origem diversa, efeito do visitação/turismo predatório na região; e *alteração do nível freático* (piezométrico), causado por alterações ambientais superficiais.

De forma sucinta podemos ilustrar, de forma esquemática, a gênese dessas cavernas da seguinte forma, em 5 fases:



FASE 1 FASE 2 FASE 3 FASE 4 FASE 5

Fase 1: Deposição do “Arenito (bimodal) Botucatu” e derrame de lavas basálticas (não representadas), procedidos por processos de litificação e silicificação. A figura ilustra as estratificações cruzadas de grande porte e estruturas sedimentares que refletem características de deposição em ambiente desértico.

Fase 2: Estruturação por descontinuidades de caráter tectônico, gerando fraturas (falhas, juntas e fraturas isoladas). Muitas dessas estruturas podem ter origem na reativação de estruturas do embasamento durante processos neotectônicos caracterizados na área. Essas falhas definem três sistemas de fraturas, orientados basicamente a NNE, NW and WNW.

Fase 3: Percolação de fluidos através de fissuras, durante o estágio freático, e dissolução parcial de grãos ao redor dos planos de fratura e estratificaçãocion e entre os grãos. O envelope dessas estruturas torna-se friável e incoeso, desenvolvendo uma grande porosidade secundária nas rochas e aumentando ainda mais sua permeabilidade, tornando o material mais suscetível à erosão física.

Fase 4: A evolução então apresenta dois tipos de erosão, já entre as fases vadosa e freática. Desenvolve-se uma erosão laminar a partir de processos de escoamento superficial (não representado) e remoção mecânica de grãos, formando pequenos canais. Com o tempo há um aumento desses canais e desenvolvimento de galerias, salões e corredores.

Fase 5: A fase final ocorre com o abatimento de blocos, segundo a estruturação tectônica da caverna. A exudação de soluções silicosas por fissuras e poros promove a geração de alguns espeleotemas como estalactites centimétricas, além de acumulação de calcedônia, predominantemente no teto e feições de corrosão. Com o descenso do nível piezométrico a caverna torna-se finalmente inativa.

Conclusões

As cavernas de arenito da Província Espeleológica da Serra do Itaqueri apresentam gênese resultante de processos sedimentares (estratificações e bimodalidade do arenito), geomórficos (escoamento superficial), erosivos (*pipping*) e, ressaltado nesse trabalho, condicionantes estruturais (arenização e abatimento de blocos). Esse controle estrutural dá-se por falhas direcionais dextrais e subordinadamente por fraturas de Riedel, do tipo R, R’, X e T. As extremidades das falhas direcionais possuem região de distensão gerando abatimento de blocos e região de cisalhamento, responsável pela remoção mecânica de grãos (arenização).

O sistema de falhamento regional e direção dos *sets* das estratificações cruzadas, de direção preferencial a NNE, coincide com a orientação da grande maioria das cavernas encontradas na área. O fraturamento regional obedece as atitudes NNW e NW, coincidente com as orientações da Gruta do Sapo e Abrigo do Rochedo. Este sistema de fraturamento regional e da Gruta do Fazendão não concorda com o sistema de falhas, sendo estas fraturas, provavelmente, de origem mais recente e responsável pela origem das cavernas e seu desenvolvimento por abatimento de blocos.

Os abrigos da região encontram-se ainda ativos, dado o processo de pipping observado, assim como as grutas e tocas, dada a presença de infiltrações de água por descontinuidades observadas em seu interior e processos de exsudação.

O eixo de tensão regional (σ_1) é de direção WNW (RIBEIRO, 2001), corroborando com as direções das falhas que condicionam a gênese e evolução das cavernas, segundo o sistema de Riedel, gerando abatimento de blocos nas regiões de tração (T de Riedel) e arenização nas regiões de cisalhamento (R e R’ de Riedel).

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Carsic Complex From Cabeço da Pedra do Sino

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Summary

The study presented here was developed by members of *Associação de Estudos Subterrâneos e Defesa do Ambiente* (Subterranean Studies and Environment Protection Association) during 1999/2000 and 2001. Localized in Maceira, Lisboa, Portugal, the cave system was - before the studies were started - referenced as a group of small caves (entrances) within the Vimeiro region limestone (Upper Kimmeridgian). Subsequently it was found that the system develops into an orthogonal pattern, after a series of both desobstruction and surveying work. The configuration was shown to have 11 entrances and an extension of 900m. The study will show that the system is of shallow phreatic formation.

Photo: A.E.S.D.A. - Rui Mergulho 2000 – Chifruda Cave – Maceira - Portugal

Location

The limy top hill (locally known by Cabeço da Pedra do Sino) where the Texugo´s Cave is situated belongs to the district of Lisbon and it is located close to the limits of the municipalities of Torres Vedras and Lourinhã, being positioned in this last one. To the SE we have the village of Ribamar and to the NNE the village of the Maceira. The cave is located at a distance of 625 m from Ribamar and 1250 m from Maceira.

The Lourinhã Fault is sited in the East side of the limy area of Cabeço da Pedra do Sino in a NNE-SSW direction.

The access normally is made from Maceira, along side one of the margins of the Ribamar stream, which flows, towards the Alcabrichel River.

Geology and Geomorphology of the Region

The Texugo´s Cave is located in the top of the Limy unit of Vimeiro (part of Layers of Alcobaça), which begins in Casais dos Netos, and ends at the North going up to Casais dos Arneiro, to the South.

According to the cut of (F. P. TEIXEIRA SILVA, 1989), the unit is constituted, from its lower middle part to the top, by calcareous rocks strongly bioclasts (calcareous algae), in general with oncoliths. The set develops throughout more compact and more poor in fauna calcareous rocks.

The sedimentation of this unit, with a thickness of about 160 m, was occurred in a frankly marine environment, of little depth and weak energy, still well illuminated and oxygenated.

From the base to the top it is possible to found variations in the features of the marine environment. This unit is probable on a saliferous anticline (MANUPPELLA et al., 1999).

The age of the formation of Vimeiros limestone is recognised to be from the Upper Kimmeridgian, due to the micrographical study of the cut, carried out under M. M. Ramalho orientation. It was possible to identify the presence of *Alveosepta jaccardi Schrodt*, *Campbelliella striata* (Carozzi) and *Everticyclammina virguliana Koechlin* (MANUPPELLA et al., 1999).

The Calcareous rocks of Vimeiro encircles a tifonic valley, where Maceira is located, originated by the extrusion of Dagorda marls dated from the Hettangian, injected in the Lourinhã fault.

The tifonic valleys, according to the definition of Paul Chauffat, are limited to a series of faults and have the deep raised through more recent soils, and in contact with these, in its entire perimeter.

These areas are generally of great importance for their hidrominerals and for the presence of certain minerals, as gypsum and mineral salt, amongst others factors (P. G. ANACLETO, 1965).

In this case, the gypsum outcrops in the core of the diapir of the Maceira / Vimeiro (G. C. FRANCE et al., 1961) without, being subjected to any exploration.

In this area there is commercial exploration of two springs of mineral water in the Vimeiro Spa, situated in the valley of the river Alcabrichel. These springs are located in the SE far end of the Hattangian outcrops, called Rainha Santa Isabel and Fonte dos Frades (Saint Isabel Queen and Monks Fountain).

Rainha Santa Isabel waters emerge of calcareous rocks while the ones from Fontes dos Frades arrive at the surface in the contact fault between marls and calcareous rocks.

Beyond the Fault of Lourinhã and the diapiric contact, it is possible to observe on the map another set of transversal faults.

They are the results of tectonic processes and of great tensions, causing complete alteration in the original position of the stratus. Thus, along outcrops side is possible to obtain very different values for strike and dip.

The top hill where the Texugo´s Cave is located has stratus with a dip of 15º NW. Its West slope is very abrupt, being the highest point 65 m and the lowest one 35 m on the East and 45 m on the West (at rivers levels which bound the top hill).

The bottom of the valley interconnected to the West slope resembles a small Canyon that would have been formed by the river erosion.

It is possible to observe Lapias with rounded off edges at the surface over the underground system, and in the West valley it is visible the ceiling collapse of a cave forming a small Canyon.

Speleogenesis and Cave Description

The complex in study has a total extension of approximately 900m of galleries. These are of average difficulty of progression and follow the orientation of the limestone layer fracturation. The orientations, almost perpendicular, promote an extensive web of labyrinthic galleries providing a complex exploration, only accomplished with surveying support.

The system possesses, in totality, eleven entrances subdivided in three zones of the hill under study. In the hill's North zone, is the *Cova do Urso* (the Hollow of the Bear). The cave crosses the hill in a West-East direction, with galleries of vertical/joint form and maximum height of 8 meters. It has a medium precipitation and deposition of calcite, which increases in its interior, emerging with frequency stalactites and stalagmites. At ground level, the clay deposits are frequent in the final part of the cave. The cave has a single connection with *Cova da Chifruda* through a narrow (20 cm) and high (4 m) gallery.

The *Cova da Chifruda* (North zone), has a semi-vertical entrance and, in its interior, a shaft of 4 m providing access to the top level as the *Cova do Urso*. In the cave, it is possible to verify the existence of main galleries (following the main fracture systems) and of low and ample rooms, with several clay deposits and areas with a large deposition of calcite. The cave does not present any large enough connection that allows the passage to the remaining complex (*Cova do Texugo and Gruta da Pedra do Sino)*, despite the proximity 38 m and the identical arrangement of galleries.

In the Central zone, and turned to the West, are the *Cova da Presa* (the Hollow of the Prey) and the *Lapa da Meio* (the Cave of the Middle). These two caves, of small dimensions, represent old entrances to the system and are obstructed with consolidated clay of difficult removal. Nonetheless, the main galleries oriented to the interior of the hill can be observed. These small entrances have large clay deposits at ground level. Also in the Central zone, but to the East, exists the *Lapa da Pulga* (the Cave of the Flea); one of the four entrances to the East for the main system of galleries. The *Lapa da Pulga* has, in all its extension and at ground level, large amounts of clay. The connection with the *Cova do Texugo* (the Cave of the Badger) is through a narrow (0.30 m) gallery with a level change of 4 m.

In the South zone of the hill, it is found the most important (known) part of the system, with an entrance to the West (*Cova do Texugo*), four to the East (*Pedro do Sino*, *Lapa da Luz*, *Cova do Mongo* and *Lapa da Pinha*) and a vertical entrance in the top of the hill (*Pedra do Sino II*). In this zone is well apparent the large number of main galleries (high 6m of vertical/joint configuration), successively intersecting each other through narrower galleries of a smaller cross-section and height. It is also possible to verify, on those same interceptions, the existence of collapses of the ceiling. In these galleries, it is rare to observe calcite deposits and the limestone rock is regular and with marks of physical erosion. Visualising the galleries cross-section, it can be evidenced that two distinct formation levels exist. At the top, they meet with a higher frequency, varying from 3 m to 1.0 m, with an abrupt variation for the remaining portion of the gallery, which is almost constant (averaging approximately 0.5 m), funnelling a little towards the base. This type of cross-section is directly connected on with the speed of formation of the galleries, very slow in the early stage and increasing near to the base. The existence of zones with clay deposits is also visible in the system, originating from the rise and fall of the water level

Conclusion

Given the pattern of the galleries that compose the system and because it is situated between two water courses, we are led to believe that it was initially created due to the variation of the water level associated to the excavation of the stream bed of the *Ribamar* stream (Shallow Phreatic or Water Table Theories – iniciated by Swinnerton, 1932). This happened in a period when the watercourse at East was found in a superior level when compared with the level at the present time. Later, with the increasing change of level of the watercourse at East, the widening by mechanical action of moving water occurred on some galleries. We also believe that the great accumulation of sediments that is verifiable throughout almost all the complex, took place in a sufficiently short time period (last homogeneous and very thick layer), possibly due to agricultural use of the land to the North.

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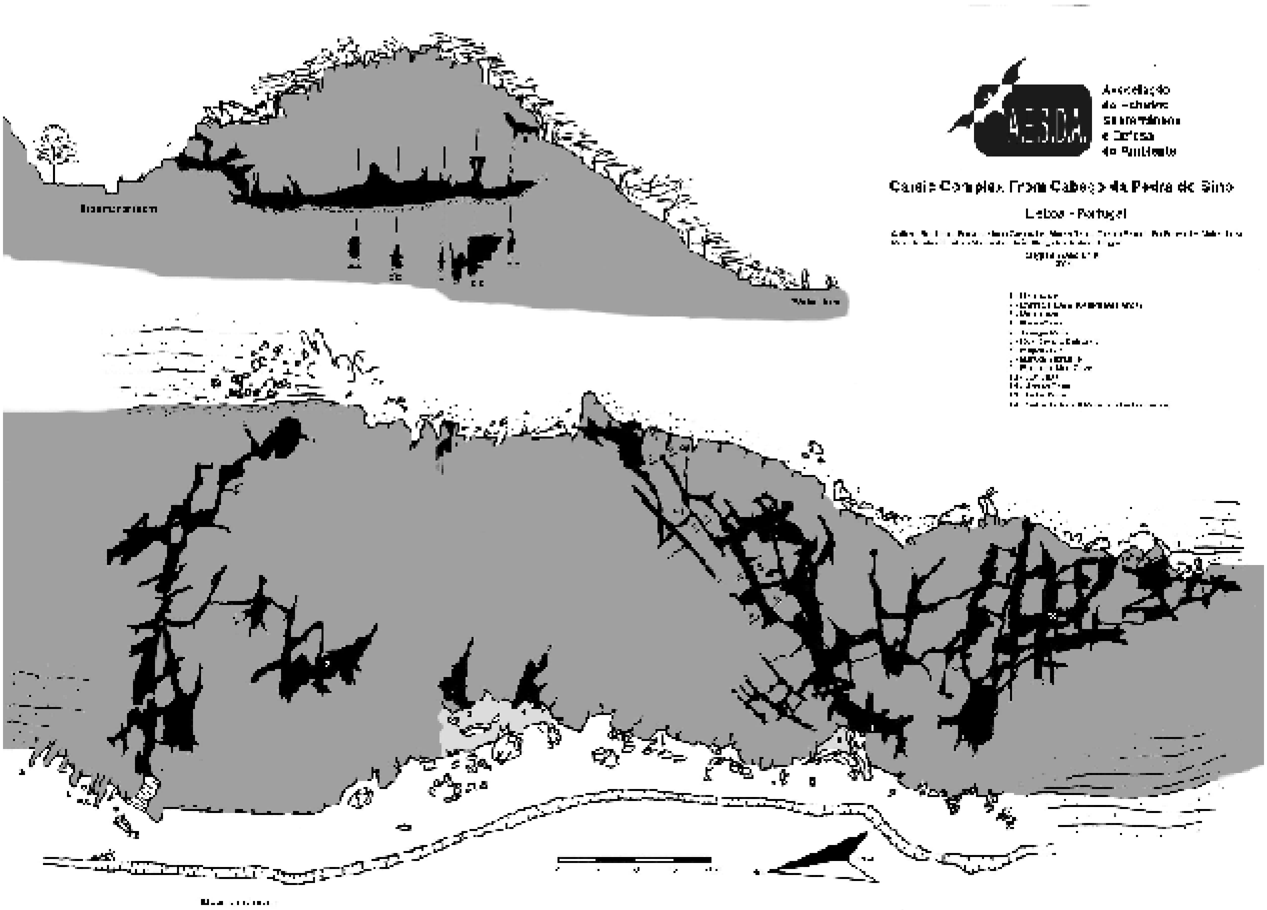
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Carsic Complex From Cabeço da Pedra do Sino
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The Dolomite Caves of Sierras Bayas, Southeastern Buenos Aires, Argentina

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Abstract

By far, limestone, gypsum, basalt and clastics caves are well documented in Argentina but dolomite caves have not been clearly mentioned in the speleological literature of this country yet. The Sierras Bayas site is close to the Olavarría town in Buenos Aires, Argentina. Three depositional sequences of Precambrian age compose the Sierras Bayas epiclastic Group. In particular the lowermost shows two sedimentary facies assemblages: a sequence of quartz - arkosic sandstones and shales and other composed of stromatolitic, calcite cemented dolostones and shales; stromatolites indicating an age of 800 – 900 Ma. These rocks are presently exposed along quarries whose operations led to the discovery of well-developed caves and galleries, the focus of this work.

Four isolated caves have been topographied but, in fact, it is proposed here that they form part of a unique system composed of partially or totally communicated conduits. Up to now 83,27 m were mapped with a maximum difference in elevation of almost 7 meters. During the last decades they have been intentionally filled up with rocks and debris, probably by local miners, causing the isolating of several passages and moreover, the total burying of many of them. In spite of this a descriptive work has been held in some cavities with very significant results.

Explored cavities are subhorizontal and small: the largest of all totals 45,37 m in length with a difference in elevation of 6 meters. Concretions such as stalactites, curtains and stalagmites are barely developed and are few in numbers, they are composed of aragonite and calcite but dolomite was also found. On the contrary, other types of depositional features are dominant and comprise thick calcite/aragonite crust, botroidal like accumulations, etc. Numerous dissolutional speleothems were found including ceiling pockets of different sizes and shapes, some scallops, notches, niches and a pothole. The natural sediment fill consists mostly of medium to fine debris and collapsed breccia.

It is proposed here that these are semiactive caves, this assumption is based upon the sporadic water flow observed in some conduits of the Matilde Catriel and Mallegni cavities. Finally, it is proposed that they are polygenetic caves. Matilde Catriel displays tubular passages, has an elliptical cross section and large scallops indicating a phreatic origin although presently it is evolving under vadose conditions. La Nueva and Santa Lucia, both at shallower depths, show steep entrances, smaller dissolutional features and water trickling confirming the slow evolution in an epiphreatic environment.

Geological Setting

The Sierras Bayas Group is located in Buenos Aires province, Argentina and belongs to the Sierras Septentrionales range (Figure 1). This geological province extends with northwest direction along 300 km exhibiting an igneous-metamorphic basement of 2000 Ma and the oldest unmetamorphosed precambrian sedimentary deposits of the country. The highest point of the range is 500 meters above sea level. The structure corresponds to fault bounded and tilted blocks and a gentle folded strata. Three depositional units composed this Group, the oldest is named Villa Mónica Formation (55 m) which shows two facies assemblages. The lower one is quartz-arckosic and comprises shallow marine siliclastics: conglomerates, arckosic sandstones and laminated shales and the upper one corresponds to shelf stromatolitic dolostones and shales (~35m). The Rb/Sr data for these levels indicate and age of 800/900 Ma (POIRÉ, 1993) which coincides with the age suggested by the stromatolitic assemblage found in this research. The following two depositional sequences are Cerro Largo Formation and Loma Negra Formation. The first represents a shallowing trend with chert breccia at the base that passes to fine stratified shales (glauconitic), fine grained, cross-stratified sandstones, arenites and finally claystones. The second comprises red and black micritic limestones interpreted as an environment of carbonate ramp, shelves and lagoon (POIRÉ, 1993).

In particular, the Villa Mónica Formation, the focus of this work, hosts the caves analyzed here. It represents a gradual marine transgression with the development of littoral sub-environments as it is pointed out by the presence of shales and very fine sandstones with trace fossils at the top. A climate change to tropical conditions led to the evolution of a carbonate sequence and well-developed columnar and stratified stromatolites. These organisms built important domic biostromes of originally magnesium calcite but presently they constitute dolostones due to diagenesis. Periodic sub-aerial exposures occurred later and iron rich shales were deposited over this sequence. Carbonates were also subjected to karst processes with the development of caves, karstic terraces and collapse dolines (BARRIO et al., 1991).

Locally, the strata are folded in a plunging syncline with an east-northeast axe. Caves are located in the northern end of the fold where dips are no higher than 20º. A system extensional and transtensional faults constitute the main structural framework of the site. Normal faults are axially oriented and related with release during folding and are considered the main controlling factor of the dissolution. Apart from them there are numerous strike slip ones with a gently sinistral displacement that secondarily contributes to that processes.

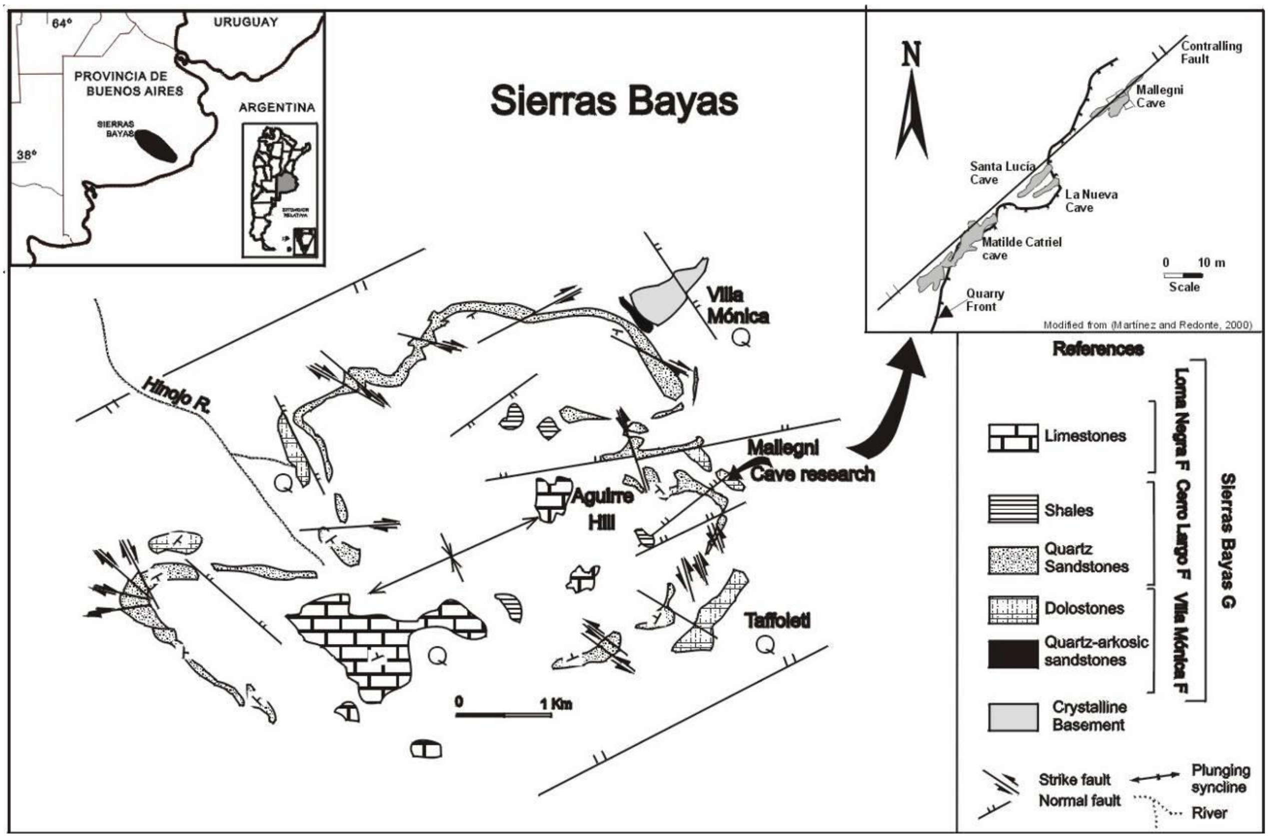

Figure 1: Geological map of Sierras Bayas outcrops and quarries (Q) distribuition. Plan view of the studied caves.

Speleological Setting

The mining activities of the Mallegni quarry have unburied a series of caves in the dolostones of the Villa Mónica Formation. The cavities resulted from karst phenomena developed during the Quaternary times although a series of dissolutional features found in bedding planes suggest that similar processes could have occurred during the lower Paleozoic (BARRIO et al., 1991; BARREDO, 1997).

Identified as Mallegni, Matilde Catriel, Santa Lucia and La Nueva, they are located between 250-270 m above sea level. Climate is template to moderately warm and humid with a mean rainfall of 850 mm per year. Temperatures range from 15°C to 30°C during summer and from 5° to 15 °C in winter with a mean annual of 14.1ºC.

Caves explored are aligned parallels to the bedding dip and are clearly controlled by the normal axial faults and cracks. They also follow the geological contact between the dolostones and the cuspidal impermeable shales of the lowest facies (Figure 1). The detailed topography carried on up to now indicates a partial horizontal development of only 83,27 m with a maximum difference in elevation of only 7 meters (MARTÍNEZ AND REDONTE, 2000).

The explored cavities are almost dry, water trickles and drops in some joints and concretions but no permanent currents were observed. Internal temperature shows a mean of 17 °C and moister reaches nearly 95 % in some passages. Matilde Catriel (253 m.a.s.l.), the largest and most important of all, is subhorizontal and totals 45,37 m in length with a partial difference in elevation of 6 meters (Figure 2a). The entrance consists of two vertical pits of more than 2 m deep; these holes are part of the numerous pits developed along joint and fault planes that were exposed during rock blowout. Its main gallery shows a rather lenticular profile with elliptical smaller conduits (Figure 2b) and minor meandering passages.

Speleothems correspond to barely developed stalactites, very few incipient stalagmites and curtains, thick botroidal like accumulations, coatings, petrified cascades and remnants of gours. Dissolution by imbibition of carbonates formed a dolomitic powder (mostly silty) with isolated quartz grains that covers great part of walls, building a weathering crust.

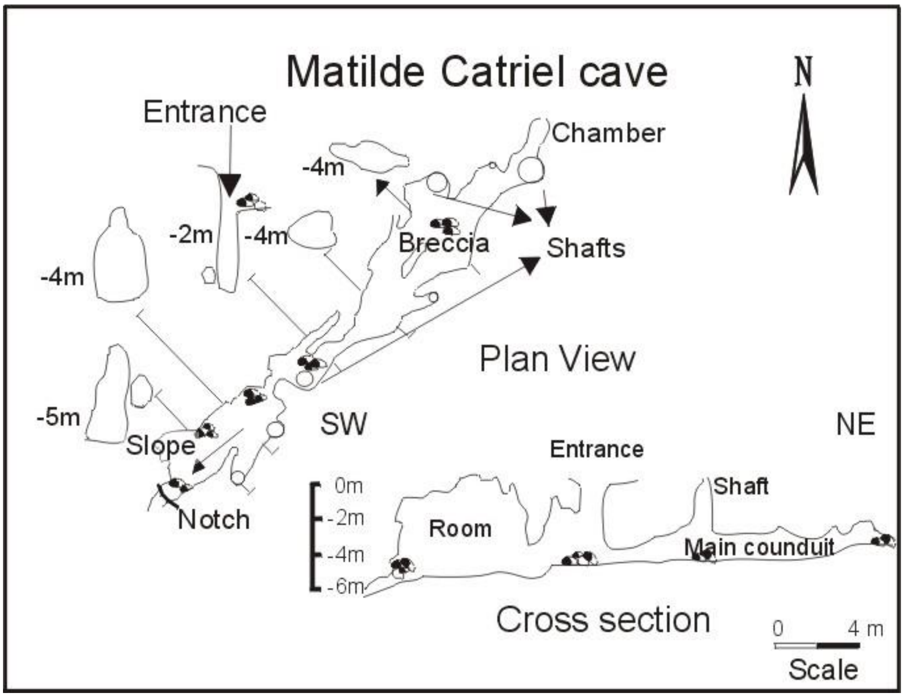

Figure 2a:Plan view and extended profile of the Matilde Catriel cave (modified from MARTÍNEZ AND REDONTE, 2000).

Manganese oxides appear as films or as dendrites on these surfaces together with iron oxides.

All these depositional features are composed of acicular and massive aragonite, rhombohedral, calcite, and scarce yellowish dolomite (Figure 3). Externally, they are mostly white with slight yellowish, dark brownish to reddish tones. These latter are also associated with iron oxide rich clay deposits (*terra rosa)*. Calcite is also present as aggregates of white translucent crystals, ranging from 1 to no more than 3 mm in length, as needles and also as pseudohelictites (these latter over calcite crusts). Dolomite was detected in thin section conforming rhombododecahedral and curved crystals, some of them with an aragonite core. Aragonite presents frequent calcite replacements.

The dissolutional speleothems are numerous and well preserved. Ceiling pockets are of different sizes and shapes, but mostly are independent, simple, semi-circular in cross section and always associated with a fissure (Figure 4). They are large, up to 90 cm in diameter, the bottom is rounded and the axe almost vertical. Few composite pockets were detected: they form groups up to three in number, laterally connected and no larger than 10 cm. Only one independent pocket in levels occurs in this cave, it is 30 cm wide, and shows two smaller and inner cups that reaches 15 cm. As in the first case, it is associated with a fissure.

Horse–shoes shaped wall niches (up to 50 cm) are more frequent in the southern portion of the gallery.

Scallops were found in some walls but they are bad preserved, it seems more likely that they form part of a network of niches cut into the surface of the dolomite. In spite of this it could be possible to differentiate, in few of them, the deeper portion from the shallow one. Among them tiny and angular pendants exist. Finally, semi-circular, sometimes flute like notches occur longitudinally over the walls and ceiling.

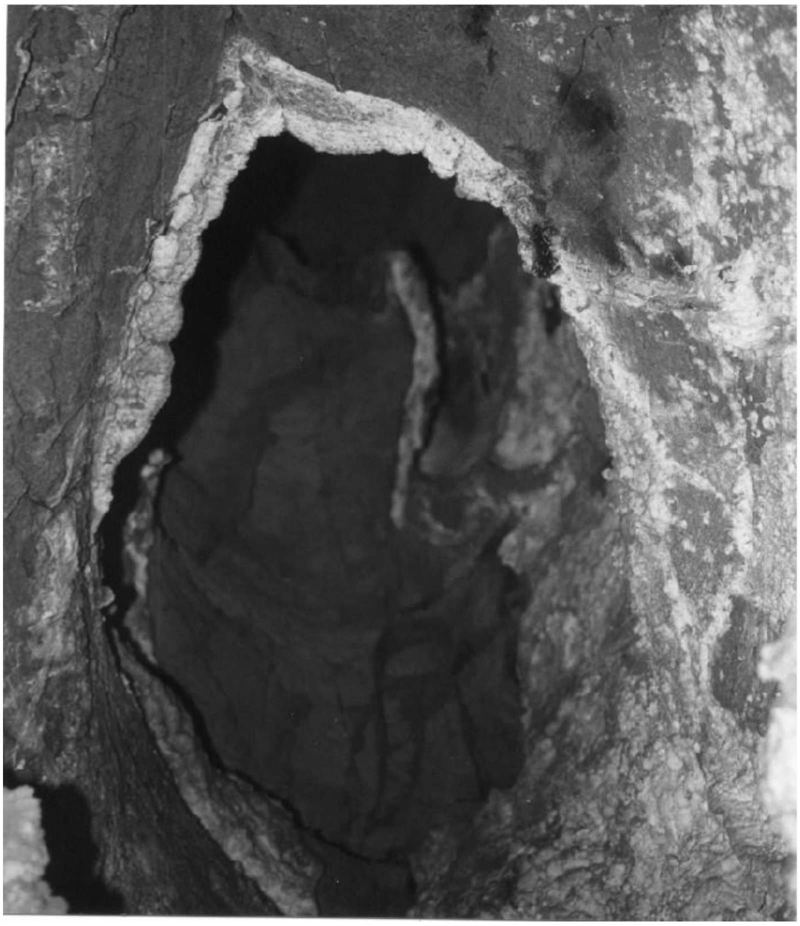

Figure 2b: Secondary conduit with elliptical profile. See also the aragonite deposit coating it almost entirely.

The floor is covered by sediments however some pits and a pothole (?) could be unburied. It is semi-spherical and slightly elongated indicating the outflow side, the axe vertical. The maximum diameter of the opening measured is 8 cm, the bottom rounded and smaller, depth is 3,5 cm. It is common to find aggregates of calcite crystals with sparitic cement protruding out of the fissures and building a reticulate framework. Dendrites and red iron oxides layer the walls.

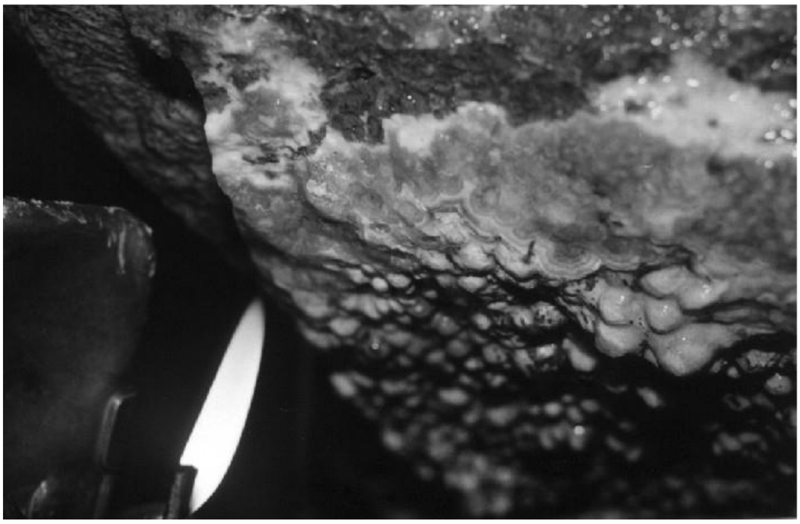

Figure 3: Aragonite coatings with calcite replacements (whitish tones). Note water films over the wall.

Floor deposits (*allochthonous and auochthonous)* consist of medium to fine debris and blocks up to 0,70 cm long. The first includes soil clay (loess derived) minerals, quartz grains/pebbles. The second, clay undetermined minerals, quartz, dolomite and lithoclasts (up to pebbles). Collapsed breccias comprise fan shaped piles of angular blocks and clasts related with minor faults and joints. Seldom boulders are piled up as a consequence of roof downfall.

Short-lived channeled flows with a classical anastomosing morphology transport part of these materials. Coarser grains show a subangular to subrounded surface with few of them imbricated. Fines deposits are mostly massive but certain parallel to wavy laminae can be identified. Some passages have been intentionally filled up with loam, rocks and other foreign materials so further details were not available.

The other cavities are less developed. Mallegni is 19 m in length, Santa Lucia only 11,9 m and La Nueva, 7 m. They present steep entrances (nearly 50°) but a gently south dipping floor of no more than 2°. Depositional and erosional features are basically the same but by far less developed. Gravity processes are more significant than those of the main cavity presumably by the human impact.

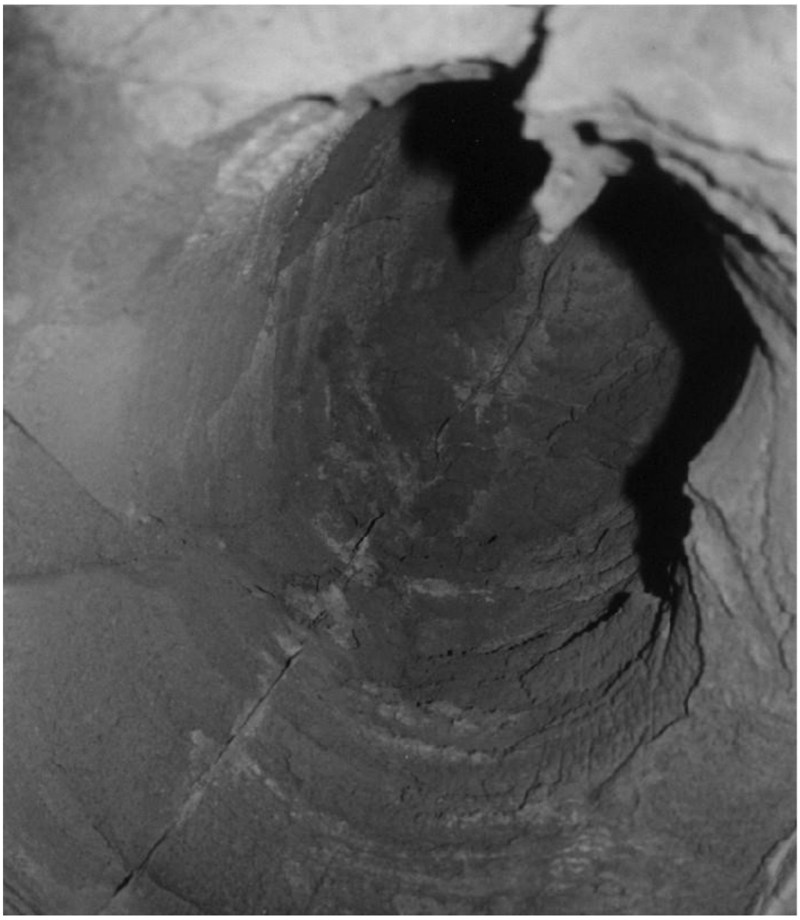

Figure 4: Ceiling Pocket: simple and semi-circular. Note the clear association with a fissure.

Proposed Model

If it is true that up to now cavities explored are few and apparently isolated they form part of a larger system. Evidences gathered during field works and the inhabitants' testimony permit to certify this hypothesis and even more, to suggest that caves are partially or totally communicated.

Matilde Catriel was deliberately filled with foreign materials thus some western secondary conduits and possibly important branches are now hidden.

In fact, the southern portion is completely obliterated, the gallery should follow as it is suggested by the presence of a well developed notch which emerges from the floor. To reinforce this latter, recent labors met a hole almost 30 m deep, south and close to the this wall, possibly meaning that a down level passage is related to that dissolutional feature. Another key element is that 2 km south a small resurgence was observed after a rainfall. On the other hand, Santa Lucía is separated from this cave by only 5 m (Figure 1). The ends of both show similar characteristics: a small circular chamber of 2 to 3 m in diameter with barely developed notches and solution cups. La Nueva cave is proposed here to be a lateral and shallower branch of Santa Lucía; Mallegni (263 m.a.s.l.) is located 15 m north clearly following the main structural trend and showing faint current indicators that point out to a mainly west-southwest flow.

Surrounding labors discovered caves that follow the southwest trend, not only in the same hosting rock but in the overlying limestone as well. Some others seem to follow a northeast trend consistent with the syncline plunging. All these unexplored cavities are said to be larger and more complex than the ones described here but these data could not be validated during this work.

Based upon passage morphology, it is proposed here that the "system" is composed of polygenetic caves. The main gallery of Matilde Catriel is almost tubular (Figure 2a), subhorizontal and has a subrounded to sometimes conspicuous elliptical cross section indicating a phreatic origin. The cave relief composed of very well developed ceiling pockets, large scallops produced under slow flows and solution cups in the ceiling, reinforce that assumption. However, at the moment this part of the system is semiactive and is evolving under vadose conditions. Secondary conduits are tubular and subhorizontal too, but few others, located near de entrance (and the entrance itself) are steeper with shafts associated to major fractures; very small scallops were also found. The cave is almost dry although after a rainfall percolation through these pits and through the structural discontinuities increases to such an extent that these vadose conditions become obvious. The pothole found may also suggest that turbulent water moved fast over the floor under such environment. Some bell shaped ceiling pocket might be associated with water trickling down the fissures. Stalactites are growing up and are always wet with stationary drops or are trickling. In some small conduits where moister reaches 100 % and where there is no dropping, humid walls show solutions cups probably resulted from water condensation. Sporadic flooding is also possible as it could be deduced during this research. As a response to a heavy rain, a small spring was observed 2 km south. Percolation increased substantially but a little portion of the Matilde Catriel southern end was temporally flooded. A maximum flooding level line was observed indicating 30 cm in depth, fine debris uniformly covered the floor as a massive deposit. A smooth channel was also incised when flooding ceased and water was insumed towards the southern notch, swash marks were also found. It seems likely that the lowest levels not enough capable to absorb all the water and the presence of underlying impermeable facies gave place to the overflowing of this part of the "system". A direct consequence of this latter is that water level rise resulting in the partial flooding of the upper passages and thus becoming temporally active. Further conclusions are speculative due to the human impact yet if these assumptions are correct there might be flooded tunnels downwards which again points out to a larger system than that explored here. To sustain such conclusion it is worth mentioning that recent hole measurements indicates that the phreatic level is in between 15 to 20 m deep, less than 8 m from the deepest point of Matilde Catriel.

Concerning the other cavities, Mallegni exhibited a well developed floor channel but no evidences of flooding were observed, all the remaining conduits indicate a vadose evolution. La Nueva and Santa Lucia showed huge amounts of water pouring through the pits, intense dropping and joint associated trickling as for the rain, but no phreatic conduits.

Concluding Remarks

During the last decades mining activities increased producing a remarkable change in the landscape. Outcrops once laterally continuous are now gone or indented by quarries and open pits. Lots of caves have been discovered and rapidly destroyed. These caves have been discovered long ago and it is said that the last native head (Mapuche) sheltered in one of them at the end of XIX. His wife narrated lots of stories about the "abysm" and so the cave was named Matilde Catriel in her honor. Like this, there are hundred of tales which assure that caves were once "bigger". Explosions introduced new fractures, produced rock fall downs and even more, some galleries totally crumbled. Likewise, foreign material was intentionally brought in. Concretions were also vandalized: removed or broken and left aside as waists. As a consequence explorations could not progress beyond the quarry boundaries but if the caves discovered in each open pit were joined together this system could reach more than 6 km (Figure 1).

In spite of all this, the detail research held here permitted to arrive to significant conclusions. Apparently isolated caves are part of a unique system, partially or totally connected. Field works suggest a phreatic origin for at least Matilde Catriel cave, being less obvious in the others. The system is semiactive and is being reworked under vadose conditions, concretions grow gradually and only after an intense rain percolation becomes important. The flooding observed makes it possible to think in lower and deeper conduits still under phreatic conditions.

Acknowledgments

Thousand of years are needed to achieve the state of this simple beauty, less than a breath to destroyed it. The author wants to thank to those who are helping to preserve this natural environment and to Gustavo Lentijo, Eduardo Tedesco and Aldo Filliponi who assisted the field works.

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Avaliação da Vulnerabilidade Intrinseca a Poluição de Aqüíferos Cársticos em Ambientes Tropicais Através da Utilização do Programa SINTACS[1]

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Abstract

The evaluation of the pollution intrinsic vulnerability of karst aquifers in a tropical environment using the point count system SINTACS

In the last 15 years the U.O. 4.7 and 4.9 of the National Group for the Defence against the Hydrogeological Catastrophes evaluated the pollution vulnerability of several karst aquifers in the temperate zone by using the SINTACS point count system.

The present paper is the first attempt to apply the same method to importants karst springs in a tropical area, in São Paulo State, Brazil. Their catchment areas extend more than 24,2 km^2 and are mainly located inside the High Ribeira State Turistical Park (PETAR) which is characterised by the Atlantic forest with a tropical humid climate without arid periods. The karst aquifers consist of limestones and dolostones surrounded and interbedded with metamorphic siltstones and sandstones. The karst systems are well developed, with a flood flow rate of about 3.6 cm/s (April 1997) thus corresponding from medium to high velocity systems (SMART e HODGE 1979).

In order to obtain the vulnerability map for the aquifer feeding the karst spring it has been necessary to prepare several digital thematic maps (geological, geomorphological, hydrogeological, speleological, ecc) which represent the base layers for the SINTACS evaluation of a specific GIS for the intrinsic and integrated vulnerability of the whole studied area.

In the present paper the used criteria for defining the values of the different parameters to be used in the SINTACS model are shortly discussed.

Resumo

Nos últimos 15 anos as unidades operativas 4.7 e 4.9 do GNDCI - Grupo Nacional pela Defesa das Catástrofes Hidrogeológicas do CNR (Conselho Nacional de Pesquisa), Itália, avaliou a vulnerabilidade em que se encontram os aqüíferos cársticos em regiões de clima temperado usando o programa SINTACS.

Este artigo tem como objetivo mostrar a aplicação do método em importantes ressurgências carsticas numa zona de clima tropical, no Estado de São Paulo, Brasil. A area de estudo apresenta uma superfície de 24,2 km^2 que em parte está inserida em terras pertencentes ao PETAR – Parque Estadual Turístico do Alto Ribeira. A área de estudo apresenta clima tropical úmido, vegetação de mata Atlântica. Os aqüíferos cársticos apresentam metacalcários e metadolomitos alternados com filitos e metarenitos. Os sistemas cársticos são bem desenvolvidos com velocidade média em torno de 3,6 cm/s (abril 1997) que corresponde a média dos sistemas classificados por SMART and HODGE (1979) como de alta velocidade.

Para se obter o mapa de vulnerabilidade intrínseca de um aqüífero devem ser preparados antes outros mapas temáticos como geológico, geomorfológico, hidrogeológico, espeleológico, etc) que representam os layers básicos para o programa SINTACS ou mesmo um GIS onde tem-se como resultado final a carta de vulnerabilidade intrínseca ou integrada da área como um todo.

No presente artigo o critério utilizado para definir os valores de diferentes parâmetros para serem usados pelo modelo SINTACS são discutidos brevemente.

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Introdução

A área de estudo compreende os sistemas cársticos Pérolas-Santana, Grilo e Zezo, localizados no município de Iporanga, a su-sudoeste do Estado de São Paulo, na região do alto curso do rio Ribeira, no distrito espeleológico do Vale do Ribeira (KARMANN e SANCHEZ 1986 e KARMANN 1994), Brasil.

Geomorfologicamente, a área a ser estudada encontra-se sobre o flanco sudoeste da Serra de Paranapiacaba, de relevo montanhoso, com amplitudes topográficas de até 700 metros. Esta região constitui uma zona de transição entre o Planalto Atlântico e a Baixada Costeira chamada de Serrania do Ribeira (IPT 1981a). Na Serrania do Ribeira existem os altiplanos interiores e as áreas carbonáticas estudadas são situadas em um destes altiplanos, chamado Planalto do Lajeado, cortado transversalmente pelo rio Betari, que representa o nível de base.

O clima do Vale do Ribeira, de um modo geral é classificado como tropical úmido (GUTJAHR 1993), onde não são observados períodos de seca total. O índice de pluviosidade médio varia entre 1500 e 1850 mm, sendo que a média de 1974 a 1993 foi de 1604 mm (KARMANN *op. cit.*). A cobertura vegetal densa é típica de mata Atlântica.

Descrição dos Sistemas Cárticos Estudados

Os rios Roncador, Furnas e Córrego Grande, que apresentam águas que correspondem àquelas das ressurgências dos sistemas cársticos estudados (Pérolas-Santana, Grilo e Zezo respectivamente) representam tributários da margem direita do Rio Betari, que por sua vez é afluente da margem esquerda do Rio Ribeira.

Os sistemas cársticos Pérolas-Santana, Grilo e Zezo são do tipo misto onde devido ao rebaixamento topográfico da superfície carbonática em relação as rochas não carbonáticas ao redor, ocorre importante injeção d'água alogênica em relação a recarga autogênica dos aqüíferos cársticos (KARMANN *op. cit.*).

Os sistemas estudados apresentam as seguintes características:

Pérolas-Santana: apresenta o sumidouro principal no Córrego Mendes, a 150 metros da entrada principal da Caverna de Pérolas e a ressurgência principal se encontra na entrada da caverna de Santana. Além de Santana e Pérolas faz parte do sistema a caverna Tobias.

Grilo: apresenta sumidouro principal no córrego Sumido e é constituído da caverna Grilo, cujo o seu rio subterraneo é principal afluente do rio Furnas.

Zezo: o seu principal sumidouro localiza-se no Córrego Consteca e apresenta a sua ressurgência principal na caverna Zezo.

Geologia Regional e Local da Área de Estudo

A área estudada é inserida em um complexo de rochas supracrustais vulcano-sedimentares, de grau metamórfico baixo a médio, denominado genericamente de Grupo Açungui (CAMPANHA 1991). Os terrenos cársticos que foram estudados pertencem às Formações Bairro da Serra e Betari, que fazem parte do Subgrupo Lajeado, que é constituído de uma seqüência metassedimentar de grau metamórfico baixo (zona da clorita), nas proximidades do Gabro de Apiaí. A Formação Betari é a unidade basal do Subgrupo Lajeado e é formada de metarenitos, metarenitos arcosianos e arenitos heterogêneos. A Formação Bairro da Serra apresenta unidades formadas de metacalcários, sendo em geral calcíticos e localmente dolomíticos, com intercalações de filitos sericíticos e siltes carbonáticos.

Elaboração do Mapa de Vulnerabilidade Integrada Através do Programa SINTACS

Para a elaboração do mapa de vulnerabilidade integrada foi usado um programa de cálculo específico para avaliação da vulnerabilidade intrínseca (CIVITA 2000; CIVITA *et al*. 1991) realizado pelo GNDCI/CNR, Itália. O programa é baseado num sistema paramétrico de pontuação e pesos, que foi especialmente adaptado ao ambiente cárstico e experimentado com sucesso em algumas das principais áreas cársticas italianas.

Pela primeira vez foi utilizado em um país caracterizado como clima tropical.

O acrônimo do programa deriva das iniciais dos sete parâmetros principais (escritos em italiano) que são considerados para a avaliação da vulnerabilidade intrínseca de uma área de estudo: (1) ***s**oggiacenza*: distância vertical do nível do freático até a superfície externa do sistema em questão; (2) ***i**nfiltrazione efficace*: infiltração que realmente penetra no solo; (3) *non saturo*: compreende a zona entre a superfície do freático e a base da camada de solo antes da superfície externa. Esta zona insaturada é a segunda linha de defesa do aqüífero em questão pois a primeira é o solo; (4) *copertura*: tipo de solo que cobre a área cárstica; (5) *acquifero*: constitui-se das características hidrogeológicas do aqüífero; (6) *conducibilità idraulica*: condutibilidade hidráulica do aquifero; (7) *superfície* (acclività): declividade do terreno.

O programa requer que a área de estudo seja dividida em uma malha de quadrados elementares cujas dimensões devam ser as menores possíveis permitindo assim a caracterização da heterogeneidade do aqüífero cárstico. Para a área estudada (24,2 km^2), foi realizado uma base cartográfica na escala de 1:25.000. A malha foi elaborada em quadrados com lados que correspondem a 200 metros. Para cada quadrado é definida uma série de características geológicas, hidrogeológicas, pedológicas, hidrodinâmicas, etc, que são combinadas entre si para a obtenção dos parâmetros utilizados no programa SINTACS. O programa após haver calculado para cada um dos parâmetros um peso correspondente segundo uma avaliação da específica da situação hidrologica ou de impacto calcula a vulnerabilidade intrínseca. O valor numérico, assim obtido para cada quadrado, é transformado em porcentagem e subdividido em 6 classes de vulnerabilidade (extremamente elevada, muito elevada, alta, média, baixa, muito baixa ou nula) que vêm representadas num mapa com diferentes cores. O mapa de vulnerabilidade integrada é deste modo, obtido através do mapa de vulnerabilidade intrínseca onde foram calculados todos os produtores ou redutores em potencial de contaminação de um aqüífero cárstico.

Este mapa é fundamental porque fornece uma base indispensável para um correto planejamento do território e também porque è diferente dos mapas de Hidrogeologia, pois é facilmente compreensível por aqueles que não são da área, facilitando o serviço das autoridades locais, que devem garantir a manutenção da qualidade, das águas que são contidas em um determinado aqüífero cárstico.

Parâmetros SINTACS

Espessura da Zona Vadosa (Soggiacenza)

Na área de estudo foi atribuído peso 1 para a região dos filitos, granitos e a do dique de diabásio. Para a zona do córrego Mendes peso 10 significando que a espessura da zona vadosa é muito baixa. Os sistemas Grilo e Zezo recebem peso 8, os metarenitos, a área da caverna de Pérolas peso 2 e a área que compreende as cavernas de Tobias e Santana recebem o peso de 1. Atribui-se um peso de 3 para as áreas que compreendem as cavernas Grilo e Zezo.

Infiltração

A região estudada apresenta uma notável quantidade de precipitação anual cuja média é de 1604 mm (última série histórica). Considerando-se uma evapotranspiração elevada (acima de 70%), aos litotipos presentes e ao índice de fraturamento e carstissismo considera-se uma infiltração média para a área onde encontram-se os sumidouros e uma infiltração baixa para as outras áreas.

Efeito de Autodepuração da Zona Insaturada

A zona insaturada é a parte do subsolo que se encontra entre a base do solo e a zona saturada (zona de oscilação) do aqüífero. Esta zona é sujeita a oscilações verticais da água subterrânea, e limitada na sua parte inferior pela superfície piezométrica.

Foi atribuído peso 10 aos sistemas cársticos e drenagens, ou seja, não existe nenhuma depuração por parte das rochas ali presentes. Verifica-se ainda que o efeito de depuração aumenta gradativamente conforme se afasta dos sistemas cársticos e drenagens estabelecendo peso 9 e 8 para estas zonas. As áreas cobertas por filitos ganham peso 1 (o mesmo ocorrendo com os granitos) pois são quase impermeáveis e o pouco de água que penetra o faz de modo muito lento. Já para as áreas cobertas com metarenitos o peso atribuído e 4 devido a uma razoável permeabilidade das mesmas.

Tipologia de Cobertura de Solos

Os solos presentes na área de estudo apresentam geralmente espessura elevada, ou seja, acima de 1 metro, com exceção das áreas onde se localizam os sistemas cársticos e a zona do dique de diabásio. Nestes locais se podem observar afloramentos de rocha onde quase não existe solo. A permeabilidade é baixa nas áreas onde encontramos filito mas é elevada nas áreas onde se apresentam outras rochas atingindo valores máximos na zona dos sistemas cársticos.

As classes de solo são representadas pelos solos franco argiloso e franco limoso desenvolvidos a partir das rochas carbonáticas e filíticas respectivamente. O solo franco arenoso corresponde as rochas metareníticas da Serra da Boa Vista que se encontram a noroeste da área. Onde encontramos os sistemas cársticos com suas respectivas drenagens verificamos que existe pouco ou quase nenhuma cobertura de solo e sim rochas aflorantes.

Aqüífero

O aqüífero estudado é caracterizado por apresentar uma permeabilidade muito alta devido ao alto carsticismo e fraturamento das rochas carbonáticas. Os sistemas apresentam velocidade alta para os fluxos d’água sobretudo porque se tratam de sistemas de condutos o que se pode concluir que são muito vulneráveis a altas concentrações de contaminantes hidroveiculáveis, determinados somente pela diluição.

Condutibilidade Hidráulica

Nos sistemas cársticos estudados foram efetuados testes com traçadores fluorescentes (rhodamina-WT) por AYUB (1998) com o objetivo de determinar as rotas de fluxo de tais sistemas como também a velocidade e a vazão dos mesmos. Foram detectados neste trabalho perdas de água dos Sistema Zezo para o Sistema Grilo e também deste último para o Sistema Pérolas-Santana o que se pode concluir que se trata de um sistema cárstico único. Para o sistema Pérolas-Santana os testes com traçador deram resultados em torno de 3,6 cm/s. Portanto, atribui-se pesos de elevada condutibilidade para a áreas dos sistemas cársticos e áreas laterais a estes e pesos baixos para outros litotipos.

Declividade da Superfície Topográfica

A declividade da área de estudo é muito variada havendo desde trechos de planície até trechos de declividade muito elevada. Para o cálculo da pontuação para o parâmetro declividade foi utilizada uma base topográfica 1:25.000, que permitiu de determinar 5 classes de pendência, expressas em percentual: uma primeira faixa entre 1 e 15 %, uma entre 15 e 19%, uma entre 20 e 24%, uma entre 25 e 29% e finalmente superior a 30%.

Mapa de Vulnerabilidade Intrínseca e Integrata

O mapa de vulnerabilidade intrínseca è obtido através da sobreposição das 7 cartas dos parâmetros SINTACS brevemente descritos. A este foi aplicado o peso correspondente a área de rocha fraturada, visto que prevalece este tipo de permeabilidade nas rochas carbonáticas presentes no aquifero.

O mapa de vulnerabilidade intrínseca assim obtido evidencia, na maior parte da área de recarga do acqüífero cárstico, a baixa e a baixíssima vulnerabilidade (acumulativamente além de 50%). Isto ocorre devido ao fato que a área de estudo apresenta rochas praticamente impermeáveis (não carbonáticas) e os metacalcários aflorantes consentem apenas uma pequena infiltração por causa dos espessos solos quase impermeáveis.

As áreas de elevada e elevadíssima vulnerabilidade, respectivamente 5% e menos de 3% do total, correspondem a sumidouros e zonas de percolação direta nos rios subterrâneos principais. Portanto, mais da metade da área cárstica è caracterizada por haver uma vulnerabilidade média (11%) e uma vulnerabilidade alta (21%).

O mapa de vulnerabilidade integrada, que se obtém através da sobreposição dos pontos de perigo real e potencial de contaminação ao mapa de vulnerabilidade intrínseca, evidencia os poucos centros de perigo a montante das ressurgentes, que não podem influenciar praticamente na qualidade das águas. Portanto, no momento, pode-se considerar que o risco de contaminação do Sistema cárstico Pérolas-Santana è muito baixo.

Conclusões

O programa SINTACS tem-se demonstrado valido para a caracterização da vulnerabilidade intrínseca também em países de ambiente tropical.

Naquilo que concerne a qualidade das águas armazenadas no sistema cárstico Pérolas-Santana o risco de contaminação resulta ser atualmente mínimo mesmo porque a existência de um parque natural, que abrange boa parte do sistema (o restante esta contido em área de APA – Área de Proteção Ambiental) deve ser uma garantia suficiente para a proteção de suas águas.

Entretanto, o notável crescimento da atividade turística nos últimos anos poderá criar condições de contaminaçao para as águas. Esta situação deve ser bem conhecida das autoridades do PETAR, que devem, de qualquer modo, evitar uma excessiva frequentação e/ou comportamentos não eco-compatíveis na região, cuja vulnerabilidade pode ser controlada através da utilização de programas como o SINTACS, ferramenta importante para a preservação do meio ambiente.

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Espessuras da zona vadosa	**Infiltração**	**Efeito de autodepuração da zona insaturada**	**Tipologia de cobertura**	**Tipo de aqüífero**	**Condutibilidade hidráulica**	**Declividade (%)**
Córrego Mendes (10)	Sumidouros (5)	Sistemas cársticos e drenagens superficiais (10)	Sutil o ausente (10)	Sistemas cársticos e drenagens superficiais (10)	Sistemas cársticos e drenagens superficiais (10)	<15 (5)
Sistemas Grilo e Zezo (8)	Metarenito, granitos, filitos (2)	Área laterais aos sistemas cársticos e drenagens superficiais (9-8)	Franco arenoso (6)	Áreas laterais aos sistemas ticos (8-9)	Áreas laterais aos sistemas ticos (8-9)	15-19 (4)
Metarenitos (7)	Dique de diabásio (2)	Metarenitos (4)	Franco limoso (4)	Metarenitos (4)	Metarenitos e granitos (2)	20-24 (3)
Cavernas Grilo e Zezo (3)	Ressurgências e Cavernas (2)	Filitos, granitos e dique de diabásio (1)	Franco argiloso (3)	Filitos, granitos e dique de diabásio (1)	Filitos e dique de diabásio (1)	25-29 (2)
Caverna Pérolas (2)						> 30 (1)
Cavernas Tobias e Santana (1)						
Filitos, granitos e dique de diabásio (1)						

Tabela 1 – Classes dos diversos parâmetros de SINTACS determinadas na área dos sistemas cársticos de Pérolas-Santana, Grilo e Zezo e relativas pontuações

Collapse Dolines and Passages of Postojnska Jama Cave System

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Abstract

The surface above the longest Slovene karst cave Postojnska Jama Cave System (20 km) is characterized by numerous dolines and collapse dolines. We have 17 collapse dolines in the area of 2,55 km^2. They vary in depth, shape and size. Some have steep slopes where collapse blocks look fresh others are relics of former collapse dolines with gentle slopes. The deepest collapse doline is basically the entrance shaft to Pivka Jama Cave (77 m), the biggest collapse doline is Vodni dol (600x240x60 m). Most of collapse dolines is situated near the crest of Postojna anticline, on it's northern flank. Development and especially deepening of collapse dolines like Velika and Mala Jeršanova doline, Vodni dol and Kozja Jama has a genetic connection with the lowering of Postojnska Jama Cave System active water passage into SW and NW passages due to the regional tectonic uplifting.

Introduction

The surface above the longest Slovene karst cave Postojnska Jama Cave System (20 km) is characterized by typical karst features as dolines and collapse dolines (CAVE REGISTER IZRK ZRC SAZU). Between numerous dolines we determined 17 to be significant collapse dolines. GOSPODARIČ (1976) related their position to the cave passages ground plan, and to the contact between limestone and flysch. Thereby he tried to find a connection between the defined geological structural element directions such as fault zones, anticline and syncline axes, with the collapse doline locations.

With detailed tectonic-lithological mapping of the area around Planina polje, Pivka and Črna Jama ČAR (1982, 1983) included the position of collapse dolines to geological structure. In 1996 (ŠEBELA) the situation of some dolines above Postojnska Jama Cave System was connected with collapse chambers in the cave. In 2000 (ŠEBELA & ČAR) detailed geological studies of Velika Jeršanova doline have been performed. This is one of less expressed collapse dolines above the Postojnska Jama Cave System. The actual shape of it represents a relic of a former well expressed collapse doline.

Based on CRAMER's (1944) work the collapse doline should be a direct result of a cave roof collapse, appearing on the karst surface. An additional condition is very usual, viz. »the diameter exceeds the depth« (GAMS et al., 1973). HABIČ (1963) stated that collapse dolines enlarge with underground water flow taking the collapse material away. Collapse dolines result simple falling-in of cave roofs. Calculations show that the primary cave chambers reduce, when moving towards the earth surface, owing to the loosening of the collapsed mass (ŠUŠTERŠIČ, 1968). According to LOWE & WALTHAM (1995) the collapse sinkholes represent a variety of closed depressions that form by collapse of the rock above an existing cave passage or chamber. Collapse dolines are funnel-shaped or deep shafts formed by the collapse of a cave roof. They may contain a lake if the water-table is sufficiently high (FARRIS-LAPIDUS, 1990).

Collapse Dolines and Geological Structure

Postojnska Jama Cave System is developed in Upper Cretaceous limestones. Cave passages are developed inside bedding planes which are deformed into Postojna anticline, which axis direction is NW-SE. This is also the most common direction of fault zones in the area and is called Dinaric direction. Tectonic deformations of the area belong to tectonic activities after the Eocene flysch deposition. In 1998 a detailed tectonic geological map of the cave passages was published (ŠEBELA, 1998). Beside geological structure of the area, the surface and underground karst features were studied.

We selected 17 collapse dolines. They vary in depth, shape and size. In Table 1 we showed the altitude of the bottom of collapse doline in meters, the length of long and short axis in meters, depth of the collapse doline, prevailing direction of long axis, surface area determined by upper edges and directions of prevailing geological structures.

NUMBER and NAME	ALTITUDE OF THE BOTTOM in m	ENTRANCE TO THE CAVE	LONG AXIS in m	SHORT AXIS in m	DEPTH in m	PREVAILING DIRECTION OF LONG AXIS	SURFACE in m^2	PREVAILING GEOLOGICAL STRUCTURES
1.Pivka Jama	473	Pivka Jama of Postojnska Jama Cave System	75	45	77	46^0	3.152,00	fault zones 30/75, 160/90
2.Drča dolina	529	/	120	95	31	347^0	9.403,00	fissured zone 160/90
3.Kozja Jama	502	/	210	120	73	6^0	22.043,00	fault zone 130/70, 150/70
4.Ruglovica	506	Ruglovica	30	20	52	90^0	615,00	fissured zone 150/80
5.SE from Ruglovica	559	/	20	20	10	0^0	285,00	fissured zone 0/90, 20/80
6.Vodni dol	497	/	600	240	60	56^0	123.713,00	fault zones 70/90, 130/80, 150/70
7.S from Drča dolina	523	Matevž passage of Postojnska Jama Cave System	350	140	32	125^0	35.421,00	fissured zones 160/90, 20/80
8.Črna Jama	531	Črna Jama of Postojnska Jama Cave System	80	75	39	0^0	4.775,00	fault zone 0/90
9.Magdalena Jama	549	Magdalena Jama of Postojnska Jama Cave System	10	10	20	0^0	149,00	fissured zone 150/80
10.near Magdalena Jama	530	/	205	185	30	25^0	28.441,00	fault zone 140/90
11.near M. and V. Jeršanova dolina	549	/	225	155	21	120^0	23.698,00	fissured zones 160/90, 170/90
12.Mala Jeršanova dolina	539	Zguba Jama	245	235	21	25^0	41.944,00	fissured zones 0/80, 30/90
13.Velika Jeršanova dolina	535	/	300	280	40	310^0	69.717,00	anticline 140/75, fault zone 140/90
14.N from Jama Koliševka	536	/	90	75	29	90^0	5.415,00	fault zones 30/90, 130/90
15.Jama Koliševka	553	Jama Koliševka	60	50	17	0^0	2.303,00	fault zones 130/90, 30/90
16.Stara Apnenica	554	/	130	125	41	103^0	12.250,00	fault zones 130/80, 150/80, 70/90, 80/90
17.Kafrna dolina	573	/	40	25	20	90^0	926,00	fault zones 70/90, 80/90

***Table 1. Morphological and geological characteristics of collapse dolines above the Postojnska Jama Cave System*.**

Some collapse dolines have steep slopes others are relics of former collapse dolines. Vodni dol (bottom at 497 m) is the most extensive collapse doline (600x240 m and 60 m deep). The second is collapse doline south from Drča dolina (350x140 m and 32 m deep) and the third is Velika Jeršanova doline (300x280 m and 40 m deep). The deepest collapse doline is the entrance shaft to Pivka Jama Cave (77 m). Kozja Jama is the second deepest collapse doline with the depth of 73 m, and Vodni dol is the third deepest collapse doline with 60 m. Between 17 collapse dolines 4 (Pivka Jama, Kozja Jama, Ruglovica and Vodni dol) have lower bottom than is the entrance sink of river Pivka into the cave (511 m), but they are anyway higher than the downstream sump in Pivka jama. We have the possibility to reach underlying cave passages from 7 collapse dolines (Table 1). From collapse dolines Pivka jama, the one south from Drča dolina, Črna Jama and

Magdalena Jama we have the access to the passages of Postojnska Jama Cave System. The smaller caves Ruglovica, Zguba Jama and Jama Koliševka, which are also accessible from collapse dolines, are situated at higher levels than passages of Postojnska Jama Cave System.

The Velika Jeršanova doline (a.s.l.=535 m) is situated on the surface above the Postojnska Jama Cave System. Its deepening undoubtedly interrupted the continuation of Pisani rov (a.s.l.=535,5 m) towards N. Through the Velika Jeršanova doline the Postojna anticline crest runs in the direction of NW-SE. The same direction has the Jeršan fault. The Velika Jeršanova doline today does not have the typical shape of a collapse doline. The main cause for the untypical collapse shape of Velika Jeršanova doline is its formation in the Postojna anticline crest, its shaping in thin bedded clay - rich limestones and intensive erosional lowering of the area. Regarding the actual shape of the slopes and outer edges, the Velika Jeršanova doline is a relic of a former well shaped collapse doline (ŠEBELA & ČAR, 2000).

Longer axes of collapse dolines were determined according to the longest distance between upper edge and across the collapse doline bottom. Shorter axis is perpendicular to the longer axis and runs through the collapse doline bottom (Figure 1). Tectonic structural elements which were used for rose diagram (Figure 3) were taken from detailed geological maps in the scale 1:5.000 (ČAR, 1983; ČAR & ŠEBELA, 1997; ŠEBELA, 1994; ŠEBELA & ČAR, 2000).

On 2 rose diagrams (Figures 2 and 3) we presented the comparison among principal orientation of collapse dolines and principal directions of tectonic structures which can be observed inside the collapse dolines. The most common direction of longer axis of collapse dolines (Figure 2) is N0-10^{0}E (29,4%), the second most common direction is N90-100^{0}E (17%). Regarding geological structural elements which can be detected in collapse dolines fault and fissured zones prevail. Velika Jeršanova doline is developed inside the Postojna anticline axis. Two most prevailing orientations of tectonic structures (Figure 3) inside collapse dolines are N40-50^{0}W (15,2%) and N20-30^{0}W (15,2%). Three directions, which are N10-20^{0}W, N0-10^{0}E and N30-40^{0}E, represent 12% each.

We can conclude that the most common direction (29,4%) of collapse dolines longer axis fits to the tectonic zones orientation in the same direction with just 12%. The prevailing longer axis direction of collapse dolines is not the same as is the prevailing direction of tectonic zones. Collapse dolines longer axis orientation is more consistent than are directions of tectonic zones.

Conclusions

Most of the collapse dolines is situated on the northern flank of Postojna anticline. The Postojna anticline runs through Velika Jeršanova doline (number 13 on Figure 1) and continues south from the collapse doline near Magdalena Jama (number 10 on Figure 1). Just four collapse dolines are situated on the SW flank of the anticline. The surface area of collapse dolines marked with numbers 1-13 (Figure 1) is developed at lower altitudes than is the southern area. Development and especially deepening of collapse dolines like Velika and Mala Jeršanova doline, Vodni dol and Kozja Jama has a genetic connection with the lowering of Postojnska Jama Cave System active water passage into SW and NW passages. Regional tectonic and hydrologic processes which caused the uplifting of area SE and E of Postojnska Jama Cave System influenced the lowering of the active waters into the lower passages in the direction towards SW and W. By studying the evolution of early karst aquifers, GABROVŠEK (2000) pointed out that after the breakthrough the water-table will decline. This can be one of important periods for intense deepening of collapse dolines.

With statistical evaluation of most frequent directions of the collapse doline longer axes orientation and most frequent directions of the fissured zones we realized that there is not a good statistical correlation. The direction of most longer axes doesn't correspond well with the most common direction of tectonic zones. Some collapse dolines as the one S from Drča dolina (number 7 on Figure 1) have Dinaric orientation (NW-SE), others like Vodni dol (number 6 on Figure 1) have cross-Dinaric orientation of the longer axis. In just five collapse dolines (Drča dolina, Črna Jama, Magdalena Jama, Ruglovica and collapse doline near Magdalena Jama) there is just one prevailing tectonic zone, all others are situated at the crossing of two or more important tectonic zones. According to Čar (1982) the crossing of fissured zones is especially favorable for development of collapse dolines.

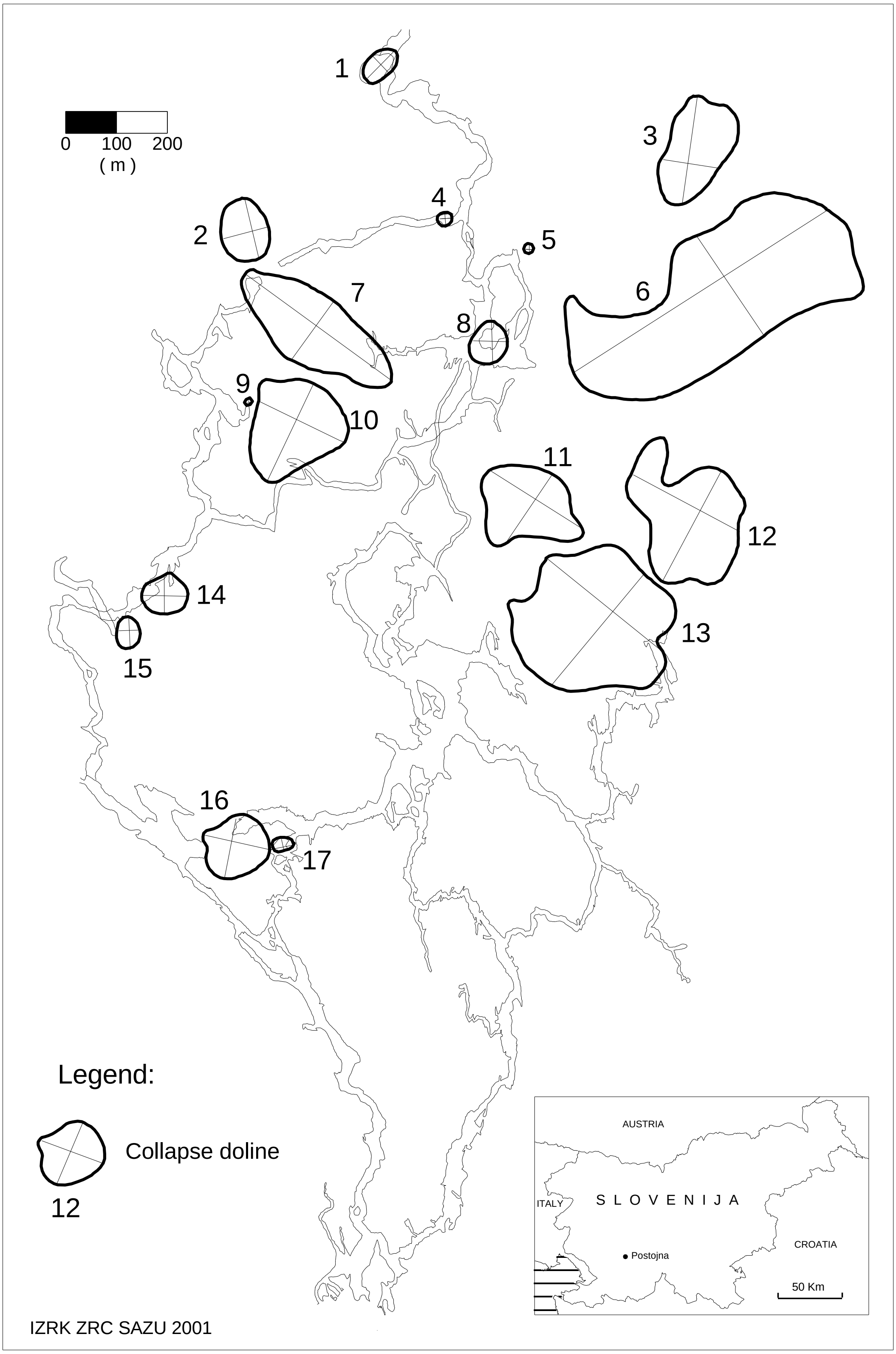
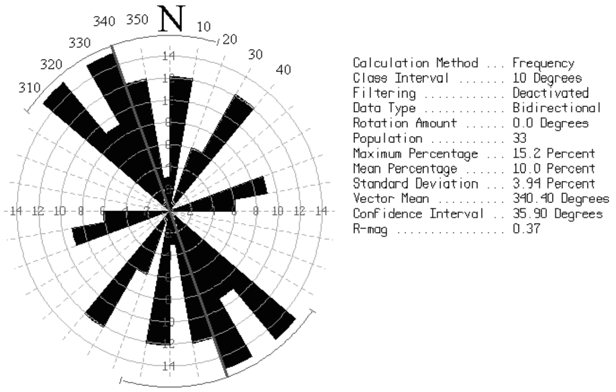


Figure 1. Position of collapse dolines above the passages of Postojnska Jama Cave System. The crossing between longer and shorter axis represents the collapse doline bottom. Numbers of collapse dolines are explained in Table 1.

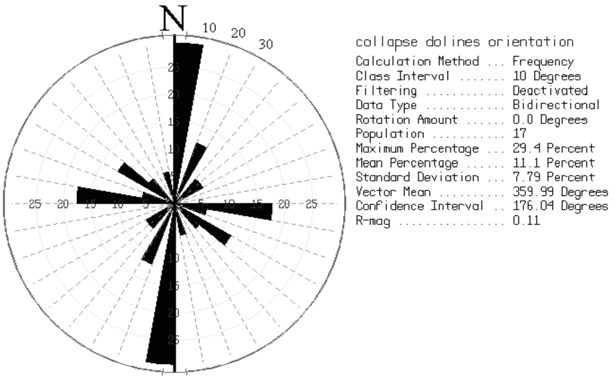
Processes of surface corrosion and erosion and development of collapse dolines morphologically lowered the area with the highest density of collapse dolines. Collapse blocks and cave sediments which have not been carried away by active waters plug some passages of Postojnska Jama Cave System on the NE edge. The fact is that most of principal tectonic zones which control the development of collapse dolines are younger than Eocene flysch. The oldest cave sediments found in Postojnska Jama Cave System are 0,73-

0,90 Ma years old (ŠEBELA & SASOWSKY, 1999) and regarding their position in the cave we conclude that in the time of their deposition the collapse dolines have not been developed at the stage which can be observed today. They might have existed but their collapse blocks have not plugged the passages yet. The final lowering of Velika Jeršanova doline to the level of cave passages can be related to the period younger than 0,73 Ma (ŠEBELA & SASOWSKY, 1999) what is the age of cave sediments with collapse blocks which plug the NE edge of cave system.



```
Calculation Method ... Frequency
Class Interval ....... 10 Degrees
Filtering ............ Deactivated
Data Type ............ Bidirectional
Rotation Amount ...... 0.0 Degrees
Population ........... 33
Maximum Percentage ... 15.2 Percent
Mean Percentage ...... 10.0 Percent
Standard Deviation ... 3.94 Percent
Vector Mean .......... 340.40 Degrees
Confidence Interval .. 35.90 Degrees
R-mag ................ 0.37
```

Figure 2



```
collapse dolines orientation
Calculation Method ... Frequency
Class Interval ....... 10 Degrees
Filtering ............ Deactivated
Data Type ............ Bidirectional
Rotation Amount ...... 0.0 Degrees
Population ........... 17
Maximum Percentage ... 29.4 Percent
Mean Percentage ...... 11.1 Percent
Standard Deviation ... 7.79 Percent
Vector Mean .......... 359.99 Degrees
Confidence Interval .. 176.04 Degrees
R-mag ................ 0.11
```

Figure3

Figure 2. Rose diagram of the most common direction of collapse dolines longer axes. Longer axes are calculated regarding their direction, the longer length of axis is not calculated with stronger values.

Figure 3. Rose diagram of directions of tectonic zones measured inside collapsed dolines. Data for tectonic zones were taken from ČAR, 1983; ČAR & ŠEBELA, 1997; ŠEBELA, 1994; ŠEBELA & ČAR, 2000.

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Speleogenesis in Cenozoic Limestones, Southeastern Australia

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Abstract

Southeastern Australia has extensive areas of Cenozoic limestones. These include both Oligo-Miocene marine calcarenites and calcilutites and Pleistocene dune calcarenites. This paper will illustrate the factors involved in speleogenesis in these limestones and outline the relationships between speleogenesis, hydrogeology and lithology in relatively young limestones.

These limestones, whilst more extensive in area than the Palaeozoic impounded karsts of eastern Australia, are less well known especially for cave exploration. However they have both extensive and intensive cave systems including the flooded cenotes of the Mount Gambier area, the large caves of the semi arid Nullarbor Plain and maze-like systems in the Pleistocene dune ridges.

Speleogenesis in these lithologies is an interplay between the groundwater conditions and the lithification and diagenesis of the calcareous sediments. As such sediments are highly variable in their calcareous content, the solution/precipitation balance also varies from site to site. This variability is combined with both high primary porosity and permeability resulting in diverse surface and underground karst features.

The caves are dependent on the ability of the calcarenites to develop sufficient structural strength in the form of an indurated layer. This "caprock" is necessary for the development of many karst forms, especially caves, as it gives the relatively unconsolidated calcarenite structural strength. The caprock develops in both limestone sequences where conditions are favourable but somewhat better in the Pleistocene dunes.

The development of cave systems is also directly related to the groundwater conditions. Evidence of fluctuating groundwater conditions over time can be seen in the caves, especially the drowned cenotes of the Lower Southeast of South Australia. The inter-relationship of groundwater conditions and relatively horizontal lithologies, combined with the development of an indurated layer are the keys to understanding speleogenesis in these limestones.

Introduction

Karstification is a complex process controlled by the nature of the lithology, tectonic structure and climatic conditions. In particular, lithological variation of porosity, chemical composition and strength can be extremely high. Whereas massive, well jointed and relatively chemically pure limestones are traditionally perceived as having the best karst development, the extensive but relatively poorly consolidated Cainozoic shallow marine carbonates and Pleistocene dunes in southern Australia have developed extensive karst systems and can offer interesting insights into speleogenesis.

Cenozoic Geology of Western Otway Basin

Although southeastern Australia has a complex Cenozoic geology involving Eocene and Plio-Pleistocene volcanism, deposition of cool water and coastal carbonates characterises a substantial area of coastal and continental shelf areas. The Otway Basin in southwestern Victoria and southeastern South Australia is a typical sedimentary basin and includes Miocene and Oligocene marine limestones and Pleistocene calcareous dune and beach facies. Both these limestones are generally poorly lithified but their responses to karst forming processes, despite some strong similarities are not identical. The limestones vary in texture and lithology, and are not equally soluble. Although the limestones extend northward, progressively thicker non-calcareous sediments and volcanics limit karst potential.

Lithologies

The Tertiary marine limestones are generally horizontally bedded; well-sorted fine to medium grained bioclastic cool water carbonate sandstones of variable purity and cementation. They were deposited in shallow marine environments during the Oligocene and early Miocene and are extensive across the basin. More than one geological formation is calcareous (KENLEY, 1971) but the limestones that extend to the north and east show very little karst development. The limestone is a relatively soft and poorly cemented rock that develops localised thin case hardening and limited calcrete capping. It is locally well jointed with generally northwest joint trends in the western part of the basin and a northeastern trend in the east. The sequences of Tertiary limestones show variable purity; predominantly calcite with a variable presence of aragonite, and have intermittent beds of more siliceous material. The Tertiary limestones are similar to those of the Nullarbor, but although there are some similarities of cave styles there are none of the huge passage systems that occur there (GRIMES & WHITE,1996).

Overlying the Tertiary limestone in many areas of the Otway Basin are Pleistocene aeolian calcarenite (aeolianite) stranded dune ridges and beach facies. These Pleistocene deposits are well sorted fine to medium grained bioclastic carbonate sands of variable purity showing crossbedding, variable cementation, strong laminations and a well developed kankar or caprock. Dating of a sequence of dunes overlying some of the coastal area, by thermoluminescence techniques, indicates they were deposited and stranded over the past 800 thousand years (HUNTLEY et al., 1993). Particular dunes at Codrington and Bats Ridge, which have a high degree of karstification, have been dated at 238 ± 45 ka to 244 ± 74 ka, and 295± 35 ka respectively (WHITE, 2000b).

The Cenozoic limestones of the Otway Basin show some similarities in their variable cementation, variable purity of calcium carbonate and poor consolidation, but also show strong differences in their bedding, jointing and ability to develop a strong caprock or kankar. The passage orientation of the karst features in the two types of limestone is distinctive. Cave passages in the dune limestones show a spread of passage directions whereas cave passages in the Tertiary limestones are more obviously directional; commonly either NE-SW or NW-SE reflecting the jointing patterns of the limestones. It is differences such as these, which are important in the differential development of the karst.

Speleogenesis in Oligo-Miocene Limestones

The Otway Basin can be divided into two quite distinct karst provinces: the southeastern South Australian and the western Victorian provinces. The more westerly extends further east than described by MARKER(1975). The boundary zone of the two provinces is the narrow tectonically active zone associated with the Portland area. Significant differences in the karst occur between the two provinces.

Karst in the Tertiary limestones is characterised by single linear joint controlled systems showing extensive horizontal development and collapse features. The karst development is directly related to lithological variation, especially between the eastern and western sections of the basin. In the east, the Tertiary (Port Campbell) Limestone is extensive in but is of variable carbonate purity and has only limited cave development despite the extensive area of carbonates. Spectacular limestone rock stacks are found along the coast. These rockstacks show prominent basal notches and are up to 50m high.

More extensive karst occurs in the Naracoorte and Glenelg River areas. Important Pleistocene vertebrate deposits occur in a number of caves eg. Victoria Fossil Cave (Naracoorte), McEachern Cave (Glenelg River). Many caves show impressive sand cones. Phreatic preparation can be seen in the walls and roof pendants are a feature of some caves, but the easily eroded nature of the soft limestone precludes many of these being preserved.

Major cavern development in thought to have occurred in the very late Pliocene and early Pleistocene. (MORIARTY et al 1998, MORIARTY et al 2000). Speleothem dating and environmental reconstructions show cyclical alternation of "Wet Phases" and more arid phases over the past 500ka (AYLIFFE et al., 1998; MORIARTY et al., 2000). The dates indicate that the major caverns were formed over 500ka ago, probably during the period of high water tables in the Pliocene (MORIARTY et al., 1998). It is clear that major solutional development in caves in the Naracoorte area ceased prior to 500,000 years ago. and the caves have since undergone modification by collapse, minor solutional activity and filling with both clastic and chemical sediments. The initial conduit development is in a direction oblique to the dune direction and away from the present direction of the sea and further development as the result of beam failure in the relatively "weak" Miocene limestone roofs resulted in collapse especially where passages intersected. Evidence of the solutional origin of the passages is present on the walls but only limited areas of the roof due to the large amount of collapse. Solutional cave development has possibly been reactivated during wetter periods over the past 500ka is most probably minor and has mainly been in the removal of the collapse material, but is difficult to document

Cenotes, drowned collapsed dolines, are a common feature of the Mt Gambier part of the basin where water tables are relatively high.

Speleogenesis in Pleistocene Dune Calcarenites

Karst in the Pleistocene limestones is characterised by shallow sinuous systems with multiple entrances, low flat, wide chambers and horizontal development, solution pipes and roof avens and extensive cap rock (kankar) development. The dune landscape has characteristic interdune lakes & swamps that have increased the aggressivity of the surface and ground waters.

Although there are a number of dune areas where karst development has occurred, two particular sites (Codrington and Bats Ridge) show the karst development in these dunes very clearly. Codrington is an area of cave development in a mid Pleistocene dune ridge predominantly composed of calcareous sand. The characteristic karst features are found in this dune which is considerably lower in altitude than the more seaward two dunes, indicating some landscape lowering. (BERRYMAN & WHITE, 1995). Karst features also occur in more complex mid Pleistocene dune sequence at Bats Ridge. This ridge, about 100 m above present sea level, has a general alignment north east/south west, with low spurs on the northern side. There are peat swamps in the swales on both northern and southern sides of the dune, some of which hold water in wet seasons (WHITE, 1994).

The characteristic landforms associated with these Pleistocene calcarenite strandline ridges are the result of karst processes of solution and collapse. The caves are shallow with horizontal development and have formed under a hardened cap rock (kankar layer) in the calcarenite dune. This formed as the result of solution and redeposition of calcium carbonate, under sub-aerial conditions. The cementation is primarily as meniscus cement that confirms that diagenesis has occurred under sub-aerial conditions. The position of the caves within the dune can reflect a previous higher water table. These near coastal dune systems show karst development that is contemporaneous with lithification (syngenetic karst). (WHITE, 2000a).

There is very limited calcite speleothem development; often expressed as moon milk or calcite straws in both the limestone types.

Hydrogeology

Groundwater is essential for the development of karst features. The development of karst features in landscapes dominated by high primary porosity and minimal, if any, secondary porosity associated with joints, differs significantly from that in karst landforms where secondary porosity development occurs. This is largely due to the relationship between groundwater movement in these zones. In addition, coastal karst groundwater systems are often influenced by the boundary between seawater and freshwater and this junction as well may contribute to the development of karst.

Very little work has been conducted on the groundwater systems of the Otway Basin in relation to the development of karst in the region. Examination of existing groundwater bore records indicated that despite the existence of a large number of bores, most of these are for stock and domestic purposes and little groundwater monitoring has occurred. Nevertheless, assumptions about groundwater flow processes can be made drawing on theory of flow systems (FREEZE & CHERRY, 1979). A significant component of future studies could be to examine whether these flow processes do indeed exist. It can generally be assumed that groundwater flow is towards the coast, based on the relatively uniform lithology towards the coast and assumptions about flow between land and water bodies.

The Tertiary Limestone forms a major aquifer in the region and the Gambier Limestone has been referred to as one of the best aquifer systems in Australia (STADTER, 1999). In the western area of the basin there is a well-developed water table sloping gently towards the coast. with two zones of steeper gradients, along the line of the Kanawinka Escarpment and to the north of Mount Gambier. MARKER (1975) reported a correlation between high cave densities and zones of steep gradients and with areas of greater than normal depth to the water table. Certainly there is ample evidence of karstification at times of different water tables than the present, as many of the cenotes of the Mount Gambier area have submerged speleothems and mudcracks and stomatolites are found up to 2m above present water levels. (GRIMES & WHITE, 1996).

Although more than one aquifer system has been shown to occur within the Oligo-Miocene limestones, examination of the bore logs suggests that where the aeolian calcarenites overly Tertiary limestone, generally only one aquifer system occurs within the calcarenites. In spite of this, while the general flow direction is towards the coast, minor variations occur as a result of localised flow within the dune systems, similar to localised flow systems which have been shown to exist within glacial till on the Great Plains of northern USA. The similarities are important, suggesting that localised flow processes may only occur seasonally and may sometimes override a general coast flow of groundwater.

Collection of groundwater levels in February 1994, indicates a close relationship between the watertable level and cave floor levels, and suggests that the watertable effected an important control over cave development (BERRYMAN, & WHITE, 1995). However, it must be noted that any correlation of present cave levels with present watertable levels must be considered in the light of recent anthropogenic changes to the water table. In this instance, although there are not data to support it, development of drains within the swales between the dunes, in many of the areas over many years, has resulted in a lowering of the watertable, in the vicinity of the drains, if not overall.

Nevertheless, there is sufficient observational evidence to suggest that groundwater levels do contribute to the development of karst in the region. In order to link this to landform development it is perhaps more important to consider the role of groundwater in relation to sea level and changing sea levels. The karstification in these dunes can be correlated with the overall high water tables that in turn relate to higher sea levels. Dune formation in particular, relates to higher than present sea levels and the fluctuating sea levels of the Pleistocene had corresponding higher ground water tables.

Conclusion

Karstification in lithologies that have not been traditionally regarded as having high potential for caves can bring insight into the interplay of factors controlling speleogenesis. The variation in host lithology, hydrogeology and an ability to develop a structurally competent roof must be taken into account in the context of the time available for solution and speleogenesis.

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Cave Development in Central Scandinavia

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Abstract

Metacarbonate outcrops occur in most nappes of the central Scandinavian Caledonides, but their numbers, lengths, areas and foliation dip-angles decline to the east. Caves of all complexities occur in the higher metalimestone-bearing nappes, from valley shoulder positions down to valley floors, and in (commonly homoclinal) *Vertical, Angled,* and *Non Stripe* karst types that guide internal morphologies. Total cave dimensions show no systematic trend when normalised against the *length* of outcrops, and are not related to catchment areas. Vertical distributions of outcrops and cave entrances are essentially random. Cave depth is always much smaller than the outcrop vertical range: caves in *stripe karst* have formed entirely within an upper 50m-thick zone of fractured rock. Similar cave inception, development and removal processes may have operated across the whole area from the time of the Caledonian Orogeny, and under the direct, and indirect, influences of the many glaciations since the late Miocene.

Introduction

The author is studying the caves in the Caledonian nappes of central Scandinavia in a region based on the *Helgeland Nappe Complex* (HNC). The study area extends eastwards from the Atlantic coast via stratigraphically lower nappes to the Caledonian thrust-front in Sweden, an area of some 40,000km^2.

The Central Scandinavian Caledonides

Contemporary geological research indicates that the rocks along the western coastal belt of Scandinavia derive their composition and structure from a highly complex system of mountain building associated with the plate tectonic opening and closing of the Iapetus Ocean, from late Precambrian to mid Palaeozoic times: the Caledonian Orogeny (GEE & STURT, 1985; GAYER, 1985; SOPER *et al*., 1992; VAN STAAL *et al*., 1998). Thus the region is part of the Caledonian - Appalachian fold and thrust mountain belt that once formed a continuous linear chain extending some 10,000km, from what is now Spitsbergen to the modern Gulf of Mexico, with an average width of about 1000km (GAYER, 1985: Editorial). Subsequent orogenies, and the opening and spreading of the Atlantic Ocean, have caused the mountain chain to be broken up into many geographically dispersed and geologically varied terranes, of which 20 have been identified, and which now reside on both sides of the Atlantic (BARKER & GAYER, 1985).

Some of the dispersed terranes include metamorphic carbonates that either contain, or may contain, karst caves. These occur in Spitsbergen, Shetland (FAULKNER, 2000a), Scotland, Ireland (FAULKNER, 2000b), Greenland, Canada and the USA, as well as in Scandinavia. One of the aims of the study is to make comparisons among these various karst environments.

In Scandinavia, the remnant rocks of the Caledonian Orogeny lie along the 1800km-long Scandian mountain chain. Most were originally formed at the western edge of the Baltic craton, on the eastern side of the Iapetus Ocean, although the westernmost probably derive from the Laurentian craton, to the east of rocks that now form East Greenland. The closure of Iapetus produced a complex series of thrust-sheets and nappes as the rocks of the Caledonides were transported southeastwards on to the rocks of the older Baltic craton.

Four major *allochthons* are recognised in Scandinavia: Uppermost, Upper, Middle and Lower. In the study area (STEPHENS & GEE, 1985), the Uppermost Allochthon comprises the Helgeland Nappe Complex and the Rødingsfjell Nappe Complex (RNC). The Upper Allochthon comprises two groups of individual nappes: the Køli Nappes and the Seve Nappes. In general, stratigraphically lower nappes are encountered when travelling west to east. Each major allochthon contains folded combinations of basement and metasedimentary cover rocks of Late Proterozoic to Silurian or even Devonian ages. The metamorphic grade of the nappe pile generally increases from sub greenschist facies at the base, up to medium amphibolite facies (or higher) at the top. The higher nappes also contain granitic emplacements and volcanic dykes.

Following the building of the early Palaeozoic Scandinavian Caledonian mountain range, the Caledonide structures are thought to have been eroded to a peneplane by the Carboniferous. Uplift of the Baltic Shield in the Mesozoic, Scandian uplift during the Cenozoic, and then differential erosion have combined to recreate the Scandes to the form that exists today (PEULVAST, 1985). The study area is practically devoid of post Caledonian sediments. Exposed bedrock is prevalent between about 400m and the present peaks that reach above 1200m. Below the tree line, vigorous summer mountain streams also reveal the underlying lithology in the valley floors.

Scandinavian Metacarbonates

The metacarbonate outcrops occur commonly as long and narrow "stripe karsts" (HORN, 1951), and run roughly north to south. Subsequent to carbonate deposition in river estuaries and warm shallow seas that started in Precambrian times, the sedimentary limestones were repeatedly compressed, folded and subducted to depths reaching tens of kilometres as Iapetus closed. The consequent high temperatures and pressures caused the original limestones, dolostones and non-carbonate rocks to flow in a ductile manner and recrystallise. Commonly, the original bedding structures were completely lost. The rocks cooled, and pressures fell, as tectonics and erosion brought them towards the surface, which they reached by early Devonian times. A new *foliation* was formed. The chemistry of the original sediments commonly also changed, depending on the availability of silica and other minerals. The extremes vary from pure calcite and dolomite recrystallising as pure calcite and dolomite marbles, through various calcite to dolomite exchange reactions, to the production of calc-silicate rocks in which all carbonate has been consumed. The marbles can be seen in several forms from pure white to dark grey, but they also occur as bands of alternating colours, for example white/black, white/red, or yellow/ brown.

Cave Exploration

Since the first exploration, during geological mapping, of karst caves in Scandinavia in about 1870, a steady increase has been recorded, mostly in the county of Nordland in Norway (ST.PIERRE, 1988). Rates of cave discovery and exploration were intensified by sporting cavers, beginning in the 1950s in Norway, and in the 1960s in Sweden. Many caves up to several kilometres in length have been explored. A recent discovery is Tjoarvekrajgge, in northern Nordland. At over 500m deep and over 12km long, it is now the longest in Scandinavia.

In the central Scandinavian study area, over 840 karst caves have been recorded by the author, with a total passage length of some 74km. Summaries for the south Nordland part of the area were provided by FAULKNER (1987; 1992; 1996; 2000c). The longest caves are Korallgrottan (c. 6km) and Labyrintgrottan (2.5km), which are both in Sweden. In the Norwegian part of the area, two stream caves, Toerfjellhola and Stor Grubblandsgrotta, are both nearly 2km long. The deepest cave is Ytterlihullet. Its depth of 180m is exceptional for the area. Cave cross-sections vary from under 1m^2 (frequently) up to 100m^2 (rarely). The caves occur at altitudes from over 800m down to sea level, and many contain powerful streams in spring and summer.

The Central Scandinavian Carbonate Outcrops Database

For convenience, the study area has been subdivided into 20 zones/nappe groups on a geological basis. The zones generally follow the stratigraphically descending sequence down through the Caledonian nappe pile. A computer-based database has been compiled with information from geological maps and other reports, organised by zones. Each separate carbonate outcrop occupies one row in the database tables, and information about the outcrop is held in 25 fields. Topographical maps have also been studied, and all instances of possible mapped karst features have been recorded. These features are predominantly the sinks or risings of surface streams, but may also include such items as lakes without outlets, and individual caves.

Central Scandinavian Cave Databases

Information about the caves from published references, from a Sveriges Speleolog-Förbund database, and from data assembled during field study trips is stored in two databases. Each recorded cave occupies one row in the tables, and data about the cave is held in 38 fields. Each cave is allocated a *Cave Type* from a list defined by the author. The main cave types are quickly identifiable from cave surveys, and do not pre-judge the method of cave or passage formation:

S Predominantly a single shaft, blocked at its base

A Single linear passage, with a simple staircase profile

B Single meandering passage, with a simple staircase profile

C One level rectilinear network

D One level dendritic network, with simple staircase profiles

E Tiered linear passages, connected by shafts

F Tiered rectilinear network

G Multilevel dendritic, with simple staircase profiles

H Complex multilevel network with steeply sloping passages

The topographical position of each cave is recorded in a *Cave Location* field, adapted from LAURITZEN (1981; 1990):

P Paleic surface cave

G Other gently sloping surface cave

S Valley shoulder cave

R Ridge crest cave

W Hanging valley wall cave

F Valley floor cave

C Coastal cave, along the Atlantic-facing strandflat

M Marine cave, above the strandflat, but invaded by the sea at the start of the Holocene

Karsts

The outcrops database presently records almost 950 entries, comprising a total carbonate area of 850km^2. Only 55 of the outcrops have been identified as dolomite, covering an area of 47km^2. Metacarbonate outcrops occur in most nappes, but their number, mean length, area (relative, total and mean), and angle of dip generally decline as the nappes are descended. Many of the HNC outcrops are close to vertical. Less than 15% of the total length of 3100km of mapped carbonate outcrops has been visited by cavers looking for caves.

Above the Seve Nappes, exokarst and endokarst are relatively common phenomena. This is demonstrated by the number of karst features shown on topographical maps, by the number of caves recorded in the Cave Databases, and by the relative ease of their discovery. The means for the study area are 1.3 mapped karst features per 10km length of carbonate outcrop, and 1800m of passages in 20 caves in every 10km visited outcrop length.

The study area provides a natural laboratory for studying the effect of outcrop dip on karst geomorphology. A classification of the karsts into 4 main *Karst Types* has been utilised:

V: *Vertical stripe karst* in which the generally homoclinal angle of dip varies between 80^o and 90^o

A: *Angled stripe karst* where the homoclinal angle of dip varies between 45^o and 80^o

C: *Complexly folded karst* where the folds are visible in cave passages

N: *Non-stripe karsts* where the angle of dip is less than 45^o and the outcrop is broad in relation to its length.

Type C is rare. Type N includes sub-horizontally foliated outcrops, and outcrops refoliated by contact metamorphism.

Caves

The mean length of the explored caves is 87m and the mean vertical range is 9m: there are over 400 recorded caves that are less than 100m long and less than 10m deep. Many of these consist of a single passage. However, several caves over a kilometre in length and over 100m in depth occur in the area, and some of these display an extremely complex arrangement of inter-linked passages at several levels.

A distinctive suite of *internal* cave features can be recognised especially for caves in *vertical stripe karst*. Vertically tiered passages that may be connected by vertical shafts only occur in vertical stripe karst. It is seen from inside such caves that the vertically foliated limestone supports three main orthogonal joint systems. Thus vertical stripe karst can support cave morphologies that are similar to those in horizontally-bedded limestones, within the confines of the narrow outcrop. They include such features as anastomoses, phreatic tiered passages, vertical shafts and avens, vertical meandering vadose streamways and small networks of joint-aligned vertical rifts. The survey sections show a tendency for tiered shallow and fairly symmetrical phreatic loops to form along the strike. Below these abandoned phreatic loops there is commonly a vadose passage that carries the present allogenic stream from its sink-point entrance towards the resurgence. Along this stream passage there may be one or more sumps that occupy the lowest levels of the cave. The distinctiveness of vertical stripe karst may be compared to that of horizontal sedimentary limestones with a dip between 2 - 5^o. According to FORD & EWERS (1978, p1793), there are important probabilistic differences between such flat-lying strata and strata which dip more steeply.

The widths of the vertical carbonate outcrops in the study area vary from the infinitesimally small up to c. 1000m. However, as the vertical outcrops are almost entirely within the Uppermost Allochthon, which contains many aquiclude layers within the carbonates, the effective width of the vertical stripe karst rarely exceeds a few tens of metres.

In angled stripe karst, passages at different levels are typically offset down-dip. Shafts and avens are steeply inclined. Phreatic loops are less symmetrical and utilise aslant dip and joint directions. In stripe karst caves, water flow is almost always either directly or generally *along* strike. The non-stripe karsts support a variety of passage forms and linkages. Water flow may be generally *across* strike. Very few horizontal outcrops are known, but in one, a single-level rectilinear network cave has formed in sub-horizontal metacarbonates below a mica-schist caprock. Its plan morphology is probably guided by two sets of fairly widely spaced vertical joints that are orthogonal to each other.

Observations

1 Approximate Dimensional Consistency Across the Zones

Karstic frequencies and total cave dimensions tend to follow the trend of declining carbonate outcrop extent when traversing the zones from west to east. It is suggested that a simple normalising geological parameter that can be invoked to model and predict the numbers of mapped karst features and the total length and volume of caves is the total *length* of carbonate outcrop in each zone. Karst caves have formed in all carbonate-bearing nappes down to the lower Køli Nappes. None have been reported in the Seve Nappes nor in the lower allochthons, where there are only relatively few, small, carbonate outcrops.

2 Dimensional Independence from Metalimestone Lithology

Each carbonate outcrop has undergone various complex and individually uncertain processes of diagenesis, dolomitization, prograde and retrograde metamorphism, dedolomitization and partial conversion to calc-silicate skarns. Predominantly, the outcrops are of Low Magnesian Calcite (LMC) composition. Yellow/brown layers of a presumed (more soluble) High Magnesian Calcite (HMC) composition occur uniquely in Zone 4 of the HNC, and contain cave passages. The declining frequency of interlayered aquicludes follows a similar pattern to the decreasing metamorphic grade down through the nappe pile. As this pattern cannot be detected in the normalised frequencies and dimensions of karst features and caves in each zone, it is concluded that cave dimensions are independent of the lithological history and chemical purity of the limestone outcrops. Thus the number, length and volume of karst caves and the frequency of underground drainage are governed primarily by the solubility in acidic waters of calcitic limestone (both LMC and HMC), however it has been derived, and are little influenced by, for example, crystal size or interlayered impurities.

This independence of limestone chemistry certainly does **not** extend to pure dolomite outcrops. Although exokarst features and one short cave have been found by the author in dolostones, no *significant* caves are found in dolostone rocks (i.e. those with more than 20% of $MgCO_3$).

3 Internal Morphological Guidance by Limestone Dip

Within the general west to east decline in the angles of dip of the limestone outcrops, the dips can be very varied within each zone. The longer and deeper caves seem to form in limestones with rather shallow angles of dip. The angle of dip is a major influence on internal cave passage shapes, orientations and relationships, as discussed above.

4 Internal Morphological Guidance by Aquicludes

Where aquicludes occur, they have a very strong influence on internal cave morphologies. Additionally, many cave entrances are situated at the along-strike junction of the limestone with an aquiclude country rock, and this contact is commonly observed to form a wall of the internal cave passages.

The morphological effect of the aquicludes is most pronounced in caves in vertical stripe karst in the HNC. These are commonly formed as straight linear passages or as vertically tiered passages alongside a vertical wall of non-carbonate rock. The other wall of the passage may similarly be formed alongside another aquiclude, with the intermediate limestone being removed. The non-carbonate layers typically act as complete aquicludes if they maintain a thickness greater than c. 30cm. Where their width reduces, they can be breached by karst waters and provide “doors” or “windows” that can be walked or crawled through into passages formed in the next vertical layer of limestone. Typically, waterfalls and short, passable, sumps in the caves in vertical stripe karst occur at places where a stream flowing under mainly vadose conditions has breached a non-carbonate layer.

5 Independence of Altitude and Catchment Area

The vertical distribution of the carbonate outcrops is essentially random, and cave entrance altitudes are scattered randomly within the overall constraints of the local topography and carbonate outcrops. Furthermore, cave lengths, cross-sections and vertical ranges are essentially independent of altitude, unrelated to the local tree line and are not related to the contemporary cave catchment area. Relict caves occur randomly within the set of all caves, both in terms of entrance altitude and in geographical position. However, they are generally shorter and less deep than the active caves.

6 The Shallow Nature of Most Cave Systems

The vertical ranges of the carbonate outcrops (which can exceed 900m) do not appear to influence the depth of cave systems that have a study area mean of only 9m. The surveyed sectional profiles of the 18 deepest systems in the study area reveal that the rock thicknesses directly above the lowest parts of each cave are commonly much less than the cave vertical range, especially for the deeper systems. Only Ytterlihullet (Non stripe karst) has a rock thickness (80m) greater than 55m above the lowest parts of its streamway. The greatest rock thickness above any cave formed in vertical or angled stripe karst is about 50m.

Hence many caves in the study area gain depth below a gently descending surface slope to which they keep within a relatively close range. This suggests that caves in vertical and angled stripe karst have formed entirely within an upper zone of fractured rock which has a maximum thickness of 50m. This may be compared to the epikarst or subcutaneous zone of sedimentary limestone, but in the case of metamorphic stripe karst, there is no lower “percolation” zone and perhaps no cave development below the level of fracture porosity.

7 Consistent Pattern of Cave Types and Morphologies

The distribution of Cave Types is fairly consistent across all zones. All Cave Types can occur in most Karst Types, and in most Cave Locations. In all zones, two thirds of all caves consist of a single linear or meandering passage, and these commonly represent the shorter caves. The longest cave in each zone commonly has the most complex type of passage arrangement. Relatively few caves have more than one active stream. High-level static sumps are rare, as are abandoned vadose passages. There is a high frequency of multiple entrances for the caves (the area mean is 1.5 entrances per cave), although many of these are relict, and even short caves can have many entrances. There is a very low frequency of significant chambers, and it is expected that these are concentrated in the more complex caves. There are also very few large boulder chokes in the caves, and only 34 unpassed boulder chokes have been counted in the whole study area. Only about 5% of the caves contain significant speleothems or other chemical deposits. These must therefore be regarded as consistently rare, although those that do exist can be very distinctive. Some 21% of the caves are reported to contain significant clastic deposits. There is much evidence for the complete inundation of some caves during large modern flood events, and the consequent progressive movement and flushing of earlier deposits down, and eventually out of, the caves.

Discussion

The above observations confirm that the major dimensions and much of the internal cave morphologies are independent of zonal geographic position and individual cave altitude. This suggests that similar cave inception, cave development and cave removal processes operate, and have operated, across all zones of the whole study area, and for similar periods of time.

This outcome is hardly surprising, as all the zones share a common geological history after the Devonian, as discussed above. The whole area has since suffered multiple glaciations during the late Miocene, the Pliocene and, especially, the late Pleistocene, when huge ice caps formed over the whole of Scandinavia. (JANSEN & SJÖBERG, 1991, deduced from studies of ice-rafted detritus (IRD) in the Norwegian Sea that small scale glaciations started as early as 5.5 Ma b.p. MANGERUD *et al*., 1996, p22, noted that small, but significant, IRD pulses dated from 11 Ma b.p., i.e. early in the late Miocene). These glaciations have dominated the evolution to the present landscape that is still shaped by the geological structures. The climatic changes since the start of the Holocene have been fairly uniform across the whole study area. Any moderating influence of varying tree line, mean annual temperature and mean annual precipitation on karst development is considered to be slight.

As the whole area is almost devoid of post Caledonian sediments, the timescale of possible karst development is very long. Carbon dioxide was available in rainwater from before the original formation of the Caledonides, and BASSETT (1985) mentioned palaeokarst in northern Norway dated from the mid-Ordovician. Thus, the various cave processes may possibly be normal components of landscape development since the Caledonian Orogeny. Within the continuum of processes, individual caves may develop relatively quickly or slowly, and persist in the landscape for short or long time periods, depending on geological constraints and topographical inheritance. Hence the known caves may represent a range of examples from long persistence caves through to more recently developed caves.

Many kilometres of bedrock have been eroded from above the present surface since the Caledonian Orogeny, but due to the random nature of the vertical distribution of the present carbonate outcrops and their general alignment with tectonic structures it seems likely that the distribution of such outcrops in previous landscapes would be similar to that of today. (That is, they would occupy about the same proportion of land area and have a similar distribution of length, width and area as today. They would generally be aligned north to south or NNE to SSW, and occupy all parts of the vertical range). The vertical range of each outcrop would however depend on the degree of uplift applicable at the time. Additionally, they would comprise similar lithologies and contain similar amounts and types of non-karstic impurities. Thus, at the zonal scale, the geological distribution of lithologies can be regarded as roughly a constant since the Caledonide events. The conclusion that each zone represents a continuum of processes of cave inception, development and removal with a distribution of timescales being represented for each phase, may perhaps be extensible to any time period back to the early Devonian. For all this time, the whole area can be regarded as a single entity regarding climate and uplift so that at each point in time the same karst processes should apply across the whole region. As arid periods would slow down all erosional and solutional processes and very wet periods would speed them up, these effects would moderate the age distribution of the caves. However, at any one point in time, the physical distribution of caves, their total lengths and volumes should remain roughly related to the contemporary lengths of the carbonate outcrops.

The effects of uplift, peneplanation and glaciation may moderate this general model as erosional processes could generate a deeper and a longer set of caves during times of high uplift, and a total destruction or total infilling of caves would occur during peneplanation, tectonic sinking or marine invasion. Internal cave morphologies across the whole study area may also have varied across geological time due to the effects of the multiple glaciations. It has been shown that Scandinavian karst caves became flooded and acted as component parts of glacial hydraulic regimes during the onset, maturity and recession of the Scandinavian ice caps (e.g. LAURITZEN, 1986). Thus total cave dimensions, and the proportion of phreatic to vadose passage elements across the study area, may have increased in a consistent fashion across the whole area during periods of glacial activity.

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The Formation of Large Chambers, With Examples from Laos and Other Countries

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Abstract

Formation of large chambers is discussed on the basis of geological heterogeneity existing in stratigraphic successions. Given structural conditions lead to a given type of chamber. Most favourable are dipping strata forming a convex up anticline flank close to a syncline axis in a small wavelength folded section, with limestone underlain by different, erodible, rocks: this is the case of the Sarawak Chamber. Large chambers are in most of the cases sloping and this affects their stability in a good way. They are often, if not always, made up of coalescent voids, which have their own individual stability. The role of the individual voids is of paramount importance for the stability of the whole chamber. The chamber fill (boulders) also plays a role in sustaining chamber walls.

Introduction

More and more large underground chambers are becoming known in the world, though the “Number 1” Sarawak Chamber in Sarawak, Malaysia, remains unrivalled. No full explanation of their stability has been proposed so far, and it is still too often said with some exaggeration -and written- that the laws of physics cannot explain them. This may be due to the fact that, perhaps the theory is incomplete, but specially that the large chambers may have been taken for what they are commonly not: simple volumes. Instead, one can often easily recognise in them a composite shape, with several vaults which are co-existing laterally and/or vertically, though a few chambers show an apparent regular shape, salle de La Verna for instance.

The author has discovered in limestone and mapped more than nine large chambers in Laos, three in the Philippines, plus one in andesites (salle Jules Verne), located in the dome of the Soufrière active volcano, Guadeloupe (French West Indies). The related observations have brought elements of thinking, which are used in this paper. Knowledge from bibliography is added as well.

Discussion

Characteristics of Large Chambers

The classical first approach to large chambers has been commonly oversimplified, as they are often referred to by 3 dimensions only (length, width and height), which are not by themselves indicative of the cause of the void formation and stability, except that for such a large void can form, rock export is necessary, in solution or mechanically, which requires the action of a significant underground stream.

The 3 dimensions only give the size of the -horizontally extensive- parallelepiped with the same dimensions, into which the chamber can be entered. Chambers are commonly sloping and the real height (i.e. the distance from floor to roof, perpendicularly to the slope) is often much smaller than the vertical height. A chamber would be already better described by the smallest parallelepiped into which it can be entered, which would be in most of the cases oblique instead of horizontal. Surface area is given by a number of authors, but it is usually a projected surface. Using the volume is more helpful, though it is rarely accurate.

Let us review the main characteristics of a large chamber:

A large size, out of which it is of paramount importance to highlight the individual (coalescent) volumes,

An irregular cave floor, largely covered with boulders, usually sloping, not always in one direction only,

The presence of an active, temporary or fossil stream. For instance, a stream associated with a chamber, directly in it or directly underlying it, is found in the following chambers: Sarawak Chamber (Malaysia), salle des Miaos (China), Sagada Chamber (Philippines), salle de La Verna (France). In Laos, it is the case of Tham En (Fig. 1, A), another Tham En (Fig.1, E) and Tham Thon (C) for instance. Temporary flows are encountered in Tham Koun Dôn (B) and in Nam Non (J) (Laos), to a smaller extent in the Panayoran Chamber (Philippines).

Presently dry chambers exist in Majlis Al Jinn, though its flat bottom part is covered with clay (Oman), Torca del Carlista (Spain), Nam Non (Laos, D).

The salle Jules Verne (55x35x11 m, with a ca 30 degrees slope) is in andesite and was generated by explosions (MOURET, 1985). The Furna de Enxoffre in Graciosa Island (Açores) is in basalt and 200 m wide (C. THOMAS, 1997). It is due to the surface solidification of a lava lake, with subsequent downward removal of the molten lava.

Cave walls (often of limited apparent height, as their base is buried below boulders) with a variable, though usually steep, inclination.

Open passages at the ends and possibly on the sides, which ensure a minimum section to which the whole chamber envelope has to converge morphologically.

A roof with a variable shape, which varies between a nearly flat surface in a few cases (Tham Koun Dôn, B), a half-cylinder vault in rare cases (in average size chambers which are indeed enlarged galleries), domal shapes (in Majlis Al Jinn, as a semi-dome of 4 million m3, 60000 m2, 300x200x120m, HANNA et al, 1997; in La Verna, as a dome overlying a funnel-shaped lower part, 270x230x165m, GILLI, 1984) and, more commonly, complex shapes (salle des Miaos, 700x215x100m, 120000 m2, 7 to 10 million m3 (volume twice La Verna), BARBARY et al, 1989).

Composite Shape and Structure of Large Chambers

Complex shapes of the roof are clearly formed by associated unitary volumes, which have a lateral and a vertical distribution. In the Panayoran Chamber, an elongated chamber with maximum dimensions of 275x165x80m, (MOURET, 1994b), the end part is clearly made of a gallery type vault, with an axis inclined down to the end. The main part of the chamber is larger (though still elongated) and much higher; the shape of the roof, a kind of dome, is clearly visible and this dome is bounded by the adjacent inclined gallery type vault. The intersection of the dome and the inclined vault draws a relatively regular arch. There is no doubt that the dome stability is largely ensured because of this arch. Such a setting is classical in religious architecture, where transept domes are stable because lateral vaults are present in the four perpendicular directions, for instance in Périgueux or Chartres cathedrals (France).

Thorough examination of chamber roofs show that this kind of complex setting is not rare in cave chambers. In salle des Miaos, two domes are mentioned.

Comparing the architecture of natural underground chambers and man-made structures is therefore possible and, in any case, fruitful. First of all, basic forms need to be reviewed: arches. They can be classified in no less than four main types: normal, surbased, lancet, rampant. In architecture, each type allows the stability of overlying walls or vaults. In caves, each of these shapes should allow stability of overlying rock. Normal arch may correspond to regular vaulted passages in homogeneous rocks for instance, surbased arch to large volumes largely filled up with boulders (Tham En large entrance chamber in Laos, A), lancet arches to the effect of joints or faults, rampant arches to sloping vaults following dipping beds (as in Sarawak Chamber, Fig. 2-3). A simple volume may be the result of the juxtaposition of repeated arches.

In monuments, forces which are exerted on or transmitted by arches are directed in directions which depend on the arch shape, i.e. towards the outside of the arch or onto sustaining pillars. In both cases this means that, in caves, equivalent arches and the overlying rock can be supported by the full rock masses around the chamber (i.e. the outside of the arch) and that they are stable in this way.

Additional vaults can be present on top of complex arch systems or on top of other vaults (Fig. 4), which is a building principle of cathedrals, fact also present in caves. In caves, this applies to large chambers, but also to the connection with smaller passages of different directions.

A variety of roof shapes can exist in caves if structural rock factors and cave history are favourable to arch formation. The presence of several arch lines across a chamber may allow a composite roof with two or several juxtaposed domes. Arch lines may correspond to the intersection of different vaults (groined vaults).

Structural Factors Favourable to Large Chambers Formation

For a karst chamber forms, besides a stream to export the rock, the following structural factors are necessary:

Strata or a strata complex with a favourable thickness. Thinner strata are less prone to generate large vaults than thicker ones.

Strata with a sufficient mechanic resistance. Shaly limestone (Lias of Périgord, France) or poorly diagenitised limestone in Bali (Indonesia, author's explorations) allow only chambers of limited extent though still significant, but no real large chamber. To the opposite, an excellent combination is a resistant limestone and an underlying, erodible, usually impervious, rock: Sagada Chamber, salle de La Verna, etc. A somewhat different combination is shown by giant cave passages in West Borneo, up to 45 m wide despite they have a low height (surbased arch), which have a basalt roof and a sand/shale alternation forming the floor (MOURET, 1994a).

A favourable dip. Horizontal or low angle dips combined with thick strata may allow large chambers, as the Panayoran Chamber. Often, dip is around 10 to 20 degrees. This is the case in the Sagada Chamber, the Tham En caves large entrance chambers (A, E), the Tham Thon Chamber (C). The inclined Sarawak Chamber is the most impressive example: the folded strata clearly form the roof and the lower wall of the chamber (GILLI, 1993; Fig. 2).

Other settings can be exceptionally found, such as in salle Jules Verne and Furna de Enxoffre where the roof is formed by vertical prisms. The high friction along the surfaces between prisms ensures vault stability.

Boulders against the walls also bring stability, in preventing caving in or in slowing down chamber enlargement, which would otherwise lead to roof failure. With this respect, two main cases exist:

1.The chamber is elongated in the dip direction. In the Tham En entrance chamber, one in the largest in the world (A), the dip is around 10 to 15 degrees along the longitudinal axis and sub- horizontal in the transverse direction. The cross-section is elongated in this transverse direction. The width is of ca 155 m, with a maximum extension to ca 215 m and the height is only 5 to 30 m, because of the boulders on the floor. In this case, the controlling factor of cave stability is the width, which represents the maximum vault length, because in the long axis direction of the chamber, the vault is only the result of a repetition of juxtaposed arches, with a cylindrical symmetry. The visible part of the large vault near the cave entrance is shaped as a surbased arch and the boulders against the walls ensure a better stability. This is probably why such a large entrance chamber can exist. With this respect, a sub-longitudinal low which is likely located above the underground stream which flows below the boulders, has no impact on stability but it enlarges the chamber volume. It joins the chamber wall where this one turns: the stability is preserved by this shape, which corresponds to a shorter vault width, onto which the rest of the vault can increase its stability.

2.The chamber is elongated perpendicularly to the dip direction, as in the Sarawak and Sagada Chambers. The cross-section profile is very characteristic, with a vault following the dip to a significant extent. The very specific structural context of the Sarawak Chamber, below the flank of a small wave length anticline next to a faulted narrow syncline (GILLI, 1993), likely explains the existence of the chamber. This setting creates an effect of rampant arch, as for gothic cathedrals. The force exerted by the vault is largely transferred laterally to the cave wall, because of the shape. To some extent, the vault partly acts as a wall. The lower wall of the chamber is also the lower part of the arch.

In the upper part of the chamber, the upper wall has a moderate height. Located below the limestone vault, it is inclined towards the chamber and made up of sandstone (Fig. 2). The sloping chamber floor between the lower wall and the upper wall is sandstone as well and covered with limestone boulders. The floor slope is a very important fact. The chamber would not exist if it was not inclined, because the rampant arch effect would not exist. The real vault starts at the top of the sandstone wall. In other words, the space protected by the arch is only the upper part of the distance from chamber floor to roof. The bottom part is due to sandstone removal in the "shadow" of the vault and besides the internally sloping upper wall.

The Sagada Chamber (95x59x10-20m, oblique height) shows a comparable setting, though it is not exactly the same: dipping strata, lower part close to a stream in the downdip direction, partial inward dipping upper wall. It is also an inclined chamber.

Besides these basic cases, many others exist, which are more complex. In any case, an existing dip favourable to the existence of a chamber slope is a favourable factor to stability. A number of chambers have a longitudinal low axis bordered by two slopes of boulders (Panayoran Chamber, Tham En (A), salle des Miaos, though it is less clear;) some others have such an axis in a direction perpendicular to their elongation

(Tham Koun Dôn, B): such settings are favourable to wall stability and to larger volumes. The roof of Tham Koun Dôn Chamber is relatively planar, inclined, and the walls are not so high (ca 10-30 m): the central transverse low axis adds significant volume.

Domal chambers are more difficult to explain, but two critical factors already discussed can be used. First, large chambers such as salle de La Verna formed initially at the contact surface between overlying gently dipping limestones and underlying subvertical strata including limestone and largely erodible schists. The overlying limestones exactly played the role of a rigid surface below which the void developed at the contact of vertical limestones and schists. Then, progressively, after the void enlarged, the vault started collapsing and developed into a dome. The void corresponding to the vault is located only in the overlying limestones. The stability of the hollow void in the schists is mainly ensured by the funnel shape of the lower part of the chamber, with peripheral slopes limiting the height of cave walls on three sides. This lower void is in the “shadow” of the limestone vault.

In this way, we can compare the salle de La Verna with the Sarawak Chamber (and many others), with an upper part subject to given geological conditions, bearing a specific vault (evolving by successive collapses) and a lower part, mainly subject to erosion/dissolution. That is to say that the vault effect is borne by not all the chamber cross-section, but by the more resistant part above. Depending on the chambers and their geological conditions, the vault effect may be ensured by a variable proportion of the rocks encountered in the stratigraphic succession.

Conclusions

The elements discussed in this paper lead to consider large chambers as composite voids, which are made up of individual volumes with their own stability, but which also have all together a global stability. Excessive geometric changes in relation with the evolution of even one of the voids may lead to a collapse, local or of the whole chamber, depending on the existing geometric shapes.

It is also considered that a chamber best requires a rigid rock in a strata set which has an excellent mechanical resistance, which acts as a cover above less resistant rocks. The vault shape and its size are controlled by the cover rock. Dipping strata bring additional stability to chambers, by arch effect.

These elements of discussion may be used as a basis for further research on the topic, which should further establish our knowledge on large chambers.

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Hydrogeology and Cave Explorations of the Lost River Dobra: A Case Study of Underground Flow in the Dinaric Karst

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Abstract

The Dinaric karst region covers about 50% of Croatian State territory. Due to well developed and diverse karst forms, both on the surface and underground the area is known as "classical karst". One of the well developed phenomenons are lost rivers, as the river Dobra in the NE part of the area. The Dobra River sinks in the very town of Ogulin and after 4.5 km reappears as the strong karst spring Gojak. In the eighties, the longest cave of Croatia has been explored at the entrance side, 16 391 m long Đulin ponor - Medvedica Cave System respectively. Recent explorations are directed towards the Gojak spring where the 2 166 m long Spring Cave Gojak has been discovered. The geomorphologic phenomenons of the area and its genesis are the result of lithological characteristics of rocks, geological structure, hydrological and hydrogeological relations. On this basis the possibility of further explorations and prospects for connection of cave systems have been made.

Introduction

River Dobra is the classical example of the karstic lost river. Its upper course, known as the Ogulinska Dobra which springs at the foothills of the Velika Kapela mountain, and sinks 30 km SE in the Đulin ponor at the Ogulin-Oštarije karst platform. After sinking and 4.5 km of underground flow, reappears on the surface at the strong permanent karstic spring Gojak. The lower part of the river, now known as the Gojačka Dobra, flows in the NW direction where it joints the Kupa River. Large quantities of sinking water, which during the rainy season discharge can surpass 100 m^3/s, formed a complex network of cave channels in the karst underground.

Review of Exploration

Đulin ponor and the nearby Medvedica Cave have been known to the local population long before since the large cave entrances are located within the town of Ogulin. Initial speleological explorations were made by J. Poljak between 1925 and 1935, when the first charting of the caves was done (POLJAK, 1926, 1935). The next explorations were conducted by M. Malez in 1954 and 1955 (MALEZ, 1956 a, 1957). The total length of caves was not significantly increased, but his topographic plan was more precise than the former of Poljak and reported 750 m of explored channels in Đulin ponor and as many in Medvedica Cave. The last exploration conducted by M. Čepelak and cavers mostly from the "Velebit" Speleo Section and several from the "Željezničar" Speleo Section, between 1984 and 1986, brought new unexpected results. The Đula Sinkhole and Medvedica Cave have been explored and connected in one 15 701 m long cave system (ČEPELAK, 1987). The results of recent periodical explorations are not so prestigious, but the total length increased to 16 396 m, making the Đulin ponor - Medvedica System the longest cave of Croatia.

Hard caving and fairly reduced possibility of major discoveries in the upstream (entrance) part of the River Dobra underground, directed explorations towards the outflow zone i.e., the Gojak spring. In the summer of 1998 the short entry siphon has been successfully passed. The following year members of the Caving Club "Željezničar" explored a 2 166 meters long cave system, with a general strike in the southwestern direction towards Ogulin and the system Đulin ponor - Medvedica (KUHTA et al., 2001).

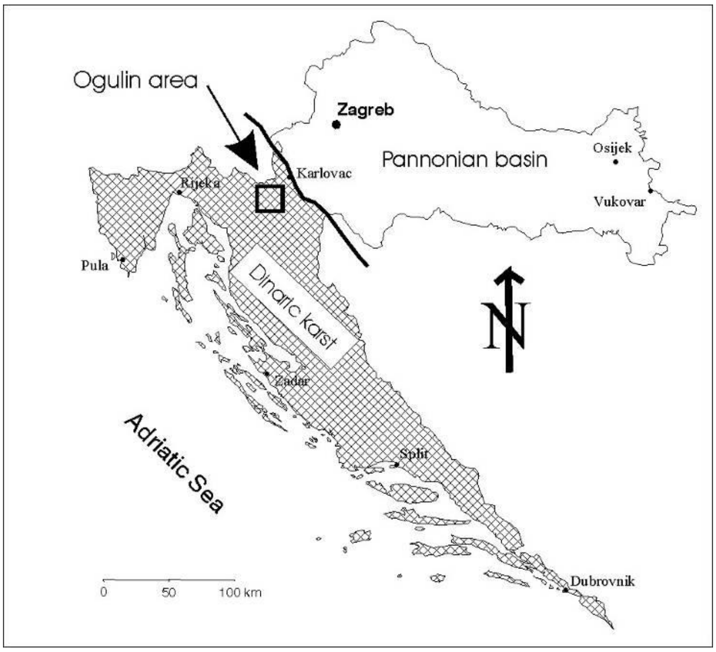

Fig. 1 Position of the study area

Morphology of the Caves

The complex network of the underground channels in Đulin ponor - Medvedica Cave System can be divided in three general units. The first is dry during average water levels, and forms an web of channels between Đulin ponor and the entrance passage of the Medvedica cave. This is a sort of filter that holds most of sweepings driven underground by water stream during flooding. The second, medium part includes a main channel with branches on several levels. The third unit forms several westward trending channels in the final part of the cave. They have been developed under the influence of one strong tributary groundwater stream. The vertical distance from the entrance of Medvedica (highest point of the cave, 315 m a.s.l.) to the lowest point at the final siphon lake is 83.5 meters (Lake of the skinny frog, 231.5 m a.s.l.).

Strong hydrologic activity in the cave does not permit stalactite and stalagmite processing, but explicate erosive formations are numerous.

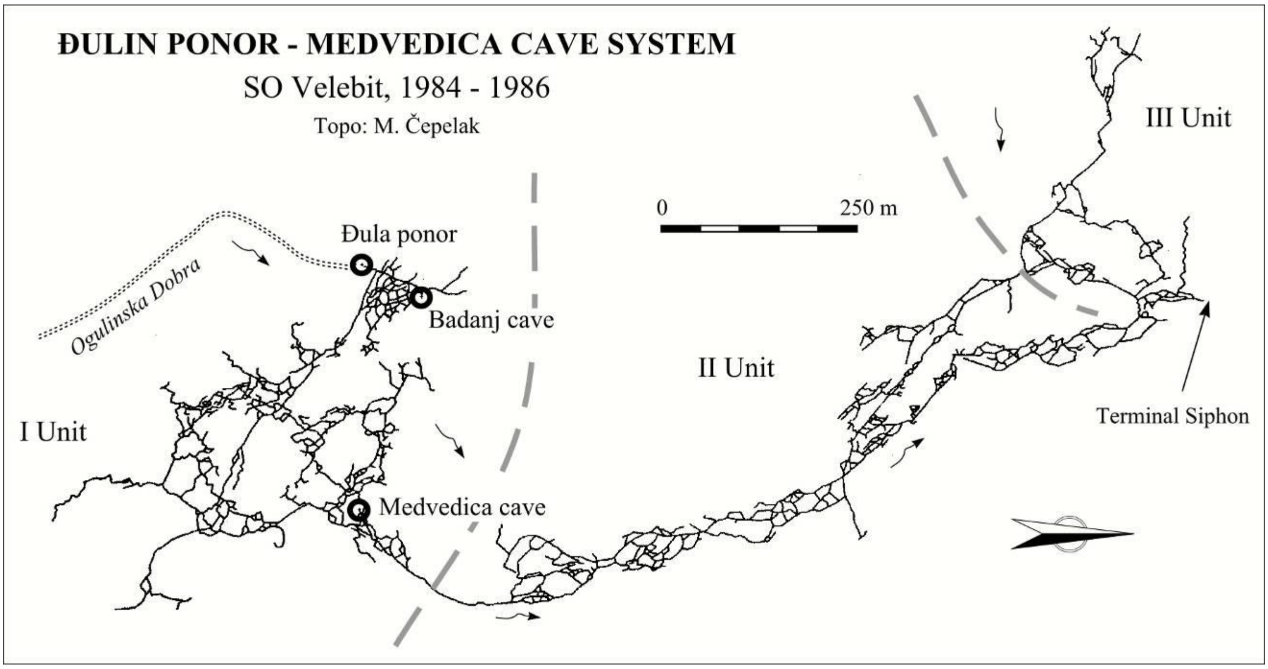

Fig. 2 Shematic topographic plan of the Đulin ponor - Medvedica cave system

With the total investigated length of 2166 m the Spring Cave Gojak is one of the most important speleological phenomena in Croatia and the longest caves investigated behind a submerged siphon. About 15 meters long and only 5 meters deep entrance syphon is located on 189 m a.s.l. In a morphological sense the Spring Cave Gojak is a branched speleological object too. This is confirmed by the fact that 1410 m of underground channels or 65% of total cave length was investigated in satellite channels. Since there are possibilities of further investigation of some satellite channels this ratio will grow.

The general strike of the cave is in the southwestern direction towards Ogulin and the system Đulin ponor-Medvednica. The width of up to 20 m of the Main channel of the cave makes it an unique example of a subsurface water flow in karst which is 756 m long. The channel terminates with a siphon lake deeper than 25 m. The large dimensions of the submerged part of the channel indicate a possibility of successful diving through this obstacle and would allow further investigations of the cave. The most distant point reached from the entrance along the main channel in a straight line is 575 m, and the elevation difference of water levels is approximately 10.5 m.

Smaller caves are of simple morphology and they have not larger speleological importance, but they completing understanding of genesis and development of hydrogeological relations on the area concerned.

Caves Skorašnik (24 m) and Drenovac (116 m) are the part of fossil sinkhole systems of the first and second generation. It should be mentioned that the Drenovac cave has been discovered during hydroenergetic tunnel excavation (MALEZ, 1956). The cave is located at the elevation of 297 m a.s.l. Vertical cave (pit) Kod tri bora (- 63 m) is the deepest cave explored in the hilly area between Đulin ponor and Gojak spring, in the zone of predominantelly vertical circulation respectively.

Very important is Sodolska cave explored in the length of 290 m. The cave functions as a periodical spring, active during extremlly high water conditions.

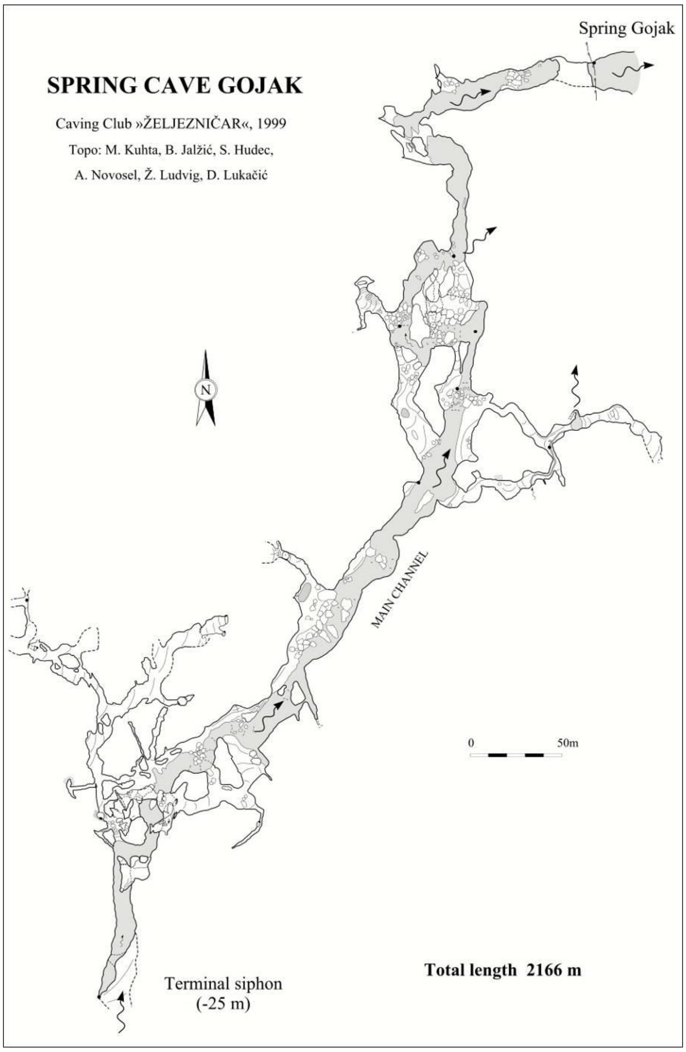

Fig. 3 Topographic plan of the Spring Cave Gojak

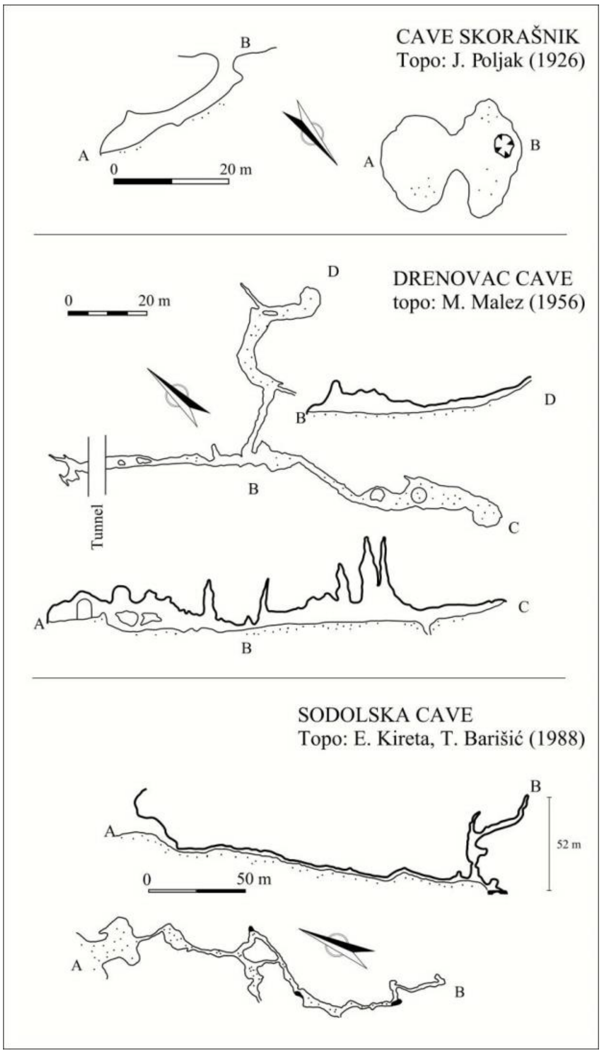

Fig. 4 Topographic plans of some smaller caves

Geology

The cave systems are formed in the distinctive karst morphology of the Ogulin area. The geological structure is mainly composed of Jurassic and Cretaceous dolomite and limestone layers. The largest Đulin ponor - Medvedica Cave System and Spring Cave Gojak are completely formed within the Aptian (K_1^4) foraminiferal-algal limestone. The central part of a symmetrical syncline structure between them, the hilly area respectively, is composed of Albian (K_1^5) foraminiferus limestones. In the regional sense the area is a part of large nappe structure related to the tangential tectonic movements during the so called Middle Eocene Pyreneean orogenetic phase. The predominantly dinaric northwest - southeast trending structures; folds, normal and reversal faults, have been effected by younger, mainly block tectonics.

Hydrogeological Relations

The Đulin ponor-Medvedica Cave System is a natural drainage channel for the water of the lost river Ogulinska Dobra and its tributaries. Its catchment area is about 380 km^2, with the mean annual precipitation of 1700 mm. Typical karstic features of the river are well expressed by the discharge ratio which varies from 0.12 m^3/s to 154 m^3/s. The mean annual flow rate is 9.7 m^3/s. The natural hydrological conditions have been drastically changed at the beginning of sixties, when the Bukovnik Dam and reservoir at the upstream part of Dobra river have been constructed (about 2 km from the Đulin ponor entrance), and water transferred by a diversion tunnel to the Gojak Hydroelectric Power Plant, located nearby the Gojak spring. After that time, only during the rainy season or exceptionally heavy rain events, water sinking in the natural drainage system, the Đulin ponor - Medvedica Cave System respectively. The mentioned changes did not influence or obstruct the study of hydrogeological relations and genesis of the largest cave system in Croatia. Moreover, in some aspects they contributed to explorations (physical caving).

The present situation is only one stage in the frame of permanent karstification processes. Geomorphological phenomena are a direct result of the lithological characteristics, geological structure, hydrgeological properties of rocks and the changes in hydrological and metereological conditions, particularly during the Quaternary. The relief forming processess must be considered dynamiclly, through time, becouse the present state is only a momentary reflex of the interaction of endogenous and exogenous processes. The material traces in the shape of morphological phenomena and younger sediments (river valleys, river terraces, underground phenomrna etc.) enable at least a partial reconstruction of the geomorphological development of a terrain and, more importantly provide insight into the genesis of the actual hydrological relationships and groundwater dynamics.

The northern side of the Ogulinsko polje shows visible traces of earlier streams that followed almost in the same direction as the cave system toward area of old sinkholes. The first generation of sinkholes is located slightly above the present polje level. The physical remnants are rare, but the cave Skorašnik confirmed their existence. The sinkholes of the second generation are developed along the northeastern border of Ogulinsko polje, immediately along the foothills of morphological barrier toward Gojak spring area, at an elevation range from 315 to 320 m a.s.l. Boulders and young Quaternary deposits fill the entrances and caving explorations are not possible. The remnant, or better to say, a part of the second generation sinkholes is the cave Drenovac discovered on the route of the diversion tunnel, deeper in the carbonate massive (297 m a.s.l.). the Đulin ponor - Medvedica cave system belongs to the third, the most developed generation of sinkholes. The elevation of the Gojačka Dobra riverbed in the canyon in front of the entrance of Đulin ponor is about 273 m a.s.l. The karstification processes are advancing and the fourth generation of sinkholes is apearing in the upstream part of Dobra riverbed (Hreljin, 5 km NW). Today, these sinkholes are in shape of slightly widened fractures, causing some water loses from river and the reservoir.

During normal hydrological conditions, before the dam construction, the lost river Ogulinska Dobra was permanently sinking through the entrance of Đulin ponor and the fourth generation of sinkholes. At present the downstream part of riverbed is mostly dry, and only the youngest, upstream sinkholes are active. The fourth generation of sinkholes is connected with the older Đulin ponor-Medvedica cave system and collects the water which appears deeper in the cave as permanent underground flows, even when the entrance is dry. It seems that the underground flow in the second unit of channels is related on water loses from reservoir area. Strong underground inflow observed in the third unit probably is connected with upstream sinkholes near Hreljin. This water flows through still unknown passages of the karstic system and reappears on surface through the Spring Cave Gojak.

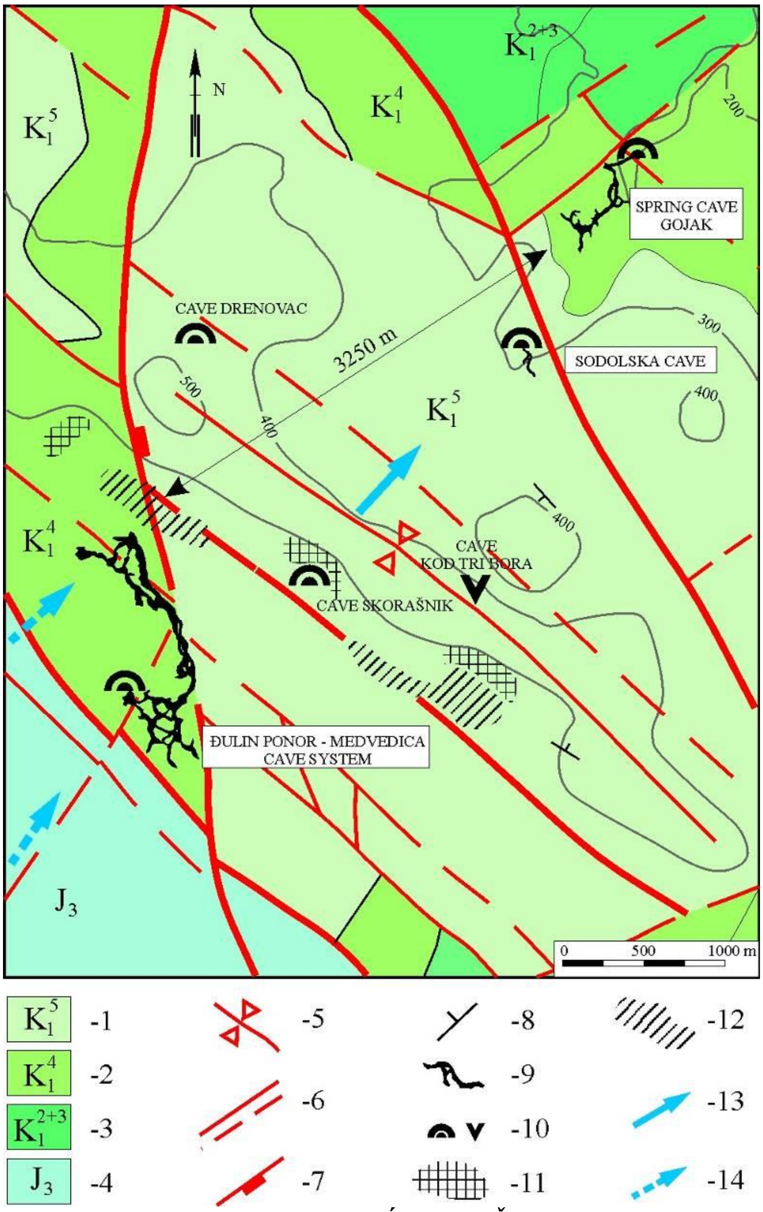

Fig. 5 Geological map of the investigated area (after: VELIĆ & SOKAČ, 1981). Legend: 1) foraminiferus limestone; 2) foraminiferal-algal limestone; 3) limestone and dolomite; 4) algal-foraminiferal limestone and dolomite; 5) syncline axis; 6) faults; 7) relatively descended block; 8) bedding; 9) simplified plan of the most important caves; 10) cave and pit (jama) entrance; 11) area of the first generation sinkholes; 12) area of the second generation sinkholes; 13) general groundwater flow direction; 14) groundwater flow from the sinkholes of the fourth generation

During the rainy season the reservoir capacity is to low and the overflow sinks in Đulin ponor - Medvedica Cave System. After heavy rains, and snow melting, the discharge of Ogulinska Dobra River increases to the more than 100 m^3/s. Under such conditions, the discharge capacity of the cave system is to low to accept all the water, and also the outflow capacity of the Gojak spring is restricted. The level of Ogulinska Dobra at the entrance of Đulin ponor rise in these cases more than 40 m. Occasionally the Dobra River flows over the canyon flanks and floods some parts of Ogulin city. The highest observed level was 322 m a.s.l. (+49 m). Finally a part of water flows through the fossil riverbeds toward the sinkholes of the second generation on the NE edge of Ogulinsko polje and activates the old underground drainage system. As a consequence, the Sodolska cave located on elevation of 230 m a.s.l., 41 m over the Gojak spring (189 m a.s.l.) respectively, becomes active too with discharge of several m^3/s.

The hydraulic connection between Đulin ponor and spring Gojak has been proved by a tracer experiment carried out with uranin during a low discharge season (2 m^3/s) in 1948. All relevant springs in the area have been observed but the tracer was detected only on Gojak spring; 84 % of injected tracer reappeared, the underground flow velocity was 5.4 cm/s. The cavers main interest is the possibility for further explorations and prospects for the connection of cave systems. Taking in account the indentation of already explored caves, the whole system should be longer than 50 km.

Based on the results of speleological exploration the main geometrical parameters of the karst underground were determined. The distance between terminal siphons in the Đulin ponor-Medvedica (231.5 m a.s.l.) and Spring cave Gojak (200.5 m a.s.l.) is 3250 m, with a vertical difference of 31 m, with a hydraulic gradient of 9.5 ‰. For the comparasion the general gradient of Đulin ponor -Medvedica (from the lowest entrance to terminal siphon) is 39 ‰ and 18 ‰ in Spring Cave Gojak.

In spite of the fact that the area between them is composed of permeable foraminiferus limestones the geological situation is generally unfavorable. The main tectonic discontinuities strike NW-SI and are perpendicular to the groundwater flow direction. They were formed during the last kinematic stage of the contraction tectonic phase, and from the hydrogeological point of view they act as local barriers and disperse the groundwater flow.

Hydrogeological observations indicate that the discharge increase of Ogulinska Dobra river is accompanied with high water turbidity, but at the same time, the turbidity of the Gojak spring is changes slightly. It was also observed that when the river overflows its banks and water reachs the sinkholes of the second generation, from the Sodolska cave an outflow of large quantities of muddy water occures.

In wiev of all these facts, the area between Đulin ponor - Medvedica Cave System and Spring Cave Gojak somewhat slander channels and deeper sifonal circulation are expected to occur. Some progress will be done in the zone of permanent circulation, but the siphons would be deeper and longer. The behavior of the karstic system during flooding, and remnants of old caves indicate that real prospects are related to exploration of inactive or periodically active channels, located on several levels over the zone of permanent circulation. In an such intensively karstified area, mutual connection of these levels is very probable. Maybe the entrance to thit system is the unexplored terminal siphon of the Sodolska cave.

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Bat Guano Influence on the Geochemistry of Cave Sediments from Modrič Cave; Croatia

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Abstract

The entrance to the Modrič cave is located at the altitude of 30 m above sea level some 70m away from the major coastal highway Rijeka-Zadar in Croatia. The cave was formed within Cretaceous limestones, and is characterized by slightly inclined to horizontal chambers and channels, which have a total length of 829 m. Baseline contents of elements both in sediments and percolating waters were determined. Silty loams with guano contain abundant quartz, illite and taranakite and minor vivianite and high concentrations of Cu (2869 mg/kg), Zn (951 mg/kg) and Cd (28 mg/kg). Also sediments mixed with guano are enriched with light REE as well as elevated concentrations of U, Th, Rb and Hg in comparison with local topsoil. Sediments with bone fragments contain abundant quartz, illite, calcite and hydroxylapatite and minor carndallite and lower contents of heavy metals. All sediments analysed showed various degrees of contamination by Cu and Zn from dispersed guano.

Introduction

The entrance to Modrič cave locted in the central part of the Croatian coastal region was used by local population as a natural shelter for centuries, but the underground network of channels and chambers was discovered in 1985. Since the cave was naturally sealed from its entrance an opening was chiseled through opened fissures in the limestone. The local authorities managed to prevent devastation of speleothems by controlling of entries made to the cave system. The favorable morphology and numerous stalagmites, pillars, flowstone, helictites, draperies (KUHTA et al., 1999) etc., as well as the paleontologic and archeological remnants (MALEZ, 1987) preserved in the cave sediments made it attractive as tourist destination. Therefore a comprehensive study, which included mapping, analysis of waters, and cave sediments, as well as age determinations (KUHTA et al., 1999) was undertaken to evaluate the baseline conditions within the cave before its utilization.

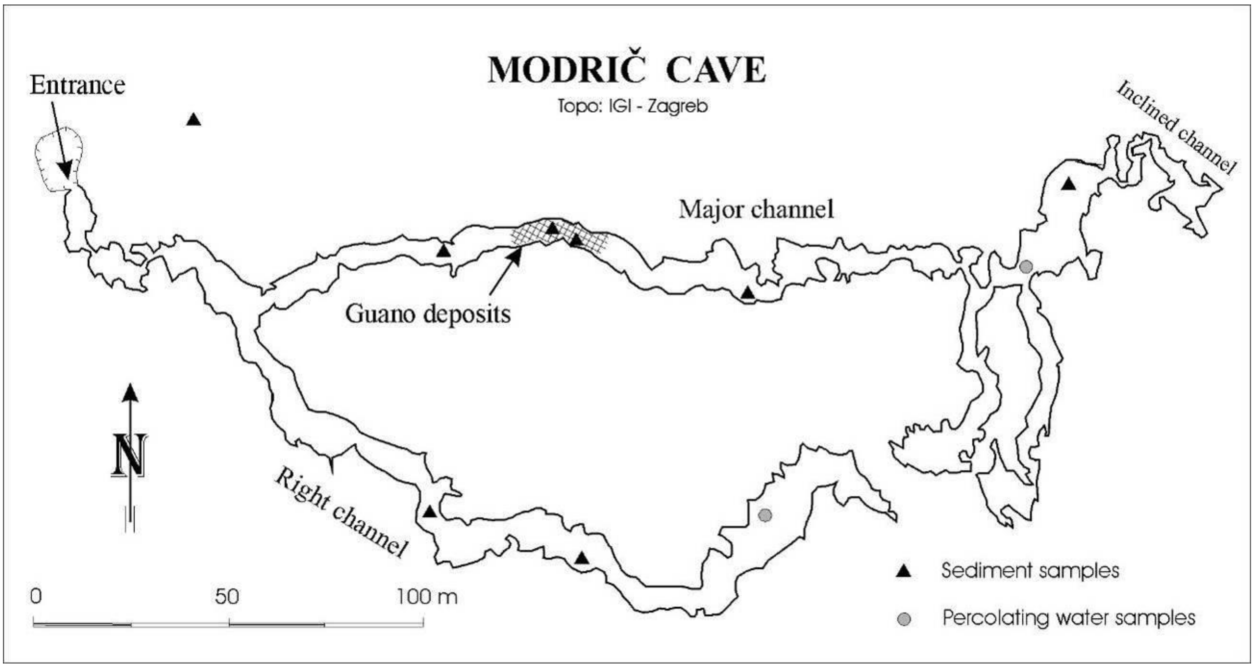

Fig. 1 Location of samples from the Modrič cave.

The vicinity of a major highway and recent war activities (1991/1992), implied to possible negative impacts on this vulnerable environment. The frequent occurrence of a thin dark crust on the floors in most depressions and on sediments was especially interesting in this sense. This was determined to be finely dispersed guano. Guano (bat guano, bird guano, penguin guano) similar to phosphates in general is a well-known source of heavy metals.

Heavy metal movement with water in sediments and soils requires that the metals be in soluble phase or associated with mobile particles and as such can have impacts on the quality of ground water. The objective of this study was the investigation of heavy metal concentrations and the movement of elements derived from bat guano in a cave environment.

Geology, Hydrogeology and Cave Morphology

Modrič cave formed within the Cenomanian-Turonian well bedded limestones. The limostenes consist of poorly sorted bioclasts with a dense sparite matrix. Within the beds the occurrence of the lamellibranchiata *Chondrondonta joannae* is quite frequent. The layers often contain lenses of platy limestones containing foramenifera and rarely macrofossils. The youngest quaternary beds that cover the bedrock are thin chromic cambisols, which accumulated in openings of karstified fissures and local depressions.

The wider region of the cave is located within the contact zone of the Adriatic carbonate platform structural complex and the Dinaric carbonate platform. The surface manifestation of the contact zone is a 2.5 km wide fault zone termed the Velebit fault (HERAK, 1986). This regional tectonic structure consists of a series of parallel faults with a general strike NW-SE, two of these faults are located to the north and to the south of the cave. The limestone beds have a general strike NW-SE with a dip angles ranging from 20 to 40°and inclination towards the NW. The faults and numerous networks of tectonic fissures formed during several tectonic events that shaped the morphology of the landscape had a key role in the formation of subsurface karst phenomena including Modrič cave.

The cave is located within a series of well permeable highly karstified carbonate rocks. The surrounding karst is characterised by the absence of surface flows and a fast direct infiltration of precipitation waters and a development of complex underground geomorphologic features. The infiltrated precipitation waters are drained through the complex systems of karstified fissures directly towards the sea. There are no concentrated discharges of fresh water along the coast so outflow of the water probably occurs in a depressive manner. The cave is located above groundwater level and outside the present zone of active circulation. The dimensions of the underground chambers indicate an important hydrogeological role of this region in the geological past. Modrič cave formed as a consequence of groundwater activity, during which groundwater flowed from the regional Velebit Mt. karst aquifer towards the terrain located at lower altitudes, i.e. towards the morphological depression of the present sea channel the Velebit channel. Active parts of this system exist near by in the form of submarine springs Modrič (-30 m) and Zečica (-45 m) and the coastal spring Velebit.

The entrance to the cave (1.8m x 1.3m) is located at the altitude of 30 m above sea level some 110m away from a major coastal highway Rijeka-Zadar. The basic morphological features of the cave are slightly inclined to horizontal chambers and channels, which have been explored in the total length of 829 m. From the entrance the cave extends generally towards the east. The elevation difference from the lowest point in the middle of the Major channel (Glavni kanal) and the highest point in the inclined channel (Kosi kanal) is 29 m. In most parts of the cave the width of the passages ranges from 2 to 8 m and in parts extends up to 14m. As a consequence of stalagmite formation and flowstone deposition on several places the channels were almost closed so it was necessary to widen them. The sediment deposits are found in larger chambers and varies depressions within the cave. The sediments are mainly silt loams and clay silt loams of reddish-brown to brown colour (5YR to 7.5YR), with calcareous debris and numerous bone fragments of Holocene fauna (*Ursus Spelaeus*), human bone remains and remnants of eneolithic pottery (MALEZ, 1987). The structure of the sediments is quite chaotic, lacking visible stratification, with variable thickness from several centimetres to probably over 1.5m. Dark brown and white bat guano deposits occur in several places covering the sediments up to 1 m over a surface of several square meters (central part of the main-Glavni kanal-channel). A thin grey layer that covers the damp sediments and the floor of the cave was determined to be of finely dispersed guano. The bats are not frequent residents of the cave today, since the entrance was first opened in 1985.

Methodology

Typical sediment samples (sediments with bone fragments from various depths from the sediment profile, sediments mixed with guano, dark mud coatings over sediments and dark crusts with dissolution surfaces on flowstone) and soil samples from the surface above the cave were selected for geochemical and mineralogical analyses. The objective of the geochemical study was to determine the baseline concentrations of elements (total and aqua regia extraction), their mobility and mineral phases (sequential extraction) that control their mobility and to asses possible anthropogenic influences especially as a consequence of heavy traffic from the nearby highway. Detailed analysis of 20 cave sediment samples was performed.

Major and trace element values including REE were obtained after $LiBO_3$ fusion by ICP-MS, also additional analysis were performed after *aqua regia* (HNO_3: HCl, 1:3) extraction to verify the high heavy metal contents in the sediments. The residence sites of metals in the sediments were identified by sequential extraction performed with the aid of a modified combination of procedures proposed by TESSIER et al., (1979) and HALL et al., (1996). Sequential extraction of the sediment samples was performed to give the following five fractions: adsorbed (AD), bound to carbonate (CC), bound to iron and manganese oxides (FEMN), bound to organic matter and sulphides (OR) and residual (RES). The amount of exchangeable fractions of elements was determined after extraction with 1M KCl. All solutions were analysed for Zn, Cu, Fe, Mn, P and Ni by a Jobin Yvon 50P simultaneous inductively coupled plasma-atomic emission spectrophotometer (ICP-AES) and Pb and Cd by a Pye Unicam SP9 flame atomic absorption spectrophotometer (AAS) using an air-acetylene flame. Filtered (-45μm) samples of percolating drop water were analysed by ICP-MS. Mineral composition of selected samples was analysed with a Philips diffractometer (CuKα radiation) equipped with a graphite monocromator and proportional counter.

Results and Discussion

The X-ray diffraction analysis showed that the acid (pH<3) sediments with variable contents of guano contain abundant quartz , illite and taranakite and minor vivianite, the almost "pure" guano sample had a similar composition but amorphous matter prevails. Sediments (bone fragments present) with no visible guano presence (pH>6) contain abundant quartz, illite, calcite and hydroxylapatite with scarce carndallite. The dark crusts with dissolution surfaces on flowstone consist of fibrous (2mm below the surface) and pinkish white earthy masses (5-10mm wide) of hydroxylapatite and sporadic calcite. From the chemical analysis results of total contents of elements ($LiBO_3$ fusion) in Table 1 it is visible that, P_2O_5, Cu, Zn, Th, U, Sb and Cd have higher concentration in cave sediments especially those under the direct influence of bat guano. *Aqua regia* extraction of 12 sediment samples from various depths and locations within the cave gave Cu concentrations ranging from 34 to 450 mg/kg, Zn from 181 to 1181 mg/kg and Cd from 0.3 to 4.3 mg/kg. Almost "pure" bat guano contained high concentrations of Cu (2869 mg/kg), Zn (951 mg/kg) and Cd (28 mg/kg). Very high concentrations of these elements (Zn 1181 mg/kg; Cu 385 mg/kg; Cd 4.3 mg/kg) were found in the dark fine mud coatings (approximately 5mm thick) that cover most of the floor sediments. These coatings are finely dispersed guano deposited by water in various pools and depressions. The content of these metals is usually much lower in sediments from deeper parts of the cave sediment profiles especially Cu whereas Zn concentrations are regularly elevated (in comparison to topsoil). Namely sediments from deeper horizons do not contain neither guano nor minerals derived from it but contain only quartz, illite, calcite minor feldspar and also some bone apatite. Although bat guano contains 2869 mg/kg of Cu only 0.7 mg/kg (0.03%) were extracted by 1M KCl while at the same time 78 mg/kg of Zn were extracted from a total of 951 mg/kg (i.e. 8.2 % of exchangeable Zn) also due to the acidy of these sediments the mobility of Al was also high. Therefore it is possible that the waters that percolate through the guano into deeper parts of the profile carry much more Zn and accumulate it there. Copper is obviously less mobile and retained in the surface layers. The sediment samples also contain higher concentrations of U and Ba as well as Hg (sediments with guano 790 μg/kg, topsoil 405 μg/kg). The distribution of rare earth elements in cave sediments with guano shows a slight enrichment of light rare earths (LREE) in comparison to European shale (ES) and depletion of heavy rare earths (HREE), while sediments and topsoil in general have similar distribution pattern to ES with only a slight enrichment of La in topsoil (Fig. 2).

Some of the percolating waters collected from the ceiling were also found to be enriched in these elements. The "uncontaminated" filtered (-45μm) waters contained in average 2 μg/L of Zn, 0.012 μg/L of Cd, 0,4μg/L of Cu and 0.08 μg/L La, 0.04μg/L of Ce, while the guano polluted filtered drop water contained 22 μg/L of Zn, 0.46 μg/L of Cd, 3,5μg/L of Cu and 0.157 μg/L La, 0.29 μg/L of Ce, a several fold increase. These waters were also found to be saturated in respect to hydroxylapatite. Sequential extraction was used to determine the metal-bearing phases in the cave sediments and for discrimination of possible lithological and environmental effects. The mobility and bioavailability of the metals decrease approximately in the order of the extraction sequence. The operationally defined extraction sequence follows the order of decreasing solubility of the geochemical forms of the metals; hence the exchangeable fraction may indicate which metals are most mobile. The results of chemical sequential extraction analysis show that most of the Zn and Cu in cave sediments and the hydroxylapatite crusts are mainly controlled by the iron and manganese hydroxide (FEMN) and the organic fractions (OR) (Figs 3 & 4), the organic fraction plays an important role in sediment samples with direct influence of guano and in hydroxylapatite crusts while in samples with bone fragments the hydroxide control is dominant.

	Topsoil above the cave	**Sediment with bone frag.**	**Sediment Below guano**	**Sediment with Guano**
Depth	0-25cm	40-60cm	20-30cm	0-5cm
pH $_{H2O}$	6.07	6.36	6.77	3.19
SiO_2 %	40.12	55.26	44.88	35.45
Al_2O_3%	18.14	14.49	16.68	13.95
Fe_2O_3 %	7.21	6.06	6.2	5.54
MgO %	1.14	0.69	1.22	0.93
CaO %	2.36	5.79	9.43	16
Na_2O %	0.33	0.14	0.26	0.21
K_2O %	1.28	1.71	2.03	1.54
TiO_2 %	0.98	1.03	0.92	0.81
P_2O_5 %	0.31	5.51	3.36	5.84
MnO %	0.18	0.05	0.16	0.14
LOI %	27.8	9.1	14.7	19.4
Ctot %	7.63	0.19	1.3	3.28
Stot %	0.14	0.01	0.01	0.03
Co mg/kg	19.9	8.5	17	14.5
Rb mg/kg	98.6	90.7	123.2	95.6
Sr mg/kg	70	270	74	75
Th mg/kg	15.5	16.7	22.1	17.1
U mg/kg	3.2	5.8	5.9	7.4
V mg/kg	170	139	167	154
Cu mg/kg	32	63	62	165
Zn mg/kg	102	359	269	557
Ni mg/kg	57	25	53	41
Pb mg/kg	46	21	26	21
As mg/kg	28	16	22	20
Cd mg/kg	1.7	1.5	1.4	2.8
Sb mg/kg	0.5	0.7	1.2	1.3
Ba mg/kg	245	333	337	288

Table 1 Chemical composition of selected cave sediments and topsoil.

The residual (RES) fraction holds more than 45% of the total Zn content of the hydroxylapatite crusts indicating an incorporation of Zn into the crystal structure. Guano influenced sediments contain 5 to 10 % of Zn and Cu in the most mobile fractions the adsorbed (AD-less) and carbonate (CC-more). These the most liable fractions of elements in the case of pollution studies are used predict contamination usually of an anthropogenic source while in this case for influence on the quality of percolating cave waters.

Other potentially toxic elements (Pb, Cr, Ni, Co, As) analysed were found to have higher contents in topsoil and which are well within the regional geochemical baselines for Western Croatia (MIKO et al., 2000).

Although the primary goal of the study was to determine geochemical baseline values for the cave sediments and environment as well as possible influences from several decades of heavy traffic or war activities in the vicinity of Modrič cave the influence of bat guano as a natural contaminant obviously exceeds possible anthropogenic contributions.

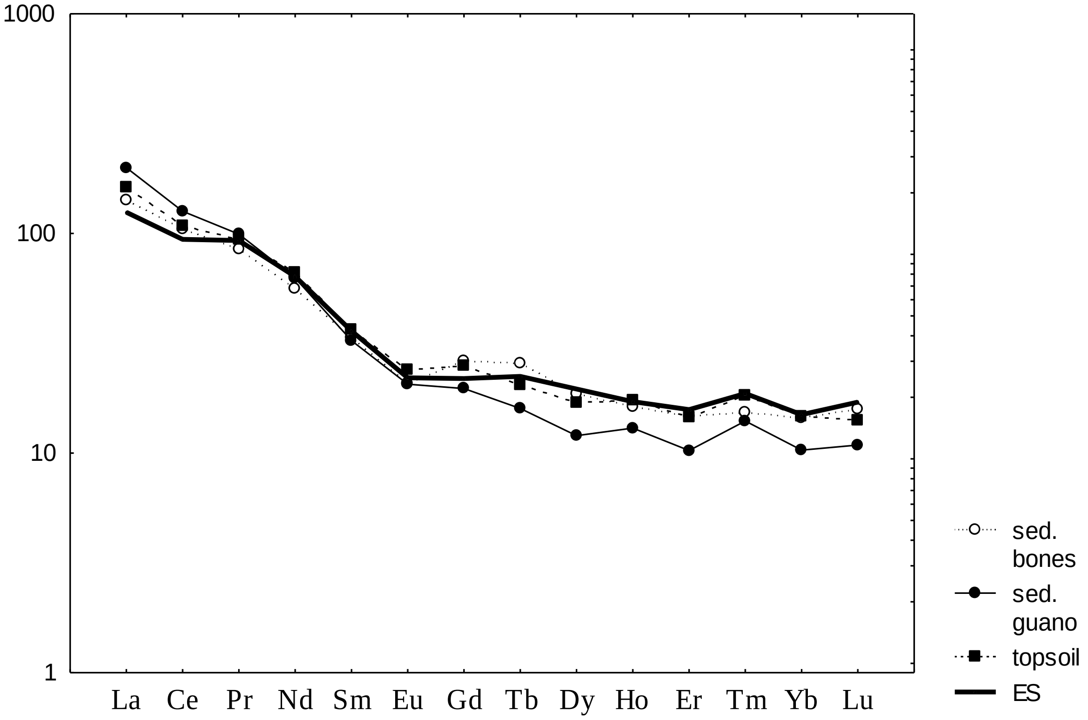

Fig. 2 Normalized REE patterns for cave sediments containing and those lacking guano, and topsoil, ES- European Shale.

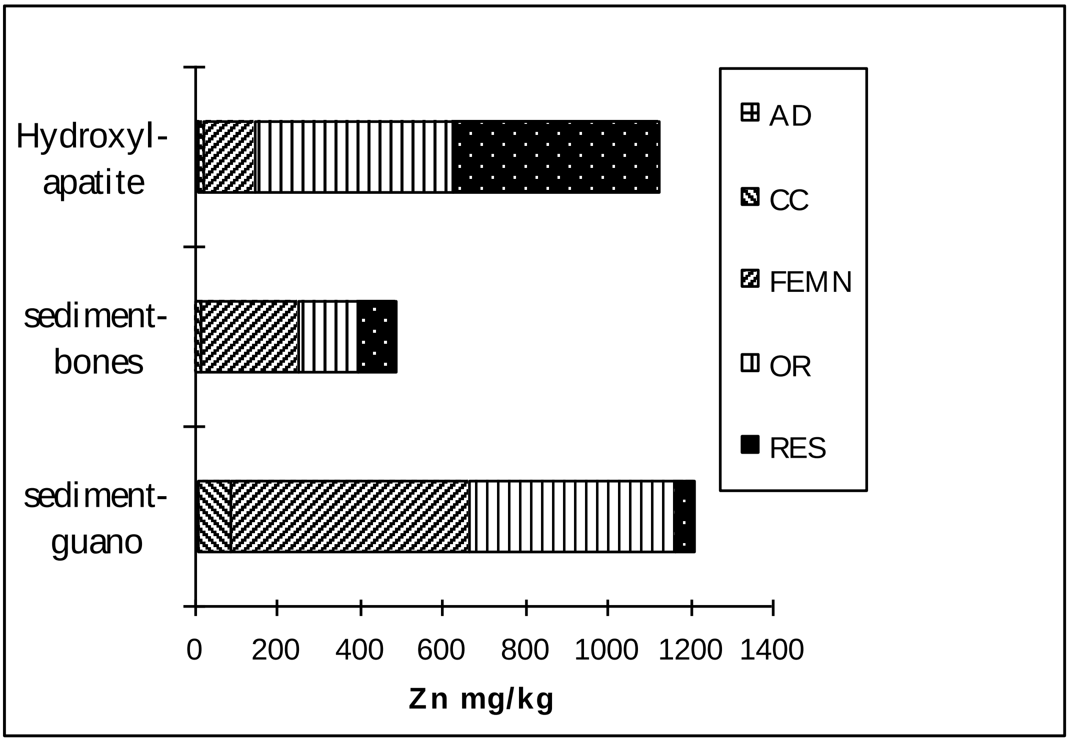

Fig. 3 Zinc concentrations in the cave sediment fractions, hydroxylapatite= hydroxylapatite crusts on flowstone.

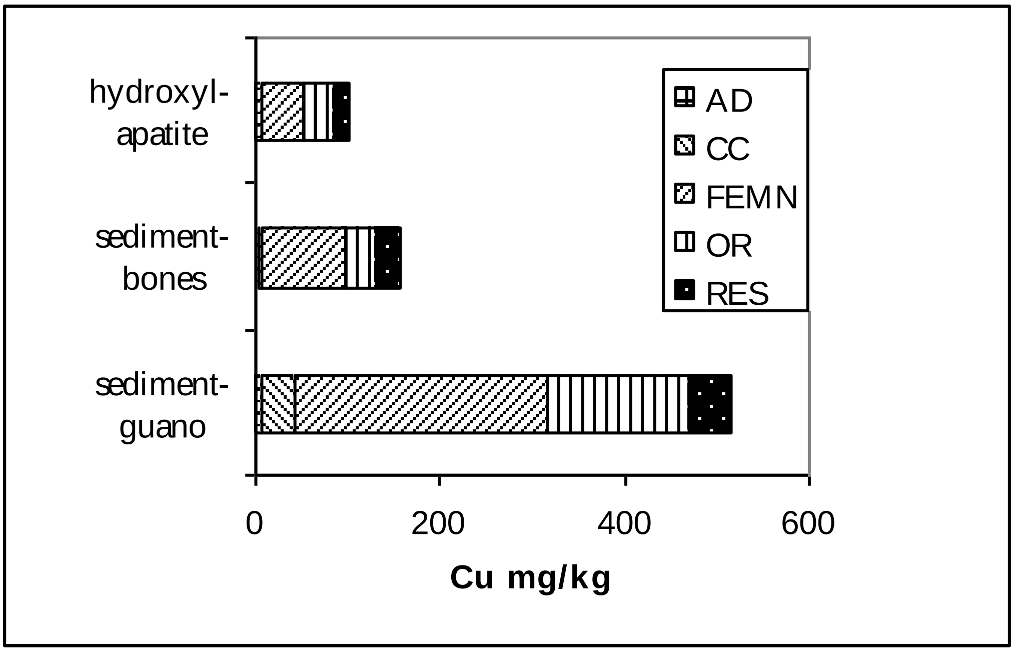

Fig. 4 Copper concentrations in the cave sediment fractions, hydroxylapatite= hydroxylapatite crusts on flowstone.

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Karstification Dynamics and Development of the Deep Caves on the North Velebit Mt. – Croatia

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Abstract

In an area of approx. 25 km^2 on North Velebit Mt. in the last 10 years more than 200 caves were discovered and explored. The system Lukina jama - Trojama (-1392 m) and Slovačka jama (-1301 m) are the deepest caves in Croatia and the 12th i.e., 18th cave of the world. Furthermore, significant depth was reached at Patkov gušt (-553 m), Ledena jama (-536 m) and Jama Olimp (-531 m).

The development of large caves was analysed in respect to the geology, hydrogeological relations, karstification processes and paleoclimatic conditions. Neotectonic movements with summary amplitudes of about 1600 m, the Bakovac fault and its interruption of the Velebit complex barrier extension, as well as the concentrated recharge during interglacial stages of Pleistocene are recognised as the main factors contributing the speleogenesis.

Introduction

Velebit Mt. is the longest (145 km), and according to many, the most beautiful mountain of Croatia. Its strike is NW-SE direction, and it spreads over three Croatian regions: Lika, Dalmacija and Hrvatsko primorje. North Velebit is the mountain region between Adriatic sea and Ličko-Gacko polje. It begins at Vratnik saddle in the north and spreads over to Veliki Alan saddle on the south, with the length of 30 km. The wideness of the massif in the area above 1000 m is also 30 km. The middle parts of the massif reach the heights of almost 1700 m (Mali Rajinac, 1699 m). Although the distance from the sea is only several km, the region of Velebit Mt. is in the mountain climate type. Medium annual precipitation on the north Velebit is in the range from 1500 to 2000 mm. In the highest parts of the massif, the snow stays on the ground over 100 days per year. The medium annual temperature is around 4°C.

The Velebit region is the part of Dinaric karst region, which covers southern half of Croatian territory. The distinct carbonate geology was favourable for development of surface and underground karst geomorphologic phenomena. Although the data of first speleologic investigations of north Velebit mountain region dates from the beginning of 20th century, the systematic investigations did not begun until seventies. Because of the geomorphologic characteristics of surface relief, the area around Hajdučki, Rožanski and Begovački kukovi, the middle, the highest part of north Velebit massif respectively, was considered especially attractive. Extremely hard passability of this area is probably the reason of poor results of these investigations. Up to 1990 only dozen objects with max. depth of 143 m were investigated. At the beginning of the nineties this region was visited by Slovakian speleologists (Student University Club from Bratislava). Lukina jama (Manual) in which they descended up to depth of 195 m was among the first found objects. In summer of 1993 Croatian speleologists, gathered in Commission for Speleology of Croatian Mountaineering Association, organized the first major expedition in that area. At this time Lukina jama was investigated up to unexpected depth of 1355 m. This result initiated numerous investigations in the next few years in which Slovakian speleologists took part together with Croatian speleologists. The last results are very impressive. More than 200 speleogic objects were investigated on the detailed area of around 25 km^2, and the pit system Lukina jama - Trojama and Slovačka jama is ranked among the deepest pits in the world. Up to these investigations the deepest pit in Croatia was the pit Stara škola on Biokovo Mt. 576 m deep, and the deepest pit on Velebit region was ponor on Bunovac (south Velebit) 534 m deep.

In regard to the results achieved up to now, the discussed area of north Velebit is speleologicaly most important area of Dinaric karst region. In the following text the most important natural elements, contributing to the development of such intense karstification processes and genesis of extremely deep speleologic objects in this area are presented.

Morphology of the Deepest Objects

Pit system Lukina jama - Trojama with the depth of 1392 m is the deepest pit in Croatia. The entrance of Lukina jama is at 1438 m above sea level and the entrance of Trojama is placed at 1475 m above sea level. They were investigated in the period from 1992 to 1994. Lukina jama is almost vertical from the entrance up to the depth of 550 m with one inclined snow shelf at the depth of 320 m. From 50 to 320 m, the deposits of snow and ice are on the walls, so the pit temperature in this part is 0°C. At the depth of 520 m there is the connection with Trojama. The continuation of pit is distinctly vertical and there are only 2 places suitable for camping - in the meander at the depth of 743 m and in the great hall with dimension 85×70 m at the depth of 950 m. At the bottom of the pit there is the hall with dimensions 20×5 m with two syphons. Southeast syphon was dived in the length of 57 m ant it continues further. In deeper parts of the pit the air temperature is from 2 to 4°C, and the water temperature in the syphon is 4°C. The bottom of the pit system, reached up to now, is at only 83 m above sea level, with the distance from the sea of around 10.5 km. The length of the system is 1078 m.

Slovačka jama is at 1520 m above sea level. The pit is 1301 m deep and its investigation began in 1995. As opposed to majority of pits in north Velebit, in Slovačka jama there are no snow and ice, what is the consequence of horizontal entering part of the pit. The pits morphology is complex and it can be divided in several entireties. The old part of the pit is stretching up to -514 m. At the depth of -350 m the fossil horizontal canal was found, from which numerous vertical canals are separated. The deepest one, hydrogeologically active, is Velebni canal on whose bottom there is the combination of horizontal canals whose investigations have not finished yet. The characteristics of the pit are narrow, hardly passable meanders, especially between the depths from 600 to 700 m. The air temperature in upper parts of the pit is from 3 to 5°C, and at the bottom it is from 6 to 8°C. The length of this object is 2414 m.

Pit Patkov gušt is 553 m deep and completely vertical, and was investigated in year 1997. The opening of the pit is at 1450 m above sea level, in the slope of the sinkhole with dimensions 100×75 m. The aperture of the pit is around 65×30 m big. From the depth of 50 to 135 m on the walls there are thick deposits of snow and ice. At the depth of 105 m there is the narrowest place of the pit (2×1.5 m) that was filled with snow and ice in the year 2000. After the depth of 130 m the pit widens and with almost the same profile, it goes all the way down to the bottom.

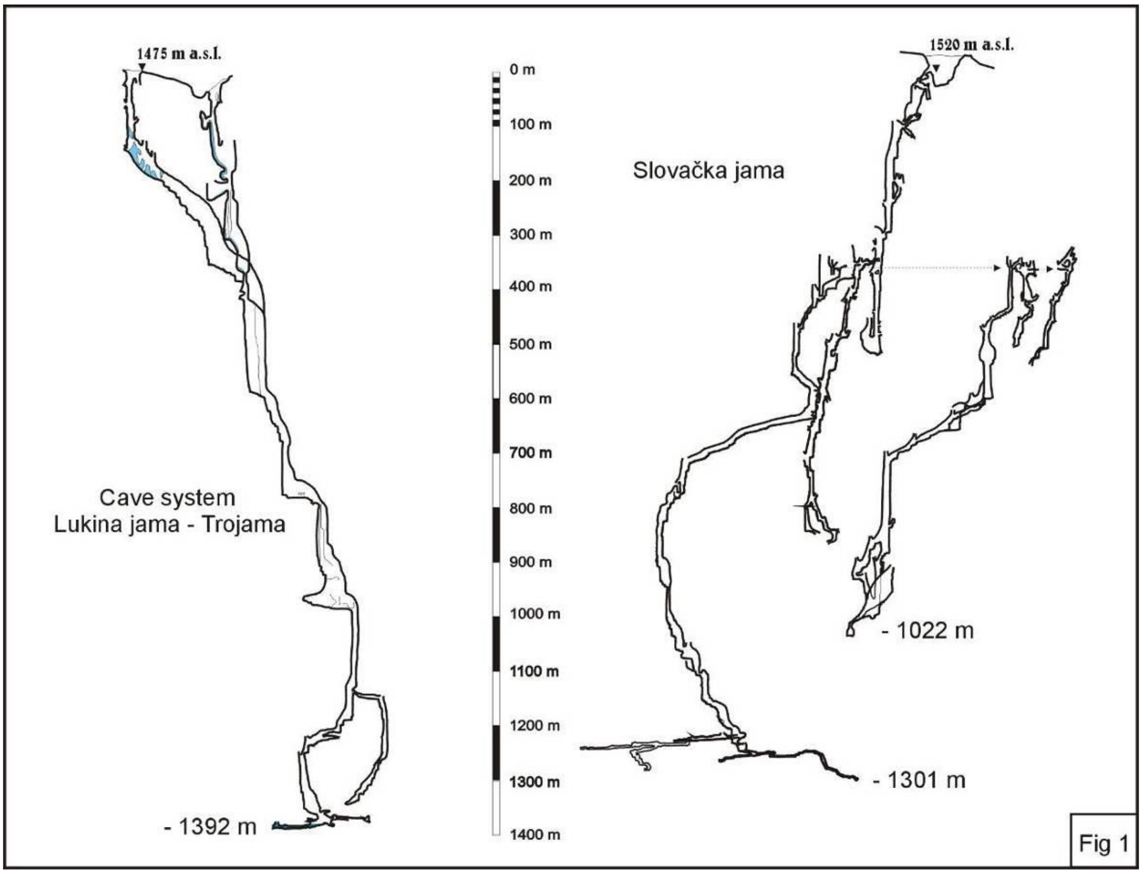

Fig 1

The walls are completely or partially covered with ice coating up to 300 m depth. The ice breaking is constant danger, so, after the investigations in the year 1997, the pit was visited all the way to the bottom only once. The pit ends with the hall with dimensions 40×30 m.

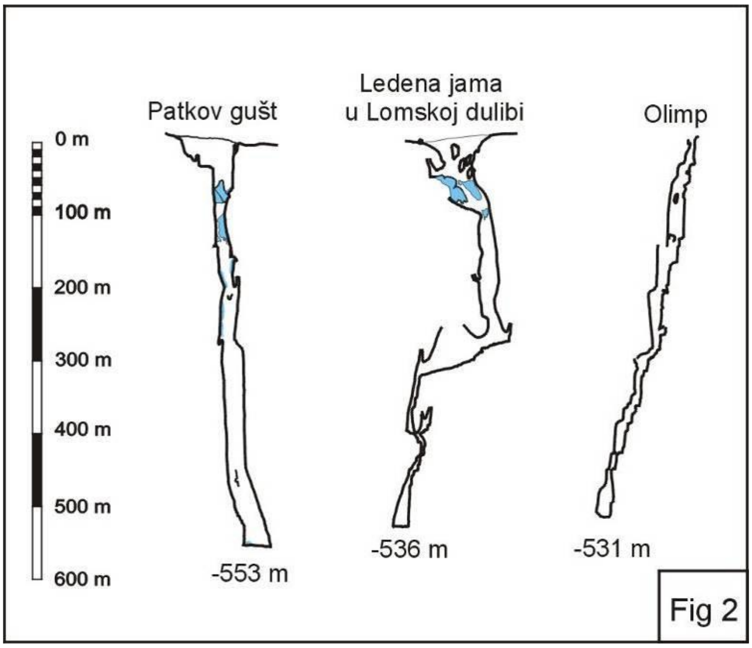

Fig 2

Ledena jama (Ice pit) in Lomska duliba is 536 m deep. For the first time it was investigated in 1977, when the depth of only 62 m was reached. The further advancing was obstructed by thick layers of ice. Only in 1992 the passage was found through the ice cork 40 m thick. The melting of ice leads to creating the new passages so, up to now, there are three openings in the ice. Morphologically, the pit is simple. It consists of two vertical sections and great hall with dimensions 80×50×60 m in the middle part of the pit. After the narrow part, at the depth of 473 m, which was widened by carving, one comes into smaller hall. The bottom with ground plan of 10×5 m is covered with gravel through which the water is seeping. The pit investigation was finished in the year 1996.

Pit Olimp is 531 m deep. The investigations were carried from 1998 to 2000. Although the pit is at the altitude of 1380 m, there are no snow and ice inside. The reason for that is relatively small aperture (6×3 m) in which the big stone block is fixed. The pit is of simple, knee-like morphology with numerous narrowings and shelves, which emerged mostly by fixing of rock blocks and debris in joints. The air temperature in the pit is 4°C and the water temperature is 5°C.

Lithostratigraphy and Hydrogeological Properties of the Rrock Units

The studied area of Velebit Mt. is composed of lithostratigraphic units in range from Middle Triassic to the Paleogene age. The MiddleTriassic deposits are mostly composed of limestones. In the uppermost part laterally, the tuff and tuffite occur. The lower part of Upper Triassic is characterised with the sequence of clastic rocks up to 200 m thick represented by shale and sandstones. Carbonate sedimentation proceeded with 250 m thick dolomite deposits. Due to a lower permeability as the consequence of lithological composition (clastic and dolomites), and structural position in the central part of an anticline structure, the Triassic sediments form the complex hydrogeological barrier of Velebit Mt. The largest part of Velebit Mt. is composed of Jurassic sediments, which have been continuously deposited under almost the same conditions and contain carbonate rocks only. In the composition of deposits the limestones prevail but the dolomites are present too. Generally, the Jurassic sediments are very permeable unit but on some locations dolomite retards the groundwater flow and acts as the relative barrier (Apatišan area). The thickness of Jurassic deposits is approximately 2850 m.

In the investigated area, the well permeable Cretaceous sediments have not greater importance. At a narrow belt along Adriatic coast they are represented by limstone-dolomite alteration. In the Lika region on the other side of Velebit Mt. (Lipovo polje) deposits are composed of limestones intercalated by dolomite and calcareous breccias.

The significant part of the area concerned is covered by Jelar formation of Upper Paleogene age. Its origin is closely related on strong tectonic movements, which effected the area during that time. In the hinterland (Lika region) they are partly permeable but on higher positions at Velebit Mt. calcareous breccias are highly permeable. The best prove for the mentioned is the spectacular landscape of Hajdučki and Rožanski kukovi area, as well as the numerous karstic phenomena and the deepest caves of Croatia among them. The thickness of calcareous breccias is up to 300 m.

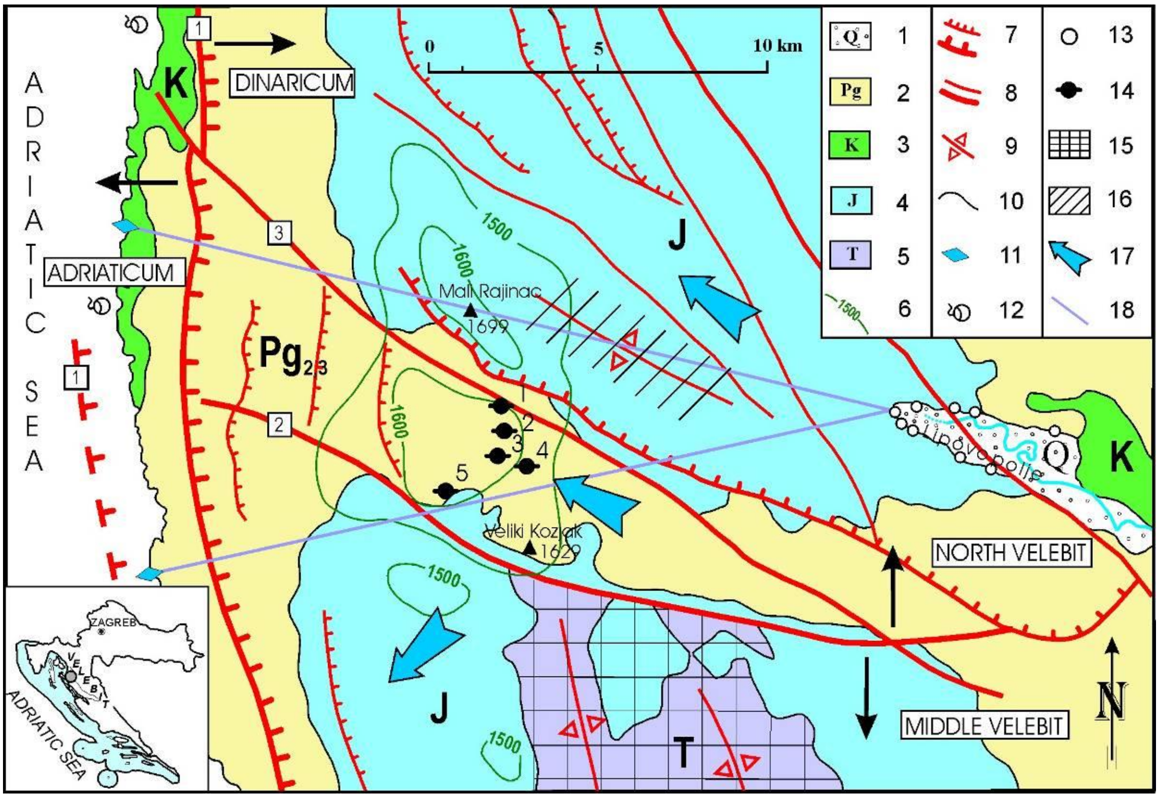

Fig. 3 Simplified geological map of the North Velebit area. Legend: 1) alluvium deposits; 2) calcareous breccias of Upper Paleogene; 3) Cretaceous carbonate rocks; 4) Jurasic carbonate rocks; 5) Triassic carbonate and clastic rocks; 6) summary amplitudes of vertical neotectonic movements (in metres); 7) reverse faults, (1) Velebit fault; 8) normal faults, (2) Bakovac fault, (3) Lomska duliba fault; 9) anticline axis; 10) geological boundary; 11) coastal spring; 12) submarine spring (vrulja); 13) sinkhole; 14) deep caves, (1) Ledena jama, (2) Lukina jama-Trojama, (3) Patkov gušt, (4) Olimp, (5) Slovačka jama; 15) area of Velebit complex barrier; 16) relative barrier; 17) general groundwater flow direction; 18) groundwater flow direction tested by tracing.

Tectonic Basis of Karstification Processes

Conceptual basis of geotectonics of the Dinarides established HERAK (1986) in the view of mobilistic theory i.e., the plate tectonic. In the structural pattern of the main body of the Dinarides four dynamic and paleogeographic units are differentiated. The investigated area, as well as the whole Velebit Mt., is situated within structural complex of the Dinaric carbonate platform (Dinaricum), along its contact zone with Adriatic carbonate platform (Adraticum).

The geological structure is the consequence of two main periods of tectonic activity. During the Tertiary tectonic cycle, which lasted from Eocene to the end of Miocene, compressive movements oriented NE-SW reached their cumulative maximum with orogenesis of the Dinarides. As the consequence of mentioned regional tangential stress, the deep nappa structures, folds and regional faults of Dinaric strike (NW-SI) have been formed. During the later, Neotectonic period, the main stress changed to N-S, resulting in further uplift and transpressive deformation of older structures, which were broken in the smaller structural units and tectonic blocks.

On the basis of geology of the studied area and the basic tectonics involved, distinctive areas, structural units and faults that influence the hydrogeology of the terrain and karstification processes development are presented on Fig. 3. The map was prepared in accordance with data from previous studies BAHUN (1974), PRELOGOVIĆ (1989) and PAVIČIĆ (1997). Numbers mark the most important faults that effected the development of numerous deep caves in the investigated area.

The regional longitudinal reversal Velebit fault (1) located in the coastal area, on the surface manifested as 4-6 km wide faulting zone, represents the boundary between Dinaricum and Adriaticum megastructural units. The tangential movement is estimated on 6-8 km.

The Bakovac fault (2) is very strong normal fault. The horizontal movements along it are not observed but the vertical displacement is estimated on about 1500 m (PRELOGOVIĆ, 1989). The fault interrupted extension of the Velebit complex barrier and significantly effected the hydrogeological relations in the area. In geomorphologic sense, the Bakovac fault represents the boundary between Middle and North Velebit.

The Lomska Duliba fault (3) is located on the northern boundary of the investigated area. The vertical displacement is estimated on 150 m.

All mentioned faults have been very active during Neotectonic period. The vertical neotectonic movements were estimated on the basis of deformations of the Jelar formation, position of the Pliocene and Quaternary deposits, comparison with neighbouring areas and disposition and deformation of geomorphologic elements. In the area concerned, the summary amplitudes of these movements reach 1600 m.

Karstification Dynamics

The first favourable conditions for karstification occurred in the Dinaride area after the Pyrenean orogeny, when large masses of carbonate rocks were exposed to exogenous processes. However, the Neotectonic movements, which commenced in Miocene and were intensified toward the end of Pliocene and the beginning of Pleistocene, played the major role in the reshaping of the landscape and the development of karstification. At that time, Velebit Mt. was uplifted together with other mountain ranges, while depressions developed as isolated karst plateaux and poljes. Recent studies performed in the Dinaric karst terrain indicate that the present landscape is very young. The majority of the most important and developed morphological features were created during the Lower Pleistocene and Holocene (FRITZ, 1992).

The investigated area is located at the highest (1250 - 1676 m above sea level), central part of Velebit Mt. The general karstification processes as well as the hydrogeological relations are directed by the position of erosion basis i.e., the lost rivers of the Lika region (550 - 480 m above sea level) on the east and the Adriatic Sea westward. The Velebit hydrogeological barrier has a very important role and controls the groundwater conditions and underground discharge from the Lika region toward sea.

The advanced karstification stage at the elaborated area is recognisable from the surface geomorphology, but in the underground the results are even more spectacular. In the last 10 years more than 200 caves were discovered and explored in the area of only 25 km^2. The system Lukina jama - Trojama (-1392 m) and Slovačka jama (-1301 m) are the deepest caves of Croatia and the 12th i.e., 18th. caves of the world. Furthermore, the significant depth was reached at Patkov gušt (-553 m), Ledena jama (-536 m) and Jama Olimp (-531 m). In some areas the density of caves is higher than 40 on one km^2 (Hajdučki kukovi 48, Vratarski kuk 42). Regarding the morphological characteristics the vertical caves (pits, jamas) are dominant and represent 98 % of all explored speleological features.

The development of so strong karstification processes at the studied area was contributed by several major factors.

Along the Bakovac fault the Triassic clastic and dolomite deposits, which built up about 75 km long complex hydrogeological barrier of Velebit are displaced. To the north of the Bakovac fault, the impermeable rocks lie significantly deeper beneath the surface, enabling deeper karstification and groundwater drainage from the Velebit karst hinterland (Lika region) towards the Adriatic sea.

On the other hand, the constant uplift of Velebit Mt. at all, during Neotectonic phase, was the most intensively expressed in the studied area (summary amplitude of the 1600 m). The karstification processes tended to compensate these movements and on the way toward erosion base they developed network of deep underground channels, the cave systems respectively.

The large number and density of caves is the consequence of favourable lithology. Namely, the uppermost part of terrain built up the massive calcareous breccias that are very liable to karstification. The mentioned fact is prooved with the results of cave exploration conducted in same deposits on the other parts of Velebit Mt. (LUKIĆ, 1991), as well as with always present exceptionally indented landscape of such areas.

As already mentioned, the underground discharge from the Lika region supported karstification inside the mountain massive, but the dominantly developed vertical caves indicate the very important role of vertical circulation through the deep unsaturated zone. During the latest geomorphological investigations the traces of Pleistocene glaciation have been established in the North Velebit region for the first time. According to BOGNAR et al., 1992, the cirque, valley and plateau glaciation types have been determined. Based on that, during interglacial periods of Pleistocene i.e. ice melting, the strong and concentrated recharge can be supposed on some locations. The concentrated recharge in the highly situated karst area significantly contributed to the development of the karstification processes and genesis of deep caves.

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Has Deep Karst a Fractal Behaviour?

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Abstract

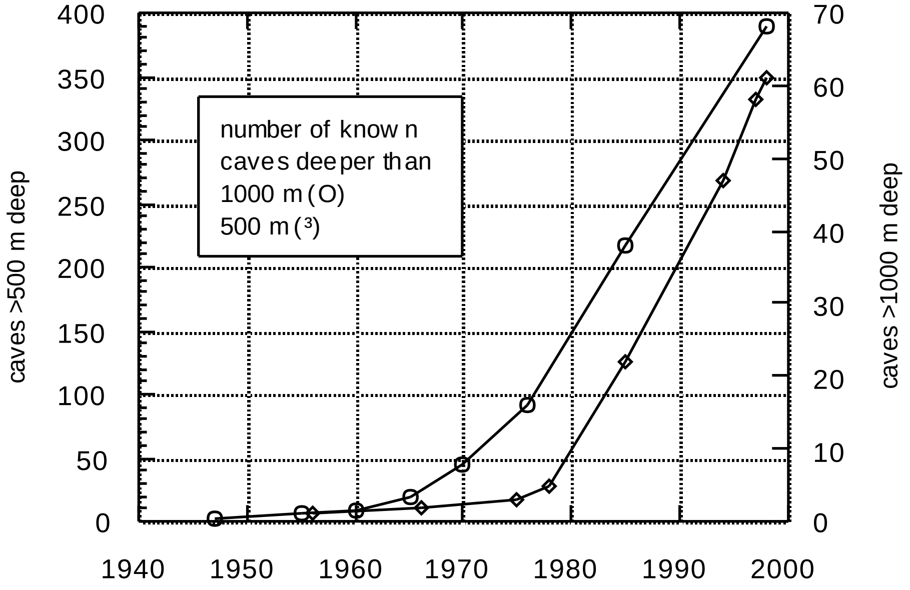
In the last 50 years the cavers explorations have increased exponentially the number of known caves enabling to built a consistent database. We have used the SIS-INRIA catalogue to analyse the distributions of length and depth of world caves. The cave length appears to be scale invariant that indicates fractal behaviour of genetic processes. The cave depth has a scale length of roughly 270 meters, probably connected with mountain scale dimensions.

Speleology is quite old but the modern approach was born in the last half of XX century. The length of all the conduits explored in Italy now amounts to 2300 km, and we may guess a world figure around 15000 km, but the explorative work has just begun. The table below shows the density of conduits in some large and well-explored caves.

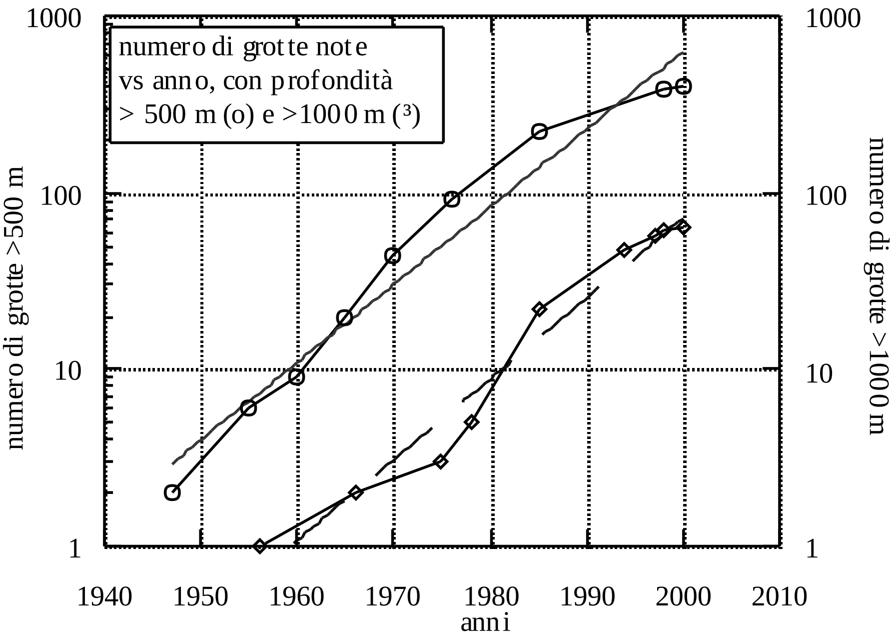
Cave system	Surface[km^2]	Lenght [km]	Vol. density[km\km^3]	Surf. density [km/km^2]
Jewel	6	120	120	20
Mammoth	80	550	34	7
Pierre st.m	20	50	1.7	2.5
Hyournedo	10	90	9	9
Piaggia bella	4	40	10	10
Col delle erbe	1.8	14	8	8
Corchia	3	50	14	16

In the table is possible to see that the surface density of caves is quite regularly, pointing to a ratio around 10 km of conduits per km^2 of field. We may suppose that the total length of caves is of the order of many millions of kilometres, hundredths times more than the explored up to now.

We may have a confirmation of this looking the distribution of number of known deep caves vs. time:



The graph shows a steep rise, but it does not show a well defined behaviour or a clear law. If we redraw it on semi-log scale we obtain:



It is possible to see that the increase is almost linear on time versus the logarithm of the number of caves, meaning that the number of explored caves increases geometrically, but it is possible to see a slowing rate in the lasts 15 years.

The next table shows the time required to double the number of known deep caves:

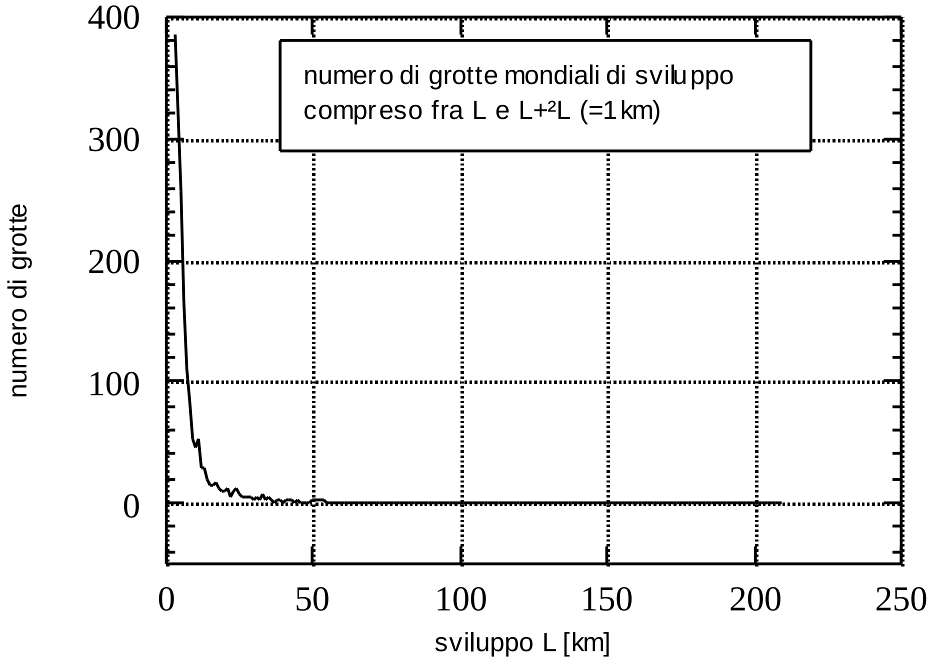
Time to double	1960-1985	1985-2000
>500 metres	5.5 y	17 y
>1000 meters	5.5 y	9 y

Exponential increases like these shows that we are very far from a complete knowledge of the deep karstic world.

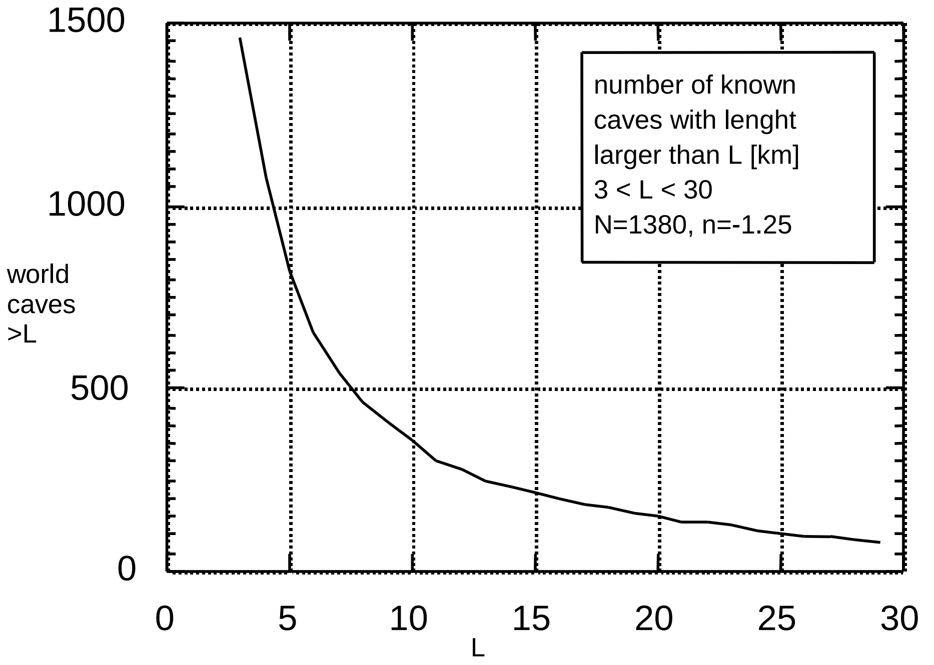
Let us discuss some features of this world as a whole.

In recent years large cave archives have been produced. We have considered here the deepest and longer caves list given by Eric Madeleine (SIS-INRIA, Sophia Antipolis, France) that consider a sample of 1400 long and 1000 deep caves, to extract some details on their distribution.

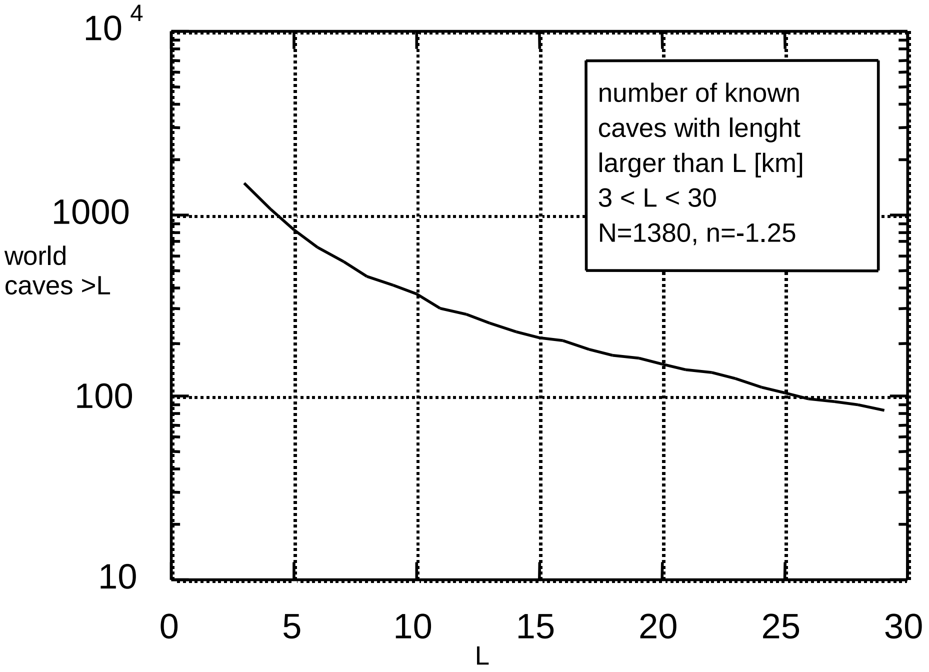
At first we consider the number of known caves longer than a fixed length L, i.e. the cumulative distribution of the caves length.



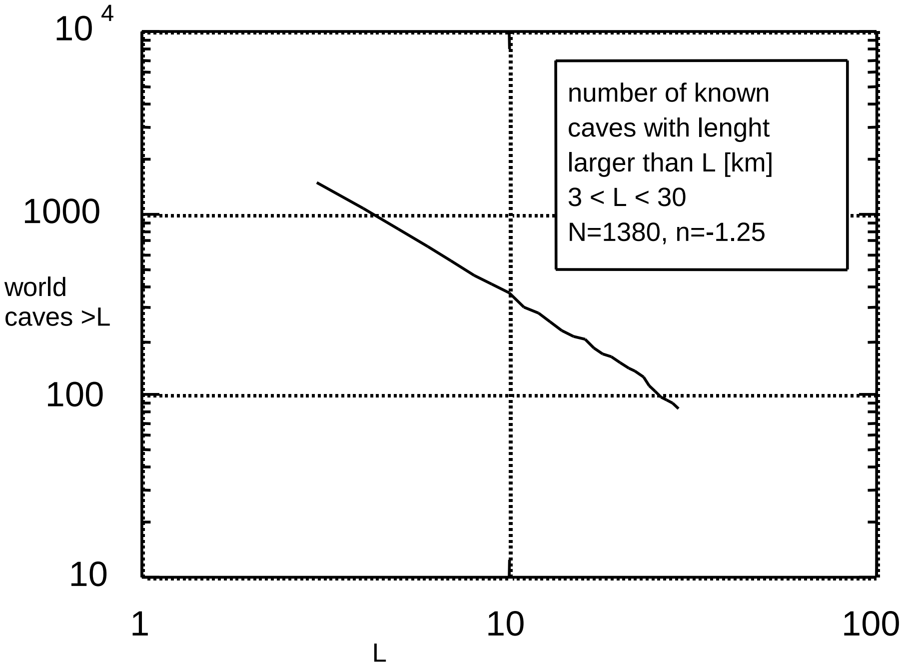
Let us focus our analysis in the length range up to 30 km:



Again, it seems a good idea to analyse it with semi-log scale.



The graph above shows us that the cumulative distribution is not exponential. If we use now the log-log scale we discover something:



As the cumulative distribution is a straight line, we conclude that there is a linear law connecting log(L) and log(N):

$$\log(N) = k\log(L) = \log(L^k)$$

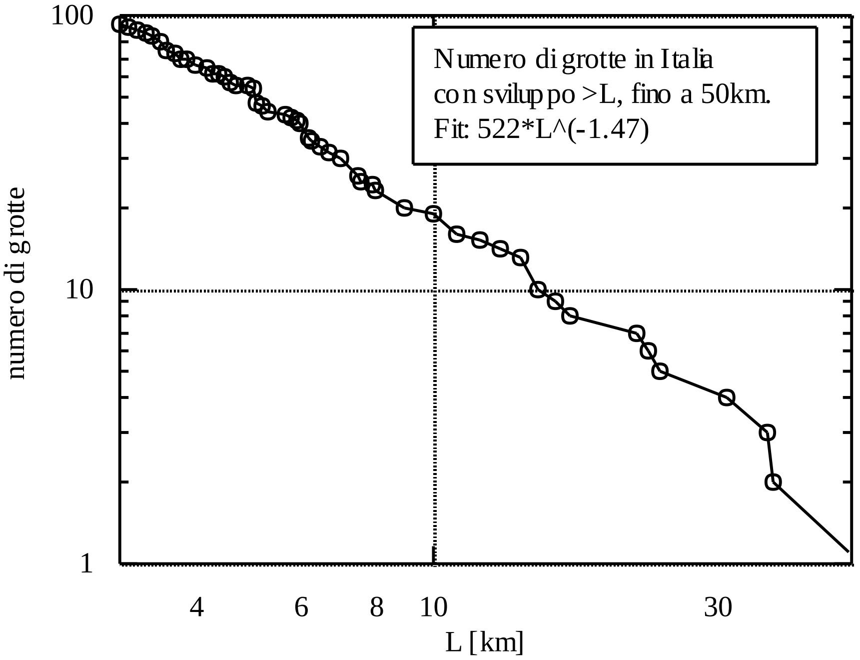
$$N = AL^n$$

Than there is, a power law connecting the lengths of the caves.

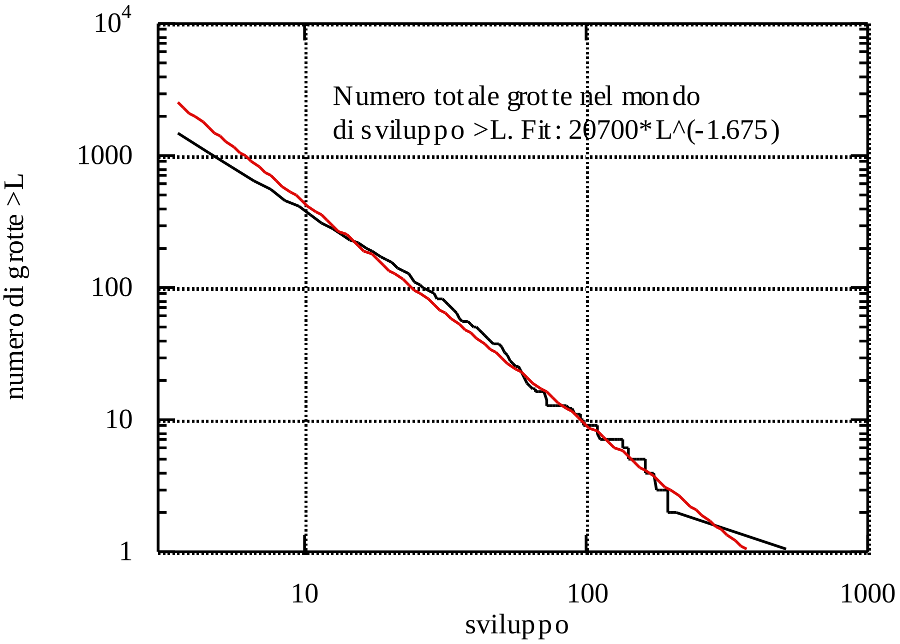
A similar law in physical systems describes processes scale-invariant, and is generally given by hidden fractal behaviour of generating processes (TURCOTTE, 1992).

The spectral index n is –1.25 for cave lengths between 3 and 30 km.

Let us check if the spectral index is related to some specific type of karst, analysing the data of a single country: we have used the Italy a sample.



The power law behaviour is unchanged, only the spectral index shows a small change. The global distribution is:

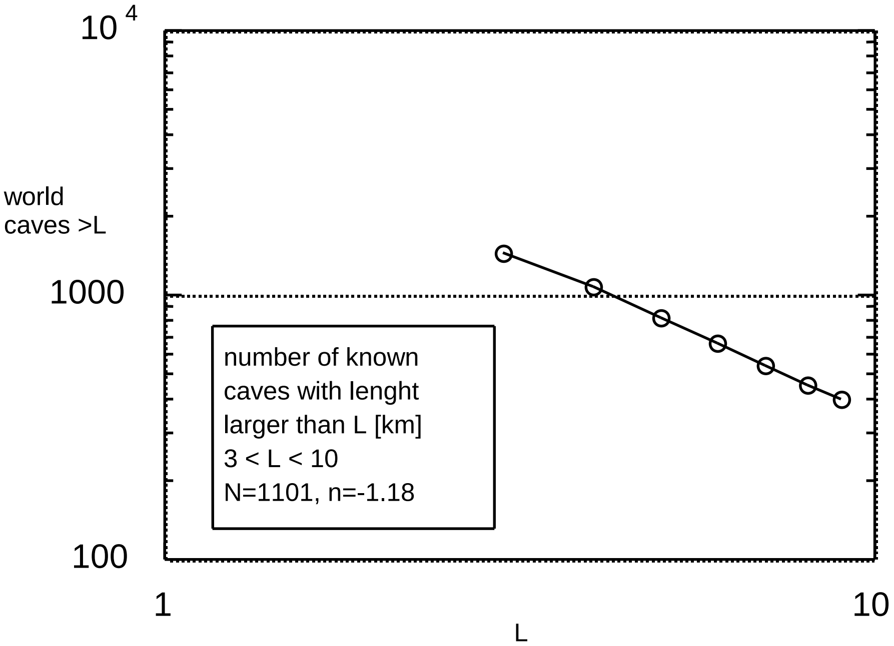


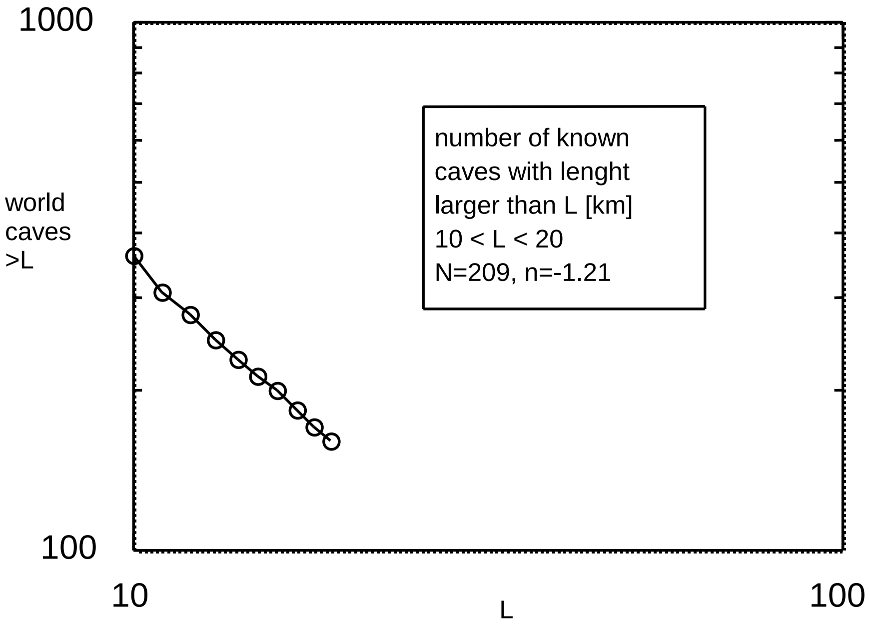
The global course is linear, nevertheless showing important fluctuations, mainly in the higher part, where the statistic is very poor.

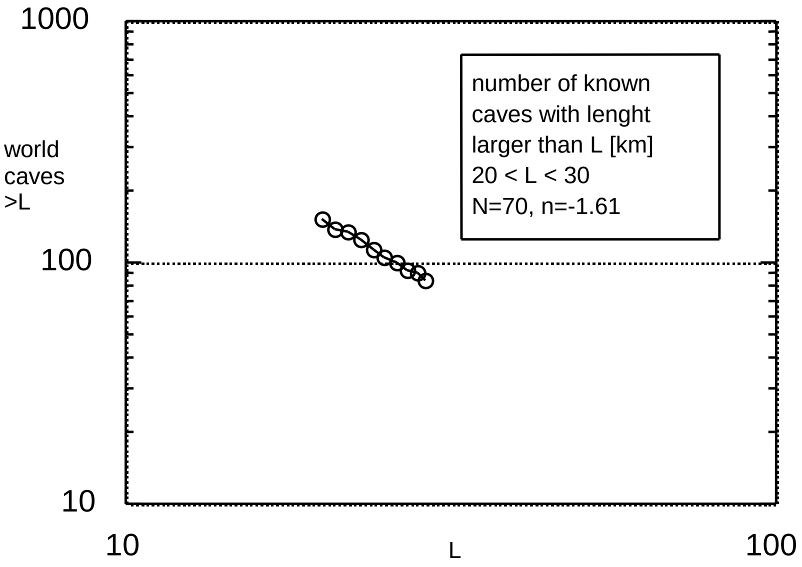
Obviously, this distribution is given by a large amount of different contributing processes. Some of them are physical, and typically resulting in a fractal behaviour: fragmentation of the sedimentary fields, fragmentation in different hydrological systems, fragmentation of rock and so on. Other are not connected with the geological system but with factors related to their knowledge: number of entrances, practical difficulties, local history of researches and so on.

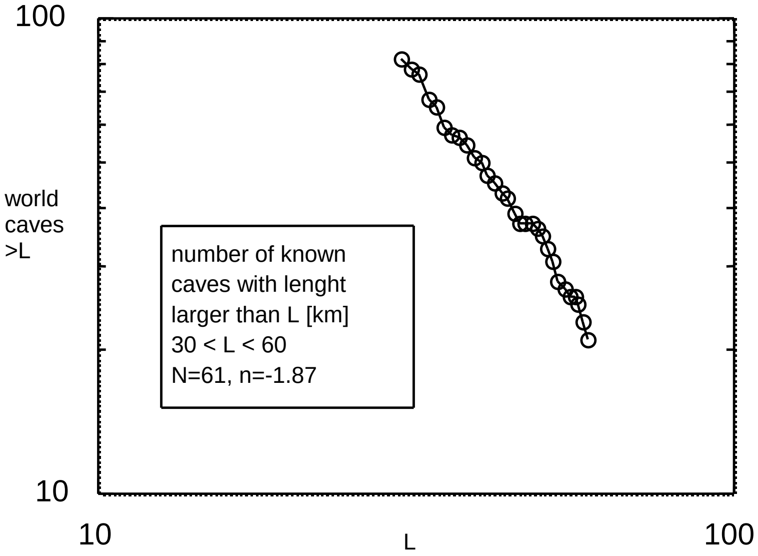
It is reasonable to look for larger details, considering different intervals of the cumulative distribution. We have divided the 3-560 km in different ranges.

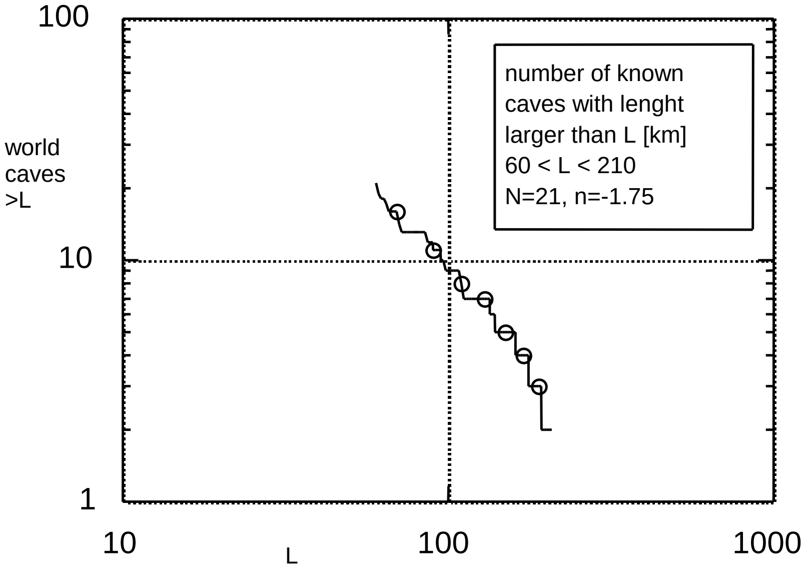
The first 3≤L<10 km, is probably the most representative due to its large statistic (1100 elements) and the world diffusion of involved caves. The spectral index is –1.18.




1000
100
10
100
L
world
caves
>L
number of known
caves with lenght
larger than L [km]
10 < L < 20
N=209, n=-1.21


1000
100
10
10
100
L
world
caves
>L
number of known
caves with lenght
larger than L [km]
20 < L < 30
N=70, n=-1.61





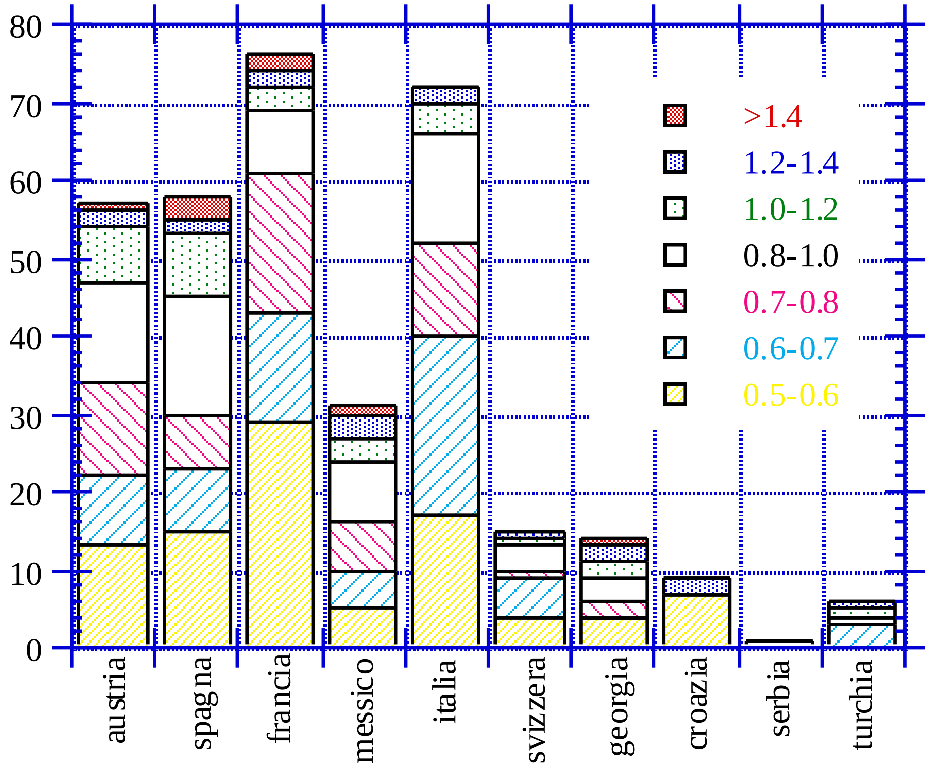
The other ranger shows a strong increase of spectral index, despite their quickly reducing statistics. The last decrease does not appear to be statistically significant, and would be stronger if Mammoth-Flint Ridge caves were included.

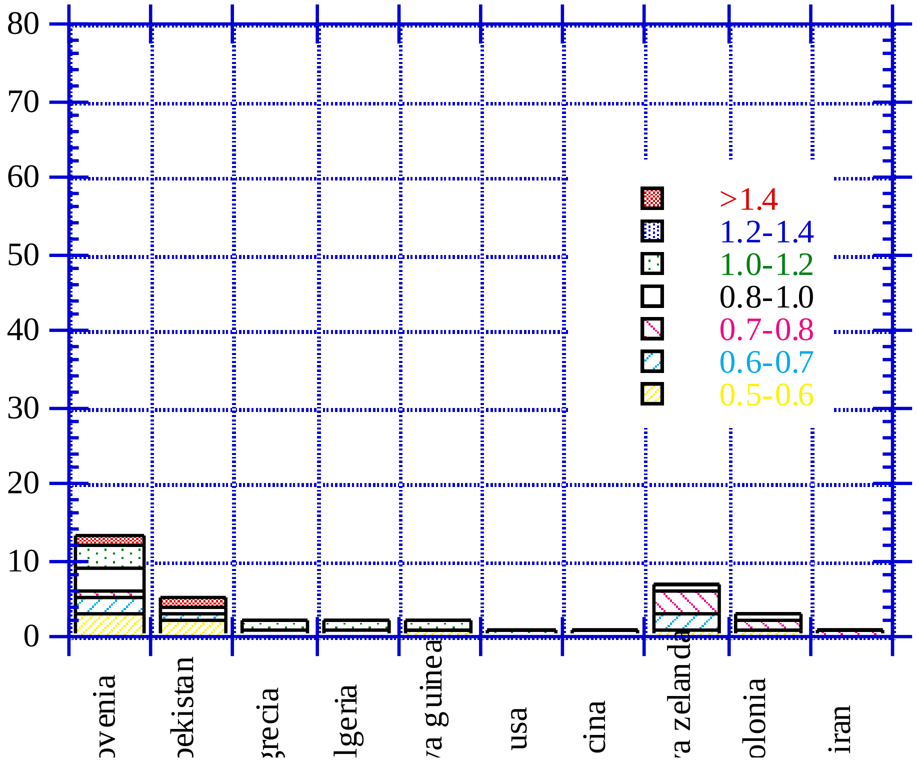
Range	Elements	Spectral index n
3≤L<10	1101	-1.19
10≤L<20	209	-1.21
20≤L<30	70	-1.71
30≤L<60	61	-1.87
60≤L<210	21	-1.75

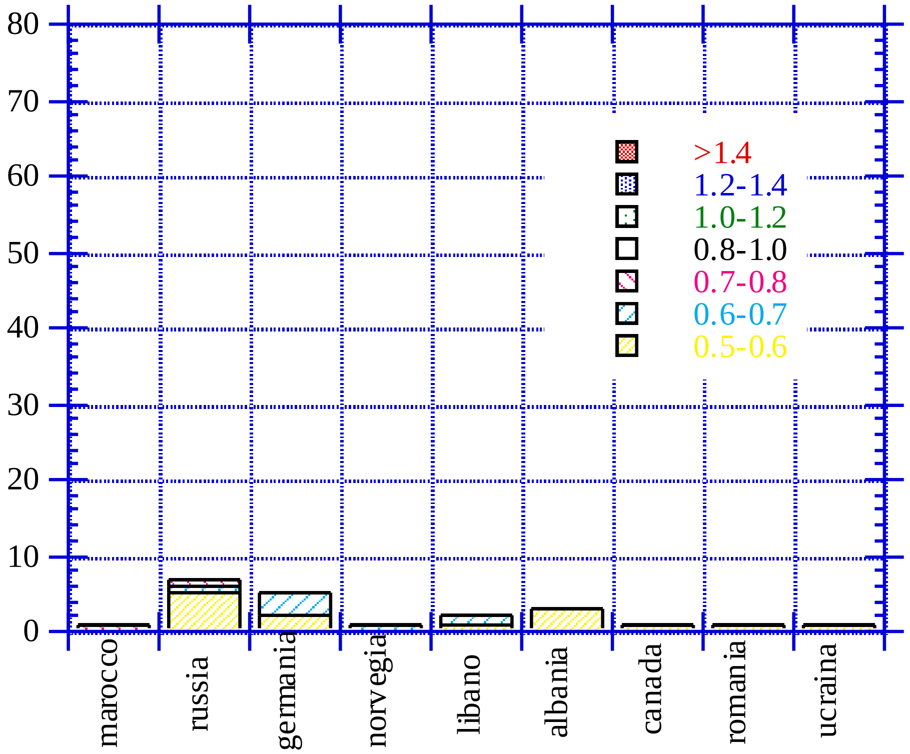
Let us consider now the deep caves. Physically the meaning of the cave depth (altitude difference between the highest and lowest points of caves) does not appear to be very pregnant because the loss of information is too strong.

If we consider the world distribution of deep caves it is also evident that the “deep caves” information come from researches that are not in worldwide scale.

On the almost 350 caves deeper than 500 meters, 22% are in France, 21% in Italy, 17% in Spain and Austria, that is more than ¾ of deep caves are in four countries that represents less than 0.5% of lands.

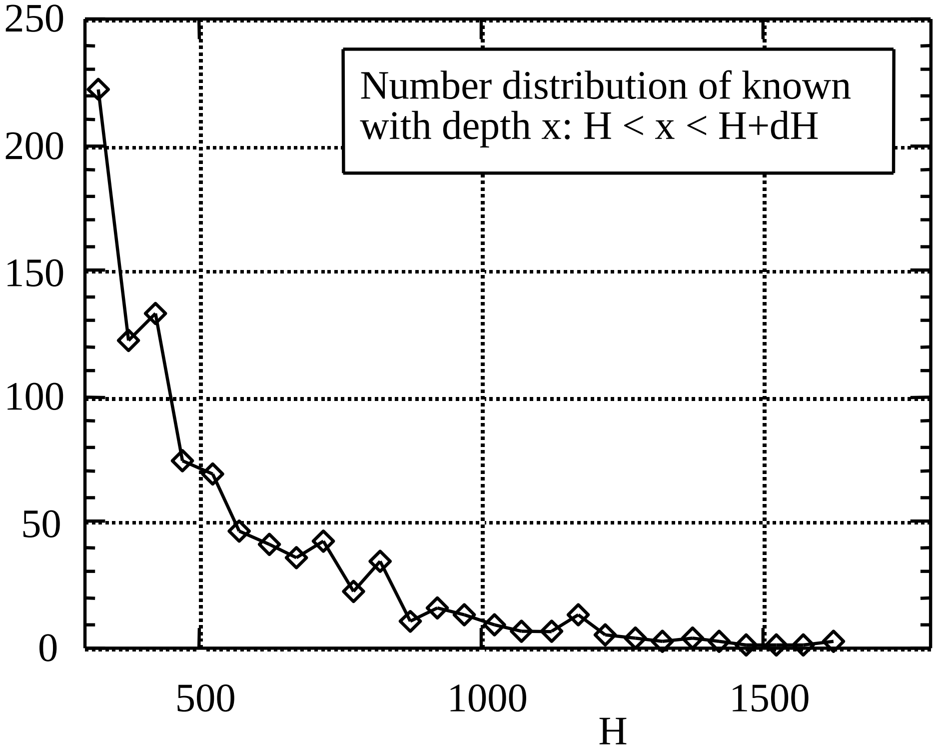


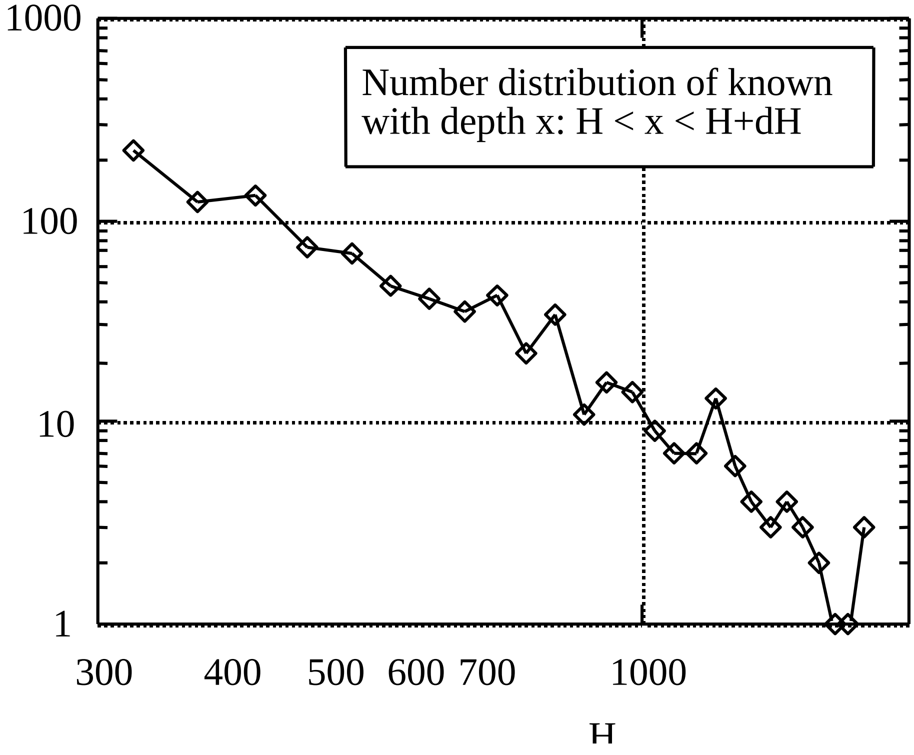


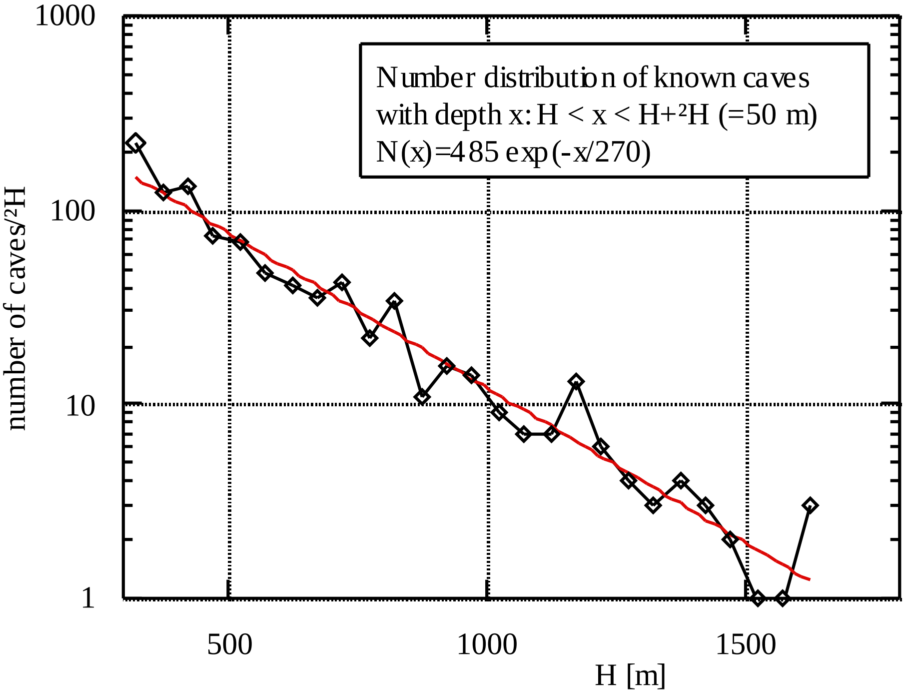


The analysis of the distribution is very interesting. We are going to do it with the differential spectra, that is the number of caves of depth x laying in the interval $H \le x < \Delta H$. We have chosen a ΔH step of 50 meters.

The distribution on linear scale does not give interesting results. Also the redrawing on a log-log scale does not show a hidden law.


Number distribution of known
with depth x: H < x < H+dH
250
200
150
100
50
0
500
1000
1500
H


Number distribution of known
with depth x: H < x < H+dH
1000
100
10
1
300
400
500
600
700
1000
H



Analysing it on a semi-log scale we obtain an impressive result.

The straight line shows an exponential behaviour with a typical length, showing that the cave depths are not scale invariant. So, it really exists a scale law for the cave depths, and in fact one can understand the typical length involved in a cave, just looking at a sketch of its vertical section. The fit of the data is:

$$N = A\exp\left(-\frac{x}{p_g}\right)$$

$$A = 4080$$

$$p_g = 270\text{m}$$

This distribution is Poissonian-like and may be interpreted as follows: exploring a cave, in any mountain, it is possible to go down one meter more with a probability equal to 1/240…

The real meaning is probably that it corresponds to the average karstic limestone thickness, that is, the inner dimension scale of karstic phenomena could be directly connected with the external scale of the mountain dimensions.

Conclusions

The cave statistic becomes to be sufficient to perform global analysis. The cave length appear to be scale invariant appointing to a fractal behaviour of genetic processes, but the statistics have to be extended to small caves.

The cave depth has a length scale of roughly 270 meters and is probably connected with mountain scale dimensions.

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Glacial Karst Phenomenology

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Abstract

Twenty years ago some caving groups around the world begun to study the karstic phenomena into the glaciers. A general view of genetic phenomenology of glacial conduits is given.

The roaring shafts (or glacial whirlpools) into which the torrents plunged attracted the attention of the first glaciologists. In 1898 Vallot explored the "*Grand Mulin*" on the *Mer de Glace* on the French side of *Mont Blanc,* descending to a depth of 60.5m.

At that time, no differentiation was made between speleology and glaciology, so those holes were considered to be caves just like the ones formed in limestone. However, as they were almost impossible to tackle using existing techniques the speleologists ended up by losing interest in this particular branch of caving.

So the white surfaces became the domain of the glaciologists unacquainted with karst phenomena. In the Twenties, was noted that on the *Lys* glacier the swallow-holes formed in the same area year after year notwithstanding the movement of the ice (MONTERIN, 1930). He concluded that they must be stable structures like a whirlpool in a river, continuously formed by new water; when the ice reaches that point it takes on the form of a cave, always more or less the same.

But by then glaciologists and karst speleologists had gone their different ways, each coining different terms for the same structures. Cavers forgot about caves in the ice, and glaciologists forgot that they operated in a karst environment (PATERSON, 1969, NYE, 1976).

And so we come to the early Eighties. By now there are techniques and men capable of undertaking the descents and, as often happens with research, when the time is ripe a problem is tackled simultaneously by different groups working independently. Polish speleologists set about the *Svalbard* on *Hansbreen,* the Swiss start on the *Gorner* glacier and in Iceland. The French have another go at the *Grand Mulin* , and the Italians attack the *Gorner* and the *Miage.*

The challenge gathers interest and starts to be tackled systematically. The *Union internationale de spéléologie* sets up a committee and organises periodic meetings on the subject.

The Italian group have the most systematic experience of speleological expeditions and wide-ranging research, with operations in the Alps, Karakorum, Tien Shan, Svalbard and in Patagonia (BADINO, 1995). They soon realise that crevasses and caves have to be considered separately because, if a glacier has a large number of crevasses, the water is absorbed uniformly without the concentration of energy that allows the water to hollow out caves. With the aim of guiding the research in the right direction, we have tried to bridge the gap between glaciologists and karst speleologists going back to the beginning of the century, and linked to the insurmountable technical difficulties posed by the glacier caves.

At the beginning of the Seventies two glaciologists (ROTHLISBERGER, 1972, SHREVE, 1972) tried to build models of what can happen under glaciers: critical areas, conditions for existence, plasticity, etc: However, their research referred to the formation conditions of channels on the rocky bed, a type of water flow of little interest except for the last few tens of metres before the water comes out into the daylight, where the glacier becomes thin. In practice, the ice was not considered capable of supporting karst phenomena in itself, but only as an interface with the rocky base.

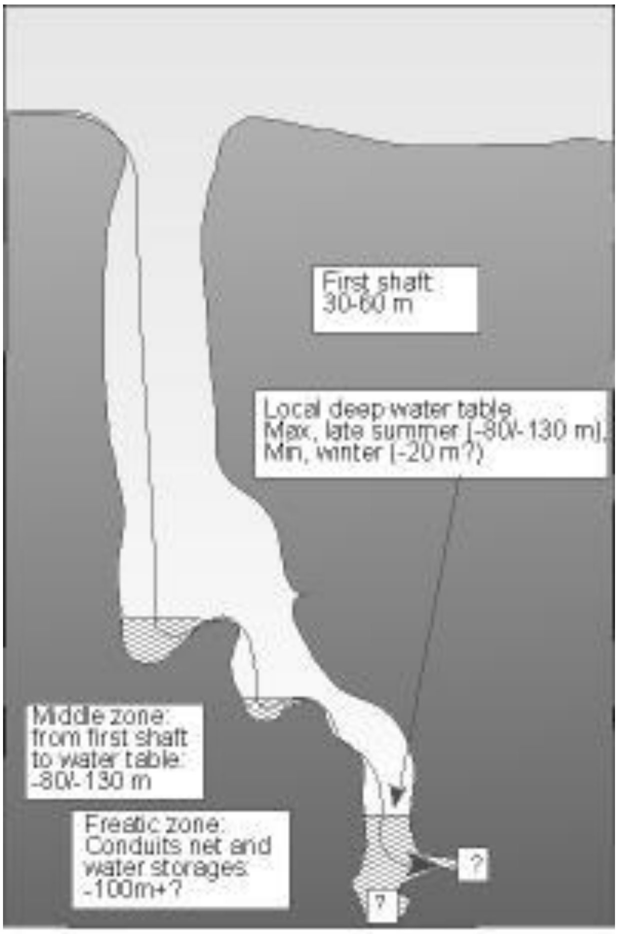
The explanation of this limitation is simple: at that time it was impossible to carry out an experiment in the field, and the structures which could be observed at the mouth of "mountain" glaciers are always situated precisely at the ice-rock interface. Another difficulty encountered in building models was that the calculation of formation conditions of the drainage network, highly cyclical due to the seasons, necessitated the use of digital computers which were rather inaccessible at that time.

Exploratory campaigns and the development of a simulation programme have enabled us to outline the general characteristics of water flow inside the glacial mass.

The incompatibility between the presence of crevasses and the formation of karst phenomena has limited the speleologists' interest to vast, level glaciers. As there also has to be water in the liquid state, the temperature should be around 0°C. In short, it should be a "temperate" glacier.

With regard to the overall structure of cavities, in general they open with a shaft about 40-60m. deep, created by the falling water, but the torrent often disappears into inaccessible cracks at the shaft bottom. Sometimes, however, the first waterfall gives access to an impressive environment where the torrent rushes along a sort of sub-glacial canyon, with shallow waterfalls and brief horizontal stretches, finally to disappear into a pool and drain away (Fig. 1). In general the canyon becomes smaller and smaller and the terminal pool of water is situated about 100 m. under the surface (BADINO&PICCINI, 1995).

The insertion of the mechanical characteristics of the ice of these "karstic" glaciers into a series of mathematical models developed by the *Dipartimento di fisica generale dell'Università di Torino* has enabled us to clarify the overall phenomen of intra-glacial water flow (BADINO, 1990, 1992, 1994) .



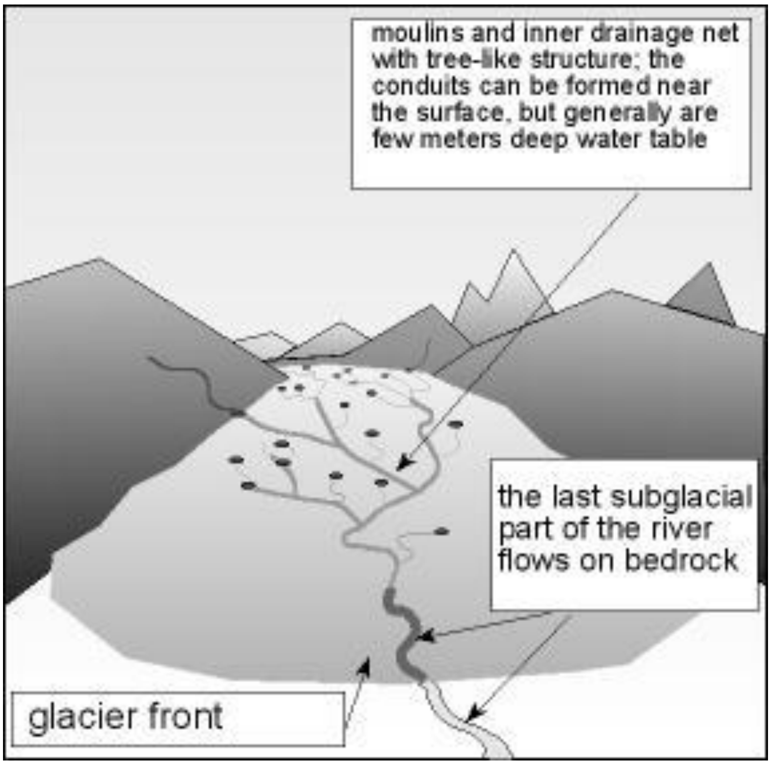
The first essential characteristic regards the plastic behaviour of the ice, which at low pressure is similar to rock, whereas at high pressure it behaves almost like a liquid. More precisely, the deformation it undergoes is proportional to the cubic root of the strain to which it is subjected, and this enables us to calculate an "average" life span (collapse time scale) for every cavity that forms in the glacial mass, on the basis of the pressure to which it is subjected, i.e. its depth below the surface (HOOKE, 1984).

A cavity (cave or crevasse) at a depth of a few metres has a much longer duration than the local evolution time of the ice (being dragged downhill, seasons) and therefore its plasticity has little importance in its development; it is as if it were carved out of rock. A cavity at a depth of 70-80 metres has an average life span of approximately one season; so that is the maximum depth at which structures linked to seasonal cycles can survive. Below that depth, collapse times are shorter; structures last as long as the agents that form them remain in activity, after which they collapse and disappear inside the mass of fluid ice.

The drainage structures nearer to the surface, where the plasticity is negligible, are therefore rather simple; the streams form and swell in depressions in the glacier, often in areas where glacier tongues converge, moving at different speeds. The internal friction causes melting and consequently the formation of depressions. The torrent rushes there and finds its way underground where the concentrated flow of energy is more than the minimum required to perforate the surface at that point, and so a "glacial whirlpool" forms. (Fig. 2)

Inside the whirlpool the potential energy of the falling water is released into the air at the point where the water strikes. As it is an air pressure system in isothermal conditions (any increase of water enthalpy is utilised in the melting), the system develops proportionally to the energy released by the waterfall. For the first fifty metres the falling water meets no resistance from plastic collapse so the cavity becomes larger and larger throughout the season.

But as the waterfall deepens, the ice walls tend to collapse into the cavity which narrows into the characteristic canyon form. The widest points are those where energy is released, that is the pool of water at the base of the shaft and, in general, where the torrent flows, which doesn't facilitate the work of the researcher …



This simple model seems to explain most of the internal forms of glacial whirlpools, with some notable exceptions, which we shall discuss. Since the first expeditions, it has been clear that the structures through which we advanced with great difficulty must only be a small part of the internal structures of the glacier. The caves tended to be vertical, so they had to be tributaries of the main drainage system which was presumably located beneath the small pools of water where the torrents disappeared at the end of the caves.

On the basis of our observations it seemed that, contrary to what had previously been believed, the torrents did not get as far as the rocky bed, but went to fill one or more of the phreatic strata at the "plastic behaviour" limit of the ice. Our hypothesis was also supported by other clues; some explorers had taken us into tunnels with a roundish section, similar to those which form underwater, by means of resurgence, in calcareous karst phenomena. It was therefore reasonable to try to construct melt-water flow models within the aquifers.

The physical process is slightly more complicated. The collapse times of the cavities within the aquifers is reduced, as what counts is the difference between the pressure of the ice and the pressure in the cavity. If the latter is full of water, the collapse is delayed. As you go deeper, the water pressure rises more quickly than the pressure of the ice because of the increased density (100kg/cub.m. compared with 917); resulting in the formation of deep water deposits, then *jokulhlaup*, and instability, which, in certain conditions, might possibly trigger off a surge of the glacier.

Karstic excavation is also the result of the release of potential energy in the fall between the points upstream and downstream of the melt-water flow network. In this case, however the definition of the model is extremely delicate, because of the key role played by the loss of charge along the channels, a parameter which depends critically on their form, and on water flow conditions, etc.

The main novelty in the phenomenon of intra-glacial melt-water flow, however, regards the overall structure of the network of drainage channels. In fact, the process is no longer isobaric or isothermal as the temperature in equilibrium between water and ice depends on the pressure. From 0°C at atmospheric pressure it decreases by 7.5 millikelvins for every increase of one atmosphere.

In a hypothetical U-shaped sub-glacial channel - a common form in calcareous aquifers (*valchiusane* sources*)* - at the highest point upstream the temperature is about 0°C, but as the water flows down, its pressure increases and, when it becomes "too warm" with respect to the surrounding ice, it uses up excess internal energy to melt the ice on the walls. Therefore the descending stretch of the U-shape becomes wider.

On the contrary, in the ascending stretch, the water which moves towards lower pressures, resulting colder than the ice, solidifies on the walls.

So the process evolves whereby the descending parts widen and the ascending parts become narrower, rendering the passage of the water more difficult. In such a structure, the level of the pool upstream rises to compensate for the increasing impedance in the ascending parts but cannot exceed the level of the outside surface without overflowing. At that point, the glacial whirlpool outside fills with water and forms a lake, but the internal flow stops and the drainage continues elsewhere. So, inside the ice either the U-shaped structure doesn't succeed in forming, or it tends to close up.

It's worth noting that the descending part can continue to exist even in the absence of drainage and, dragged downhill by the movement of the glacier, can become a potentially menacing reservoir.

The interdependence between pressure and temperature in equilibrium of water and ice also has a considerable effect on the single channels. In most case, intra-glacial water flow takes place in turbulent conditions, with a complete stirring up of the fluid as it rushes along the channel, whose ceiling is warmer than its floor by almost on thousandth of a degree for each metre of diameter. When the water strikes the floor, it excavates; when it touches the ceiling, it deposits.

The result is that the tunnel moves gradually downwards. The movement is very slow, but it gains speed with the increasing diameter of the tunnel and the speed of the water. In typical intra-glacial water flow conditions, as described in the calculations, tunnels move down one metre per week, which means that the entire network of channels tends to "settle" as low as possible.

Another physical effect which helps to define the structure of the sub-glacial drainage network is the tendency to eliminate possible by-passes. Suppose we have two tunnels that connect two points of the glacier in parallel. The difference in pressure at the tunnel ends will obviously be the same; so if one has a lesser impedance than the other (because it is wider, or shorter) the flow has a strong tendency to favour it, and to concentrate the excavation in that tunnel. The second branch, gradually abandoned, collapses progressively and finally disappears.

As we are dealing with rapid processes, we cannot expect the drainage network to be very complex; it will tend to take the form of a tree which connects the various shafts and then flows into a single catchment channel. This flows under the ice for about 100 metres until, in the vicinity of the end of the glacier tongue, the thinning of the ice above it makes the river spread out over the glacier bed in search of an outlet. From there, by means of one torrent (and a large channel, as in the *Batura* and *Enilchek* glaciers) or numerous torrents, the water emerges into the daylight.

When the sub-glacial channels are full, they behave like structures in equilibrium between excavation caused by loss of charge of the water during transit and filling due to the caving in of the channels. When the flow stops, for instance during the cold nights, the tunnel gradually becomes narrower and impedance increases. Therefore, when the flow resumes, the release of energy will be greater and the excavation will be faster until the previously existing conditions are re-established. In the same way, a temporary increase of the flow enlarges the channel in excess of the section of equilibrium, to which it will return as soon as the flow decreases.

The diameter of these tunnels remains reasonably uniform; any narrowing of the passage, due to collapse, creates an increase of impedance and a concentration of local energy release until uniformity is reinstated.

So, the dimensions depend on the pressure of the ice on the walls, as well as the gradient, shape and depth of the tunnel. Obviously, local tension of the ice, the inclination of the glacier surface and bed, and the depth of the aquifer will all affect the dimensions.

To give a general idea: a tunnel with a flow of 1000kg. of water per second, at a depth of 100m. will have a stable diameter of approx. 0.9 metres and the water will have a speed of almost 1.5 metres per second. If the flow is reduced to 100kg. per second, the diameter of equilibrium becomes 35 centimetres and the water will flow at 1 metre per second.

These figures given by the model are consistent with the few fragmentary sections we have been able to observe.

We have seen how rapid variations in the flow result in slight fluctuations around the structure of equilibrium, in fact calculations and direct observation both show that daily cycles do not cause significant variations.

The situation changes considerably when the variations take place over a longer time span than that of the collapse of a tunnel, for instance with the onslaught of the cold season. The deep flows stop and the channels gradually begin to cave in, in a process contrasted only by the hydrostatic pressure of the aquifers pushing upwards. In the *Gorner* glacier the speed of this rise was approx. two metres per week, rather slow but sufficient to fill the cavity almost up to the surface.

This rising process is rather complex, and a detailed study could provide information on the deep structure of aquifers and on the risk of catastrophic phenomena; for example, the presence of basins included at the end of the network considerably accelerates the rising speed.

In Spring the network still exists, but a bit further downstream and under more pressure than a few months earlier. The external flow of water starts up again in the same way as the previous year, perforating the ice in more or less the same places, as these are linked to the tensive structure of the glacier, which in turn is determined by the binding conditions of the rock. The downstream parts of the network are dragged towards the glacier front and crushed, while upstream, deep within the "new" glacial whirlpools, others are formed.

Therefore, the deep network also proves to be a structure that fluctuates around a pattern of equilibrium according to the seasons, and virtually moves upstream at the same speed as the glacier moves downhill.

The freatic tunnels inside the glaciers are extremely unstable; once abandoned by the water they cave in, and the deeper they are, the more quickly they collapse. So, a consistent network of fossil tunnels like those that can be found in calcareous mountains, probably doesn't exist in glaciers.

Direct observation of these water flow networks is therefore extremely difficult. In practice it is only possible to visit the superficial part where collapse times are much longer, but often these channels are fragmented by the forward movement of the glacier, and above all by ablation. The "stable" submerged part with an active flow of water, is almost inaccessible.

However we are perfecting techniques to explore it in late autumn, when the water has finally stopped but the overall rise of the aquifer is still slight.

We have already delineated "normal" intra-glacial water flow conditions. The exposed parts of the network which can be directly explored are rather few, whereas the submerged parts require an enormous technical effort. It is a fact, however, that structural variations in sub-glacial caves are manifold, and above all are linked to meteorological conditions in the area, and the local situation of the ice.

Most of our efforts are therefore concentrated in search of particular conditions which would enable us to explore more thoroughly. We found the most favourable conditions in the glaciers supplied by *lo Hielo Continental Sur* in Patagonia, some 22,000 square kilometres of ice. The glacier tongues that drain it can descend as low as 300 - 400 m. above sea level, where ablation is very intense. In addition the orography permits the formation of very wide glacier tongues with a regular gradient. The glacier nuclei are practically impenetrable to water, and extremely transparent.

In these conditions, on the one hand, fantastic environments are created by the light which acts as a "wave guide". In fact, high frequency light is propagated more easily, with the result that every crack seems to emit blue light and the cave walls appear luminescent to a depth of 80-90 m. below the surface.

The other, and structurally more important, effect is that the flow of energy necessary to perforate the deeper parts is much greater than normal.

Rivers that flow under the glacier surface do so superficially, overcoming the first "permeable" stratum of ice to a depth which can vary from a few decimetres to about twenty metres. Then, when they come up against the glacier's "impermeable" nucleus, they flow over it.

So, just below the surface, and parallel to it, drainage networks form which can be explored when the flow is reduced. One of these, situated in a minor glacier and only partially explored, extends 1200 m. and is the longest endo-glacial cavern known to date.

Glacio-speleology was born very recently as a branch of amateur speleology, but it is already succeeding in clarifying many of the processes that occur in glaciers, and in delineating the world contained inside them. In the short term this will improve accuracy in evaluating the "mass balance" of vast, temperate glaciers, precisely those which are used to estimate global climate changes.

In the longer term it will lead to a better understanding of transitory and catastrophic phenomena, characteristic of just those glaciers where karst phenomena are present.

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Cross-Formational Flow, Diffluence and Transfluence Observed in St. Beatus Cave and Sieben Hengste (Switzerland)

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Summary

Observations in St. Beatus Cave and neighboring caves revealed complex water flowpathes that can be used for explaining the behaviour of tracing experiments. The observations prove that even in vadose conditions, cross-formational flow, diffluences and transfluences are a quite common feature. Therefore, also the vadose karst has a very complex organisation.

Introduction

Tracing experiments in karst often evidence "strange" flowpaths. Many of these results have had hitherto only theoretical explanations and no directly observable analogon. Observations in caves provide nice examples explaining this type of "strange" behaviour. We will mainly concentrate on the vadose parts of a karstic aquifer. As a general rule, water flowpaths in the vadose part are considered as being vertical to subvertical, until they reach either the phreatic parts or an aquiclude rock, on which they then flow towards the spring. The first impression of St. Beatus Cave matches exactly this rule (Fig. 1). However, detailed observations show that there are many differences to it, which shall be explained here.

The St. Beatus Cave is located in central Switzerland, north of Lake Thun and south of the Sieben Hengste mountain (Fig. 2). The cave is spring of a catchment area that extends to the north. There is no connection to the catchment or the caves of the neighbouring Sieben Hengste area (Häuselmann & Otz 1997), that constitutes one of the biggest cave complexes of the Alps, with a total of 280 km of surveyed passages.

The stratigraphy is presented in Figure 1: Over the siliceous limestone (lower Cretaceous), that is medium karstifiable, lie the 30 to 50 m thick Drusberg marls, which in almost all cases constitute an aquiclude and therefore the base for the subterranean flowpaths. The lower Cretaceous Schrattenkalk (160-320 m) then follows, a very well karstified pure limestone, in which almost all caves develop. On top of the Schrattenkalk lies the Eocene Hohgant series, a complex mixture of sandstones, sandy limestones and shales, that is usually only permeable along fractures.

Cross-Formational Flow

The boundary between Drusberg and Schrattenkalk is not a sharp one. Especially in St. Beatus Cave, we observed three beds of limestone within the uppermost Drusberg layers. This interbedding is due to the changes in sea level and consequent sediment deposition. At least one of those limestone layers disappears towards the entrance of the caves (Figs. 3 and 4).

The observations of those different interlayers has been possible because there are several cave passages in them, that alternate between the limestone parts. Why are passages there? One possible explanation would be that the sedimentation of Schrattenkalk and Drusberg interfingers as shown in Fig. 3, and that the different water courses then are trapped between Drusberg layers. Whereas this might be a possibility for the initial capturing of the waters, observations show repeated jumping between the layers, which cannot be explained any more by simple trapping (Fig. 4). The structure of the rocks (fractures etc) has to play a role.

It is well known that relatively thin aquicludes can be cut by the erosional forces of a vadose stream, allowing the water to flow into the strata below, as is the case in the Faustloch meander in Sieben Hengste (for location see figure 2). The morphology of the galleries of St. Beatus Cave, however, show that the jumping (both up and down the strata!) already occurred in phreatic state. There are even some small parts of St. Beatus Cave that developed entirely within the marly parts of the "aquiclude". The same thing is observed in nearby Bärenschacht (Sieben Hengste system), where most of the "Galerie des mille visages", about 200 m long, developedstraight across the Drusberg marls on the left side of a thrust fault. Some tens of meters farther down, a phreatic gallery again crosses an upthrusted Drusberg block without any sign of following the limestone that lies some meters higher.

Those examples show that cave genesis is well possible within, below and across "aquicludes" under phreatic conditions. Later vadose flows in those conduits may follow those flowpaths or create new ones, leading to some strange results tracing experiments often display.

Figure 1: Longitudinal section through the St Beatus caves

Figure 2: Overview over the cave region of Sieben Hengste with some localities

Figure 3: Possible explanation for the primary origin of the different water courses

Figure 4: Schematical sketch through St Beatus Cave and the location of the galleries.

Figure 5: The diffluences in St. Beatus Cave. The numbers refer to the text

The Diffluences

Anyone knows the famous children's game about the water from the home well, that flows into the small brook, that reaches the river, which in turn joins the stream that flows into the sea. Adult persons call it "dendritic system" and claim that it is ubiquitous on Earth. Hydrogeologists, however, have a more differenciated picture of reality, since they know that under phreatic conditions, water flows according to its head, and that a karst region might have several sources connected to one injection point (see the example of Totes Gebirge in Austria by Maurin & Zötl 1964). So far, so good. Now, we know that resembling flowpaths also are proved by tracing experiments in regions where the phreatic realm should be much lower than the geologic barriers (p.ex. in some parts of the Swiss Jura). If we can exclude the above mentioned possibility of aquiclude karstification, another answer to this behaviour must be found.

One possible answer lies in the fact that vadose diffluences (rivers parting and taking two different ways) also exist and that they are much more numerous that one might think. In the St. Beatus Cave, we found at least six proven diffluences (Fig. 5). The first one can be seen just behind the entrance to the cave. There, the water course divides from a lake dammed by sinter and breakdown, and joins only at the surface. The second is the brook coming from the sewage station from Beatenberg. It is met as a whole in the far end of Erosionsgang and later divides, reappearing in Bachgrotte and Spaghetti-grotte. The third, small one is the seepage in Erosionsgänge that divides on sinter floor. The fourth one is found in Alibaba, where a waterfall partly splashes into Alibaba and partly into the main gallery of Westgang. The fifth one is in Biwakgänge, where a lake, dammed by sinter, is emptied through both sides, inflow coming from the ceiling of the cave. The sixth one at the entrance of Der Vermisste, where the water divides on Sinter floor. There is even a seventh one in the Tourist part, that divides only under flood conditions.

Other vadose diffluences are found in Kaltbachhöhle, Senkloch, K2, Bärenschacht, and the Cave System of Sieben Hengste, all caves being in Sieben Hengste region (Fig. 2). This enumeration is by far not complete. All cited examples are **not** dependent on local geology, but inherent to karstological features.

As a conclusion, it seems that vadose diffluences are not as rare as assumed, but seem to be quite a common feature for underground rivers. In all of the examples cited above, the water finally reappears at the same spring. But, of course, this is by no means obligatory, and depending on the voids encountered, flowpaths divided in vadose conditions might join quite different springs.

An extreme case of division is encountered near the entrance of Bärenschacht (Fig. 2). The small river disappearing just before reaching Bärenschacht entrance flows into Beatus cave (Häuselmann & Otz 1997). If there is high flood, it rushes down past Bärenschacht and flows down on the surface. Every water falling to the left side of this brook, within some 100 m^2, will join Bärenschacht and therefore Bätterich spring.

Transfluences

It is known that, if karst rocks are overlain by impermeable caprocks, there are surface streams that often flow in another direction than the karstic flowpaths below. It is less known that the same thing may happen even if there's no caprock present. The Emme river flows through a gorge between Hohgant and Schrattenfluh that is cut into the Schrattenkalk (Fig. 2). In the same Schrattenkalk, the waters coming from the Schrattenfluh flow in direction of Lake Thun, so almost the opposite way. There is, at least in normal conditions, no indication of waterloss in the Emme gorge nor indication of present or former caves. We admit that in geologic time, this Emme crossing might disappear and the river may eventually dry up in profit of the subterranean system. However, for historic times and for tracing experiments, today's state is important and is being measured.

Transfluences are also observed in St. Beatus Cave. The Hohe Nordgang and the Ostgang were created at the same time and under phreatic conditions. They are divided by the uppermost Drusberg intercalation (see Fig. 4). Today, flow in both galleries is essentially vadose. The Hoher Nordgang river crosses the Ostgang several times without loss of water, until they eventually join to form the main gallery. Here, the division is due to geologic structure.

Another transfluence is known in Sieben Hengste, where a small brook from the Dakoté entrance of the Cave System (Fig. 2) flows in southeast direction, whereas a rivulet in Blatersystem, some 150 m below, flows in southwestern direction.

Conclusion

All the observations presented here are observable analoga to the behaviour of tracing experiments. Especially in St. Beatus Cave, we observed all three cases of flow, therefore the cave represents a sort of a "hydrogeological model" that is observable *in situ*.

Cross-formational flow, diffluences and transfluences virtually explain all "strange" results of dye tracings in karst regions. One problem, however, still exists for those dye-tracings where *in situ*-observations or p.ex. the structure of the bedrock are not known: It will often be quite impossible to tell which of those three types is dominant and responsible for the result of the dye tracing experiment.

Acknowledgements

The dye tracing that yielded "inexplicable" experiment was financielly helped by different caver's organisations and the Hydrologisches Büro Dr. Otz in Bellmund. The cavers (especially Alex Hof) are thanked for many fruitful discussions. Without their mapping, this work would have been impossible. We thank the St Beatus Cave Society, who allowed the access to the cave. The present paper was created during my PhD time with the help of P.-Y. Jeannin and M. Monbaron. The

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Quantitative Annual Speleothem Records of Temperature and Precipitation in the Past – A new tool for Reconstruction of past karst denudation rates

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Abstract

Calcite speleothem luminescence depends exponentially upon soil temperatures that are determined primarily by solar infrared radiation in the case when that cave is covered only by grass or upon air temperatures in case that cave is covered by forest or bush. In the first case, microzonality of luminescence of speleothems can be used as an indirect Solar Insolation (SI) index, but in the second - as an paleotemperature proxy. So, in dependence on the cave site we may speak about "solar sensitive" and "temperature sensitive" paleoluminescence speleothem records like in tree ring records, but in our case record may depend either only on temperature or on solar irradiation (SHOPOV et. all, 1996 a,b).

In case of Rats Nest cave, Alberta, Canada we reconstructed annual air temperatures for last 1450 years at the cave site with estimated error of 0.35 ^{0}C, while the error of the direct measurements is 0.1 ^{0}C. For this purpose we obtained a stacked 66000 data points paleotemperature record from Rats Nest cave, Kananaskis karst region, Alberta, Canada. It covers last 1450 yrs with resolution of about 8 days for most of the time span. Paleoclimatic records has been derived from speleothem luminescence, calibrated by actual climatic records from near climatic station in Banff, Alberta. The sample was dated by two14-C dates, U/Th dating, autocalibration and annual bands counting dating. All produced consistent age, best estimated as 1450 +/- 80 years.

A reconstruction of the past annual precipitation rates for the last 280 years has been obtained from speleothem annual growth rates, derived from the distance between annual luminescence bands, calibrated by actual precipitation record from near climatic station in Banff, Alberta, Canada

We demonstrated the potential of the quantitative theory of solubility of karst rocks (SHOPOV et. al, 1989,1991a) in dependence of the temperature and other thermodynamic parameters to make reconstructions of past carbonate denudation rates.

Obtained data are important for estimations of the significance of the contribution of karst denudation to global CO_2 amount and cycle.

Introduction

Speleothem growth rate variations represent mainly rainfall variations (SHOPOV et al.1992, 1994). Speleothem luminescence visualises annual microbanding (SHOPOV et al. 1991b). We used it to derive proxy records of annual precipitation around the cave site by measuring the distance between all adjacent annual maxima of the intensity of luminescence. The resultant growth rates correlate with the actual annual precipitation (summed from August to August).

Results and Analyses

We studied the top of a 35 mm long stalagmite from Rats Nest cave (RNC), Alberta, Canada. We measured a stacked 66000 data points luminescent record from Rats Nest cave, Kananaskis karst region, Alberta, Canada. It covers last 1450 yrs with resolution of about 8 days for most of the time span (SHOPOV, et al., 1998). Paleoclimatic records has been derived from speleothem luminescence by calculation of average annual intensity of luminescence and measurement of annual growth rate values.

Obtained annual records has been calibrated by actual climatic records from near climatic station in Banff, Alberta, located in the same valley, 50 km northern of the cave (SHOPOV et. all, 1996 a, b). This way we reconstructed annual air temperatures for last 1450 years at the cave site with estimated error of 0.35 ^{0}C, while the error of the direct measurements is 0.1 ^{0}C. For this purpose we obtained a reconstruction of annual precipitation for the last 280 years at the cave site. The estimated statistical error is 80 mm/ year. Annual speleothem growth rate was independent on the intensity of luminescence, on annual temperature and on solar luminosity for the same time span (zero correlation). This stalagmite was dated by 14- C and autocalibration dating . Both methods produced consistent age of 1450 +/- 150 years (2 sigma) of the base of the stalagmite. The 14-C date is corrected for "dead" carbon, by its measurement in modern speleothem calcite in RNC.

Intensity of luminescence was not dependent on actual precipitations and sunspot numbers solar luminosity index (zero correlation). Speleothem growth rate variations represent mainly rainfall variations. Speleothem luminescence visualises annual microbanding we used to derive proxy records of annual precipitation for the cave site.

By comparison of luminescent records with other solar proxy records we obtained a reconstruction of growth rates and precipitation in the last 6400 years (with averaged time step of 41 years) for Iowa, near Cold Water Cave, US. For small parts of this speleleothem formed about 2000 years ago we achieved record time step of 6 hours per measurement in speleothem luminescence record allowing resolution of several days (SHOPOV et al., 1994).

Annual luminescence microbanding was used very successfully for relative and absolute dating of speleothems by Autocalibration dating (SHOPOV ET AL, 1991-b). This dating method appear to be more precise than TAMS ^{14}C and AMS U/Th dating for this young sample. It produced date which completely agrees with the results of the other methods in the frames of their experimental error, but have better precision of 1450 +/- 80 years.

We used the quantitative theory of solubility of karst rocks of SHOPOV et. al, (1989,1991a) in dependence of the temperature and other thermodynamic parameters to make reconstructions of past carbonate denudation rates. This theory produced equations of the dependence of the carbonate denudation rates in dependence on the temperature or on the precipitation. We used an estimate of the averaged denudation rate in the region based on integrated data of the carbonate hardness or the water from springs, rivers, cave pools and dripping water and average precipitation rate (of 470 mm/yr) from meteorological data. Obtained denudation rate is 14 mm/kyr or 38 t/km^2 per year. We used this as starting point and substituting our proxy records of the annual temperature and the annual precipitation reconstructed variations of the and for the last 1250 years in dependence on the temperature (fig.2). Both reconstructions are made for equilibrium conditions and do not take into account variations of the evapotranspiration, but they produce quite reasonable estimate of the variations of carbonate denudation, which is within observed variation of 8- 20 mm/ kyr (86% variation). Temperature dependence of carbonate denudation due to temperature dependence of solubility of the carbonate dioxide produce only 9.3 % variation in the denudation rate in result of the reconstructed variation of 4.7 deg. C. Precipitation dependence of carbonate denudation produce 79 % variation in the denudation rate in result of the reconstructed variation of 300 mm/yr from the driest to the wettest year.

Conclusion

It is demonstrated, that speleothem luminescence proxy records of annual values of the climatic parameters can be used for reconstruction of the carbonate denudation variations for a time span far exceeding all historic records.

It is demonstrated, that variation of carbonate denudation due to temperature dependence of solubility of the carbonate dioxide is negligible relatively variation due to precipitation variations.

Acknowledgements

This research was supported by grant NZ 811/ 98 of Bulgarian Science Foundation to Y. Shopov and a NSERC strategic research grant to D.C. Ford.

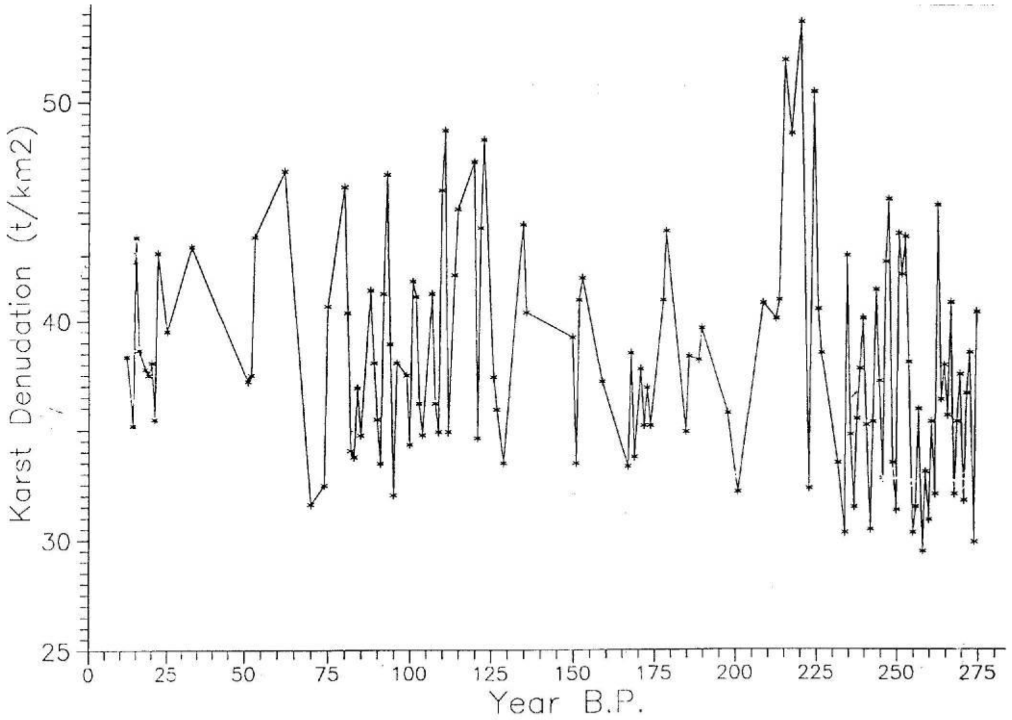

Fig.1Reconstruction of variations of carbonate denudation rate in Kananaskis karst region, Alberta, Canada in the last 280 years in dependence on the precipitation

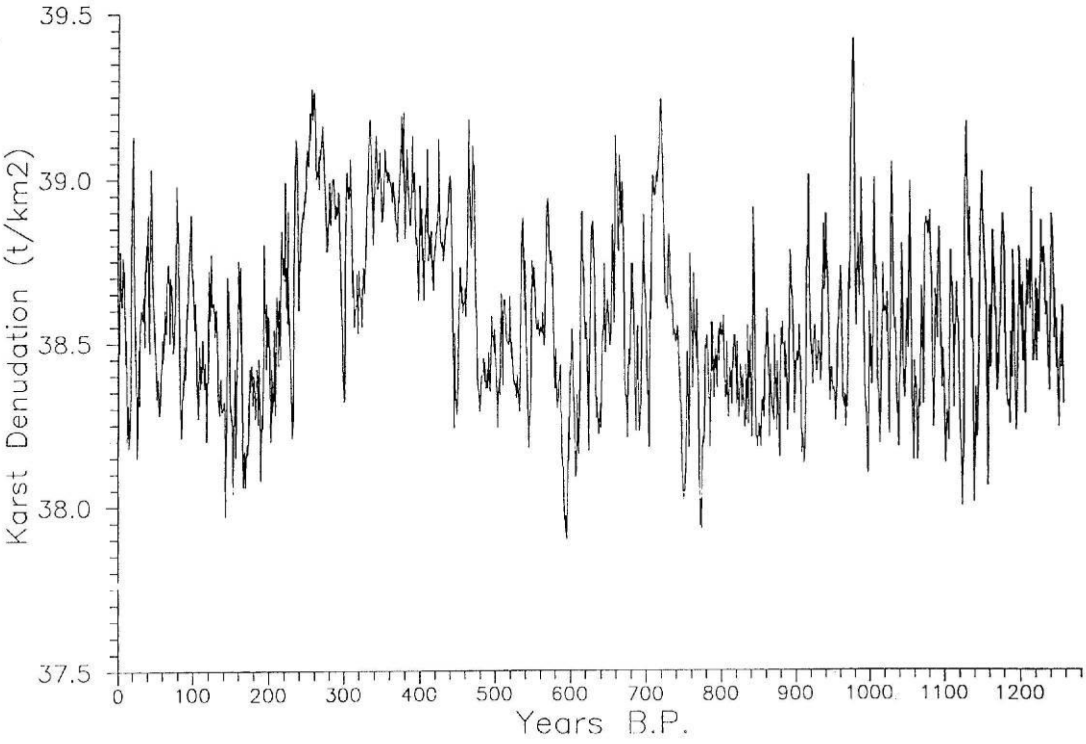

Fig.2. Reconstruction of annual variations of carbonate denudation rate in Kananaskis karst region, Alberta, Canada in the last 1250 years in dependence on the temperature.

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Quantitative Annual Speleothem Records of Temperature, Precipitation and Solar Insolation in the past – A Key for Characterisation of past climatic systems

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Abstract

We studied luminescence of speleothems from Cold Water cave, Iowa, US and Rats Nest cave, Alberta, Canada. A reconstruction of the past annual precipitation rates for the last 280 years for Kananaskis country, Alberta, Canada has been obtained from speleothem annual growth rates.

In dependence on the soil surface exposition we measure either solar sensitive or temperature sensitive paleoluminescence speleothem records:

- In case of Cold Water cave, Iowa, US we obtained high correlation coefficient of 0.9 between the luminescence record and Solar Luminosity Sunspot index and reconstructed sunspot numbers since 1000 AD with a precision within the experimental error of their measurements;

- in case of Rats Nest cave, Alberta, Canada we measured correlation coefficient of 0.67 between luminescence intensity and air temperature record for the last 100 years and reconstructed annual air temperatures for last 280 years at the cave site with estimated error of 0.35 ^{0}C, while the error of the direct measurements is 0.1 ^{0}C.

Introduction

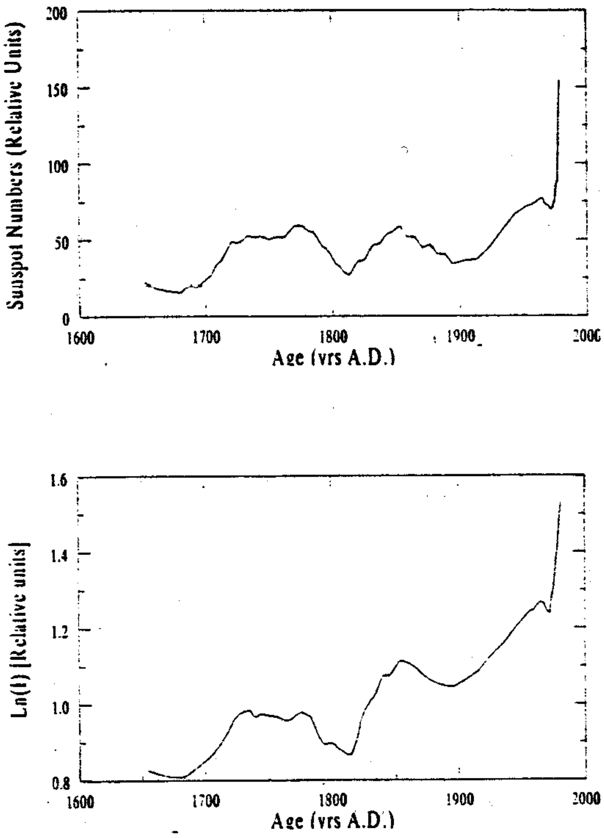
Calcite speleothem luminescence depends exponentially upon soil temperatures that are determined primarily by solar radiation in the case when that cave is covered only by grass or upon air temperatures in case that cave is covered by forest or bush. In the first case, microzonality of luminescence of speleothems can be used as an indirect Solar Insolation (SI) index, but in the second - as an paleotemperature proxy. So, in dependence on the cave site we may speak about "solar sensitive" and "temperature sensitive" paleoluminescence speleothem records like in tree ring records, but in our case record may depend either only on temperature or on solar irradiation.

Methods and Material Studied

Speleothem growth rate variations represent mainly rainfall variations (SHOPOV et al.1992, 1994). Speleothem luminescence visualises annual microbanding (SHOPOV, 1987, SHOPOV et al. 1991). We used it to derive proxy records of annual precipitation at the cave site by measuring the distance between all adjacent annual maxima of the intensity of luminescence. The resultant growth rates correlate with the actual annual precipitation (summed from August to August). We studied the top of a 35 mm long stalagmite from Rats Nest cave (RNC), Alberta, Canada to measure quantitative records of annual temperature and precipitation. For this purpose we obtained a stacked 66000 data points paleotemperature record from Rats Nest cave, Kananaskis karst region, Alberta, Canada. It covers last 1450 yrs with average resolution of about 8 days. Paleoclimatic records has been derived from speleothem luminescence, calibrated by actual climatic records from near climatic station in Banff, Alberta. The sample was dated by two14-C dates, TIMS U/Th dating, autocalibration and annual bands counting dating. All produced consistent age, best estimated as 1450 +/- 80 years. The 14-C data were corrected for “dead” carbon, by its measurement in modern speleothem calcite.

Results and Analyses

We obtained high correlation coefficient of 0.9 between a luminescence record from Cold Water cave, Iowa, US and Solar Luminosity Sunspot index (Fig.1) and reconstructed sunspot numbers since 1000 AD with precision within the experimental error of their measurements. This luminescence record is a part of a 7075 +/- 295 yrs record well dated by 5 U/Th TIMS dates (SHOPOV et al., 1994).



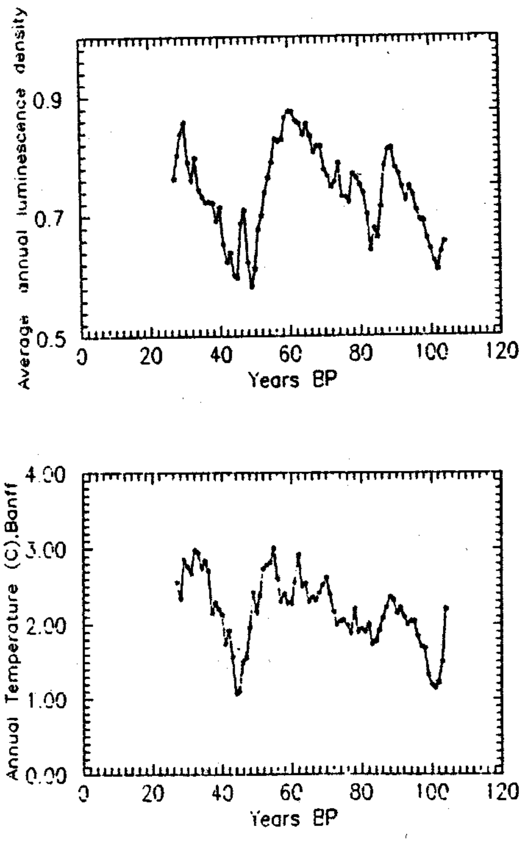


Fig.1. (left up)- Twenty year average sunspot records since 1700 AD, (left down)- Optical density of luminescence of a speleothem from Coldwater Cave, Iowa (USA).

Fig.2. (right up)- Average annual luminescence density of a speleothem from Rats Nest Cave (Canada) (right down)- Annual temperature, Banff, Alberta (Canada).

A reconstruction of the past annual temperature for the last 280 years has been obtained from average annual speleothem luminescence intensity calculated from the 66000 px record, calibrated by actual temperature record from near climatic station in Banff, Alberta, Canada. We obtained reasonably good correlation (correlation coefficient of 0,68) between the annual temperature for the last 105 years (recorded at the closest weather station - Banff, located in the same valley, 50 km northern of the cave) and the average annual speleothem luminescence intensity (Fig.2). We used obtained regression coefficients to reconstruct annual temperature for the last 280 years at the cave site (Fig.3). The estimated statistical error is 0.35 ^{o}C. Intensity of luminescence was not dependent on actual precipitations and sunspot numbers (zero correlation).

Speleothem growth rate variations represent mainly rainfall variations. A reconstruction of the past annual precipitation rates for the last 280 years has been obtained from speleothem annual growth rates, derived from the distance between annual speleothem luminescence bands, calibrated by actual precipitation record from near climatic station in Banff, Alberta, Canada. We obtained reasonably good correlation (correlation coefficient of 0,57) between the annual precipitations (from Banff, Alberta) and the annual growth rate of the speleothem. We used obtained regression coefficients to reconstruct annual precipitations for the last 280 years at the cave site (Fig.4). The estimated statistical error is 80 mm/ year. Annual speleothem growth rate was independent on the intensity of luminescence, on annual temperature and on solar luminosity for the same time span (zero correlation).

Speleothem luminescence visualizes annual microbanding we used to derive proxy records of annual precipitations for the cave site. Annual luminescence microbanding was used very successfully for relative and absolute dating of speleothems by Autocalibration dating. This dating method appear to be more precise than TAMS ^{14}C and AMS U/Th dating for relative dating of short time intervals and only dating method for speleothems with little uranium, younger than 2000 years.

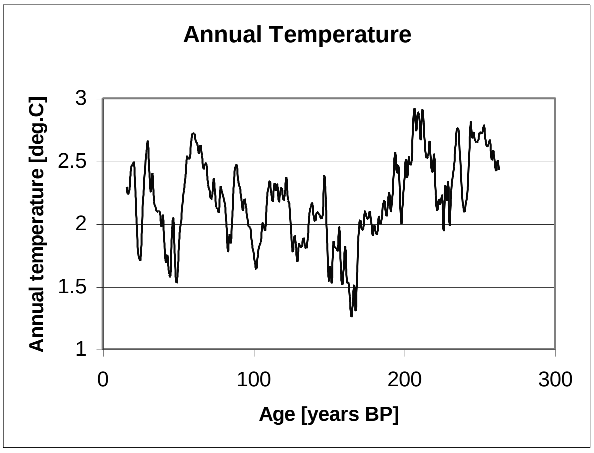


Fig. 3

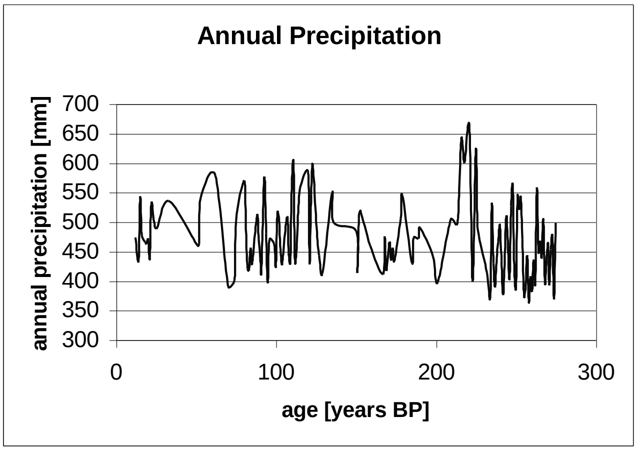


Fig. 4

Fig.3 (Up) Annual temperature in the last 280 years for Kananaskis country, Alberta, Canada derived from annual intensity of luminescence of a stalagmite from Rats Nest cave, Alberta, Canada

Fig.4 (Down) Annual precipitation (from August to August) in the last 280 years for Kananaskis country, Alberta, Canada derived from annual growth rate of a stalagmite from Rats Nest cave, Alberta, Canada

Conclusion

It is demonstrated, that speleothems can be used as natural climatic stations with annual resolution for purposes of climatology and agrometeorology for a time span far exceeding all historic records.

Acknowledgements

This research was supported by a CNR-NATO outrich fellowship of Y.Shopov, grant NZ 811/ 98 of Bulgarian Science Foundation to Y. Shopov and a NSERC strategic research grant to D.C. Ford.

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Preliminary Results of the Glacio-Speleological Expedition on Tyndall Glacier

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Abstract

In the months February and March 2000 the "Associazione La Venta" organized a speleo-glaciological mission on the Tyndall Glacier (Patagonia, Chile). In the ablation zone a well-developed surface drainage network occurs and supraglacial streams plunge down into moulins. The major streams have a wide catchment area and experience a discharge of some $m^3 s^{-1}$; these streams feed huge moulins located about 7 km upstream the front of the glacier. The two largest moulins experience 24 hours cyclic phenomena of rising and decreasing of the internal water level. Probably this kind of behaviour cannot be explained only by the input discharge changes, and we presume that the deformation of the englacial conduit plays also a relevant role. Along the East margin of the glacier we discovered also three large glacier caves formed at the contact between ice and lateral moraines or basal bedrock.

Key Words: Glaciology, englacial hydrology, glacier caves, moulins, Tyndall Glacier, Hielo Continental

Introduction

In the months February and March 2000 the “Associazione La Venta” organized a speleo-glaciological mission on the Tyndall Glacier (Patagonia, Chile). The mission benefited of a grant by the Italian Foreign Affairs Ministry, and it was realized with the help of the Magellan University di P.ta Arenas (Chile) and the logistic support of the “Torri del Paine” National Park.

The investigated zone was the lower part of the ablation zone, below the elevation of 700 m a.s.l., where a preliminary analysis by aerial photos permitted to individuate a well developed surface drainage network (Fig. 1).

The base-camp was installed in a lateral valley, reachable by 5-6 hours walking from Guardieria Grey, on the bank of Laguna Grey. From the base camp, it was possible to gain easily the medial sector of the glacier at an altitude of about 600 m. The first tours allowed to recognize the areas where thermokarst processes have the maximum development and to individuate the best paths to reach them.

The Tyndall Glacier

The Tyndall Glacier is one of the widest valley glaciers that originate from the Hielo Continental Sur.

It is located at 51° 05’ and 51° 17’ of South Latitude and at 73° 16’ and 73° 28’ of West Longitude. The total length is about 22 km, with a width of 10 km at the northern part and a width of 2 km at the front. The flow direction is SSE. Altitudes ranges from 1500 m, at the diffluence from the icefield, to 200 m at the front.

In the ablation zone, below 800 m of altitude, the glacier exhibits a rugged topography, due to transverse bands of fractured ice, where the high sun melting forms a dense network of parallel sharpen ridges. These rugged bands are separated by relatively planar and a few fractured zones where a surface drainage of meltwater can develop. Supraglacial streams feed some flat depleted areas where the water is absorbed by small fracture. In some cases meltwater plunges down into moulins that feed directly the englacial drainage network.

The glacier is divided in two major ice streams by a thin central moraine. Along the moraine the glacier is just a little lower in respect of lateral areas; in this area, a large amount of meltwater converges.

Thanks to the high insulation and rain, the surface melting is very high. During the period of our mission we measured a melting ablation of about 800 mm, with a mean ablation of 70 mm/d, and a maximum daily ablation of 120-130 mm/d. According to these few data we can suppose that in the warmer months (February and March) the ablation can easily exceed 2 m per month.

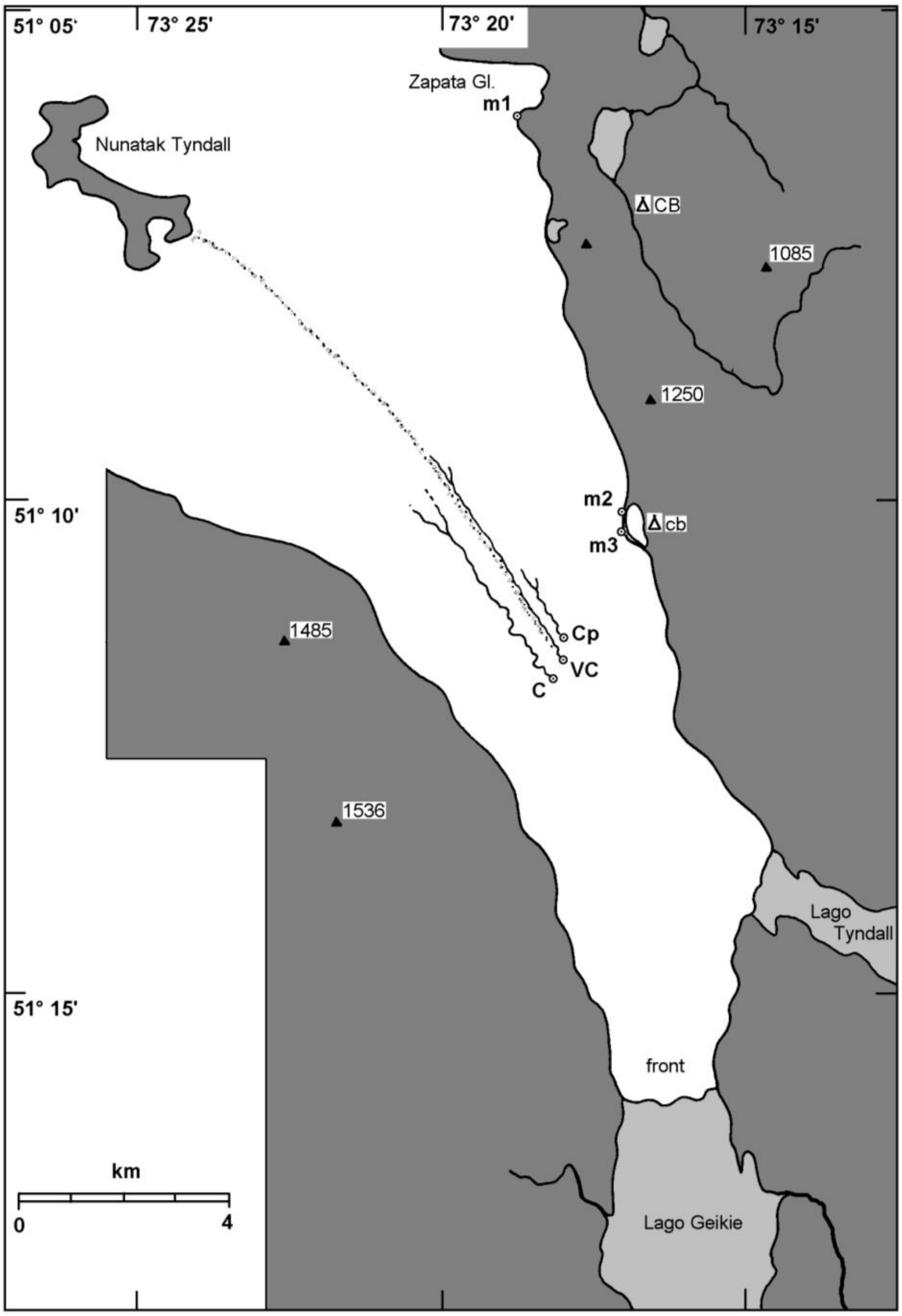

Fig. 1- Sketch map of Glacier Tyndall, with the position of major streams and moulins: C) moulin "Capo"; VC) moulin "Vice-capo"; Cp) moulin "Capino"; CB) base camp; cb) advanced base camp; m1-m2-m3) marginal contact caves.

The Moulins

During the surveys on the glacier, we have traced approximately 50 moulins. About the half of these were localised in the area close to the base-camp, but most of them were small and narrow shafts, no more than 20 m deep. The most developed moulins and the largest ones were discovered about 10 km downstream, in a wide flat area where several streams flow coming from NNW. In particular three large streams flow in the central depleted part of the glacier. They have a wide catchment area and experience a discharge of some

$m^3 s^{-1}$; these streams feed huge moulins located about 7 km far from the front, just upstream a transverse band of fractured ice.

We named the three moulins "Capo" (the boss), "Vicecapo" (Vice-boss) and "Capino" (the little boss).

The "Capo" is probably one of the largest moulin ever discovered in the world. The feeding stream runs in a large ice-valley, about 100-150 m wide and 20-30 m deep, that we followed upward for 4 km without see the end. We have reason to believe that this stream begins from Nunatak Tyndall, about 12 km upstream. The discharge of "Capo" river probably reaches 6-8 $m^3 s^{-1}$ during the high-melting periods.

The entrance of this moulin is a deep canyon, 4-5 m wide and about 15 m deep. The stream falls into the moulin with an impressive waterfall that made any attempt to descend into it impossible.

The "Vicecapo" is just a little smaller. The stream flows in a rectilinear incision about 40-50 m wide and 10-15 m deep; discharge ranges from 1 to 3 $m^3 s^{-1}$, in the warmer days. The entrance is a spectacular shaft, 6 x 10 m in the upper part, which was sounded till a depth of 103 m.

The "Capino" is a deep shaft where a stream of about 1-2 $m^3 s^{-1}$ falls down. An attempt to descend into it stopped at a depth of 40 m because of the power of the waterfall.

In this area we discovered about 30 minor moulins, with entrances ranging from a dimension of some m to 20 m in plan. Most of them develops on ESE-WNW transverse fractures and are formed by a shaft 15 to 40 m deep. Only one moulin has a horizontal pattern.

Hydrodynamic Behaviour of Large Moulins

During the investigations on the Tyndall glacier, we frequently observe phenomena of rising and decreasing of the water level inside moulins of the lower zone. In some occasions the filling-in of water involved all the moulins and was probably caused by a raise of englacial water level due to an increase of the surface melting. In others cases we observe the filling-out of only some isolated moulins, probably due to a temporary local occlusion of the englacial drainage conduit (BADINO, 1995).

A particular behaviour was observed in the two largest moulins, the "Capo" and "Vicecapo", which experience a water raising-decreasing phenomena of about 24 hours. Only in one occasion we had the possibility to follow a full cycle, measuring the level of the water inside the first shaft of "Vicecapo" and the discharge of the in-flowing stream. The measure of water level and discharge are presented in Fig. 2.

At 13.00 of February 28, the water-level was 91 m below the rim of the entrance and it was raising at a rate of about 20 $m h^{-1}$. At 18.00 the moulin was almost completely full, with the level of water just 5 m below the rim.

The water stood at the maximum level for less than an hour, than the level began to decrease with an accelerating rate. At 23.00 the level was at –103 m, the limit of our possibility to measure it.

Assuming constant dimension in the plan of the shaft of about 50 m^2, we can calculate the amount of water stored in the moulin and the discharge of englacial drainage. In the Fig. 3 we can see that the immobilized water reaches the maximum value just an hour before the maximum of removed water drainage.

The increasing of hydraulic pressure produces an accelerating flow that ranges from 1.4 to 2.3 $m^3 s^{-1}$.

Probably this kind of behaviour cannot be explained only by the input discharge changes, because there is not a linear relationship between the water level and the removed water discharge. We presume that the deformation of the englacial conduit play also a relevant role.

Unfortunately the error of the measurements and the lack of minimum levels do not allow making a mathematical model of the hydrodynamic behaviour of this moulin. Probably, further studies and a more precise measure of level and discharge could allow getting experimental measurements of the deformation rate of englacial conduits (BADINI, 1995).

Marginal Contact Caves

Along the East margin of the glacier, we discovered several glacier caves formed at the contact between ice and lateral moraine or basal bedrock (ERASO & PULINA, 1992). Most of them were small and impenetrable, and frequently affected by the collapse of the entrance.

Three of these caves could be surveyed for more than 100 m. One of them was located in the Zapata Gl.,two others were near the advanced base-camp (Fig. 1). The former is a typical marginal cave, about 130m long, which is formed by a small lateral creek.

The two longest marginal caves, named “Pesce superiore” and “Pesce inferiore”, were explored for more than 200 m, and they are respectively an out-flowing cave and an in-flowing cave. The upper one probably act as on over-flow emergence that is activated when the surface melting exceed the capacity of basal network to drain the infiltration water; in this case, usually during rainy days, a flow of about 3-4 m^3 s^{-1} comes out of the cave and fills a lateral basin forming a lake. The lake improves its level till the water flows over a rock threshold and falls in a lower small basin, where subglacial conduits capture the water again.

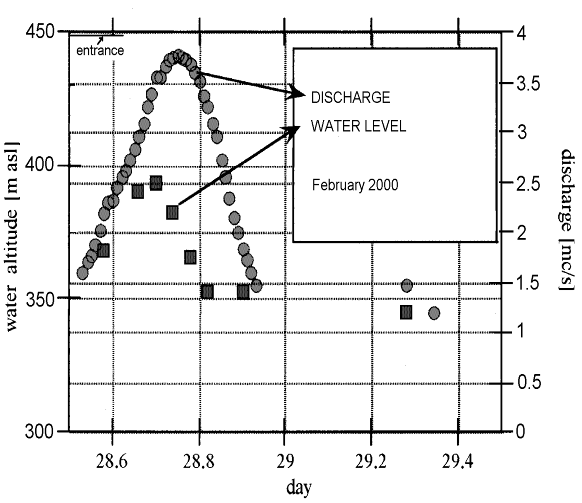

Fig. 2

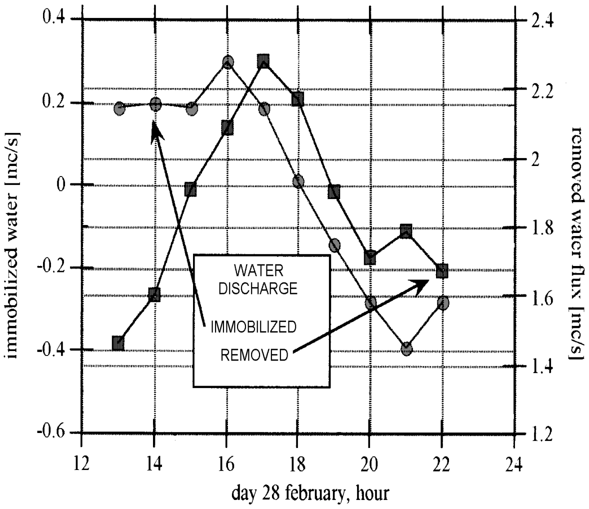

Fig. 3

Fig. 2 – Discharge and water level vs time in “Vicecapo” (entrance altitude 448 m a.s.l.)
Fig. 3 – Immobilized and removed water discharge vs time in Vicecapo

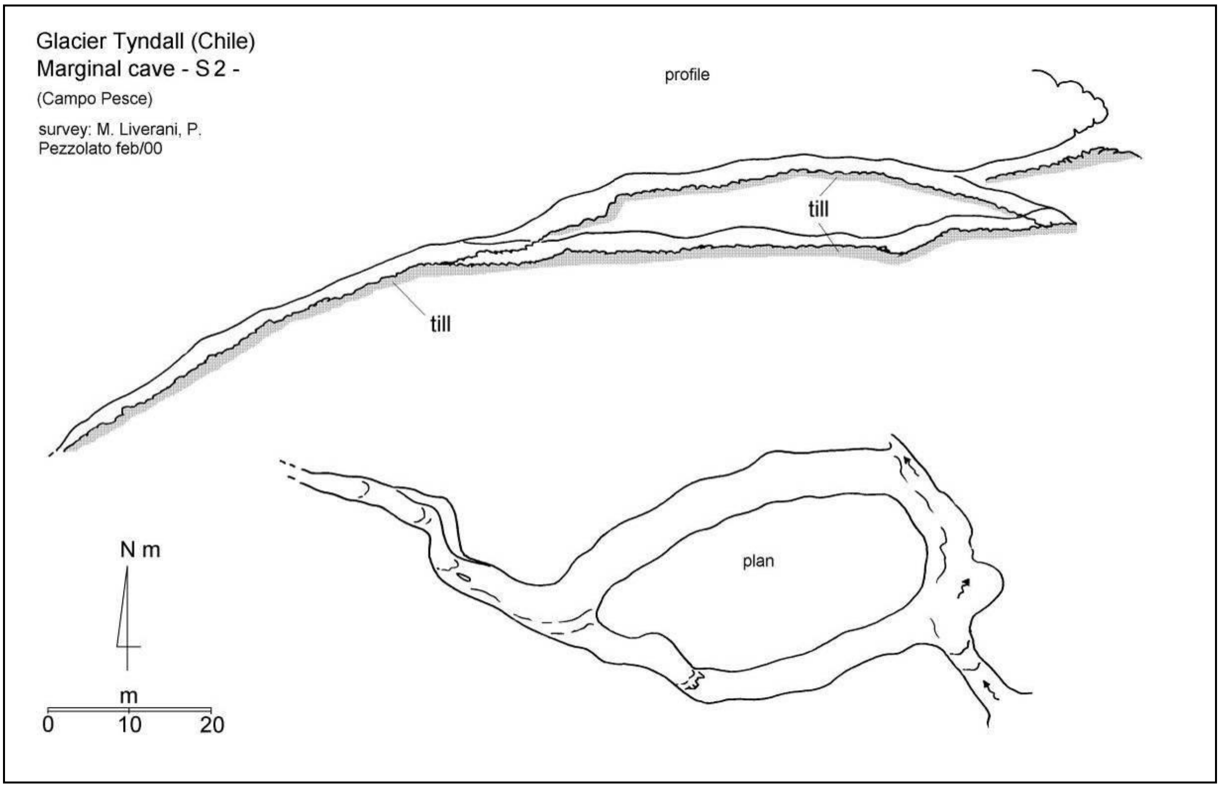

Fig. 4 – Topographic profile and plan view of the major marginal caves explored in the Tyndall Glacier (survey by Ass. La Venta, March 2000).

Conclusions

A first preliminary investigation on Tyndall Glacier has allowed verifying the occurrence of well-developed supraglacial drainage and related thermokarst caves. In particular, three streams flowing in the central part of the glacier, feed large moulins, among the major moulins ever discovered in the glacier of South America.

Two of these englacial caves experience a cyclic large-scale oscillation of internal water level. This particular phenomenon seems to be controlled not only by the discharge fluctuations but also by a cyclic rearrangement of englacial drainage conduit as a response of diurnal changes of discharge.

A detailed monitoring of water level and of discharge fluctuations could permit to better understand the mechanism of ice deformation due to water pressure changes.

Acknowledgments

We wish to thank the General Direction for the Promotion and the Cultural Cooperation of the Italian Foreign Affairs Ministry, the Magellan University di P.ta Arenas (Chile), the “Torri del Paine” National Park, and Claudio Zuppin of the Meccatronica of Trieste for the use of phreatimetres.

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Caves in the Glaciers of Terra Nova Bay (Victoria Land, Antarctica)

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Abstract

In the 2000/2001 expedition of the Italian Programme of Research in Antarctica (PNRA) some investigations on karst phenomena in ice have been carried out around the Italian Station of Terra Nova Bay, on the western coast of the Ross Sea.

Some caves have been explored in the glacial terminus of glaciers reaching the sea and an other one has been found on the summit of Mt Melbourne, a volcanic cone 2700 m high. The caves on the coast have been generated by a dry process of speleogenesis due to sublimation of ice. The process is driven by temperature difference between the core of the glacier ice and the quite warmer sea water under the fast ice at the bottom of the caves.

The Mt Melbourne subglacial cave is generated by the heat of the volcanic rocks; also in that cave the water vapour state is of fundamental importance because in such a state the water is carried out from the cave.

Introduction

The glacial karst (thermokarst, due to melting of ice) is likely limited to the mountain regions or the high latitudes zones were the annual mean temperature reaches 0 °C. Under this value, the core of the ice bulk is under the freezing point and all the water that percolates is transformed in ice, seals all the meatuses and stops any further percolation. That is what happens on the Svalbard Islands, where a mean temperature just a little below 0°C is enough to reduce the thermokarst to an occasional phenomenon. So we deduced that around Terra Nova Bay, where the mean annual temperature is -14 °C, not even the ghost of karst in ice could exist.

Geographic Overview

We could explore the territory from the Italian Base of Terra Nova, placed on a granitic peninsula in a broad inlet of the western coast of the Ross Sea, at 74° 41' 42" S lat. and 164° 07' 23" E long.

The Base is open only during the warm season (from October to February) for about 80 people. Beside the Base rise the Transantarctic Mts, whose relief is often higher than 3000 m. South of the Base outlet glaciers cross the mountains and drains the ice of the inlandsis. The bigger of them, the David Gl., forms the Drygalski Ice Tongue, several dozens kilometres long. On the north huge valley glaciers flow from the mountains to the sea. The Italian Base is placed between the region of the Dry Valleys to the south, where a belt near the coast shows deglaciated areas and a northern region with a more extended ice cover and deglaciated zones are quite rare.

The mean annual temperature is -14 °C, the warmer month is January (mean temperature -2 °C), the colder ones are May and August (-23 °C). The vertical rate of the air temperature is 0.52 °C/100 m; in summer is 0.7 °C/100 m. The permafrost is everywhere, few decimetres under the ground. Of course the water (in the liquid state) is present by chance. Only in the warmest month some small creeks have been observed, fed by zones where ice and firn are exposed to the sun or to the radiation of rocks warmed up by the sun. Small lakes are present in the deglaciated zones of Tarn Flat and of the Northern Foothills; on the Hell's Gate Ice Shelf a meandering stream (with a discharge of few dozens litres / second) drains the water formed by irradiation on the surface of the blue ice. Some other small creeks flow on the eastern side of Mt Melbourne, where dark volcanic rocks outcrop from the ice.

There are also indirect evidences of water: a doline in ice has been mapped (and seen by one of us) on the surface of the Priestley Gl., but at the time of our scouting we find just a circular frozen lake, perhaps the filled doline. In other points there is a morphology due to flowing water: a gully near the Base, downstream of

Carezza Lake; on the northern side of Edmonson Point an alluvial fan is present. Besides these evidences, the presence of thermokarst has to be forgotten (but thermokarst and speleogenesis in ice are not the same).

The first target of our scouting has been the snout of the Campbell Glacier, where we had seen that in the ice cliff of the glacier ice tongue some large caves were open. Their initial stage is tectonic, in fact they are crevasses closed in the upper part. When that caves are large, the effect of the load of the roof is evidenced by a parabolic profile of the ceiling, similar to the profile of the broad caves inside carbonatic mountains. It seemed to us to too easy to explain the processes of spelogenesis that produced so large caves at a temperature far below 0 °C.

The ice at the terminus is stable enough to ensure a rather safe exploration in the caves with the exception of the entrance where ice falls are often visible.

Inside the cave two opposite facts are present: temperature is 15-20 °C below 0° and the ice walls show evident solution forms. The synoptic vision is that of a clear karstic cave.

Some of them are swept by strong flow of cold air, sometimes colder than the mean local temperature. The floor is flat and smooth, and is a little bit lower than the fast ice outside the cave. On the walls there are scallops and rills elongated along the dip. From the ceiling stalactites hang, sometimes covered by sublimation crystals. All this morphology denotes both sublimation and melting/freezing processes.

The main process that govern the genesis of all that unexpected morphology is obviously that of the heat exchange: the caves are exactly at the contact between the glacier ice coming from the Transantarctic Mts, that has a temperature approaching the mean annual temperature of the air, about -18° C, and the sea that under the fast ice has a temperature of -1,9 °C.

In the perspective of Thermodynamics that is the place of thermic contact between two "heat sources", that is two systems able to yield heat and maintain the same temperature, because of their heat capacity that can be considered infinite. As a first approach to analyse the process we decided to measure the temperatures inside the ice to understand if, how much and in which direction the heat flows.

An other question is linked to the sea salt. We came out from the caves dotted by white salt spots, due likely to the fall of sublimation crystals. So not only there is a difference in temperature, but also a contrast between salty and fresh ice.

The measurements have been carried out in three caves, chosen among the others because nearby the Italian Base, enough safe, nice shaped and presence of air flow. Two of them are on the Campbell Gl. Ice Tongue, the third is in an unnamed glacier flowing from the slope of Mt Melbourne, near Baker Rocks.

Despite the impression of a slow evolution of the morphology of the caves, we noted that a small niche we excavated in the wall to sample ice, in few days was smoothed and striated by karstic processes working at -20 °C.

We found that the floors are quite warmer than the walls and that is the key to understand the process of that dry speleogenesis. The water vapour pressure of the floor ice is higher than that of the ice of the ceiling. So the floor warms up and moistens the air in contact; the air rises and, if it is not driven outside the cave, reaches the dew point and forms sublimation crystals releasing the latent heat at the same time. Probably it is this latent heat of sublimation that warms some air up whose flow besides the ice crystals moulds the rills.

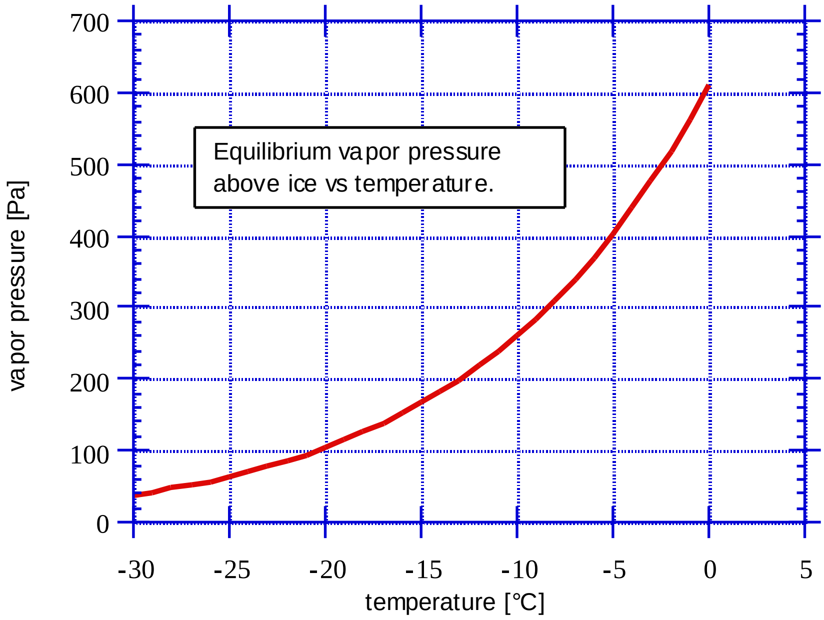
In future we will have to investigate the factors controlling the processes in those peculiar environments, that is the heat exchange, the air flow inside the glacier (that is colder than expected), the role of the salt.

A more simple to understand but more astonishing cave we visited in the Terra Nova Bay zone, during a short survey at the end of our expedition, has been that formed at the contact of the ice with the warm surface of the Mt Melbourne volcano. The heat from the rocks surface flows into the ice, here at a temperature around -30 °C, and affects it by melting, sublimation and air circulation. Broad caves are here developed, whose main interest is to be a relatively warm place in a severely cold environment. There are peculiar biological associations that caused the place to be declared a reserve to be visited only after a permission of the SCAR and cautiously to avoid contamination. The cave was explored three times by Italian glaciologists and biologists few years ago before it were declared as reserve. Similar caves were found on the Mt Erebus (a volcano near the Mc Murdo and Scott Bases), by a party of the expedition of Tazieff in the Fifties.

The entrance of the cave is visible from far because the air rich in humidity coming from the ice melt by the volcano's heat flows outside and at the contact with the cold atmosphere deposits by sublimation a vertical "pipe" around the entrance, that stands up like a chimney. The ice is here thick just few dozens metres, but the cave is well developed, we walked inside for more than a hundred metres in a broad warm tunnel, without finding the provenance of the air. We didn't smell any volcanic gas.

The process is analogous to the one of other sub-glacial caves found in far regions, mainly in Iceland, but here is dominated much more by the water vapour state, than the liquid one, like the caves observed in the coast. Inside the cave there are the three states of the water: solid, liquid and gaseous, but is only the last that leaves the cave, in form of plumes of vapour, carrying 4.8 g of water every cubic metre. The cave is eventually a structure that represents the equilibrium between erosion, related to the air flux and the volcano's heat, and the collapse of the vault, due to the ice plasticity and flow. At the entrance of the cave we observed an air flux of about two cubic metres at second, with a related transport of 10 g/s of water vapour, equivalent to an erosion of about a ton of ice every day.

The only continent that was considered without ice caves is so revealing peculiar and enigmatic karst processes.



Analysis of the Investigations Carried Out in the Field

In the XVI Expedition of the PNRA we started to study three caves open in the ice cliff at the contact with the fast ice. Inside the caves we measured the vertical temperature rate of the floor and the horizontal rate of the walls at about one metre from the floor. We repeated the measurements after ten days. In that time interval the thermal wave has a displacement of 0.75 cm.

Campbell Gl. 1. Cave without sensible air circulation. The heat subtracted by the ice walls is 8 W/m^2. The heat coming from the floor is 4 W/m^2. In the ten days lapse both walls and floor have been warmed up probably by air entered from the broad entrance.

Campbell Gl. 2. Is a large cave with a strong air flow that force the surfaces to a lower than expected temperature (here the mean annual air temperature is around -14 °C). One possible explanation (but we are not sure) is that the crevasses act as cold air traps so that the glacier could maintain its temperature below the mean annual temperature. Here too the floor is warmer than the ceiling, but it absorbs heat rather than supplying it, probably because the measurement was made far inside (70-80 m) from the glacier terminus, at a great distance from the zone of heat balance between sea water and glacier ice. The heat absorbed by the glacier is 1.8 W/m^2 on the floor and 2.2 W/m^2 in the walls.

Baker Rocks 1. The cave is somewhat different from the two previous ones, is rather narrow and elongated. There is an opening in the ceiling, through which the snow accumulates on the floor. The cave is not far from the grounding line of the glacier. The heat flow is 3.7 W/m^2 coming from the floor (the measures have been made at a dozen metres from the fast ice), and 1.7 W/m^2 going inside the walls in our first visit and 4 W/m^2 in the second one. The warming up of the walls is quite strong and, because of the position of the measurement point deep inside the glacier, cannot be explained by a process lasting only ten days. The heat balance is influenced by the strong air flow and mainly by the insulation of the snow covering the floor, responsible of the stability of the thermal profile in the two measurements.

As a comparison we display the thermal profile of the fast ice 30 m outside the cave of Baker Rocks. Here the ice is really warmer, but the heat (2.8 W/m^2) flow is comparable to the one inside the cave.

Mt Melbourne 1. This is a cave originated by the fumarolic activity at the summit of the Mt Melbourne volcano. The cave opens at the contact between the rocky surface of the volcano and the ice cover, here some dozens metres thick. The gallery is rather regular, 5 metres large and 2-3 metres high; we went inside for about two hundred metres without finding an end. The graphic shows that the wall absorbs 4.5 W/m^2 and the process is regular at all.

Moulins and Contact Caves in the Gornergletscher (Switzerland): Morphology and hydrology

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Abstract

The Gornergletscher is located in the mountain group of M. Rosa (Swiss Alps). The ablation zone is relatively flat and a few fractured; this morphological condition allows the surface drainage of meltwater. Supraglacial streams often plunge down into moulins that feed directly the englacial drainage. Repetitive investigations, since 1985, have allowed surveying more than 40 moulins and contact caves; some of them have been explored to the englacial water table (from – 30 to –140 m). The life of the moulins ranges from 3 to 5 years and it depends on the local ice flow rate: the faster the movement, the shorter the life period. Field observations suggest that an important role in controlling the development and the geometry of moulins is played by the level of englacial water.

Key Words: Glaciology, englacial hydrology, glacier caves, Gornergletscher

Introduction

In October 1985 and 1986 a group of Italian speleologists performed the exploration of deep moulins in the Gorner glacier (PICCINI & VIANELLI, 1987). In the following years Swiss, Italian and French cavers carried out new explorations of moulins and marginal contact caves (WENGER, 1994; PICCINI, 1999). Behind all these investigations, we can undoubtedly assert that the Gornergletscher is one of the most detected glaciers in the world by glacial speleologists, and that it is an exceptional site to study the evolution of moulins and their hydrological behaviour.

Since 1998 a new campaign of investigation was commenced by a group of Italian researchers coming from the Dipartimento di Scienze della Terra of Firenze, Dipartimento di Fisica Generale of Torino University and from the Associazione Culturale "La Venta". The aim of this research is the hydrological and morphological characterisation of moulins. In this paper we presented a brief and preliminary note on the results.

Glacial Morphology of Gorner

The Gornergletscher is located in the Alpi Vallesi and it is made up by the confluence of different ice streams descending from the mountain group of M. Rosa.

The whole glacial basin covers a surface of about 65 km^2 (from the I.G.S. map of 1996) with a maximum length of 14 km. The equilibrium line (ELA) is presently located about at 3250 m.

The maximum thickness of the ice is probably more than 400 m, and the maximum width is about 2 km.

Below the elevation of 2600 m, the glacier is divided in three different ice streams by two major medial moraines. The central ice tongue, the largest one, is fed by the Grenzgletscher, whose accumulation zone is located between the M. Rosa (4634 m) and the M. Lyskamm (4562 m).

In the ablation zone, between the altitude of 2400 and 2600 m, the glacier displays a wide flat zone, which has a surface of about 5.5 km^2. Here, the morphologic and structural settings of the ice allow the development of a remarkably structured network of supraglacial streams, which feeds several lakes and moulins (Fig. 1). Most of moulins are located in the confluence zone of the Grenzgletscher, where the entrances seem to be aligned along NE-SW lineaments. Another group of active moulins is located in the lowermost part of the glacier; some of them have wide feed basins (larger than 1 km^2), and experience large in-flowing discharges. All the moulins are located along extension zones controlled by the geometry of the glacier bed.

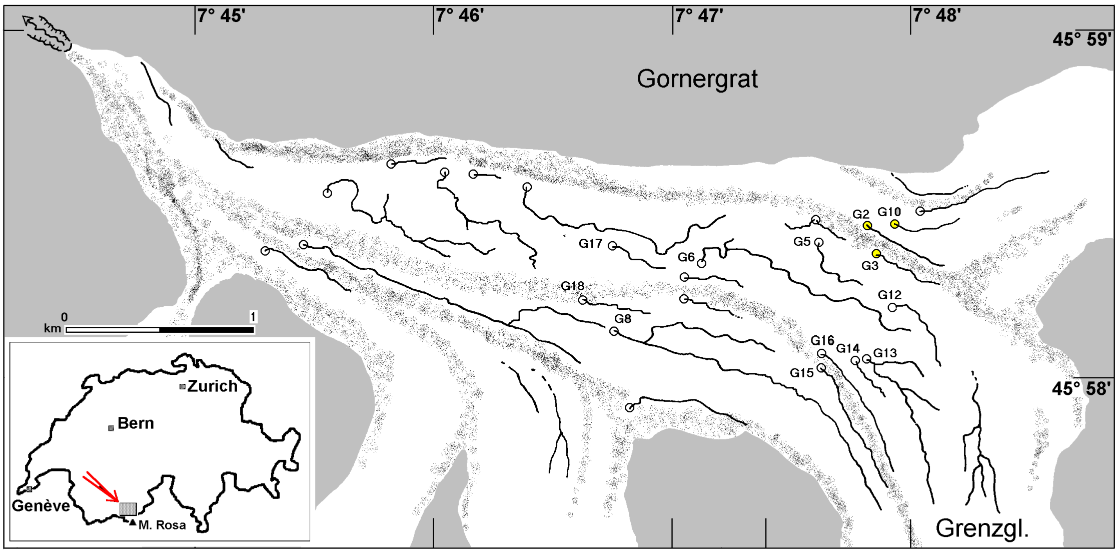

Fig. 1 – Sketch map of the ablation zone of Gorner, with the main supraglacial drainage. The small circles indicate the position of the moulins traced in 1999 and 2000.

Marginal Caves and Moulins

Two morphological and genetic types of glacier caves have been surveyed on the Gorner: marginal contact caves and supraglacial swallow-holes (ERASO & PULINA, 1992; PICCINI, 1999).

Marginal caves form at the contact between ice and lateral moraines or basal bedrock; most of them are small, impenetrable, and frequently affected by the collapse of the entrance.

The largest marginal caves (Fig. 2), more than 200 m long, are located upstream the confluence of Gornergletscher with Grenzgletscher. These caves act as subglacial outflows of a marginal ice-dammed lake, named Gornersee, which forms and is completely empty during the summer (ROTHLISBERGER, 1972, BEZINGE, 1973). A large tunnel, developed along the contact between ice and moraine or bedrock, makes up these marginal caves.

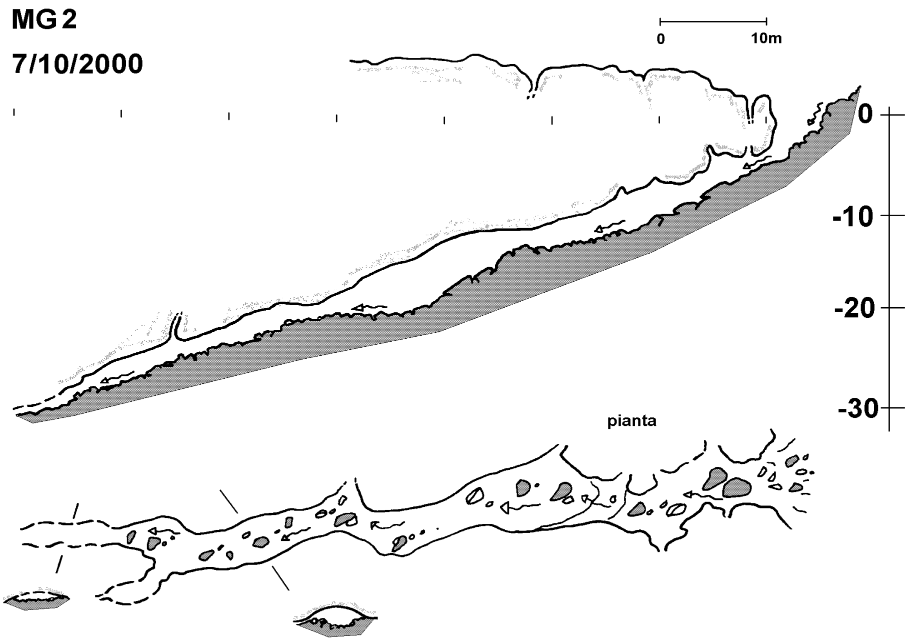

Fig. 2 –Profile and plan view of the marginal contact cave of Gornersee (survey L. Piccini & A. Romeo, October 2001).

Moulins are usually structured like a vertical shaft, sometime followed by a high and narrow canyon.

The entrances have dimensions ranging from some tens of cm up to 10-15 m. An important morphologic difference concerns the evolution stage. The new moulins, at the beginning of summer, have small elliptical entrances, with the major axis in the direction of an extension fracture. At the end of the seasonal period of evolution (usually the end of October) the entrances exhibit an elongated shape because of the regressive erosion of the waterfall rim.

The vertical pattern of moulins varies from almost perfectly vertical (ice shafts) to horizontal (epidermic moulins) (Fig. 3 e 4).

Moulins form where a crevasse cuts a surface stream and the pattern of the first shaft is always controlled by the geometry of the fracture (HOLMULUND, 1988; BADINO & PICCINI, 1995). The lower part is often oriented in the direction of ice flow and so it is probably controlled by the hydraulic gradient.

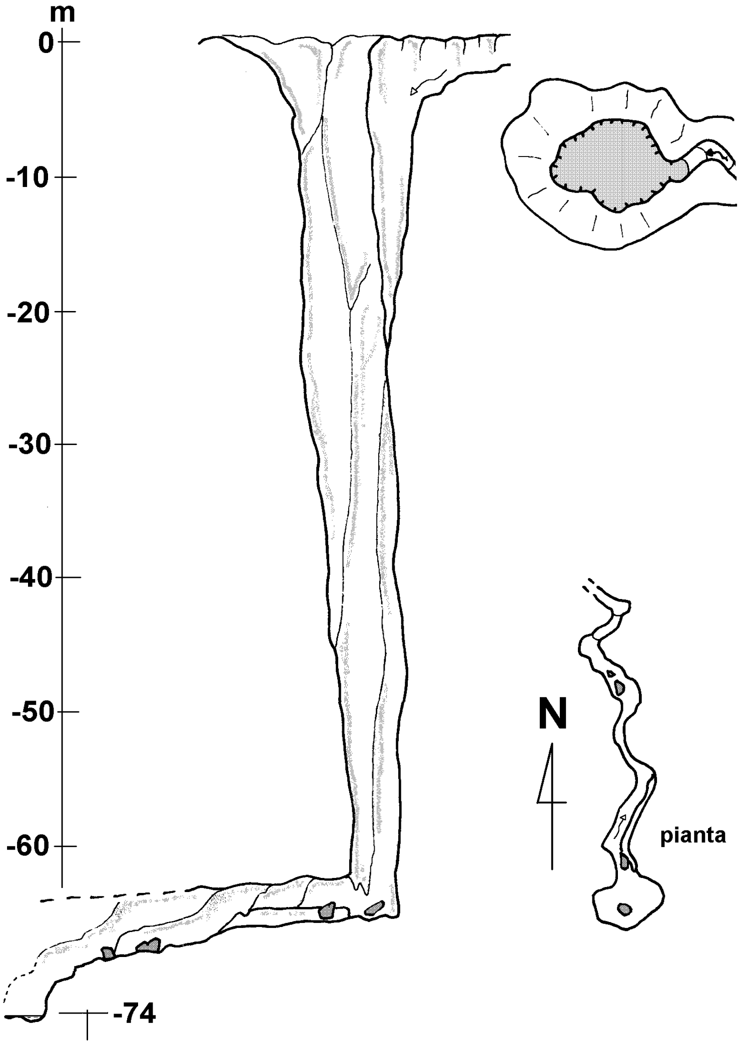

Fig. 3 – Profile and plan view of a typical vertical moulin of Gorner (G16: survey L. Piccini, October 1999)

In the upstream part of ablation zone, (2550-2600 m), the moulins have a vertical pattern, with a first shaft, 40-80 m high, followed by narrow and steep canyons. In the middle-low part of the ablation zone, the geometry of moulins is progressively less steep going down-glacier

Moulins are here characterised by a small first shaft, followed by a gently steep meandering canyon (Fig.5).

According to our surveys the depth of moulins does not seem to be influenced by the in-flow discharge.

In our opinion, the different geometry of moulin mainly depend on: (i) the local stress distribution, (ii), the mechanical properties of ice and (iii) the fluctuations of englacial water level, which lead the first evolution stage. The first factor is probably the most important, but a relevant contribute of the others cannot be excluded (BADINO, 1995).

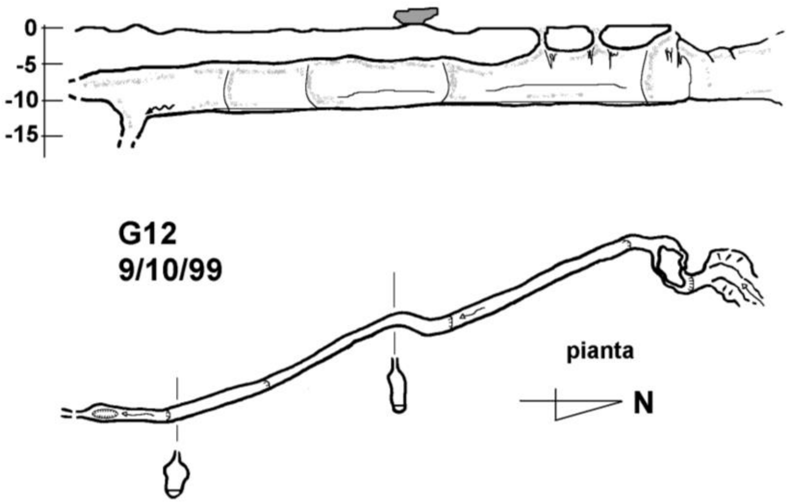

Fig. 4 – Profile and plan view of a horizontal moulin of Gorner (G12: survey A. Romeo, October 1999)

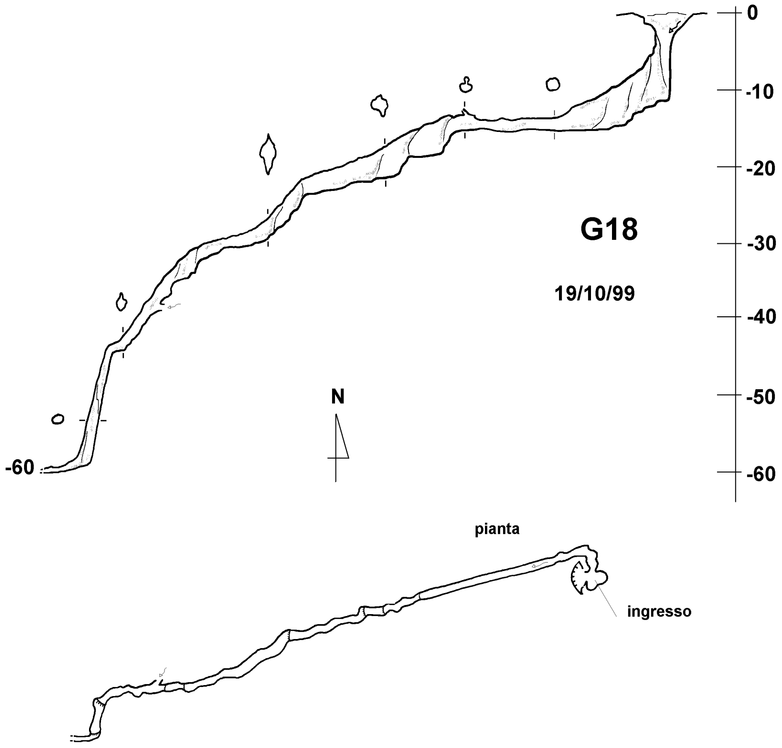

Fig. 5 – Profile and plan view of an inclined moulin (G10: survey Ass. La Venta, October 1999)

Hydrology and Evolution of Moulins

Thanks to the E-W orientation, the Gorner experiences a high insulation, for that reason the surface melting is probably more than 3 m a^{-1} of water in the ablation zone. Supraglacial runoff begins in May, by the melting of snow, and continues to the end of October. Usually, at the end of June the glacier surface is free of snow beneath 3000 m. According to our measurements, we can assume a surface ice melting of 20-30 mm d^{-1} in the months July and August; in October surface melting reduces to few millimetres. During the summer time, the meltwater specific discharge ranges from 0.23 to 0.35 m^3 s^{-1} per km^2 (Piccini, 1999).

A network of supraglacial streams, located mainly near the medial moraine, drains melting water.

The largest streams, whose feed basins are wider than 1 km^2, have a maximum discharge of 1-2 $m^3 s^{-1}$ and a minimum discharge often lower than 10-20 l s^{-1}. In the period of maximum melting, the total discharge of infiltration through moulins probably reaches 10 $m^3 s^{-1}$.

During the high-melting season (June-September), the largest moulins experience diurnal fluctuations of discharge, which displays a minimum, early in the morning, and a maximum, late in the afternoon. The ratio between minimum and maximum flow is frequently more than 1:100, but the diurnal excursion of discharge heavily depends on daily weather conditions.

In the period of minimum discharge, when moulins are accessible, the depth of water level ranges from few meters to more than 100 below the ice surface. Indeed, the water table has a complex geometry and it is possible to find very different levels in moulins only few tens of meters far. Namely, we don't know much about the high-discharge conditions. In particular we don't know how much the water rises in the moulins.

In the beginning of the melting season we can observe two kinds of moulins: the reactivated ones, heritage of the previous year, and the new moulins, formed by the capture of a stream feeding an older moulin.

The formers don't show relevant modification during the evolutionary season, probably because they can use the previous englacial drainage conduit, which is preserved during the winter, although reduced in the dimension. Thus, when the moulin is reactivated the water table rapidly falls to the ordinary summer level.

In the new moulins, the connection with the englacial network is, in the initial stage, characterised by a low hydraulic conductivity and thus the water table is very near to the surface and descends slowly with the progressive widening of the water-filled conduits.

Repetitive surveys of the same moulins along a period of one year have shown that the internal geometry is subject to seasonal changes controlled by the hydrodynamic and by the collapse of ice in the deepest part.

In particular we observe an upward retreat of the waterfall base-pools and the change of inclined conduit into a sequence of shaft and horizontal passages.

Conclusions

On the ground of our investigations we can assert that the spatial distribution of moulins remains almost the same year after year and that the main morphological features show also only little differences. This fact suggests that the position and the pattern of moulins depend on the distribution of stress inside the glacier and on the effect of this on the surface topography and hydrology (HOLMULUND, 1988; BADINO & PICCINI, 1994).

Most of the supraglacial channels survive during the winter, thus every spring the drainage network is reactivated with only small differences from the previous year. At the beginning of the melting season the moulins are completely filled by water, the pressure of water is probably responsible of the reactivation of moulins, unless a new moulin is formed upstream. So, the development of moulins is the consequence of the seasonal evolution, during the all the period when the cave is active (BADINO, 1995).

Our observations seem to indicate that in the last 15 years the number of moulins and their period of life are increasing. Further studies are necessary to understand well the cyclic life of moulins, whose increasing could be referred either to a lower movement rate of the glacier or to different climatic conditions.

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Atualização da Distribuição de Cavidades Significativas da Província Carbonática Espeleológica de Arcos-Pains-Doresópolis

[Updating the Caves Distribution of Arcos-Pains-Doresópolis Speleologic-Carbonatic Province]

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Abstract

The Arcos – Pains - Doresópolis Speleologic-Carbonatic Province (APDSCP) is situated on the Southwest São Francisco River Basin, including the following towns: Arcos, Pains, Doresópolis, Córrego Fundo and Bambuí.

The increasing of the explorations, maping and studies in the APDSCP, since 1980 decade, was made and executed by several speleological groups like ESPAM (Espeleogrupo Aníbel Matos), GBPE (Grupo Bambuí de Pesquisas Espeleológicas), NAE (Núcleo de Atividades Espeleológicas) e GAPE (Grupo Agster de Pesquisas Espeleológicas). The last one (GAPE) has emphazised importance atributed due to the continuous region exploration, which allowed this group to publish two reports at the XXI Congresso Brasileiro de Espeleologia – Curitiba (PR), 1991. They are: “A gruta do Éden” e “A Província Arcos-Pains”, this last one adding up to a total of 38 caves.

Since the 1990 decade, a significant increasing in the caves collection of APDSCP was detected. This fact is attributed to a several academic reports realized in the region added to Environments Reports Licences made by consultants of calcareous and dolomites mining. It has became possible due to a greater inspection by Governmental Environments Departments, who implemented the following laws:

- Resolução nº 005/87 – CONAMA, determinating the speleological studies enclosuring to Environments Impact Reports;
- Portaria nº 887, 15/06/90 – IBAMA;
- Decreto Governamental nº 99556 – 01/09/90, refering to brazilian caves protection.

At the XXIII Brazilian Speleology Congress realized in the city of Monte Sião (MG), Guano Speleo IGC-UFMG members presented an article titled “Novos Dados de Cavernas da Província Arcos-Pains”, showing a table and map with 88 caves. In 1998, at the XL Brazilian Geology Congress in Belo Horizonte city (MG), under title “Distribuição das Cavernas da Província Espeleológica Arcos-Pains”, a total of 110 caves was showed in a table containing the main characters, beyond a map with respective localizations. Even in this event, it was presented another academic studies about this region.

In the last three years, a considerable increasing rate ocurred in the universe of explored and mapped caves, mainly by the continuous acting of Environment Consultancies that produced karstic-speleological reports including caves characterizations and maps with respective localizations. Guano Speleo IGC-UFMG activities had the same importance in developing “Projeto Pains – Desenvolvimento Sustentável da Província Arcos-Pains-Doresópolis”, working with the ancient collection recovery and complementing as well as new data acquisition at the speleological sector.

It will be intended to be presented in this event the Speleological Province Databank Updating in a table with explored and mapped signficant caves. It will contain eleven columns with mumerical data about linear length, horizontal projection, depths, toponimy, UTM and exploring date, beyond the caves names and its

town localization, the data source, detailments (if it is mapped or not) and even the appearance of water stream inside.

The table above presents the whole explored significant caves, distributed according with linear lenghts:

2 caves with linear lenghts over 1000 meters;

128c aves with linear lenghts over 50 meters;

2 caves with linear lenghts over 500 meters;

103 caves with linear lenghts over 30 meters;

110 caves with linear lenghts over 100 meters;

89 caves with linear lenghts over 15 meters.

Localização e Aspectos Geológicos

A Província Carbonática Espeleológica de Arcos – Pains - Doresópolis (PCEAPD) localiza-se na borda sudoeste da Bacia do Rio São Francisco, englobando em parte, os municípios mineiros de Arcos, Pains, Formiga, Córrego Fundo, Doresópolis, Bambuí e Iguatama.

Quanto a localização geológica, posiciona-se no Grupo Bambuí, em sua Facies Carbonática (constituída por calcários, dolomitos e margas), localmente intercalados a áreas de transição (calcários lenticulares, em meio a rochas pelíticas). Está limitada a sul e oeste por pelitos, a norte por psamo-pelitos, sudoeste por quartzitos e milonitos do Grupo canastra, além da Seqüência Vulcano – Sedimentar de Piun-í e a leste pelo embasamento Granito – Gnáissico de Formiga – Camdeias.

Histórico

Os primeiros estudos de cunho espeleológicos se restringem a levantamentos desenvolvidos através da Sociedade Espeleológica Excursionista (SEE - UFOP) na década de 60. Destaque para o mapeamento de Lima (1961) da Gruta da Cazanga (MG-077) em Arcos. Os trabalhos da SEE na região terminam no primeira metade da década de 70 com destaque para o mapeamento de outras duas importantes cavidades.

Com a intensificação dos trabalhos de prospecção e mapeamento espeleológicos e estudos de caráter geológico dentre outros na referida província, a partir da década de 1980, realizados por grupos de espeleologia como o ESPAM (Espeleogrupo Aníbal Matos), GBPE (Grupo Bambuí de Pesquisas Espeleológicas), NAE (Núcleo de Atividades Espeleológicas) e GAPE (Grupo Agster de Pesquisas Espeleológicas), tendo este último grande destaque pela contínua exploração da região ao apresentar dois trabalhos no XXI Congresso Brasileiro de Espeleologia – Curitiba (PR) em 1991, intitulados “A Gruta do Éden” e “A Província Arcos - Pains”, sendo, neste último, somado um total de 38 cavidades.

No início da década de 90, houve considerável aumento do acervo espeleológico da PCEAPD devido à maior freqüência dos trabalhos apresentados de cunho acadêmico (monografias, disciplinas de graduação e teses de pós-graduação) e principalmente aos relatórios envolvendo Licenciamentos Ambientais realizados por consultorias para minerações de calcário e dolomito. Este fato tem sua causa em parte explicada devido à intensificação da fiscalização por parte dos órgãos de controle ambiental que se apoiam principalmente nas seguintes leis referentes à proteção das cavidades subterrâneas em território nacional:

- Resolução 005/87 do CONAMA, que determina a anexação de estudos espeleológicos aos Relatórios de Impacto Ambiental;
- Portaria nº 887, de 15/06/90, do IBAMA;
- Decreto Governamental nº 99556 de 01/09/90,

No XXIII Congresso Brasileiro de Espeleologia de Monte Sião (MG), foi apresentado por membros do Guano Speleo IGC-UFMG[1] artigo intitulado “Novos Dados de Cavernas da Província Arcos - Pains”, onde foram apresentados tabela e mapa com 88 cavidades plotadas. Em 1998, no XL Congresso Brasileiro de Geologia – Belo Horizonte (MG), sob o título de “Distribuição das Cavernas na Província Espeleológica de

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[1] Grupo de espeleologia fundado em 1993, por ex-membros do extinto GAPE, do NAE e da SEE.

Arcos-Pains”, foi exibido um número total de 110 cavidades exploradas, com suas principais características listadas em forma de tabela, juntamente com mapa (escala 1:50 000) e suas respectivas plotagens. Ainda neste evento, foram apresentados trabalhos de cunho acadêmico sobre a região.

Nos três últimos, ocorreu um considerável aumento do número de cavernas significativas exploradas e mapeadas, principalmente pela atuação contínua de consultorias de cunho ambiental que produziram relatórios “cársticos - espeleológicos” com caracterizações, plotagens e mapeamento de cavernas, sendo os mesmos atualizados pelo Guano Speleo IGC-UFMG, o qual envolve-se hoje no “Projeto Pains – Desenvolvimento Sustentável da Província Arcos – Pains - Doresópolis”, trabalhando na recuperação e complementação de parte do antigo acervo e obtenção de novos dados.

Mineração	**Cavernas >15m**	**Cavernas > 30m**	**Cavernas > 50m**	**Cavernas >100m**	**Cavernas > 500m**	**Cavernas > 1000m**	**Total de Cavernas**
Min. Amargoso	4	2	--	--	--	--	6
Brasical/Brisolo-	10	1	2	3	--	--	16
Calcinação Pains	3	3	--	1	--	1	7
CBE(GrupoJ. Santos)	13	12	14	15	--	--	54
COMIG/(Timburé)	3	3	4	3	--	--	13
CSN (Arcos)	2	4	2	3	--	--	11
Mineração Ducal	12	1	4	2	--	--	19
MineraçãoGecal	1	5	5	2	--	--	13
MineraçãoICAL	10	33	28	17	--	1	89
Mineração Leal Rosa	--	2	1	1	--	--	4
Pains Cal	4	1	2	6	--	--	13
Quinbarra SA	--	3	12	6	--	--	21
Quinvale	15	12	12	1			40
Mineração Saldanha	--	2	2	3	--	--	7
Mineração Solo-Fértil	--	1	1	3	--	--	5
Supercal	--	3	2	1	--	--	6
Mineração Timburé	3	1	1	--	--	--	5
ESPAM	--	--	2	3	--	--	5
E.S.B.M.A. (Iguatama)	3	2	1	1	--	--	7
Guano Speleo(+GAPE)	--	8	13	28	2	--	51
GBPE	--	--	12	4	--	--	16
L. E.Sanches	3	3	4	3	--	--	13
NAE	3	1	4	1			9
S.E.E.	--	--	--	3	--	--	3
TOTAL	**89**	**103**	**128**	**110**	**2**	**2**	**434**

Tabela Quantitativa da distribuição das cavernas na Província Espeleológica Carbonática Arcos – Pains - Doresópolis – Minas Gerais - Brasil

Resultados

Será apresentada neste evento a atualização do banco de dados da PCEAPD, sob a forma de um tabela de caracterização das cavidades significativas exploradas e/ou mapeadas. Esta contém onze colunas onde serão incluídos os seguintes dados: desenvolvimento linear, projeção horizontal, desnível, toponímia, UTM, data da exploração, além dos nomes das cavidades e dos municípios em que se inserem, a fonte dos dados, detalhamento (mapeada ou não) e ainda informação sobre a presença de curso d’água perene em seu interior.

Como um dos resultados deste trabalho - onde ressaltando-se tabela na qual foi possível a compilação de um total de 434 cavidades significativas exploradas, distribuídas de acordo com os intervalos de desenvolvimentos lineares sugeridos:

2 cavidades com desenvolvimentos lineares superiores a 1000 m;

2 cavidades com desenvolvimentos lineares superiores a 500 m;

110 cavidades com desenvolvimentos lineares superiores a 100 m;

128 cavidades com desenvolvimentos lineares superiores a 50 m;

103 cavidades com desenvolvimentos lineares superiores a 30 m;

89 cavidades com desenvolvimentos lineares superiores a 15 m;

A tabela de caracterização de cavidades significativas não será anexada ao presente devido as suas elevadas dimensões (500 cavidades com descrições resumidas em dez colunas).

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Le Karst du Sud-Est du Piauí (Brésil): Premiers éléments chronologiques

[The Karst of the Southeastern Piaui (Brazil): First chronological data]

[O Carste do Sudeste do Piauí (Brasil): Primeiros elementos cronológicos]

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The Karst of the Southeastern Piaui (Brazil): First Chronological Data

The southeastern Piauí state overlies the contact between the north of the São Francisco craton and the Parnaíban sedimentary basin, presenting a significant geological diversity. There are several small and deeply karstified hills. The Pre-Cambrian limestone went through a first emersion during the Primary Era, being submerged by the Silurian-Permian Parnaíba sea. Afterwards, it experienced a second emersion more than 350 millions years ago. Karst evolution has been continuous since then, culminating in the present stage of residual hills. Some morphological elements give an insight into a long and complex evolution in an area that lacks precise chronological data.

Key-Words: karst, Pre-Cambrian limestone, geomorphological evolution, Brazilian Northeastern, Piauí, São Francisco craton, sedimentary basin of Parnaíba.

O Carste do Sudeste do Piauí (Brasil): Primeiros Elementos Cronológicos

O sudeste do Piauí engloba o contato geológico entre o norte do cráton do São Francisco e a parte sul da bacia sedimentar do rio Parnaíba, apresentando uma diversidade geológica significativa. Em particular, ocorrem pequenos morros bastante carstificados. Após uma primeira fase de emersão na Era Primária, os calcários do período Pré-Cambriano foram recobertos pelos arenitos silurianos-permianos do mar do Parnaíba. Seguiu-se uma segunda emersão a mais de 350 milhões de anos. As fases cársticas se sucederam até que a erosão reduzisse o relevo ao estágio atual de morros. Alguns elementos permitem evidenciar várias fases de uma longa e complexa evolução em um setor onde faltam referências cronológicas claras.

Palavras-Chaves: carste, calcários Pré-Cambrianos, evolução geomorfológica, Nordeste, Piauí, cráton do São Francisco, bacia sedimentar do Parnaíba.

Résumé

Le sud-est de l'état du Piauí, recouvrant la rupture entre le nord du craton du São Francisco et le bassin sédimentaire du Parnaíba, présente une variété géologique importante pour le Brésil. En particulier, se développent des petits massifs fortement karstifiés. D'âge pré-cambrien, les calcaires qui les composent, après une première phase d'émersion au Primaire, sont recouverts par la mer siluro-permienne du Parnaíba, avant de connaître, depuis plus de 350 millions d'années, une seconde émersion. Les phases karstiques s'y sont succédées jusqu'à ce que l'érosion réduise à l'état actuel de chicots, une extension majeure de calcaires. Certains éléments morphologiques permettent de dégager quelques phases d'une évolution longue et complexe dans un secteur qui manque de repères chronologiques clairs.

Mots-Clés : karst, calcaires pré-cambriens, évolution géomorphologique, Nordeste, Piauí, craton du São Francisco, bassin sédimentaire du Parnaíba.

Le Sud-Est de l'état du Piauí est une région karstologique méconnue du Nordeste brésilien (fig. 1), située à l'intérieur du semi-aride "polygone des sécheresses". A la limite de l'influence des masses d'air atlantique apportées par les alizés de sud-est, et des masses d'air continental équatorial, le haut bassin du Piauí est soumis à un climat semi-aride chaud, avec des pluies d'été (classe BShw de Köppen). La sécheresse y dure en général de mai à octobre. La moyenne des précipitations est de 650 mm/an, mais, en dehors des contraintes thermiques et hydriques, ce chiffre n'a guère de signification en raison d'une extrême irrégularité génératrice de grandes sécheresses catastrophiques ou d'inondations. En effet , sur le même site, on peut relever une année 250 mm, voire même 0 mm, et l'année suivante plus de 1.100 mm [EMPERAIRE, *in* ARNAUD *et al.*, 1984].

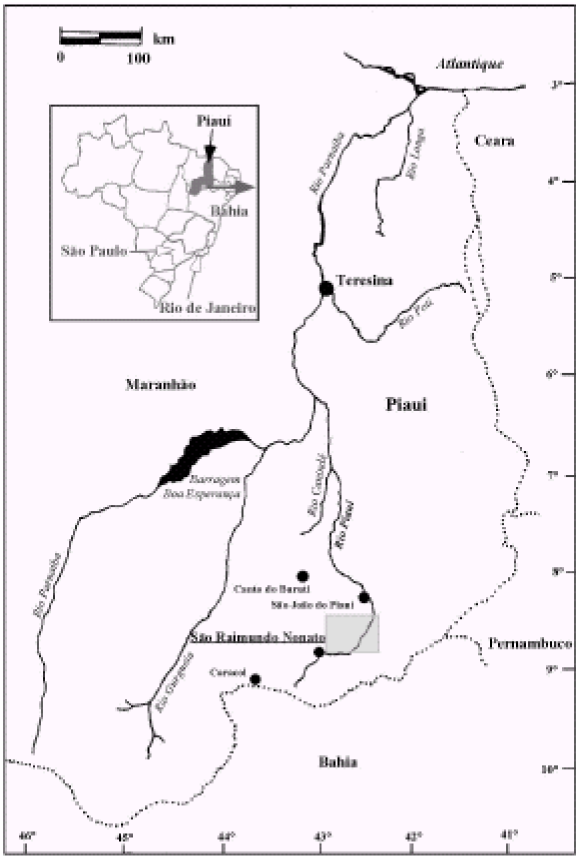

Figure 1 : situation de l'aire d'étude. Location of the studied area.

Le secteur d'étude est délimité par les coordonnées géographiques, 8°30' et 9° de latitude sud, et 42° et 43° de longitude ouest, et s'étend sur les municipes de São Raimundo Nonato, Coronel José Dias, São João do Piauí et Canto do Buriti.

Dans cette zone, a été créé, en 1979, le Parc National de la "Serra da Capivara", déclaré en décembre 1991, "patrimoine culturel de l'humanité" par l'Unesco, pour sa richesse archéologique exceptionnelle [PROUS, 1991].

Deux ensembles de massifs calcaires [RODET, 1997] sont connus (fig. 2). Le premier se développe entre la cuesta et la route fédérale BR-20, entre le "sítio do Garrincho" (São Raimundo Nonato) et "Barragem" (Coronel José Dias), selon um alignement assez régulier de 8 mornes. Le second s'étend à l'est, entre "Barragem" et "Borda", en un grand nombre de petits mornes faiblement élevés au-dessus du pédiment. Les travaux réalisés ont mis en évidence des relations stratigraphiques entre

chacune des unités calcaires, et il semble s'agir d'une seule et même unité dont seules les pointes les plus élevées percent audessus de l'épandage détritique du glacis [RODET, 1993].

Le Contexte Géologique

La région étudiée se situe sur le craton pré-cambrien du São Francisco, au pied de la cuesta du bassin siluro-permien du Parnaíba dont le front domine une vaste dépression subséquente méridionale (fig. 2). Les matériaux arrachés à la cuesta gréseuse et conglomératique sont épandus en un long glacis sur un pédiment, la *planície*, modelé à partir du rio São Francisco, fleuve majeur du Nordeste s'écoulant plus au sud [PETRI et FULFARO, 1988]. De cette platitude émergent quelques reliefs résiduels. Beaucoup sont des inselbergs de gneiss ou de quartzites, mais certains, au pied même de la cuesta, sont des chicots calcaires, des *serrotes* et dês *morros*, à la morphologie karstique très développée [PELLERIN, *in* ARNAUD *et al.*, 1984].

Le socle, archéen et protérozoïque inférieur, est composé au sud de gneiss et migmatites (Groupe Caraïba) et au nord de micaschistes (Groupe Salgueiro). Cette dernière série renferme en outre des niveaux de calcaires métamorphiques et de quartzite qui apparaissent en relief dominant. Accompagnant lê cycle tectonique Brasiliano (680-450 millions d'années), une première phase d'émersion laisse supposer une karstification très ancienne (dépression du Serrote do Artur) qu'aurait fossilisée la submersion siluro-permienne du Parnaíba, mais sés témoins sont délicats à identifier.

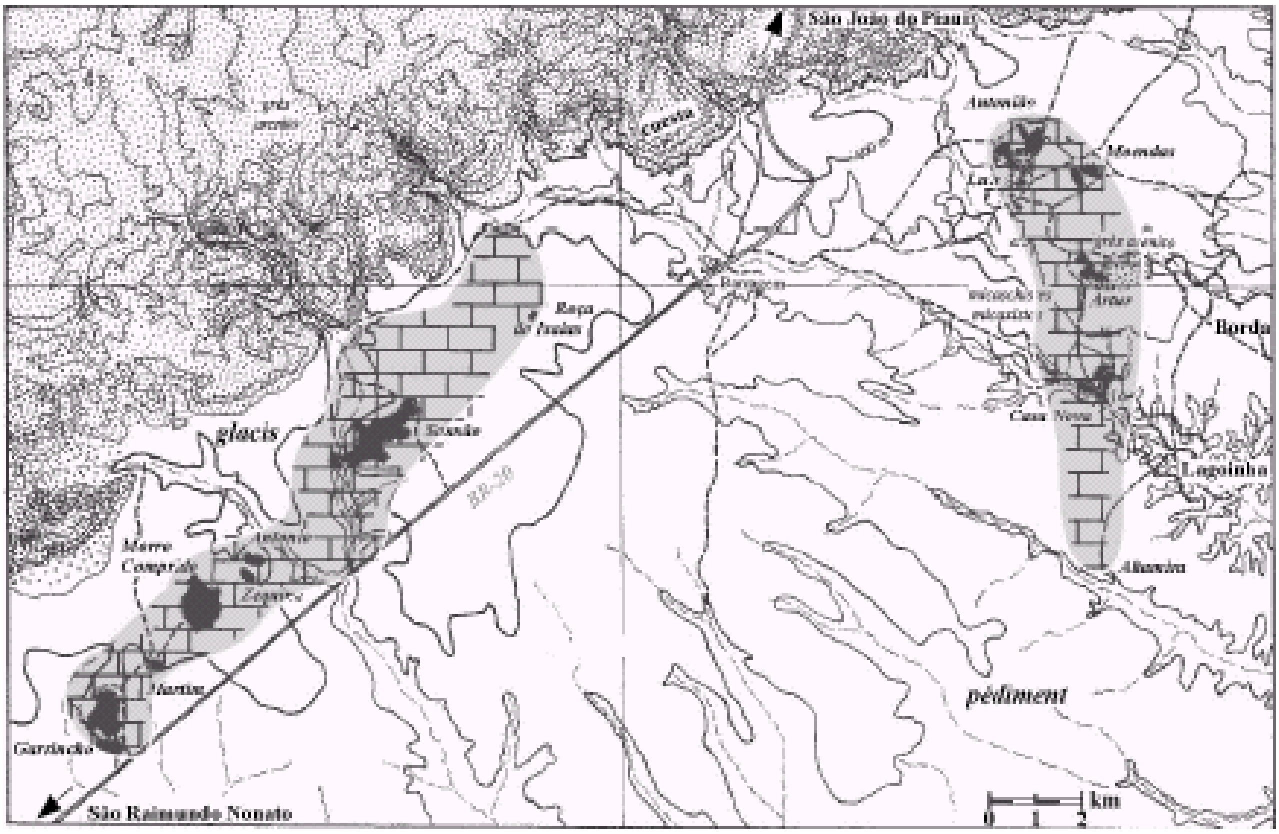

Figure 2 : les massifs calcaires de l'aire d'étude. The limestones unities of the studied area

Après cette phase sédimentaire à faible diagenèse (grès quartzeux, surmontés de conglomérats quartzeux, dans lesquels l'érosion a dégagé la cuesta), l'émersion fini-permienne initie une phase d'évolution continentale en relation avec l'évolution du cours du paléo-fleuve São Francisco. Jusqu'au Santonien, lê cours inférieur est orienté vers le nord (golfe marin du Parnaíba), ce qui doit limiter l'évolution continentale de la région étudiée. Il faut attendre le soulèvement post-crétacé pour permettre le dégagement de la cuesta et de la dépression subséquente [AB'SÁBER, 1972]. Cette surrection est responsable d'une phase d'endoréisme du paléo-São Francisco durant le Mio-Pliocène (plateforme de calcaires blancs lacustres de Bom Jesus da Lapa à Juazeiro-Petrolina, de 10 m de puissance [BRANNER, 1910]) qui draine le bassin du haut-Piauí, avant qu'enfin se réalise la capture par un fleuve côtier baianais (cascades de Paulo Alfonso). Pendant ce temps, le rio Parnaíba se développe vers le sud et un de ses affluents, le rio Canindé atteint, par érosion régressive, la dépression subséquente. Il en résulte la capture du bassin du haut-Piauí, dont le cours d'eau s'enfonce d'une vingtaine de mètre dans le pédiment, en abandonnant son parcours vers le São Francisco.

C'est la situation actuelle.

Le karst relique du Haut Piauí Au-dessus du pédiment, les sommets des dépôts calcaires ont subi une karstification intense et profonde, avec introduction des débris arrachés à l'environnement non carbonaté (glacis). Il en résulte un comblement des conduits par des éléments grossiers (notamment des galets de quartz) et fins (argiles de décantation). Ces paléo-drains comblés de remplissages fortement indurés, sont aujourd'hui recoupés par l'érosion, et illustrent une première "phase" de karstification, d'âge possible tertiaire, avec un cavernement profond et dense de la masse. Le ciment siliceux des comblements d'argiles rubéfiées à galets de quartz, assure une homogénéisation et une forte résistance :on retrouve des planchers à substitution de la calcite par la silice, ce qui laisse supposer une longue phase d'ennoiement en climat chaud. C'est aussi l'indication d'une succession complexe de types dynamiques dont il n'est pas possible, actuellement, d'élaborer la chronologie. Depuis le Pléistocène, l'ensemble s'exonde et s'assèche. Le niveau de base hydrologique est représenté par le paléolit du rio Piauí vers lequel se réalise le drainage de la dépression et du front de cuesta. La capture du rio Piauí, par la percée du rio Canindé à São João do Piauí, engendre un enfoncement du drainage, d'au-moins 20 m sous le glacis, qui se répercute dans les massifs calcaires. Cette dernière phase est relativement récente, fini-tertiaire ou Quaternaire ancien. Les mornes, très cloisonnés par la tectonique qui les individualise morphologiquement, sont dans la partie Est, des écailles calcaires, bousculées par une phase tectonique chevauchante.

Dans la partie occidentale, on observe une succession d'ondulations dont la cartographie reste à faire.

Le karst nu se développe essentiellement dans les mornes ou serrotes, ce qui n'exclut pas des surfaces calcaires au niveau du pédiment. On y distingue des formes de corrosion en kamenitza, et d’autres en rainures (rillenkarren), dégageant par coalescence des lapiés (spitzkarren). Cette morphologie superficielle se surimpose très souvent à des formes souterraines recoupées par l'érosion (bases de puits ou parois de galerie). Les mégaformes superficielles résultent généralement de tels recoupements et sont rarement des formes originelles. Des avens et des grottes donnent accès à l'endokarst. Le karst couvert concerne des étendues beaucoup plus importantes. Cependant les conditions de l'aridité, la nature dês couvertures du glacis et la végétation serrée de la caatinga en limitent l'expression. On observe, ici ou là, une doline généralement peu profonde (plusieurs centaines de mètres de diamètre pour quelques mètres de profondeur), une perte ponctuelle (en période de pluie), mais aucune source, aucun aven. Localement, on peut rencontrer quelques crypto-lapiés exhumés de leur couvert argileux, près des pistes, mais, l'absence de forme exceptionnelle et surtout une faible densité des phénomènes caractérisent ce paysage de glacis [RODET, 1995].

Une évolution complexe : la toca da Coroa de Frade

Les mornes calcaires sont extrêmement réduits en dimension et ne s’élèvent à plus de 100 m au-dessus du glacis. Ils soulignent un aspect résiduel que confirme la présence de nombreux recoupement par la topographie de paléo-drains. Sur un potentiel d’un millier de cavités, à peine une soixantaine ont été explorées. L’aspect fragmentaire du karst est renforcé par la dimension relique des développements souterrains (moins de 400 m pour la plus longue grotte), ce qui ne doit pas masquer la densité des indices morphologiques d’une évolution complexe et variée. Ainsi, la Toca da Coroa de Frade, cavité majeure du Serrote do Antonião, présente de nombreuses variations du drainage, illustrées par l’organisation de ses conduits (fig. 3):

1 – Là où est établi le vallon qui isole le serrote da Bastiana du serrote do Antonião, a été identifié un paléo-collecteur oriente sud/nord (axe 1 du schéma d’évolution), aujourd’hui détruit (quelques éléments endokarstiques isolés ont été retrouvés).

2 - Le pendage stratigraphique favorable a facilité le glissement du drainage souterrain vers l’est par un grand nombre de petits conduits de fuite jusqu’à l’établissement d’un deuxième collecteur (axe 2 : *galeria da Alegria*). Les conditions géomorphologiques restent stables puisqu’on ne note pas de déviation notable du drainage karstique. On peut penser que lê pédiment s’abaisse légèrement sans modification fondamentale du relief.

3 – Par contre, avec la troisième phase, on note une première influence sur le drainage souterrain par un coude soudain de l’aval du drainage vers l’est, indiquant une modification des conditions de drainage et donc du relief extérieur, peut-être due à un enfoncement plus fort du niveau de base et le creusement d’un vallon vers l’est (capture karstique ?).

4 – La phase 4 confirme la modification radicale des conditions de drainage, puisque le sens d’écoulement s’inverse et décrit une boucle vers le sud (axe 4-4), avant de retrouver sa direction septentrionale. L’éloignement vers l’est du drainage est un élément important.

5 – la cinquième phase confirme l’évolution précédente, l’abaissement du niveau de base entraînant l’enfoncement du drainage souterrain et des captures, tandis que l’influence orientale augmente. On peut rapprocher cette observation de celle de l’évolution de la Toca da Barra do Antonião, grande cavité proche qui est peut-être alors recoupée par la surface.

6 – La situation actuelle montre, par delà la fossilisation saisonnière de la cavité, son inadaptation à la topographie locale. On note la duplication des exutoires actuels (6), l’un au nord qui retrouve l’orientation

initiale des phases 1 et 2, l'autre à l'est qui s'oriente résolument vers le sud. A l'intérieur de la cavité, cette duplication du drainage est soulignée par une ligne de partage des eaux (6-6) : celles qui atteignent la cavité au nord, rejoignent l'exutoire nord, tandis que celles qui rejoignent la partie méridionale de la grotte, se dirigent vers l'exutoire sud (Galeria do Sapo).

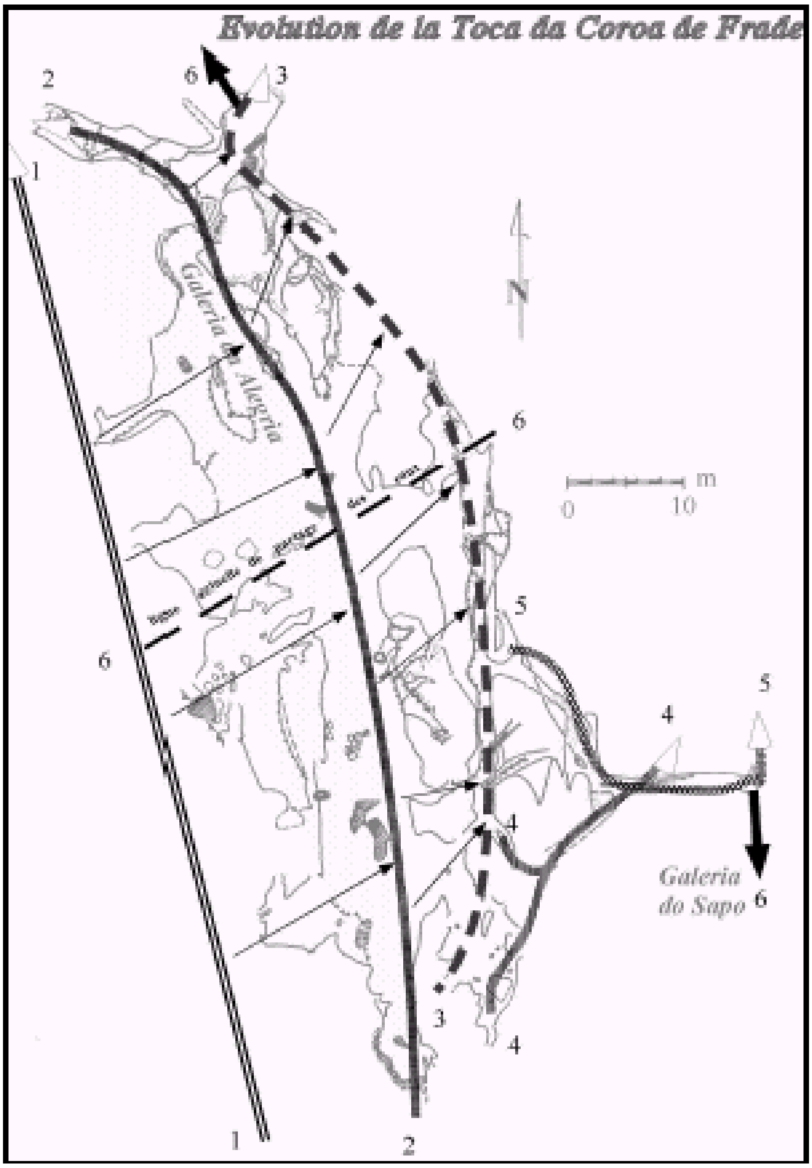

Figure 3 : évolution du drainage dans la Toca da Coroa de Frade. Underground drainage evolution in the Coroa de Frade cave

Le Serrote do Antonião : essai de Chronologie

L'introduction de ce schéma dans l'extension actuelle du massif calcaire est particulièrement parlante (fig. 4). On peut maintenir la comparaison avec l'évolution de la Toca da Barra do Antonião, ancien axe majeur de drainage du massif, dont les eaux fuient elles aussi vers le sud. Si l'on affine la comparaison entre les deux cavités, on peut distinguer :

1 - une première phase (axes 1 et 2) pendant laquelle les deux cavités doivent évoluer en parallèle, sans liaison directe affirmée.

2 - Lors d'une seconde phase (axe 3), l'évolution locale semble favoriser le développement de la Toca da Barra do Antonião, semble-t-il plus proche du bord du massif calcaire.

3 - Cette préférence se confirme dans une troisième phase (axes 4 et 5), lorsque cette dernière domine clairement le drainage souterrain du massif, soustrayant les eaux de la partie occidentale vers la partie orientale, jusqu'à la trépanation et la destruction de la cavité.

4 - La quatrième et dernière phase est l'actuelle (axe 6), où la pauvreté des précipitations ne permet pas l'entretien d'un drainage pérenne. L'isolement du serrote dans la topographie locale est suffisant pour permettre une diffluence du drainage souterrain et le morcellement de l'ancienne unité hydrologique.

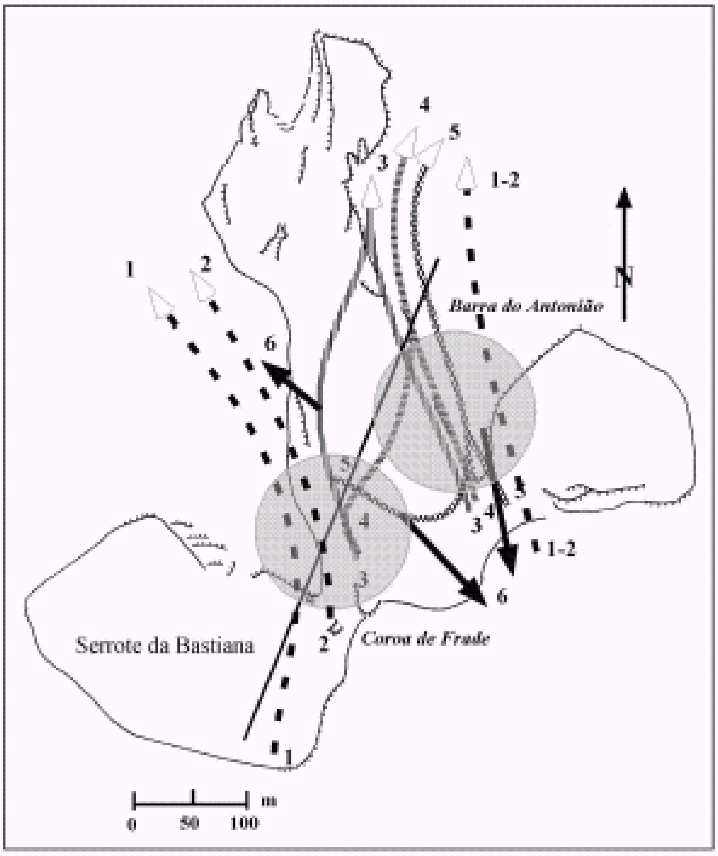

Figure 4 : variations du drainage karstique dans le serrote do Antonião. Karst drainage evolution in the Antonião's hill

Conclusion

Reconstituer l'évolution des vieux ensembles karstifiés des zones semi-arides du Brésil, est une tâche délicate en raison de la durée des phases d'érosion et du manque de repères clairs qui définissent les régions tropicales. Cependant l'examen des phénomènes endokarstiques et de leur situation morphologique, peut livrer parfois des éléments chronologiques, souvent très isolés mais qui localement permettent des propositions de travail.

Si l'on doit tenter une reconstitution chronologique de la région karstique de São Raimundo Nonato, fondée sur dês événements dynamiques, on est tenté d'associer la grande rupture hydrologique identifiée dans plusieurs cavités (phases 3 à 5) à la capture du haut Piauí par le rio Canindé, et son enfoncement d'une vingtaine de mètres dans le pédiment, descente qui n'a pas encore été récupérée par la morphologie en raison des conditions climatiques défavorables. Cet abaissement a pour conséquence l'enfoncement du drainage en amont dans le glacis et, donc, du drainage karstique. Ainsi, la modification de la morphologie de surface morcelle les reliefs et désorganise les circulations souterraines.

La multiplication des observations dans l'ensemble de l'aire d'étude devrait conforter le schéma d'évolution proposé.

L'utilisation de méthodes adaptées de datation pourrait, en fixant cette chronologie, apporter les ancrages temporels qui font défaut aujourd'hui.

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Role of Bacteria in the Growth of Cave Pearls

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Abstract

The growth of micritic cave pearls have been studied based on ones collected in Perlova Cave (Slovakia). The pearls display rough surfaces and irregular internal lamination. Several living bacteria have been detected inside the biofilm which covered still growing cave pearls.

These bacteria produce organic matter from inorganic, gaseous CO2 dissolved in water and hence cause oversaturation with respect to calcite within the bacterial surroundings. Thus calcite precipitation is due to the bacterial metabolism. SEM investigations indicate that the precipitation proceeds upon the surfaces of the bacterial cells. This process results in mineral replicas of bacterial cells and finally causes almost complete obliteration of primary microbial structures The bacteria uptake preferentially 16O and cause relative enrichment of heavier isotope (18O) in the bacterial surroundings and in precipitating calcite.

Introduction

Cave pearls, known also as cave pisoids, have been reported in literature for a long time (HILL & FORTI, 1997). This group of speleothems includes a broad spectrum of grains varying in shape and internal structure. Best known are the forms with smooth, lustrous surface and regular concentric lamination. The smooth and shining outer surface of these pisoids is related to abrasion on contacts with neighbouring grains and substrate (BAKER & FROSTICK, 1947).

Additional recognised prerequisites for their growth include the presence of suitable nuclei for the grain growth, supersaturated state of the solution from which the grains crystallise, and constant, balanced supply of water to the environment of their growth (GRADZI—SKI & RADOMSKI, 1967; DONAHUE, 1969).

Many authors have pointed out that cave pisoids include also other forms, namely ones whose internal structure is much less regular (BAKER & FROSTICK, 1947; THRAIKILL, 1963, 1976, GRADZI—SKI & RADOMSKI, 1967; DONAHUE, 1969; JONES & MACDONALD, 1989). Such pisoids have uneven, rough surfaces.

No coherent concept of their origin has been hitherto proposed. The aim of this paper is to explain the origin of the irregular cave pisoids in the context of their growth environment.

Material and Methods

Of the 21 caves from which cave pearls have been studied, the best conditions for complex study on their growth were found in the recently discovered and relatively little visited Perlova cave (Perlov·

jaskyÚa). Analyses made with the aim of explaining the conditions of pearl growth included chemistry and isotopic composition of water as well as chemical and mineral composition, stable isotopes ratios and internal structures of the pearls. Moreover, some pearls were aseptically collected and delivered to a microbiological laboratory, where microorganisms were isolated and identified in biochemical tests.

Speleological Setting

Perlova Cave is situated at altitude of 910 m in the Mala Fatra mountain group (Central Carpathians, Slovakia; Figure 1) (MR¡ZIK, 1987; HOL/BEK & KLESKE“, 1993). The area above the cave is covered with deciduous forest, and the rock mass above the cave is about 10 m thick. The temperature in the cave varies between 5.1 and 6.8 °C.

Water collects in stepped gour pools, from about 15 cm to more than 1 m wide, and a few centimetres deep (Figure 2). The water is supplied by drip from the ceiling and walls and by overflow from higher gour pools to the lower ones. Drops fall from the height of only 1.5 m or less, so the water in the pools is nearly stagnant. The intact fragile moonmilk gours testify that the flow of water is never violent. Calculations made on the base of the results of the chemical analyses, using WATEQ program, have shown that the water is supersaturated with respect to both, calcite and aragonite. Some of the gour pools contain more than a hundred pisoids, from a few millimetres up to more than 3 cm in size (Figures 2, 3). No pisoids were found cemented to the bottom.

Figure 1

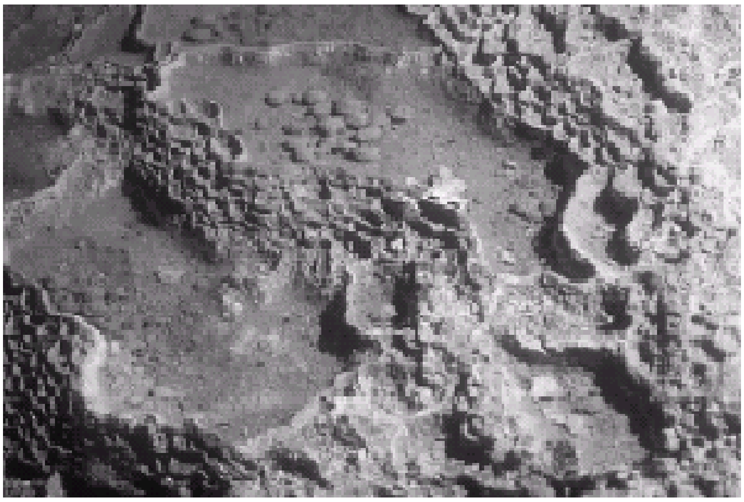


Figure 2

Figure 1 : Location of Perlova cave

Figure 2 : Stepped gour pools with irregular cave pearls

Results

The irregular pisoids from Perlova cave have rough outer surface, no nuclei, subtle and irregular lamination and no corrosional surfaces in their internal structure (Figure 3, 4). They are built of low-Mg calcite and contain up to 5.5 weight % of non-carbonate admixture and up to 0.46 weight % of organic carbon. Observations in light microscope and SEM have shown that these pisoids are built mainly of micritic calcite. Abundant cavities between the crystals make for the high porosity (above 80%) and low density (up to 1.4 g/cm3) of the pearls of this kind.

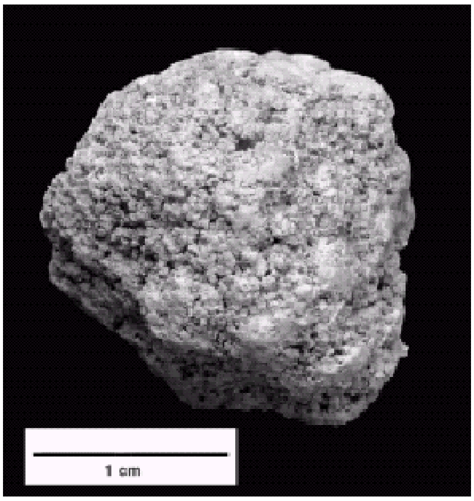


Figure 3

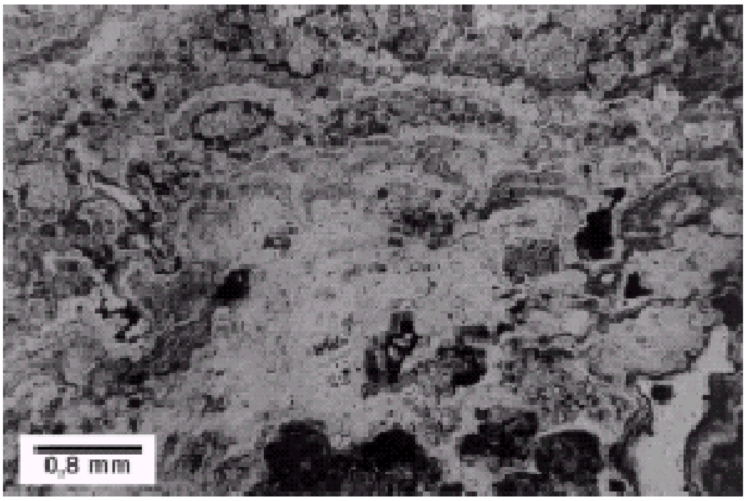


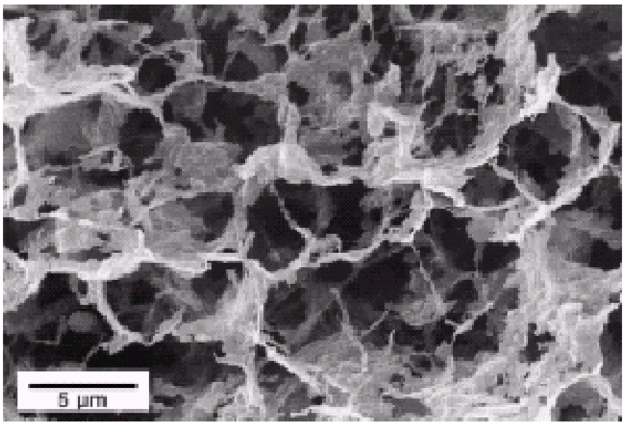
Figure 4

Figure 3 : Irregular cave pearl, note the distinct rough outer surface

Figure 4 : Cross section through irregular cave pearl, internal lamination is visible; transmitted light, II nicols

The outer surfaces of these pearls are covered with a thin mucous, spongy layer ñ biofilm (Figure 5). It is built of live microbial cells, their extracellurar polymeric substances and a mineral fraction.

The mineral fraction consists mainly of calcitic replicas of microbes. The replicas are identical in size and shape with the living cells (Figures, 6, 7). The living cells and their replicas occur together with regularly shaped calcite crystals in the external parts of the pearls. Such crystals are the main component of the inner parts of the pearls.



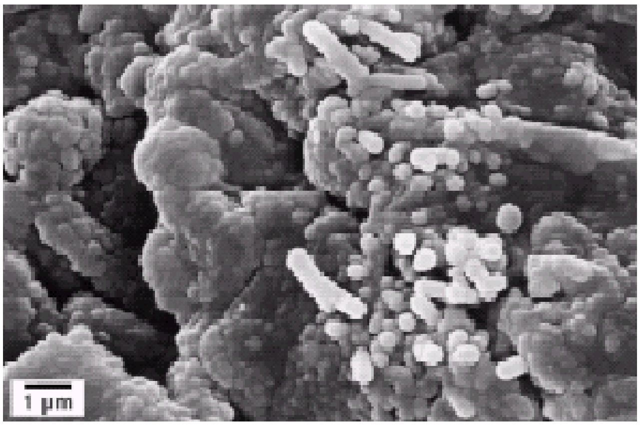


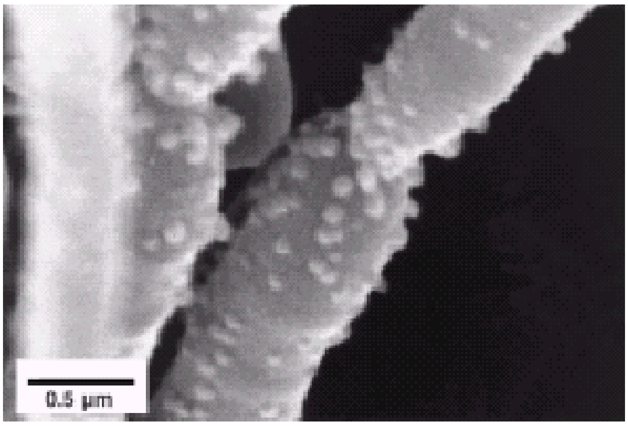
Figure 5 *Figure 6*

Figure 5 : Biofilm covering the surface of irregular cave pearl, SEM image

Figure 6 : Bacterial fabrics of irregular cave pearls

Microbiological study revealed the presence of various bacteria within the studied pearls. All studied samples included hydrogenoxidising bacteria (knalgas bacteria) and dinitorgen-fixing bacteria.

The most common of the first group were *Xanthobacter autotrophicus* and X. *flavus*, and of the second group - *Arthrobacter crystallopoietes*.



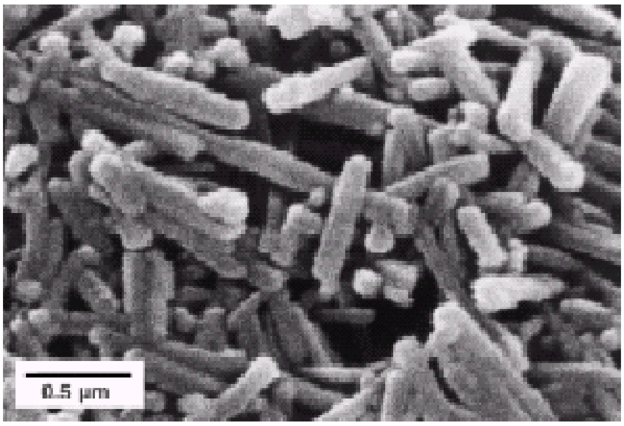


Figure 7 *Figure 8*

Figure 7 : Living (?) bacterial cells overgrown with minute calcite crystals

Figure 8 : Calcified replicas of bacterial cells

Growth of Irregular Cave Pearls

Process of Calcification

The presence of calcitic replicas of bacterial cells shows that calcification occurrs in living cells or simultaneously with their death (cf. JONES & KAHLE, 1986). In the next stage, the replicas become the nuclei of crystal growth and are successively overgrown with calcite crystals (cf. GUO & RIDING, 1994). The final stage of this process are regular crystals of calcite micrite with few ghostsî of the microbial replicas. The process of calcification obliterates the primary bacterial fabric (cf. SZULC & SMYK, 1994, GRADZI—SKI et al., 1997).

Mechanism of Calcification

Calcification is caused by disturbance of chemical balance within the pearls and the its surrounding biofilm. This disturbance results from microbial physiological processes. The main role is played by chemolithoautrophic hydrogen-oxidising bacteria (cf. ARAGNO & SCHLEGEL, 1992), which cause extracellular secretion of calcite by consumption of CO2 (cf. SIMKISS, 1986).

This process is active in conditions of high carbonate alkalinity and availability of Ca++ ions (cf. KEMPE & KAèMIERCZAK, 1990; MERTZ, 1992). The hydrogen-oxidising bacteria are indirectly

dependent on the supply of organic matter because the hydrogen they use is a by-product of heterotrophic dinitorgen-fixing bacteria (EADY, 1992; ARAGNO & SCHLEGEL, 1992). The hydrogenoxidising bacteria absorb preferentially the light oxygen isotope (16O) in CO2 or O2. This results in a relative enrichment of their immediate surrounding, including the extracellular calcite, in the heavier isotope (18O).

The Role of Biofilm

The biofilm on the surface of growing pearls controls the rate of ion diffusion from the environment (cf. DECHO, 2000). It is due to this action that only calcite is precipitated though the water in which the pisoids grow is supersaturated with respect to calcite and aragonite (cf. BUCZYNSKI & CHAFETZ, 1991). The biofilm causes also mechanical trapping and binding of mineral grains (CUNNINGHAM et al., 1995; JONES, 1995). As a result, many non-carbonate mineral grains are incorporated into the pearls. The biofilm insulates the pearl surfaces, protecting them in times when environmental conditions become unfavourable, for instance during drops in the pH of the environment, securing the uninterrupted growth of the pearls.

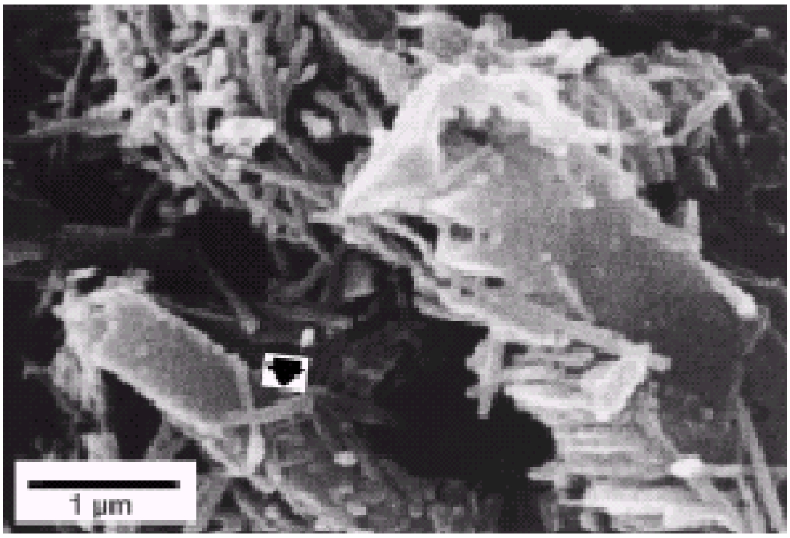


Figure 9 : Micrite calcite crystal with ìghostsî of bacterial replicas (arrow)

Growth Conditions of the Irregular Cave Pearls

The development of the irregular cave pearls proceeds in conditions of low energy of the environment, which enable growth of the delicate biofilm on their surfaces (cf. LORCH & OTTOW, 1985; PEDLEY, 1992). Growth of such pearls begins on a floating fragment of biofilm, i.e. a cluster of living bacterial cells (PAERL, 1975). Their further growth in the low-energy environment is due to a back-feeding process. Biogenic calcification controls the growth of porous internal fabric of the pearls, which, in turn, enables the growth of the pearls in the low-energy environment (cf. FOLK & CHAFETZ, 1983; VERRECCHIA et al., 1997).

Conclusions

1. Irregular cave pearls grow due to biogenic calcification caused by physiological processes in the hydrogen-oxidising bacteria.

2. The growth of these pearls proceeds in a low-energy environment.

3. Calcification requires availability of Ca++ ions, organic carbon and high carbonate alkalinity.

4. Processes of biogenic mineralisation result in precipitation of calcite as the only mineral phase and control preferential enrichment of calcite in the heavy oxygen isotope.

Acknowledgements

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Dark Coloured Laminae Within Speleothems as an Indicator of the Prehistoric Man Activity: Case Study from Domica Cave (Slovakia), Preliminary Results

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Abstract

The paper deals with the dark coloured laminae which occur within speleothems in Domica cave (Slovakia). The laminae are composed of charcoal particles and organic aromatic compounds.

The components were formed during combustion of wood inside the cave. Thus, they are connected with the prehistoric man activity. It is in concordance with the earliest archaeological studies which proved that Domica was settled during Neolithic times. Uranium series dating the laminae are in progress.

Introduction

The prehistoric man activity is often recorded in caves. Besides typical archaeological materials, such as pottery or flint tools, some traces of men can be recognized within speleothems (HILL, 1982).

Some of the most spectacular ones were found in Domica cave, situated in Slovakian Karst (ROTH, 1948; PETR¡NEK, & POUBA, 1951). The origin of this laminae is an aim of this paper. Moreover, an attempt at using such laminae as a tool in dating prehistoric manís activity is made.

Domica Cave

Domica cave is located in Slovakian Karst, near the Slovak - Hungarian border (Figure 1). The cave is more than 5000 m long (DROPPA, 1970). The name Domica refers to the Slovakian part of a big cave (25 km long), whose Hungarian part is named Baradla.

Figure 1

Figure 2

Figure 1 : Location of Domica cave
Figure 2 : Neolithic vessel partly covered with flowstone, Domica cave, Sien Odvachi

Domica cave was settled by prehistoric man during Neolithic times (BART¡, 1963; LICHARDUS, 1968). Afterwards the entrance was blocked by a boulder chock and the cave was not accessible up to the twenties of the last century. There are four periods of Neolithic human inhabitation. The first is connected with early Neolithic StarËevo - Karanovo - Kriö pottery, the second with Linear Neolithic pottery, the third with B¸kk culture while the fourth with late B¸kk culture (LICHARDUS, 1968). Many archaeological materials were found in Domica cave, that is more than 45 000 fragments of pottery, numerous flint and bone tools (Figure 2). More than 85% of all archaeological materials belong to B¸kk culture and thus the cave is one of more important sites of this culture in Slovakia. Neolithic men settled cave periodically, probably during winter seasons by several hundred years. The cave was a place of subterranean exploitation of fine grained deposits for producing pottery, a source of water, as well as, a holy place. The foot traces indicated that Neolithic man visited deep, completely dark, part of the cave, as far as a few hundred meters away from the entrance.

Dark Coloured Laminae

The cave is also famous for numerous speleothems. Dark coloured laminae occur inside some of them. The laminae were found in several small stalagmites as well as in flowstones situated in the hall called Sien Odvachi and the lower part of the passage called Panenska Chodba (Figures 3-5). Macroscopically, the laminae are less than 0.8 cm thick. In same cases the lamina is composed of a few thinner ones.

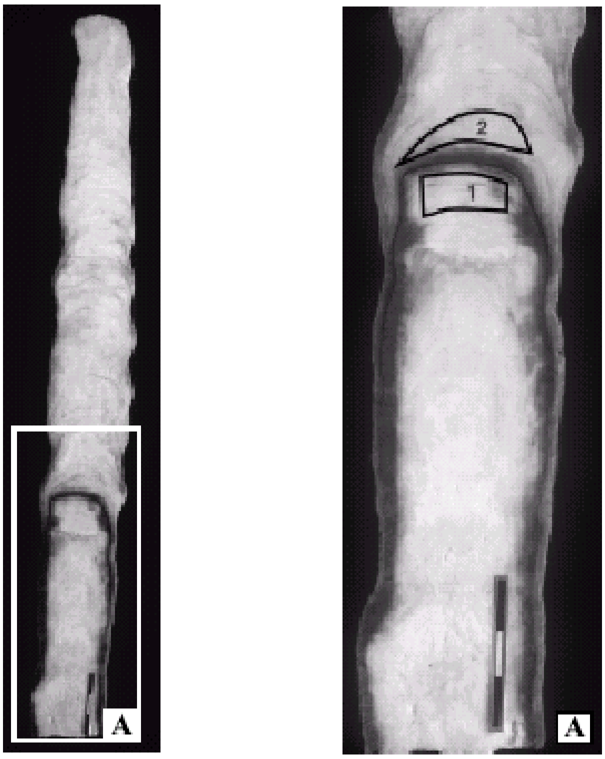


Figure 3

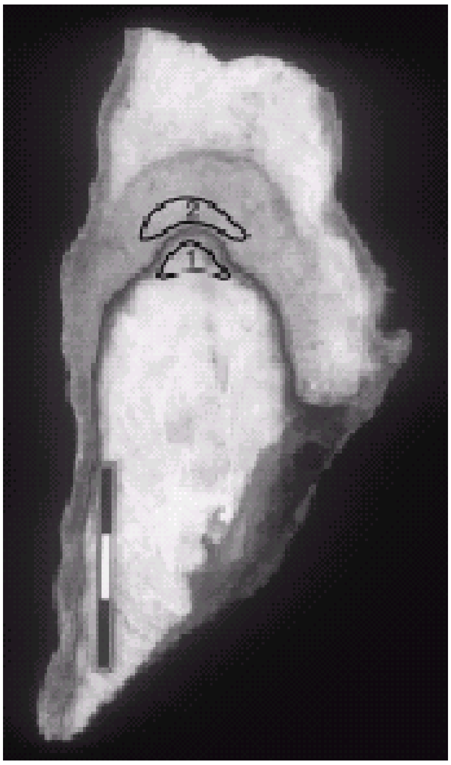


Figure 4

Figure 3: Polished slab of a stalagmite from Sien Odvachi hall (specimen 1); position of dated samples are indicated; scale bar 3 cm.

Figure 4: Polished slab of a stalagmite from Sien Odvachi hall (specimen 3); position of dated samples are indicated; scale bar 3 cm.

The dark coloured laminae are built of opaque particles and semiopaque components. The former possess angular shape and jet black colour (Fig. 6). They differ in size and shape. The smallest are only some micrometers long, while the largest are up to 1 mm long. The shape of opaque particles is isometric or elongate. Under a petrographic microscope some of the particles display porous internal structure. The opaque particles are nonfluorescent. All the above characteristics prove that particles in question are charcoal fragments (PATTERSON et al., 1987). The above statement is confirmed by the observation of their internal structures by means of SEM (Figures 7-8). The majority of the particles is characterized by homogenization of cell wall ultrastructure (SANDER & GEE, 1990; JONES & CHALONER, 1991; VAUGHAN & NICOLS, 1995). Some of them are destroyed by cracking which leads to disintegration of larger particles.

The processes of homogenization are due to combustion of wood in the temperature of about 400°C (JONES & CHALONER, 1991; VAUGHAN & NICOLS, 1995).

The semiopaque components are intensively brown in transparent light and display yellow-brown UV fluorescence. It indicates that they are composed of non carbonized organic compounds (TEICHM‹LLER & WOLF, 1977; DREVIES & YUREVICZ, 1985).

These components occur together with charcoal particles. The opaque and semiopaque components, which the form dark coloured laminae occur on uncorroded calcite crystals (Figure 6) and, seldom, on corrosional surfaces (Fig. 9). In the former case they wrapped the crystal terminations with the layer so thick that younger crystals start to grow competitively (cf. GONZ¡LEZ et al., 1992; SUNAGAWA, 1994).

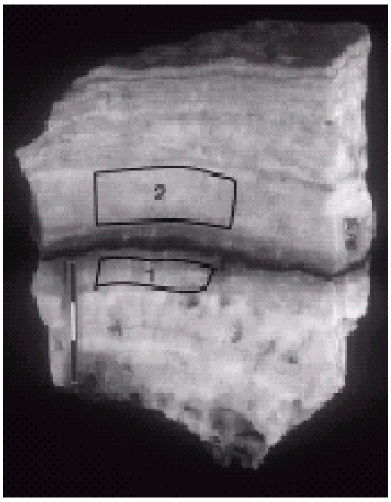


Figure 5

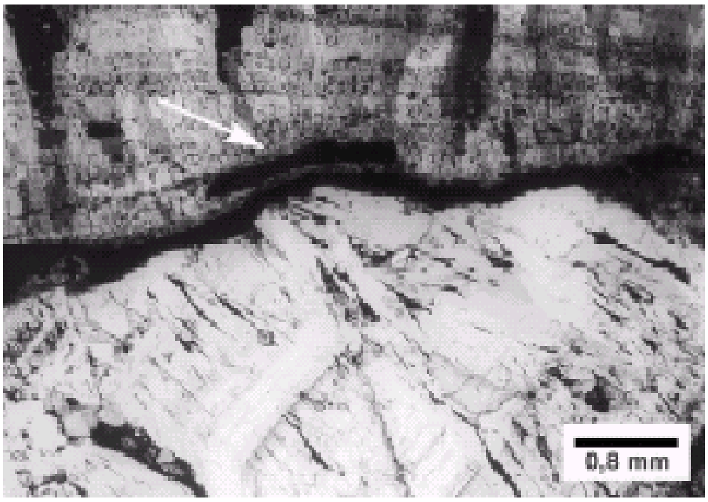


Figure 6

Figure 5 : Polished slab of a flowstone from Panenska chodba passage (specimen 7); position of dated samples are indicated; scale bar 3 cm

Figure 6 : Charcoal particles and organic compounds occure on the corrosional surfaces, note the tiny spike shape of large charcoal particle (arrow), thin section

Deposition of Dark Coloured Laminae

The laminae in question were deposited when Neolithic men settled the cave. The small particles of charcoal together with aromatic organic compounds were formed during combustion of wood inside the cave. They were spread around due to convection flow of hot air (CLARK, 1988) and subsequently were trapped on the surface of speleothems (cf. BURNEY & BURNEY, 1993) and, in the end, formed dark coloured laminae. The origin of such laminae seems to be a relatively common feature connected with the human activity and therefore the laminae are good indicator prehistoric settlement in caves. Charcoal particles and dark laminae have been found also within speleothems in other caves of Slovakian Karst (KUNSK›, 1939; B¡RTA, 1961; KU»ERA, 1964), some caves in the Cracow-WieluÒ Upland, Poland (GRADZI—SKI et al., 1996) and a cave in Norway (LAURITZEN et al., 1990). Soot derived from torches of prehistoric miners was recognized in the Mammoth Cave System and Salt Cave too (BENNINGTON et al., 1962; WATSON, 1966; HILL, 1982).

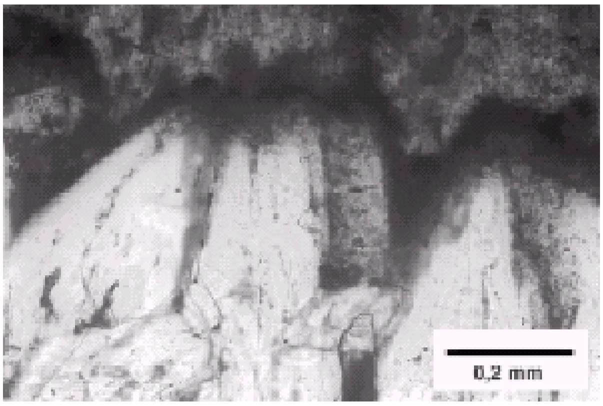


Figure 9 : Charcoal particles and organic compounds covered uncorroded calcite crystlas, thin section

Dating of Prehistoric Man Activity

In the light of the above presented origin of dark coloured laminae they are good indicator of human inhabitation in caves. Thus, it is possible to date the episodes of human activity on the base of these laminae by using standard dating techniques for speleothems (e.g. Th/U or 14C).

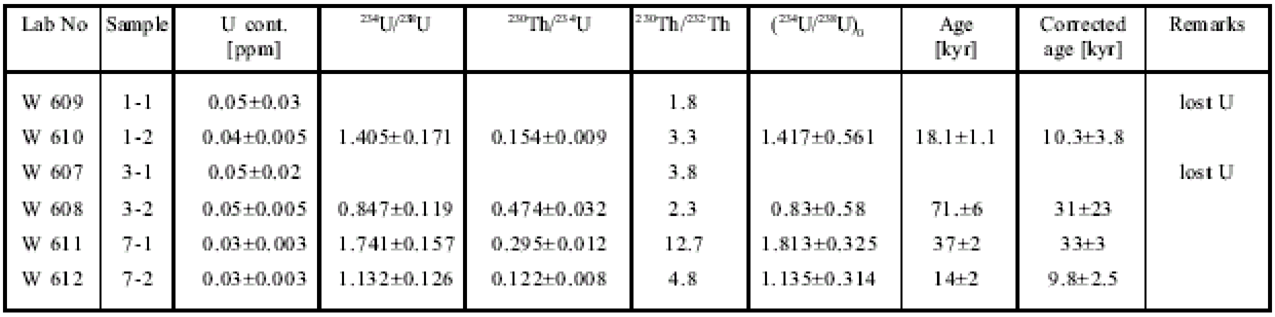
The samples of 4-14 g in weight were cut just below and above the dark coloured laminae in three speleothem samples. After cleaning and adding 228Th/232 U spike, the samples were dissolved in ca. 7M HNO3. Uranium and Thorium separation were done using chromatography method. After purification, the U and Th fraction were electroplated on stainless steal discs. Activities of U and Th

isotopes were measured by an a-spectrometry using OCTETE PC equipment (ORTEC product). The spectra were processed by ÑURANOTHOR 2.0î programe. Quoted errors are 1s.

The results of preliminary analyses are shown in Table 1. All samples are very low in Uranium content (0.03-0.05 ppm). They contain significant amount of 232Th and hence need correction for nonradiogenic Thorium. Unfortunately, we have no information about isotope composition of detrital contamination in these speleothems. At present, we are able to use only correction assuming value 230Th/232Th activity of detrital contamination equal to 1.5±0.5 (cf. IVANOVICH & HARMON, 1992). Low Uranium content and the above correction increase the errors and thus further work is necessary to obtain better results.

The dark laminae in sample 7 are younger than 33±3 ka and older than 9.8±2.5 ka. One can compare this age with the age of charcoal detritus collected within the cave clastics in another part of Domica and dated using 14C method in the sixties. The age of charcoal is 6080±75 ka (B¡RTA, 1964). Hence, the dark lamina seems to be older than charcoal, even taking into account a possible error of the upper age limit. However, due to the above presented imperfections of the so far obtained uranium dates, the problem should be regarded as being still open.

Table 1. U-series dating results



Lab No	Sample	U cont. [ppm]	$^{234}U/^{238}U$	$^{230}Th/^{234}U$	$^{230}Th/^{232}Th$	$(^{234}U/^{238}U)_0$	Age [kyr]	Corrected age [kyr]	Remarks
W 609	1-1	0.05±0.03			1.8				lost U
W 610	1-2	0.04±0.005	1.405±0.171	0.154±0.009	3.3	1.417±0.561	18.1±1.1	10.3±3.8	
W 607	3-1	0.05±0.02			3.8				lost U
W 608	3-2	0.05±0.005	0.847±0.119	0.474±0.032	2.3	0.83±0.58	71.±6	31±23	
W 611	7-1	0.03±0.003	1.741±0.157	0.295±0.012	12.7	1.813±0.325	37±2	33±3	
W 612	7-2	0.03±0.003	1.132±0.126	0.122±0.008	4.8	1.135±0.314	14±2	9.8±2.5	

Conclusions

1. Dark laminae occurring in speleothems in Domica cave are coloured due to charcoal particles and organic compounds.

2. Charcoal particles and organic compounds developed during wood combustion inside caves.

3. Dark laminae in speleothems are good indicator of prehistoric settlement in caves.

Acknowledgements

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Mapeamento Topográfico e Geoespeleológico da Gruta do Bacaetava, Colombo -PR/Brasil

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Abstract

The Gruta do Bacaetava (PR-0003) is one of the most known and visited cave, in the state of Paraná, having quotations and references about it since the past century. This cave, also is one of the first caves mapped in the state of Paraná (MARTIN e CASTRO, 1965). Because these reasons, specifics researches , involving different areas of study, were made aiming to provide information for an adequate management of the Gruta do Bacaetava. This work presents the specific results of the topographic mapping and geospeleological characterization of the cave. These results helps to provide some basis for the creation of the Parque Municipal do Bacaetava management plan (ECOSSISTEMA CONSULTORIA AMBIENTAL / GEEP-Açungui, 1999).

Resumo

A Gruta do Bacaetava (PR-0003) é uma das cavernas mais conhecidas e visitadas do estado do Paraná em função de sua proximidade com os centros urbanos e pelo fácil acesso. Foi uma das primeiras cavidades a serem mapeadas no estado (MARTIN e CASTRO, 1965), sendo encontradas citações e/ou referências a seu respeito desde o século passado. Devido ao interesse na sua conservação, a Gruta do Bacaetava foi objeto da realização de levantamentos específicos, visando subsidiar a execução de um manejo adequado. O presente trabalho vem desta forma apresentar os resultados das atividades de mapeamento topográfico e caracterização geoespeleológica, como etapas necessárias à elaboração do Plano de Manejo do Parque Municipal da Gruta do Bacaetava (ECOSSISTEMA CONSULTORIA AMBIENTAL / GEEP-Açungui, 1999).

Localização

A Gruta do Bacaetava, localiza-se na porção norte do município de Colombo, na Região Metropolitana de Curitiba, na divisa com o município de Rio Branco do Sul. A ressurgência da gruta localiza-se nas coordenadas 25º13´54"S e 49º12´26"W (Figura 1).

Introdução

As informações acerca da Gruta do Bacaetava, vêm sendo reunidas e organizadas pelo Grupo de Estudos Espeleologicos do Paraná (GEEP-Açungui), desde a sua criação em 1986. O primeiro mapeamento da caverna foi executado por MARTIN e CASTRO (1965). COLLET. et. al. (1976), executaram uma nova topografia dividindo a cavidade em duas, “Bacaitava I” (galeria inferior) e “Bacaitava II” (galeria superior). Em 1994 um novo levantamento foi executado pelo GEEP-Açungui, quando se comprovou tratar de uma mesma caverna, em função da existência de uma interligação entre as galerias (GEEP-Açungui, 1995). Embora já existisse um mapeamento anterior, optou-se por uma retopografia em detalhe da cavidade, devido à possibilidade da implantação de infra-estruturas auxiliares à visitação, a serem definidas no Plano de Manejo.

Concomitantemente à execução do detalhamento topográfico, executou-se a caracterização geoespeleológica da gruta, visando, dentre outros objetivos, a determinação de possíveis áreas de risco aos visitantes.

Fisiografia

Segundo MAACK (1981), a área localiza-se na zona subtropical, com temperatura média anual em torno de 16ºC, estando as chuvas regularmente distribuídas, com uma pluviosidade média anual de 1450 mm. Devido a sua posição geográfica esta área encontra-se sujeita ao fenômeno da geada, assim como a presença de frentes frias provenientes da Antártica.

A região pertence a bacia hidrográfica do rio Ribeira e é cortada na direção E-W pelo rio Bacaetava que atravessa a gruta de mesmo nome. À montante da cavidade, a bacia do rio Bacaetava apresenta uma área aproximada de 21,6 km², abrangendo os municípios de Rio Branco do Sul e de Almirante Tamandaré.

Geologicamente a área situa-se na margem sudeste da Plataforma Continental Sulamericana e engloba unidades geológicas do Cinturão Móvel Ribeira (BRITO NEVES e CORDANI, 1991). Na região da caverna este cinturão é composto principalmente por rochas deformadas de diferentes graus metamórficos pertencentes ao Grupo Açungui. As rochas carbonáticas na qual se formou a caverna estão inseridas na Província Espeleológica Alto Ribeira (KARMANN e SANCHEZ, 1979).

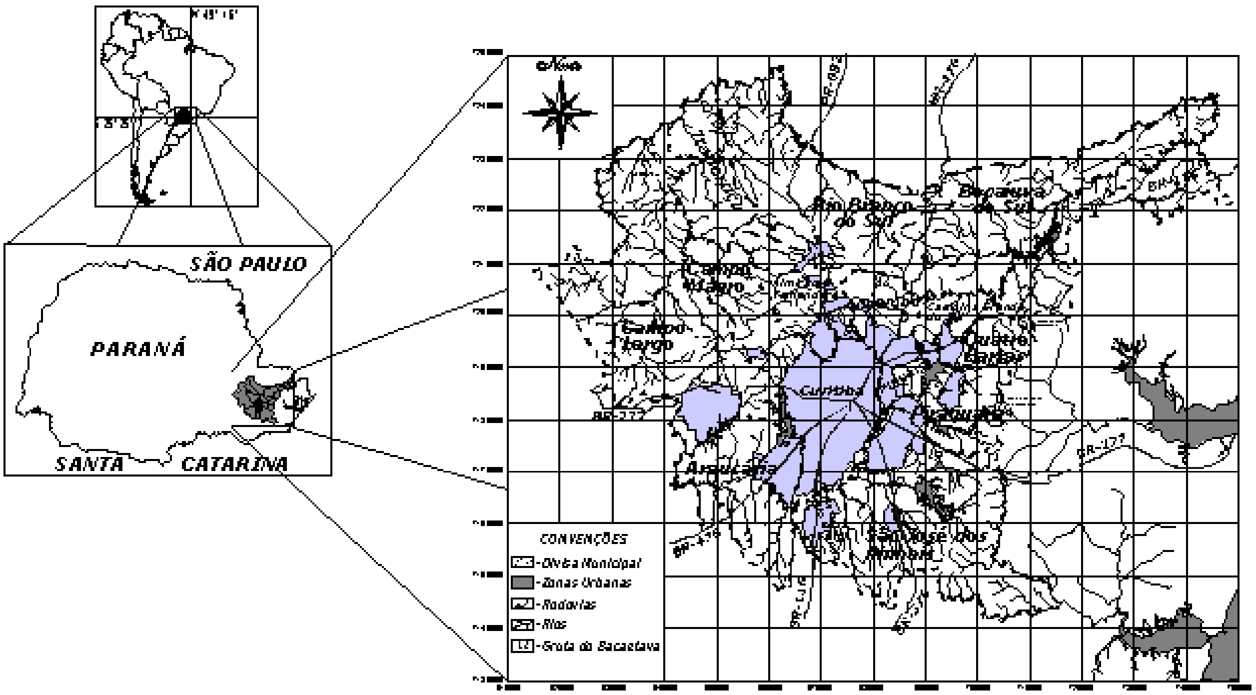

Figura 1 – Localização da Gruta de Bacaetava

Materiais e Métodos

O levantamento do meio físico da gruta do Bacaetava constou das seguintes etapas: coleta de informações em escritório (bibliografia, mapas, bancos de dados); coleta de dados em campo; produtos e resultados.

a) Topografia

O método para o levantamento topográfico da gruta do Bacaetava foi o usualmente utilizado pelo GEEP-Açungui em levantamentos espeleológicos, adequado à classificação da União Internacional de Espeleologia (UIS). O mapa topográfico elaborado considerou como base as Normas e Convenções Espeleométricas (SBE, 1991).

Para a topografia interna, utilizou-se de bússolas, miras e trenas. A base já existente foi previamente digitalizada e plotada em escala adequada (1:500) para o detalhamento topográfico da cavidade. De posse desta base, percorreu-se a caverna plotando os elementos de interesse para efeitos do manejo, tais como: espeleotemas; lagos subterrâneos; drenagens (perenes e/ou permanentes); acúmulos de resíduos; além de interferências antrópicas.

Concomitantemente a este processo, executou-se uma topografia complementar, visando principalmente estabelecer o perfil topográfico da caverna e obter alguns cortes longitudinais de interesse. Neste levantamento topográfico complementar estabeleceu-se como meta a elevação do grau de precisão /

detalhamento da topografia anteriormente existente, que era 3C para 4D pelo método UIS. Durante a fase da análise dos dados topográficos, constatou-se alguma variação em relação ao posicionamento do contorno da galeria da cavidade. Isto ocorreu devido à elevação do grau de detalhamento/precisão do novo levantamento executado em relação às antigas bases topográficas existentes. Em vista disso, considera-se o resultado da topografia ora apresentada como sendo um novo levantamento, tendo este utilizado as bases antigas apenas como fonte de comparação.

Realizou-se ainda uma nova topografia de detalhe, em todo o trecho onde se definiu o uso público no interior da cavidade, de modo a subsidiar seu planejamento adequado.

b) Geoespeleologia

Ao longo dos levantamentos geológico e geoespeleológico efetuou-se o caminhamento pelas galerias da caverna e por uma mineração desativada nas proximidades da gruta. Procedeu-se a marcação de pontos no mapa-base de COLLET *et al*. (1976), descrição e delimitação das litologias, medidas de atitudes, descrição dos espeleotemas, das estruturas e das feições da caverna.

Na fase de análise, houve o tratamento dos dados coletados resultando em mapas geoespeleológico e topográfico, interpretações a respeito da gênese e evolução da caverna, avaliação da situação ambiental atual, bem como as recomendações e restrições do meio físico em relação ao uso público.

Resultados

a) Geoespeleologia

A gruta do Bacaetava caracteriza-se por dois níveis diferenciados de carstificação, formados em uma lente de rocha carbonática da Formação Capirú (Grupo Acungui). Esta unidade é representada por metadolomitos que apresentam uma alternância rítmica de níveis claros de composição predominantemente carbonática e níveis escuros de composição carbonato-pelítica. Essa variação e responsável pelo intemperismo diferencial dos estratos observado no interior da cavidade. Apresenta um grau metamórfico baixo (fácies xisto-verde) e uma foliação penetrativa (Sn) paralela ao acamamento.

Estruturas sedimentares primárias são raras, normalmente associadas aos níveis de composição carbonato-pelíticas. Embora bibliografias citem a presença de estruturas estromatolíticas na área (FIORI e GASPAR, 1993), estas somente foram evidenciadas na frente de lavra das proximidades do sumidouro

A atitude do acamamento varia em torno de N80W/65SE, sendo que este plano apresenta-se suavemente dobrado, conforme pode ser observado no mapa geoespeleológico (Figuras 2 e 3).

São observadas fraturas em praticamente toda extensão da caverna, apresentando um sistema principal de direção N30-40E e N10-20W. Estas estruturas apresentam mergulhos subverticais, normalmente transversais ao acamamento e à galeria principal da cavidade

Com base nas diversas evidências encontradas durante o mapeamento é possível concluir que a evolução da caverna teve seu inicio com o desenvolvimento condutos e galerias condicionadas aos planos de acamamento da rocha, fraturas ou na interseção desses planos. Esse processo ocorreu em regime freático que a partir de um rebaixamento do nível do lençol freático, evoluiu em condições vadosas conforme observado na galeria superior da caverna. Neste estágio, iniciou-se a formação dos principais espeleotemas, destacando-se as estalactites, estalagmites, colunas e escorrimentos, pérolas, travertinos e coralóides. Os diversos abatimentos de blocos, principalmente ao longo das fraturas e planos de acamamento de rocha, são os principais responsáveis pelo aumento do volume da caverna e pelo aspecto escalonado do teto próximo ao sumidouro. Atualmente a gruta é caracterizada por processos de incasão nas porções mais instáveis, pela evolução da galeria principal pela ação do rio Bacaetava e pela formação de espeleotemas em praticamente todos os segmentos da cavidade.

b) Topografia

A topografia, tanto da área interna quanto externa à gruta do Bacaetava, possibilitou a definição de uma série de dados essenciais para a definição do manejo.

O novo mapeamento (Figuras 2 e 3) teve como resultado uma projeção horizontal de 672 m, desenvolvimento linear total de 695 m e desnível absoluto de 25 m. Sobre o mapa topográfico foi calculada a área de projeção da cavidade (5.920 m^2) e o volume aproximado (29.773 m^3). Além disto, possibilitou a correlação entre as galerias superior e inferior, bem como a amarração topográfica das infra-estruturas já existentes e previstas para apoio ao visitante.

A partir da topografia externa, foi possível: identificar a entrada da galeria superior da Gruta do Bacaetava que encontra-se situada 20 m acima do sumidouro da cavidade; identificar um abismo de 16 m de desnível que interliga a galeria superior e inferior da gruta e que atualmente encontra-se obstruído por blocos; localizar o paredão da frente de lavra em relação a cavidade concluindo desta forma que a distância que separa os dois pontos é de 75 m em projeção linear; verificar que a camada calcária existente sobre a gruta tem uma espessura que varia entre 7 e 20 m.

Discussão e Conclusão

A Gruta do Bacaetava, devido a sua importância regional, sofreu durante vários anos um processo de degradação pela visitação sem controle e pela atividade das mineradoras. Esse processo causou diversos problemas ambientais no interior da cavidade tais como: quebra de espeleotemas, pichações, assoreamento da drenagem subterrânea e acúmulo de material estéril das minerações que depositam seus rejeitos diretamente sobre o rio Bacaetava.

O trabalho ora apresentado, diagnosticou fisicamente a gruta, visando a execução do seu efetivo manejo. Com base nisso, o levantamento físico determinou, como condicionante a sua visitação à interdição da área do sumidouro da cavidade por tratar-se de uma zona intensamente instável e com presença de muitos blocos abatidos. Isso, somado ao fato da proximidade (menos de 300 m) de minerações ativas, executando detonações freqüentes, inviabilizou o uso deste trecho da caverna.

A nova topografia executada teve como objetivo final a maior precisão possível, visando a implantação de um manejo adequado para a cavidade. Levou-se em consideração a correlação da gruta com os seus elementos externos, como forma de garantir a integridade da caverna devido as atividades realizadas em seu exterior. Ainda considerou-se a amarração da topografia com infra-estruturas existentes ou a serem implantadas visando uma perfeita localização espacial.

Conclui-se que os estudos, além do seu interesse cientifico, apresentam uma função aplicada e fundamental na conservação e manejo da Gruta do Bacaetava.

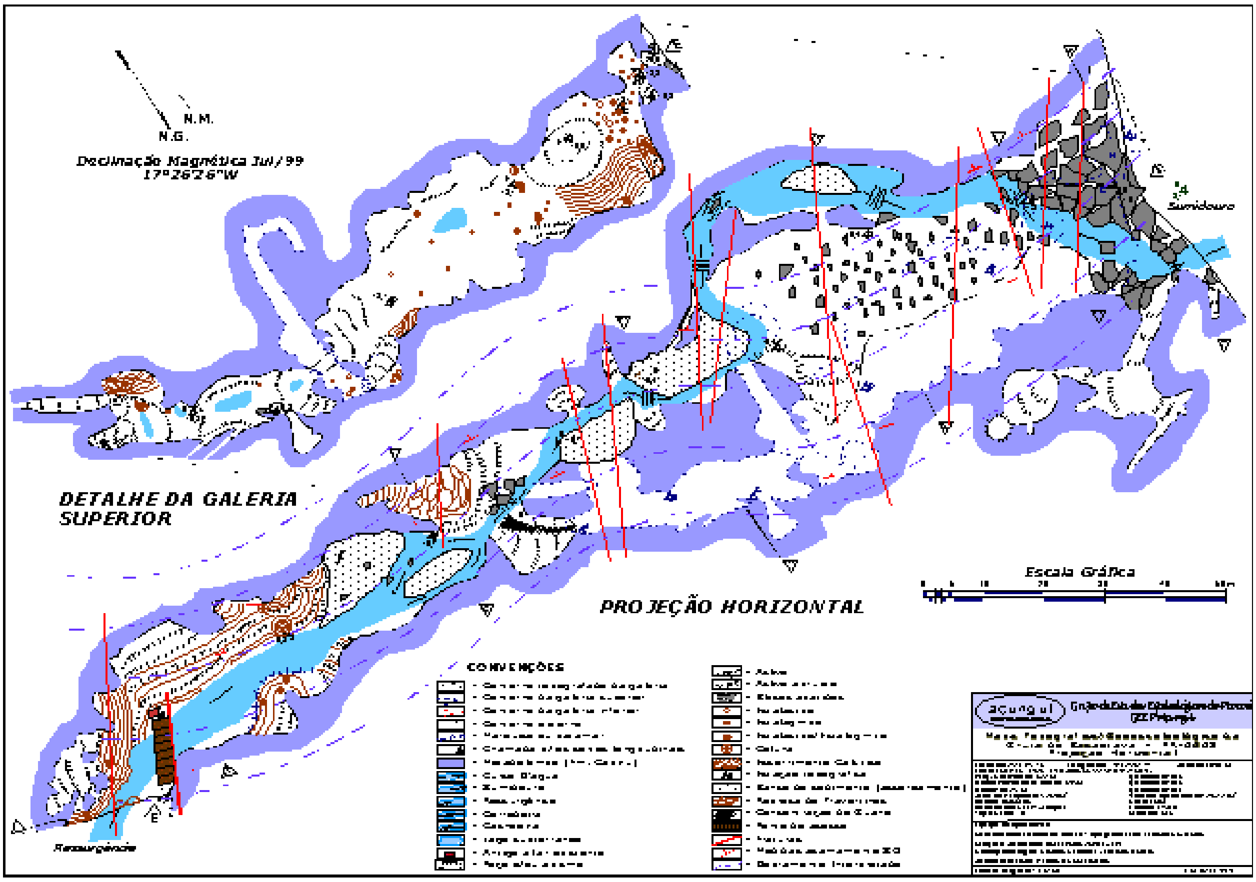

Figura 2: Mapa Topográfico/Geoespeleológico da Gruta do Bacaetava (Projeção Horizontal)

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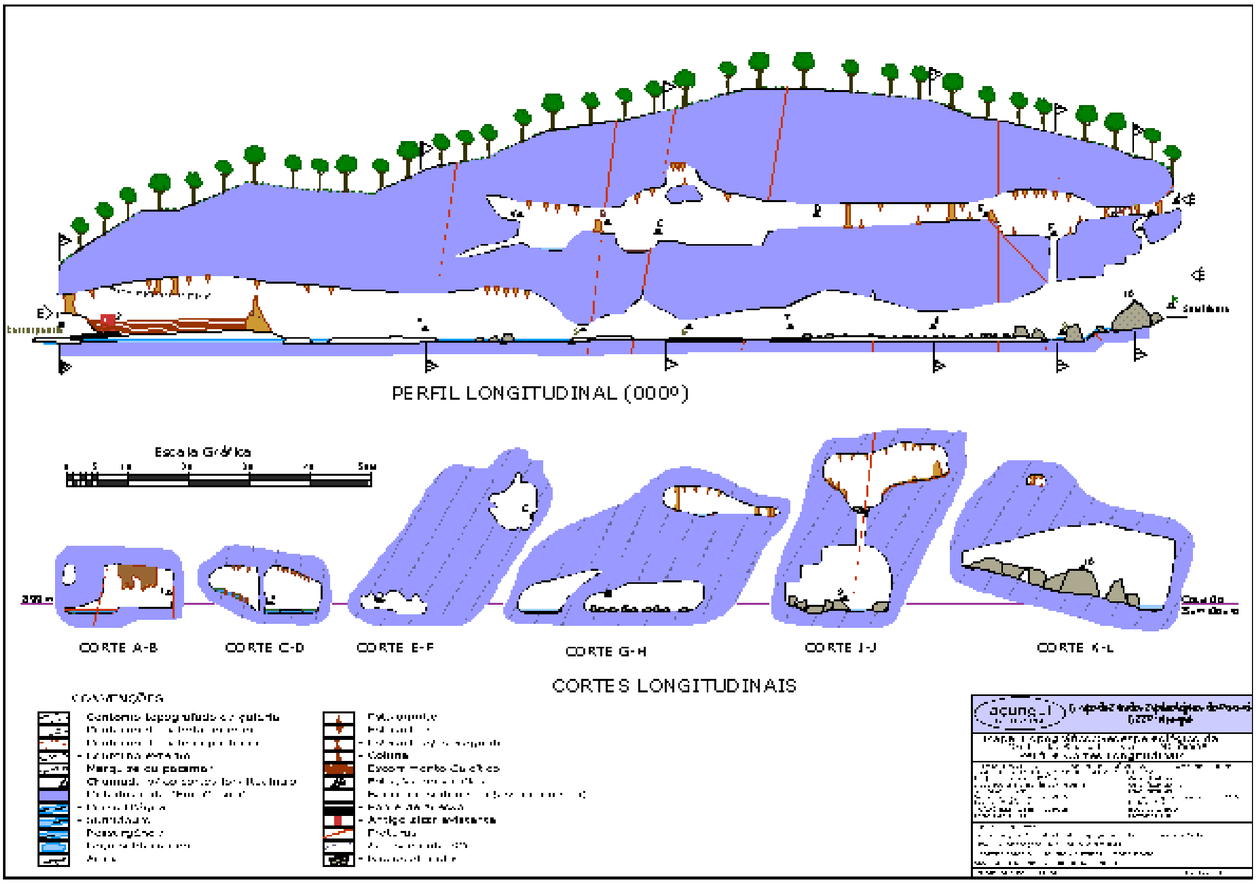

Figura 3: Mapa Topográfico/Geoespeleológico da Gruta do Bacaetava (Perfil e Cortes Longitudinais)

Intensity of Prolonged Solar Luminosity Cycles and Their Influence Over Past Climates and Geomagnetic Field

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Abstract

Calcite speleothems luminescence depends exponentially upon soil temperatures that are determined primarily by solar visible and infrared radiation. So microzonality of luminescence of speleothems was used as an indirect Solar Insolation (SI) proxy index. For Cold Water cave, Iowa, US we obtained high correlation coefficient of 0.9 between a luminescence record and the experimentally observed Solar Luminosity Sunspot index.

We measured a luminescent speleothem record from Jewel Cave, South Dakota, US. It is still the first available experimental solar insolation proxy record with sufficiently long duration to reproduce the orbital variations. This record covers 89300- 138600 yrs B.P. with high resolution. It reveals determination of millennial and century cycles in the record.

This solar insolation proxy record contains not only orbital variations, but also solar luminosity self variations, producing many 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 found also cycles with duration of 6000, 4400, 3300, 2500, 2300, 1900 and 1460, years (in order of decreasing intensity) with amplitude ranging respectively from 3 to 0.7 % of the Solar Constant.

Latest results suggest that these millennial solar luminosity cycles can produce climatic variations with intensity comparable to that of the orbital variations. Known decadal and even century solar cycles have negligible intensity (100 times less intensive) relatively to this cycles. Solar luminosity (SL) and orbital variations both cause variations of solar insolation affecting the climate by the same mechanism. In spite their influence over the geomagnetic field involve fundamentally different mechanisms, determined by the properties of the solar wind.

Introduction

J. CROLL (1864) and M.MILANKOVICH (1920) demonstrated that orbital variations of the Earth's orbit cause significant variations of the amount of solar radiation received by the Earth's surface (solar insolation- SI). Since 1930 most scientists started to believe that glacial periods (ice ages) are result of such variations.

Recent measurements (WINOGRAD et al, 1988, 1992) of a cave deposit from Devils Hole (DH), USA which is the best dated paleoclimatic record, demonstrated that the end of the former glaciation (Termination II) came 10 000 year before the moment suggested by the orbital theory. Some scientists consider this as a denial of the orbital origin of glaciations, because it demonstrates that the result appears far before the reason.

Up to now there were no quantitative proxy records able to demonstrate how big were variations of the solar luminosity in geological time scales. In the last years (SHOPOV et. al., 1994, 1996) measured such records covering a sufficiently long period to contain orbital variations.

Results and Discussion

We measured a luminescent solar insolation proxy record in a speleothem (JC11) from Jewel Cave, South Dakota, USA (SHOPOV et al.,1998, STOYKOVA et al., 1998). This record covers 89300- 138600 yrs BP with high resolution (34 years) and precision of measurements better than 1%. It reveals determination of millennial and century cycles in the record.

We extracted orbital variations from the JC11 record by a band-pass Tukey filter set for frequencies of 41, 23 and 19 kyrs. So the remaining signal contains only SL self-variations. The most powerful cycle in this record with period of 11.5 kyrs appears to be a bit more powerful than the precession cycle and a bit less than the total orbital component of the SI variations.

This TIMS U/Th dated JC11 record exhibits a very rapid increasing in solar insolation at 139 kyrs ±5.5 kyrs BP (95% confidence level) responsible for the termination II. This increasing precedes that one suggested by the Orbital theory with about 10 kyrs and is due to the most powerful cycle of the solar luminosity with period of 11.5 kyrs superposed on the orbital variations curve. This cycle was found previously to be the most intensive one in the $\Delta^{14}C$ calibration record (DAMON & SONETT, 1991) and was interpreted to be of geomagnetic origin. Our studies suggest that this is a solar cycle modulating the geomagnetic field. The Devils Hole ^{18}O record suggests that termination II had happened at 140 ±3 kyrs B.P (WINOGRAD ET AL, 1992). It follows precisely the shape of our experimental solar insolation record. This result is confirmed by an other U/Th dated luminescent solar insolation proxy record in a speleothem from a Duhlata cave, Bulgaria 10 000 km far form the JC11 site. These records suggest that the solar luminosity contribution to the solar insolation curves has been severely underestimated so far.

The Orbital theory pressumes that the solar luminosity is constant during geological periods of time. Recent studies demonstrated that this presumption is not precise. Direct satellite measurements of the solar constant demonstrated that it varies with time as much as 0.4% during the observation time span (HICKEY et al., 1980), but there are experimental data suggesting that it varied much greater during geological periods (SONETT, 1984, STUIVER & BRAZIUNAS, 1989). SONETT (1984) analysing the 14-C solar proxy record found that the cycle with a period of about 900 yrs has intensity 5- 7 times higher than that of the century cycle. STUIVER & BRAZIUNAS (1989) calculated MEM spectra of the same record and demonstrated, that longer solar cycles are more than one order of magnitude stronger, than the solar cycles covered by direct measurements. In order to compare quantitatively intensities of all cycles presented in our data we designed a special algorithm and relevant computer program, which plots the periodogramme in coordinates (Cycle Intensity/Period). Calculated periodogrammes of the JC11 luminescent record demonstrated, that the solar cycle of about 900 years has intensity only 3-4% of the 11500-yr cycle and the solar cycle about 420 years has intensity less than 2.5 % of the 11500-yr cycle. So the 11500-yr cycle should have intensity of several orders of magnitude higher, than the observed century and sub- century cycles.

We obtained many other cycles, more intensive of them with duration of 6000, 4400, 3300, 2500, 2300, 1900 and 1460, years (in order of decreasing intensity) with amplitude ranging respectively from 3 to 0.7 % of the Solar Constant (tab. 1).

A cycle with duration 10026 (+1254/ -834) yrs. was found in records of the intensity of the geomagnetic field of the Earth (TRIC et al., 1992). We identified this cycle with the 11.5 yrs. one in the luminescent record and we calibrated intensity of all other cycles in the geomagnetic record to the luminescent cycle. The cycles which are found in both records are with duration of 4400, 2500, 3950, 2770, 1950,1460,2090, 1200, 900 (tab. 1).

Increasing of the ice volume and related sea level change during glaciations produces changes in the inertial moment of the Earth and resulting changes in the speed of Earth’s rotation (TENCHOV et al., 1993).. Orbital variations cause also some deformation of the solid Earth and redistribution of the Ocean masses (MOERNER, 1976, 1983). In result theoretical curves can be used only for qualitative reference. For quantitative correlation it is necessary to use experimental records of the solar insolation, because they contain also variations of the solar luminosity and number of others not covered by the Orbital theory.

Conclusions

Strongest solar luminosity cycle (with period of 11500 yrs) modulates the geomagnetic field and production of cosmogenic isotopes. It is as intensive as orbital variations, so modulates the Earth's climate. A number of shorter intensive SL cycles have intensity far stronger that the known century solar luminosity cycle.

Cycle [Yrs]	VSC [W/m2]	PSC [%]	GEOM [%]	C14 [%]
11500	100.6	7.33	7.33	7.33
7800	27.5	2.00		
6160	41.5	3.02		
4400	24.4	1.78	6.2	
3950	25.1	1.83	4.32	
3400	24.1	1.76		
2770	12.6	0.92	3.25	
2500	16.3	1.19	4.70	
2300	12.5	.91		
2090	7.28	.53	2.26	
1958	11.26	.82	2.82	
1770	8.5	.62		
1670	9.1	.66	1.01	0.73
1460	10.0	.73	2.42	
1280	4.8	.35	0.71	
1195	4.5	.33	1.22	0.40
1145	4.5	.33	1.92	
1034	4.26	.31	1.62	
935	3.02	.22	1.2	
835	3.6	.26	0.6	0.56
814	2.6	.19		
775	2.3	.17		
750	2.6	.19		0.56
670	2.06	.15		
660	2.47	.18		
610	1.78	.13		0.48
570	2.06	.15		
550	1.78	.13		
538	2.06	.15		

Table 1 Cycles of the Solar Luminosity (in Years), relevant variations of the Solar Constant expressed in W/m2 (VSC) and in % from the Solar Constant (PSC) compared to cycles of Solar Wind proxies- Intensity of the Dipole of the Geomagnetic Field (GEOM) and inverted rate of production of 14C

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Influence of Solar Luminosity Variation on Glaciations and Time Shifting of Termination-II

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Abstract

Calcite speleothems luminescence depends exponentially upon soil temperatures that are determined primarily by solar visible and infrared radiation. So microzonality of luminescence of speleothems is used as an indirect Solar Insolation (SI) proxy index

We measured a luminescent solar insolation proxy record in a speleothem (JC11) from Jewel Cave, South Dakota. This record has been dated by 6 TIMS U/Th dates with 2 sigma error of 0.8-5.5 kyrs. It covers 89300-138600 yrs B.P. with high resolution (34 years) and precision of measurements better than 1%. It reveals determination of millennial and century cycles in the record. This record exhibit a very rapid increasing in solar insolation at 139 kyrs +/- 5.5 kyrs (2 sigma error) responsible for the termination II. This increasing is preceding the one suggested by the Orbital theory with about 10 kyrs and is due to the most powerful cycle of the solar luminosity with duration of 11.5 kyrs superposed on the orbital variations curve. Solar luminosity variations appear to be as powerful as orbital variations of solar insolation and can produce climatic variations with intensity comparable to that of the orbital variations.

Introduction

M.Milankovitch demonstrated that orbital variations of the Earth's orbit cause significant variations of the amount of solar radiation received by the Earth's surface (solar insolation- SI). Scientists consider that glacial periods (ice ages) are result of such variations. The orbital components which cause variations of solar insolation are: eccentricity, precession and Earth's obliquity.

Recent measurements of a cave deposit from Devils Hole (DH), USA which is the best dated paleoclimatic record, demonstrated that the end of the former glaciation (Termination II) came 10 000 year before the moment suggested by the orbital theory (WINOGRAD ET AL, 1992).

Until recently there were no quantitative proxy records able to demonstrate how big were variations of the solar luminosity in geological time scales. SHOPOV (1987) was the first one to introduce a technique for preparation of such records.

Methods and Material Studies

Calcite speleothems (stalagmites etc.) usually display luminescence which is produced by calcium salts of humic and fulvic acids derived from soils above the cave. These acids are released by the decomposition of humic matter. Rates of decomposition depend exponentially upon soil surface temperatures that are determined primarily by solar infrared radiation. So the microzonality of luminescence of speleothems can be used as an indirect Solar Activity (SA) index (SHOPOV, 1987).

Time series of the SA index "Microzonality of Luminescence of Speleothems" are obtained by Laser Luminescence Microzonal analysis (LLMZA) of cave flowstones (SHOPOV, 1987). LLMZA allows measurement of luminescence time series with duration of hundreds of thousands years , and nevertheless the time step for short time series can be as small as 6 hours (SHOPOV et al., 1994) allowing resolution of 3 days.

Results and Analyses

We measured a luminescent solar insolation proxy record in a speleothem (JC11) from Jewel Cave, South Dakota, USA (SHOPOV et al.,1998, STOYKOVA et al., 1998). This record covers 89300- 138600 yrs BP (fig. 1b) with high resolution (34 years) and precision of measurements better than 1%. It reveals determination of millennial and century cycles in the record.

We extracted orbital variations from the JC11 record by a band-pass Tukey filter set for frequencies of 41, 23 and 19 kyrs. So the remaining signal contains only SL self-variations. The most powerful cycle in this record with period of 11.5 kyrs appears to be a bit more powerful than the precession cycle and a bit less than the total orbital component of the SI variations.

This TIMS U/Th dated JC11 record exhibits a very rapid increasing in solar insolation at 139 kyrs ±5.5 kyrs BP (95% confidence level) responsible for the termination II. This increasing precedes that one suggested by the Orbital theory with about 10 kyrs and is due to the most powerful cycle of the solar luminosity with period of 11.5 kyrs superposed on the orbital variations curve. This cycle was found previously to be the most intensive one in the $\Delta^{14}C$ calibration record and was interpreted to be of geomagnetic origin. Our studies suggest that this is a solar cycle modulating the geomagnetic field. The Devils Hole ^{18}O record suggests that termination II had happened at 140±3 kyrs B.P. It follows precisely the shape of our experimental solar insolation record. This result is confirmed by an other U/Th dated luminescent solar insolation proxy record in a speleothem from a Duhlata cave, Bulgaria (fig.1c) 10 000 km far form the JC11 site. These records suggest that the solar luminosity contribution to the solar insolation curves has been severely underestimated.

The Orbital theory has 2 presumptions:

1. That the solar luminosity is constant during geological periods of time.
2. That the Earth behaves as an absolute solid body independently of the orbital variations.

Recent studies demonstrate that both these presumptions are not precise. Direct satellite measurements of the solar constant demonstrated that it varies with time as much as 0.4% during the observation time span (HICKEY et al., 1980), but there are experimental data suggesting that it varied much greater during geological periods (STUIVER et al., 1989).

In order to compare quantitatively intensities of all cycles presented in our data we designed a special algorithm and relevant computer program, which plots the periodogram in coordinates (Cycle Intensity/Period). Calculated periodograms of the JC11 luminescent record demonstrated, that the 11,500-yr cycle has intensity of several orders of magnitude higher, than the observed century and sub- century cycles.

The best theoretical calculations of the orbital variations of the solar insolation have been made by BERGER (1978, 1992). His theoretical curves explain about 1/2 of the signal in the existing proxy paleotemperature records (IMBRIE et al., 1993) derived from sea cores and polar ice. But a more precise correlation demonstrates that a significant part of it is not due to the components of the orbital variations (IMBRIE et al., 1992, 1993) in such proportions as in the theoretical solar insolation curves. In order to overcome this disagreement IMBRIE (1985) introduced his ETP index of orbital variations, which is a sum of separate components of orbital variations in proportions other than those suggested by Milankovitch theory. IMBRIE (1985) does not offer an explanation why the real ratio between the orbital variations is different from the theoretical one.

Increasing of the ice volume and related sea level change during glaciations produces changes in the inertial moment of the Earth and resulting changes in the speed of Earth’s rotation (TENCHOV et al., 1993). Orbital variations cause also some deformation of the solid Earth and redistribution of the Ocean masses (MORNER, 1983). In result theoretical curves can be used only for qualitative reference. For quantitative correlation it is necessary to use experimental records of the solar insolation, because they contain also variations of the solar luminosity and number of others not covered by the Orbital theory.

Conclusions

Solar luminosity variations contribute to Earth’s heating almost as much as the orbital variations of the Earth’s orbit (Milankovitch cycles). Their most prominent cycle (with period of 11,500 yrs) must be also taken into account for a proper explanation of the timing of the last deglaciation. Speleothem records (being the best dated paleoclimatic records) may serve as a reliable tool for studying the mechanisms of formation and precise timing of glaciations.

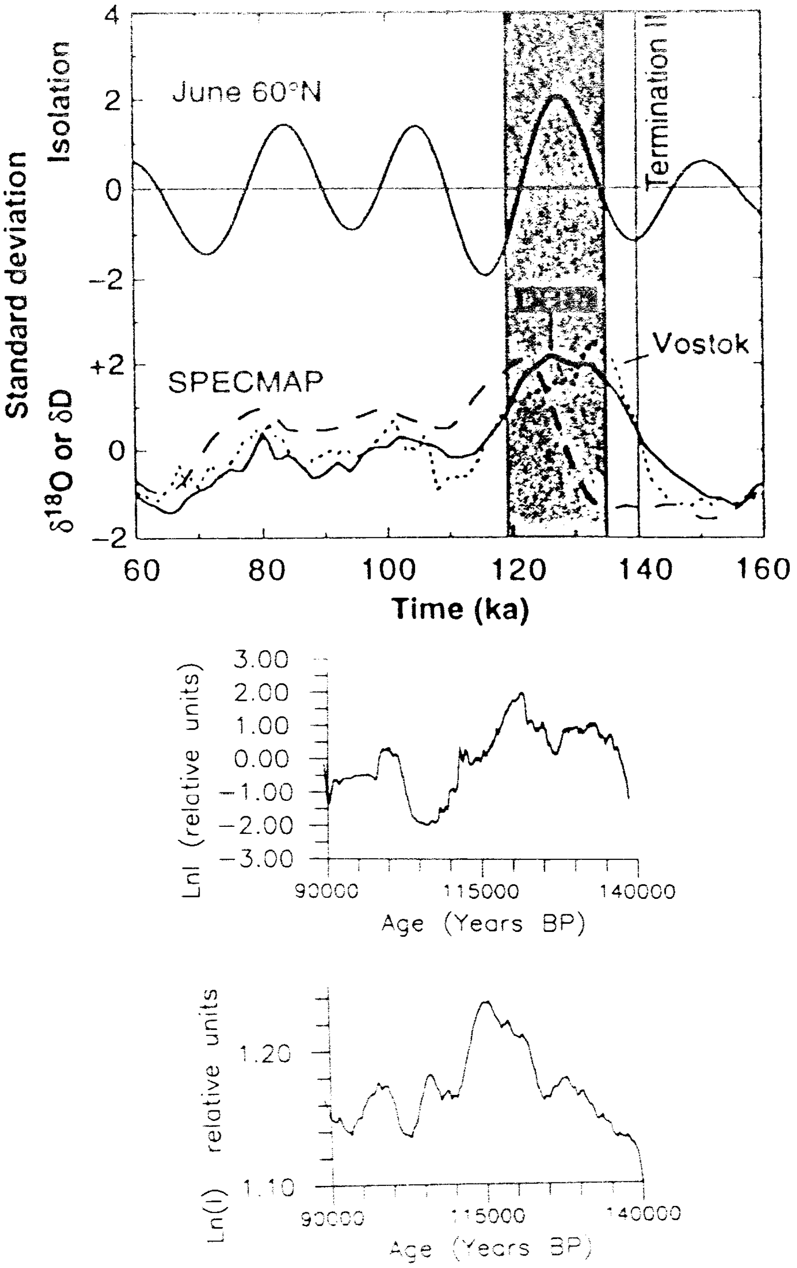

Figure 1. (a) The theoretical insolation curve compared to Devils Hole (DH-11), Vostok, and SPECMAP stack stable isotope curves (Winograd et al.,1992). Shading represents high sea level stands (at or above modern levels). (b) Jewel Cave (South Dakota) JC11. It is TIMS U/Th dated in 6 points with 2σ error varying from 0.8 kyrs (for 89.3 kyrs BP) to 5.5 kyrs (for 138.7 kyrs BP). (c) Duhlata Cave (Bulgaria), DC-2 luminescence Solar Insolation proxy record. It is TIMS U/Th dated in 4 points with 2σ error varying from 1 kyr (for 89.3 kyrs BP) to 23 kyrs (140 kyrs BP).

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Basic Theoretical and Methodological Aspects of Geoecological Research of Cave Geosystems

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Abstract

Cave geosystems are appreciated as specific geoecological systems in the lithosphere. Their spatial differentiation is caused by properties of physical-geographical sphere components. A determination of partial quasi homogenous topic units (speleolithotopes, speleomorphotopes, speleohydrotopes, speleoclimatopes and speleobiotopes) and complex quasi homogenous units (speleotopes) respects the vertical structure of cave geosystems. Relatively homogenous choric units (speleochores, set of speleochores) correspond with the horizontal structure of cave geosystems. Time-spatial changes of cave geosystems are characterised by particular developmental states (regime, dynamics or evolution). A total carrying capacity of the cave, as a speleochore or set of speleochores, depends on the occurrence of particular speleotopes and their stability. Knowledge of the spatial structure and time-spatial changes of cave geosystems generates a precondition for the solution of various analytical and synthetical tasks including environmental problems of karst landscape.

Introduction

Applying the system approach in geoscientific disciplines is successively reflected also in the research of karst and caves. Existing published studies refer to the interaction among components of physical-geographical sphere and explain their very intense mutual relations (f. e. JAKAL, 1986). Likewise they emphasize a complex conception of specific karst and caves geosystems. However a spatial and chronological aspect of their research is not prevailingly presented in the context of theory and methodology of complex physical geography or geoecology.

Cave geosystems as specific geoecological systems are characterised by specific features of biocomponent, speleoclimate and water as a part of hydrosphere and lithosphere in the zone of hypergenesis, as well as by absence of pedogenetic processes and photosynthesis (GERGEDAVA, 1983; CIKISEV, 1987 and others).

The complex geoecological approach of cave geosystems interpretation is a necessary requirement for the recognition of their spatial differentation and behaviour in time, as well as changes of their spatial structure in certain chronological periods. The outstanding feature of cave geosystems is a spatial (vertical and horizontal) structure and their time-spatial changes, i. e. regime, dynamics or evolution (BELLA, 1998).

Spatial Structure of Cave Geosystems

The more extensive caves usually consist of various parts, which are different by the features of underground environment (morphology, segments of underground water flows, lakes, seepage of atmospheric water, occurrence of carbonate speleothems, etc.). It is desirable to determine the logical spatial units with a certain stability of natural structure on the basis of natural conditions analysis for the purpose of practical tasks. BELLA (1998) distinguishes cave geosystems of topic (from Greek, local) and choric dimension.

Vertical structure. The determination of partial quasi homogenous topic units (speleolithotopes, speleomorphotopes, speleohydrotopes, speleoclimatopes and speleobiotopes) respects the vertical intercomponent structure of cave geosystems. Speleotopes represent the complex quasi homogenous and threedimensional cartographic units of cave environment with nearly equal lithological, structural-tectonic, morphological, morphometric, speleoclimatic, hydrological and biospeleological conditions.

According to a dominant direction, activity and sequentiality of dynamic relations, speleotopes as complex topic cave geosystems are divided into intracommunicative primary and secondary speleotopes (vertical relations are predominant), postintracommunicative speleotopes (intracommunicative speleotopes in the inactive developmental stage), extracommunicative primary and secondary speleotopes (horizontal relations are predominant), and postextracommunicative speleotopes (extracommunicative speleotops in the inactive developmental stage).

Horizontal structure. Relatively homogenous choric units correspond with the horizontal structure of cave geosystems. A speleochore represents an ordered group of several speleotopes interconnected by one-direction flow of mass and energy, i. e. horizontal relations (paradynamic range, catena, cascade). Within the framework of morphochores J. Minar (2000) distinguishes a historical (genetic) or recent (morphodynamic) spatial interaction of georelief elements.

Primary active and inactive fluviokarst speleochores, secondary active and inactive fluviokarst speleochores, and combined fluviokarst speleochores are distinguished according to the originality or posteriority and activity of processes; one-phase and more-phase speleochores according to developmental stages.

The secondary acorrelative (reverse) type of speleochores relates to the original inactive fluviokarst phreatic cave passage in case of a backward direction flowing of vadose stream as compared to the previous phreatic water flow. The secondary correlative type of speleochores is equivalent to the identical direction of vadose and phreatic water flows. Combined speleochores are marked by the modification of their original character in certain sectors of cave passages.

The more extensive caves usually consist of several speleochores, i. e. a set of speleochores. We can distinguish synchronous and asynchronous sets of speleochores according to the developmental chronological period. According to the character of genesis they include harmonic (equal morphogenetic processes) and disharmonic sets of speleochores (different morphogenetic processes). Harmonic synchronous and asynchronous sets of speleochores include: conjunctive (connected fluviokarst speleochores in the direction of water flow), disjunctive (branched fluviokarst speleochores in the direction of water flow), conjunctive-disjunctive (fluviokarst speleochores with lateral conjunctive and disjunctive branch passages), collateral (branched and consecutively connected fluviokarst speleochores in the direction of water flow), parallel (main fluviokarst passages – speleochores are connected by a „pirate“ passage), non-branched, conjunctive and conjunctive-disjunctive single paragenetic sets of speleochores (genetic sequence – fluviokarst drawdown and invasion vadose caverns in the ponor part and caverns with mixture of phreatic and watertable-levelled segments in the middle and spring part of cave system, etc.).

Time-Spatial Changes of Cave Geosystems

The spatial structure of geosystems is not stable, it changes in time in dependence on input of mass and energy. Interpreting the time-spatial changes of cave geosystems particular developmental states refer to appropriate speleotopes and respondent speleochores or sets of speleochores. The several asynchronous features of time-spatial changes of surface and underground part of karst geosystem are in consequence of a „barrier“ position of cave geosystems against outside influences.

Regime (rhythm). The behaviour of geosystem is a continual sequence of processes delivering a mass and energy in the geosystem. This interaction keeps the state of geosystem peculiar to a certain chronological interval or stage. The rhythm is one of behaviour regimes of geosystem (NEEF et al., 1973; DEMEK, 1987). The annual course of underground water flows, the sequence and intensity of atmospheric water seepage, the seasonal change of current air direction in dynamic vertical dissected caves and the seasonal glaciation of some caves are examples of cave geosystems regime.

Within the framework of the seasonal rhythm of geosystems, BERUCASVILI (1986) interprets „steks“ (concrete states of geosystems as a consequence of spatial and chronological synthesis of geomasses and geohorizons) and „etocycles“ (trajectories of regular cyclical changes of „steks“ during year).

The self-regulation is a property of geosystem to keep typical states (regimes, state values of relations among components) during its functionality. Irreversible changes effect the transformation of geosystem to a different stability state (f. e. a disturbance of speleoclimatic conditions in ice hollows in consequence of opening new surface entrances or siphons leading to non-ice parts). The capacity of resistance is the ability of geosystem to withstand application of forces that have a trend to deflect the geosystem from its momentary typical state in a certain chronological interval (f. e. an equalization and compensation of speleoclimatic changes in consequence of visitors´ movement in show caves). The self-regulation of geosystem, as well as the capacity of resistance are connected with the behaviour of geosystem (DEMEK, 1987).

Dynamics. It represents changes of geosystems that include succession stages series connected with an effort to accomplish their stability, i. e. a climax in dependence to the geoecological invariant change

(SOCAVA, 1979; DEMEK, 1987). Some examples of cave geosystems dynamics are: the glaciation of drawdown inactive fluviokarst caverns beginning since the discontinuity of primary continued cave parts, the cave geosystem change of an inactive fluviokarst passage originated by the underground water flow in the phreatic zone since the time its successive transformation in the vadose zone without the fluvial effect and the hydrological active phase of cave genesis.

According to developmental chronological stages we can distinguish one-phase and more-phase speleomorphotopes. The development of one-phase speleomorphotopes relate to the dynamics of cave geosystems. More-phase speleomorphotopes are modelled by geomorphological processes in more developmental stages in dependence on the invariant changes, that exceed a framework of dynamics.

Evolution. It presents changes that include the alternation of geoecological invariants and the change of its spatial structure (SOCAVA, 1978; DEMEK, 1987). The evolution of cave geosystems is connected with the origin of cave passages in several chronological stages or periods (developmental process in the geological chronological scale, alternation of invariants). The more-phase speleomorphotopes include coincidence (consecutive morphogenetic process are identic or compatible with primary morphogenetic processes) and aincidence speleomorphotopes (modification of previous forms is in consequence of the effect of dissimilar non-compatible processes). The spatial structure of speleomorphotopes associated in choric units is changed during a successive development of caves (development of new branch passages in the horizontal dimension or multiple passages in the vertical dimension, in some cases invasion passages and wells interconnect developmental levels). The evolution of cave geosystems includes also other changes of invariants (fossil caves originated by morphogenetic process that correspond with natural conditions in past geological age, etc.).

Stability of Cave Geosystems

The utilisation of caves (show caves, speleotherapy, water source and other activities) increased with the development of human society. The deterioration of cave geosystems is caused both by accompanying negative anthropogenic phenomena „in situ“ and secondary negative phenomena with contamination sources outside the caves or karst areas (BELLA, 1992). The determination of geosystem stability is important for utilisation and protection of karst landscape and caves.

We can consider following fundamental stability categories of cave topic and choric geosystems: very instable geosystems with a slight carrying capacity value, instable geosystems with low carrying capacity value, medium-stable geosystems with normal carrying capacity value and comparatively stable geosystems with increased carrying capacity value in relation to anthropogenic activities (BELLA, 1997).

Conclusion

Knowledge about the spatial structure and time-spatial changes of cave geosystems not only contributes to the completion of existing karstological and speleological knowledge, but also generates a precondition for the solution of other analytic and synthetic tasks. Except for the tasks related to geomorphology, hydrology, climatology and other geoscientific disciplines, environmental problems of karst geosystems are topical. Presented theoretical and methodological approach of cave research demands a complex geographical mapping and visually suitable cartographic formulation of thematic content of maps.

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Protection and Management of Show Caves in Slovakia

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Abstract

According to the Act of the National Council of the Slovak Republic No. 287/1994 on Nature and Landscape Protection, all the caves should be considered nature monuments. The most important caves are designated national nature monuments. The caves as a public property are included in the amended version of the Constitution of the Slovak Republic from 2001.

Twelve caves have been opened to the public in Slovakia to date. Their appropriate and optimal utilisation rests in monitoring of visitors´ impact on natural environment of caves, including its regulation. All the show caves are designated national nature monuments. The Ochtinska Aragonite Cave, Domica Cave, Gombasecka Cave and Jasovska Cave have been included in the World Natural Heritage since 1995, Dobsinska Ice Cave since 2000. The protection and management of the show caves in Slovakia are under the responsibility of the Slovak Caves Administration in Liptovsky Mikulas – a qualified institution of nature protection of the Ministry of the Environment of the Slovak Republic.

Caves in Slovakia and Slovak Caves Administration

The extent of karst regions in Slovakia represents an area of over 2,700 sq.km. More than 4,250 caves occur in this country. The strictest 5th level of legislative protection is related to the caves. Reasons for their protection are geomorphological values, representation of unique calcite, aragonite or ice filling, osteological and archeological findings, and historical memorabilia.

The Slovak Caves Administration realizes the protection and management of twelve show caves in Slovakia. Its nature protection activities also refer to the caves that are genetically connected with the show caves. Basic characteristics of the show caves are shown in Table 1, the total number of visitors in 1996–2000 is shown in Table 2. Simultaneously, this institution manages the reconstruction and building of objects and technical devices of show caves. It also takes part in realisation and development of speleotherapy and speleoclimatic stays in these caves.

Protection, Utilisation and Management of Show Caves

A show cave is an educational locality where a part of underground spaces is technically adjusted for cultural and educational purposes or other community based utilisation at the same time with keeping the stability of cave geosystems and supporting their protection. Show caves rank among caves that are the most attacked and utilized by man. Their protection requires an enhanced attention.

The main tasks of caves complex protection and management are: basic documents preparation for show caves legislative protection; elaboration of specialists' viewpoints and documents for decision making of state executive offices; elaboration and realization of upkeeping programs to maintain cave geosystems stability; projects elaboration on show caves protected zones declaration; realization and coordination of research, exploration, documentation and other activities in these caves; monitoring and evaluation of cave environmental conditions and impact of the rate of visitors and other utilisation of cave geosystems; projection and enforcement of show caves operation regime; specialists' supervision of accessibility works in caves; supervision of licensed activities realization in show caves, etc.

The practical protection includes liquidation of undesirable „lampflora" and realization of preventive actions against its growth (the electric input of a new electrical installation in the Ochtinska Aragonite Cave was reduced by one third, as well as in the Domica Cave and Dobsinska Ice Cave by changing the lighting units), installation of devices against a mechanical destruction of sinter filling (new barriers and underground remote video control system in the Demanovska Cave of Liberty and Ochtinska Aragonite Cave), determination of visitors regime and limits in potentially threatened caves (ten persons for one guide in the Ochtinska Aragonite Cave), construction of cave entrance closures, etc.

Table 1. Basic characteristic of show caves in Slovakia.

Belianska Cave Belianske Tatry Mts. (Belianske Tatras)	890 m a.s.l., 2,350 m long, tourist path 1,135 m, carbonate speleothems, front parts were known in the first half of the 18th century, opened to the public since 1882, lightened since 1896
Bystrianska Cave Bystrianske Foothills	565 m a.s.l., 2,000 m long, tourist path 490 m, carbonate speleothems, discovered in 1923, opened to the public in 1939–1940, reopened since 1968, speleotherapeutic procedures since 1971
Demanovska Cave of Liberty Nizke Tatry Mts. (Low Tatras)	870 m a.s.l., 8,126 m long, tourist path 1,800 m, part of Demanova Cave System (31.5 km in length), carbonate speleothems (rimstone dams, spathite stalactites, pagoda-like stalagmites, columns, draperies, flowstone, moonmilk, shelfstone, pearls), discovered in 1921, opened to the public since 1924
Demanovska Ice Cave Nizke Tatry Mts. (Low Tatras)	840 m a.s.l., 1,750 m long, tourist path 650 m, part of Demanova Cave System, ice filling in the lower parts, first written mention in 1719, old inscriptions on walls, open to the public in the eighties of the 19th century, reopened since 1952
Dobsinska Ice Cave WORLD HERITAGE Spis-Gemer Karst, Slovak Paradise	971 m a.s.l., 1,232 m long, tourist path 475 m, total volume of ice filling is more than 110,000 cubic meters, maximum thickness of ice is 26,5 m, 12 species of bats, discovered in 1870, opened to the public since 1871, lightened since 1882
Domica Cave WORLD HERITAGE Slovak Karst	339 m a.s.l., 5,300 m long, tourist path 1,315 m, genetical entity with Baradla Cave in Hungary, carbonate speleothems (shields, rimstone dams, columns), 15 species of bats, important archeological site (Neolithic Era), discovered in 1926, opened to the public since 1932, boat trip
Driny Cave Male Karpaty Mts. (Lesser Carpathians)	399 m a.s.l., 680 m long, tourist path 410 m, carbonate speleothems (draperies, flowstone, stalagmites, stalactites, rimstone dams), discovered in 1929, opened to the public since 1935
Gombasecka Cave WORLD HERITAGE Slovak Karst	250 m a.s.l., 1,525 m long, tourist path 285 m, carbonate speleothems (unique straw stalactites), discovered in 1951, opened to the public since 1955, first speleotherapeutical procedures in 1968
Harmanecka Cave Velka Fatra Mts. (Great Fatra)	821 m a.s.l., 2,650 m long, tourist path 720 m, carbonate speleothems (stalagmites, flowstone, draperies, rimstone dams, moonmilk), 9 species of bats, discovered in 1932, opened to the public since 1950
Jasovska Cave WORLD HERITAGE Medzevska Upland	257 m a.s.l., 2,704 m long, tourist path 550 m, carbonate speleothems, 17 species of bats, archeological site, the oldest inscription on the wall from 1452, opened to the public in 1846, reopened since 1924, speleotherapeutical procedures since 1995
Ochtinska Aragonite Cave WORLD HERITAGE Revucka Highland	642 m a.s.l., formed in a lens of Paleozoic crystalline limestones, 300 m long, tourist path 230 m, unique aragonite filling (kidney-like forms, needle-like forms of anthodites, spiral forms of helictites), discovered in 1954, opened to the public since 1972
Vazecka Cave Kozie chrbty Mts. (Goats´ Crests)	784 a.s.l., 530 m long, tourist path 235 m, carbonate speleothems, palaeontological site (bones of cavern bear), discovered in 1922, opened to the public in 1933, after reconstruction since 1954

Because the realization of practical protection depends on detailed knowledge of cave natural conditions, the Slovak Caves Administration supports a geoscientific research (geology, geomorphology, hydrology, speleoclimatology, biospeleology) and consecutive geographic synthesis that are aimed at the stability and carrying capacity of cave geosystems. Since the half of the nineties, the monitoring of speleoclimatic changes, caused by the rate of visitors, has been accomplished in the Ochtinska Aragonite Cave, Dobsinska Ice Cave, Driny Cave and Vazecka Cave; hydrological monitoring continues in the Domica Cave and Jasovska Cave; geomorphological and mineralogical research of the Ochtinska Aragonite Cave resolved underground caverns genesis and creation of aragonite filling; geological research of structure and tectonic conditions in the Dobsinska Ice Cave evaluated a stability of overlying rock; the underground glacier movement had also been observed in this cave; radioisotopic dating and paleomagnetism research of speleothems from the Demanovska Ice Cave and Demanovska Cave of Liberty contributed to the geochronology of the Demanova Cave System; monitoring of chiropterofauna is realized continuously, etc.

Table 2. Number of visitors in show caves of Slovakia in 1996–2000

Cave/Year	1996	1997	1998	1999	2000
Belianska Cave	88 450	89 203	100 783	104 096	115 225
Bystrianska Cave	30 250	31 874	29 939	27 433	27 195
Demanovska Cave of Liberty	127 404	135 047	157 744	158 004	161 879
Demanovska Ice Cave*	60 220	**52 486**	53 861	62 570	76 331
Dobsinska Ice Cave*	84 000	73 844	79 602	82 537	84 454
Domica Cave	26 957	24 815	23 464	24 081	22 534
Driny Cave*	38 450	39 512	36 478	35 812	35 083
Gombasecka Cave*	16 586	15 278	14 633	14 276	13 194
Harmanecka Cave*	23 509	21 495	21 983	21 466	20 978
Jasovska Cave*	12 676	22 501	21 553	18 119	16 542
Ochtinska Aragonite Cave*	27 800	29 696	26 447	30 221	30 482
Vazecka Cave	32 775	32 091	28 517	27 731	27 027
Total	**569 077**	**567 842**	**595 004**	**606 346**	**630 924**

(* seasonally opened caves)

Our attention is also directed to documentation and registration of cave research, exploration and monitoring results. We are setting up a geographic information system on show caves on the platform of a digital three dimensional model of cave spaces. Undocumented parts of several show caves (Demanova Cave System, Jasovska Cave, Belianska Cave, Domica Cave) are surveyed in cooperation with the Slovak Speleological Society.

The exactingness and narrow specialness of some tasks necessitates the cooperation of caves protection department with scientific institutions or speleological organisations. Show caves research knowledge can be applied also for other caves and karst area in Slovakia. The Slovak Caves Administration organized seminars and scientific conferences where attained results were presented (Protection of Ice Caves, 1995; Show Caves – Research, Protection and Utilisation, 1996; Research, Protection and Utilisation of Caves, 1997, 1999).

Show caves operation strictly depends on building and reconstruction of objects and technical devices at the cave entrances on the surface and in the underground spaces. The building of a new entrance object of the Jasovska Cave was finished in 1996, the one of the Dobsinska Ice Cave in 1998. The new electrical installation of the Ochtinska Aragonite Cave and reconstruction of foot-path part of the Dobsinska Ice Cave were realized in 1997. The sound system in caves enables providing a commentary in foreign languages. The state of underground technical devices (foot-paths, electrical installation), stability of overlying rock, the cave safety plan and observance of other safety regulations for visitors moving (Safety Regulations for Caves No 3000/1975 SBU) are controlled by offices of State Mining Administration. Yearly mining safety inspections in individual show caves are accomplished at the beginning of tourist season with participation of these offices.

Show Caves as Educational Localities

The show caves present educationally important localities, concentrating a great attention of large community. Therefore these caves have an important mission for the environmental education. The majority of show caves are situated in nature protected areas. The commentary in the show caves should have also educational character with regard to the necessity of nature protection. Permanent expositions on natural values and cultural memorabilia of caves are installed in the entrance objects of the Domica Cave, Ochtinska Aragonite Cave, Jasovska Cave, Dobsinska Ice Cave. Educational paths are installed along foot-paths from valley parking-places to some show caves (Harmanecka Cave, Belianska Cave, Demanovska Ice Cave, Dobsinska Ice Cave, Demanovska Cave of Liberty).

Conclusion

The protection and reasonable utilisation of show caves in Slovakia is of state interest. According to karst area location, show caves are situated appropriately in the whole territory of this country, however, more concentrated in the Slovak Karst and the Low Tatras regions. Caves in the radius of the Low Tatras, the High Tatras and the Slovak Paradise tourist resorts (Demanovska Cave of Liberty, Demanovska Ice Cave, Belianska Cave, Dobsinska Ice Cave) have the largest number of visitors. The Slovak Caves Administration manages the maintenance of individual show caves properly and evenly. There are not heavy differences as for their protection, research, technical equipment and publicity. The propagation of show caves has to respect the necessity of cave protection (visitors' regime and limits).

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Roman Mining in the Valongo System (Portugal)

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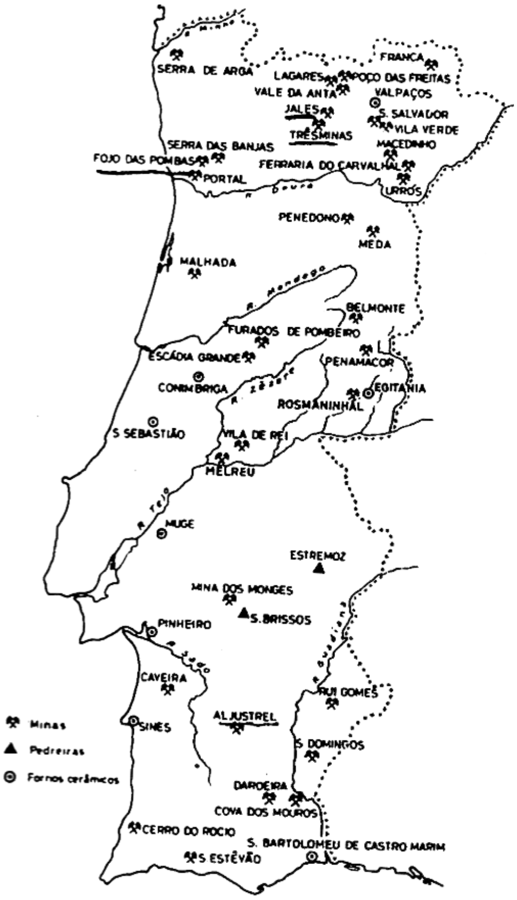
Summary

Mining was one of the most important economic activities during the roman period. The extraction would, in many occasions, subsidise the expenses of the Legions. The Romans intensively explored all occupied territories, adapting and developing new mining techniques specific to each local. In Portugal many are the examples of mining exploration, namely of gold and copper. The Valongo mining system is a paradigmatic example of gold extraction in this part of the Empire; being as well the most important work developed by the Association in an artificial cavity, with reference to the fields of Surveying and the application of special Speleological techniques in shale rock.

This paper has the **purpose** of presenting a brief resume about the mining techniques used by the Romans, especially in Valongo, a Roman site in the North of Portugal.



The **first two centuries** A.D. where actually the apogee of this activity in the Peninsula.. And it was its gold that made possible the payment of all expenses of the Roman Legions. In the words of Plutarcus (Cat. 10; Front.4, 7-35), the army expenses where supported by the Hispania mineral resources; and Diodorus (V, 36-38) said that “when the Romans conquered the Peninsula, Italics in great number exploited the mines obtaining enormous richness.” According to Pliny, the gold from the northwest of the Peninsula in the first century granted the Roman exchequer about 20.000 roman pounds per year, about 6.5 tons/year, , [(Garcia Bellido, 1970), Artur Martins, s.d.].

The Mining Activities

The mining activities where developed in three distinctive manners:

Placer Mining, in river alluviums, rich in gold or tin. The Tagus River, is an example Douro, Minho and Alva Rivers has well.

Open-Pit Mining, where great craters where opened in the landscape, as an example we have Três Minas Place.

Level and Shaft Mining, to reach and follow the ore veins. Three paradigmatic examples in Portugal are Valongo, Aljustrel and Jales.

The amount of gold, taken from the geographic area between Valongo and Castelo de Paiva (24 km away), was extremely significant – about 20/40 gr by ton of sedimentary schist. In this area is situated the **Serra de Santa Justa, in Valongo.**

As a proof of this chronological period, were found, in the 60's, several artefacts, such as metal jars and roman lamps.

This sort of woks involve a great amount of dangers. The main problems can be identified as being the **lack of light, ventilation problems, the constant presence of water and the need to drain it.**

The Romans developed several **solutions** for the mentioned problems as well for several other ones. In order to minimize the ventilation problems, made worse by the temperature rise as the depth increases in the shafts, as well the accumulation of toxic gases, additional air shafts were created to improve the air circulation inside the mine witch promoted convection currents that would bring the fresh air from the surface to the interior of the mine.

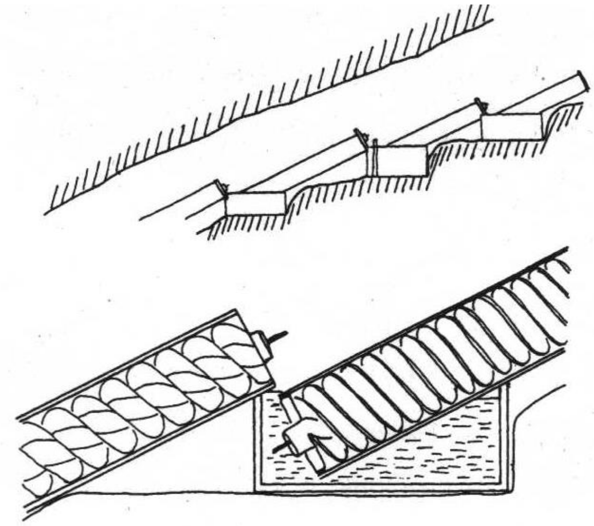
Regarding the illumination of shafts and galleries, the romans used their daily objects – such as roman lamps – placing them in niches excavated in the walls of galleries being worked. Several of these lamps were found in mines explored by the romans, assuring the chronology of the mining works. Stone and terracotta dishes with fuel were equally used, and much likely torches, placed in better ventilated places; Diodorus makes references to small lamps placed in miners heads in order to improve the illumination in the individual workplace.

Roman lamp in a nich (Valongo)

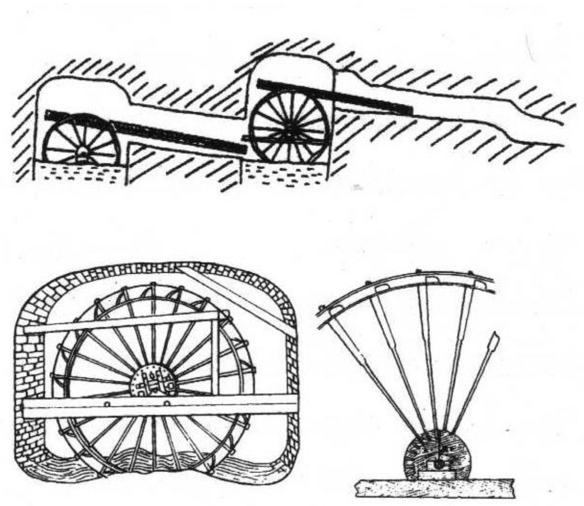
Underground water accumulated in the new shafts was drained by systems created specially for that purpose. Therefore the **Archimedes or egyptian screw**, witch consisted in a group of several big length helix, rotating in a never ending system.

The **waterwheel** used in groups was another system used for draining purposes; they were build in wood, with bronze axis and buckets.

However, given their morphology, not all of the mines could use those techniques and devices; in this cases the draining was made by carrying the water in esparto buckets and bags, adapted to this task.



Parafusos de Arquimedes



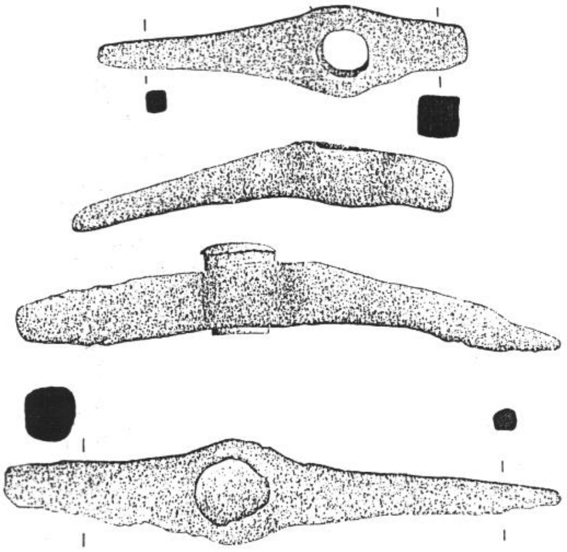
Noras em associação e roda para a extracção de água

In **Santa Justa (Valongo**) gold mines the draining was made by digging **a twin shaft**, at a short distance from the main one. The principle was to move the water from one shaft to the other, consecutively. Therefore one of the shafts cold be dried , allowing the digging work to proceed. There were also galleries named ***"cuniculo qui metallis subducet" (draining galleries),*** made with the purpose of carrying the water out of the mine, to a distant place, usually a creek. This method was commonly used in fairly large mines such has Valongo.

Shafts were also opened in order to allow the ventilation and peoples access to the mine.

Other materials were used in the mining activities, such has wooden stairs, iron tools (used to remove the ore); esparto sandals and berets for the miners, ropes also in esparto used to bring the ore to the surface.

For the production of this materials and the maintenance of a large contingent of men, who worked on the mines, was surely necessary the development of several economic activities such as agriculture and cattle raising, to feed the workers, ropery, carpentry, woodworkers and blacksmiths providing all the utensils used in the mines and the gold ore processing as well.



Iron picks

The Valongo Roman Mines

Due to the lack of archeological studies there are not many published articles about this site.

However its historical importance recognized since 18th century. One of this written examples from 1758 *Memórias Parochiaes,* that read as follows: *"Na dita serra pella parte do Norte sitio de Espinhaço de Cam se acham fojos porem quazi tapados algum ainda conserva a altura de vinte palmos, e como ella he ramo da de Valongo e de santa Justa aonde ha muitos com escadas subter-raneas, he sem duvida que os seus fojos se tirou no tempo dos romanos muita quanti-dad de ouro, de que hião repletos os Preconsules que governavão a Hespanha no tempo da republica e ainda do Imperi como dis Plinio e não ha muitos annos sendo vivo o Senhor Rei D. Joam o 5º por ordem sua vejo hum mineiro a esta serra, e que achara o ouro [...]".*

References to the existence of this mines and the large amounts of gold extracted are traceable since Pliny, therefore proving the economic importance of Serra de Santa Justa mining activities.

Analysing the shafts and galleries extension we must conclude that large amounts of gold ore was extracted from this place, for an extended period of time.

To achieve all this work, was undoubtedly necessary a great number of slavery work. In order to assure the security a large amount of legionaries were present.

Much likely (although there is no archeological evidence of the fact), for such a great number of persons, a large amount of equipments to support the mining activity; specific mining equipment, daily objects and food supplies would be indispensable.

Surely an habitat and its necropolis, as well as places to process the gold ore would be part of the landscape.

The roads are another important subject of study. Probably with its analyses we can obtain information about the gold routes and its destinations. This roads were surely connected with several mining exploration sites, and were certainly the faster and safer way to carry this good.

The only Serra de Santa Justa study elements available were collected in 1961 during an unobstruction performed by the Serviço de Fomento Mineiro in Fojo das Pombas. The artefacts found during the woks were published in " Achados Romanos na mina do Fojo das Pombas (Valongo)" by Luís de Albuquerque e Castro. Several pottery artefacts, a II century roman lamp (Ponsich II B) and twelve metal objects.

This was the first study made with an archeological perspective, to witch some continuity should be given in order to bring more knowledge about this important roman site.

This mine has twin shafts to reach the gold veins, water draining and ventilation.

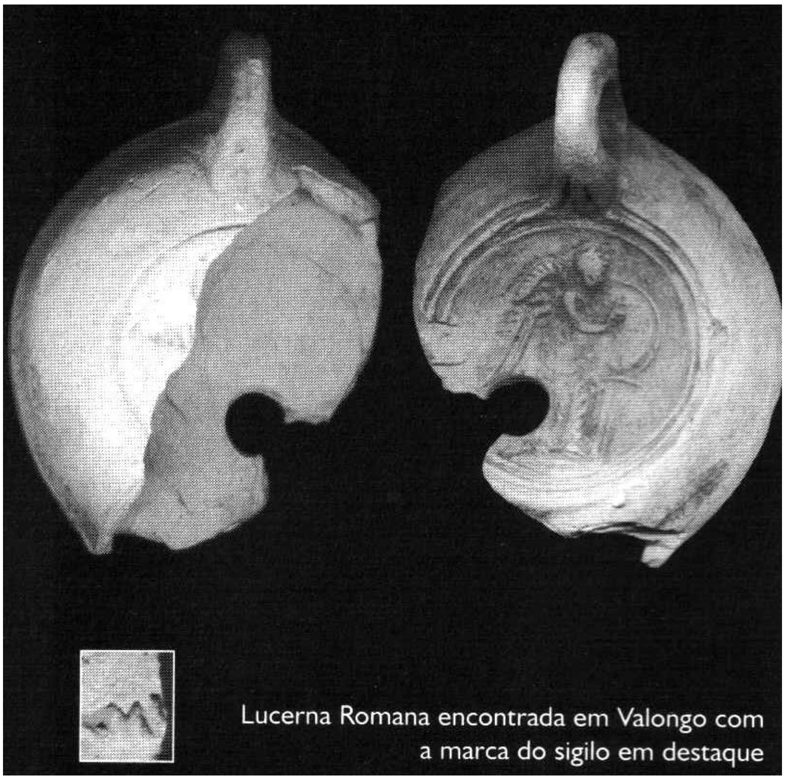
The other draining technique in Valongo was the use of draining galleries, as mentioned above. One of those galleries, 350 meters in length, ends on a small creek. This same river could also be used to wash the gold ore. There is also the possibility for the existence of equipments used to process the ore in location, due to the large production of the mines. To confirm this large amount of gold extracted we have the analyses made by the Direcção-Geral de Minas e Serviços Geológicos (Mello Nogueira, 1935) showing that the ratio ore/gold was 84grams per ton.

At the moment we do not have any kind of archeological findings connected with this ore processing in Valongo.

The shafts and galleries opening was made with metal picks, from witch marks can be observed on the mine walls. We can also observe niches on the walls, where roman lamps were placed.

Last year another roman lamp was found, during an A.E.S.D.A. espeleological activity. In this lamp we can observe a winged female figure in the *discus*. She´s turned to the right side and caries a disc (*Clipeus*), on the top of a altar like column. The figure is a *Victoria*, one of the usual themes since the first century.

In our study we looked for several *Victorias,* in order to compare them, but found none similar to this one except the one found in the same mine, in 1961. We can attribute this lamp to Dressel 20 tipology and Ponsich II B2.



Lucerna Romana encontrada em Valongo com a marca do sigilo em destaque

In the bottom there is a sigil with the letter M and part of the letter V. This leads us to think that its origin reports to the MUNTREPT potterys and the potter called L.MUNATIONS (Belchior, 1969)

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Bom Santo Neolithical Necropolis

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Summary

Discovered in 1993 during a speleological prospection campaign in Montejunto Mountain Ridge led by *Associação de Estudos Subterrâneos e Defesa do Ambiente* (Subterrean Studies and Environment Protection Association), the Bom Santo Cave is one of the most important noelithical cave necropolis at an European level. This presentation will show how important was the cavers' role in the discovery, study and preservation of the site. In addiation, the communication will present the study's findings until the present date.

Introduction

The cave of Bom Santo was discovered in 1993, during survey work led by AESDA (Associação Estudos e Subterrâneos e Defesa do Ambiente), from Torres Vedras, central coastal Portugal (Regala, 1995; Zilhão & Araújo, 1993). Integrated in the karstic system of the Montejunto/Aire e Candeeiros mountain range, the cave is located at 350 meters above sea level, on the eastern slope of the Montejunto mountain. The whole system is part of the Estremadura limestone massif, where a series of cavities occupied during Prehistory has been identified and investigated since the 19th century (Cardoso & Soares, 1995; Leitão *et al*, 1987; Zilhão, 1984; Zilhão & Carvalho, 1996).

Description of the site

Upon its discovery, it became clear that the cave had three levels, two of which had been intensely used as a cemetery, likely during Prehistory. Observation of the few ceramic vessels visible at the surface suggested a Neolithic chronology for the occupation. The number of bones observable on the surface of the rooms and galleries and their level of preservation were promising and seemed to indicate that the cave had remained undisturbed since its utilization as a funerary space.

Recognition of what Algar do Bom Santo could mean in terms of mortuary archaeology research for this time period led to the unfolding of a series of events that made archaeological research possible at the site, during 3 field seasons (1994, 1995 and 1997). In 1994, the main goal was to define the dimensions of the cave as a whole, to characterize the type of occupation that was dominant in the cave and to test the apparent good level of preservation of the funerary context recognizable at the surface (Duarte, 1998). Simultaneously, cave topography was initiated.

Firstly, we tried to understand the relationship of the large boulder that sealed the entrance recognized by the speleologists when they first found the site, with the use of the cave during Prehistory. Its removal exposed its shape and position, suggesting that it had been purposefully placed at the entrance, sealing the burial.

Secondly, all the rooms and galleries where human bones where visible were measured, in order to define the dimension of the cemetery. The total area was estimated at 285 square meters, divided into 11 rooms (cf. slide with room dimensions).

Thirdly, we thought it was important to test the real state of preservation of the archaeological assemblage as a whole; that is, it became pivotal to test, in taphonomic terms, if the magnificently preserved mortuary assemblage visible today at the surface corresponds to the original distribution of the human remains placed at the site. This evaluation could only be efficient if careful and detailed description of the remains were ensured before exhuming the bones. The strategy adopted by the team was to test two rooms: the entrance area (designated as Room A) was selected on the basis of spatial convenience. In fact, curiosity of the local population led to the constant arrival of visitors at the site, during excavation. The fact that the team was excavating at the entrance made the contact with the public easier.

The second room was selected given its excellent state of preservation and the fact that it had once been continuous with Room A, before a large roof fall separated both spaces.

Excavation of Room B during the first field season allowed verification of the apparent level of preservation of the assemblage. In fact, in one square meter excavated, it became clear that what appeared to be one skeleton lying on the surface actually corresponded to the remains of 3 adults and 3 subadults, all compressed in a stratigraphic sequence of almost strictly human remains, with little sediment associated (Duarte & Arnaud, 1996).

During the second field season, a fourth question was given special attention, that is, an estimation of how many individuals were deposited in the cave cemetery and where they had been placed. A detailed inventory was performed along the 11 rooms used as funerary spaces in order to define how many individuals were represented. The remains of a minimum of 111 individuals could be recognized at the surface, but only one was complete; in reality, the skeletons represented in this tomb do not constitute the remains of complete bodies but they are, instead, the result of the manipulation of the body of the deceased, practised by the people who chose this tomb as the final home to their ancestors, family and companions.

Confronted with the fact that Algar do Bom Santo is not the place of primary disposal of the dead chosen by these people, research went one step further – to try to investigate the steps of manipulation, their spatial location, and the role of this particular assemblage in the complex procedures that rule the relationship with Death in this population.

The assemblage characterized, its reliability tested, it became important to maintain the information on Video. A professional team from the Portuguese National Television ensured that all rooms and bone assemblages were visually documented to prevent the possibility of robbery and disturbance by external factors. The visual recording done proved important, given the unfortunate event that took place in November 2000. The cave was robbed and the bones at the surface were partially disturbed. Visual comparison of the assemblage before and after the theft was the basis used in the elaboration of the necessary inventory of lost elements demanded by police investigation.

Information potentially provided by the archaeological assemblage contained in Algar do Bom Santo is too important to be completely removed by current investigation. The research strategy for this context has been to pinpoint specific issues and to direct excavation towards answering the questions defined before archaeological intervention.

To date, we know that Algar do Bom Santo was used during the latest phase of the Neolithic, as defined in Portuguese archaeology; it is part of a group of mortuary assemblages inside caves, where human remains are disposed at the surface, apparently disconnected, accompanied by rare ceramic vessels, globular in shape and with no decoration, few lithic artefacts, mostly flint blades and geometric segments of composite tools, few polished axes and adzes. These latter were almost always placed in pairs, side by side – one adze, one axe - accompanying specific skeletal remains.

Radiocarbon dates obtained for the site confirmed this diagnosis and placed it within the Late Neolithic mortuary sites known in Portugal (e.g., Araújo & Lejeune, 1994, Cardoso *et al.,* 1992; Cardoso & Cuna, 1995; Serrão & Marques, 1971, Soares, 1994; Soares & Cabral, 1993).

Spatial distribution of the bones demonstrated that human remains were placed in specific places, according to chosen procedures, defining sub-units within the cemetery, on circular or sub-circular spaces internally defined. Whether they correspond to biologically related groups (such as families) may possibly be made clear by DNA fingerprinting and this line of research will be considered in the near future.

The nuclei created inside the cave suggest the symbolisation of what might correspond to separate tombs. Inside each of these units, human remains from all age groups and both sexes are present. This heterogeneous distribution suggests no differential treatment on the basis of gender or age. In fact, the assemblage contained in Room B, almost completely excavated (about 95% of the room has been excavated and the bones exhumed and analysed) shows evidence of vertical accumulation of remains from different individuals, belonging to several age groups, both males and females.

Quantification of the human remains exhumed suggests that preferential treatment was given not to individuals but to specific body parts. In fact, and given the level of preservation of each bone group, it appears that special attention was paid to the cranium and to the long bones of the lower limb. Higher concentration of certain bone groups suggests a secondary character for the assemblage, reinforcing the diagnosis based on the spatial distribution of bones inside the whole cave.

Final Considerations

Excavation of Room B, however, revealed the presence of a partial rib cage, not associated with the remaining skeleton. This suggests an even more complex picture for the behaviour of these populations in the face of death. In fact, the presence of segments of the skeleton might imply that the secondary nature of the Algar do Bom Santo cemetery is possibly local or dual; i.e., provenience of some bones is possibly distant, while others had been possibly manipulated during the different steps of the mortuary procedures within the spatial limits of the cave itself. Further investigation on the details of spatial organization and taphonomic alteration of bones is in course, in order to answer these questions.

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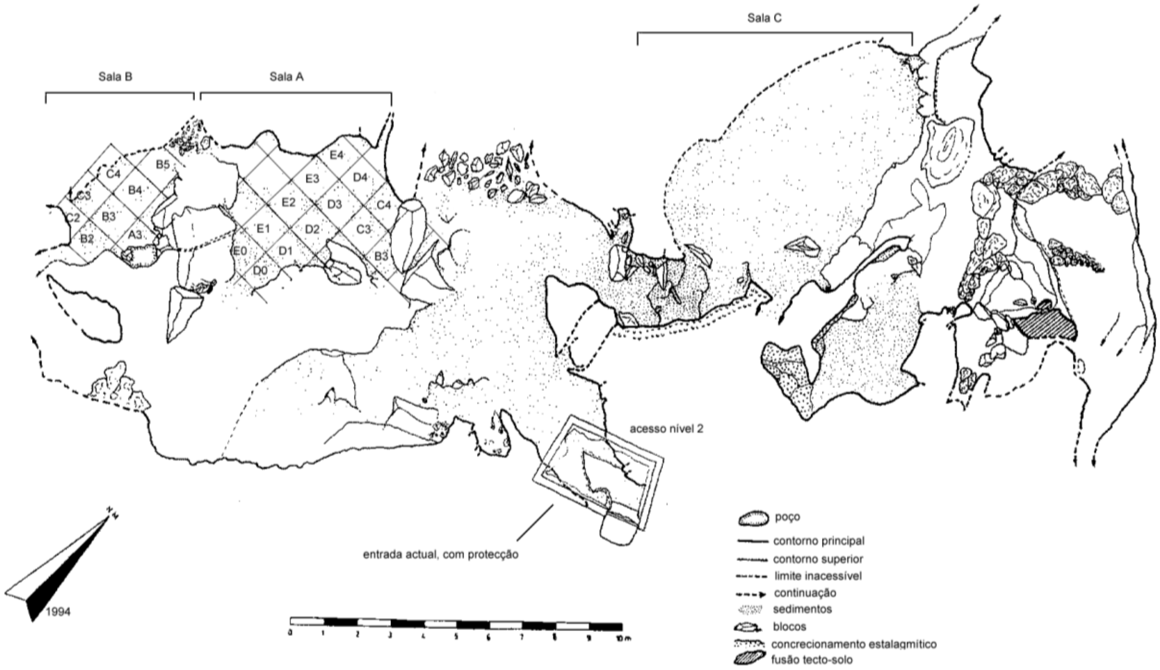
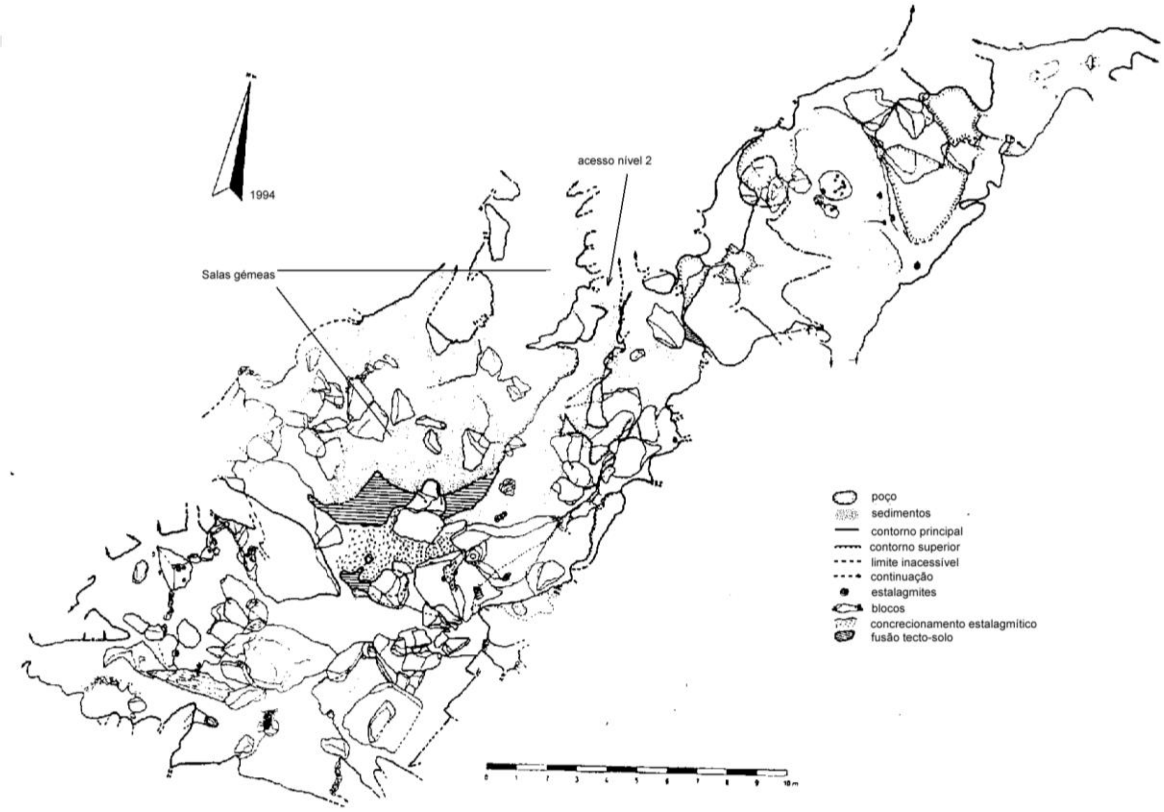


Level 1 - Bom Santo Neolithical Necropolis



Level 2 - Bom Santo Neolithical Necropolis

A.E.S.D.A. Associação de Estudos Subterrâneos e Defesa do Ambiente

Topo A.E.S.D.A. (Associação de Estudos Subterrâneos e Defesa do Ambiente) – 1994 – Torres Vedras - Portugal
Original Scale: 1/50 – Authors: Rui Mergulho, Emanuel Carvalho, Teresa Julião

Melrose Caverns: A Late Pleistocene Vertebrate Locality in Virginia, U.S.A.

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Abstract

A 1- by 2-meter site within Melrose Caverns, Rockingham County, Virginia has yielded significant vertebrate remains. Work at the site has produced an assemblage of 46 vertebrate taxa including amphibians, fish, birds, reptiles, and mammals. The bone deposit appears to represent the den site of a small mammalian carnivore and possibly other contributors. A significant find is *Geomys* sp., a first record for Virginia. *Geomys* sp. is an extirpated form that now lives in western and southeastern U.S. The Melrose fauna includes other extirpated forms which now live in the west: *Microtus ochrogaster* and *Spermophilus tridecemlineatus*; extirpated forms which now live in more northern areas: *Phenacomys intermedius* and *Synaptomys borealis*; and the extinct: *Mylohyus fossilis*.

The nearest *Geomys* sp. occurrence is a fossil occurrence in New Trout Cave in West Virginia. Lower levels of the New Trout Cave site date older than 30,000 years ago and contain *Geomys* sp. and *Cryptobranchus alleganiensis*, but the small rodent, *Microtus xanthognathus*, is not present. *Geomys* sp. and *Cryptobranchus alleganiensis* have not been found in the upper levels of latest Pleistocene age where the extirpated *Microtus xanthognathus* is relatively common.

An attempt to date the Melrose Caverns site failed when no collagen was found in the bone sample sent for AMS dating. The presence of *Geomys* sp. and *Cryptobranchus alleganiensis* and the absence of *Microtus xanthognathus* are evidence that the Melrose Caverns site may date as early Wisconsinan. The recognition of early Wisconsinan sites is problematical in that they lack the extinct microtines that distinguish Irvingtonian sites, there is little to distinguish them from later Pleistocene sites and they are too old to date by carbon methods.

Introduction

Awareness of how few of Virginia's caves were known to contain paleontological resources and a subsequent brief series of caver finds of Pleistocene-aged remains in the mid-1990s, prompted a paleontological inventory of the Commonwealth's caves. The Paleontological Resource Inventory of Virginia Caves (PRIOVAC) initiative was first permitted in October 1996 to make surface collections of non-human vertebrate and invertebrate remains in caves. One such collection made in Melrose Caverns in March 2000 contained the remains of *Phenacomys intermedius* (heather vole) – an extirpated animal, which now lives in more northern areas. Additional surficial collections yielded more extirpated forms, including *Geomys* sp. (pocket gopher), and an extinct peccary. An additional permit, to allow a limited excavation of the site, was applied for and received in October 2000. This paper details our findings at the Melrose Caverns bone site through February 2000. The cave resources of Melrose Caverns are protected, as they are in all non-federally owned caves in the Commonwealth, by the Virginia Cave Protection Act.

Physical Setting

Melrose Caverns is a 410 m-long cave (HOLSINGER, 1975) in the middle-Ordovician New Market Limestone in the Valley and Ridge physiographic province. The cave is developed in a small wooded hill, bounded to the east by a normally dry stream course. At least four natural entrances are known, all of which are sealed or gated, in addition to the gated tunnel-entrance to this former commercial cave. The commercial entrance was opened by tunneling at the rear of the cave, approximately 40-m from the deposit. The floor sediments were trenched in some areas of the cave during commercialization. Floor trenching exposed a depth of sediment up to 0.4-m along the two-meter-long alcove in which the bone deposit is located. The width of the alcove is about three-quarters of a meter across the upper sediments. Initial collections were from the upper 15-cm of the deposit. Excavation revealed a meter-wide passage or elongate solution pocket oriented parallel to the cave passage trend and behind the quarter-sphere shaped alcove.

Faunal Remains

Prior to the start of the excavation, surficial collections of exposed bone matrix yielded the remains of *Phenacomys intermedius* (heather vole), *Geomys* sp. (pocket gopher), *Spermophilus tridecemlineatus* (thirteen-lined ground squirrel), *Synaptomys borealis* (northern bog lemming), *Cryptobranchus alleganiensis* (hellbender), and the extinct *Mylohyus fossilis* (peccary). The vole, pocket gopher, ground squirrel, and lemming are all extirpated from the state, while the hellbender is extirpated from the Potomac River basin, in which the site is situated. The record of *Geomys* sp. is a first for the state.

Matrix was wet screened to recover fragments coarser than about 0.5- to 0.7-mm. Carbonate-cemented clasts were solutionally reduced by the use of dilute acetic acid. The upper 15-cm contained the fragmental remains of about 44 vertebrate taxa (Table 1) including amphibians, fish, birds, reptiles, and mammals. Most of the identified remains are teeth, jaws, and cranial fragments. Some post-cranial elements have been identified to taxa. This upper layer contained single elements of three different carnivores: a canine of *Procyon lotor* (raccoon)**,** a premolar of a Mustelidae (large weasel or mink), and a caudal vertebra of a large long-tailed Felidae (cat). The next lower 10- to 13-cm have further defined some taxa to species, increased the numbers of individual faunas, and added only two more records. *Lutra canadensis* (river otter) is represented by a radius and fits well with the aquatic faunal portion of the assemblage. A possible determination of *Spilogale putorius* (eastern spotted skunk), by a deciduous molar, represents a fifth carnivore.

The location of the site and its faunal assemblage lead us to conclude it represents the den of at least one carnivore. The combination of fish, tree frogs, and small rodents presents an interesting assemblage, especially if the site represents a single carnivore. The sucker, catfish, hellbender, muskrat, and river otter imply a sizeable flowing stream in contrast to the dry streambed that presently exists near the site.

Site Dating

A bone fragment, suspected to be part of a peccary skull, was submitted to the National Science Foundation (NSF) Accelerator Mass Spectrometer (AMS) laboratory at the University of Arizona for an AMS radiocarbon measurement. The sample proved to lack collagen and could not be carbon-dated.

A late Pleistocene age of the bone deposit is implied by the presence of: *Mylohyus fossilis* (extinct peccary) and extirpated forms presently living in the western U.S. - *Microtus ochrogaster* (prairie vole) and *Spermophilus tridecemlineatus* (thirteen-lined ground squirrel), extirpated forms presently living in the northern U.S. or Canada - *Phenacomys intermedius* (heather vole) and *Synaptomys borealis* (northern bog lemming), and *Geomys* sp. (pocket gopher) - an extirpated form that now lives in western and southeastern U.S. The nearest site that contains a similar fauna is the New Trout Cave deposit in West Virginia (GRADY & GARTON, 1982). This site also is located within the Potomac River Basin, which presently lacks *Cryptobranchus alleganiensis* (hellbender). Lower levels of the New Trout Cave site date older than 30,000 years ago and contain *Geomys* sp. (GRADY, 1984) and *Cryptobranchus alleganiensis*. Curiously these lower levels lack *Microtus xanthognathus* (yellow-cheeked vole) a common microtine in upper layers of the site and in many other sites of latest Pleistocene age in the Virginias (MCDONALD *et al.*, 1998). Because of the absence of the extinct microtines that distinguish Irvingtonian sites, the Melrose bone site is suspected to date as early Wisconsinan.

We plan to attempt another AMS bone date when we find an adequate sample. As excavations advance in depth and into the narrow fissure behind the alcove another dating opportunity may await. Within the fissure, a narrow stalactite can be seen protruding through the upper layers of the deposit. Perhaps the base of this calcite speleothem will lie within the deposit and be adequate for a U/Th date for a horizon within the deposit.

Scientific Name	Common Name	Minimum #
Osteichthyes	**Bony fish**	
Cyprinidae	minnow(s)	1+
Catostomidae	sucker	1
Ictaluridae	catfish	1
Amphibia	**Amphibians**	
Cryptobranchus alleganiensis	hellbender	1
Caudata	salamander(s)	1+
Hylidae	peeper(s)	2+
Reptilia	**Reptiles**	
Squmatra	lizard	1
Colubridae	non-poisonous snake(s)	1+
Aves	**Birds**	
Anatidae	?small duck	1
Mammalia	**Mammals**	
Sorex cinereus Kerr	masked shrew	12
Sorex (Microsorex) hoyi (Baird)	pygmy shrew	2
Blarina brevicauda	short-tailed shrew	3
Parascalops breweri	hairy-tailed shrew	1
Condylura crystata	star-nosed mole	1
Eptesicus fuscus	big brown bat	7
Pipistrellus subflavus	eastern pipistrelle	7+
Myotis sp.	bat	20+
Corynorhinus sp.	big eared bat	2
Lepus americanus	snowshoe hare	1
Leporidae	rabbit or hare	1
Tamias striatus	eastern chipmunk	1+
#Spermophilus tridecemlineatus	thirteen-lined ground squirrel	1
Tamiasciurius hudsonicus	red squirrel	2
Glaucomys volans	southern flying squirrel	2
Neotoma magister	Alleghany woodrat	2
Peromyscus sp.	deer or white footed mouse	10
#Phenacomys intermedius	heather vole	2
Clethrionomys gapperi	red backed vole	1 or 2
Microtus pennsylvanicus	meadow vole	9+
Microtus chrotorrhinus	yellow nosed vole	1 or 2
Microtus pinetorum	pine vole	17
#Microtus ochrogaster	prairie vole	7
Microtus pinetorum or *ochrogaster*	vole	7
#Synaptomys borealis	northern bog lemming	3
Synaptomys cooperi	southern bog lemming	2
Ondatra zibethicus	muskrat	1
#Geomys sp.	pocket gopher	3
Zapus hudsonius	meadow jumping mouse	20+
Napaeozapus insignis	woodland jumping mouse	4
Procyon lotor	raccoon	1
Mustelidae	large weasel or mink	1
?*Spilogale putorius*	?eastern spotted skunk	1
Lutra canadensis	river otter	1
Felidae	large cat	1
**Mylohyus fossilis*	long nosed peccary	2
Odocoileus virginianus	white-tailed deer	1

Table 1. Vertebrate fauna from Melrose Caverns bone site (# - extirpated from state, * - extinct).

Summary

The presence of remains of the extirpated small rodent *Phenacomys intermedius* prompted inventory speleologists to further investigate a small exposed bone deposit in Melrose Caverns. The site yielded remains of the extinct peccary *Mylohyus fossilis* and additional extirpated small rodents, including *Geomys* sp. – a new state record. The location and assemblage of some 46 fish, amphibians, reptiles, and mammals appears to represent a den site of one or more carnivores. An attempt to radiometrically date a bone sample failed for lack of collagen, however, faunal similarities to a West Virginia site, about 50-kilometers away, suggest the site may date as early Wisconsinan. Stratigraphic excavation and fine-mesh wet-screening techniques are in-use in the documentation of this significant site.

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Carste e Paleoecologia em São Raimundo Nonato – PI, Brasil

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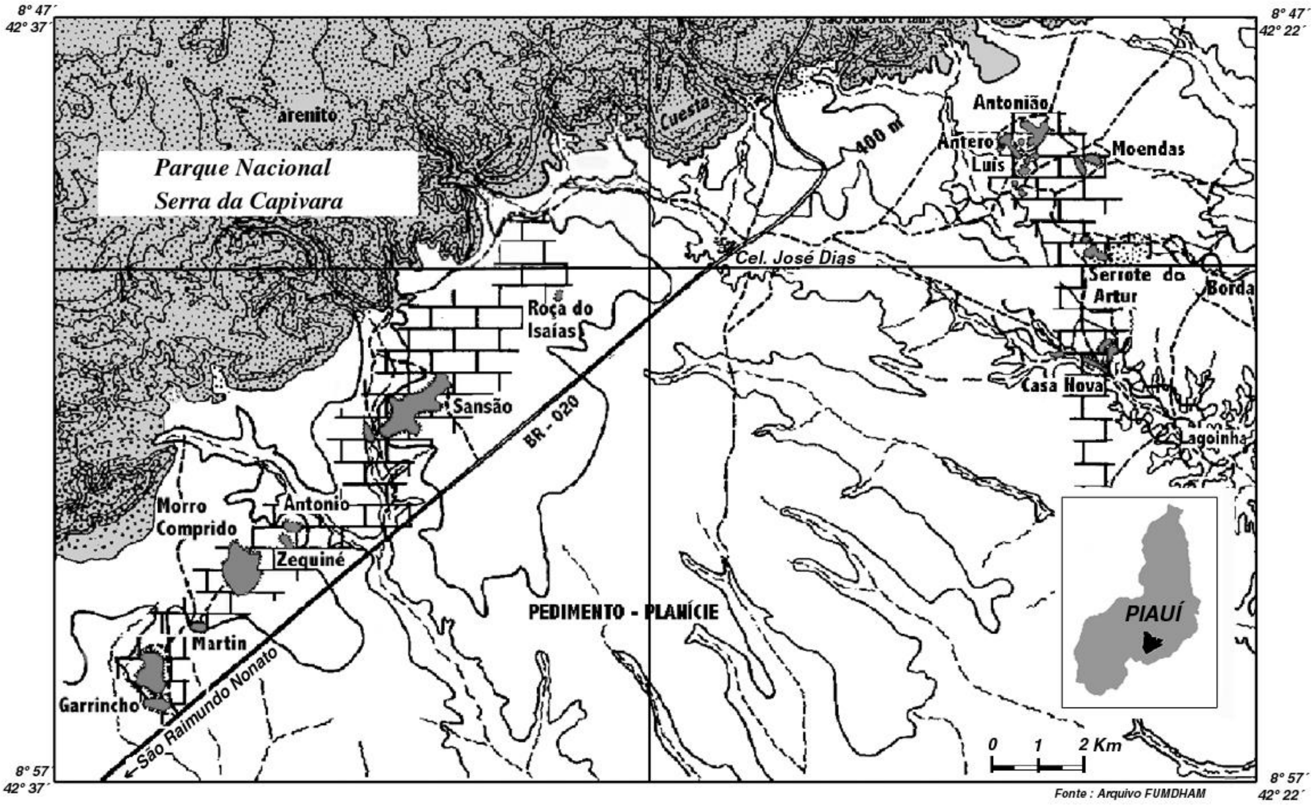
Abstract

In the Southeast of Piauí state, a karstic area of reduced dimensions is home to a large numbers of hollows containing archaeological and palaeontological remains and palaeoclimatic data. These hollows, wich are situated in vicinity of the Serra da Capivara National Park, are directly related to the other archaeological sites in the region. The site at Toca da Janela da Barra do Antonião Toca do Serrote do Artur, Toca de Cima dos Pilão e Toca do Garrincho stands out as the main sites of the carstic region, where excavations have uncovered evidence of a rich Pleistocene fauna, human burial, rock paintings and stone tools associated with the megafauna. Taken together, the analysis of these remains will enable a greater understanding of Brazilian prehistory and of the evolution of Brazil's natural environments.

Resumo

No sudeste do Piauí, uma área cárstica de dimensões reduzidas abriga uma centena de cavidades com vestígios arqueológicos, paleontológicos e dados paleoclimáticos. Estas cavidades, localizadas no entorno do Parque Nacional Serra da Capivara, mantêm uma relação direta com os demais sítios arqueológicos da região. Devem ser destacadas as Toca da Janela da Barra do Antonião, Toca do Serrote do Artur, Toca de Cima dos Pilão e Toca do Garrincho como os principais sítios do domínio cárstico, onde escavações evidenciaram uma rica fauna pleistocênica, sepultamentos humanos, registros gráficos e indústria lítica associado à megafauna. Em seu conjunto, as análises destes vestígios propiciarão uma melhor compreensão da Pré-história brasileira e da evolução do seu meio natural.



Fonte : Arquivo FUMDHAM

Figura 1 – Localização da Área Cárstica do PARNA Serra da Capivara – PI, Brasil

Introdução

Estudos Paleoclimáticos da Província Espeleológica do Parque Nacional Serra da Capivara, PI – Brasil: Primeira Aproximação.

Pesquisas interdisciplinares sistemáticas chefiadas pela Dra. Niède Guidon vêm sendo efetuadas desde meados de 80 na área cárstica de São Raimundo Nonato pela Fundação Museu do Homem Americano – FUMDHAM. As cavidades prospectadas e escavadas revelaram vasto material arqueológico, paleontológico e dados paleoclimáticos. Diversos outros sítios do domínio arenítico foram escavados, onde os dados arqueológicos e sedimentológicos vieram reforçar o conhecimento do contexto regional. A reflexão sobre o conjunto destes dados, facilitada pelas novas tecnologias de análise e datações dos registros, propiciará uma melhor compreensão da evolução ecológica e cultural da região.

Localização

A Província Espeleológica de São Raimundo Nonato localiza-se no sudeste do Estado do Piauí entre as latitudes 8º 47’ e 8º 57’ de latitude sul e 42º 37’ e 42º 22” de longitude oeste, estando inserida na área de proteção sul do Parque Nacional Serra da Capivara.

As cavidades estão distantes 4 km em média dos limites do Parque Nacional, inseridas no complexo espacio-funcional da Toca do Boqueirão da Pedra Furada, sítio arqueológico referência da região. Neste sítio, vestígios da presença humana remontam à 50.000 anos BP, a mais antiga evidência arqueológica da presença humana nas Américas.

Clima e Vegetação

O clima atual da região é semi-árido, classificado como Bshw (Koppen), com precipitações irregulares ao longo do tempo e do espaço, com médias anuais da ordem de 650 mm. A estação das chuvas ocorre entre outubro a final de abril. As chuvas são, em geral, localizadas e de curta duração. A temperatura média anual é elevada (28ºC), com máximas de 45ºC, mínimas de 22ºC e médias de 31ºC.

O nível hidrológico de base é o Rio Piauí, rio intermitente que percorre o sul e leste do Parque. As reservas hídricas se restringem a açudes, barragens e “caldeirões”, depressões na rocha, geralmente de dimensões reduzidas, que reservam água tanto para a fauna quanto à população local.

A vegetação típica é a caatinga (arbustiva e arbórea) xerofítica e caducifólia, ressaltando-se a ocorrência de formações florestais nas ravinas e fundos de vale, locais de maior concentração hídrica.

As Cavidades e os Dados Paleoclimáticos

A Área Cárstica ao sul do P.N.S.C. é caracterizada como um carste testemunho, metamorfizado, com a ocorrência de quase uma centena de cavidades distribuídas em vários “serrotes” (morros residuais) em dois alinhamentos principais. As cavidades são, em geral, de pequenas dimensões, muito superficiais e com intensa ocorrência de processos clásticos. A maioria destas cavidades constitui-se de sítios arqueológicos e paleontológicos, sendo atualmente, alimentadas somente por águas meteóricas.

Nos estudos realizados no carste, foram consideradas as feições das cavidades (ocupação / utilização pelos animais e o homem pré-histórico), as características hidrológicas, o zoneamento dos depósitos físicos e químicos com possibilidades de estudos detalhados.

Escavações foram realizadas em alguns sítios calcários, destacando-se a Toca do Garrincho, Toca de Cima dos Pilão, Toca da Janela da Barra do Antonião e Toca do Serrote do Artur. Foram evidenciados vestígios humanos como sepultamentos, material lítico, registros gráficos, estruturas de combustão, além de vasto material paleontológico e amostras de sedimentos.

Da Toca da Janela da Barra do Antonião, um vasto abrigo-sob-rocha, foi escavada uma superfície de 720 m^2 até 1990. Apresentou uma rica fauna composta de 50 *taxa* de micro a megamamíferos, além de quelônios, anfíbios, jacarés, peixes e 42 espécies de aves. Ocorrências de indústrias líticas em níveis pleistocênicos e marcas de uso em alguns ossos atestam a contemporaneidade do homem com a megafauna da região.

A Toca do Garrincho apresentou um parietal humano, dois dentes humanos em estratigrafia de 10.020 ± 290 anos BP (GIF 9335) em associação com a macrofauna pleistocênica. Um manto estalagmítico logo acima dos dentes humanos parece separar os depósitos pleistocênicos dos holocênicos.

Da Toca de Cima dos Pilão, escavada entre 1986 e 1990, foram retirados uma rica indústria lítica, restos humanos datados em 10.390 ± 80 anos BP (BETA 27345), além de registros gráficos e cerca de 500 restos de macromamíferos identificáveis. Vários mantos estalagmíticos se intercalavam nos depósitos fossilíferos.

A Toca do Serrote do Artur, sondada em 1987 e escavada em 1995, apresentou uma fauna diferente dos outros sítios, mais próxima da atual e com menor diversidade do que a fauna pleistocênica. Sedimentos com matéria orgânica puderam ser datados em 6890 ± 60 anos BP (GIF 10515) e 8490 ± 120 anos BP (GIF 10516). Estas datações atestam a sobrevivência tardia de 5 gêneros da megafauna : *Propaopus, Hoplophorus, Glyptodon, Equus e Paleolama* (Faure, 1999 : 447). Vários episódios de preenchimento, intercalados com mantos estalagmíticos puderam ser observados.

O conjunto dos dados provenientes das escavações dos sítios cársticos e areníticos, além dos estudos botânicos, palinológicos, geomorfológicos, arqueológicos, paleontológicos (relações biogeográficas e biocronológicas), antracológico e espeleológicos, permitiram traçar uma primeira aproximação do contexto paleoecológico da região.

O período entre 50.000 a 10.000 anos BP, e que corresponde às fases Pedra Furada 1 à 3, é caracterizado como tropical úmido, com sedimentação física e química constante e com intensas quedas de blocos. Para Guérin (1996: 95), o conjunto da fauna de mamíferos, que data do Pleistoceno Superior é testemunha de uma paisagem caracterizada pela savana arbustiva, entrecortada de zonas florestais conspícuas, com o clima muito mais úmido que o atual.

Entre 10.000 e 7.000 anos BP, o que corresponde às fases Serra Talhada 1 e 2, parece começar o período de transição das formações mistas para a savana. As quedas de blocos se tornam esporádicas, parecendo ser o início do processo de extinção da megafauna.

Por último, ocorre a transição para o semi-árido. Este período corresponde à fase Agreste, caracterizado pela caatinga arbustiva e arbórea densa, de difícil penetração. Os gêneros remanescentes da megafauna tornam-se extintos, sobrevivendo apenas os mamíferos de pequeno porte. O caudal hídrico torna-se intermitente, com quedas esporádicas de blocos. É a paisagem que observamos hoje.

Deve-se ressaltar que esta aproximação se baseia nos dados provenientes das diversas áreas de estudos, necessitando de um maior detalhamento nas análises e datações dos registros para que a seqüência ecológica seja estabelecida com maior precisão.

Possibilidades de Datação e Análise de Sedimentos Físicos e Químicos

Nos depósitos físicos e químicos que se formam em uma caverna, milhares a milhões de anos da evolução da paisagem podem ser registrados. As precipitações de calcita podem preservar os melhores registros da dissolução do calcário na região: material clástico, minerais diversos, poeira, matéria orgânica, de ácidos húmicos, moléculas, esporos e pólen a ossos (Ford, 1997: 271). Condições paleoambientais podem ser apreendidas pela observação da superfície ou seções de espeleotemas. Discordâncias claras na estratigrafia refletem mudanças no regime de deposição / erosão.

Os sedimentos físicos também são rica fonte de informação. Episódios de ocupação humana e animal podem ser preservados nos depósitos entre os mantos estalagmíticos. Podem ser analisadas sua composição, formas de deposição, conteúdo fossilífero, matérias orgânicas diversas. Estudos sedimentológicos também podem ser feitos sob a ótica da Antracologia, Palinologia, Paleobotânica, Arqueologia e Paleontologia.

Por outro lado, as técnicas de datação dos depósitos têm se desenvolvido muito nas últimas décadas, onde as cronologias podem ser estabelecidas com a precisão exigida. Os métodos de datação têm como propósitos, datar a deposição, paleotemperaturas e outras mudanças que possam ser preservadas nas amostras. Estes métodos podem ser absolutos, relativos ou por marcadores, destacando-se entre eles, a Série de U, C^{14}, ^{18}O: ^{16}O, TL, ESR, OL, Racemização de amino-ácidos, Paleomagnetismo além da estratigrafia e correlações espaciais. Apesar da ampla possibilidade de utilização dos métodos de datação, exigências técnicas das condições das amostragens e o alto custo são restrições ao seu uso.

Conclusão

O contexto cultural, tão bem estabelecido na área de São Raimundo Nonato, carece de seu correspondente ecológico. As cavidades carbonáticas e os abrigos areníticos da área arqueológica são extremamentes ricas em depósitos fossilíferos, que devidamente analisados e datados, poderão servir de base para a reconstituição do contexto paleoecológico da região. Espera-se poder estabelecer relações entre as variações climáticas, a paleoecologia e a evolução cultural das populações pré-históricas da região.

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Pre-hispanic Ritual Use of Caves in the Rio La Venta Region, Chiapas, Mexico

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The knowledge of archeological remains in natural caves of the Rio La Venta area, Chiapas (Mexico), has notably increased since 1993, when La Venta Exploring Team began his long-term spelological exploration. The Rio La Venta Archaeological Project, stemmed by the speleological one in 1997, is currently drawing up a catalogue of archeologcal caves of the area, once inhabited by Zoque indians. Analysis and excavations of ritual activity areas (offerings, burials, child sacrifice, etc.) is showing their wide distribution and their chronological variations, always related to the cult of water deities paid by indians groups living in a highly karstified area extremely poor in surface waters. The article resumes the results of our work and deals with the main lines of ongoing research.

Previous Researches

The rio La Venta region lies in the municipalities of Ocozocoautla, Cintalapa and Jiquipilas, in western Chiapas (Mexico), an area traditionally inhabited by Zoque indians since Preclassic times. The analysis of the many archaeological sites of this region is providing useful data to understand the pre-hispanic development of this particular branch of the Mixe-Zoquean family, still poorly known despite the fact that its relevance for the early mesoamerican cultural developement had been convincingly demonstrated (see, for example, LOWE, 1977; LEE 1986). In this paper we will deal only with the archaeological remains located inside the many caves that dot this highly karstified region.

The presence of archaeological remains in the natural caves of the rio La Venta region was first reported in 1945, when Matthew W. Stirling visited caves and open-air archeological sites of the area during various excursions made while he was excavating at Piedra Parada (Ocozocoautla, Chiapas). Stirling described the archaeological features he saw in the caves and wrote a brief report about them in a letter sent to *American Antiquity* (STIRLING 1945) and a slightly longer one in an article for the *National Geographic Magazine* (STIRLING 1947). His complete field notes remained unpublished since 1989, when Maricruz Pailles translated and published it with an analysis of the ceramic material collected by Stirling (PAILLES 1989).

Stirling visited 5 caves on both sides of the rio La Venta canyon (and the local inhabitants told him about various others) and all of them contained huge amounts of pottery vessels, a tipical kind of offering that we call “massive offering”. Diagnostic ceramic types such as White-rimmed Blackware and Incised Blackware in the form of bowls with flaring sides suggest that these offerings had been deposed mainly during the Early Classic period (ca. 250-600 d.C.). Apart from the amounts of bowls, the caves contained various modeled censers and the inner room of one of them (Cueva de los Cajetes) was separated from the outer one by a dry-wall of limestone slabs with a little, central, access.

In 1947, Mr. Arnold Snell and Mr. Wallace Miner, two U.S. citizens engaged in a hunting trip in Chiapas, visited eight caves and an open-air archaeological site in the vicinities of Cintalapa and the rio La Venta canyon. They collected some of the archaeological remains found in the caves and brought them to the U.S., where they were studied by Arden R. King (KING, 1955). All the cavities contained Classic period pottery and the most interesting material were from a large rock-shelter at the base of the La Venta canyon, where they collected various specimens of Incised Blackware and a large wrapping of fibrous sheaves called “shaman’s bundle”. The bundle contained various fragments of cords and textiles, *copal* balls, vegetables, two oyster shells (*Ostrea* sp.) and a thorn awl from a palm (*Acrocomia mexicana* or *Pyrenoglyphis balanoidea*) wrapped in a handle of palm boot fiber and probably used as an autosacrifice implement. The materials collected by the two hunters showed one of the most important carachteristics of the dry caves of the area: the perfect conservation of perishable materials in spite of the surrounding lush tropical forest environment. In 1953, Robert Russell explored part of the jungle area near Piedra Parada and discovered three monumental complexes. In the note he sent to *American Antiquity* , apart from describing the ruins, Russell states that “The entire area is liberally [sic] dotted with caves. Those I visited are carpeted with sherds, in one to a depth of over one foot. This suggest that the caves were used for religious rituals over a very extendend period" (RUSSELL, 1954). In 1958, Frederick A. Peterson, Field Director of the New World Archaeological Foundation, "was assigned the awesome task of making a survey of the many caves and archaeological sites reported for the Ocozocoautla-Cintalapa subregion, in the Rio La Venta drainage" (LOWE, 1959). In five months of field-work Peterson explored over fifty caves with archaeological remains, collecting pottery specimens and describing the archaeological contexts in his field-notes, unfortunately still unpublished. Scanty descriptions of his work can be found in a couple of popular articles (PETERSON, 1961a, 1961b), in publications devoted to other works he made in western Chiapas (PETERSON, 1963a, 1963b) and in brief mentions of his colleagues (LOWE, 1959; LOWE & MASON, 1965). From this references we can assume that the majority of caves he explored contained Early Classic materials, often in the form of "massive offerings"; one cave contained more than 20.000 whole vessels of White-rimmed Blackware. In 1968, Thomas A. Lee began a survey of the area for the New World Archaeological Foundation. He studied three caves in the Rio La Venta region and made excavations in the large rock shelter previously visited by Arnold and Snell, now called Cueva de la Media Luna, where he detected a Late Preclassic-Protoclassic occupation (ca. 300 BC- AD 250); during this period, a plastered and painted platform was built in the cave, supporting a wattle-and-daub upper structure composed of various rooms; nineteen offerings were buried along the platform front and stairway, consisting in palm-fiber bundles and couples of pottery bowls put in a mouth-to-mouth position and wrapped in palm fiber. The bundles contained cords, fiber and *copal*, while the mouth-to-mouth offerings contained fibers, *copal*, gourd pendants and human hair. A pit near the platform contained the burials of four individuals, associated to other seven fiber bundles and covered by a massive offering of 519 White-rimmed Blackware pottery bowls. A later—and less understood—Late Classic frequentation was identified on the base of the presence of few ceramic material and by the probably contemporaneous red geometric rock paintings on the cave walls. The other caves explored by Lee were the Cueva Colmena, containing a massive offering of hundreds of Late Classic pottery bowls and a child skeleton, and Cueva Cuatro Hacha, with a red rock-painting depicting an "ax" with four inner dots (LEE, 1985); similar painting are quite common on the canyon cliffs and in various caves and *simas* of the region.

Between 1969 and 1993 the Rio La Venta region has been the object of various speleological expeditions organized by the Accademia dei Lincei (Italy), Circolo Speleologico Romano (Italy), Speleo Club Mottois (France), Gruppo Speleologico Bolognese (Italy), MUCC (Canada), Speleo Club Martel (France) and various sardinian speleo clubs; in this same time-span was carried out the first expedition by some the founders of the La Venta Association who, in 1990, made the first complete descent of the Rio La Venta (see DE VIVO & GIULIVO, 1999, for a sinthesis of the speleological history of the area and for specific bibliographic references). Many of these expeditions found archaeological materials and reported them in their publications. Among these, two are the main results worth to be mentioned here: the discovering of the cave named Tapesco del Diablo by the members of the Speleo Club Martel and the first descent of the river made by the La Venta Association members.

The Tapesco del Diablo, a cave located 50 meters on the vertical cliff over the river bed, was excavated by mexican archaeologists with the technical aid of the french speleologists. In this cave, whose access was closed by a wooden grid ("tapesco"), they found some of the most important archaeological materials ever found in the area. In the cave main room they found a stone-slabs structure containing the burials of three individuals; associated with the burials they found a stone ax with the original wooden handle, textile fragments, conch pendants, calcium-solphate needles, maize cobs, a grinding stone, various potteries and five fiber bundles. One of the bundles contained a basket inside which they found a little wooden chest-mask covered by mother-of-pearl and representing a death god in the form of a human skull, a bone needle probably used for autosacrifice, forty perforated conch-shells and various seeds, mainly cocoa's. Another bundle contained a child sandal, a comb, 23 gourd pendants and a woooden chest-mask depicting the face of an old man. The floor of the main room and of the main gallery of the cave were literally covered by pottery vessels (some of which stuccoed and painted) and grinding stones; in the gallery a two-meters wide platform was built against the rocky wall and a small lateral chamber toward the end of the cave contained a group of three stuccoed and painted vessels, three onix vessels and two alabaster tripod vessels, together with a bone pendant in the form of a crouching juaguar, 3 conch pendants, two net ponds and an obsidian blade. All the materials recovered in the Tapesco del Diablo are of Late Classic date (SILVA RHOADS & LINARES VILLANUEVA, 1993; LINARES VILLANUEVA, 1998).

In the meanwhile, the evaluation of the spelological and archaeological potential of the canyon by the La Venta Association members during their descent of the river led to the organization of the long-lasting Rio La Venta Project.

The Rio La Venta Archaeological Project

In 1993, after the first descent of the river, the Rio La Venta Project won the Rolex Award for Enterprise that permitted the organization of the first grand-scale expedition in the area. More than thirteen expeditions had been carried out since then, giving a fundamental contribution to the geographic, speleological and archaeological knowledge of the area. Leaving aside the important speleological results (cfr. BADINO et al., 1999), let's concentrate here on the archeological ones.

During their 1993-1996 explorations the italian speleologists identified 32 caves containing archeological materials such as pottery, human bones and walls dividing the caves' chambers. Many other caves of archeological interest were seen on the canyon cliffs during the descent of the river. These findings and their close relationship with the spelological and hydrogeological context of the area led them to the idea of trying to give impulse to a formal archaeological research.

A first attempt to contribute to the archeological investigation of the area was made in 1994 when the La Venta Association members brought the mexican archaeologist that exacavated the Tapesco del Diablo to El Castillo, a big rock shelter they had discovered 80 meters high on the canyon cliff, located in one of the most impressive turns on the canyon. The big shelter (40 meters wide and 14 meters deep) contains a group of artificial, stone-built and stucco-plastered terraces, arranged as an "anphitheatre" around a central horizontal lithic slab that seems some sort of altar. A niche-like seat overlooks the canyon, and a fine-line incision, representing two face to face individuals with *máxtlatl,* necklace, earrings and feathered headdress, was found on the stuccoed surface of one of the terraces. Unfortunately, the archaeologists only made a collection of surface pottery fragments (LINARES VILLANUEVA, 1998).

The occasion for a long-lasting archaeological investigation came in 1997 when the La Venta Association organized the first campaign of the Rio La Venta Archaeological Project, directed by the italian archaeologist Giuseppe Orefici and by Thomas A. Lee, Eliseo Linares Villanueva and Carlos Silva Rhoads. Since the next year and till today the project has been directed by Thomas A. Lee and the author of this paper, who took part to the first expedition as field archeologist (OREFICI, LEE & DOMENICI, 1999).

During the 1997 expedition, the archeological project—apart from exploring and mapping some impressive open-air monumental sites not described here—focused on the excavation of three caves in the canyon: Cueva del Lazo, Camino Infinito and El Castillo (OREFICI, 1999; DOMENICI & LEE, 1999, 2000 in press).

The Cueva del Lazo is located on the canyon cliff, 250 meters over the river bed. On the inner surface, covering an area of about 250 square meters, there were textile fragments, cords ("lazos") and pottery fragments, among which a modeled three-dimensional jaguar from a censer lid. The excavation carried out in the cave led to the discovery of ten burials of childrens of an age comprised between six months and two years and a half, with only one of them aged between seven and eight yeras; many of the childrens (nine, at least) were wrapped in textile funerary bundles tied by fiber cords and showed textile turbants on their heads. Three of the child showed artificial cranial deformation. One of the child skulls had the *foramen magnum* artificially enlarged, probably to extract the cerebral mass (DRUSINI, 1999). Among the items associated with the burials there were a bone perforator, a horn of a young deer, fiber bracelets with conch beads, a necklace with two conch and one bone pendants and an implement made with little animal teeths probably used for tattooing or skin scarifying.

The child burials were associated with Late-Terminal Classic ceramic materials and they were intruding in a floor exposed in various parts of the cave. Below this floor, a little test pit revealed another floor, probably belonging to the first occupation of the cave. The surface presence of Late Preclassic and Early-Middle Classic materials could give a hint on the possible chronology of the previous and scarcely investigated occupations of the cave.

Various vegetal remains were recovered by the excavation such as beans (*Phaseolus sp.*), chili-peppers *(Capsicum sp.*), avocados (*Persea sp.*), *xícama* (*Pachyrrhizus sp.*) and cotton (*Gossypium sp.*). The presence of maize (*Zea mays*) was very high, with a total of more than 1200 corn-cobs weighting 4.8 kilos (PIACENZA, 1999).

The Camino Infinito cave is located on the right-hand cliff of the canyon and its 60 meters high access opens at 350 m above the river-bed, on the top of a big detritical cone whose ascent is very hard and risky ("camino infinito" means aptly "neverending trail"); for this reason we had to reach the cave descending from the top of the 500 meters high cliff with the aid of ropes. The big main room was almost free of archaeological remains, apart from an amount of pottery fragments near the end of the cave. The excavation of this "mound" brought to light three ladle censers with stamped interior and stamped handles (with images of a monkey, a jaguar paw and a fantastic animal resembling a dragon or a canid) and an architectonical basalt sculpture in the form of a jaguar's head. These items, together with the amount of pottery fragments, laid over an ash lens containinig fragments of a child's skull. All the pottery seems to be from the Late-Terminal Classic period.

The third cave explored was El Castillo, were a surface material collection had been already made in 1994 (cfr. *supra*). Apart from drawing a better topographical map and completing the surface collection, two small test pits were excavated in the central terrace. Among the items found on the surface there were an handle of a ladle censer in the form of a dragon and a fragment of a child skull, the last one located inside a little crack in the rear rock wall. All the pottery recovered from El Castillo is of Late-Terminal Classic date.

In the following field-seasons, the Rio La Venta Archaeological Project devoted mainly to the study of the open-air sites located in the tropical forest above the canyon, in order to have a better understanding of the wider cultural and social context of the ritual activity areas identified inside the caves (DOMENICI & LEE, 1999, 2000 in press). Anyway, during the several field-seasons we had the opportunity to explore other seven caves with surface archeological material. Two of them, explored in 2000, were particularly interesting: the Cueva de las Calaveras contained various whole and broken Early and Middle Classic pottery specimens and, in the final gallery, a big amount of human skeletons (surely more than ten individuals) spared on the ground; in the Cueva de José Juan, also explored in 2000, almost 200 whole White-rimmed Blackware bowls of Early Classic period were deposed at the feet of a calcitic formation hanging from the rocky wall of the cave.

Some Observations About Typology and Chronology of Cave Use

We are aware that the 62 archaeological caves reported by the above mentioned investigators (and we should add the "more than fifty" caves explored, but not published, by Peterson) represent only a minor part of the total number of caves with archaeological remains in the rio La Venta area. Many others had been seen but not explored on the canyon cliffs (for example, caves sealed by man-made walls) or had been mentioned by local inhabitants or spelologists. Despite the fact that our sample is indeed not completely representative, we think that the available data permit us to trace a rough sketch of the typological and chronological variability of the ancient use of caves in the region. The following sketch must be hence considered as a preliminary one, that need to be tested by future researches.

We think that the available data point to a mostly ritual use of the caves; this kind of use fits well with archeological and ethnohistorical data from the zoque-speaking area and from various other mesoamerican regions. The presence of utilitarian wares and implements such as the grinding stones in caves of very difficult access has led various investigators to propose that the caves could have been used as temporary refuges in periods of warfare. We cannot rule out this possibility, but we think that these utilitarian implements could also be considered as traces of long permanences in the caves linked to their ritual function, for example during some kind of ascetical retreats. Moreover, the many contemporary open-air sites of the region—where surely the Zoque indians usually lived—do not show any defensive feature that suggests a warlike social environment.

The difficult access to some of the caves, mainly the ones located on the canyon cliffs, need some more consideration. Various caves can today be reached only with the aid of modern climbing technical material and we can only guess how risky was for the ancient indians to reach them and we must imagine that they had a good climbing ability. In some cases, such as El Castillo, one can observe small natural terraces running along the cliff that were protected with a low wall in order to walk on them to reach the cave. We suspect that the very activity of reaching the caves was part of some kind of ritual training. The comparison of the local data with extra-regional ones allows to think that most of the ritual carried out in the caves were linked to the underworld water deities, whose role in a so highly karstified area (very poor in surface water) can be well imagined. These water-related rituals seems to fit well with archaeological contexts such as bowls deposed near or under stalactites in order to collect the dripping water, a custom that was also common among the mayas who used this "virgin water" for ritual purposes. Many of the "massive offerings" are also located near calcitic formations. The same relation with water deities seems to be evident in the many child burials (Cueva del Lazo, Camino Infinito, Cueva Colmena), as we know that many mesoamerican groups related childs with the cold-forces of watery underworld. As we will see, local ethnohistorical data seem to confirm the non-ordinary character of these child burials. Another kind of use of the caves is the funerary one (eg. Tapesco del Diablo, Cueva de las Calaveras, etc.), but again we cannot know if these burials were ordinary-ones or if they were instead intendend as some kind of offering. We know that the open-air sites contain burials, but our knoledge of this matter is still to poor to give us a good idea of the ancient funerary patterns of the region. Various kinds of man-made structures had been located in the caves. There are walls dividing different rooms with low accesses (eg. Cueva de los Cajetes, Las Cuevas, etc), walls completely sealing some cave on the canyon cliff, low terraces (Tapesco del Diablo, El Castillo) or solid platforms (Cueva de la Media Luna). In general terms, we can suggest that archeological materials such as massive offering, censers, child burials and shaman's bundles containing thorns, needles, copal and minerals, point to rituals such as ascetical retreats, medical treatments, divination, offering, sacrifices and autosacrifices, all them well established in the mesoamerican religious tradition. These ritual activities surely changed over the time. The most ancient evidence of archeological materials in a cave comes from the Cueva de la Media Luna, where the first occupation dates to the Late Preclassic period (ca. 300 BC). Probably the use of the caves began even earlier, since the oldest open-air sites of the region date back to the Early Preclassic. After the first poorly known frequentation of the cave (represented by some pottery fragments and hundreds of sweet-water shrimps), during the same Late Preclassic period, the Zoque indians of Cueva de la Media Luna built the platform and the upper wattle-and-daub structure and buried their offerings and burials. On the base of the kind of offerings, we suspect that the cave could have been the seat of some shaman or priest. The main period of cave is the Early Classic (AD 200-600), when the most common activity seem to be the "massive offering" of bowls. The number of caves with this kind of offerings, as the number of vessels deposed in every one of these, is really impressive. We do not know the reason for this apparent ritual "intensification" and "specialization", and we can only suggest that it must be related with cult of water and rain deities. The deposition of "massive offerings" seem to have come to an end toward the end of Middle Classic period (ca. 600), since the only later example known to us is the Late Classic one in Cueva Colmena. This strong change in the ritual activities between Middle and Late Classic is surely linked to the wider social and cultural developement of the area, that during Late and Terminal Classic shows an abrupt change in various cultural aspects. The Fine Orange ceramic pastes originated on the Gulf Coast completely replaced the old Blackware tradition and a new, monumental architectural style (with beautifully built stone structures) had a wide diffusion in the jungle over the canyon, replacing the old tradition of earthen mounds. This new cultural phase seems to cover the period beetween AD 600 and AD 1000, that is, corresponding to Late and Terminal Classic periods, with the possibility of an Early Postclassic extension. We will limit to note here that we don't believe in a "physical" replacement of the local inhabitants and that this changements are probably related to a strong cultural influence coming from the mayan people settled on the Gulf Coast.

The Late-Terminal Classic ritual activities show a strong tendence towards child burials and sacrifices (Cueva del Lazo, Camino Infinito, Cueva Colmena, El Castillo) that, as we already noted, could be related with water petition to the rain gods. In this same period the rich offerings of the Tapesco del Diablo were deposed and the El Castillo's structures were built.

We lack any data concerning the use of caves during the Postclassic period, an epoch scarcely represented in the open-air sites too. Anyway, we suppose that ritual activities in caves must have continued uninterruptedly, since various colonial documents show that they continued at least until the beginning of the XIX century.

In fact, In a recent work Dolores Aramoni cites acts from trials against zoque indians accused of sorcery. In 1685, the zoque woman María Sánchez from Jiquipilas witnesses that her father, who was a famous *brujo* (sorcerer), wanting her to know "what is inside the mountain", took her various times in a cave where she met supernaturals. She says also that her father and his compaions used to bring dead childrens,*copal*, candles and flowers in the caves as presents for the "devil". Still in 1801, the zoque Tiburcio Pamplona from Quechula, accused to be a *brujo*, said that the *naguales* (shamans' alter-egos) lived in a place called Ipstec ("Twenty Houses"), a place corresponding to the mountain ridge on the north side of rio La Venta (today called Veinte Casas); he said also that when the *naguales* want to kill someone they used to throw him in the rio La Venta canyon (ARAMONI, 1992).

Future Researches

An agreement has been established with the New World Archaeological Foundation in order to get access to Pterson's unpublished field-notes and materials, in order to add his data to the ongoing cataloguing of archaeologcal caves of the area. Future field-reserch of the Rio La Venta Archaeological Project will concentrate on the identification and excavation of ritual activity areas in dry caves.

Despite the fact that more than forty years have passed from Peterson's work, the big amount of still unexplored caves force us to conclude with his same concluding words: "we should [...] go back and do some more exploring" (PETERSON, 1961b).

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Manufacturing Evidence of Bone Tools From the Petralona Cave

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Abstract

The discovery of a widely applied, multiple method on the use of various bone tools from different animals lead to a new view upon the manufacturing, as well as social, achievements of Archanthropinae 700.000 years ago. By this work new evidence is presented on the subject, mainly concerning the comparative study of bone tools distribution and other findings into the layers of the Petralona cave.

The extended excavations at Petralona cave provided a large number of findings. Among them, hundred fossil taxa (man included) are recognized and several hundreds of stone tools, made on bauxite, quartz, limestone and stalagmitic row material (A. POULIANOS 1971, 2001, N. POULIANOS, 1995, 2000 - www.aee.gr). Some aspects on the bone tools have already been presented by the author (cf. above), but their complete study is in progress, since new evidence is still coming up.

Bones were mainly transported into the Petralona cave by prehistoric humans. Most of them, as well as the stone tools, are found between layers 2 and 18, i.e. of about 500.000 and 700.000 years ago. This is the span time when only few carnivores are traced in the cave and human activity prevails. On the contrary, among earlier layers (below 18), where most of carnivore fossils are found, the bones of herbivorous animals are very scarce and without signs of elaboration, indicating that after the formation of the 18th layer the main bulk of bone material was transported into the cave by the prehistoric hunters. This observation is reinforced by the discovery within the upper layers of peculiar findings, such as a rhino skull, an isolated elephant tusk fragment etc, which could have been transported inside the cavern only by humans.

A huge amount of thousands of bone fragments, concentrated on a few sq. meters (~100), also indicates that man had intentionally transported them. Besides their nutritional value, bones were useful for tool - manufacturing and rarely as firewood.

Most of the bone tools are not directly detected as such, since they have been altered by the cave microclimate and sinter covering. However, combined observations allow concluding that a certain process for their elaboration was followed. The diaphysis of the limb bones of various animals has often been longitudinally intersected and the so produced concave (half-tube) fragments were used as long knives or blades. After this treatment, their edges were immediately ready to cut. It is observed that during the use of these concave edges, their (tube-like) shape gradually turns to be flattened (or even slightly convex), until they become useful no more. Four main degrees (I-IV) of use are distinguished by the author and regard hundreds of such implements. Besides long knives, shorter ones and scrapers were also produced, when the diaphysis were broken in smaller pieces, presumably also in the case when the longitudinal intersection was not successful. In many cases the splinters produced during the above process were used as needles, a fact which is also evident from the four different degrees of use, mentioned above (see fig. 1-4).

Another, yet less widely applied, method of the Petralona prehistoric inhabitants, was that of selecting bones with useful shape in order to easily produce needles, borers and knives. The metapodials (metacarpal and metatarsal - II, III) of equids, by sharpening their distal part and maintaining the round proximal one for handling, produced perfect needles and borers, with only little elaboration (fig. 5-6). Similarly, the ulnas of mid-sized animals, with their natural olecranon - handle, were good for knives, blades or even “swords” (fig 7). Same is applied to elaborated scapulas, but only as borers (fig 8).

It is self-evident that for the bone tool manufacturing there was no need to elaborate by the traditional way used on the stone tools. However, among the Petralona findings, there is an exception to this norm, which regards a clearly flaked piece of diaphysis. It could represent an experiment concerning the resistance of the bone material upon flaking, or it may just be a result of playing (i.e. by young individuals). The fact that only one flaked bone fragment has been found, indicates that it was not a defused practice, but on the other hand this unique finding confirms once more the above general observations on bone tool manufacturing.

It is also worth mentioning that a bear and a hyena mandible were found among the upper layers and in a different way of those found in the lower ones. They miss only of their condyles and wings (ramus verticalis), so they could be useful as very strong scrapers, saws- along their teeth, or even as borers by their canines (fig.9-10).

The concentration of stone and bone tools has been discovered in different parts of the cave. Stone tools are mainly found near the ancient entrance, while bone tools in slightly deeper chambers, most probably indicating a division of labor.

The above remarks complete our views on the tool making technology of the Petralona man and suggest a highly developed social life during Lower-Middle Pleistocene.

FIGURES 1-4: Bone tools - the four degrees of elaboration of diaphysis, referred in the text (size ½).

FIGURES 5-8: Bone tools from the Petralona cave, referred in the text (size 2/3)

FIGURES 9-10: Mandibles of a hyena and a bear, referred in the text (size 3/4).

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La Reconstitution de la Préhistoire Grecque à Travers les Trouvailles Archéologiques des Grottes

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Abstract

It is not easy going through the Greek prehistoric period by means of studying the findings of its karstic forms. Greece, which lies in the southeastern end of Europe, is reach in calcareous rocks, and filled with caves, rock shelters and dolines. Most of these karstic forms were by human from the time of his apparition in the Aegean and are still used today. Despite all the problems that have occurred on the archaeological research – owing to the great tectonic activity of the territory as well as the diachronic usage of natural cavities by man that have disturbed the landfilings – the excavation results of caves and rock shelters mainly, have proven to be of major importance for the re-establishment of the land's past. The prehistoric times recherche in Greece is based on both in the human remains and in the fragments of human activity that were left or buried in caves. As far as this duration is concerned, his presence in the caves and rock shelters is constant until the end of the Neolithic where the Greek prehistoric period comes to an end. An important role in the proliferation of the archaeological research of the caves has played the rapid growth of speleology in Greece in the past few years, while the help of Greek speleologists new caves are found from time to time that show sighs of prehistoric inhabitance. None is in position to know whether we sill ever be able to excavate all these caves.

Résumé

Parcourir la préhistoire grecque à travers l'étude des trouvailles archéologiques des karsts, n'est pas très facile. La Grèce, un pays à l'extrémité sud-est de l'Europe, est riche en calcites, par conséquent, les grottes y foisonnent, abris sous roches et des dolines en nombre considérable également. La plupart de ces karsts ont été utilisés par l'homme dès le moment de son apparition dans le contexte égéen, et leur utilisation continue jusqu'à aujourd'hui. Malgré les problèmes auxquels la recherche archéologique se heurte souvent (à cause de la séismicité de la région, qui s'ajoute à l'utilisation continue des cavités naturelles par l'homme, phénomènes qui ont provoqué la perturbation des sédiments), les résultats des fouilles, surtout dans les grottes et les abris sous roches, jouent un rôle primordial à l'effort de reconstitution du passé du pays. La recherche sur la préhistoire de la Grèce s'appuie d'un côté sur les vestiges humains et de l'autre côté sur les restes de l'activité humaine qui étaient abandonnés ou enterré dans les grottes. En ce qui concerne la durée de sa présence dans les grottes et les abris sous roches, ceci a continué jusqu'à la fin du Néolithique, moment qui marque l'achèvement de la préhistoire grecque. Un rôle important sur le développement de la recherche archéologique dans les grottes, a joué ces dernières années le développement de la spéléologie grecque, tandis qu'à l'aide des spéléologues grecs, on localise de temps en temps de nouvelles grottes, qui nous livrent des vestiges préhistoriques. Personne ne saurait être en mesure d'affirmer avec certitude le temps où la réalisation des fouilles, sur l'ensemble des grottes repérées, deviendra un héritage scientifique.

Introduction

La Grèce, un pays avec une grande tradition pour ce qui est des découvertes de l'antiquité classique et hellénistique, a récemment seulement tourné son intérêt vers le passé plus lointain. Après les grades découverts des Delphes, des Mycènes et de Knossos, on a finalement commencé la recherche de notre préhistoire. Pour avoir une idée de ce qui est la préhistoire de la Grèce, grosso modo, le paléolithique finit en Grèce vers 10 000 ans av. J.C. où commence le mésolithique, puis vers 7000 ans avant J.C. commence le néolithique, tandis que l'age du bronze occupe en Grèce la période protohistorique, bien qu'elle occupe le premier type d'écriture déchiffrée, le linéaire B. Ce petit pays de l'Europe, riche en calcaire, occupe plus de 10.000 grottes et abris sous roches, pour ce qui concerne ceux qu'on a déjà exploité, et où on a fait des fouilles systématiques. Et nos grottes nous ont livré plusieurs informations sur la présence de l'homme, sa vie, et ses coutumes. La recherche systématique des grottes commence en 1927 par Markovits qui au cours d'une thèse de doctorat, a fouillé plus de 500 grottes grecques, et continue avec la fondation de la Société

Spéléologique de Grèce en 1950, qui a ouvert le chemin pour la fondation de la spéléologie scientifique et la formation des nouveaux spéléologues. La communauté scientifique a commencé à s'intéresser aussi vers la préhistoire des grottes.

Le Paléolithique Inférieur

L'homme atteste sa présence ou son passage en Grèce pour la première fois, par un crane, qui appartient au genre *Homo sapiens neanterdalensis,* et qui nous a laissé dans la grotte de Petralona en Macédoine. On a trouvé ce crane en 1968, puis ceci a été daté par des méthodes physico-chimiques vers 250 000 ans avant notre ère (XIROTIRIS, 1981). Malheureusement on n'a pas d'autres informations pour la vie humaine de l'époque. Mais cette même grotte comme aussi plusieurs d'autres, nous a livré plusieurs informations sur la faune de l'époque, qui occupe plusieurs espèces archaïques, comme *Ursus Deningeri, Canis lupus mosbachebsis, Ursus Spelaeus, Crocuta spelaea intermedia, Panthera leo spelaea,* etc. (TRANDALIDOU, 1996), en nous aidant reconstituer l'environnement de l'époque. Suivant les paléontologues tous datent du Pléistocène Moyen.

Le Paléolithique Moyen

Heureux contraste, le Paléolithique Moyen a eu une meilleure chance dans le milieu grec. Au moins cinq grottes ont livré des vestiges de cette époque: Maara en Macédoine (TRANDALIDOU, 1996), Kalamakia a Mani (DARLAS, 1999), Kefalari et Franchthi en Argolide (JACOBSEN, 1987-1993) et Théopetra en Thessalie (KYPARISSI, 1999, 2000). Parmi celles citées, deux, Théopetra et Franchthi, montrent bien la continuité de l'occupation de chaque site, voire la transition d'une phase à l'autre, jusqu'à la fin du Néolithique. L'importance de ce fait est qu'ainsi la continuité de la vie dans le milieu grec est-elle assurée depuis au moins le Paléolithique Moyen. Nos grottes ont livré surtout un outillage Moustérien classique, où dominent les pointes et les racloirs, et où le débitage Levallois est pratiqué. En suite, les outils deviennent à la fois plus nombreux et plus petits, en constituant un micro-mustérien. Pour leur production on utilise surtout le silex et le quartz, bien abondants tous les deux dans les régions grecques. La faune est aussi bien représentée dans les grottes. Les exemples d'espèces qu'on rencontre les plus souvent sont l'*Ursus Spelaeus,* les cervidés, le rhinocéros, les carnivores, etc.

Le Paléolithique Supérieur

Le Paléolithique Supérieur est connu surtout par les grottes et les abris sous roche qui se trouvent au nord, en ΄Epire, mais aussi au sud, en Péloponnèse. Parmi les abris sous roche certains étaient aussi des grottes, qui ont été ainsi transformé par l'érosion et l'action tectonique très intense dans le milieu grec. La glaciation du Würm est connue par le Pinde, où les géologues ont reconnu la formation de glaciers, tandis que le niveau de la mer était assez inférieur, on l'estime vers 100 m au-dessous de celui actuellement. En ce qui concerne le climat, il était très froid et sec (BINTLIFF, 1977). Sauf les deux grottes déjà mentionne, Franchthi et Theopetra, deux autres connues depuis les recherches de Markovits, la grotte Zaimis et Ulbrich, occupent aussi une stratigraphie continue depuis le Paléolithique Supérieur jusqu'a la fin du Néolithique. L'outillage trouvé dans les sites qui nous intéressent, montre des analogies avec celui de l'Aurignacien et surtout du Gravettien de l'Europe occidentale. Il comporte des grattoirs, des lamelles à bord abattu, mais aussi des microlithes et des microburins. Pour leur production on utilise les calcaires locaux, et parmi eux domine toujours le silex. L'attestation pour la première fois d'outils en obsidienne de Mélos dans la grotte de Franchthi en Argolide, est le premier indice d'une navigation pratiquée en Egée dès la fin du Paléolithique Supérieur (PERLÈS, 1979). La faune connue par les sites de l'époque reflète le changement dans l'économie de la chasse suivant les conditions climatiques de la région. D'autres grottes occupées cette époque, surtout ceux d'Epire, comme Klidi et Boila, ont été utilisés pour la fondation des modèles d'occupation humaine, voire leur utilisation par l'homme préhistorique, bien qu'aucun de ce modèle n'est encore confirmé, tandis qu'ils restent des points des débats scientifiques (GALANIDOU, 1997).

Le Mésolithique

La transition Tardiglaciaire/Holocène caractérise en Grèce la transition Paléolithique/Mésolithique. Les oscillations climatiques de l'époque sont bien marquées sur plusieurs diagrammes polliniques. Le Mésolithique de la région qui couvre le Xe et le IXe millénaire BP, est connu par les fouilles effectuées sur cinq grottes, ceux qu'on connaît déjà par les périodes précédentes sur lesquelles s'ajoute la grotte de Cyclope à Youra, et très récemment on a trouvé des sites en plein air qui sont contemporains, comme à Maroulas de Kythnos. Les découvertes dans ces grottes ont donné un outillage qui, en ce qui concerne le plan des traditions techniques, est différent des courants du Mésolithique en Europe. Il comporte surtout une industrie sur éclats, où dominent les pièces à retouche latérale, les coches, les denticules et les petits grattoirs, marquée ensuite par un retour au microlithisme (PERLÈS, 1995). Ce changement montre l'importance des pratiques de collecte (végétaux, mollusques terrestres et marins, et petite pêche) et la diminution de la chasse aux grands mammifères. Il est important de souligner que la présence de l'obsidienne de Mélos, même dans l'île de Youra aux Sporades, au nord de l'Egée (SAMPSON, 1998) assure cette fois, la pratique de la navigation. La faune par contre, à défaut de grands mammifères, a subi deux conséquences: elle a modifié d'une part l'alimentation vers de nouvelles tendances, comme les mollusques et les ressources aquatiques, ainsi que la pêche a commencé à jouer un plus grand rôle. Le grand nombre d'hameçons et des os des poissons trouvés à Youra et à Franchthi, sont les preuves des ce fait (SAMPSON, 1998). D'autre part la diminution de la chasse, conséquence d'un milieu appauvri ou difficile d'exploiter, était la cause principale pour la mobilisation de peuplades mésolithiques vers les côtes, qui les aidaient à trouver et à exploiter de nouveaux biotopes. Surtout par Franchthi on a d'informations sur la consommation des céréales sauvages, tandis qu'on occupe aussi les premières moules pour leur préparation. Au cours du Mésolithique, les grottes ont été utilisées aussi comme lieu d'enterrement à Théopetra (STRAVOPODI, 1995) et à Franchthi (CULLEN, 1995), et on attende les résultats de la comparaison entre les vestiges des deux grottes pour avoir nos premières informations sur les coutumes funéraires de l'époque.

Le Néolithique Acéramique et Ancien

L'acquisition du Néolithique en Grèce est connue par plusieurs séquences stratigraphiques des sites en plein air, mais aussi des grottes. La particularité des grottes se trouve sur le fait que celles-ci présentent une stratigraphie sans rupture, depuis les phases précédentes. Ainsi trois grottes, Franchthi, Théopetra, et Youra aux Sporades (SAMPSON, 1998) nous ont livre des matériaux, correspondant au début du processus de la néolithisation de la Grèce. Malgré les débats sur la question du caractère allochtone ou autochtone du néolithique de la région, les études qui continuent sur ces grottes vont éclairer notre point de vue sur le Néolithique Acéramique. En ce qui concerne le Néolithique Ancien, de nouvelles grottes s'ajoutent à ces mentionnées ci-dessus. Il s'agit de celle de Kefalari à Argos, et celle des Limnon à Kalavrita (SAMPSON, 1997). L'apparition de la céramique en quantités massives est à remarquer, bien qu'elle témoigne de techniques bien constituées. Cette céramique modelée à la main comporte des formes fermées (jarres) et ouvertes (plats, bols), monochromes au début, décorées plus tard, surtout avec des motifs linéaires. L'industrie lithique fondée pour la plupart en silex, comporte aussi d'autres roches dures, comme le quartz, tandis que l'obsidienne de Mélos est dominante surtout au centre et au sud de la Grèce. Les lames sont utilisées telles quelles, soit tronçonnées pour produire des microlithes, où retouchées pour former des grattoirs, des burins, des pointes et des perçoirs. Les restes fauniques abandonnées dans nos grottes montrent les formes domestiques mêlées à des formes sauvages (mouton, porc, bœuf), tandis que la chasse joue toujours un rôle important dans l'alimentation. Les espèces végétales comportent-elles aussi des éléments sauvages qui font l'objet de la cueillette, et des espèces cultivées, indication de l'exercice de pratiques agricoles. Pour la première fois on atteste la présence des figurines dans les grottes, mais ils sont peu nombreux, tandis que les inhumations continuent: la sépulture est individuelle, et le corps est déposé étendu sur le dos dans une fosse.

Le Néolithique Moyen

Généralement pour le Néolithique Moyen, on peut remarquer une fréquentation inférieure dans les grottes, peut-être pour des raisons climatiques ou autres qui ne sont pas encore claires. Mais les grottes occupées depuis le Néolithique Ancien continuent à être fréquentées. Ce qui est remarquable à cette époque c'est un nouveau type de céramique qu'on appelle *Urfirnis*, trouvée dans les grottes occupées cette période, caractérisée par une surface sombre d'aspect métallique, qui porte des décors peints en brun et en gris foncé. L'outillage progressivement perd son originalité, ainsi que les lames et l'obsidienne continuent être à dominants, et les microlithes tendent à disparaître.

Le Néolithique Récent et Final

Une vraie préférence à la fréquentation des grottes, est à remarquer sur ces deux phases. Plus d'une dizaine de grottes fouillées systématiquement s'ajoutent à celles occupées déjà (PAPATHANASOPOULOS, 1996). Cette préférence qu'on n'est pas encore prêt à expliquer, reflète peut-être de nouveaux types d'utilisation. Les grottes occupées se trouvent dans la plupart des cas près d'un site occupé par les mêmes habitants (SAMPSON, 1997 et 2000). Ceci conduit certains archéologues sur la proposition des modèles sur l'occupation humaine des ceux grottes. Suivant ces modèles, il est probable que les grottes jouent le rôle lieu de stockage du surplus de l'agriculture ou de l'élevage ou encore un lieu de refuge permanent, voire saisonnier. La céramique que nos grottes nous ont livrée reflète les caractères locaux que leurs visiteurs résument, le même procès aussi avec l'outillage. Il est important de noter le grand nombre des figurines trouvées sur les couches des deux phases, ainsi que l'augmentation du dépôt des ossements. Plusieurs gens ont été inhumés dans des grottes. Des cas particuliers consistent un enfant enterré dans un vase, ce dernier installé dans un deuxième vase, dans la grotte de Kouveleiki A' (KONTAXI *et al.* 1995), ou de sépultures secondaires, comme dans le cas d'Alépotrypa à Diros (LAMBERT, 1972). Malheureusement parmi toutes les grottes occupées au Néolithique Récent et Final, seulement une, celle de l'Antre Corycien (TOUCHAIS, 1980), a été fouillée horizontalement sur toute sa surface. Ainsi bien qu'on dispose d'un grand nombre de matériaux archéologiques, on n'est pas encore capables de préciser la fonction que les grottes ont joué dans la vie des gens de l'époque.

Conclusion

En arrivant à la fin de ce petit voyage en Grèce en ayant comme point de départ nos grottes et les vestiges archéologiques qu'elles nous ont livres, il faut à remarque deux choses: premièrement la grande importance de la collaboration pluridisciplinaire pour la suite de la recherche préhistorique. Cette collaboration commence par les spéléologues, indispensables pour la découverte des nouvelles grottes, mais aussi l'exploitation du grand nombre de grottes sous-marines qui se trouvent en Grèce, continue avec celle des paléontologues (SYMEONIDIS et THEODOROU, 1984), indispensables eux aussi, comme en plus les géologues et les biologistes, pour la reconstitution du passé lointain, et surtout la reconstitution du paléoenvironnement (GKIONI, 2000). Deuxièmement, l'importance qu'on doit à la protection de nos grottes. Sauf la beauté que celles-ci nous offrent, elles sont aussi une source d'information exceptionnelle, et unique. Il faut les protecteur pas seulement comme un héritage naturel, mais aussi comme un héritage culturel, indispensable pour la suite de notre recherche préhistorique. La recherche archéologique a encore un long chemin qu'elle s'impatiente de parcourir.

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Recovering Fossils From Underwater Caves

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Abstract

In this report we describe an airlift equipment used for collecting fossil material from an underwater cave in Central Brazil. The airlift system is composed of a gas fueled engine connected to a hard plastic pipe that brings the sediment up to the surface and to a thinner hose that pumps compressed air into the pipe. The pipe and the hose are 200 meters long and have a copper opening. The hose opening penetrates the pipe opening and has dozens of small holes. The compressed air is blown through these holes provoke a turbulence resulting in a pressure differentiation that brings to the surface water plus sediment. This system has proved to be very effective bringing the material undamaged from up to 40 meters depth.

Background

The research program "Quaternary Mammals from Brazil" (SALLES *et al.*, 1999) is developed under a broad perspective on the geo-biological history of the South American continent. The main goal of this program is to reveal mammalian micro and megafauna fluctuations during the last 2,5 Myrs. Thus, we expect to contribute to paleontological and geo-climatic reconstructions of Brazilian Quaternary scenarios (BROOKS & MCLENNAN, 1991).

Our research focus has been the fossil material deposited in limestone caves presently distributed along the Brazilian savannas. Caves are considered areas of special paleontological interest since they may accumulate fossil-rich sediments carried by water. They also represent natural traps for larger mammals (PAYNE, 1983.) or may serve as a shelter for animals such as owls, that regurgitate therein pellets rich in non-digested osteological material (ANDREWS, 1990). However, paleontological studies on Brazilian caves are still scarce (LUND, 1838; VOSS & MYERS, 1991). This is specially true for microvertebrates, that are considered to be the best indicators of climatic changes due to their diverse and refined ecological association with the environment (AVERY, 1982; KORTH, 1979). One of the reasons for this lack of studies are the difficulties regarding the logistics for paleontological exploration inside caves.

This report concerns paleontological exploration specifically in underwater caves. Due to their extreme conditions, human impact in these caves is nearly absent, what makes them even more appealing for paleontological studies. On the other hand, highly sophisticated techniques are required to recover the fossil material and interpret the associated taphonomy and stratigraphy (KORTH, 1979).

In fact, underwater paleontological and archeological explorations are limited to open waters, so far no methods have been reported for use in overhead diving conditions. We report here an experiment using an airlift system to be used in paleontological studies under such conditions. The purpose of the system is two-fold: 1) to recover small-sized fossil material brought up by the "lifted" water; 2) to remove deposited sediments in order to expose bigger-sized fossil material, that can be then hand-picked. In this study we describe the airlift technique as a means to promote undewater paleontological exploration.

Technical Procedures and Results

In January 2001, the airlift technique was implemented for the first time on the paleontological exploration of the underwater cave Buraco do Japonês. This limestone cave is part of the Serra da Bodoquena complex (http://www.unb.br/ig/sigep/), located in Mato Grosso do Sul (Brazil; CECAV/IBAMA, license number 006/00, process number and register in IBAMA 02001.002336/00-32). The dive is technically classified as a full cave dive, due to a very narrow restriction that occur on the first eight meters from the entrance. In addition, the dive is particularly difficult given the great amount of fine sediments encountered on the cave floor that brings visibility to level zero with nearly any contact.

A team of eight professional cave divers, leaded by Antonio Libertino, in collaboration with paleontological researchers, has carried out the first airlift experiment to recover fossils. The divers have used special cave diving equipment (including dry suits) and various respiratory gas mixtures, such as Nitrox, Trimix and pure oxygen (used for decompression). The exploration of the Buraco do Japonês cave has reached a linear distance of 330 meters from the entrance and a maximal depth 56 meters. However, the paleontological sites were confined to the first 210 meters with a maximal depth of 43 meters.

The airlift promotes a pressure differential in order to lift water columns, guzzling material with different densities up to the surface. This equipment is specially useful for paleontological exploration because it does not use rotors or palettes that cause damage to the lifted material. After a series of tests, we have constructed a special airlift with the following technical description. A 15 cubic feet (or 425 liters) per minute compressor operates on a 170 PSI/pound labor pressure and has a gasoline fueled engine of 4 HP with a 200 liter reservoir. The compressor is connected to two tubes. The first tube is a highly resistant annealed plastic pipe (2 inches of internal diameter and 200 meters long) that goes underwater and brings the sediment to the surface. The second tube is a thinner rubber hose (¼ inch of diameter and is also 200 meters long) that blows compressed air into the underwater system. The collecting pipe has a copper reinforced opening 60 cm long and 45º angulation with a sphere valve that allows the operator to control the sediment flow. A 5kg ballot is attached to this end of the main pipe, stabilizing it. The total weight of the operating opening is about 7.5 kg. The rubber hose is tied to the main pipe along their 200 meters. To the final end of this hose is attached a copper tube (30 cm long) that penetrates into the main pipe. This tube has a large number of tiny holes that blow compressed air into the main pipe provoking a large scale turbulence (i.e, *venturi* system). The turbullence results in a pressure differential that causes the water (plus sediment) to be lifted to the surface. The collected sediment went through a screenwashing system of three sieves.

Our first airlift experiment produced an average of 16 liters of water plus sediment per minute. 47 hours were needed of deep diving in order to airlift for just 9 hours that yielded 8640 liters of water plus sediments removed from the cave. The airlift technique has been successful under depths of 13, 16, 19, 23, 27, 30, and 40 meters.

Conclusions

Approximately 550 vertebrate fragments were recovered from the screenwashing process. Most fragments showed signals of having been extensively rolled. No signs of fractures, possible due to the airlift system, were found. Therefore, the airlift system proved to be extremely useful in recovering intact small fossil fragments. Due to the limited time available for this experiment we were not able to demonstrate exposed larger fossil bones previously covered sediments..

The fragments collected through the airlift comprised mainly of teeth, maxilae, vertebrae, long bones and osteoderms of mammals. The identification of this material is still undergoing but it has already revealed a very diverse fauna including mammals amphibians, crocodilians, lizards, snakes and invertebrates. Among mammals members of different orders were identified such as Xenarthra (armadillos), Carnivora, Artiodactyla (deers), Rodentia (agoutis and capibaras), Primates (howler monkeys) and Notoungulata (Toxodontidae), a representant of the extinct Pleistocene megafauna of South American Mammals. It is worth mentioning that a large number of other vertebrate fossils were hand picked. Given the preliminary status of the taxa identification and the fauna diversity encountered, the perspectives of underwater paleontological exploration in Brazil are very good.

Acknowledgements

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Archaeology and Caves in the Carstic Province of Arcos-Pains-Doresópolis, Minas Gerais

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Abstract

In the limestone province, in which are situated in the towns of Arcos, Pains and Doresópolis, 200 kilometers South-West of Belo Horizonte, prehistoric archaeological evidence in caves has already been identified in the nineteenth century. Since then, limited archaeological research has been done. The mapping of caves since the 1980's revealed a great number of archaeological sites. In 1998, archaeologists and students of the speleological group *Guano Speleo* reopended the discussion and started a sistematic search and registration of sites, participating of an interdisciplinary study, led by researchers of the *Instituto de Geociências (IGC-UFMG)* of Belo Horizonte. New sites, with pottery, lithic, bone, rockpainting and charcoal were discovered. Large concentrations of material were found in the illuminated entrence of caves, but differently from other carstic regions, better known by archaeology, also in afotic places, penetrating 40 to 50 meters into the natural cavities.

Introduction

All limestone areas, thanks to certain specific caracteristics, hold potentialy important archaeological data. This kind of relief with natural shelters, lakes, rivers that disappear and reappear from the limestone and the thick forestsgalleries (woods that follow the border of rivers), always attracted man, since prehistoric times. In the Carstic Province of Arcos-Pains-Doresópolis, we can find a rich archaeological heritage, as significant as the Lagoa Santa plateau and the Peruaçu river valley. All of these regions are situated in the state of Minas Gerais. Apart from the abundance of natural resources, the caves and shelters function as if they were timecapsules, preserving a great variety of archaeological evidence, many of these with large cronological depth.

Researches of the Past and Present

The limestone formations in the towns of Arcos, Pains and Doresópolis have been the stage of archaeological findings since the nineteenth century (Eschewege, 1944).

However, the main archaeological initiative was taken by researchers of the *Instituto de Arqueologia Brasileira/RJ (IAB)*, for the PRONAPA-project (Nacional Program for Archaeological Research), between 1969 and 1974. This team, led by Ondemar Dias Jr., made fieldtrips and registrated over 30 sites (Dias Jr.,1974). The material collected was of a diverse nature: lithic instruments, charcoal, pottery, etc. Besides the definition of the Piumi-fase as a part of the Una pottery tradition, little information was published (Dias Jr., 1971/1974, Prous, 1992). Later, at the end of the 1970's, the Privince was visited by members of the *Setor de Arqueologia* of the Federal Uinversity of Minas Gerais (UFMG), led by André Prous, who published some dispersed information (Prous, 1992).

The speleological prospection, ironicly, has been since the 1980's until now, the responsable for the localisation of major part of the sites.

At the end of the last decade, an interdisciplinary project was undertaken by researchers of the *Instituto de Geociências (IGC)* of the Federal University of Minas Gerias (UFMG), with the intention to elaborate a program of sustainable development for the province. The big number of caves containing prehistoric material in its interior created the need for an archaeological survey, that is being realized by archaeologists of the Guano Speleo group. Over 20 caves are already registered, and a variety of material was discovered: gravings in stone, uncovered burials, stone instruments, shells, charcoal and a great number of sherds, some already covered by carbonatic deposits. This relation between prehistoric groups and caves is unique in the state of Minas Gerais and demands carefull interpretation.

This work, until now, has been limited to searching for archaeological evidence on the surface or in eroded areas and in registrating the sites without any kind of intervention.

The Archaeological Material

After almost two years working in the region, we noticed that the shelters with material rarely are to be found in places of difficult access, like the top of the limestone massive, or far from water, for example.

The archaeological material is in many cases seen at the entrance of the caves, that is, at the sheltered and illuminated part, but, sometimes, it extends upto 30, or sometimes even 50 meters inside. This happens, for example, in the caves *Gruta de Massambará* and *Gruta do Capoeirão* (see last page for *Table 1* with relation site x material evidence). This is not common in Minas Gerais. In the two carstic regions, best known by archaeology, Lagoa Santa and the Peruaçu Valley, such phenomenon doesn't occur in the same intensity.

In many cavities, hundreds of sherds are scattered on the surface, sometimes accomponied by rests of bonfire, alimentation, spindles, other times by human bones and polished axes. In the rockshelter *Abrigo da Lagoa do Peixe* we found concentrations of flakes of various types in eroded places. What surprised us then, was the total absence of pottery. It could be that we here are dealing with hunter-gatherers, knowing that these, in general, didn`t make pottery and had a flaking technic that was different from the ceramist groups.

The sherds we found in the caves, have not yet been analysed systematicaly. However, some characteristics were observed. The pottery we are dealing with has different shapes, sizes and thickness, has no decoration and, occasionaly, has red or white coating. Some times we see sherds with black walls, because it was burnished. No reinforcement of the walls, tipical of the Tupiguarani, was detected. At least three forms were identified, thanks to fragmentated rims we found: (1) a smaller form, with an open rim, the wall inclined internaly and a round bottom; (2) a bigger form, with a thicker wall, that inclines internaly, a closed rim and tending to be globular; (3) an open vessel with a wall that inclines externaly. The pottery, thus, seems to be multifunctional because of the diferent sizes and shapes.

Final Considerations

What could have been the relations between the prehistoric indians and the caves? The caves could have been used for various activities and by diferent kinds of groups. But, these natural cavities, we beleieve, were not the prefered permanent places to live, and this for two reasons. The first, because of a logic of convenience: why live in a hole, in many cases a humid place, where diferent kinds of animals frequently look for shelter and where it is impossible to accomodate a large number of people, when there are resourses, space and a favorable climate to build a settlement in a more salutary place, close to a stream, for example? The second reason we find in the archaeological evidence. In the regions of Lagoa Santa and in the Peruaçu Valley, the cavities were also used as a temporary shelter, a place to bury the dead and for storing provisions. Thus, for complementary activities.

Nevertheless, we have a new element that makes the carstic province of Arcos-Pains-Doresópolis diferent: the fact that we find achaeological material, with bigger frequence then elsewhere, in the afotic area of the caves.

Table

Table 1: relation between the sites found and visited by our team and the main kinds of evidence

		Type of Evidence					
Sites	**Town**	**Lithic**	**Pottery**	**Rock-painting**	**Human Remains**	**Charcoal**	**Fauna**
Abrigo L, de Peixe	Doresópolis	X					
*Perdição I	Pains	X		X		X	
*Perdição II	Pains			X			
Gruta Capoeirão	Doresópolis	X	X				X
*Gruta da Dobra	Pains	X				X	
*Sorvetão	Pains		X			X	
Isaías	Pains		X				
*Anemólitos	Pains		X				
*Gruta Marinheiro	Pimenta	X	X	X		X	X
Gruta do Brega	Pains		X			X	
Gruta Milagres	Pains		X				
Abrigo de Carro	Arcos			X		X	
Gruta Paranoá	Pains		X				
*Buraco Sujo	Pains		X			X	
*Loca de Pedra	Pains	X				X	
*Gruta ½ Encosta	Pains		X			X	
Dolina dos Machados	Doresópolis	X	X				
*Gruta do Osso	Pains	X	X		X		X
*Abelhas	Doresópolis	X				X	
*Lagoa de Peixe II	Doresópolis		X				
*Ti'Rafa	Pains		X	X			
*Favo de Mel	Pains	X	X			X	X
*Gruta dos Peixes	Iguatama		X				
Gruta Massambará	Pains	X					

* Sites found by our group.

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Quaternary Continental and Marine Deposits in the Caves of the Aegean Islands, Crete and Coastal Peloponessus and their Importance for Understanding Past Environmental Changes

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Abstract

Aegean sea islands and Crete make up one of the few areas worldwide with continental sediments rich in fossils of endemic Quaternary Mammals and in few cases with marine sediments also. On the other hand mainland caves are rich in Quaternary Mammals of normal size. During the last 30 years studies carried out by the University of Athens has brought to light impressive continental fossils from the past and new localities, which have provided science with *some* of the hidden bits of data from the past. In parallel a lot of effort has been given for dating upper Quaternary fossil Mammals, sea Molluscs and marine Terraces. All these bits of information represent pieces from the pazzle of the past environmental changes. We have just to collect all availbale pieces hidden in caves, arrange them together and get the final picture from our past.

Greece is rich in fossiliferous caves or in caves containing archaeological findings. Studying the fossiliferous caves we are obliged to deal with two different categories in respect to their Quaternary fossil fauna. Caves on the mainland have yielded non endemic fauna. It is important to note that continental fossils can be used for direct biostratigraphical correlation. The same is true for marine sediments. On the contrary this is not true for the fossiliferous sediments from the caves of the islands. Island caves include endemic fossil mammals. Endemic Island fossils can be correlated only with the help of adequate absolute dates. What is more important, there are only very few areas in the whole world, where endemic Quaternary mammals can be excavated and studied. There are also some Greek islands where Quaternary fauna includes continental forms (Kythera, Kefallonia). This occurs because these islands were not completely isolated during critical periods. Isolation events can be correlated with the major climatic events of the Quaternary. The same is true for the mainland caves. During cold periods, and low sea level a lot of coastal caves were accessible to land mammals. During cold periods, the decrease of the sea level minimized the distance of some islands from the nearby mainland. At these moments Mammals with good swimming capabilities managed to cross the sea corridors toward the islands. Migration is believed to have occurred in a sweepstake mode, but I feel that we must accept migration of small groups capable to give descendants and not the migration of lonely animals incapable to find partners of the opposite sex to give birth. These Mammals include elephants, hippopotamus and deer, all very good swimmers capable to cross the sea corridors to the nearby islands. After the first trip to the island, with no return ticket, they had to stay there, survive and evolve or become almost instantly extinct. The area of the islands was during cold periods larger than today. Due to the absence of natural enemies (big carnivores and man) on these islands Mammals did not have any good reason to cross the same sea corridor in the opposite direction. Even if they sometimes managed to do it, we cannot prove it. They stayed on the islands and they evolved to endemic forms, usually smaller than their mainland ancestors. They had a nice quite life, with some bad moments. Once in a while nearby volcanoes through up in the air great quantities of volcanic ash that covered the islands, polluted surface water and destroyed the grasslands necessary for providing food. When the phenomena were intensive, the endemic forms could not survive. When the phenomena were mild, endemic forms managed to go on, for thousand of years, up to the next period of unfavorable conditions (THEODOROU, 1988). Some times the islands endemics were lucky enough to meet new incomers from the mainland. The interbreeding provided new genetic material and new forms evolved. The change of world climate and the increase of temperature had as result the flooding of the available low grasslands on the islands. Sometimes water flooded even the places where Mammals used to live. Other times Mammals were not lucky because man arrived on their islands, possibly at a moment when they had taken already the one-way to their extinction from natural causes. During the critical period that followed the last sea transgression after the last major climatic minimum around 18.000 y ago, man, volcanism and climatic conditions competed each other. The looser was always the lively endemic Mammals, on the islands but also their non endemic cousins on the mainland though the influence of Volcanism was insignificant on mainland where animals could easily go away and avoid the falling volcanic ash. Sea level changes can be documented in addition to the depositional events by destruction events or traces available in numerous caves in the wider Aegean area by notches and traces of sea level indicators. And the same must be true for Earthquake events of long periods causing some caves or cave roofs to collapse, though no serious work has beeb done in this field. Some times man has left his traces in the same sediments. The processes mentioned continue to our times. Its not a coincidence that sea otters, only a few steps away from their extinction are hiding and breeding today in the small coastal caves of the Nature Reserve of North Sporades, protected, at least on paper, from the greediness and ignorance of man. The story continues, only the actors have changed. The last words have not been written yet, since sediments continue to be deposited in hundreds of caves, typing slowly the archives of the future. The magnificent information for this story is not stored only in the few caves mentioned in this paper as examples. It is stored in numerous caves, in the hard disks of the Quaternary and in the continental and marine sediments of Aegean Archipelago wider area.

Charkadio cave on the small island of Tilos (Dodecanese) (SYMEONIDIS, 1972. BACHMAYER *et al*., 1984, THEODOROU 1983, 1988, http://www.tilos.edu.gr) has given endemic deer, which became extinct by the fury of the volcanic activity of the majestic Aegean Volcanic Arc, before about 140.000 y. The last European Elephants became extinct on the same island just about 4.000 to 3.500 y ago as it is shown by their valuable remains in the same cave after prospering on the Island for more than 40.000 y. We are still working hard excavating the necessary information to find out, and document beyond reasonable doubt, who has given the final shot for their extinction, man or nature?

The numerous coastal caves of northern Crete (KUSS 1975, SONDAAR *et al.* 1986, SONDAAR 1986, MARINOS *et al*. 1976, THEODOROU 1985, SYMEONIDIS *et al*. 2000) only slightly scratched by the modern palaeontologist, still hide in their extremely rich sediments fossils, of deer and elephants and sometimes hippos, micro mammals and fossil birds. The fantastic myth about Odysseus and the one eyed Cyclopes represents the first attempt of man to explain the occurrence of bones, tusks and elephant skulls (with the unique nasal opening for the trunk - the Central Eye of the mythical Cyclopes) on Crete and possibly on other Mediterranean islands. The submerged elephant bones at the Vamos cave near Chania Crete belonging to a new endemic elephant species –*E. chaniensis* , first presented to science just a few months ago (SYMEONIDIS *et al*. 2000) and the submerged hippopotamus fossils of Diros Cave on southern Peloponessus oblige the most doubtful of us to accept that environment was drastically changing long before the Ozone problem, or the CO^2 crisis. Long before the first internal combustion engine. If we want to understand what happens now with climatic changes we have to understand what happened at the past. We have to look closely to the caves and their magnificent dirty, ugly, wet mud or hardened sediment deposits and look well at the broken or fallen, by past earthquakes, stalagmites and stalactites. Science has just started to download from the cave sediments the well coded information about the environment that man faced at this corner of our planet a few thousands year ago. We should do one more step. We must correlate carefully and date (ZACHARIAS, 1998, BASSIAKOS *et al*., 2001) all major events, with a multi-methodological approach the information from CON-(tinental) sediments with MAR-(ine) sediments found in numerous caves of Eastern Mediterranean Sea in a joint CONMAR - approach. The real problem is that only scientists with adequate speleological background, and field experience in promising cave systems can understand and evaluate correctly the quality and magnitude of information and the hidden possibilities that cave sediments can offer to us, only if we look carefully.

Caves sediments, continental and/or marine make up the real playground of Quaternary climate. Speleologists, scientists or experienced cavers, have learned to look well bellow the surface.

A lot of data wait to be recovered.

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O Primeiro Povoamento da América do Sul

[The First Settlement of South América]

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Abstract

The present paper focuses on caves in the states of São Paulo and Minas Gerais in Brazil, where there is indubitable evidence of human occupancy dating to approximately 13,000-14,000 years BP. If migration via the Behring Straits actually took place between 20,000-21,000 years BP this occupation is quite important.

Since the discovery of a non-asiatic skeleton in Minas Gerais (Lapa Vermelha IV), the situation has become even more problematic, and a more detailed investigation is called for. This investigation will be complicated by the fact that the passage from the coast to the uplands no longer exists. At the time, the sea level was much lower than it is today, and the coastline then was located far from the present coast.

Alguns Elementos Fornecidos pelas Cavernas Brasileiras

O Sambaqui Fluvial de RIBEIRÃOZINHO III

Locado na Caverna SP 138 em Set/1987

Relatório de um Corte Teste em um Novo Sambaqui Fluvial em Caverna

Localização

Sul do Estado de São Paulo

Município de Apiaí (CEP 18320-000)

Norte do Parque Estadual Turístico do Alto Ribeira (PETAR)

340 km de São Paulo - Capital

120 km do mar

Na mata primária

Altitude 515 m - A.N.M.

Entrada da Caverna Ribeirãozinho III - SP 138 (S.B.E.)

Longitude 48° 30’32” - W.GR.

Latitude 24° 20’31” - S.

Nome da ocorrência; Ribeirãozinho III

Pesquisador responsável; Guy Christian Collet

A descoberta dos sambaquis fluviais no Vale do Ribeira, em 1975 e a posterior localização desses sítios conchíferos em caverna e abrigos sob rochas de altitude, mostrou que certos povos em épocas remotas (mais de 10.000 anos), utilizavam rotas migratórias fixas de maneira regular consumindo recursos alimentares locais adaptados às regiões atravessadas e as estações do ano.

Os sítios assinalados por nós, são exclusivamente constituídos de moluscos pulmonados terrestres, herbívoros e com restos de caça de mamíferos de porte médio. As altitudes variam de 30 a 900 m acima do nível do mar.

Cronologicamente constatamos o seguinte: primeiro - o Geógrafo Richard Krone (1908), localizou em seus levantamentos topográficos 03 (três) pontos hoje totalmente destruídos, onde os sítios arqueológicos correspondem perfeitamente à descrição dos que encontramos em Apiaí e Iporanga (SP). Segundo - o Prof. Dr. Kiju Sakai em 1938/39, estudou vários amontoamentos de caramujos na região de Pedro de Toledo (SP). 35 km do litoral e publicou os resultados no Japão em conseqüência da guerra. Lamentavelmente as descobertas não foram divulgadas e o mundo arqueológico brasileiro ignorou totalmente esses dados.

Finalmente, pesquisas espeleológicas na região de Iporanga (SP) possibilitaram ao Departamento de Arqueologia da SBE - Sociedade Brasileira de Espeleologia daquela época (1975), dirigido por G.C. Collet, descobrir outros sítios conchíferos similares aos descritos pelos dois estudiosos citados.

A prospecção de campo na região, baseada na similitude geomorfológica de diversos pontos, permitiu ao mesmo grupo a localização de muitas outras estruturas idênticas. Infelizmente estes restos culinares representam um interesse particular para os moradores do lugar que, após moagem, utilizam-nos para adubar hortas, alimentar galinhas e utilizam as grandes e belas conchas do mega-bulimus como adorno e lembranças.

O resultado, após tantos anos, é a quase total destruição da maioria dos sítios. Só escaparam da aniquilação aqueles escondidos na mata fechada ou em entradas de cavernas. Ribeirãozinho III é o último localizado em gruta.

A Conquista da América

A procura de vestígios, os mais antigos, da presença do Homem sobre o continente Sul Americano foi sempre para os arqueólogos uma secreta preocupação. Até os espeleólogos, com esses lugares privilegiados que são as cavernas, estão interessados no assunto, tentando, eles também, a seu modo, trazer alguns elementos positivos ao imenso “quebra-cabeça”, que parece relativamente simples, mas que por múltiplas razões e circunstâncias coloca em cheque os mais qualificados especialistas, as teorias mais prováveis ou plausíveis, as tecnologias mais sofisticada. O Brasil, país com dimensões continentais, deveria possuir alguns vestígios da passagem, migração, deslocamentos destes grupos que a 8/9.000 anos atrás chegaram à extrema ponta Sul da América. Precisamos encontrar vestígios sobre rotas migratórias destes primitivos que, incontestavelmente teriam idades superiores a essas datas já bastante antigas.

Preocupados com essa falta de elementos, nós espeleólogos do Estado de São Paulo, apresentamos para quem quer estudar material malacológico, ferramentas do Sílex, sepulturas, etc..., que se enquadram perfeitamente nos dados indispensáveis para marcar um ponto sobre o mapa que mostra o caminho dos pioneiros Americanos.

Collet e seu grupo de espeleólogos em 1974 não só acha o primeiro lugar do KRONE como localiza um novo sítio, na ocasião da sua destruição parcial pela retificação de uma estrada tortuosa da região.

Um estudo geomorfológico comparativo, já citado anteriormente, até agora 2 ocorrências, mostra alguns parâmetros comuns, pelo menos a esses 2 primeiros. Estudando os mapas à grande escala (1/10.000) onze locais são escolhidos por se enquadrarem razoavelmente com os parâmetros geográficos e geológicos de Anta Gorda e Januário. Só falta associar os vestígios arqueológicos. Evidentemente não há caminhos ou trilhas definidos para se chegar aos lugares assinalados nos mapas e são muitos quilômetros a pé.

A plotação dos Sítios sobre o mapa, nos mostra claramente uma linha direcionada do Planalto Central (+/- 1.000 m de altitude) para o litoral passando na altura de IPORANGA (SP) e ITAOCA (SP).

Uma outra rota migratória afastada um pouco ao Norte, quase a 200 km., paralela à primeira na mesma direção, porém desta vez como eixo a cidade de Pedro de Toledo (SP).

Essa última concentração de ocorrências, não se achando em região calcária e portando de caverna, nos foi comunicado pelo Prof. KIJU SAKAY, que nos tinha mostrado algumas estruturas similares, todas em campo raso e a margem de córregos locais. O Prof. KIJU estava ciente das nossas descobertas através de uma publicação que um senhor japonês tinha achado na USP.

Felizmente, os vestígios arqueológicos mais bem conservados são aqueles localizados em abrigos sob rocha, entradas de cavernas ou francamente em cavernas.

O estudo sobre a presença destes restos muito antigos (para o Brasil) não foi efetuado com meios financeiros suficientes nem dispondo de tempo adequado para poder ampliar os resultados já obtidos, que julgamos excelentes e penetrar em certas regiões da Floresta espessa, quase primária (Mata Atlântica), o que teria com certeza revelado numeroso outros sítios. Mas o que nós já localizamos consiste em provas suficientes para chamar a atenção dos arqueólogos que se dedicam ao estudo dos diversos povoamentos do nosso Continente.

Nossas descobertas suscitaram trabalhos de mestrado alguns anos atrás e também muitas críticas por ter este vasto programa de prospecção, sido realizado por espeleólogos. Mas isto já era esperado e comprova mais uma vez que, para descobrir vestígios arqueológicos muito antigos é preciso percorrer o campo (quase sempre difícil) e além de Ter uma boa preparação pré-histórica , abrir os olhos.

Collet chama de “Sambaquis Fluviais” essas novas ocorrências no estado de São Paulo para os diferenciar dos Sambaquis Marítimos (costeiros) compostos, eles, de milhões de berbigões e ostras, todos moluscos bivalves , todos de origem marítima.

Lembraremos também que, o único arqueólogo ativo que estudou um crânio de “Lagoa Santa” (lapa vermelha) é o Dr. WALTER NEVES, que remodelando e dando volumes as faces de uma caveira descoberta há 20 anos atrás (Luzia 13.500 anos), especialistas determinaram, já faz também muitos anos, que os habitantes dos “Sambaquis Fluviais” eram da raça de Lagoa Santa o que é também um indício da antiguidade dos nossos migrantes.

Seria interessante lembrar, em poucas linhas, as características principais dos sítios concheiros, caramujais (sítio coquiller) que nos redescobrimos, já faz 25 anos.

Localização

A grande maioria destes sítios conchíferos se localiza em terrenos planos assemelhando-se aos sítios colinares ou seja +/- 70 % deles se acham na barra de córregos perenes com rios mais importantes, todos fora de alcance das enchentes periódicas sazonais. Alguns geminados, chamados assim por se encontrarem repartidos de cada lado de um córrego menor, os primitivos viviam com esse abastecimento de água potável em áreas às vezes bastante desiguais. É comum encontrar perto das ocorrências arqueológica , afloramento de grandes blocos de granito, o que de vez em quando facilita a localização dos “Sambaquis Fluviais”.

Um outro tipo de localização é em abrigo sob rocha no pé de barrancos ou até como no alto Vale do Ribeira, debaixo de imensos amontoamentos de matacões de granito, muitas vezes formando superfícies cobertos passando 100 m², oferecendo excelente proteção; esses lugares freqüentemente chamados de casa de pedra ou casas de bugres, são atualmente, quase que sempre utilizados para abrigar o gado à noite durante o frio ou época de grandes chuvas.

O terceiro tipo de sítio é aquele encontrado em caverna ocorrências arqueológicas mais bem conservadas, não estando em superfície perturbados pelos cultivos nem pela penetração de raízes de árvores frutíferas ou mata silvestre da flora tropical exuberante. Os animais fuçadores a grandes galerias, como raposas, tatus, pacas, raramente fazem as suas moradias nessas cavidades naturais e principalmente nestes sedimentos concheiros.

Alguns destes sítios conchíferos de áreas abertas chegam a Ter 500/800 m² como em Januário. Mesmo em cavernas a sua percepção não é sempre evidente, principalmente quando pisoteados pelo turismo intenso durante quase 40 anos (Morro Preto) ou em abrigo sob rocha (Temimina) onde a sedimentação eoliana recente recobre tudo com vários centímetros de material orgânico (em função do desmatamento parcial) e aonde muitos pássaros tomam o seu banho de poeira. Também os animais que fazem galerias provocam algumas perturbações em superfície até 40 cm de profundidade. Aqui pouca vegetação, alguns arbustos e cipós espinhosos. Em zona florestal densa, os abrigos, sempre e até recentementeforam utilizados por caçadores de fauna de médio porte como catetu, anta, veados, pacas ... presença marcada por numerosas fogueiras superficiais que felizmente não afeta muito o subsolo.

Conteúdo

De modo geral o conteúdo é relativamente homogêneo não tendo diferença marcante de um sítio para outro, mesmo sendo afastados várias dezenas de km.

Os caramujos maiores são os Megallobulinus Gamatus que chegam a 125/130 m/m de comprimento para um diâmetro de 75 ou mais milímetros. Seguem os Megallobulinus Yporanganus com 95 m/m de comprimento por 45 de diâmetro. Como se sabe esses Gastrópodes são terrestres herbívoros e constituem aproximadamente 60% do volume do sítio.

O material lítico é raro e pobre. Nas camadas mais profundas aparecem muitos seixos rolados tendo sido fragmentados por choque térmico (Januário-Itaoca). No abrigo Maximiano, artefatos de calcário, quartzo e diabásio foram achados com algumas pontas de ossos polidos.

Em todos, restos de esqueletos esparsos, numerosas sepulturas humanas, restos de tartarugas, roedores, répteis, caranguejos, ossos de pássaros, batráquios, bivalves de água doce, vértebras de grandes peixes ...

Lembramos que os estudos antropométricos foram efetuados por especialistas do Rio de Janeiro (Drª ALVIN MARILIA C.MELLO) nos informando que os ocupantes dos Sambaquis Fluviais faziam parte da raça “Lagoa Santa”.

Um outro pequeno mistério que seria interessante de estudar e solucionar; a presença na região de Itaóca de peças líticas muito elaboradas e caprichadas, com formato próximo de certas pontas do extremo sul do continente (achados dentro da Caverna Fell e datados de 8.300 anos no Chile). Elas são qualificadas do tipo “Rabo de Peixe”. Outras são morfologicamente próximas dos artefatos de Cactus Hill, costa oeste dos USA. Enfim, algumas de amplas dimensões são de espessura extremamente fina, deixando dúvida quanto a sua utilidade vista a sua grande fragilidade (ver artigo de Collet sobre “Material Lítico de Itaóca/1974").

Seria bom lembrar que estes paleoíndios deviam descer, provavelmente, muito mais longe que os últimos vestígios localizados, visto que o nível do mar devia estar alguma coisa como 20 m, no mínimo, mais baixo que o atual, o que representa em projeção vertical sobre a plataforma continental, um recuo de vários, talvez, dezenas de quilômetros em relação ao litoral dos nossos dias. Portanto nós estamos de posse de dados incompletos das rotas migratórias da época, não sabendo quais eram os seus hábitos e moradias em fim de linha, as dizer nos últimos 150 km até a costa. Eram Sambaquis Marítimos (sítio "coquiller") como aqueles que conhecemos que datam só de 4 a 6.000 anos?Grande probabilidade que sim, porém é mera suposição.

Os estudos geomorfológicos e domínios naturais do continente Sul Americano dos últimos 30.000 anos indicam que entre 13 e 18.000 anos BP depois do regresso do máximo da última grande glaciação, imensas porções do território estavam cobertas de savanas, estepes arbustivas, cerrados ralos com raros bosques de vegetação mais intensa nos locais mais úmidos. Enfim, mais para baixo, desembocando sobre o cone sul, as planícies sem fim, secas e semi-áridas, terminando a área de estepes na terra do fogo, fim de linha porque fim de terra firme.

Essas condições não ofereciam grandes dificuldades a esse progresso, provavelmente lento, porém, constante, de rústicos povos nômades, com algumas etapas, visto que de vez em quando se encontravam micro regiões mais arborizadas e acolhedoras, no pé de grandes escarpamentos de rocha oferecendo melhores recursos alimentares vegetais e uma concentração de pequena e média fauna que possibilitavam paradas prolongadas, reparadoras de fadigas, ferimentos, doenças. Algumas reservas e provisões podiam ser feitas para a próxima marcha.

Considerando a possibilidade ou eventualidade do trajeto Ter sido feito por via marítima, ele também pode Ter sido relativamente rápido.

As costas sul-americanas estando relativamente livres de tormentas, ciclones, tornados, tufões, ... a navegação de cabotagem é tranqüila. Existem evidentemente as correntezas contrárias, porém, sem grande influência sobre pequenas embarcações à vela, muito perto do litoral. Já imaginou, barcaças de 15 a 18.000 anos atrás?!.

É por esse motivo que insistimos para que, o que os espeleólogos de São Paulo descobriram dentro do seu perímetro calcário do Sul do Estado, seja estudado seriamente, visto que, esses antiguíssimos sítios arqueológicos não foram datados, na época das escavações, sobre amostras recolhidas no fundo das sondagens, mas a 2/3 da espessura do sedimento por se achar material mais em condições. Apesar disto, as datações davam 10.800 anos.

Vamos imaginar o que poderia ser 50 a 60 cm mais abaixo. Dentro dos artefatos manufaturados recolhidos existem dois bifaces de quartzo tipo Europeu, um inteiro, outro a 2/3 do seu volume primitivo, achados no meio de excrementos de vacas na periferia de um curral.

Essa região de Itaóca ao Sudeste do Estado de São Paulo mereceria ao nosso ver, uma prospecção sistemática mais intensa que aquela que nós praticamos para localizar cavernas e as ocorrências de caramujais, reportamos mais de 30 sítios, sem ver o potencial do lado do Paraná.

Nosso dever o fizemos: achar sítios, indicando uma grande antiguidade, todos relacionados e com posicionamento geográfico exato (GPS) e comunicados às autoridades.

Esperamos, mais uma vez que, esse trabalho de longos anos seja avaliado seriamente e tomado em consideração. São poucos no mundo os dados fiáveis e as datações precisas. Então, queremos que especialistas Brasileiros (ou outros) se aproveitem deste esboço, juntem a outros, para tentar elucidar o grande quebra-cabeça que é a saga dos primeiros homens sobre o Continente Americano.

São Paulo, Novembro de 2.000

Nova Área de Arte Rupestre: Serra do Lajeado, Tocantins
[A New Brazilian Rock Art Area: Serra do Lajeado, Tocantins]

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Abstract

This paper addresses the ongoing research on 19 pictograph sites that have been identified up to now in rock shelters of Serra do Lajeado, located in the central region of the State of Tocantins. It focuses primarily on the style and the contents of the pictures as well as technology of production, the properties of the material and tools used.

The prehistoric inhabitants of Serra do Lajeado produced a rock art with many distinct features through long periods of time. One of the aims of that analysis, especially when related to super positioning and other stratigraphic observations on the wall, is to present some chrono-stylistic aspects associated with different sectors of the surveyed area.

Introdução

Até o momento, o projeto de resgate do patrimônio arqueológico na região impactada pela construção da UHE Luis Eduardo Magalhães no médio curso do Rio Tocantins realizou quatro etapas de campo voltadas exclusivamente à arte rupestre.

Caracterização Ambiental e Delimitação da Área de Pesquisa

A área de estudos situa-se entre os paralelos 9º 45’ e 10º 15’ de latitude sul, e os meridianos 48º 13’e 48º 19’ de longitude oeste, na região central do estado do Tocantins, paralela à depressão do Tocantins/Araguaia. Trata-se de um dos conjuntos de serras de diferentes feições que se destacam na topografia devido ao contato falhado entre as rochas sedimentares da Bacia do Parnaíba e as cristalinas pré-cambrianas (Mantovani 1990).

Na maior parte de sua extensão longitudinal, a serra acompanha a calha maior do rio Tocantins, em seu médio curso. Seu principal tributário nesse trecho é o rio Lajeado, que corre paralelamente a uma média de oito km ao leste, por cerca de 60 km, encaixado entre duas fileiras de montanhas que compõem a Serra do Lajeado entre a cidades de Monte do Carmo e Tocantínia

O conjunto de relevos associados à serra destaca-se de sua zona de piemonte ocidental por um desnível em média de cerca de 300 a 450 m atingindo, por vezes, cotas superiores ao nível de 700m. Possui uma superfície cimeira ora plana, ora apresentando leves ondulações inclinadas para um grande número de veredas que tomam nascentes no topo das chapadas marcadas por vales profundos, denominados vãos pela população local.

Esses relevos acentuados são sustentados, em sua maior parte, pelas litologias areníticas da Formação Pimenteiras, de idade devoniana, composta de arenitos finos a grosseiros e, sobretudo, por siltitos, siltitos foliáceos, ferruginosos e argilitos, apresentando alternância de cores branca e arroxeada (Mantovani 1990). Já a formação Serra Grande, segundo esse autor, ocupa posição basal na sedimentação ligada à bacia do Parnaíba e aflora, sobretudo nas cornijas das chapadas, que possuem uma altura em torno de uns 80 metros, apresentando declives verticais, às vezes pontualmente negativos, formando os abrigos sob rocha onde se encontram os sítios pré-históricos.

Os sítios rupestres estudados localizam-se em três trechos serranos da Área de Proteção Ambiental do Lajeado, à margem direita do Rio Tocantins, delimitada ao sul pelo rio Taquarussu Grande, ao norte pelo córrego Lajeadinho. No eixo este-oeste a pesquisa situa-se entre o vale do rio Lajeado e a planície do Tocantins. São contextos locacionais distintos na estrutura da paisagem onde o sítio mais ao norte dista 48 km do mais ao sul, em vôo de pássaro. As gravuras em lajedos no leito do Tocantins estão entre essas coordenadas.

Os Sítios Arqueológicos

O universo de pesquisa é de 21 sítios rupestres, muitos deles aparentam não terem sido visitados pelo homem atual, haja vista seu alto grau de integridade.

Em muitos sítios as unidades gráficas permitem um reconhecimento instantâneo de representações do mundo sensível, enquanto outros comportam quase que exclusivamente composições gráficas não reconhecíveis ou, ainda, uma combinação entre elas. O fato de diversas figuras frequentarem sítios distintos, independentemente de sua inserção geográfica, muitas vezes com formas diferentes de apresentação gráfica, confere à região uma grande variedade temática e estilística.

O nosso universo de pesquisa é ainda pequeno e seria fútil qualquer tentativa em se estabelecer um estilo que viesse a caracterizar a arte rupestre da serra do Lajeado. Entretanto, já podemos observar algumas preferências temáticas associadas a marcadores geográficos que delimitam claramente alguns territórios. Ao caminhar entre sítios próximos, observamos que preferências temáticas e técnicas, seja em painéis, seja em ocorrências esparsas, estão circunscritas por vãos onde correm riachos ladeados por expressiva mata galeria.

A seguir apresentamos uma síntese dos conjuntos rupestres, agrupados segundo sua inserção na paisagem.

1º Conjunto

São sete sítios, localizados na região sul da área pesquisada, na micro bacia do Ribeirão Água Fria, próxima à capital do estado, Palmas. Embora apresentem a mesma configuração geomorfológica e condições de acesso parecidas, são muitas as particularidades em suas manifestações parietais quando consideradas conjuntamente. Mesmo distantes do Rio Tocantins, é possível vislumbrá-lo enquanto uma linha no horizonte. As grotas são inúmeras, com muita água brotando dos paredões cujos cumes se estendem em um platô para o leste, onde estão as cabeceiras do Lajeado e inúmeras fazendas.

Sendo contíguos, podemos notar que, embora a temática seja basicamente a mesma - representações do mundo animal e grafismos geométricos - a diferenciação na confecção técnica e na frequência com que os temas comparecem, se acentua à medida em que atravessamos três vãos, ou seja, os vales profundos que delimitam claramente conjuntos de paredões.

Algumas dessas diferenças parecem ser idiossincráticas O aprofundamento do estudo analítico dos grafismos permitirá confirmar ou não essa hipótese e levantar outras sobre o contexto de autoria da arte. No momento, já podemos distinguir alguns poucos painéis que foram utilizados uma única vez, em oposição a outros que apresentam uma verdadeira estratigrafia pictural. Cada um daqueles painéis foi aparentemente concebido para formar uma composição, realizado por uma única pessoa e respeitado pelas gerações sucessoras, uma vez que não há sobreposições e nem aproveitamento do espaço entre os grafismos.Cabe ressaltar que, a despeito das particularidades, as características básicas são as mesmas: temática voltada para a representação de cervídeos, pássaros, lagartos, pouquíssimos antropomorfos e representações geométricas que a literatura arqueológica costuma denominar de pectiniformes e grades. Importante notar a quase total ausência de bicromismo, uma escolha estilística que permite estabelecer um contraponto cronológico com os demais setores da serra onde a arte rupestre está sendo estudada.

Podemos traçar paralelos com as diferentes tradições rupestres brasileiras, reforçando a hipótese de que a região foi palco de grande interação cultural antes do contato com o homem branco.

Nesse sentido, um dos sítios pertencentes a esse bloco, o Boqueirão do Sucuri, apresenta uma incursão bastante particular e isolada na nossa pesquisa. Trata-se de um painel que nos remete a Montalvânia, em Minas Gerais. Sua realização é provavelmente uma das últimas no sítio. São figuras grandes e impactantes compostas diretamente sobre um delicado conjunto de pequenas aves e cervídeos confeccionados, anteriormente, em apurada técnica de filigrana.

Ainda nesse mesmo conjunto de sítios, o Vão Grande, à beira do córrego de mesmo nome, é o maior dos sítios conhecidos. Um dos seus painéis, que eleva-se a cinco metros do solo, é composto majoritariamente por grafismos típicos do médio São Francisco e que deu nome à Tradição preponderante naquela região. São utensílios, se é que podemos a nos arriscar a interpretar grafismos pelas associações que nos ocorrem com o mundo sensível e cujo formato não é tão óbvio como no caso dos antropomorfos e zoomorfos. Em todo caso, uma vasta gama de arpões, propulsores e tipitis estão representados em diversas dimensões e tonalidades de vermelho. À medida em que caminhamos para o norte, essa temática persiste, em menor escala, contrariamente aos sítios conhecidos ao sul do Vão Grande, em que não aparece absolutamente.

O sítio Abrigo do Poção traz uma das raríssimas cenas de todo o corpus. Um conjunto de personagens humanos, formando um semicírculo, com pleno domínio da perspectiva. Parecem estar dançando. Já no sítio Ponta da Serra temos a única cena de caça até o momento descoberta, adornando a entrada da caverna, tal qual um friso. Ambas as ocorrências poderiam nos remeter à Tradição Nordeste, do sul do Piauí, que tem entre suas características definidoras a existência de cenas. Entretanto, o fato de serem ocorrências isoladas nos impede de estabelecer uma filiação. Assim, se nos dispusermos a buscar elementos relacionando a arte rupestre do Lajeado às demais províncias brasileiras, deveremos voltar os olhos para os vales dos afluentes do Rio São Francisco.

A Tradição Planalto também comparece uma vez ou outra com seus grandes peixes na posição vertical e cervídeos de preenchimento quadriculado e focinho chapado, mas de forma bastante pontual.

2º Conjunto

O conjunto de sítios localizados no trecho central da área de pesquisa insere-se em uma paisagem bastante distinta dos enfocados até o momento, dos quais dista em torno de 25 km. Acompanhando a calha do Tocantins, no seu trecho mais próximo às águas, as escarpas são muito mais íngremes e altas. Os abrigos têm conformação diferente, de menor inclinação negativa, portanto com pouca sombra. A água é rara e se tem uma visão muito próxima e de longo alcance do Tocantins. Nessa área temos conhecimento de seis sítios com arte rupestre e, situado entre eles, um abrigo com material cerâmico e lítico na superfície, mas sem pinturas. A essas escarpas correspondem, no lado oposto, encostas que se debruçam para o vale do Lajeado. Quanto às manifestações gráficas, os principais pontos de distinção são o tema e as escolhas técnicas. No sítio Bico de Pedra predominam imagens que retratam o homem; na verdade temos pelo menos dez versões do tema elaborado de forma bastante original. Outro ponto de distinção é a opção marcante pela bicromia. Amarelo e vermelho estão igualmente presentes na maior parte dos desenhos. O sítio em questão exibe uma concentração maior de grafismos em relação ao conjunto pictórico de Palmas, ou seja, o suporte foi ocupado várias vezes sem maiores considerações pelas realizações anteriores. Aqui e ali comparece algum grafismo típico daquele conjunto, como os pequenos pássaros vermelhos e os motivos de grades.

3º Conjunto

Nessa mesma latitude, mas do lado oposto da serra, já no vale do Lajeado, onde uma cadeia de montanhas o separa do Tocantins, o acesso aos sítios é muito mais fácil, a vegetação novamente exuberante, com bastante água. As manifestações rupestres são parecidas com as do Bico de Pedra e sítios circunvizinhos, não exatamente os antropomorfos, mas onças e cervídeos bicrômicos de apresentação gráfica praticamente idêntica. Esse tipo de grafismo é um elemento crono-estilístico importante, pois aparece apenas uma vez na região de Palmas e em relação estratigráfica com o que é específico de lá.

Conhecemos sítios em ambos os lados de vale, tanto na planície como nos paredões. Entre eles existe um sítio bastante *sui-generis*. Sem relação com as onças bicrômicas que distam menos de um kilômetro. É composto por centenas, talvez mais de mil pequenas pinturas de grande diversidade, muitas vezes miniaturas de grafismos conhecidos em outros sítios. Malgrado o precário estado de conservação, o aprofundamento da análise permitirá estabelecer hipóteses sobre a função do sítio que, à primeira vista, aparenta ser um local de convocação ou de reunião, para onde se dirigiam os mais diversos representantes dos grupos que habitavam a região.

Em relação às gravações, podemos afirmar ser uma técnica utilizada quase que exclusivamente nos lajedos situados no leito do Rio Tocantins, cujos motivos são similares às Itacoatiaras do agreste pernambucano (Aguiar, 1986). Há algumas exceções, duas ou três em todo o *corpus* da arte levantado até agora, totalmente dissociadas dos lajedos. Entretanto, localizamos algumas pinturas retratando essa temática bastante típica das águas. São três pinturas, uma delas no abrigo da Jibóia (região de Palmas) e as outras duas na Serra do Carmo I, pertencente ao conjunto da área central da pesquisa. Em razão de sua posição topográfica e da tinta utilizada no abrigo da Jibóia, estamos bastante inclinados a afirmar tratar-se de ocorrências tardias no bojo dos conjuntos picturais, o que não é suficiente para estabelecer relações de antiguidade entre gravações e pinturas.

Todas essas considerações apontam para uma possível ocupação da região por grupos pré-históricos ligados culturalmente a outras regiões de Minas Gerais, Goiás e Tocantins. Os estudos, ainda embrionários, procurarão entender em que direção apontam as transformações visualizadas na arte rupestre da região.

Atualmente estamos no estágio de preparação do material levantado - fotos, croquis e cópias em plástico - para darmos início à classificação das figuras, estudos de cronologia relativa e de filiação às demais ocorrências rupestres brasileiras, de modo a abordar questões pertinentes ao processo de ocupação da região.

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Fossil Remains of a Cave Tube Worm (Polychaeta: Serpulidae) in an Ancient Cave in Slovenia

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Abstract

Calcareous tubes, matching those of the modern cave tube worm *Marifugia cavatica* Absolon & Hrabe (Polychaeta: Serpulidae) in shape and dimensions, were found attached to the wall of a fossilised cave on the Kras plateau, W Slovenia. Due to (1) the supposed absence of any marine influences in that cave, (2) the fact that *Marifugia* is the only freshwater serpulid known at all, and (3) the mentioned similarity, we suppose that the fossil tubes belonged to the same species or its ancestor. The exact datation would give the first direct data about the minimum "cave age" of an animal species.

Towards the end of its hydrological activity, the passage was filled with clay and flowstone. The roof of the passage has been removed by karst denudation and cave is now exposed to the surface.

Paleomagnetic datation of the sediment fill shows minimal possible age of 1,7 Ma which is in accordance with the geomorphological observations.

Introduction

During the geomorphologic research of the Kras plateau in past years we focused our attention to the unroofed caves. This are segments of caves, which were formed in the depth but they are exposed to the surface as a result of the karst denudation which dissolved and removed all the rock layers above them. They are the oldest remains of caves in this area and the oldest sediments have been preserved in them (MIHEVC, 1996; MIHEVC & ZUPAN 1996; MIHEVC *et al.*., 1998; BOSAK *et al.*., 2000).

In the Črnotiče limestone quarry, we studied a large unroofed cave, filled with speleothems and allochtonous alluvial sediments. The quarry is situated on the S edge of the Kras, on the Podgorski kras plateau, W Slovenia (45° 33' 57" N, 13° 52' 48" E). The surface of the plateau is levelled at about 450 m a.s.l., dismembered only by numerous dolines. The deepest cave is 150 m deep, but no active flow can be reached trough it. Karst springs with maximum discharge of several $m^3s^{-1}$are few km away, at the foot of the plateau, at elevation of about 50 m a.s.l.

The quarry exploitation opened the fossilised cave step by step, making study of the former cave passage and its sediments possible. A profile of the sediment was dated with paleomagnetic method. Its minimum age was 1.77 Ma (BOSAK *et al.*., 1999).

New, side passage of the cave was quarried out in the year 2000. In this passage, which was also filled with sediments, we found calcareous tubes that were attached to the cave wall. These tubes are very similar to those of the Dinaric cave tube worm *Marifugia cavatica* (MIHEVC, 2000). The clay deposit in the cave obviously protected the fragile tubes since the time when an underground river flowed through the cave.

Description of the Profile and Fossils

The uncovered side passage profile with fossil tubes is 4-8 m wide and more than 17 m high. Laminated clays were deposited in its lower part. In the middle, there is an erosional discordance of the sediment above which quartz sands and some layers with pebbles are deposited. Sand and pebbles, brought in the cave by a sinking river originate from Eocene flysch rocks. Above them 7 m thick layer of flowstone was deposited.

The calcareous tubes are attached to the wall in the lower part of the passage between 426 and 427 m a.s.l. They are placed separately or in groups of up to several hundred individuals. Unfinished ones accompany tubes of supposedly grown up animals. The end parts of tubes, which were perpendicular to the wall, were broken off, probably when we were removing the clay sediment from the wall; anyway, we were able to wash them out of the sediment.

The remains of the fossilised tubes attached to the cave wall were removed together with the rock they were attached to. Tubes could also be picked out of the sediments that were in the contact with the wall. A profile of the sediment was taken for the paleomagnetic datation. The tubes were compared with the recent tubes of the serpulid *Marifugia cavatica.*

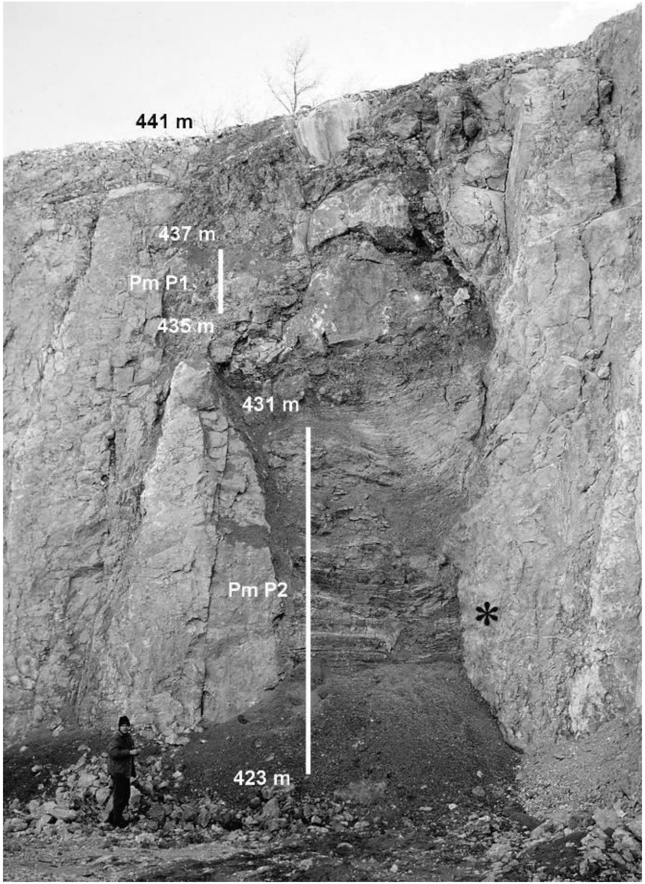

Figure 1 - View of the crosscut unroofed cave in Črnotiče quarry. Legend: ∗ the position of the tubes; PmP, PmP2 levels of the paleomagnetic profiles.

Datation of the Sediments

There are two profiles of cave sediments dated by the paleomagnetic method, i.e., (PmP1) profile in main passage composed of laminated cave (algal) limestones with intercalations of red clays, (BOSAK *et al.*., 1999), and (PmP2) profile in a side passage, 20 m distant, with finds of worm tubes composed of numerous typical cave fluvial cycles (conglomerate to claystone).

Within the first profile, elevation between 435 and 437 m, the long normal magnetozone was interpreted in the lower half of the log. The top part of the profile shows reverse palaeomagnetic direction interrupted by two normal magnetised zones.

The magnetostratigraphic investigation of the second profile, elevation between 423 and 431 m, proved two short reverse magnetozones within the dominant normal magnetic polarisation.

The arrangement of the distribution of normal and reverse polarity magnetozones depends on abundant unconformities of unknown duration in both profiles. According to the arrangement of individual magnetozones in a standard scales, we can assume that the top of the highest normal polarised magnetozone in our first profile could be correlated with the top of the Olduvai event (1.77 Ma) as the youngest possibility, and therefore the rest of profile must be older.

The second profile is clearly older that Brunhes/Matuyama boundary (0.78 Ma), but the arrangement of individual magnetozones indicate much higher age, very similar to the interpretation of the first profile.

Comparative Data About the Recent *Marifugia Cavatica*

Marifugia cavatica Absolon & Hrabe, 1930, is recently the only truly freshwater member of the family Serpulidae (Annelida: Polychaeta) and the only known tube worm inhabiting continental caves. It is widely, although patchily, distributed within the Dinaric Karst, from the Carso in NE Italy through southern parts of Slovenia, Croatia, Hercegovina and in western Bosnia (SKET, 1970b). Biogeographically it belongs to so called holo-Dinaric elements (*sensu* SKET, 1994).

Although it was originally considered a marine element colonising fresh cave waters directly from the sea (ABSOLON & HRABE, 1930) it is nowadays supposed to have colonised cave waters from ancient (Pliocene or Pleistocene) freshwater lakes in the region (SKET, 1997). This is a parallel to some similarly distributed stygobionts: the amphibian *Proteus*, the cockle *Congeria*, and the cnidarian *Velkovrhia*.

Marifugia is an explicitly fresh water animal, it has never been found even in brackish waters (compare SKET, 1986). It is a filter feeder with a free-swimming larva (MATJAŠIČ & SKET 1966). It can be very sparsely settled in clear and fast flowing streams while it may aggregate to very dense colonies in backwaters where larvae are not swept away by the current and where particulate organic matter can be richer. Thick masses of many layers of tubes (as described by ABSOLON & HRABE 1930) are nevertheless a unique exception.

The calcareous tube of *Marifugia* is curved and attached to substratum in its initial centimetres while detached and more or less perpendicularly erect and straight when the worm grows up. The accreted part of the tube may be flattened beneath while the vertical part is perfectly cylindrical. There is an irregular and interrupted and serrate crest along the tube, however feebly developed or even absent along the erect part. On the contrary, circular pleats are very scarce and less distinctive along the accreted part while denser and very wide along the erect part. The finished tube evidently regularly ends with such a pleat. The broken off erected parts of tubes are very often found in the sand of karst springs, together with shells of stygobiotic gastropods.

The outer diameter of erect parts of tubes is 0.65 – 0.85 mm, while it diminishes towards the thinnest parts at least down to 0.2 mm. The first part of the tube at the young animal, before it gets incrusted, is only 1 mm long and 0.1 mm wide (MATJAŠIČ & SKET 1966). The maximal width of the collar-like pleats varies among specimens and populations. However, it varies as well along the individual tube; the maximal diameter measured was 1,5 mm and its width was 0.35 mm. They may be very densely packed or very distantly set, intervals in an individual tube are also variable. The tube's walls are approximately 0.05 mm thick.

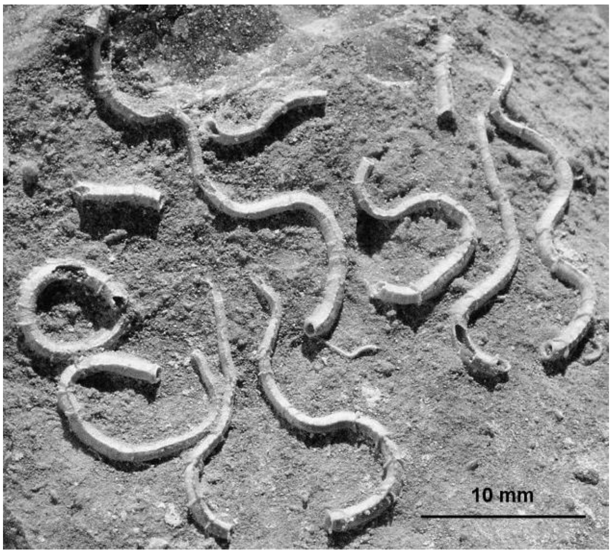

Figure 2 - A group of tubes of the cave serpulid from the profile of the unroofed cave in Črnotiče quarry. Corrosion damage to the limestone can also be observed; the tube itself is less damaged.

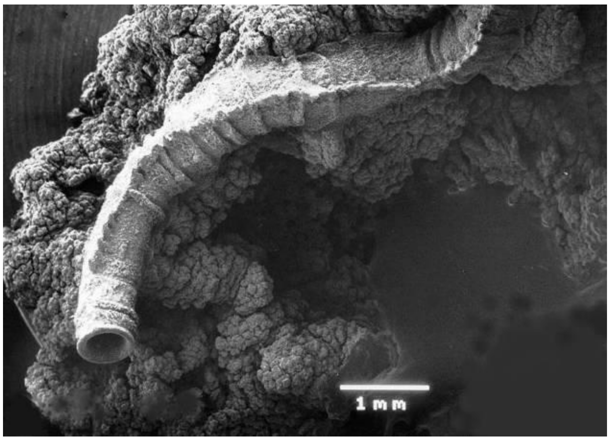

Figure 3 - The tube of the recent cave Marifugia cavatica from the cave Jama pod Krogom. The longitudinal toothed crest and the collar-like rings can be seen.

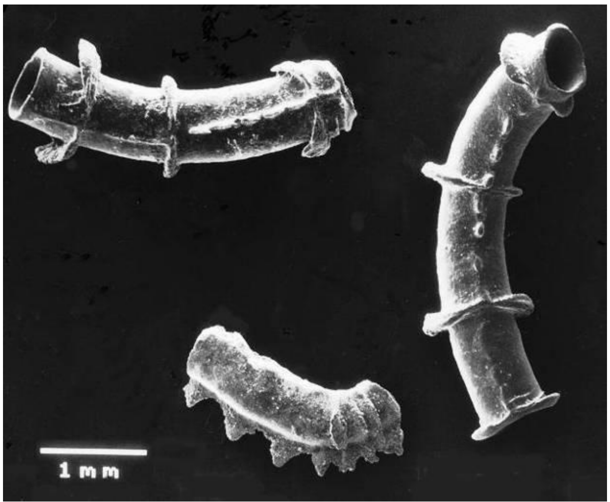

Figure 4 - Fragments of the fossilised serpulid tubes from the sediment in the roofless cave in Črnotiče quarry. Their variability is remarkable.

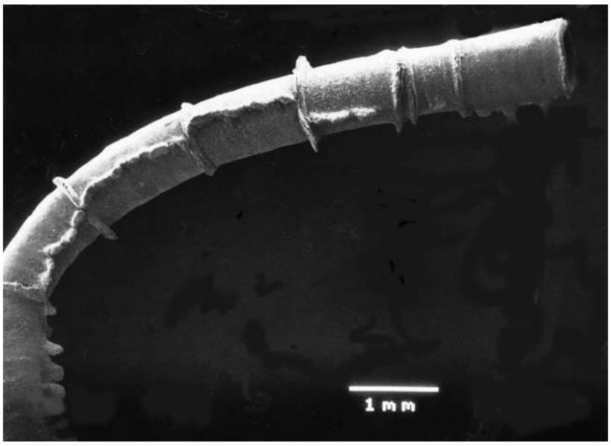

Figure 5 - The tube of a recent cave worm Marifugia cavatica from spring Tounjčica. Variability of the shape of the serrated crest and of the rings is clearly seen.

Discussion and Conclusions

The comparison of fossilised calcareous tubes from the fossil cave in Črnotiče with tubes of the recent *Marifugia cavatica* from its western localities reveals no differences surpassing those among the recent tubes themselves. They widely match in their shape and dimensions. The fossil tubes do not surpass any measures of the recent ones. Even the wall thickness is nearly equal which eliminates a possibility of corrosion in the clayey sediments.

The fossil locality is also within the general distribution area of *Marifugia* and even surrounded by some of its factual localities in the Rižana and Osapska reka spring areas, near Movraž and in the underground Reka system; they are all only 3-10 km away of Črnotiče. Since *Marifugia* is also the only known builder of such a type of tubes in freshwaters and there is no indication that the fossilised cave could have ever been flooded by the sea; therefore the identity or close relations of the fossil with the extant cave tube worm is the only parsimonious solution.

From the dimensions of the cave profile, scallops on the walls of the passage, and the sediment filling we can conclude that a large underground river formed the cave. Scallops that formed on the walls indicate a slow current. We suppose that the sessile serpulid tubes were buried step by step when the passage was partly filled with fine sediment. Later the fine sediments in the upper part of the profile were eroded and replaced by coarser sediments. In that part of the cave wall no serpulid tubes were found. This seems to have been followed by a longer dry phase when more than 7 m thick flowstone layer was deposited. Finally, the karst erosion removed the rock above the cave, ceiling and part of the cave walls, so the flowstone fill is now exposed on the surface.

Paleomagnetic dating of the two sediment profiles in the cave because of the incomplete profiles and uncorformities in them gave the minimum possible age only; the sediment from the upper part of the cave fill is at least 1.7 Ma old, therefore the sediments below it, and the fossil tubes are most probably older.

This age is in accordance with geomorphologic observations: the estimated rate of karst denudation in the area is about 60 m/Ma (GAMS, 1974) and judging from the massive flowstone now exposed to the surface, there was at least 100 m of the rock removed by karst denudation from above the cave. Also, the present water caves and springs are about 370 m below the level of the unroofed cave with the fossilised serpulid tubes.

So, according to the minimum age of those sediments we may with some certainty suppose that at the beginning of Pleistocene epoch well developed karst with large water caves populated by animals adapted to cave life existed in the Podgorski kras plateau.

The main parts of the Dinaric cave fauna had been calculated to be of the Pliocene age (SKET, 1970a). However, recent studies revealed that even some important members of it could have been retarded in colonising cave waters till quite recently, postglacially (SKET, 1997). Since also a polytopic and polychronous immigration of surface species (let alone of surface faunas) underground has been supposed, both hypotheses are not necessarily in contradiction.

The new finding is a strong argument towards the high age of the Dinaric cave fauna although a direct datation of the fossils' age would add some certainty.

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Groundwater Crustaceans as Useful Geological Tools

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Abstract

Many stygobiont crustaceans presently living in continental subterranean waters are derived from ancestral coastal marine species which stay in sediments when shorelines receded far away during the geological periods of marine regression. The dispersal ability of stygobionts in continental groundwaters is especially low. Thus the present distribution of thalassoid stygobionts fits well with that of areas formerly covered by the sea; such stygobionts may provide information about the place of paleoshores, even when marine sediments were removed by erosion. The place of paleoshores of South-West Morocco are partly known from the survey and the analysis of the present regional stygofauna. The species groups resulting from the phylogenetic analysis of genera or families of thalassoid stygobionts and the analysis of their distribution, allow to date the colonization of groundwater by their marine ancestors. Thus the emersion of a Canarian island was dated by this way, as is datable the emergence of lands in Israel and Palestine.

Introduction and General Background

Some extant aquatic subterranean species may be used by geologists to locate the shoreline of a former transgressive sea or to date the definitive emersion of a continental sedimentary basin or of an oceanic island (STOCK, 1986; COINEAU, 1990; BOUTIN, 1993a, 1993b). Among metazoans, the crustacean group is the most diversified within groundwaters, both in plain and valley aquifers and in cave rivers or lakes. Such *stygobiontic* crustaceans (*i.e.* aquatic and subterranean) are *troglobites*, in karstic open water, or tiny interstitial *phreatobites*, in saturated porous sediments. *Thalassostygobionts* live in littoral marine cave or sediments and *limnostygobionts* occur in cave and aquifer freshwaters. Only the latter are considered hereafter.

Some limnostygobionts belong to groups living also in surface freshwaters. They are derived from freshwater surface ancestors and are termed *limnicoid*. A well known example is that of the species of the amphipod *Gammarus* (CULVER et al., 1995).This kind of limnicoid stygobionts provides very few information about the period or the geological events related to the colonization of groundwaters by their ancestors, as this colonization may have occurred repeatedly at the same place and at different periods of the past, up to now. Therefore they are generally considered as uninformative for geologists.

Other limnostygobionts belong to marine groups not known in freshwaters. Due to their direct marine origin they are called *thalassoïd* limnostygobionts (COINEAU & BOUTIN, 1992; BOUTIN, 1993a, 1993b). The marine origin of such crustaceans has been proposed for a long time (JEANNEL, 1943; DELAMARE DEBOUTTEVILLE, 1957, 1960; VANDEL, 1964, GINET & DECOU, 1977 etc...). For example, out of 350 cirolanid species (isopods), some 85% are epigean, marine or littoral, whereas the other 15% are freshwater stygobites more or less resembling their marine littoral ancestors (BOTOSANEANU, 1986). These stygobionts evolved from marine ancestral populations which first colonized littoral sediments (or sometimes littoral caves) in the Mesozoic or Cenozoic periods; thereafter they adapted to brackish water, then to freshwater and settled during a marine regression when the shoreline receded. This "Regression model evolution" (STOCK, 1977, 1980) was analysed and viewed as the second stage of a "Two step model of colonization and evolution" (BOUTIN & COINEAU, 1990; NOTENBOOM, 1991; COINEAU & BOUTIN, 1992; HOLSINGER, 1994).

Thalassoid limnostygobionts consequently occur in sedimentary basins of continents formerly covered by the sea during a transgression, before the shoreline recede during the following regression. It is well known and generally accepted that interstitial crustaceans have very poor dispersal abilities (see for example HOLSINGER, 1986) and that stygobiontic populations stay in place and remain alive up today as "Living fossils" (DELAMARE DEBOUTTEVILLE & BOTOSANEANU, 1970; TERMIER, 1983), so that the most internal part of the present distribution area of a thalassoid stygobiont provides a good information about the place of the paleoshore during the maximum of the transgression (which occurred before the marine regression which will allow the colonization of groundwaters). Finally these living fossils are present markers of paleoshores. Geologists used to consider the limits of occurrence of sedimentary rocks deposited during a period of embayment as the location of the paleo-shorelines at the same period, except when there is a clear evidence of erosion of the considered layer. However in some cases these sedimentary rocks may have been completely removed by an important continental erosion. Consequently the groundwater primitively contained in these marine sedimentary formations have moved down and lasted in more ancient sediments or in the basal altered plutonic rocks, thus allowing the survival and permanence of thalassoid stygobiontic populations which remain the sole evidence of the marine transgression. Therefore the location of paleo-shorelines may be inferred only from the limits of the present distribution area of these stygobionts.

On the other hand the colonization of continental groundwaters by some thalassostygobiontic populations may have occured during the marine regression which resulted in the definitive emersion of a sedimentary basin (or an oceanic island when thalassoid limnostygobionts occur in groundwaters of an island). If it is possible to date this colonization - i.e. the ecological change of crustacean biotopes, from coastal marine environment to continental groundwaters - then it is possible to date the simultaneous marine regression. Now it is well known by paleontologists as well as by stygobiologists (DUCASSE *et al.*, 1983; BOUTIN & COINEAU, 1991, 2000) that the evolutionary rate is faster in a changing and unstable environment, such as coastal biotopes, than in a more stable biotope like bathyal or phreatic and continental biotopes. Continental groundwater appears as a conservative environment housing a lot of "living fossils". Recent colonizers of groundwater - which evolved for a longer time in littoral milieus than older colonizers - exhibit therefore a more important morphological evolution than the more ancient colonizers, which evolved in littoral biotopes for a shorter period. It is why the phylogenetic analysis of the stygobitic species forming a genus or a family, generally shows that the most primitive lineages (monophyletic groups of species) include the species with a distribution indicating a freshwater entrance during the oldest geologic periods. In contrast, the most derived lineage comprises species, the origin of which is correlated with the latest marine regression in the study area. Therefore when the divergences of a cladogram are dated, based on biogeographic and geological data from a well known region, then it is possible to infer the date of a marine regression in another region if a new stygobiontic species of the group occurs in this new region.

Moroccan stygobiontic models used in the Mediterranean Basin

The geological history of Morocco is relatively well known, and two groups of stygobiontic crustaceans occur in numerous regions of this country. They are both sufficiently diversified in many species presently well known; their phylogenetic and biogeographic study provides the possibility of dating the origin of different lineages within each group.

The family Metacrangonyctidae include to date more than 40 stygobiontic species of amphipods, about 36 of which occur in Morocco (MESSOULI, 1994). The cladistic analysis of the family clearly shows four lineages; three of them belong to the genus *Metacrangonyx* and the fourth and most derived one forms the genus *Longipodacrangonyx* (MESSOULI, 1988, 1994; BOUTIN, 1994b). The two more primitive lineages, morphologically well characterized, arise from a trifurcation dated from the Turonian regression (some 90 My BP), the third lineage appears later and in relation with the Senonian marine regression (70 My BP), and the last one, originating the genus *Longipodacrangonyx*, is related with the Lutetian regression (some 40 Ma) as the species of this genus occur only within the limits of eocene gulfs.

The cirolanid isopods of the "*Typhlocirolana* group" include to date four genera and more than 25 stygobiontic species of which about 12 belong to two genera occurring in Morocco (BOUTIN, 1993a, 1993b). The cladogram of Moroccan species exhibit exactly the same topology as that of the metacrangonyctid amphipods, showing four clearly distinguishable lineages. The two more primitive lineages (having retained a number of characteristics of extant marine cirolanids) occur in regions flooded during the Cenomano-Turonian times, the third lineage includes the most derived species of the genus *Typhlocirolana* which occurs in regions flooded during the Senonian, and the fourth lineage is formed by the genus *Marocolana*, whose distribution is included within the paleoshores of the Lutetian gulfs.

The striking similarity of the two plylogenetic cladograms and that of the two area cladograms was pointed out by BOUTIN (1993a) and suggests the same historical biogeography of the two stygobiont groups, and the same sequence of geological events in the regions where representatives of the groups occur.

Results

The age of some islands could be reconsidered from the stygobiological evidence, in Canary archipelago and in Mediterranean islands. The limits of past Tethyan transgressions on the African continent were reevaluated in the Souss and the Anti Atlas regions of Atlantic Morocco. The age of Israelo-Palestinian lands could also be reevaluated.

Fuerteventura (Canary Island) is mainly formed by volcanic rocks but in its western region the "Basal complex" is a series of metamorphic sedimentary rocks including mesozoic marine fossils. The island age was generally considered by geologists as ranging from 21 to 34 Ma (mid-Miocene to Oligocene), based on K/Ar datations of the most ancient volcanic rocks. A stygobiontic amphipod, *Metacrangonyx repens*, presently occurs in groundwaters of the "Basal complex" and is lacking in all other parts of Fuerteventura and in any other Canary islands completely formed of volcanic rocks. As *M. repens* belongs to the third lineage of Metacrangonyctidae, the colonization of emerged land by its ancestral marine populations occurred necessarily during the Senonian as in the other Moroccan regions (BOUTIN, 1993b). The age of the sampled volcanic rocks and the age of the emergence of the Basal complex appear quite different, as evidenced by its present stygofauna. The most ancient parts of the island can date back to the Senonian (70 Ma).

The occurrence of *Metacrangonyx longipes* and *Typhlocirolana moraguesi* in Balearic Islands, as these two species belong to the first **-** and more ancient - lineage of their group means that some part of the archipelago certainly emerged during the Turonian regression (90 Ma BP), even if most parts are formed of cenozoic marine sediments are more recent.

Similarly a part of the Elba Island, between Corsica and Italy, where *Metacrangonyx ilvanus* was recently discovered (STOCH, 1999) likely emerged during the Senonian, as *M. ilvanus* belongs to the third lineage of the family.

The closure of the Eastern Mediterranean, where the lands of Israel and Palestine partly - and step by step - have emerged, resulting in a present geologically heterogeneous area, is generally considered as relatively recent (Cenozoic). However in the Dead Sea region and in the Egyptian Sinai, two different species of *Metacrangonyx, M. ortali* and *M. sinaicus*, occur and belong to the third lineage, suggesting, in these areas, a Senonian emersion (some 70 Ma). Moreover, in the same Dead Sea region, several cirolanid isopods also occur, belonging to the "*Typhlocirolana* group". BOTOSANEANU & NOTENBOOM (1989) consider that all *Typhlocirolana* species from Israel can be assigned to the genus *Turcolana*, the most derived lineage of the group, located in regions where the marine embayment remained a long time after the Eocene. However BOUTIN (1993a) considers that the species *Typhlocirolana reichi* and *T. detecta* have rightfully to remain included in the genus *Typhlocirolana.* These two species, belonging to the third lineage of the Mediterranean stygobiontic cirolanids are thus another evidence of a Senonian emersion, some 70 Ma ago. Finally the Palestino-Israelian and Sinai lands are in some parts more ancient as generally considered (BOUTIN, 1997).

The limits of the Souss Eocene gulf (East of Agadir in Morocco) are known from Eocene sediments still exposed by places on the north and south margins of the Souss Basin. Thus geologists, following CHOUBERT & FAURE-MURET (1962), used to represent a narrow Eocene gulf, extending eastwards from Agadir, and covering only the present Souss valley (Fig. 1). In this region occurs the genus *Longipodacrangonyx*, forming the fourth and most derived lineage of the Metacrangonyctidae. However a site of *Longipodacrangonyx* was recently discovered just East of Tafraout, some 50 Km south of the supposed limits of the Souss Eocene gulf. Near Tafraout there is no more mesozoic sediments because when the Anti Atlas was repeatedly uplifted and especially during the last Atlasic orogenic periods, an important correlative erosion probably removed completely the superficial sedimentary formations. Finally, groundwaters, previously contained in sedimentary rocks, had to descend to the now superficial decomposed granites. *Longipodacrangonyx* which could not have arrived in its present location by active or passive dispersal, strongly suggests that in reality the Eocene "Souss" gulf extended at least 50 Km more southward, near the latitude of Tiznit and Tafraout (BOUTIN, 1998). When the continental erosion is so important, the thalassoid stygobionts may be the sole evidence of a past marine presence.

Similarly the total gap of mesozoic sediments in the plains of Tiznit and Guelmim (western Anti Atlas domain, between the High Atlas in the North and the Tarfaya Basin in the South, where Cretaceous marine sediments abound) was enough enigmatic and Tarfaya and the High Atlas were generally considered as two separated marine cretaceous gulfs. The presence of a *Metacrangonyx* species belonging to the first lineage in the Tiznit and the Guelmim regions, 30 and 40 Km West of the present coast, means that the Cenomanian-Turonian transgression connected the two regions and that the shoreline was at least 40 Km East of the present coast. During the different stages of the Cenozoic and recent orogenesis, the cretaceous sediments were removed by continental erosion before the deposit of quaternary limestones now exposed.

Figure 1 - Synthetic paleogeographic sketch map of Morocco. Dotted areas are regions covered by the Cenomano-Turonian seas; vertically hatched area shows the known limits of the Eocene Soussian gulf, from the authors. Dotted line 1 shows the minimal western shoreline of Atlantic Morocco during the Turonian and dotted line 2 the minimal southern limit of the Soussian gulf, from Boutin (1997) modified.

Conclusion

In a number of particular situations, the distribution of extant thalassoid stygobionts can provide useful evidences of past geological events. The knowledge of their specific diversity and up to date phylogeny may thus be useful out of the field of stygobiology and organisms biology.

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Morcegos Cavernícolas de Mambaí e Arredores, Goiás, Brasil

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Abstracts

The preliminary sample of bats in caves in the districts of Mambaí, Buritinópolis, Posse and Damianópolis, southeast of Goiás, in the biome of Cerrado demonstrated the occurrence of 18 species in eight caves surveyed with Japanese nets and four with entomological hand net . The species more commonly collected was *Carollia perspicillata*, present in eight of the cavities. The comparison with two other inventories accomplished in caves in Brazil demonstrate the relevance of the area for the conservation of the bats.

Resumo

O inventário preliminar de morcegos em cavernas nos Municípios de Mambaí, Buritinópolis, Posse e Damianópolis, sudeste de Goiás, no bioma de Cerrado demonstrou a ocorrência de 18 espécies em oito amostradas com redes japonesas e quatro com puçás entomológicos. A espécie mais comumente coletada foi *Carollia perspicillata*, presente em oito das cavidades. A comparação com dois outros inventários realizados em cavernas no Brasil demonstra a relevância da área para a conservação dos morcegos.

Introdução

Poucos são os inventários de morcegos realizados no centro-oeste do Brasil. O Estado de Goiás apresenta numerosas áreas carsticas, propiciando com isso grande disponibilidade de refúgios apropriados para larga diversidade de morcegos. No entanto muito pouco ainda é conhecido das espécies encontradas nestes ambientes, da diversidade de espécies e os padrões de distribuição por cavernas.

Com o crescente interesse nas cavernas no ecoturismo e o incremento de pesquisas visando o mapeamento e caracterização destas aberturas surge uma oportunidade única de conciliar o inventário de espécies de morcegos (BREDT & JÚNIOR, 1996).

Cavernas são reconhecidas pela sociedade como ambiente típico de morcegos, associando a presença destes mamíferos a proximidade destas aberturas (ESBÉRARD, 1999). Entre as 145 espécies reconhecidas para o território nacional (AGUIAR & TADDEI, 1997), com certeza 1/4 podem ser encontradas utilizando a caverna como refúgio. Estudos recentes demonstram a necessidade de se preservar cavernas também para a conservação de morcegos e a inclusão recente de sete espécies na listagem de espécies animais ameaçados de extinção do Brasil, demonstram a preocupação com este grupo.

Materiais e Métodos

Iniciamos o inventário de morcegos nas cavernas dos municípios de Mambaí, Buritinópolis, Posse e Damianópolis, na área onde está sendo proposta a Área de Proteção Ambiental de Mambaí para a conservação das cavernas. Nesta área já foram identificadas 105 cavernas.

Desde março de 2001, 12 cavernas foram visitadas para a localização de morcegos e destas, oito foram amostradas com o uso de redes japonesas. Em cada caverna utilizamos de uma a seis redes japonesas armadas de modo a cobrir a maior área possível da abertura. Em cada caverna as redes japonesas foram abertas junto à abertura ou próximas a esta e permaneceram abertas por três a cinco horas após o crepúsculo. Em locais onde constatou-se previamente a existência de maior número de aberturas armamos mais de um conjunto de redes e subdivimos a equipe.

O total de 11 cavernas foi visitada para confirmar a existência de morcegos e destas sete já foram amostradas com redes japonesas entre março e junho de 2001. Uma caverna já havia sido amostrada anteriormente por equipe da Gerência de Controle de Zoonoses do Instituto de Saúde do Distrito Federal.

As Cavernas já amostradas foram:

Gruta da Judite, Município de Mambaí e Buritinópolis, 371164UTM 8406941 UTM
Caverna Fundo de Quintal #1, Município de Mambaí, 14° 29´16,1"S 046° 07' 07,9"W
Lapa do Trombador, Município de Mambaí, 14° 32´ 25,4"S 046° 05' 51,9"W
Lapa do Rio das Pedras 1, Município de Mambaí, 14° 3' 54,1"S 046° 06' 18,2"W
Gruta da Tarimba, Município de Mambaí, 14° 24´ 42,2"S 046° 10' 28,7"W
Gruta do Landim, Município de Mambaí, 14° 32´ 25,4"S 046° 05' 05,0"W
Caverna dos Revolucionários, Município de Posse, 14° 17´ 27,9"S 046° 15' 10,9"W
Lapa do Sumidouro, Município de Posse, 14° 19´ 10,0"S 046° 14' 39,3"W
Lapa da Fazenda Guerobal, Município de Damianópolis, 14° 32´ 23,7"S 046° 16' 18,2"W

Os animais foram identificados, medidos e soltos, exceto por material testemunho depositado na coleção de referência do Projeto Morcegos Urbanos.

Resultados

O total de 18 espécies em 122 capturas foram confirmadas até o momento. As espécies já confirmadas foram:

Família Mormoopidae
  Pteronotus parnelli

Família Phyllostomidae
  Micronycteris minuta
  Lonchorhina aurita
  Mimon bennettii
  Phylloderma stenopus
  Trachops cirrhosus
  Chrotopterus auritus
  Glossophaga soricina
  Lonchophylla dekeyseri
  Anoura caudifer
  Anoura geoffroyi
  Carollia perspicillata
  Artibeus jamaicensis
  Desmodus rotundus
  Diphylla ecaudata

Família Natalidae
  Natalus stramineus

Família Furipteridae
  Furipterus horrens

Família Vespertilionidae
  Myotis nigricans

Todas as espécies foram capturadas ao entrarem ou sairem da caverna, com excessão de *Artibeus jamaicensis*, capturado em rede armada a cerca de 5 metros, em mata ciliar.

Das espécies capturadas, 33,33% apresenta hábitos alimentares insetívoros, 22,22% nectarívoros, 11,11% hematófagos, 11,11% frugívoros, 5,55% carnívoros e 5,55% onívoros (NOWAK, 1995). A família predominantemente amostrada foi Phyllostomidae com 77,78% das espécies.

Não foi ainda possível correlacionar a riqueza de espécies com caracteristicas individuais de cada caverna. As espécies de morcegos confirmadas em cada cavidade estão apresentadas na Tabela 1.

As cavernas com maior número de espécies até o momento foram a Lapa do Sumidouro com oito espécies, seguida por Lapa do Rio das Pedras IV e Caverna Revolucionária com sete espécies cada. As espécies de morcegos confirmadas em maior número de cavidades foram *Carollia perspicillata* em oito amostragens e *Desmodus rotundus* presente em seis amostragens.

Tabela 1 – Espécies de morcegos amostradas por cavidades.

	CAVERNAS AMOSTRADAS E VISITADAS											
ESPÉCIES	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
A. caudifer	X				X	X		X				
A. geoffroyi					X							
A. jamaicensis	X											
C. auritus	X					O		O	O			
C. perspicillata	X		X	X	X	X	X	X	X			
D. rotundus	X	X	X				X			X	X	
D. ecaudata	X						X					X
G. soricina	X						X	X	X			
L. aurita					X			X	X			
L. dekeyseri					X							
M. bennettii					X		X					
M. minuta	X											
M. nigricans			X									
N. stramineus			X	X								
P. parnelli					X							
P. stenopus							X					
T. cirrhosus							X					
Total Espécies	**8**	**1**	**4**	**2**	**7**	**3**	**7**	**5**	**4**	**1**	**1**	**1**

Notas: (1) – Lapa do Sumidouro, (2) Lapa da Fazenda Gurobau, (3) Caverna Fundo de Quintal #1, (4) Gruta da Tarimba, (5) Lapa do Rio das Pedras IV, (6) Lapa do Sumidouro, (7) Caverna Revolucionária, (8) Gruta da Judite, (9) Lapa do Rio das Pedras I, (10) Gruta do Penhasco, (11) Lapa do Trombador e (12) Lapa da Fazenda Buritizinho. As cavernas identificadas pelos números 4 e de 10 a 12 só foram amostradas até o momento com puçás entomológicos. X = capturas, O = observada.

Discussão

A captura de 18 espécies de morcegos em apenas oito das 105 cavernas relatadas para Mabaí e arredores (7,6% das cavidades) demonstra a importância desta área também para a conservação dos morcegos. Dois inventários realizados em outras áreas carsticas estão disponíveis na bibliografia especializada. TRAJANO (1981) amostrou as espécies de morcegos no Vale do Ribeira do Iguape, no Estado de São Paulo, em bioma de Mata Atlântica (24°S) e confirmou a ocorrência de 19 espécies de morcegos em 33 cavernas. BREDT & JUNIOR (1996) ao estudarem a comunidade de mocergos cavernícolas na área a ser afetada pela Uhe-Serra da Mesa, em Goiás, bioma do Cerrado, identificaram 16 espécies em 24 cavidades amostradas. O inventário iniciado em Mambaí só considerou até o momento 7,6% das cavidades conhecidas, levando a supor que número ainda mais elevado de espécies poderá ser relatada com a continuidade do inventário, superando o total amostrado nos dois inventários anteriores. CAMPANHA & FOWLER (1993) descreveram a captura de 12 espécies de morcegos junto a cavernas areníticas no Bioma da Mata Atlântica, em Minas Gerais, após 37 noites decesforço de amostragem.

Das espécies confirmadas na área de influência da UHE-Serra da Mesa (BREDT & JUNIOR, 1996), cinco não foram coletas em Mambaí – *Petropteryx macrotis* (Emballonuridae), *Pteronotus gymnonotus* (Mormoopidae), *Phyllostomus hastatus* (Phyllostomidae) e *Molossops temminckii* (Molossidae). As espécies ausentes em Serra da Mesa e confirmadas em Mambaí foram: *Micronycteris minuta, Phylloderma stenopus, Anoura caudifer* e *Artibeus jamaicensis* (Phyllostomidae) e *Myotis nigricans* (Vespertilionidae). Das espécies presentes em cavernas nos dois inventarios realizados em Cerrado (total de 23), 15 foram citadas por TRAJANO (1981) para cavernas em Mata Atlântica no sudeste do Brasil (65,2% espécies em comum).

BREDT & JUNIOR (1996) relataram ser *Desmodus rotundus* a espécie mais frequente em cavidades na área de influência da Serra da Mesa, diferindo de Mambaí, onde *Carollia perspicillata* foi amostrada. Tal fato pode ser decorrente da menor atividade agropecuária observada na área, não sendo, portanto, tão elevado o estímulo ao crescimento populacional do hematófago obrigatório, *Desmodus rotundus.*

Conclusões

A área proposta para a APA de Mambaí mostra-se extremamente relevante para a conservação de morcegos, já tendo sido confirmadas 18 espécies em 7,6% das cavernas conhecidas até o momento. Novas espécies deverão ser adicionadas com maior esforço de coleta idealizado para breve.

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Cavernicolous Invertebrates from Serra Geral Speleological Province, SP, Brazil

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Abstract

In order to contribute to the knowledge of cave fauna in sandstone regions, this study presents the results of terrestrial invertebrates survey of five caves in Serra Geral Speleological Province, Rio Claro - São Carlos sandstone district, in São Paulo state, Brazil. Eighteen expeditions were made to caves on the period of April to June on 2000. The results were compared with previous surveys done in some of these caves, and in some of other sandstones districts (Altinópolis, São Paulo state, and Altamira-Itaituba, Pará state), and even with the results of some survey in karst landscape. Qualitatively, cave fauna from these province shares several taxa with other known cavernicolous communities, even in limestone caves. Quantitatively, sandstone caves are distinguished only for the representative biomass, which could be explained by the numerous bat populations, providing a larger guano accumulation, and, therefore, more energy.

Introduction: The Study of Sandstone Caves

The development of caves depends so much on the lithology. Carbonate rocks present high degree of solubility, great mechanical resistance and still they occur in layers separated by joints, which may be folded or fractured by tectonic movements (what could facilitate the cave genesis). All these factors collaborate to the carbonate rocks being the most propitious lithology to development of caves. On the other hand, in Brazil and in all the world, there are also caves in other rock formations, for instance, in sandstone. The great majority of the surveys of the cavernicolous animals focused on carbonate regions, although there are some surveys in sandstone regions. With the intention to contribute to the knowledge of fauna in sandstone caves, this study presents the results of observations and analysis made in Serra Geral Speleological Province, São Paulo state, for terrestrial invertebrates.

Regional Geology

The following five sandstone caves have been studied during the present project:

Fazendão cave (SP-170, 22º24’37” S, 47º47’34” W, Ipeúna, São Paulo state): 200m long, dry, gallery in a ring way, large organic material accumulation (guano).

Paredão cave (SP-93, 22º25’45” S, 47º47’46” W, Ipeúna, São Paulo state): A single dry conduit, 60m long.

Boca do Sapo cave (SP-182, 22º24’65” S, 47º47’41” W, Ipeúna, São Paulo state): A single dry conduit in a ring way, 120m long. One large entrance with a waterfall near.

Gruta da Toca cave (SP-95, 22º11’901” S, 47º44’866” W, Itirapina, São Paulo state): Gallery of about 300m long., with stream. Large organic material accumulation (guano and plants detritus), one entrance.

Nossa Senhora de Lurdes cave (unknown geographic coordinates, Analândia, São Paulo state): Rock shelter, dry, 3m long. With civil construction at the entrance (an altar).

These caves belong to the area recognized as Rio Claro - São Carlos sandstone district, in Serra Geral Speleological Province (LINO, 1989). Fazendão, Paredão and Boca do Sapo caves are on Itaqueri mountain range and Nossa Senhora de Lurdes cave is on Cuscuzeiro mountain range. The litho-structural sequence is evident on these mountain ranges, and it is represented by the Cenozoic coverage after São Bento Group of Mesozoic, distributed in Serra Geral, Pirambóia e Butucatu Formations. Caves from Itaqueri mountain occur in Botucatu Formation, N. Sra. Lurdes in Serra Geral Formation and Gruta da Toca occurs in Pirambóia sandstone. The differences between these kinds of geological formations are reflected through the caves architecture (WERNICK, 1973).

Methodology

From April 9th to June 6th, 2000, eighteen expeditions were made to the caves in Serra Geral Speleological Province: 6 times exploring Gruta da Toca cave, 4 exploring Fazendão and Paredão caves, 3 times to Boca do Sapo cave and once to N. Sra. Lurdes cave. Sampling of macroscopic terrestrial invertebrates was done in all potential habitats, including rocky substrate (walls and ceiling) and fallen blocks, sediment banks, organic detritus (e.g. wood, guano), decomposing animals (bats), streams and pools. Collections were made using tweezers, brushes, glass and plastic pots, with and without 70% ethanol, and plastic bags. All the clues of animal presence were also observed, like eggs, eggsacs and carapaces.

A Garmin GPS model 45XL was used for confirmation of the location of the caves.

In the laboratory, sampling was made using an estereomicroscope. Subsequently, each sample was separated according to collection date and respective cave. The great majority of the biological material was identified to, at least, the family level, counting on the supervision and help from Brazilian specialists.

Results

Taxa Recorded

Table 1 shows the taxa collected during the present study. The most frequent groups were Araneae, Opiliones, Diplopoda and Orthoptera. These taxa have been considered to be frequent among the Brazilian cave-dwelling fauna in general (DESSEN et. al., 1980).

Our results corroborate the idea that the most common spider species in Brazil belong to the genera *Ctenus* (Ctenidae), *Loxosceles* (Sicariidae), *Plato* (Theridiosomatidae), and, less commonly, *Blechroscelis* (Pholcidae) (TRAJANO & GNASPINI-NETTO, 1990); still, other families were also found, like Trechaleidae, Uloboridae and Lycosidae, which could be considered accidental. Amongst the Opiliones, many individuals were observed in all the studied caves, such as eggs and young individuals. Diplopoda were only found at Gruta da Toca cave, near the stream. In this cave, a large population of Pseudonannolenidae (O. Spirostreptida) was registered. Finally, the most common macroinvertebrate, with large occurrence in Brazilian caves, were the Orthoptera, which were observed on several different substrates and in almost all the studied caves.

Other groups registered in many (or all) caves, or registered as a numerous population were: O. Collembola, O. Diptera, O. Hymenoptera, and O. Lepidoptera. Still, some groups were observed, but in small populations, like O. Pseudoscorpionida, O. Acari, O. Heteroptera, O. Blattodea, and O. Coleoptera.

Considering the relative abundance of the Classes observed, it was possible to note that the Insecta presented larger abundance than Arachnida, which was followed by Diplopoda. However, it is important to note that really numerous populations of arachnids were recorded in some caves.

Ecological Classification

Some lepidopterans, typical entrance-zone dipterans, and *Lycosa* were considered to be trogloxenes, whereas all other observed individuals were considered as troglophiles: Orthoptera, Blattodea, Collembola, Diplopoda, Pseudoscorpionida, Opiliones, Araneae, Heteroptera, other Lepidoptera etc. In São Paulo sandstone caves, no troglobites were observed so far. This fact can be explained mainly by the numerous bat populations, providing large guano accumulation, and, therefore, more energy, what may reduce the selective pressures. The shorter development of the caves is another relevant characteristic of São Paulo caves: animals have possibility to go out looking for food. Finally, at least for terrestrial invertebrates, the relative humidity is lower??? than other caves (HOWARTH, 1980 ???).

Comparison with other sandstone caves

Comparing the surveys of the invertebrates in Altinópolis sandstone district (TRAJANO, 1987), also located in Serra Geral Speleological Province, with the present study, Altinópolis presents a higher number of taxa. The fauna recorded in both districts are similar, occurring some differences. At the level of order or above, the same taxa were recorded (except Chilopoda, which was not observed in Rio Claro – São Carlos). However, in some cases, different families were recorded in each district.

Considering another Sandstone Speleological Province, Altamira – Itaituba, Pará state, where the caves are normally large, mainly horizontal and extensive, crossed by streams, and especially presenting really numerous bat populations and high temperatures (TRAJANO & MOREIRA, 1991), the biospeleological survey indicates several families and numerous invertebrates populations. In addition, there is the record of troglomorphic populations of some Crustacea. Both Speleological Provinces share many groups, including detritus-feeders and predators; however, obviously, in Altamira – Itaituba caves, the frequency and abundance are larger than in Rio Claro – São Carlos caves.

Comparison With Karstic Landscape

The cave-dwelling invertebrate fauna of sandstone landscape basically includes the same groups found on karst landscape (e.g., Vale do Ribeira Speleological Province). One of the most conspicuous difference is the number of individuals, which is higher for sandstone caves, mainly those which feed on guano. Bat populations are more numerous in sandstone caves, due the lowest density of caves in this kind of landscape, and, therefore, bats show larger concentration in a small number of caves.

On the other hand, karstic caves show higher diversity and larger distribution of invertebrates. It comes from many factors, like caves in karst landscape generally presenting great dimensions, higher stability climate and, so, relative humidity, among other physical characteristics. Furthermore, it is relevant to note that Vale do Ribeira Speleological Province is, for instance, also a biospeleological study center in Brazil, providing much information about the life in limestone.

Comparison With Previous Surveys Done in Some Caves of the Present study

Previous surveys done in Fazendão and Paredão caves (GNASPINI & TRAJANO, 1994), and in Gruta da Toca and Fazendão caves (TRAJANO, 1987) allow comparing the occurrence and diversity for these sandstone caves in a relatively short period of time.

In a general way, changes in occurrence have not been so relevant. There is no animal group registered in 1987 that was not observed on the subsequent years. Exclusively for 1994, there were Acari and Psocoptera; and exclusive groups for 2000 were Collembola, Blattodea and Trechaleidae (Araneae).

On the other hand, some common results among 1987, 1994 and 2000 were that crickets (Orthoptera) and Opiliones have been present in all the caves studied (Fazendão, Paredão and Gruta da Toca caves). In addition, Diptera, Hymenoptera, Lepidoptera, Aranea and Pseudoscorpionida occurred in all these surveys but not in all caves.

Many considerations could be made correlating these results, but the most important thing to evidence is that the cavernicolous environment have not changed so evidently during these years. Indeed, even Fazendão and Toca caves, which have a high frequency of visitors, seem to maintain the same fauna.

Final Considerations

Considering the invertebrate records in caves from Altamira, Serra Geral and Vale do Ribeira, the communities from the two last Provinces have a higher degree of similarity. This suggests that lithology is not the preponderant factor in the fauna structure, and that the relative geographical proximity between the caves, and, therefore, similar climate and epigean faunal components, would represent a strongest factor determining the occurrence of animal groups in the hypogean environment. Still, the caves physical environment in both lithologies are, in general, similar: darkness, low variation of temperature, high relative humidity, and all these factors are essential for determining and restricting the community, as does human action.

Quantitatively, sandstone caves are distinguished only for the large biomass, which could be explained by the numerous bat populations, providing a larger guano accumulation, and, therefore, more energy. Qualitatively, cave fauna from the cited sandstone provinces shares several taxa between them and with limestone cave communities.

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Morphology and Reproductive Strategies of Cave Fish of Genus *Trichomycterus* in Torotoro National Park (Potosi, Bolivia)

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Abstract

Fishes of the genus *Trichomycterus* (Siluriformes) show hypogean and epigean populations in Torotoro National Park (Andes, Bolivia). The geographic isolation makes possible a comparative study of morphology and reproductive strategies among populations from different habitats. External morphology and brain measurements were considered. Significant reduction of eyes diameter and surface of optic lobes are registered, as well as an increase in the surface of the telencephalon (olfactory lobes and brain) and cerebellum. On the contrary, the number of chromatophores is not reduced, as it would be expected, as well as the barbels length that is not larger in the cave populations. In the case of reproduction, the subterranean populations have larger eggs in smaller number in comparison with the epigean populations. We discuss the morphological and reproductive changes between hypogean and epigean populations as product of the influence of the environment in the embryonic and post-embryonic development.

Resumen

Morfología y estrategias reproductivas de peces cavernícolas del género *Trichomycterus* en el Parque Nacional Torotoro (Potosí, Bolivia). En el Parque Nacional de Torotoro (Andes, Bolivia) existen poblaciones cavernícolas y epigeas de peces del género *Trichomycterus* (Siluriformes). El aislamiento geografico hace posible un estudio comparativo de la morfología y estrategias reproductivas entre poblaciones de diferentes habitats.. Al nivel morfologico se ha considerado medidas externas y del cerebro. Se ha encontrado reducción significativa del diámetro de los ojos y superficie de los lóbulos ópticos e incremento en la superficie del telencéfalo (lóbulos olfativos y cerebro) y del cerebelo. El número de cromatóforos no es reducido como se esperaría, ni la longitud de las barbillas es mayor en las poblaciones cavernícolas. Al nivel reproductivo, las poblaciones cavernícolas poseen huevos grandes y en poca cantidad frente a las epigeas que poseen huevos pequeños y gran cantidad. En discusion se consideran los cambios morfológicos y reproductivos como producto de la influencia del medio en el desarrollo embrionario y post-embrionario.

Introduction

Trichomycterus chaberti (Durand, 1968) is an endemic cave fish of Torotoro National Park (Bolivia), only known in the Umajalanta cave. Other populations of epigean *Trichomycterus (*possibly *T.* aff. *fassli* or *T*. aff *barbouri*) inhabit rivers from canyons and valleys of the same area. These populations are geographically isolated and recent genetic study (GAZEL, 1999) considered that the three species could be separated, corresponding to the three main kind of habitat: valley, canyon and subterranean rivers.

The geographic isolation makes possible a comparative study among close species or populations at the phylogenetic sense but living independently in very different environmental conditions (cave vs. superficial rivers). This possibility is rare in the case of fishes adapted to cave life. The aim of this study is to compare morphological parameters, known to be affected by cave life adaptation, and reproductive strategies among 8 populations from Torotoro National Park area which inhabit rivers in the three main type of habitat: valley, canyon and subterranean rivers.

Methods

Study Area

Torotoro National Park is located in the Bolivian Andes (18°15’S, 65°45’W) between 2700 and 3500 meters of elevation. It corresponds to a small massif of Cretaceous calcareous marked by karstic phenomena like caves and canyons. The hydrographic network is altered by waterfalls and then presents rivers in different environments (cave, canyon and valley). From a biological point a view this situation allows only up-down migrations of the individuals and then the watershed heads could be considered as independent.

Fish Sampling

Fishes were collected with a portable electro-fishing gear delivering a current between 300 and 600 Volts. It corresponds to an adequate method for this kind of habitat and rivers and for studies of fragile or small populations. Samples of 30 individuals from each population were preserved in buffered formaldehyde (4%) and transported to the laboratory.

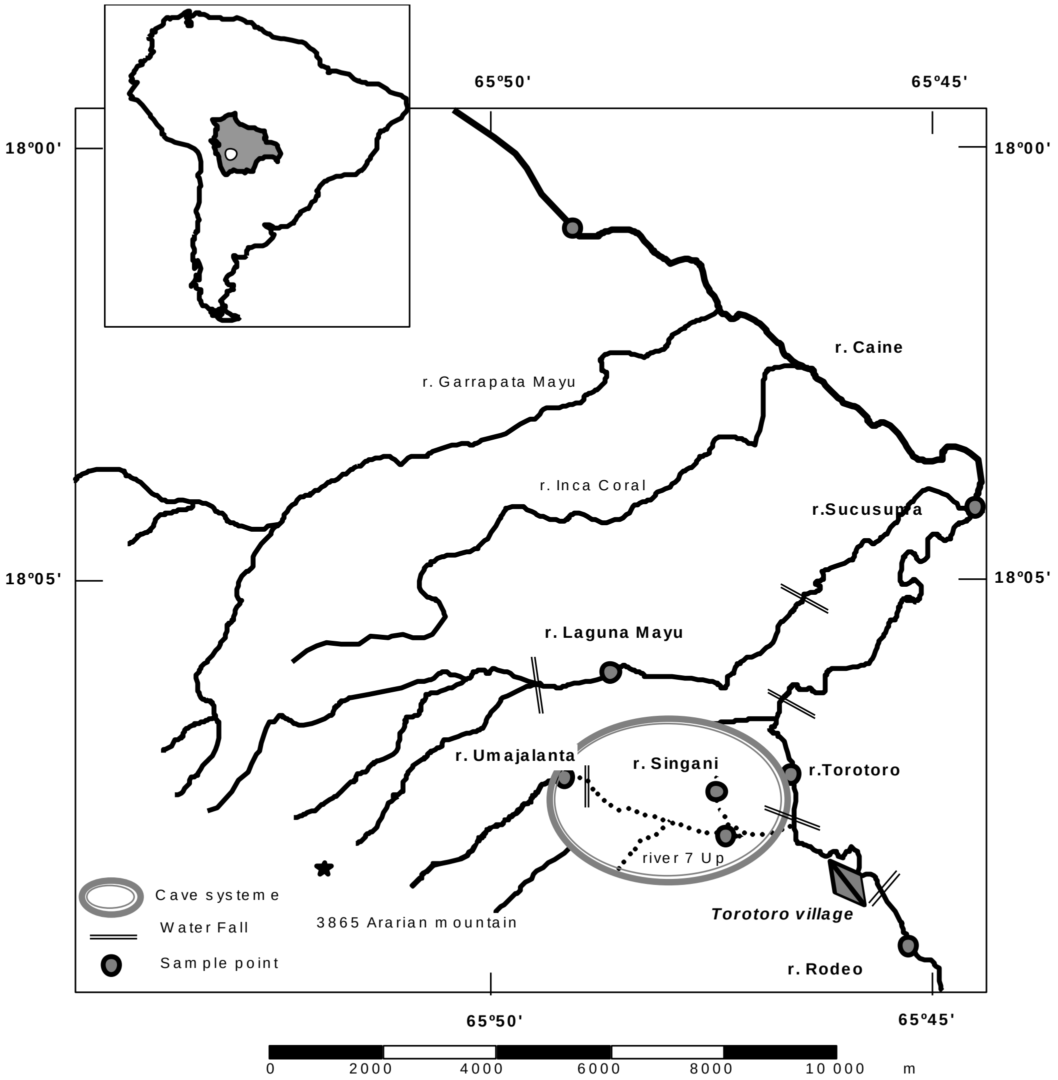

Figure 1. Hydrographic network of Torotoro National Park. The points present the fish samples populations. The circle corresponds to the subterranean part of the network in Umajalanta cave (rio Umajalanta and rio Singani)

Morphological Measures

Four morphological attributes, known to be affected by cave life adaptation (GINET & DECOU, 1977; CULVER, 1982), were considered. Length of maxillary barbels were measured from insert until tip and expressed as a ratio with the standard length of the individual. Diameters of left and right eyes were measured horizontally and expressed as a ratio between the left and right diameters average and the standard length of the individual. Pigmentation level was estimated by a mean number of chromatophores per mm^2 after counting chromatophores on 1 mm^2 in three body parts (right post cephalic region, region of the lateral line at the tip of pectoral and pelvic fins). Surface of 4 main encephalon parts (smell lobes, optic lobe, oblong medulla and cerebellum) were estimated by measuring the maximum length and width and considering they had an ovoid form. An analysis of variance was performed to determine the differences of attribute values among the populations.

Reproductive Strategy

Fecundity and eggs diameter were considered as an estimation of reproductive strategy. They were determined from mature females (corresponding in stage 5 of BAGENAL's categorization (1978). For each mature female, after the extraction of the entire gonads, eggs were counted in totality as a estimation of fecundity. Then, diameter of 30 randomly selected eggs was measured with a micrometric scale under a microscope. An analysis of variance was performed to determine the differences in number and eggs diameter among the populations.

Results

Morphology

Barbels. Significant differences existed in maxillary barbels length among the 8 populations (F = 9,039, p<0.001). However the differences did not correspond to an environmental or a spatial pattern (Fig 2). The populations of Laguna and of the superficial parts of Umajalanta and subterranean river Singani showed the largest barbels whereas the populations of the Torotoro canyon and from the Caine river showed the smallest one.

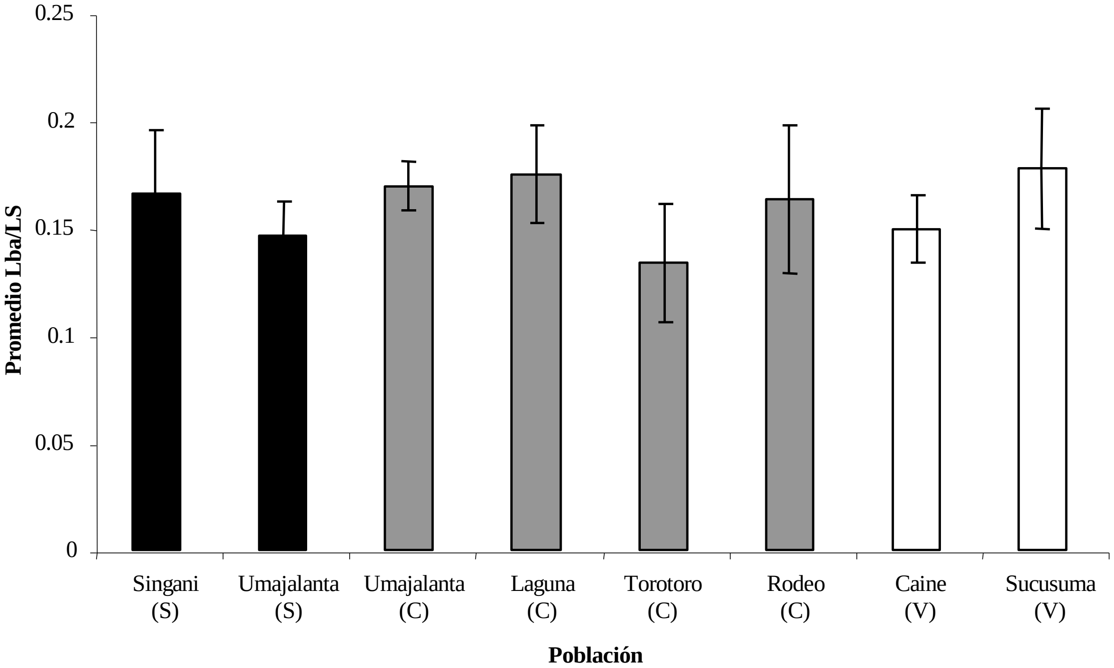

Figure 2. Mean and standard deviation of maxillary barbels length of 8 Trichomycterus populations from different habitats: subterranean rivers (S), canyon (C) and valley (V).

Eyes. There was a significant difference (F = 24.770 and p <0,001) in eyes diameter between the cave and the epigean populations. Populations of the Umajalanta system showed a reduction of eyes diameter in comparison with the other populations (Fig 3).

Pigmentation. The number of chromatophores was also significantly different among the 8 populations (F = 4.837 and p <0.001). As in the case of barbel length there is no clear pattern with an environmental or a spatial interpretation. The smallest number of chromatophores was recorded in the hypogean population of Umajalanta river, but the maximum value was observed also in the hypogean populations of Singani river (Table 1).

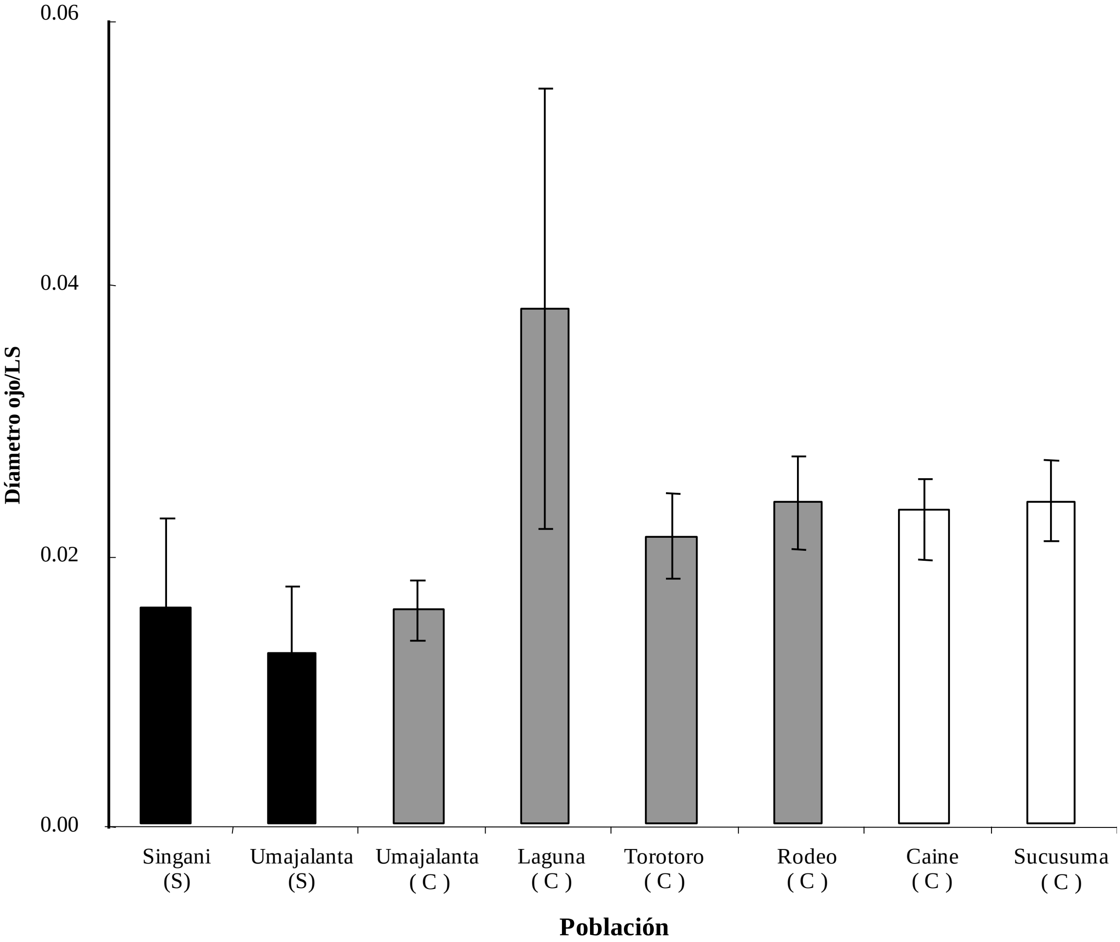

Figure 3. Mean and standard deviation of eyes diameter of 8 Trichomycterus populations from different habitats: subterranean rivers (S), canyon (C) and valley (V).

Encephalon. Optic lobes areas, telencephalon and oblong medulla areas were significantly different among the populations (respectively F = 3.097 and p < 0.05; F=11.665 and p < 0.001; and F= 2.672 and p < 0.05). Optical lobes appeared smaller in cave populations than in superficial populations (Table 1, Fig. 4) but conversely the telencephalon (which corresponds to smell lobes and brain) appeared larger in cave populations than in superficial populations. Cerebellum areas did not show significant differences among the populations (F=1.693; p < 0.163), however as for oblong medulla there was a tendency of smaller values in the canyon populations and higher and similar values in cave and valley populations.

Reproduction

The two parameters, fecundity and eggs diameter, were significantly different among the 8 populations (F = 3.273 and p = 0.007; F = 102.566 and p = 0.000; respectively). The results showed a trend from valley to canyon and subterranean rivers, which corresponds to a reduction of the fecundity and an augmentation of eggs size (Fig. 5)

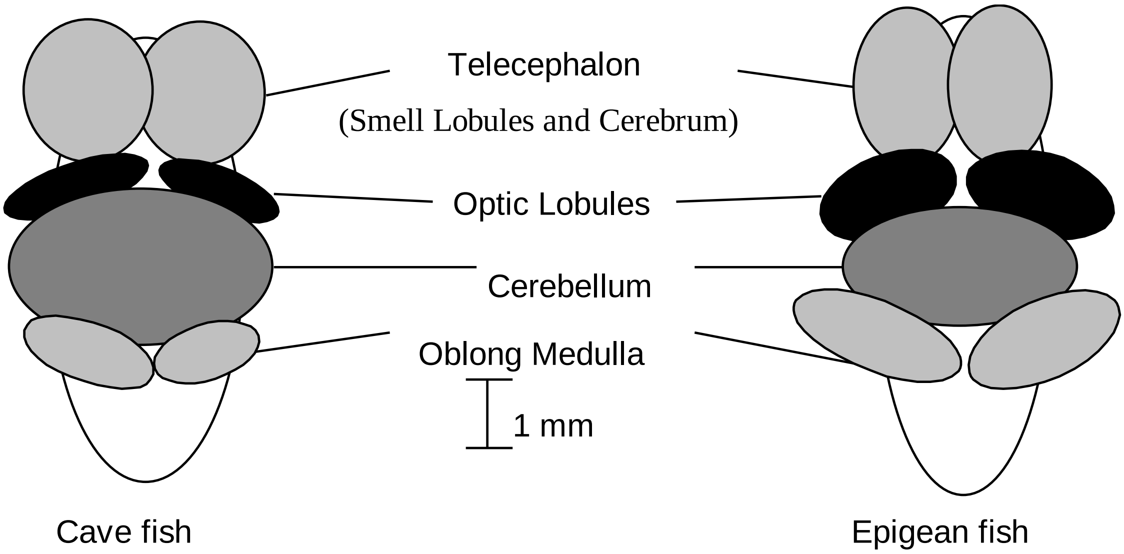

Figure 4. Comparison scheme of encephalon of epigean and hypogean Trichomycterus (based on surface calculation of each parts of the encephalon in 30 individuals

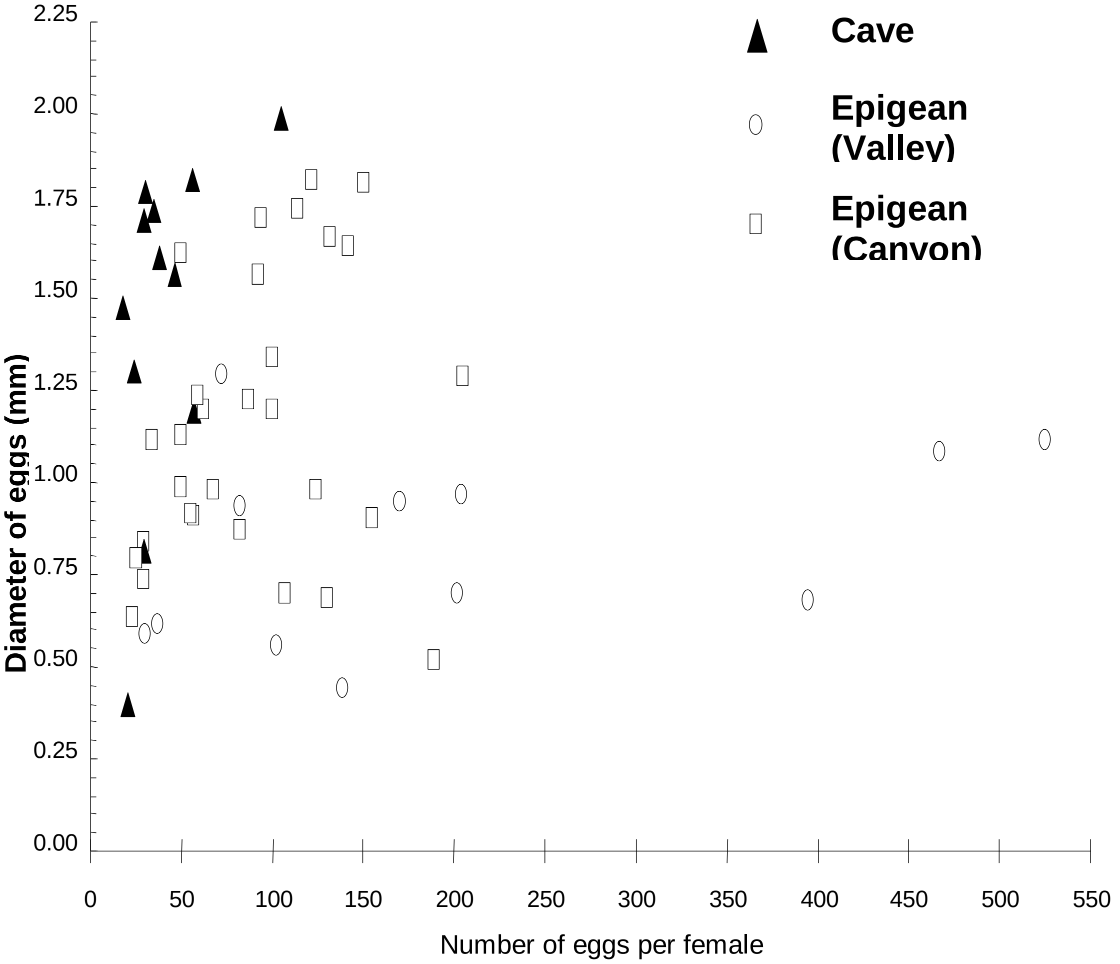

Figure 5. Relationships between eggs diameter and fecundity in 53 mature females from different habitat rivers: subterranean rivers, canyon and valley

Discussion

Eye reduction is without any doubt the most obvious adaptation of cave animals (EIGENMANN, 1909; POULSON, 1969; MITCHEL *et al.*, 1975; CULVER, 1982). The regression process begin first by the reduction in size of the optic apparatus (eyes and brain optic lobes) which result in a partial or a total blindness. According to the isolation time of the population, the regression process can evolve so far as the total loss of the optic apparatus (anophthalmy) and, in case of fishes, to deep modifications in skull structure (BREDER, 1944). Eyes of *Trichomycterus chaberti* of Umajalanta cave are still present but show a significant diameter reduction in comparison with superficial populations. The eye diameter reduction is related to a similar reduction of optic lobes in cave fish brain, showing as evident the first step of a regression process.

As compensation to the loss of vision, cave animals develop other types of sensory perceptions like chemical or tactile ones (CULVER, 1982). *Trichomycterus chaberti* do not show any evidence of barbels modifications as an adaptation to cave life. In particular we did not observed the expected pattern of an increased barbel length in the hypogean populations. Because of their behavior (nocturnal life, deep and obscure habitat use) the Trichomycteridae, like the majority of Siluriformes fishes, present in general long barbels as a pre-adaptation to cave life (BERTIN, 1958). An interpretation for the lack of pattern in barbel length could be that these organs are sufficiently long to sustain an increase of activity. This hypothesis could be supported by the significant variations observed in brain size. Telencephalon (smell lobes and brain) reached a significantly larger size in cave populations in relation to the epigean populations. Therefore, this result supports the hypothesis of an increase of smell and tactile activity in compensation of loss of vision.

Another important adaptation of fishes to cave life mentioned in the literature is the considerable reduction of pigmentation (CULVER, 1982; GINET & DECOU, 1977). In our results from the *Trichomycterus* of Torotoro the density of chromatophores was highly variable and in addition did not correspond to the expected pattern of density reduction in the cave populations. The population of *Trichomycterus chaberti* that inhabit the river Singani of Umajalanta cave possesses the highest density of chromatophores. However, during sampling we observed a real appearance of depigmentation, which seems to be produced by the concentration of melanin in the central part of chromatic cells. We also observed that this appearance was clearly reversible by exposing some individuals to sunlight during a few minutes. Therefore, for this characteristic, we can conclude that there is no evidence of an evolution of the cave population in comparison with the epigean populations.

Fecundity and eggs size modifications result in a change of the reproductive strategy of the populations, which could be classically related to the environmental conditions of the rivers. *Trichomycterus chaberti* of Umajalanta cave shows larger eggs and in reduced number (K strategy trend), while the superficial populations spread to have small eggs and in great quantity (r strategy trend). The same tendency of modification has been observed by POULSON (1963) in the Amblyopsidae fish family. It is likely that in subterranean habitats the environmental conditions are more stable than in superficial habitats and that organisms like fishes did not support any predators. These conditions could explain the modification of the reproductive strategy of populations adapted to cave life. Food rarity is another condition of the subterranean habitats. The increase of egg size could give a better autonomy at the beginning of larval stage and then could be favorable for the development of the population.

Population	Habitats	N	Eye diameter / SL		Maxillary Barbels/SL		Chromatophores /mm^2		Optic lobe /SE		Telencephalon/ SE		Cerebellum /SE		Medulla/SE	
			A	S. D	A	S. D.	A	S. D.	A	S. D.	A	S. D	A	S. D.	A	S. D.
Singani	Cave	15	0.0161	0.007	0.1662	0.03	88	37	0.0917	0.018	0.2341	0.017	0.4806	0.106	0.1015	0.013
Umajalanta	Cave	15	0.0127	0.005	0.1467	0.016	47	14	0.0913	0.014	0.2512	0.024	0.4948	0.092	0.1032	0.035
Umajalanta	Canyon	7	0.0159	0.002	0.1699	0.012	59	5	---	---	---	---	---	---	---	---
Laguna	Canyon	20	0.0382	0.016	0.1757	0.023	75	44	0.1233	0.019	0.149	0.01	0.3307	0.05	0.0676	0.014
Torotoro	Canyon	30	0.0214	0.003	0.134	0.028	77	25	0.1266	0.018	0.1652	0.025	0.3519	0.072	0.0728	0.026
Rodeo	Canyon	30	0.0239	0.004	0.1637	0.035	55	29	0.1418	0.04	0.1587	0.032	0.3855	0.137	0.1065	0.043
Caine	Valley	30	0.0234	0.003	0.15	0.016	83	32	0.1296	0.014	0.1717	0.046	0.4575	0.118	0.1267	0.021
Sucusuma	Valley	30	0.024	0.003	0.178	0.028	85	33	0.1452	0.046	0.1555	0.021	0.4395	0.131	0.1231	0.034
F			24.77		9.039		4.837		3.097		11.665		1.693		2.672	
p			<0.001		<0.001		<0.001		<0.02		<0.001		<0.163		<0.037	

Table 1. Averages (A) and standard deviations (S.D.) of morphological measurements in cave and epigean Trichomycterus in 8 populations of National Park of Torotoro (Bolivia). SL: Standard leng, SE: Surface encephalon.

Conclusion

In conclusion, from all the morphological and biological parameters considered in our study, we observed different levels of modification between the hypogean and the epigean populations of *Trichomycterus* from the Torotoro National Park. The optic perception (eyes diameter and surface of optic lobes) and the two parameters of reproduction show a clear tendency of adaptation to cave life. Pigmentation, generally affected by an adaptation to cave life, did not present any evidence of modification. Chemical and tactile perceptions (barbel length and telencephalon surface) show an intermediate situation with a nervous modification but without morphological changes. It is then likely that the populations of *Trichomycterus chaberti* of Umajalanta cave are the result of a recent incursion to the subterranean habitat and that they are in process of adaptation. It would be benefit to work more precisely on these populations to determine how the cave populations have genetically derived from the superficial ones and which part of the observed modifications is due only to the interaction with the environment in the embryonic and post-embryonic development.

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Comparison of the Culturable Bacterial Flora from Three Microenvironments from Pečina v Borštu Cave (South-West Slovenia)

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Abstract

Pečina v Borštu cave is situated in the karst area of Matarsko podolje in the south-west part of Slovenia. The cave was formed in Upper Cretaceous limestone which is in some parts of the cave extremely weathered. We have analysed samples from three different microenvironments in this cave: silver flashing droplets, water from a small pond and weathered limestone bedrock of the cave wall. In the water sample approximately 10^4 colony forming units (CFU) per millilitre were detected, whereas the weathered limestone contained approximately 10^6 CFU per millilitre. Fluorescent pseudomonads were found in all three environments. In the silver droplets a single species of a fluorescent pseudomonad was isolated. The bacterial flora in other two environments was more diverse; Gram negative nonfermentative bacteria and actinomycetes were isolated from both samples. The water contained also violet pigmented bacteria and Gram positive cocci.

Introduction

Pečina v Borštu cave is situated about 100 m above a blind valley called Jezerina where a smaller stream sinks at the contact between Eocene flysch rocks and Paleocene and Cretaceous limestones (ŠIKIĆ et al., 1972). The cave is about 250 m long and it follows the S – N direction. Active water flow is not present anymore but in some parts of the cave after atmospheric precipitation the water percolation through cave ceiling is very strong. The average annual temperature in inner parts of the cave is about 10°C but near the entrance of the cave variation of the temperature corresponds to outside changes of the temperature. Cave walls are covered by flowstone and speleothems of different ages and forms. Almost all cave walls are extremely weathered and may be seen just in cases where flowstone was not precipitated or was already corroded. Weathered zone on limestone walls varies from few millimetres to some centimetres. In the cave clastic deposits originated from flysch background are found. The main component of the deposit is quartz mixed with some clay minerals.

The karst caves are extreme environments (PEDERSEN, 2000) with constant temperatures and humidity, but generally with low nutrient input. In a single cave different microenvironments can be found. The aim of this study was to determine variability of bacterial microflora from three different niches within a single cave.

We have selected Pečina v Borštu cave because of the presence of special microenvironments: silver flashing droplets, water from a small pond and weathered limestone bedrock of the cave wall.

Silver flashing droplets are famous among speleologists as “cave silver”. Water droplets are formed near the cave entrance where cold and warm air mix and its presence is connected to condensation. We decided to take this sample to clear up if this fluorescence is connected with biological activity.

Second tested microenvironment was pond filled with water, unusual because of calcite rafts formation on its surface. This pond is periodically filled up with water controlled by raining regime. During the rain period there could be a niche for biofilm foundation and eventual calcite precipitation promoted by present microorganisms.

Weathered limestone could be referred to as one kind of “moonmilk”. This term is used to describe aggregates of microcrystalline substances of varying composition. Moonmilk could be formed as disintegration of bedrock and speleothems or as a mixed deposition of calcite crystals and water (HILL & FORTI, 1997). The extent of microbial involvement in the formation of speleothems and in weathering process of limestone is still being discussed. Microbes possess biochemical pathways which can contribute to the dissolution and mobilization of carbonates (ATLAS & BARTHA, 1997).

We have measured *in situ* pH by using Testo® pH-meter system with special electrode. Measurements of pH were made in silver flashing droplets (pH range from 7,66 to 7,65), in water of the pond (pH from 7,51 in the bottom to 7,80 on the water surface). Weathered zone of limestone is periodical wetted by percolating water and its wetness depends directly on atmospheric precipitation at surface. The pH of weathered limestone measured at the same time varies from 7,38 to 8,25 (almost at all measured points the pH values varies in range from 7,8 to 8,2; only in very damp sample the pH was 7,38) at constant temperature 10,6 °C. The value 7,38 is still in range of light aggressiveness, the other values indicate supersaturation of water solution in pores of weathered limestone zone. The pH laboratory measurements in the case of weathered limestone was also carried out and ranged from 8,0 up to 8,2.

Material and Methods

Determination of Total Bacterial Count

Samples were aseptically taken from the cave and transferred into the laboratory. Several cultivation media were tested for bacterial growth: (1) Prep medium contained 1 % weathered bedrock, 0,1 % yeast extract and 1,5 % agar. It was used to mimic the nutrient content of the weathered limestone. (2) King B (Difco, USA) is standard isolation medium that supports good growth of most heterotrophic bacteria.

Samples were diluted in a physiological solution and 0,1 ml of appropriate dilutions were inoculated on the plates. Plates were incubated at 10°C. After 14 days the bacterial colonies were counted and total number of culturable bacteria was calculated.

Characterization of Pure Cultures

On the primary plates all different morphotypes of bacterial colonies were selected and streaked onto fresh King B medium until the pure culture was obtained. Cultures were grouped according to the following tests: presence of oxidase and catalase, growth temperature, oxidative vs. fermentative metabolism, production of fluorescent pigments, motility, gelatinase, nitrate reduction, degradation of several carbohydrates and degradation of amino acids (MAC FADDIN, 1980).

Optical microscopy was also performed to determine Gram staining and cell morphology. For violet pigmented cultures the absorption spectra was determined as described in BOARD *et al.* (1992).

Results and Discussion

Cell Count of Culturable Bacteria

Cell count was determined only for water and weathered limestone, but not for silver flashing droplets due to small amount of the sample. (Table 1)

Weathered limestone contained more bacteria than the pond water. Interestingly, bacteria from limestone sample preferred Prep medium (prepared with weathered limestone), whereas the growth of pond water bacteria was better on King B medium. Obviously the bacteria in weathered limestone sample are well adapted to special nutrients available in such microenvironment.

Microbial Diversity Among Three Distinctive Samples

Bacteria isolated in pure culture were divided into five groups (Table 1).

Fluorescent pseudomonads were characterized by production of fluorescent pigment on King B medium. All of them are motile Gram negative rods, with oxidative metabolism, but differ in utilisation of sugars and amino acids.

Oxidative Gram negative bacteria with no production of fluorescent pigments were defined as Gram negative nonfermentatives.

The third group represents violet pigmented strains, which were Gram negative rods with fermentative metabolism. Regarding to absorption spectra the pigment was violacein (BOARD *et al.*, 1992). Therefore, the strains most likely belong to the genus *Chromobacter*.

The remaining two groups of Gram positive cocci and Gram positive irregular rods were characterized by their microscopic morphology.

The bacterial microflora in three studied microenvironments from Pečina v Borštu cave differs not only in cell count, but also in the community structure. In the silver flashing droplets we isolated only one strain of bacteria belonging to the fluorescent pseudomonads group. However, the presence of these bacteria is not a reason for fluorescence as droplets show no fluorescence under UV light. In the case of pond sample we isolated quite heterogeneous bacterial microflora, belonging to different groups (Table 1). Weathered limestone microflora was also heterogeneous. Fluorescent pseudomonads seem to be prevalent microorganisms which can be due to their versatile metabolic pathways.

Table 1 - Bacterial counts and their diversity in three different cave microenvironments

	HABITAT (microniche)		
	SILVER FLASHING DROPLETS	POND	WEATHERED LIMESTONE
BACTERIAL COUNT	**COLONY FORMING UNITS (CFU) / ml**		
King B	ND	$2,5\times10^4$	$4,0\times10^4$
Prep medium	ND	$1,0\times10^4$	$1,1\times10^4$
BACTERIAL GROUPS	**NUMBER OF ISOLATED STRAINS**		
FLUORESCENT PSEUDOMONADS	1	6	5
GRAM NEGATIVE NONFERMENTATIVES		6	2
GRAM NEGATIVE FERMENTATIVES *(violet pigment)*		2	
GRAM POSITIVE COCCI		1	
GRAM POSITIVE IRREGULAR RODS *(Actinomycetes like)*		4	4

ND – not done

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The Sangki System (Sumatera Barat, Indonesia)

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Abstract

The Sangki system is developed in the impressive cone-karst of Gunung Seribu (Indonesia: Sumatera Barat). The underground Sangki river crosses the limestone range from northeast to southwest. From its sink, the river can be followed on about 6 km in large galleries interrupted by several boulder zones (Ngalau Surat, total development more than 6.5 km). The passage continues downstream, but retreat was decided because of Mulu Foot desease. The Sangki river resurges among a boulder choke which cannot be entered. However, a little higher in the massif, Ngalau Ikan Sangki gives another access to the river. This fine river cave, unfortunately littered with plastic bags left by swiftlet nest collectors, was followed 1 km downstream and about 3 km upstream. At this point, we were at a few hundred metres from the extreme downstream point of Ngalau Surat, but connection was not made by lack of time. Ngalau Sopan Kijang is a third, large fossil cave which joins the Sangki river 2 km from Ngalau Ikan Sangki entrance. At last, Ngalau Puangan Hilir, a stream sink several kilometres north of the Sangki resurgence, has been explored on 1.3 km to a choke. It probably corresponds to the large inlet which arrives a few hundred metres of the downstream terminus of Ngalau Surat. The four parts of the system develop altogether 12.3 km, and their connection would make it one of the largest subterranean system in Indonesia. The Sangki system is also interesting for its subterranean fauna, now the best known of Sumatra. Several troglobitic species and a few stygobitic ones have been discovered, as listed in this paper.

Introduction

A long range of permo-carboniferous limestone extends on 100 km ENE of Padang, from Payakumbuh basin to Sungaidareh, following the general direction NW-SW of the Sumatra island. The main massifs of this range are the two impressive cone karsts of Gunung Seribu (“thousand mountains”) and Gunung Ngalau (“mountain of the cave”), separated by the Batang Kuantan river. At the foot of the extinct volcano Gunung Malintang (2262 m), Gunung Seribu stretches 35 km long for up to 5 km wide. A multitude of peaks rise up to 650 m above the level of the Sinamar river which flows parallel to the massif from 350 to 200 m of altitude.

The caves

Gunung Ngalau is the place of the first large western speleological expedition in Southeast Asia: in 1977, a Catalan group explored the large underground river of Ngalau Lagung on more than 4 km (ULLASTRE-MARTORELL, 1978). The speleological exploration of Gunung Seribu began with an expedition of the Association Pyrénéenne de Spéléologie in 1993 (BEDOS *et al.*, 1994), followed by several visits of the same group in 1995 (DEHARVENG & BEDOS, 1996), 1996 (DEHARVENG *et al.*, 1998), 1998 (DEHARVENG *et al.,* 2000) and 2000 (DEHARVENG, 2000; PRICE, 2001). Three large caves and a smaller one were explored on the system (table 1).

The sinks of the rivers Sangki and Puangan Hilir were discovered in 1993 during a short reconnaissance trip. A one day walk from the small town of Lintaubuo through Tabatpadjang led us to the place where the Puangan Hilir stream enters the mountain. François Brouquisse equipped the shaft (-61 m) and explored 156 metres on the second day (BROUQUISSE *et al.,* 1995). Meanwhile, we pushed to the Sangki river sink. After a half-day jungle walk, we easily found the entrance and followed the stream on 1.9 km in a vast gallery, by place 50 m wide and 30 m high, meandering in a roughly northeast-southwest direction. We halted in small galleries after at a large chamber (“La Grande Salle”, about 200 m x 50 m) with obvious way on.

The 1995 and 1996 expeditions focused on Ngalau Surat. Just after the large chamber, the river flows in a relatively narrow passage; and suddenly switches to a SEE-NWW direction. The size of the passage rapidly increases afterwards, with galleries often similar to the first part of the cave, though a bit smaller (often 10 m large and 20 m high). The river was followed on four more kilometres without real obstacle other than five huge boulders. At about 1.5 km from the big chamber, the river flows at high speed for 120 metres in a narrow (2 m) and straight diaclase developed in a breccia polished by water (“The Breccia”). Half kilometre later is the only waterfall of the Sangki river: + 2.5 metres. At more than 5.5 km from the entrance of Ngalau Surat, an inlet as large as the Sangki river itself arrives from the north at the level of a huge room partly filled with boulders. It was followed 150 m upstream to another huge boulder. This inlet might be the Puangan Hilir river, or, after local people, another river which sinks a few hundred metres from Puangan Hilir. Short after the inlet junction and the boulders, the main stream entirely occupies a low (about 1.3 m) and windy passage, which opens on a large meander beautifully decorated. As water level of the stream showed signs of rising, and severe foot pain was beginning to affect some of the cavers, we had to stop exploration. The trip back to the entrance lasted about 6 hours.

Table 1 - The caves ("ngalau") of the Sangki system (see bibliographical references for details)

	1993	**1995**	**1996**	**1998**	**2000**	**total mapped**	**total explored**
Surat	1749 m	2559 m	2216 m	0	0	6524 m	7000 m
Puangan Hilir	156 m	0	1138 m	0	0	1294 m	1500 m
Ikan Sangki / Sapan Kijang	0	0	0	2824 m	2141 m	4965 m	5200 m
Ngalau Batang Sangki	192 m	0	0	0	0	192 m	200 m

[Parts of the cave of Surat and Sangki have been re-mapped, accounting for the differences with values given in previous reports like DEHARVENG *et al.*, 2000)].

The exploration of Puangan Hilir was completed during the 1996 expedition. The maze of small tubes at the bottom of the entrance shaft leads to a vertical narrow passage, which gives access to a small inlet choked upstream after 100 m. Downstream, the main stream is rapidly reached. The gallery increases in size, becoming similar to those of Ngalau Surat. Two boulders slow the progression in the last 200 m explored. We stopped at a third boulder where continuation appeared to be more technical.

During the first three expeditions, we were repeatedly told of large caves near the Sangki spring. Visiting this resurgence in 1993, we only found a short fossil passage (Ngalau Batang Sangki) where we stopped at the head of a narrow 10-15 metres pitch without wind. The resurgence itself (1 to 2 m^3 per second after BROUQUISSE *et al.,* 1995) emerges from a large boulder and is not penetrable. It is only in 1998 that tongues loosened, and we were informed of two big caves near the Sangki spring. After long negotiations with the local police and Koramil (army), we got at the last moment a permit to enter Ngalau Ikan Sangki and Ngalau Sapan Kijang, the two major swallow nest caves of the area, located near the Sangki spring. In the remaining 3 days of the 1998 expedition, we mapped 2824 m of passages (of which 924 m were re-mapped in 2000), including 2148 metres of river, in large galleries, often 10-15 m in diameter. When we came back in 2000 however, the situation had completely changed. Armed militia of villagers replaced the army at the entrance of the cave. The situation was tense between the villagers and the companies which used to exploit the nests, and even between groups of nest harvesters from different villages. The traditionally sustainable exploitation of swallow nests, a huge local income (KAHAR, 2000), was only souvenir. Bands entered the cave day and night for harvesting, and the more visible environmental effect was that the river galleries were littered on kilometres with an incredible quantity of plastic bags, batteries and various abandoned instruments. Negotiations to enter the cave were also much harder. We got permit from traditional authorities (companies and police), but they were no more recognised by the militia. We were finally granted two underground trips. Sapan Kijang, a large fossil cave which is the main access to the Sangki underground river for nest harvesting, was mapped on 494 m to its junction with the Sangki river in Ngalau Ikan Sangki. In this last cave, 1.3 km of river led to a very large boulder which ended after 155 m in a very narrow and unstable passage. Beyond, 200 metres of large galleries were explored. At most a few hundred metres remain to link Ikan Sangki to Ngalau Surat.

The Fauna

Cave fauna of West Sumatra is among the best known in Indonesia (LECLERC *et al.*, in press), but that of Gunung Seribu was totally unknown. The biodiversity of the Sangki system caves is rather high, with a few highly troglomorphic species. Several of these taxa, new to science, are under description. The list given in table 2 updates and complements the previous lists of BEDOS & DEHARVENG (1998) and DEHARVENG & BEDOS (1995, 2000).

Perspectives

The cumulative mapped length of the four caves of the system is 13 kilometres. Connecting Ikan Sangki and Surat would give a 10 km through trip along the subterranean Sangki river, and will be the main objective of the next expedition. On old Dutch maps of 1893, many other caves and stream sinks are spotted in the karst above the Sangki system. Do they connect to the main collector? Will they give access to fossil passages like Sapan Kijang? Our second objective will be to look at these numerous karst features. At least, a collaborative work is planned with Museum Zoologicum Bogoriense and Padang University, to explore the effect of karst fragmentation on subterranean endemism in the karsts of Western Sumatra.

Acknowledgements

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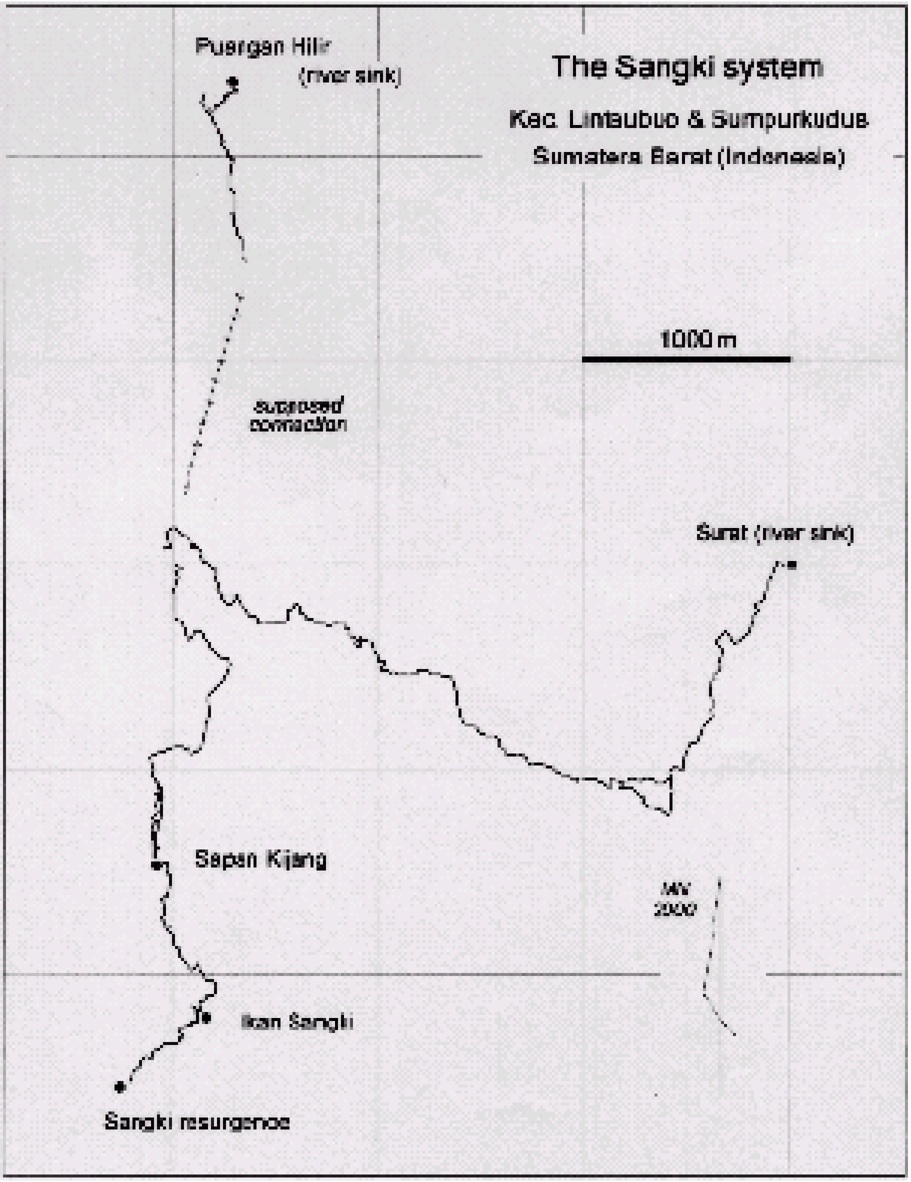

Table 2 - The fauna of the Sangki system caves. Only troglobites (T), stygobites (St), guanobites (G), wall fauna (P), important stygophiles (Stp) and important troglophiles (Tp) are listed. 1, Surat; 2, Puangan Hilir; 3, Ikan Sangki; 4, Batang Sangki. spp.: several species are present.

Plathyelminthes		
Tricladida sp.	St?	1
Annelida		
Hirudinea sp.	T,P	1
Mollusca		
Gastropoda spp.	G	1
Arachnida		
Acari: Gamasida spp.	G	1
Acari: Trombidiidae sp.	T	1
Acari: Uropodida spp.	G	1
Amblypygida: *Phrynichosarax* sp.	G	1
Araneae spp.	T	1,4
Araneae: *Heteropoda* sp.	G	1,3
Araneae: Pholcidae (?) sp.	G,P	1
Opilionida sp.	T	1,2
Pseudoscorpionida sp.	T	1
Schizomida sp.	G,T	1,3,4
Crustacea		
Amphipoda: Bogidiellidae sp.	St	1,3,4
Decapoda: *Malayapotamon brevimarginatum*	Stp	1
Isopoda: Armadillidae spp.	G,T	1,3,4
Isopoda: Philosciidae spp.	T,Tp	1
Isopoda: *Stenasellus* n.sp. nr *strinatii*	St	1
Isopoda: Trichoniscidae (?) sp.	T	1
Myriapoda		
Chilopoda: Geophilomorpha sp.	G	1
Chilopoda: Scutigeromorpha sp.	G,P	1,3
Diplopoda sp.	T	1,4
Diplopoda: Cambalopsidae sp.	G	1,4
Diplopoda: Glomeridesmidae sp.	T?	1
Collembola		
Acherontiella sp.	G	1
Coecobrya (?) sp.	G	4
Cyphoderopsis sp.1	T	1,3,4
Cyphoderopsis sp.2	G	1
Folsomina onychiurina	G	1
Oncopodura sp.	T	1
Pararrhopalites sp.	T	1
Insecta		
Blattodea sp.	G	3
Blattodea: Nocticolidae sp.	T	1,2,4
Coleoptera: Aderidae sp.	G	1
Coleoptera: *Ptomaphaginus* sp.	G	1,3,4
Coleoptera: Staphylinidae spp.	G	1
Diptera spp.	G	1
Diptera: Psychodidae spp.	G	1
Hemiptera: Emesinae sp.	G	1
Hymenoptera: *Anochetus subcoecus* (?)	?G	1
Hymenoptera: Formicidae sp.	G	1
Lepidoptera: Tineidae spp.	G	1
Orthoptera: *Rhaphidophora* sp.	G,P	1
Trichoptera: Trichoptera sp.	G?	1
Vertebrata		
Aves: Apodidae sp.	G,P	1,3
Mammalia: Chiroptera spp.	G,P	1
Pisces: *Puntius binotatus*	Stp	1
Reptilia: *Elaphe* sp.	G,P	1

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Past, Present and Future of Speleological Investigations in Morocco[2]

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Abstract

Moroccan speleological potentialities are very important over some 100,000 km^2 of exposed limestones. A valuable speleological report published 20 years ago mention some hundreds of penetrable cavities known at the moment. A number of new caves have been discovered and visited during last years, and the known part of some galeries significantly increased. For example the Wit Tmadouine network (including the longest subterranean river from North Africa), some 65 km East North-East of Agadir in the Western High Atlas, is passed from 8,5 km as mentioned in the literature to 19 km to date and is still not completely known. Other similar examples do exist in the Middle Atlas. During the "13th International Symposium of Biospeleology" held in Marrakesh in 1997, a particular attention was devoted to the fauna of caves and subterranean rivers or groundwaters. A number of cavities known only by local populations are still unknown to speleologists and biospeleologists. International collaborations between speleologists of any country, either for fieldworks or for publication of results of former explorations will be welcome by Moroccan young speleologist teams.

Moroccan speleological potentialities are very important: within some 100 000 Km^2 of exposed limestone areas, less than thousand cavities only are presently recorded and thus much speleological investigations remain to be performed.

The "Inventaire Spéléologique du Maroc", drawn up by C. LAMOUROUX and C. CAMUS, published in 1981 by the "Direction de l'Hydraulique" (Ministry of Equipment, Rabat), and the Bulletin of Speleological clubs of Rabat, Casablanca and Agadir, published in 1987, are the sole available basic data providing references of known cavities from the country.

After the departure of most French cooperation agents, the Moroccan subterranean cavities were and are still the object of many explorations, performed by different teams, especially by Moroccan-European groups. Therefore each year several expeditions and speleological sessions are organized in Morocco, in different regions of the country, and new gallery networks are frequently discovered.

The aim of our presence and participation to the 13th International Congress of Speleology is double: to present a general image of the speleology in Morocco, emphasizing the last discoveries but also and mainly to get in touch as much as possible with speleologists having already visited caves in our country, and who had not the opportunity of publishing the reports and results of their explorations. As a matter of fact during many recent prospections in different Moroccan regions, it clearly appears that most unlisted cavities however exhibit traces or marks of former non Moroccan speleologists. Therefore an insufficiency of communication and spreading of speleological information appears important for the whole community of speleologists interested in caves from this country. A better spreading of speleological information, and the publication of main results are very desirable for avoiding long and unprofitable researches of caves which are already located and known by former explorers. Moreover it is also regrettable and unnecessary to perform the topographic mapping of a cave or of a complex subterranean network if this work was already achieved by other cavers, but simply unpublished and often totally unknown in Morocco.

The publication of a new edition of the "Inventaire spéléologique du Maroc", including complements, revision and improvement of the first edition is essential for placing at user's disposal a more complete and up to date compilation of speleological data. This tremendous work will be possible only at the price of a close collaboration between the young Moroccan speleologists and the interested groups from other countries.

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[2] This paper is dedicated to the memory of our friend Hassan EL HACHTOUKI, who was an active caver. He contributed with one of us (M.M.) to the exploration of many new cavities in Morocco

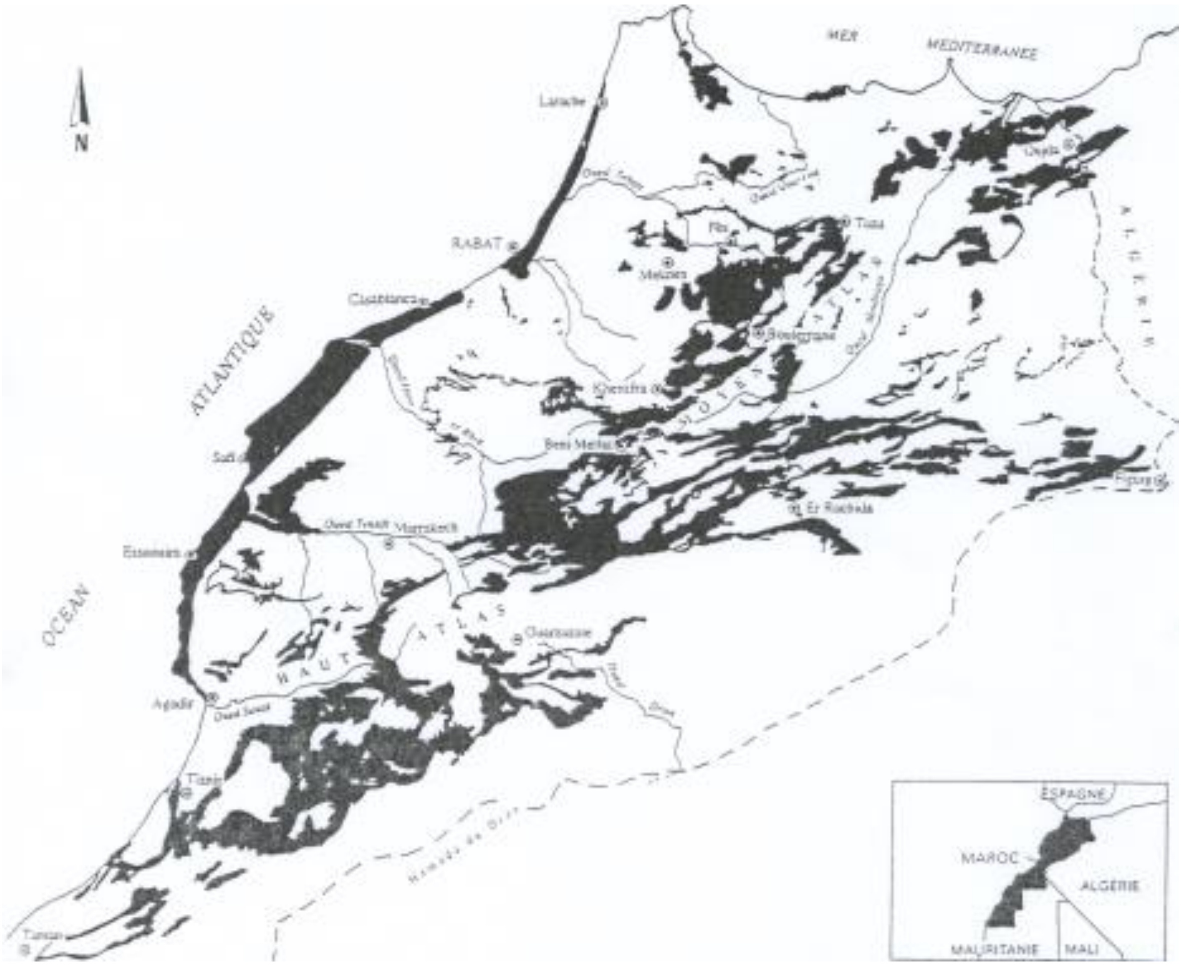

Figure 1 - Main regions of central and northern Morocco where limestones or calcareous sandstones, include or possibly include penetrable karstic cavities (from Boutin et al., 2001).

During last years the total development of several subterranean networks has been greatly enlarged after new explorations. The known part of the Win Tmadouine network for example (the longest subterranean river of North Africa located some 65 Km to the East North-East of Agadir) passes from 8,500 m as indicated in the literature to more than 19,000 m to date, and the works for freeing the galeries of obstructions are still going on. Chaara, the second subterranean river in Morocco, has been also the object of important discoveries and its development recently passes from 7,650 m to more than 10,000 m. Conversely several pits mentioned in the inventory were greatly modified or filled in by collapses; it is for instance the case of the "Aven des ours", or Bear Swallowhole; it is also the case of several other cavities which completely disappeared because of the development of built-up areas.

The Rifian region and particularly the Rifian limestone range is still very unevenly investigated. For example - not any cavity was explored to date in the Tetouan Haouz, a range 40 Km long and 1 to 4 Km broad, extending from the Jbel Moussa (848 m) near the Gibraltar Strait in the North, to the "Hercules columns" and Tetouan in the South. Similarly the Bokoyas Massif, located in the Eastern Rifian region, is still poorly known; its karstification may be limited but further exploration of a partly known cave should be worthy undertaken by diving. Last, if several cavities of the Rifian limestone ridge are known in the North, such as Kehf Gandous (- 88 m) in the Jbel Bou Zeitoun, but no penetrable subterranean water circulation has been discovered to date. Several cavities occur in the Oued Laou Gorges but the Ghar Knadel is the only one already explored. Finally the South-Eastern Rifian region, where the most expanded massif of the dorsal range occurs and exhibits the most important karstifications in the Kehf Toghobeit (- 732 m), some 180 cavities are known!

In the High Atlas most known caves are those located near main roads, even if the Jurassic limestone strata are more than 100 m thick, particularly in the High Tessaout Valley where we recently discovered the occurrence of interesting but still unexplored new caves. A long and exacting task, sometimes in hard conditions including long and difficult walks to the sites, are often necessary for a complete survey of most karstic areas located far from tracks.

In the Middle Atlas, a Moroccan-French collaboration led in 1997-98 to the discovery of several new cavities in the neighbourhoods of the Red Cave, "Chaara".

Concerning Biospeleology, since the "13th International Symposium of Biospeleology", held in Marrakesh in 1997, a particular attention was devoted to the fauna of cave, swallow holes and other subterranean habitats. In particular subterranean rivers and lakes also appear as refuges housing a remarkable biodiversity of aquatic species. The study of this fauna recently undertaken will lead to the knowledge of an unexpected animal diversity and, we hope, to a better understanding of the functioning of karstic ecosystems in our latitudes.

In conclusion, some important cavities have to be visited again, several diving surveys are urgently necessary, since the origin of subterranean waters of the two main exsurgences in Morocco, the Oum Erbia Spring and the Assif Asserdoun Spring, are still completely unknown. Great parts of several karstic massifs are still unexplored and the number of caves to survey is probably high. On the other hand we have still to regret a real delay concerning the publication of speleological results but Moroccan young speleologists are well disposed towards new collaborations either in field work or for the publication of former results.

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Pseudoniphargus (Subterranean Crustacean Amphipod) from Morocco: Systematics, Phylogeny and Ecological and Biogeographic Aspects

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Abstract

The interstitial groundwater amphipod *Pseudoniphargus* (Crustacea) is highly diversified in Morocco. Five species have been described from the northern part of the country. Recent surveys in the same region have resulted in the discovery of about ten species new for science. The phylogenetic relationships within the Moroccan species show three lineages. Freshwater species are derived from marine ancestors. Both the two-step model of colonization and evolution and the geological history of the region provide an understanding of their origin. During the Tortonian period, the marine ancestor lived in the coastal groundwater of the Tethyan South Rifian channel between the Rif and Africa. The establishment in continental groundwaters is due to the Tethys regressions in the late Tortonian and the early Messinian periods. Further diversification and speciation of extant endemic species result from the Rifian orogenesis as well as from the edification of recent hydrographic systems.

Introduction

The species of the genus *Pseudoniphargus* constitute a distinct group within the Hadzioida Superfamily (STOCK, 1980; NOTENBOOM, 1988). Species of this group are known from both continental freshwater and littoral brackish water. They are widely distributed in the central and western Mediterranean, as well as on Atlantic islands such as Bermuda and Canary islands (NOTENBOOM, 1988; SANCHEZ, 1991; STOCK *et al.*, 1986, COINEAU & BOUTIN, 1996; FAKHER *et al.*, 1999).

In Morocco, the genus *Pseudoniphargus* exhibits five known species (COINEAU & BOUTIN, 1996; FAKHER *et al.*, 1999).

Recent Discoveries

Recent surveys in the northern areas of Morocco allowed to extend our knowledge on the biogeography of *Pseudoniphargus* species, and especially to discover about ten species unknown to Science (FAKHER, 1999).

In Morocco, *Pseudoniphargus* species occur only in the northern part of the country. It seems that they never lived beyond a line going from the Idrissid Land in the West, the Peri-Rifian corridor, to the coal-basin of Jerada in the east. Such a border line corresponds also to the northern limit of the amphipods *Metacrangonyx* distribution, where the two genera co-occur at several sites (MESSOULI, 1994).

Ecology, Biology, Evolution

The new species exhibit a high endemism degree and inhabit varied biotopes such as wells, springs and caves. Water conductivity is generally high and fluctuates from 116 to 17350 µS.cm^2. One species has been collected in a thermal spring with water temperature reaching 44°C.

Pseudoniphargus length varies from 3.5 to 11.5 mm in the Spanish species *P. incantatus* Notenboom, 1986 and *P. grandis* Notenboom, 1987 respectively. In Moroccan representatives, dwarfish species exist (1.7 to 2.2 mm). These latter species probably result from progenetic evolutionary processes. During the development, the ancestors reached a precocious sexual maturity and adults retain a number of characters which can be observed at the first post-embryonic developmental stages of large *Pseudoniphargus* species. Such evolutionary process may be viewed as an energy economy in an interstitial milieu provided with low energy allocation. Processes of heterochrony may result from one or a few molecular change in developmental genes and provide a better understanding of important discontinued morphological evolution within a crustacean group.

Phylogeny

A phylogenetic study of the Moroccan species results in three distinct lineages exhibiting both original characteristics and affinities with the species from the Canary islands and the Iberian Peninsula.

The first lineage, which is composed of only one species, is characterized by the coxal plates 1 to 4 clearly longer than wide, the flagellum of the antenna 2 shorter than the last peduncular segment, and epimeral plates without spines.

The second lineage comprises elongate species which have pereiopods 5 shorter thant pereipods 4, gnathopods with short carpus, pereiopods 7 longer than pereiopods 6, and uropods 3 with the peduncle armed with lateral spines.

Species of the third lineage can be easily recognized due to the epimeral plates exhibiting at least three ventral spines.

Historical Biogeography

The present distribution of Moroccan *Pseudoniphargus* representatives shows that most of the species are located in regions which have been covered by the Tethys sea during the Tortonian period (BOUTIN & COINEAU, 1988; COINEAU & BOUTIN, 1996; FAKHER *et al.*, 1999). Furthermore, the location of different species within these latter areas in groundwater with a high content of chlorures (up to 1554 mg.L^{-1}) is an additional argument concerning the marine origin of these amphipods.

A possible historical biogeographic scenario for the Moroccan species of *Pseudoniphargus* is discussed. This scenario is based on the "Two-step Model of Colonization and Evolution" (BOUTIN & COINEAU, 1990; NOTENBOOM, 1991; HOLSINGER, 1994) on the one hand, the palaegeography and the geological history of the areas populated by *Pseudoniphargus* species on the other hand (MICHARD, 1976; DERCOURT *et al.*, 1985; ALVINERIE *et al.*, 1992; Cartes E.S.G. Maroc, 1992; DERCOURT *et al.*, 1993).

During the Tortonian period (10 Ma), Tethian marine south Rifian corridor separated the new allochtonous Rifian area from the northern African continent. The Tethyan Mediterranean domain communicated with the Atlantic ocean through this Rifian corridor. The common ancestor of all species of the Moroccan *Pseudoniphargus* lived in the interstitial sands of the littoral area of this south Rifian channel during the Tortonian period. This ancestor settled in continental freshwater due to the regressions of the western and the eastern parts of the south Rifian channel in the Late Tortonian (ALVINERIE *et al.*, 1992; COINEAU & BOUTIN, 1996; FAKHER *et al.*, 1999). Thereafter, further diversification, speciation and vicariance resulted from the Rifian orogenesis and the subsequent erosion: the edification of new important hydrographic systems contributed to evolution through vicariance and endemism in isolated valleys. Furthermore, passive dispersal of groundwater populations downstream of present rivers, extended their distribution to locations not covered by the former Tethys corridor. Such latter species are therefore secondary established; it is corroborated by sympatric and sometimes syntopic species, by the site proximity of different species, as well as by the overlap of the distribution areas of different lineages of *Pseudoniphargus.*

Aknowledgements

The investigations were supported by the Action Intégrée Franco-Marocaine n° 198/SVS/99 and the Project Pars n° 162/ Biologie

Figure 1 - Distribution of the species of Pseudoniphargus in the northern region of Morocco and extension of the Tethyan south-Rifian channel in the Tortonian period (dotted area). Small solid circles: species to be described. After the maps of the Edition du Service Géologique du Maroc, Rabat and ALVINERIE et al. (1992)

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Palaeobiogeography of the Freshwater Isopods Microcerberidae (Crustacea) from Caribbean and North America

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Abstract

Freshwater species of the interstitial Microcerberidae (Crustacea Isopoda) occur in restricted, local areas of the world, compared to the world-wide distribution of the coastal marine representatives. In U.S.A., two inland species of *Microcerberus* form the sister group of the species from Rumania and Bulgaria. On Cuba, *Yvesia* lives in brackish water of wells. The two genera exhibit plesiomorphic characters. Both plate tectonics and Tethys regressions provide an understanding of their evolutionary history. The marine ancestors lived in the littoral of the Tethys since the opening of the Central Atlantic and could have settled in freshwater of Southeastern USA at the end of the Cenomanian regression. The Caribbean plate derived from the Pacific toward the East, between the North and South American plates and small islands emerged since the Aptian. On Cuba, the ancestor of *Yvesia striata* might have been left by one of the regressions from Aptian up to the Eocene.

Introduction

Microcerberids are small isopod crustaceans living in the interstitial groundwater of marine sandy beaches and freshwater aquifers. Most species are known from littoral brackish water and belong to the genus *Coxicerberus* (WÄGELE *et al.*, 1995), which exhibits a worldwide distribution. In contrast, freshwater species occur only in limited local areas of the globe, i. e. northeastern South Africa, Morocco, Bulgaria, Rumania, ex-Yugoslavia, southern USA and Cuba (COINEAU, 1986, WÄGELE *et al.*, 1995).

Freshwater species form a monophyletic group (in progress). According to WÄGELE (1983, 1990) and WÄGELE *et al.*, (1995), inland microcerberids have a freshwater origin. In contrast, for CHAPPUIS (1954), DELAMARE DEBOUTTEVILLE (1960), COINEAU (1986), WILSON (1997) and TABACARU & DANIELOPOL (1999), freshwater microcerberids evolved from marine ancestors.

The purpose of this work is to consider the origin of freshwater microcerberids from North America and the Caribbean, based on phylogeny and palaeogeographic data.

Zoogeographic Pattern

Microcerberus carolinensis Wägele, Voelz & McArthur, 1995 is known from South Carolina, U.S.A.: Meyers Branch Creek, 33°10'54"N-81°34'53"W and 33°09'18"N-81°37'34"W (WÄGELE *et al.*, 1995), west of Charleston (Fig. 1).

Microcerberus sp., Strayer leg, occurs in NE of Anniston, Cleburne County, Alabama, U.S.A. (STRAYER *et al.*, 1995; ALBUQUERQUE & COINEAU, in prep.) (Fig. 1).

Yvesia striata Coineau & Botosaneanu, 1973 was collected by L. Botosaneanu from a well, western region of Santiago de Cuba, Cuba Island (Fig. 2).

Historical Biogeography

Microcerberus carolinensis and the closely related species *Microcerberus* sp. from U.S.A. form the sister group of species from central Europe. As previously proposed, the genus *Microcerberus* is older than the opening of the Central Atlantic dated from the Kimmeridgian-Tithonian in the late Jurassic (146-144 Ma)

(WÄGELE *et al.*, 1995). In the same way, the genus *Coxicerberus* existed before the opening of the Central and South Atlantic and the break up of the eastern Gondwana (COINEAU, 1986). Therefore, microcerberids constitute phylogenetically old lineages.

The "two step model of colonization and evolution" provides an understanding of both the establishment of marine surface ancestors in interstitial continental groundwater and of their evolution (BOUTIN & COINEAU, 1990; NOTENBOOM, 1991; COINEAU & BOUTIN, 1992; HOLSINGER, 1994). During the first stage, the surface marine ancestor actively colonized interstitial biotopes of shallow littoral bottom of the Tethys. The second step is the passive transition to subterranean freshwater during Tethys regressions (STOCK, 1980). Vicariance processes occur when the gene flow is no longer possible between the new limnostygobiont and the littoral remaining population. Further diversification may appear due to geologic events.

Hereafter, we examine if such a biogeographic model works when applied to the distribution pattern of *Microcerberus* from U.S.A. and Caribbean, based on palaeogeographic knowledge of these regions of the world.

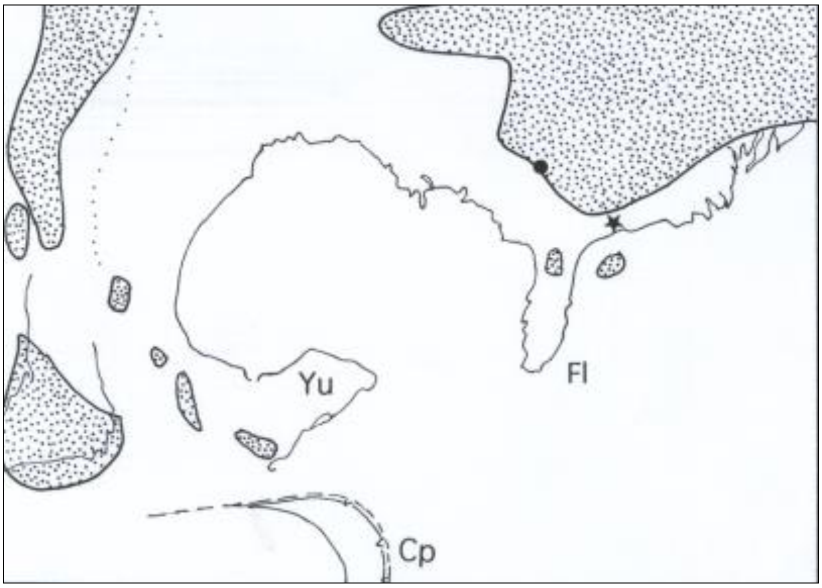

Figure 1 - Present location of Microcerberus carolinensis (*) and M. sp (.) in North America and shoreline of the Tethys during the Cenomanian, after Dercourt et al (Eds), 1993. Dotted areas: exposed lands. Below, the Caribbean plate (Cp) is drifting eastward. Yu: Yucatan, Fl: Florida.

a- Palaeobiogeography in Southeastern U.S.A.

Before the Oxfordian-Kimmeridgian, North and South America formed a continuous emerged land. The Tethys opened to the West in the Kimmeridgian: it is the opening of the Central Atlantic. Marine ancestors of the species of *Microcerberus* were already interstitial in the littoral of the Tethys (first step of the model achieved). During this time, all exposed lands of the Laurasia and the Gondwana are closely distributed compared to the following periods. Both locations of *Microcerberus* sp. and *M. carolinensis* are on exposed lands (DERCOURT *et al.*, 1993, STEPHAN *et al.*, 1990; ITURRALDE-VINENT & MACPHEE, 1999). In the Tithonian (138-135 Ma/late Jurassic), *Microcerberus* sp. site is close to the Tethys shoreline, while *M. carolinensis* location is far from it. In the Aptian, *Microcerberus* sp. site is on exposed land, and that of *M. carolinensis* is near the Tethys coast. In the Cenomanian (94-92 Ma, late Cretaceous), the Tethyan transgression reached the lower southern part of the hercinian Appalachian Monts, and therefore *Microcerberus* sp. present location. During the regression, in the latter period, the littoral interstitial ancestral species of *Microcerberus* sp. settled in fresh groundwater. The region was never flooded by the Tethys after the Cenomanian. At the same time, *M. carolinensis* sites were covered by the sea and became littoral from the late Cretaceous up to the Rupelian (30-28 Ma), but were flooded again by the Tethys from the Eocene to the Tortonian (STEPHAN *et al.*, 1990). Since the species is very closely related to *Microcerberus* sp., the common ancestor of the two species left by the Cenomanian regression in the southern part of the Appalachian range might have reached the groundwater of the dowstream part of the rivers through passive drift. The entrance in freshwater of the ancestors in the Rupelian regression cannot be assumed because the region was widely covered by Tethyan embayments after this period. Furthermore, microcerberids are known for their old age and their low evolutionary rate (COINEAU *et al.*, 1999). Vicariance evolution might have occurred due to the uplift of the hercynian Appalachian range during the orogenesis of the western ranges and the subsequent erosion by new hydrographic systems.

b. Palaeobiogeography in the Caribbean

The exposed lands (islands) of the Caribbean plate appeared in the Pacific just after the Central Atlantic opening in the Aptian and drifted to the East between North and South America (STEPHAN *et al.*, 1990; ITURRALDE-VINENT & MACPHEE, 1999). While drifting, one or several islands were quasi-permanently exposed and transgressions and regressions of the Tethys reached these lands from the Aptian up to the Middle Eocene (STEPHAN *et al.*, 1990). They will constitute the further Greater and Lesser Antillean (Fig. 2). The present location of *Yvesia striata* in southeastern Cuba corresponds to one of the Cuban blocks remaining emerged when drifting. Therefore, the marine ancestors which lived in the interstitial shallow waters of the Tethys might have been left on this block by one of the regressions from the late Cretaceous up to the Eocene periods.

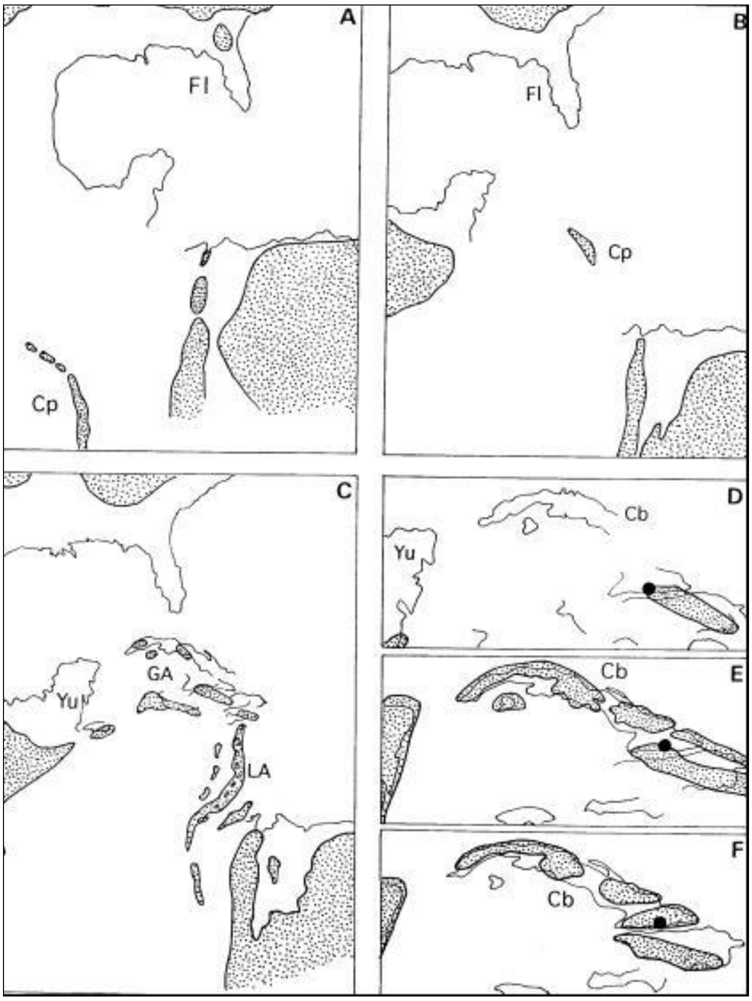

Figure 2 - Paleogeography in the Caribbean: A, in the lower Aptian; B, In the Santonian/Campanian; C, in the Maastrichtian. D, E, F, Greater Antillean in the late Paleocene (59 Ma), in the late Eocene (37 Ma) and in the early Miocene, after Stephan et al. 1990, and present location of Yvesia striata in Cuba. Dotted areas: exposed lands. Cp: Caribbean plate, Cb: Cuba, Yu: Yucatan, Fl: Florida, GA: Greater Antillean, LA: Lesser Antillean.

Discussion

The three studied species of *Microcerberus* occur in areas formerly inundated by the Tethys. From the two alternative hypotheses, marine relicts versus freshwater origin of the inland groundwater microcerberids, the palaeogeographic data strongly indicate that they are relicts of marine embayments during the late Cretaceous, or Eocene in

Cuba. Such results are in close agreement with those of HOLSINGER (1986) for the weckelliid and bogidiellid amphipods from southern North America. Moreover, the geographic location of some species of these groups is similar to that of inland microcerberids both in North America and Europe. Numerous coastal species of microcerberids in brackish water favored also the marine origin, whereas the secondary occurrence in the littoral (WÄGELE, 1983) is questionable. The marine origin is largely consistent with our results under study in Morocco. Furthermore, in Cuba, *Yvesia striata* co-occur with thermosbaenaceans, hadziid amphipods and microparasellid isopods, which all derive from Tethyan ancestors. Sympatry with other stygobionts of marine origin is also observed in Europe and Morocco. From its emersion, Cuba has never been connected to exposed lands. As seen from STEPHAN *et al.* (1990) and ITURRALDE-VINENT & MACPHEE (1999) data, the Proto-Antillean archipelago (ROSEN, 1976) never existed, according also with STOCK (1986), and the vicariance origin of stygobionts through its fragmentation is no longer valid. Nevertheless, Cuba and Greater Antillean originated from a plate arising in the Pacific and drifting eastward.

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Nitrate Contamination in Karst Aquifers in the Czech Republic

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Abstract

Surface waters in the Czech Republic as a whole reveal the mean nitrate concentration of 12.5 mg.l^{-1} (the set of 14,237 samples). The mean nitrate concentration in surface waters of the karst areas is 26 mg.l^{-1}, i.e. 2 times higher. However, many karst springs exceed the highest recommended values stipulated by legal standard for potable water in their nitrate concentration, i.e. 50 mg.l^{-1}. Springs draining forested catchments usually range between 10 and 20 mg.l^{-1} in their nitrate contents at present. Many karstic catchments include not only forests but also intensively agriculturally utilized land. The springs in such catchments were often proved contain 60–100 mg.l^{-1} nitrates. State-supported application of industrial and organic fertilizers led, mostly in the 1960s to 1980s, to gradual increase in groundwater concentrations of nitrates in karst springs. After cutting down financial support in agriculture in 1990, the amounts of industrial fertilizers used substantially decreased.

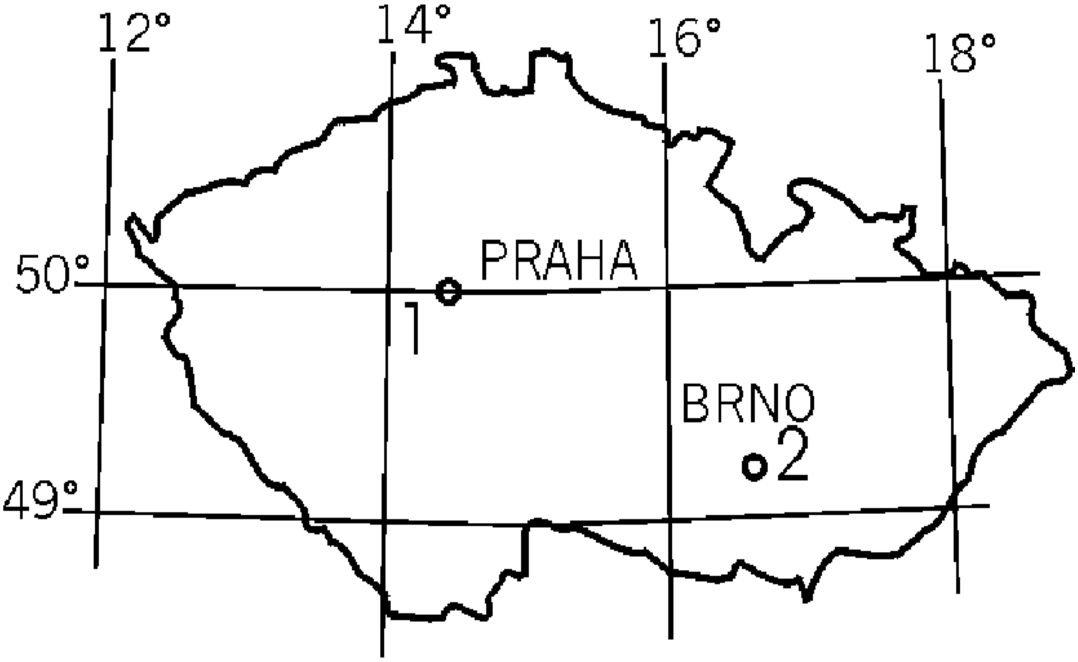

Fig.1 1- Bohemian Karst, 2 – Moravian Karst

1. Introduction, Geological Settings of Karst Areas

Nitrates belong to the most common contaminants of the surface and ground waters. In the territory of the Czech Republic, an increase and evolution of nitrate contamination of waters has been documented on drinkable water sources. Since 1920, when nitrate contents in these waters were lower than 10 mg.l^{-1}, nitrate concentrations gradually increased by as much as 25 mg.l^{-1} to the year 1966 and by as much as 55 mg.l^{-1} to the year 1989. After 1989, a political change in the state caused a radical change in agriculture (significantly decreased volumes of nitrogenous fertilizers applied), resulted also in a decrease of nitrates in drinkable water sources in the period 1989-1993. Even though the amount of applied fertilizers continued to decrease (in 1995 it was about 50% of the 1998 value), nitrate concentrations in groundwater do not continue to decrease anymore after 1993. On the contrary, a continuing increase in nitrate concentrations in some drinkable water sources has been observed (PEKNY & SKOREPOVA, 1998). Yearly increase of nitrates in natural water of about 1 mg.l^{-1} on average was given in the 1990´ (SKOREPA & SKOREPOVA 1986, VOJTECH, 1988). Washing of nitrates into surface and ground waters is influenced by a number of factors, such as quantity and form of applied nitrogenous fertilizers, precipitations and temperature in given year, quality and quantity of the soil organic matter etc. Nitrate mobility has been influenced also by the increase of atmospheric deposition of nitrogen and soil acidification in the recent years. Nitrate washing into surface and groundwater is one of the indicators of destabilization of the ecosystem. Atmospheric deposition of nitrogen is manifested especially in natural and semi-natural ecosystems, whereas agricultural ecosystems receive a large part of nitrogen from fertilizers.

Karst areas formed by various types of limestones (Silurian to Triasic) occupy about 0.9% of the total area of the Czech Republic. The Bohemian Karst with the area of about 131 km^2, situated to south-west from the Czech capital Prague, and the Moravian Karst with the area of 85 km^2, located to north-east and north from Brno belong to the largest ones (Fig.1). A number of other smaller karst areas were formed in crystalline limestones of largely Palaeozoic age. Cretaceous limestones with some karst features furthermore occur in the Czech Cretaceous Basin in the northern and central part of the republic. In general, the karst areas represent rather islands with imperfectly developed karst morphology. Only the Moravian karst area, formed by Devonian and Lower Carboniferous limestones, includes a large spectrum of well-developed karst phenomena including groundwater streams. Due to the character of aquifers and a limited occurrence of the Neogene and Quaternary cover, carbonate rocks on the territory of the Czech Republic belong into a group of collectors with a high vulnerability as nitrogen washed from soils concerns.

2. Groundwater Nitrate Concentrations

Surface waters in the Czech Republic as a whole reveal the mean nitrate concentration of 12.5 mg.l^{-1} (the set of 14,237 samples) (VESELY et al., 1986, MAJER et al., 1992). The mean nitrate concentration in surface waters of the karst areas is 26 mg.l^{-1}, i.e. 2 times higher. However, many karst springs exceed the upper limit value stipulated by legal standard for potable water in their nitrate concentration, i.e. 50 mg.l^{-1}. Springs draining forested catchments usually range between 10 and 20 mg.l^{-1} in their nitrate contents at present. Many karst catchments include not only forests but also intensively agriculturally utilized land. The springs in such catchments were often proved to contain 60–100 mg.l^{-1} nitrates (KADLECOVA & ZAK, 1998).

Important relationships between the nitrogen concentrations in groundwater and agricultural activities revealed data acquired within the frame of the project Restriction of the areal contamination of surface and ground waters (PRCHALOVA et al., 2000). The Bohemian Karst area is mostly covered with arable and other soil - forests and permanent grass growths cover only 35% of the area. As a result, groundwater with nitrate contents lower than 25 mg.l^{-1} occur just on a small part of the area (5%). Nitrate concentrations between 25-45 mg.l^{-1} are typical for 25% and those higher than 45 mg.l^{-1} for 70% of the area. On the contrary, the situation as nitrate contamination of groundwater concerns is better in the area of the Moravian Karst, because the forest and permanent grass growths cover up to 55% of the total area. Groundwater with nitrate contents lower than 25 mg.l^{-1} occur on 51%, those with 25-45 mg.l^{-1} on 33% and those with nitrogen contents higher than 45 mg.l^{-1} on 16% of the area. The latter are encountered especially in the northern part of the Moravian Karst, where there is about 65% of the arable soil. In the karst aquifers of the smaller crystalline limestone occurrences and karst mountain areas (the Jeseniky Mts. and the eastern part of the Krkonose Mts.), nitrate contents in the groundwater are in general lower than 25 mg.l^{-1}. In the Bohemian Cretaceous Basin area, the fertile soils with higher contents of basic ions are more resistant, and there is no important nitrogen washing into groundwater.

3. Case Study of the Karst Spring at Svatý Jan pod Skalou, Bohemian Karst

Karst environment is suitable for study of ground water nitrate contamination due to relatively thick undersaturated zone, to reducing conditions in soil, which enable denitrifying bacterial reactions only to a limited extent. Therefore nitrification - bacterial oxidation of organic nitrogen - predominates in soils. As soon as the infiltrated meteoric water penetrates the soil profile and gets into the rock environment of limestones, nitrates behave rather conservatively due to the prevailingly oxidation environment and rapid transport and their content neither the isotopic composition do not change considerably. The groundwater pollution by nitrates in the karst aquifer was studied in detail in the Bohemian Karst area in the central part of the Barrandian, which is formed by a discontinuous mosaic of Silurian and Devonian limestones, isolated and interrupted by non-karst rocks (volcanic and volcaniclastic basaltic rocks, siltstones and shales) and folded into anticlines and synclines. These structures are affected by transverse faults with vertical and horizontal components of movement. The area of the Bohemian Karst is a 2nd-order hydrogeological structure (VCISLOVA, 1980) underlain by relatively impermeable Ordovician rocks. The Berounka River functions as a base level in its central and south-western parts. The principal base level on its north-eastern margin is the Vltava River.

The nitrogen evolution was monitored in the spring at Svatý Jan pod Skalou and its hydrogeological catchment area located in the NW part of the Bohemian Karst (BUZEK et al., 1998). Svatý Jan pod Skalou is located 25 km SE of Prague. This biggest karst spring lies near the bottom of a 140 m deep canyon of the Kačák Stream. Here, it drains the SW part of the Holyně-Hostim Syncline formed by volcanic rocks, limestones and siltstones of Silurian and Devonian age. The spring is located at the intersection of tectonic ruptures striking SW-NE and NW-SE to N-S, in the immediate proximity of the base level. An average yield of the spring is ca. 20 l.s^{-1} and the concentration of nitrates exceeds 50 mg.l^{-1} (Fig. 2). High nitrate concentrations in the Svatý Jan karst spring document its appurtenance to the group of springs dominated by agriculturally used land in a catchment of the area of ca. 8 - 10 km^2. The discharge, temperature, chemical and isotope (δ^{18}O, δ^{15}N - NO_3^-, T) composition of the issued water were regularly monitored in 1994 - 1997 including the study of isotope composition of atmospheric precipitations. Monitoring was focused on the principal part of the Svatý Jan spring, called Ivanka and Ivan with Q_{min} of 14.1 l.s^{-1} and $Q_{max.}$ of 29 l.s^{-1} (Fig. 3). The correlation between maximal spring yield decrease and time has shown that the dominant circulation regimes of the Holyně-Hostim Syncline are those with laminar groundwater flow with different times of karst aquifer emptying. In these regimes, rocks are deformed mostly by a dense, largely equally spaced network of microfractures and small joints, and water-saturated tectonic zones play role of a buffer. Karst permeability becomes important only after heavy precipitation events, being associated particularly with shallow and rapid groundwater circulation with retardation times of several weeks to months.

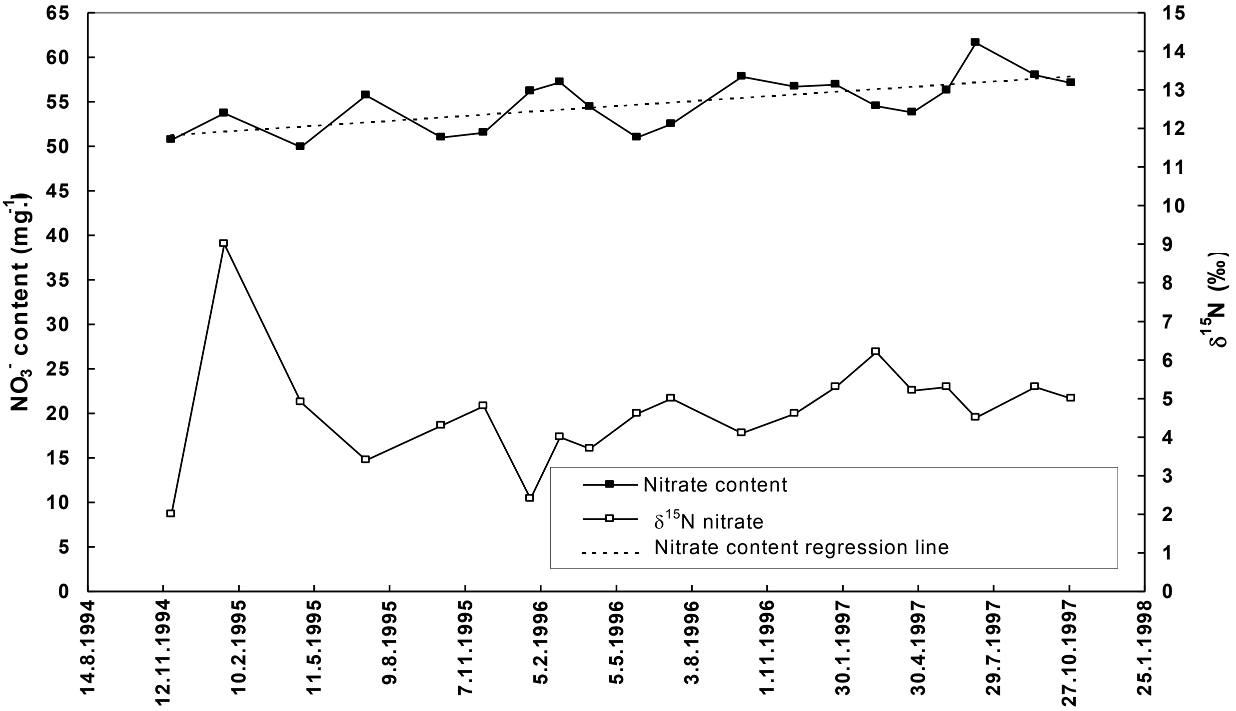

Fig. 2. Variations in nitrate concentration and nitrate isotope in the Svatý Jan spring in period 1994 – 1997

Binary model according to HORTON (1935) was used for evaluation of the share of directly infiltrating precipitations due to a low variability of the □^{18}O concentration in springs water and spring discharge. The ratio of the infiltration coefficient for the summer and winter season based on isotopic composition of oxygen from the precipitations and spring waters according to GRABCZAK et al. (1984) was used to calculate the average age of the water from tritium. It showed up that even though the amount of precipitations in the summer season is two times higher than in the winter one, the amount of water infiltrating in the deep aquifer is for both seasons approximately the same. Hydrological models according to YURTSEVERA (1983) and Flow model by MALOZSEWSKEHO (MALOSZEWSKI & ZUBER, 1996) were further used. On the basis of differences in hydrogen isotope concentrations (T) of the spring water and atmospheric precipitation, an average water retardation was determined with a 22-year circulation time in the structure, depending on the distance between precipitation infiltration and resurgence. The data on concentration of the individual nitrogen forms in soil and groundwater are not sufficient for the assessment of the importance of individual biogenic conversions in the nitrogen cycle, such as nitrification and denitrification. It is, therefore, necessary to combine data on concentration of the different forms of nitrogen with the study of changes in its isotope composition. Most of the bacterial conversions in the nitrogen cycle is connected with large-scale isotope fractionation. To describe the nitrogen cycle in the catchment of the Svatý Jan spring, the chemical and isotope composition of nitrogen in nitrates was also regularly monitored in surface water and groundwater in the infiltration area of the spring and in other three hydrogeological objects: the Bubovický potok Stream, a well near the village of Kozolupy and a spring at Sedlec. The concentrations of nitrates and δ^{14}N isotopes of nitrates are shown in Fig. 4.

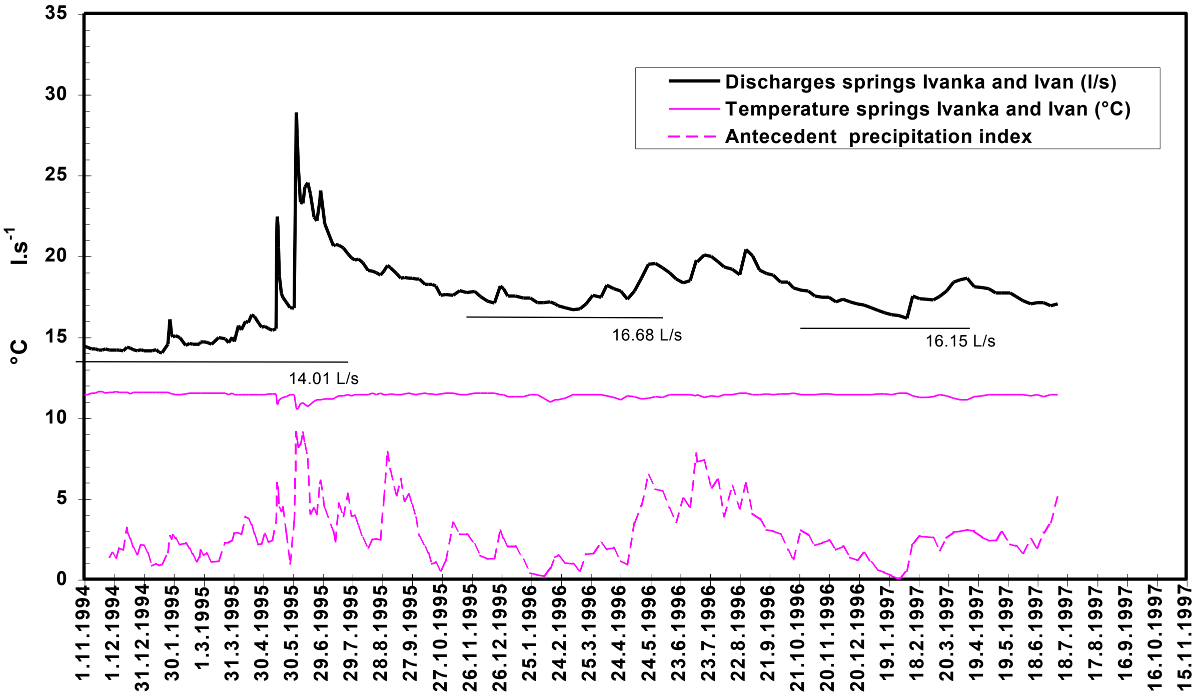

Fig. 3. Variations in yield and temperature of spring water and atmospheric precipitation in the studied period of 11/1994 - 10/1997.

A geochemical model of the origin and history of nitrate contamination of the spring was elaborated on the basis of the above given data (spring yield, nitrate concentrations, and δ^{15}N δ^{18}O and T isotopes). Three components were modelled: 1. a component with slow groundwater circulation (avg. retardation of 22 years in rock environment) and agriculturally used catchment, representing 60-70% of the discharge water 2. a component with retardation time on the order of several months and agriculturally used catchment, representing 30% of the discharge water and 3. a component with rapid circulation (retardation time on the order of several days or weeks) and forested catchment, which characterizes geographical catchment of the spring with very low nitrate concentrations represent the remaining volume of less than 10%.

The geochemical model revealed that nitrate concentrations in the Svatý Jan spring will increase due to the prevalence of the component of groundwater circulation with an average retardation period of 22 years, because water issued in late 1990s was recharged approximately in late 1970s, when nitrate concentrations in the recharging waters were still markedly increasing. Some increase in nitrate concentrations in spring water can be expected by 2005. The decrease in nitrate concentrations in spring waters in the future may be hindered by gradual washing of nitrates from a thick pile of weathering products, which fill the uneven karst surface in the infiltration area, as well as from the relatively thick unsaturated zone in limestones. The decrease in nitrate concentration in spring waters may be also hampered by diffusion of nitrates from immobile water in the karst aquifer into mobile water, or gravity water. Even though nitrogen input in agricultural soil from fertilizers decreased in the area Bohemian Karst, increase in nitrogen oxide concentrations (car traffic, gas introduction in local and central heating and gas introduction in large manufacturing plants) and even increase in ammonium concentration in local atmosphere has been registered recently. Current data on nitrate concentration in precipitations on free area range mostly around 4 mg.l^{-1} NO_3^-, in precipitations under the tree crown between 4 and 10 mg.l^{-1} NO_3^-, which probably represents one of the factors which influence present significant changes in plant assemblages in forest ecosystems

(HOSEK & KAUFMAN, 1996, HOFFMAISTER, 1999). With respect to all these facts, the real decrease in nitrate concentrations in spring water will be probably much slower than expected by a model calculation considering mobile water only.

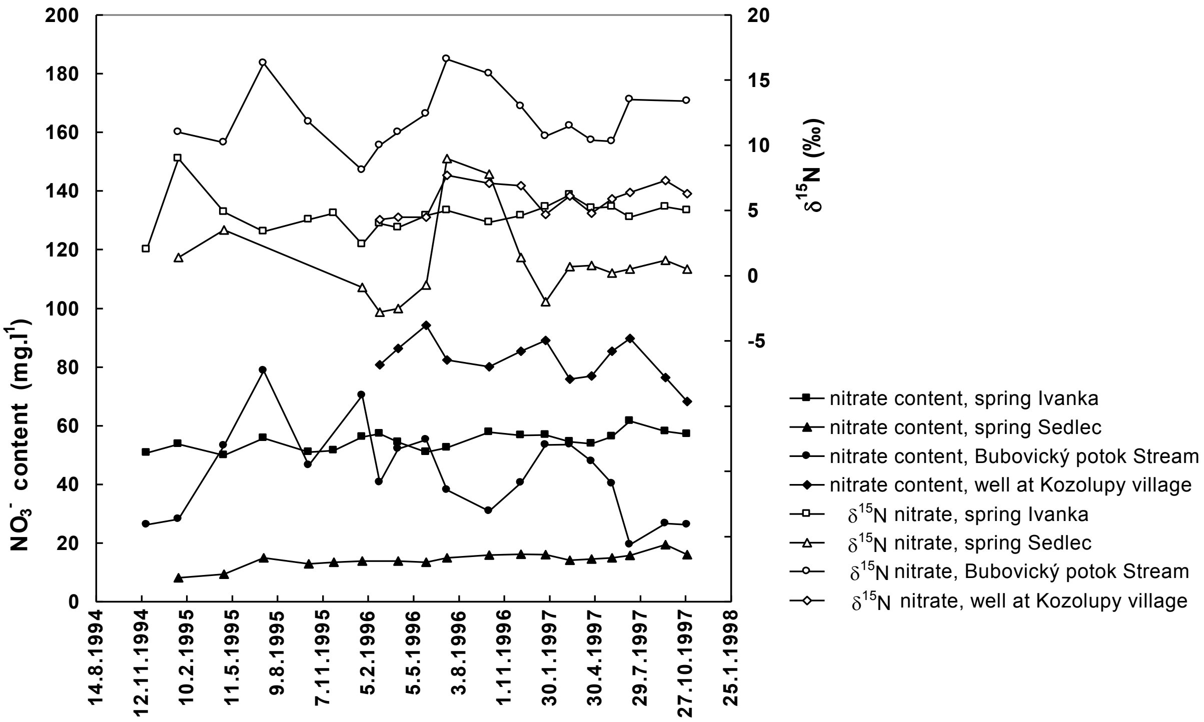

Fig. 4. Variations in concentrations of nitrates and isotopes of nitrates in the period 1994 - 1997

4. Conclusions

a. Karst aquifers on the territory of the Czech Republic belong into a group of collectors with a high vulnerability as nitrogen washed from soils concerns

b. Arable land of the karst area exhibit surplus of nitrogen, which is washed into groundwater. Fertile soils of the Bohemian Cretaceous Basin area with higher contents of basic ions are more resistant, and there is no important nitrogen washing into groundwater.

c. Some increase in nitrate concentrations in spring water Svaty Jan pod Skalou can be expected by 2005. Decreasing trend will be probably very slow due to the present higher atmospheric deposition.

d. Higher atmospheric deposition on the Bohemian Karst results in a small surplus of nitrogen in forest soil, which is reflected by a significant change in plant assemblages in forest ecosystems.

Acknowledgements

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Contribution to the Knowledge of the Groundwater Communities from Northern Morocco

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Abstract

The groundwater fauna from the Rif region, in northern Morocco, is highly diversified. Several stygobite taxa are new for science: oligochaetes (species of *Trichodrilus*, genus and species of Phallodrilinae), gastropods (new species of *Hadziella*, *Heideella*, *Pseudoislamia* and *Belgrandia*), amphipods (ten new species of *Pseudoniphargus*), and isopods (*Microcharon alamiae* has been recently described). Some taxa are reported for the first time from Morocco, i.e. the oligochaetes Phallodrilinae, as well as the crustacean *Metastenasellus* sp. (isopod). As in other Moroccan regions already investigated, the distribution of groundwater communities, especially peracarid crustaceans, is strongly related to water quality, substrate grain size and the local palaeogeography. The latter factor provides an understanding of the observed community differences both between sites and with other Moroccan regions.

Introduction

The Moroccan groundwater fauna was still poorly known until the beginning of the eighties (CHAPPUIS, 1953; BALAZUC & RUFFO, 1953; KARAMAN & PESCE, 1980; PESCE *et al.*, 1981). More systematic stygobiological investigations were recently performed, first in the Marrakesh region, then in other parts of Morocco: Goulmima (BENAZZOUZ, 1983), Tiznit (BOULAL, 1988), Guelmim (IDBENNACER, 1990), El Jadida (FAKHER EL ABIARI, 1999) and the Rifian region. These last sampling were performed with the aim of both making more complete the inventory of known stygobiontic taxa from Morocco and testing once more the possible relationships between the biodiversity of the subterranean aquatic fauna and groundwater quality**.** This paper finally presents the first data on the Rifian stygobiontic fauna.

Study Area and Methods

The Rifian domain is the Moroccan part of the Betico-Rifian arc which is the western end of the Alpine ranges in the Mediterranean Basin (FRIZON DE LA MOTTE *et al.*, 1991). It is formed by several alpine nappes including three main structural units: the Sebtides which are the deepest ones, with a base of peridotites, then the Ghomarides which are of Paleozoic, Triasic, Liasic and Eocene age, and finally the Rifian range formed by a pile of folds and small carbonated nappes of the upper Trias and lower Lias periods.

Three sampling campaigns were successively performed in the region. More than sixty wells and ten or so springs were prospected within a range of 300 km, extending from the Atlantic Ocean to the Algerian Boarder (fig.1).

The fauna of wells was generally collected using a phreatobiological net similar to the Cvetkov model, and baited traps, a more efficient method for capturing crawling species (BOUTIN & BOULANOUAR, 1983). These two methods were completed, when possible, by filtering through a plancton net the water extracted by motorized pumps. The fauna of springs was sampled with a net settled at the source when stringing the sediments just upstream from the water emergence (MESSOULI, 1994).

Results

More than 76 taxa were sampled, including 14 species of Oligochaeta, 12 species of Gastropoda and 42 species of Crustacea. The specific richness of the region stygofauna reaches 38 species (representing about 50% of the total community). The most common representatives of the stygofauna are the gastropods (eight species) and the crustaceans (26 species including eight copepods, three ostracods and 15 peracarid and syncarid crustaceans (tab.1).

This global biodiversity is roughly similar to that of other regions of Morocco previously investigated, as 50 species were collected in the Tiznit region (BOULAL, 1988), 38 taxa in the Marrakesh area (BOULANOUAR, 1995) and 59 species in the Guelmim wells, South-West of the Moroccan Anti Atlas (BOUTIN & IDBENNACER, 1989). The Rifian subterranean fauna seems enough diversified when compared with that of Europe and North America (BOTOSANEANU, 1986; JUBERTHIE & DECU, 1994; GIBERT *et al*., 1994), especially when considering the hydrobiid snails and the peracarid crustaceans.

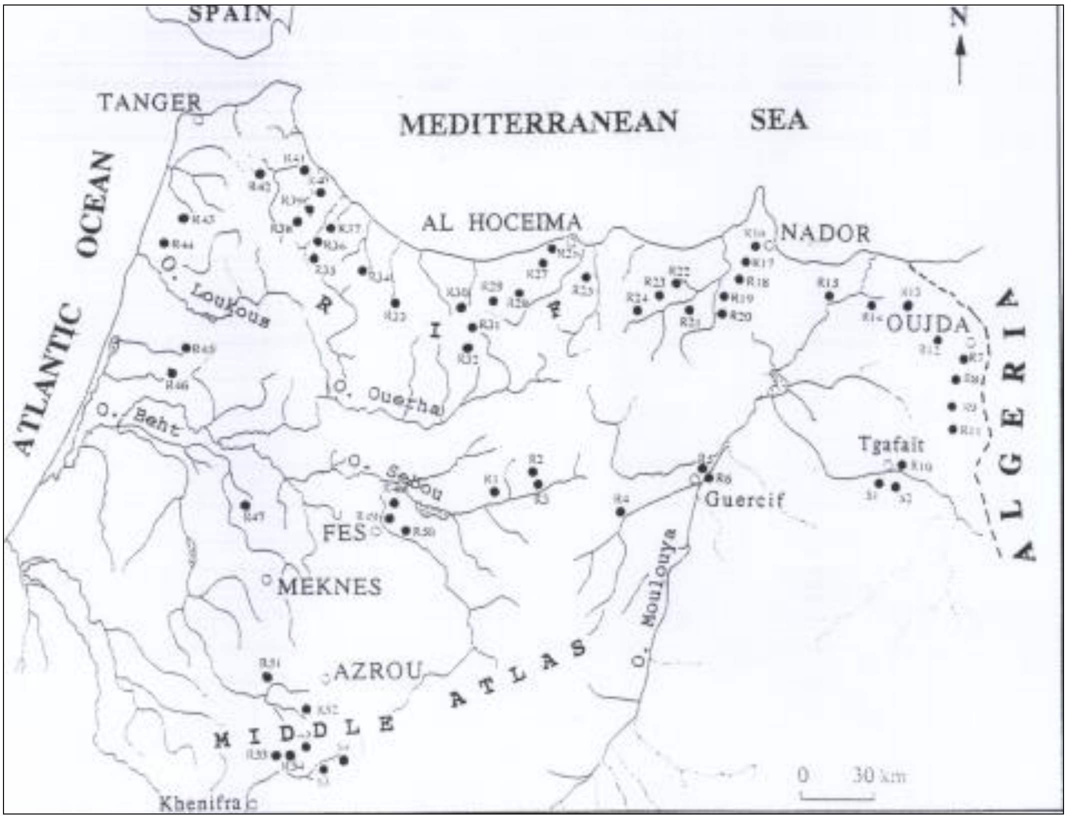

Figure 1 - Location of the study sites, wells (R) and springs (S), in the Rifian region of Morocco

The Rifian stygofauna is also characterized by a good number of species new for science and by a high rate of endemic species. Five new species of gastropods were collected, including two species also sampled subsequently in the Beni Mellal plain and three species considered as endemic of the Rif, *Giustia rifensis*, *Heideella knidirii* and *Pseudoislamia yacoubii*. Similarly a new endemic genus of Oligochaeta is a representative of the subfamily Phallodrilinae, with a distribution area limited to the North Eastern part of the Rif. Within the crustaceans several endemic species recently collected are still under study. It is the case of three different species of the amphipod *Pseudoniphargus*, of one species of the syncarid *Iberobathynella*, of one species of the stenasellid isopod *Metastenasellus*, and of 3 new cirolanid isopods which include two different species of *Typhlocirolana* and a new genus which will be published as *Rifolana* n.gen. At last one species of the Rifian isopod Microparasellidae was recently described as *Microcharon alamiae* (BOULANOUAR *et al*., 1997).

From the consideration of this faunistical list some biogeographical remarks are possible. The Oligochaeta Phallodrilinae belong to a marine group and are mentioned for the first time from fresh groundwaters in the Rifian region; it may be considered as a new evidence of the marine origin of a great part of the stygofauna. The occurrence of this representative in the Rif is certainly related to the origin of the Rifian block, derived from the complex Mesozoic and Cenozoic history of the Alboran plate, which emerged and split in the

Mediterranean in a number of blocks which subsequently drifted to North African and Iberian plates. In other respects, the occurrence of species of the amphipod *Metacrangonyx* in this septentrional region is of great biogeographical interest as it extends widely the distribution of a family only known in Morocco from the south of the Idrissid Land.

The amphipods *Pseudoniphargus* now appear as a large group of species occurring also inside the Rifian domain and not only on its southern margin where it was first discovered. Its origin is certainly related (as that of the phreolidrillid Oligochaeta) with the history of the Rifian block, especially with the late Tortonian and early Messinian closure of the South-Rifian Channel and the marine transgressions and regressions in the Rifian domain, when the Rifian block collided with the African plate (COINEAU & BOUTIN, 1996, FAKHER *et al*., 1999). Other Rifian thalassoid stygobiontic groups have representatives in other parts of Morocco, South of the Idrissid Land, and seem related to transgressions and regressions of the Cenomano-Turonian and of the Senonian or Eocene.

Table 1 - List of the aquatic subterranean species in the Rifian region (: stygobites species, ° : stygophiles species)*

Taxa	Taxa	Taxa
Foraminifera	Copepoda	Amphipoda
Ammonia tepida°	*Acanthocyclops sp.**	*Salentinella sp.**
Oligochaeta	*Diacyclops dubbocki°*	*Pseudoniphargus ruffoi**
Rhyacodrilus sp.°	*Diacyclops sp.**	*Pseudoniphargus sp**
*Phallodrilinae n.g, sp.**	*Megacyclops viridis°*	*Pseudoniphargus sp.1**
*Trichodrilus sp.**	*Metacyclops subdolus**	*Pseudoniphargus sp.2**
Gastropoda	*Paracyclops imminutus°*	*Pseudoniphargus sp.3**
*Hadziella midarensis**	*Paracyclops fimbriatus°*	*Maghrebidiella sp.**
*Heideella knidirii**	*Tropocyclops prasinus°*	*Metacrangonyx sp**
*Heideella andrea**	Ostracoda	Isopoda
Belgrandia sp.°	*Pseudocandona albicans°*	*Proasellus coxalis africanus°*
*Pseudoislamia rifensis**	*Fabaeformiscandona sp1**	*Microcharon alamiae**
Mercuria similis°	*Fabaeformiscandona sp2°*	*Typhlocirolana haouzensis aff**
*Giustia rifensis**	Syncarida	*Typhlocirolana sp.**
*Pseudoislamia yacoubii**	*Iberobathynella sp.**	*Rifolana n.g. sp.**
		*Metastenasellus sp.**

Conclusion

The Rifian groundwaters are inhabited by a relatively rich stygobiontic fauna including a number of taxa related to the ancient Mesozoic history of the Rifian block, like in other parts of Morocco, but also by original and generally endemic other taxa related to the more recent Cenozoic history of the Rifian domain. A number of these species, as they were recently collected, are still under study. Before performing a more detailed analysis of the comparative biodiversity of sampled sites, the first results show that the species richness, especially that of stygobionts, is clearly linked with groundwater quality as in other regions of Morocco.

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Contributions to the Microclimatological and Biospeleological Study of the Olhos D'Água Cave, Castro, PR, Brazil

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Abstract

The cavernicolous environment has several peculiar characteristics which influence enormously its ways of life. This study focuses on the underground microclimatology of the "Olhos D'Água Cave", located in the district of Castro, in Paraná state (Brazil). The methodology concerned in collecting and analyzing the variation of the meteorological elements (temperature, relative humidity, evaporation and air pressure). The results showed that the underground microclimate is influenced by the outside atmosphere, specially by the environment nearby opening into and out of the cave and internal variations delay also might happen. The data were collected between 1991 and 1992. Some taxa which were previously observed were confirmed, and some new taxa were listed.

Introduction

The microclimatic studies comprise aspects of high scientific interest such as underground microclimatology. The research on underground climatology, mainly that related to enclosed spaces like grottos and caves, must take into consideration the characteristics of their environments, such as absence of light, shape of the chambers, number of openings, exposition, altitude, geographic position, morphology and capacity to follow external climatic variations, (ANDRIEUX, 1965, 1971; CHEBATAROFF, 1969). The relationship between the characteristic above related and also the presence of a stream of water in the chambers lead to an eventual delay in the assimilation of external events at the cave, influencing the climate behavior.

Methodology

The area of this research was a cave called "Gruta Olhos D'Água", located in the district of Castro, in Paraná State, Brazil. It is a calcareous cave formation, mostly horizontal, and contains a stream in some seasons of the year. Its low depth and good illumination in the openings and light spots were aspects which favored both the installation of instruments and the observation of the meteorological data.

The data collection period (meteorological and biospeleological) was carried through from August 1991 to August 1992, selecting ten days in the peak period of each season. There were two winter seasons (1991 and 1992) in data collecting. The first season also consisted in a test of the registering equipment and the observer and researcher's training (VILLAR et al., 1984). The second was the data collection recording.

The daily data collection refers to the temperature, relative humidity and pressure, as well as evaporation capacity, elements which condition the formation of the underground and surface climates, according to LADDO (1966).

Firstly, among the procedures for the investigation of the climatic elements involved, was the selection of four spots inside the cave named "observation posts". Secondly, it was built a meteorological shelter just outside the main opening. This cave meteorological data were compared with those collected by the Meteorological Station in the district of Castro and with the daily weather forecast bulletins issued by the station.

The meteorological shelter contained a thermo-hygrograph, a barograph and a simple thermometer. Post 1, inside the cave, near the main entrance, contained a thermo-hygrograph; Post 2, further inside, was equipped with a thermo-hygrograph and a barograph; Post 3, in the innermost part of the cave, was equipped with an evaporigraph; Post 4, near the exit, was equipped with a thermo-hygrograph.

The daily records obtained through the diagrams from each instrument in the semi-periods of analysis (seasons) fed tables which then allowed the preparation of daily charts and tables for each season.

The identification of the cave fauna was made by means of collecting and visual identification.

Results and Discussion

The highest temperatures in the collection posts and at the meteorological station of Castro were registered in spring as shown in Table 2.

Hygrometric variation peaks occurred outside the cave environment, as Tables 1-5 demonstrate. Despite the lower variations, the hygrometric degree in "Olhos D'Água Cave" remained high, and it was not constant, generally speaking, Autumn had higher average values. Considering evaporation, the lowest averages were observed in winter, whereas the highest occurred in summer. This behavior is attributed to specific thermal variations in these seasons, as seen in Tables 1-5. Pressure values were higher in winter (Tables 1 and 5) although barometric variations were not very distinct during the other seasons. This can be accounted for by the mostly horizontal development of the cave, so that this variation is related to thermal oscillation.

Through the analysis of the climatic parameters of each post, it was observed that:

- The meteorological shelter, located outside, near the entrance of the cave, registered high temperatures in all seasons, with the maximum temperature always higher than 20°C.

- The highest humidity rates were also high for all seasons, falling below 90% only in the winter of 1992. The highest pressure values were found in winter and the lowest in summer. Post 1, near the entrance of the cave, showed the highest thermal values and the highest averages in spring, as for relative humidity. Values were always above 90% in all seasons and the minimum was never below 70%.

- Post 2, inside the cave, had maximum thermal values of about 18°C to 19°C, except for Autumn, when a maximum of 23°C was recorded.

The spots located far from the entrance in the underground environment, like Post 2, tend to be less influenced by external atmosphere, consequently showing reduced daily ranges.

- Post 3, in which evaporation data were collected, had very low values, always below 2.0 mm in all periods. The low evaporation capacity is due to the high hygrometric degree present throughout the cave.

- In Post 4, the highest temperature was recorded in summer, and the lowest was found in the test period (winter 1991). The maximum relative humidity values were always above 90%, and the minimum above 70%, except for the test period, when it reached 64%.

These conditions are extremely important to the maintenance of life in the cavernicolous environment.

The records listed below complement PINTO-DA-ROCHA´S work (1988) which was specially dedicated to the calcareous caves of Paraná State, including Olhos D'Água Cave. In that occasion two phyla were described: Annelida and Arthropoda.

In this collection which had Olhos D'Água Cave as the main target some extra taxa were observed, such as:

Class Insecta: Order Hymenoptera - *Apis mellifera* (at the entrance)

Order Lepidoptera - Noctuidae (at the entrance)

Class Reptillia: Order Squamata, suborder Ophidia - *Liophis* sp. (near the entrance).

The Opiliones (*Discocyrtus* sp.) were observed in all the periods of the research, especially on the ceiling and the walls near the entrance. Specimens of the Reduviidae family can be found from the entrance to the deeper areas, where there is absence of light.

Only in some collections (spring/summer), the presence of white owls (order Strigiformes) was observed at the second skylight. In the winter of 1991, one rodent was found distant from the entrance, but could not be identified because of its fast movements allowing only visual observation.

A non-poisonous snake, *Liophis* sp., was found in winter. The presence of an ophidian in this cave had already been noticed by visitors and some members of the university group of Speleology Research - GUPE. During the collection, in the summer time (January, 92) many amphibian larvae were photographed in the internal stream, which showed a higher volume than the one which was normally observed before.

The bats can be seen especially in the darkest areas of the cave and at the entrance where a small group was constantly present and through the guano deposited in many places of the cave.

Despite the difficulties of accessing and keeping the equipment in the observation posts and the lack of precise identifications of some specimens, researches like this are very important, because they contribute to the speleological studies clarifying doubts concerning to such peculiar environments and strengthening the recognition of the ecological conditions.

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Table 1 - Meteorological variations registered in "Olhos D'Água Cave" - Winter/91

	Temperature ºC				Relative Humidity%				**Evaporation mm**				**Pressure mb**			
	Max	Min	Ampl	Aver	Max	Min	Ampl	Aver	Max	Min	Ampl	Aver	Max	Min	Ampl	Aver
Shelter	21	5	16	11.7	96	48	38	79.9	-	-	-	-	944	925	19	932.9
Post 1	15	9	6	13.0	100	72	28	91.4	-	-	-	-	-	-	-	-
Post 2	19	17	2	17.8	93	75	18	88.6	-	-	-	-	945	925	20	933.1
Post 3	-	-	-	-	-	-	-	-	2.0	0.5	1.5		-	-	-	-
Post 4	17	7	10	13.5	97	64	33	82.4	-	-	-	-	-	-	-	-
Castro	24.4	0.6	23.8	14.1	100	54	46	89.5								

Table 2 - Meteorological variations registered in "Olhos D'Água Cave" - Spring/92

	Temperature ºC				Relative Humidity%				**Evaporation mm**				**Pressure mb**			
	Max	Min	Ampl	Aver	Max	Min	Ampl	Aver	Max	Min	Ampl	Aver	Max	Min	Ampl	Aver
Shelter	29	9	20	16.5	92	35	57	77.4	-	-	-	-	939	929	10	932.3
Post 1	22	15	7	18.1	97	70	27	93.8	-	-	-	-	-	-	-	-
Post 2	19	18	1	18.4	80	74	14	75.6	-	-	-	-	937	923	14	930.1
Post 3	-	-	-	-	-	-	-	-	1.0	0.5	0.5	0.7	-	-	-	-
Post 4	16	10	6	13.4	100	78	22	95.1	-	-	-	-	-	-	-	-
Castro	30.2	13.2	17.0	18.9	100	45	55	78.8								

Table 3 - Meteorological variations registered in "Olhos D'Água Cave" - Summer/92

	Temperature ºC				Relative Humidity%				**Evaporation mm**				**Pressure mb**			
	Max	Min	Ampl	Aver	Max	Min	Ampl	Aver	Max	Min	Ampl	Aver	Max	Min	Ampl	Aver
Shelter	25	11	14	17.4	97	55	42	80.9	-	-	-	-	935	920	15	928.3
Post 1	19	13	6	16.0	90	70	20	85.5	-	-	-	-	-	-	-	-
Post 2	18	13	5	15.3	94	86	8	89.8	-	-	-	-	937	924	13	930.9
Post 3	-	-	-	-	-	-	-	-	1.5	0.0	1.5	0.7	-	-	-	-
Post 4	21	11	10	15.2	100	80	20	93.9	-	-	-	-	-	-	-	-
Castro	29.8	15.7	21.5	100	36	64	74.5									

Table 4 - Meteorological variations registered in "Olhos D'Água Cave" - Autumn/92

	Temperature ºC				Relative Humidity%				**Evaporation mm**				**Pressure mb**			
	Max	Min	Ampl	Aver	Max	Min	Ampl	Aver	Max	Min	Ampl	Aver	Max	Min	Ampl	Aver
Shelter	20	5	15	13.3	95	31	64	80.6	-	-	-	-	938	924	14	930.1
Post 1	17	11	6	14.6	97	81	16	92.6	-	-	-	-	-	-	-	-
Post 2	23	17	6	18.0	98	92	6	94.2	-	-	-	-	940	927	13	933.3
Post 3	-	-	-	-	-	-	-	-	1.0	1.0	1.0	0.2	-	-	-	-
Post 4	17	10	7	14.9	93	84	9	88.6	-	-	-	-	-	-	-	-
Castro	24.3	11.4	12.9	16.6	100	43	57	81.4								

Table 5 - Meteorological variations registered in "Olhos D'Água Cave" - Winter/92

	Temperature ºC				Relative Humidity%				**Evaporation mm**				**Pressure mb**			
	Max	Min	Ampl	Aver	Max	Min	Ampl	Aver	Max	Min	Ampl	Aver	Max	Min	Ampl	Aver
Shelter	21	4	17	14.3	84	60	24	78.8	-	-	-	-	946	934	12	940.0
Post 1	16	11	5	13.9	97	80	17	81.8	-	-	-	-	-	-	-	-
Post 2	19	13	6	15.1	89	78	11	82.9	-	-	-	-	944	932	12	938.0
Post 3	-	-	-	-	-	-	-	-	0.5	0.0	0.5	0.5	-	-	-	-
Post 4	18	9	9	15.1	95	78	17	91.0	-	-	-	-	-	-	-	-
Castro	22.7	2.6	20.1	12.7	100	44	56	87.5								

Biological Survey of Cave Invertebrates in the Project: "Cavernas de Mambaí" - Mambaí, Posse, Buritinópolis and Damianópolis, Goiás State, Brazil[3]

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Abstract

Species richness of cave invertebrate communities was analyzed in five caves located in the Mambaí-Buritinópolis-Damianópolis-Posse Karstic complex, northeastern Goiás state, Brazil. The geological and trophic descriptions of each cave are also presented. At least 81 morpho-species belonging to 65 families of Acarina, Araneida, Opilionida, Palpigradi, Pseudoscorpionida, Scorpionida, Isopoda, Symphyla, Scutigeromorpha, Polydesmida, Spirostreptida, Coleoptera, Collembola, Diptera, Dictyoptera, Ephemeroptera, Ensifera, Heteroptera, Hymenoptera, Isoptera, Lepidoptera, Megaloptera, Plecoptera, Psocoptera, Thysanoptera, Trichoptera, Zygentoma and Tricladida were collected. The caves usually possess high resource availability (since they are hydrologically active). The caves of the area are considerably preserved, with invertebrate communities in varied complexity states. The communities of these caves undoubtedly deserve care, since the area is extremely important in the Brazilian biospeleological context.

Introduction

Although detaining an immense potential of cave occurrence in its territory, the speleological surveys in the State of Goiás are partially implemented. Inserted in the carbonatic region of Bambuí group and located in the northeast extremity of the state, the Terra Ronca State Park is where most of the biospeleological researches of the State are concentrated, conducted by researchers like DESSEN et al, 1980; TRAJANO, 1987; TRAJANO & GNASPINI-NETTO, 1990; TRAJANO, 1992; GNASPINI & TRAJANO, 1994; HORTA & MOURA, 1995. The project "Cavernas de Mambaí" (4)1 begun in 1997 and it had as initial objective to make a speleological survey of the cave occurrence in the counties of Mambaí, Posse, Damianópolis and Buritinópolis. Because of the high number of caves found in the first years of the project, from the beginning of 2001, the project was completely reformulated having as main objective the creation of a Conservation Unit of sustainable use. So, the project area was reviewed and extended, passing from 60,000 to 175,000 ha. The project is inserted in the poorest region of Goiás State, where the inhabitants do not possess alternatives of jobs, living basically of the subsistence agriculture. So, the tourism appears as a promising alternative for the inhabitants of the area, since in Brazil the natural attractive consists in an excellent ecotourism opportunity (MARRA, 2000). Ecotourism can be officially defined (by EMBRATUR) as being the path of the touristic activity that uses, in a sustainable form, the natural and cultural inheritance, stimulating its conservation and searching the formation of a conservation conscience through the interpretation of the environment. It is, therefore, in this context that the present biospeleological survey is inserted, and it intends to give support to the elaboration of a managing plan for the correct use of the speleological inheritance that exists in the area.

Study Area

The study area is located approximately 200 km from the Terra Ronca State Park. The project area belongs to the Speleological District of São Domingos (KARMANN & SÁNCHEZ, 1979). The cities included in the project are Mambaí, Posse, Damianópolis and Buritinópolis. Until now, a total of 105 caves were discovered

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[3] Project fnanced and lead by Brazilian Institute of Environmental and Renewable Natural Resources – IBAMA, through its National Center of Study, Protection and Management of Caves-CECAV

in the area. Their linear development varies from some meters until some kilometers of extension as is the case of Tarimba cave, still not totally explored, that presents until the moment about 7 km of linear development.

Explored caves

Fazenda da Extrema I Cave - Coordinates UTM Lat. 374873? Long. 8404776. Cave crossed by the Extrema stream that presents only one conduit, with two development levels. The first one, fossil, is exempt from periodic floods but the second level, located about 4 meters below, is hydrologically active, possessing a stream. In the rainy periods, its main conduct is subjected to overflows due to a strangulation existent in its median portion. The cave possesses nearly 300 meters of linear development, of rectilinear aspect, with about 4 meters width by 7 meters height. In the strangulation the gallery possesses dimensions of 1 by 1 meter. In this point there is an accumulation of argillaceous sediments and vegetal debris carried by the stream. The cave is an oligo- to mesotrophic system, possessing oligotrophic upper galleries and mesotrophic lower galleries, that receive resources continuously.

Ribeirão dos Porcos Cave - Coordinates UTM Lat.374938? Long. 8400284. The two galleries of this cave have rectilinear horizontal morphology. The conduits have lenticular horizontal sections and ceiling with near 4 meters high. The stream conduct is predominantly horizontal, developing toward the draining of the Vermelho River. The cave possesses two distinct systems: the superior galleries are permanently dry, but the basal level, located few meters below, is hydrologically active, possessing a stream. The stream conduct is near 250 meters long. This cave, as the previously cited, is also oligo- to mesotrophic, possessing oligotrophic upper galleries and mesotrophic lower galleries, that receive resources continuously.

Borá IV Cave - Coordinates UTM Lat. 380315 Long. 8393999. Cave with 1010 meters of horizontal projection. Its rectilinear galleries present horizontal elliptical morphology that, in some points, become irregular. The cave has two entrances, one by the Rio das Pedras and other by the Borá Stream. In the stretch formed by the Borá stream the cave presents ornamented ceilings (3 meters high) and accumulations of sandy sediments in the margins of the stream.

Rio das Pedras I Cave - Coordinates UTM Lat. 14°31'54 Long. 46°06'18.2'. Cave with rectilinear morphology, crossed by the Rio das Pedras river in all its horizontal projection. Its only entrance is by the resurgence of this river in an aperture of 13 meters wide by 4 meters high. The cave is predominantly rectilinear horizontal possessing galleries with horizontal elliptical format (transversal sections) with average dimensions of 5 m by 2.50 m high.

Sumidouro Cave - Coordinates UTM Lat. 14°19'10. Long.46°14'39.3"? Cave with extension of 2,000 m. This cave presents almost the main conduct following a small stream placed in the basal level. The cave has two entrances, placed diametrically opposite. These entrances have modest dimensions (3 m wide by 1.90 m high). The conduct in downstream direction has a regular morphology, presenting 4 meters width in average. In its laterals some deposits of argillaceous sediment can be observed. The cave, in the medium portion, suffered a great collapse from the ceiling, which divided it in two distinct paths. Upstream the gallery has a horizontal rectilinear morphology, with accumulation of argillaceous sediments. Downstream, the gallery becomes meandrous, more voluminous, more ornamented, divided in three levels. Near the resurgence, we observed some small lateral conduits filled with speleothems.

Methods

From April to June of 2001 the caves: Ribeirão dos Porcos, Rio das Pedras I, Sumidouro, Fazenda Extrema I had their arthropod fauna collected. The biological survey was made in all potential biotopes such as plant debris and guano piles, and streams and water collections in travertines. The invertebrates were collected with the aid of forceps, brushes, and magnifying glasses, and fixed in 70% etanol. We also used light traps and pitfall traps with liver baits. The individuals were identified until the possible taxonomic level and separated into morpho-species. Voucher specimens are deposited in the laboratory of Ecology and Behavior of Insects (Department of General Biology, Univerdidade Federal de Minas Gerais).

Results

Taxon	Rio das pedras Cave	Borá IV Cave	Ribeirão dos Porcos Cave	Sumidouro Cave	Faz. Extrema I Cave
ARACHNIDA					
Acarina	XX	XX	XX		
Araneae				XX	XX
Araneidae				XX	
Pholcidae	XX	XX	XX		
Segestriidae			XX		
Sicariidae	XX				
Theridiosomatidae	XX			XX	
Theridiidae	XX		XX	XX	XX
Theraphosidae (*Lasiodora* sp.)		XX			
Trechaleidae			XX		XX
Ctenidae		XX	XX	XX	XX
Corinidae		XX			
Sicariidae			XX		
Caponidae			XX		
Opilionida				XX	XX
Gonyleptidae	XX				
Not Identified		XX			
Palpigradi					
Eukoniidae (?)	XX				
Pseudoscorpionida				XX	
Scorpionida					
Buthidae (*Tytius* sp.)				XX	
MYRIAPODA					
Diplopoda					
Polydesmida					
Chelodesmidae				XX	
Pyrgodesmidae	XX				
Spirostreptida					
Pseudonannolenidae	XX				XX
Scutigeromorpha	XX				
Symphyla	XX				
INSECTA					
Coleoptera					
Carabidae	XX	XX		XX	XX
Curculionidae			XX		
Dermestidae			XX		
Dryopidae				XX	XX
Elmidae	XX	XX	XX		XX
Hydrophylidae	XX				
Pselaphidae	XX				XX
Staphylinidae	XX	XX	XX	XX	XX
Collembola	XX				
Entomobryiidae					XX
Diptera					
Chironomidae	XX				
Culicidae					
Dolichopodidae				XX	XX
Drosophilidae				XX	
Milichiidae				XX	
Mycetophilidae				XX	
Phoridae				XX	
Tipulidae					
Dictyoptera	XX			XX	XX
Ensifera					XX
Grillotalpidae	XX				
Phalangopsidae (*Endecous* sp.)	XX			XX	XX

Taxon	Rio das pedras Cave	Borá IV Cave	Ribeirão dos Porcos Cave	Sumidouro Cave	Faz. Extrema I Cave
Ephemeroptera	XX			XX	XX
Heteroptera					
Belostomatidae		XX		XX	
Reduviidae (*Zelurus* sp.)	XX		XX	XX	
Ploiariidae				XX	XX
Veliidae					XX
Hymenoptera					
Formicidae	XX		XX	XX	
Formicidae (*Sacryptocerus* sp.)		XX			
Evaniidae		XX			
Isoptera			XX		
Nasutitermitidae	XX		XX		
Lepidoptera				XX	
Geometridae	XX				
Noctuidae	XX		XX	XX	
Tineidae	XX		XX		XX
Psocoptera			XX		XX
Liposcelidae			XX		
Psyllipsocidae	XX				
Pseudocaeciliidae			XX		
Megaloptera					
Corydalidae (*Corydalus* sp.)		XX			
Trichoptera	XX			XX	XX
Hydropsichydae			XX		
Plecoptera			XX		
Thysanoptera					XX
Zygentoma					
Nicoletiidae	XX				
Homoptera					
Cixidae		XX			
CRUSTACEA					
Isopoda					
Plathyartrydae (*Trichorhina* sp)		XX		XX	
TREMATODA					
Tricladida				XX	

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Camiro 1.0 – The Romanian Cave Minerals Database Program

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Abstract

The present article introduces the Cave Minerals of Romania database (CAMIRO 1.0), a computer-based program that allows cataloging of all known cave mineral species including their main characteristics. CAMIRO 1.0 is a mineralogical database created using Borland® Delphi™ 4 Professional, an object-oriented, visual-programming environment that allows rapid application development. CAMIRO 1.0 is a collection of geologic, mineralogic, crystallographic, and protection information about cave minerals. It holds and organizes large amounts of information, including photos. Related information (e.g., mineralogical or crystallographic) are grouped together to form *records*. These records are gathered into several related *fields*. In order to logically group all necessary fields we have created the following three pages: *General data, Mineralogical data,* and *Crystallographic data.* Such a cave minerals database would have many various scientific purposes or it could simply be a quick and easy to surf electronic handbook. With the help of its easy–to-excess content, the database could provide cavers with basic information on identifying and describing the mineralogy of most of the strange-looking speleothems.

Motivation

Over the last 30 years, several papers and three major books dealing with various aspects of cave minerals worldwide have been published (MOORE, 1970; HILL, 1973; HILL & FORTI, 1986, 1997; MOORE & SULLIVAN, 1997; ONAC, 1999).

In 1973, Hill published the first book describing the entire cave minerals found in United States up to that period. Later, Hill and Forti published two editions (1986 and 1997) of *Cave Minerals of the World,* providing both cavers and professional mineralogists with an incredible amount of information on cave minerals and the resulting speleothems they form.

Advancements in technology (new high-tech X-ray Diffraction, SEM and TEM devices, powerful models of ICP-MS) have resulted in an explosion of new mineralogical data included in the last edition of *Cave Minerals of the World.* However, the last two editions were published 11 years apart, showing that in order to keep up-to-date information on this exponential-like curve of the cave mineralogy knowledge a computer-aided database is needed.

At least three reasons for creating such a mineralogical electronic database are as follows: (1) the data (various information and illustrations) can easily be archived, (2) to update a previous version takes a shorter time and less money than printing a new book edition, and (3) the database can be distributed worldwide so that more cavers and scientists can access it.

About CAMIRO 1.0

CAMIRO 1.0 is a mineralogical database created using Borland® Delphi™ 4 Professional, an object-oriented, visual-programming environment that allows rapid application development

CAMIRO 1.0 has the following minimum system requirements:

IBM PC/PS2 or compatible with 486 based CPU or higher.

At least 4MB free on its hard disk.

Windows 95 or later.

At least 2MB RAM.

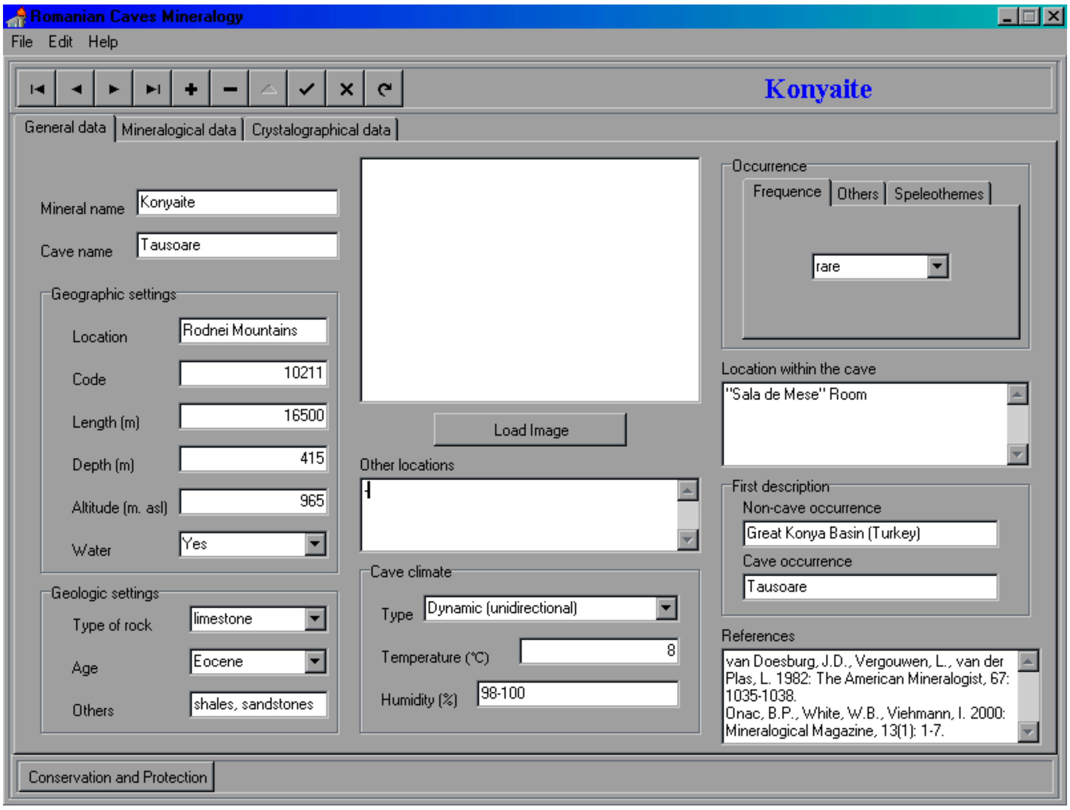
Those interested in purchasing this program are welcome to place their request with one of the authors at the above-mentioned address.

Application description

CAMIRO 1.0 is a collection of geologic, mineralogic, crystallographic, and protection information about cave minerals. It holds and organizes large amounts of information (including photos), and makes any item immediately accessible. Related information (e.g., mineralogical or crystallographic) are grouped together to form *records*. These records are gathered into several related *fields*. In order to logically group all necessary fields we have created the following three pages: *General data, Mineralogical data,* and *Crystallographic data.*

General data

This page contains fields such as: *Mineral name*, *Cave name*, *Other locations, Geographic settings, Geologic settings, Cave climate, Occurrence, First description, References, and Speleothem image* (Fig. 1). A few of these fields include several records and therefore need further explanation.



Mineral name: Konyaite
Cave name: Tausoare

Geographic settings
Location: Rodnei Mountains
Code: 10211
Length (m): 16500
Depth (m): 415
Altitude (m. asl): 965
Water: Yes

Geologic settings
Type of rock: limestone
Age: Eocene
Others: shales, sandstones

Other locations:

Cave climate
Type: Dynamic (unidirectional)
Temperature (°C): 8
Humidity (%): 98-100

Occurrence
Frequence | Others | Speleothemes
rare

Location within the cave: "Sala de Mese" Room

First description
Non-cave occurrence: Great Konya Basin (Turkey)
Cave occurrence: Tausoare

References:
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Fig. 1. General data page with its fields and records.

Within the *Geographic setting* field, information such as cave location and cave numerical code (extracted from the Romanian Cave Index; GORAN, 1982) to allow users interested in a certain cave to perform a rapid mineral search. In addition, information such as length and depth of the cave, altitude of the cave entrance, and presence or lack of underground stream was included

The type and age of rock that host the cave are the main records grouped under the *Geologic settings* field. If more than one type of rock is present this is mentioned within *Others* record.

Cave climate through its main parameters of ventilation type, temperature, and humidity is often responsible for the genesis of some mineral species in the cave environment. Knowing such information, one can better understand the deposition and stability of minerals.

Under the *Occurrence* field the three dialogue windows are *Speleothems*, *Frequency*, and *Others.* These windows allow a user to find out what types and subtypes of *Speleothems* were identified (according to the classification proposed by HILL & FORTI, 1997) and what is their *Frequency* (i.e., very common, common, rare, and uncommon). If additional remarks can be made under this main field, these comments should be placed in the window called *Others.*

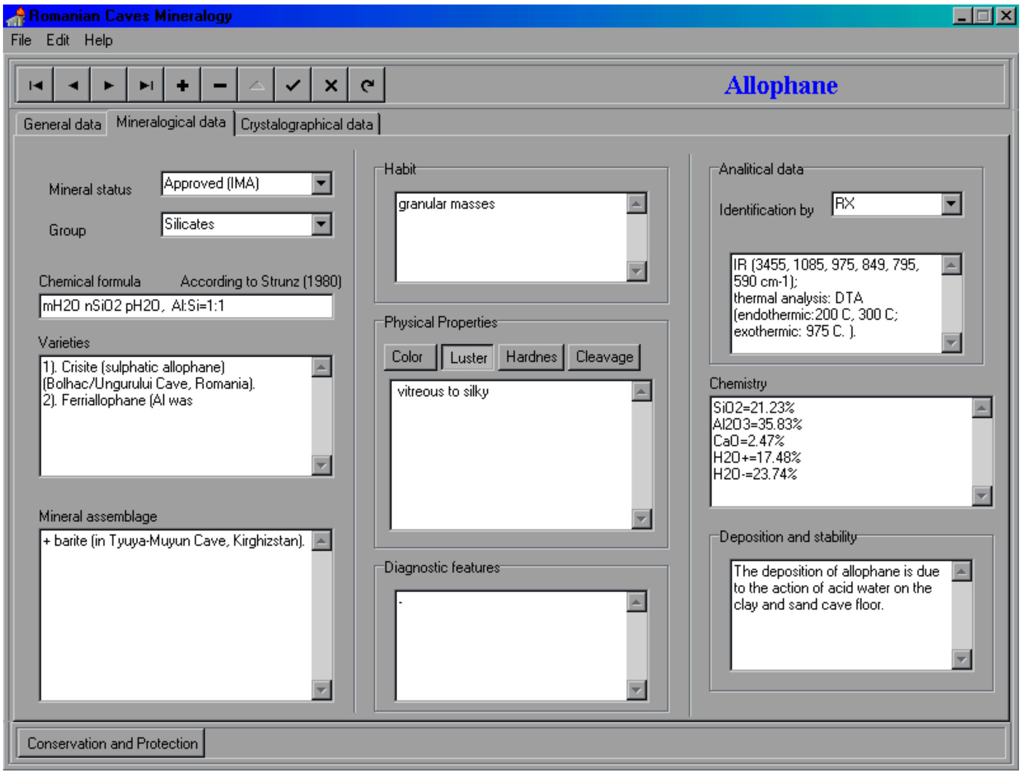
The *First description* field contains two records: *Non-cave occurrence* and *Cave occurrence.* The *Non-cave occurrence* record cites the location of those minerals that were first described outside the cave. The *Cave occurrence* field cites the first cave in which that mineral was found. When the *Non-cave occurrence* record remains empty, the user should understand that the mineral was first discovered in a cave.

Whenever a common mineral (e.g., calcite, aragonite, gypsum, brushite, etc.) was found in several caves, only that cave where the mineral is best displayed is presented in detail. Other caves were the mineral occurs are listed within the *Other location* field.

Location of certain speleothems within the cave (i.e., well-ventilated passages, aerosols-rich environment, etc.) is sometimes essential when discussing the mineral genesis. For this reason, we believe both cavers and scientists should always record this information in their field book.

Mineralogical Data

The page called *Mineralogical data* provides information that is obtained after a number of observations and laboratory analyses (Fig. 2). Foremost, the *Mineral status* (approved, discredited, or revised by IMA) is presented. The mineral is then placed within the chemical *group* where it belongs. The *Chemical formula* is given according to STRUNZ (1982). If the speleothem of a variety of a well-known mineral (e.g., selenite, which is a coarsely crystalline, transparent variety of gypsum) this information is in the *Varieties* field. Cave minerals often do not appear alone but with other minerals formed under the same set of circumstances. The *Mineral assemblage* field emphasizes what other mineral(s) was/were identified in the composition of the same speleothem. The external shape of crystals is described under the *Habit*. *Color, Luster, Hardness* and *Cleavage* represent the major *Physical properties* of a mineral and are each recorded in a different dialogue window. For those minerals with *Diagnostic features* (e.g., calcite fizzes vigorously in dilute HCl, nitrates have a very bitter, pungent taste, mirabilite forms glassy-clear crystals etc.) a special window was created.



Mineral status: Approved (IMA)

Group: Silicates

Chemical formula According to Strunz (1980): mH2O nSiO2 pH2O, Al:Si=1:1

Varieties:
1). Crisite (sulphatic allophane) (Bolhac/Ungurului Cave, Romania).
2). Ferriallophane (Al was

Mineral assemblage: + barite (in Tyuya-Muyun Cave, Kirghizstan).

Habit: granular masses

Physical Properties: vitreous to silky

Diagnostic features: -

Analitical data

Identification by: RX

IR (3455, 1085, 975, 849, 795, 590 cm-1);
thermal analysis: DTA (endothermic:200 C, 300 C; exothermic: 975 C.).

Chemistry:
SiO2=21.23%
Al2O3=35.83%
CaO=2.47%
H2O+=17.48%
H2O-=23.74%

Deposition and stability: The deposition of allophane is due to the action of acid water on the clay and sand cave floor.

Fig. 2. Mineralogical data page.

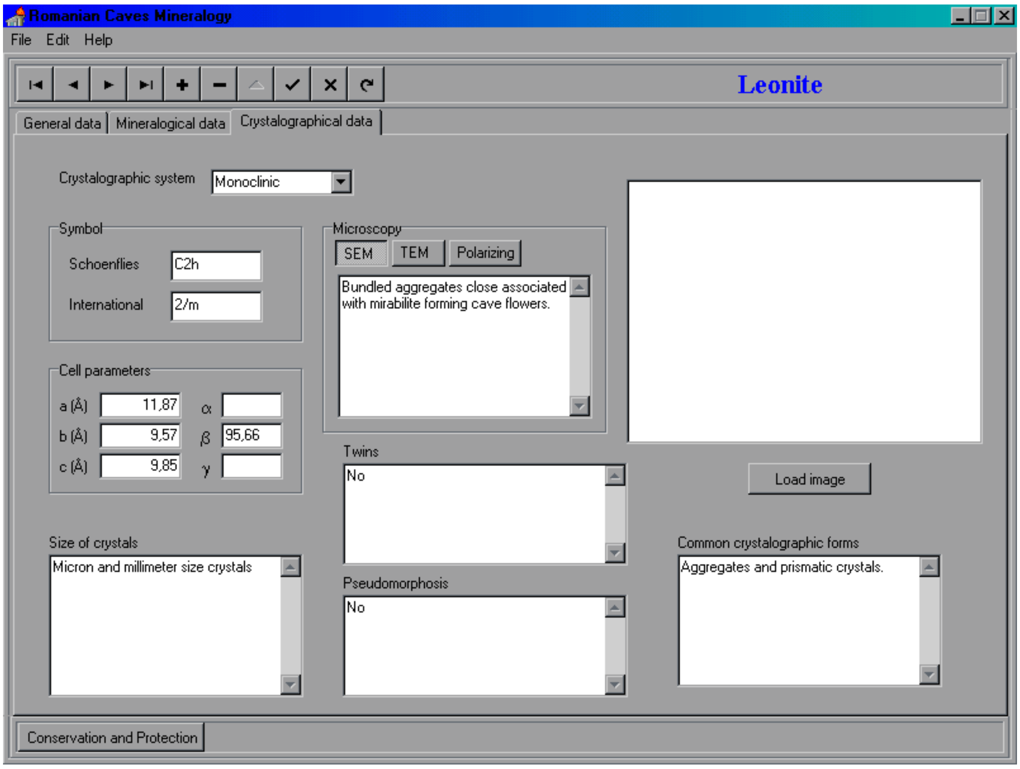
The *Analytical data* field contains an *Identification* by record, listing the main methods used to describe the mineral (X-ray, thermal, IR etc.). In addition, a dialogue window was added in order to specify any other laboratory diagnostic methods.

The *Chemistry* field displays quantitative chemical data provided by various analytic methods (XRF, EDS, ICP-MS, etc.).

The last dialogue window of the *Mineralogical data* page relates to the *Deposition and stability* of the cave minerals. At this location, cavers and scientists will find information on the cave settings under which a particular mineral formed.

Crystallographic Data (Fig. 3)

In the first field of the *Crystallographic data* page users will learn to which of the seven *Crystallographic system* the mineral belongs.



Crystalographic system: Monoclinic

Symbol
Schoenflies: C2h
International: 2/m

Cell parameters
a (Å): 11,87
b (Å): 9,57
c (Å): 9,85
α:
β: 95,66
γ:

Microscopy: Bundled aggregates close associated with mirabilite forming cave flowers.

Twins: No

Pseudomorphosis: No

Size of crystals: Micron and millimeter size crystals

Common crystalographic forms: Aggregates and prismatic crystals.

Fig. 3. Crystallographic data page.

Both *Schoenflies* and *International* notations devised for crystal classes are presented under the *Symbol* field.

Two types of data used to describe the axial elements are gathered under the *Cell parameters* field. These include (1) the cell size parameters (a, b, c) and (2) the angles between the crystal's crystallographic axes (□□□□ and□□□□□interaxial angles).

The following four fields bring specific data on the mineral under question: *Size of crystals,* the presence of *Twins* or *Pseudomorphs,* and the most *Common crystallographic forms* (i.e., prisms, rhombohedron etc.). The Load image button can display images of the crystal. This option is normally deactivated in order to increase the application speed.

All results acquired through different optical techniques are grouped under the *Microscopy* field. Observations made with an ordinary polarizing microscope (e.g., refractive indices, twins, cleavage etc.) and with more high-powered scanning (SEM) and transmission electron microscopes (TEM) (crystal fabric and structure, inclusions etc.) are recorded.

Conservation and Protection

Within each of the three pages a button located in the lower left corner opens the *Conservation and Protection* dialogue window. The purpose of this memo field is to provide a warning signal for cavers on how they should behave when entering a cave that is decorated with speleothems of different mineralogy. To preserve speleothems (minerals) in both wild and show caves, many factors must be considered. For example, when a cave hosts mirabilite speleothems it is absolutely prohibited to camp in their close vicinity. Mirabilite crystals are highly sensitive to temperature and humidity variations and will quickly dehydrate and disintegrate into a white powder.

Conclusions

The CAMIRO 1.0 application, developed using Borland Delphi 4 Professional, is a mineralogical database designed to store a variety of information on all cave minerals discovered in Romania.

Presently, this application represents the first attempt in creating a computer-aided mineralogical database that can be distributed among the speleological community. The intent is to expand it and generate a worldwide electronic catalogue of cave minerals. Such a cave minerals database would have many various scientific purposes or it could simply be a quick and easy to surf electronic handbook. With the help of its easy–to-excess content, the database could provide cavers with basic information on identifying and describing the mineralogy of most of the strange-looking speleothems.

In order to improve the present version of CAMIRO we would appreciate any comments, ideas, and observations. Major input is expected from members of the *Cave Mineralogy Commission* within the International Union of Speleology.

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El Mito de la Serpiente de las Grutas

Carlos Augusto Evia CERVANTES
-

Resumen

En la **tradición oral** del Estado de Yucatán, México, hay un **relato mítico** que tienen una fuerte presencia y que es repetido por las personas que habitan en las comunidades rurales en regiones cercanas a las cuevas. Se trata de una gigantesca **serpiente** llamada Tsukán.

De acuerdo con los testimonios obtenidos este extraño ser vive, cuida y es dueño de la gruta que ocupa. Se dice que es tan grande que su cuerpo es como el tronco de un árbol y su cabeza es como la de un caballo. Este mito tiene su origen, al parecer, en el área cultural mesoamericana y es por lo tanto una manifestación que llega hasta nuestros días desde la época prehispánica. El análisis de este mito nos condujo al conocimiento de relatos similares en otras partes del mundo con los cuales se advierten factores simbólicos comunes: el agua, la cueva y, por supuesto, la serpiente.

1.- Introducción

Conocer las tradiciones de una sociedad contribuye al fortalecimiento de su existencia y a su preservación. Específicamente la tradición oral constituye un campo de vital importancia en la cultura de los pueblos de América, porque es un indicador de la trascendencia cultural de los pueblos del continente americano a pesar de los tres siglos de dominación colonial y los dos de influencia de la civilización moderna sobre la etnia maya. Gracias a lo anterior se puede estudiar e interpretar el contenido de los relatos generados por las etnias a partir de su tradición oral. La investigación en este campo debe ser uno de los objetivos de la ciencia antropológica ya que contribuye a la identidad de los pueblos y a la preservación de los valores sociales de cada cultura. Por esta razón en este trabajo se vincula el estudio de la tradición oral con la existencia de las cavernas, las cuales son elementos del paisaje que han sido utilizadas por el hombre desde su pasado más remoto.

2.- Definición de Conceptos

Para comprender los materiales de campo es necesario definir dos conceptos que permiten entender el objeto de estudio; estos son: la tradición oral y el mito.

La tradición oral abarca tres componentes que se encuentran en la vida cotidiana de los miembros de una sociedad: memoria colectiva, oralidad y tradición.

Se entiende por **memoria** la posibilidad que tiene un sujeto o una sociedad de recordar los sucesos en el pasado lejano o cercano que han vivido los sujetos sociales. La **memoria colectiva** es el producto de las experiencias de un sujeto social o a un grupo de ellos que van de la experiencia vivida por una generación hasta el recuerdo de varias generaciones. Este saber se mantiene vivo a través de la memoria individual, pero en todo caso se encuentra en el pensamiento social. El carácter **colectivo** de la memoria se debe a que los saberes individuales se van tornando sociales y se convierte en la historia o saber de un grupo. La **oralidad** es la formulación de un intercambio verbal entre dos sujetos y nos permite entender la transmisión de los conocimientos de una generación a otra (PÉREZ TAYLOR; 1996: 26-27).

Por sí mismas, la memoria y la oralidad no irían más lejos. Se necesita de la evocación de los recuerdos, los cuales se producen en una sociedad donde hay un orden socialmente construido y reforzado por la repetición. En este sentido, la evocación del recuerdo materializa la memoria colectiva, entonces surge la **tradición,** que es la recuperación de memoria de los hechos o ideas pasados (PÉREZ TAYLOR: 1996, 15 y 19). De esta forma se constituye la **tradición oral**.

Hay una gran discusión en cuanto a los géneros que puede abarcar la tradición oral definida como se ha hecho anteriormente. Sin embargo casi siempre los autores incluyen tres categorías principales: el cuento, la leyenda y el mito. Después de revisar los materiales recogidos en el campo y de una discusión teórica realizada en otra parte con base a la aportación de los autores especializados en el tema, se concluye que el relato de la serpiente Tsukan es un mito (EVIA CERVANTES; 2000: 64-71). Por lo tanto, se ofrece ahora la definición de mito: es una **construcción social** que se expresa y transmite en el lenguaje de un grupo humano, una cultura o sociedad específica. El mito como elemento de la cultura, **persiste** a través del tiempo, pero no invulnerable a él, suele cambiar la forma. La fuente del mito es la sociedad, pero la autoría del mismo es **anónima**. El mito aborda asuntos **serios** (origen de las cosas, divinidad, monstruos fantásticos, etc) y sus protagonistas, ya sea un dios, un héroe, o un animal son de naturaleza **sobrenatural**. Si el mito contiene en su argumento algún problema o drama, éste se resuelve con actos o elementos **mágicos**.

En Yucatán, estado de México, se ha generado una forma específica de mitología relacionada con las cavernas, las cuales son elementos del paisaje con los que el hombre americano ha convivido desde sus orígenes. Las grutas tuvieron mucha importancia en la vida de los antiguos mayas, y con seguridad fueron utilizadas aún en la primera mitad de este siglo. En cuanto a los cenotes, grutas inundadas, eran los únicos depósitos naturales de agua de la época prehispánica. De allí su enorme importancia para el desarrollo de la civilización, y por lo tanto, su función en la cultura.

3.- El Mito de la Tsukan

A raíz de diversos recorridos efectuados en las comunidades rurales del Estado de Yucatán, el autor ha escuchado con marcada frecuencia testimonios acerca de la existencia de una serpiente llamada Tsukan. De acuerdo con los relatos, este extraño ser vive, cuida y es dueño del cenote o de la gruta con la que se le asocia. Para aproximar su tamaño, los que se refieren a ella, generalmente dicen que "es tan grande, que su cabeza es como la de un caballo" y que también tiene crines. Se reporta que algunos cazadores han estado muy cerca de la mítica serpiente en aquellas ocasiones en que van esconderse en la entrada de las cuevas, esperando que sus presas entren a beber agua. Sin embargo, estos cazadores, en ocasiones son sorprendidos porque en la cueva puede estar alojada una Tsukan (EVIA CERVANTES: 1996, 46).

En otras versiones se hace referencia al grosor y a la apariencia de su cuerpo, el cual se puede confundir con un tronco. De acuerdo con una versión, un campesino se sentó en lo que creyó que era el tronco de un árbol y al rato sintió que el tronco se movió por sí solo; entonces descubrió que era una Tsukan. Se dice que cuando la Tsukan está atravesada en el camino, no se le ve la cola, ni la cabeza; ambas se pierden en el monte. Los campesinos u otras personas que han tenido la experiencia de hallarla en su camino, prefieren regresar por donde vinieron que brincarla. Ellos saben que no deben intentar matarla, pues alguna desgracia les acaecería, incluida la muerte. Una de las consecuencias más frecuentes para quien ataca a ésta serpiente es la parálisis temporal o permanente en las piernas. Los campesinos son precavidos cuando están cerca de las grutas, pues la Tsukan para alimentarse sólo tienen que abrir la boca y los animales silvestres son absorbidos por el calor de su aliento. Algunas versiones dicen que la Tsukan vive en un pozo; la gente nota que cuando algún pájaro vuela sobre la boca del pozo, es atraído por la serpiente que está en el fondo; entonces el ave se mete y nunca más se le ve salir.

En otros relatos se dice que alguien dio muerte a la Tsukan, generalmente con una escopeta, pero esa acción audaz no sirve para nada porque al poco tiempo se vuelve a ver a la serpiente con crines. Ciertas versiones dicen que cuando ya están viejas, les crecen alas y vuelan hacia el mar donde se retiran para morir. Pero la especie mitológica Tsukan no desaparece.

Otro detalle que está en casi todas las versiones, es que los informantes dicen que no cualquiera la pude ver, sino es cuestión de "suerte". Al decir suerte no parecen referirse a un evento afortunado, sino a una capacidad permanente o temporal que tiene el sujeto para ver algo que no todos pueden percibir. Es como entrar a un estado anímico que perturba momentáneamente al sujeto y que deja en su memoria una huella imborrable.

En los relatos, la serpiente no es identificada con alguna de las especies conocidas, en cambio es descrita como "aire". En este caso, el término "aire" significa que el ser al que hacen referencia, es de naturaleza espiritual y no material.

4.- Los Antecedentes

El respeto y mitificación de la serpiente encontró su punto de partida entre los olmecas, considerados los portadores de la cultura madre de Mesoamérica (2500-1500 a. de C). Se ha comprobado que ejercieron su dominio desde los estados de Veracruz y Tabasco hasta regiones del centro de México, como las provincias de Morelos y Guerrero. Los olmecas no dejaron códices, pero sí un gran corpus escultórico que representa su cosmovisión. En el sitio llamado “La Venta”, se descubrió un monolito de basalto en cuya superficie está tallada la que podría ser la primera imagen de la serpiente del mundo mesoamericano. El monolito está situado en un edificio llamado Monumento 19, con rango de antiguedad aproximada entre los siglos X y VI a. de C. En él aparece la figura de una serpiente con una proporción mayor que el tamaño natural, con los colmillos visibles y sobre su cabeza hay unas bandas que sugieren plumas. Junto a ella está sentado un hombre cuya vestimenta indica cierto rango de autoridad. El conjunto ha sido interpretado como la forma ancestral de la “la serpiente emplumada” (BALDWIN; 1999: 15-17). Otro autor menciona la representación de una serpiente pintada en rojo con prolongaciones sobre la cabeza y fauces abiertas. Esta pictografía, que se encuentra en la cueva de Juxtlahuaca, ubicada en las montañas de Guerrero, se le atribuye a los olmecas (SOUSTELLE; 1995: 87-88). En este caso la asociación entre la serpiente y la cueva resulta más clara.

La influencia de la serpiente en los mayas se ha comprobado repetidamente tanto en su cosmovisión como en su arquitectura, escultura y arte cerámico (COE; 1997: 110, 146, 158 y 214). Por tanto sólo se hará una referencia muy específica que aparece en un documento indígena llamado “Chilam Balam de Chumayel”. De acuerdo con la interpretación de un investigador, se trata de una extraña serpiente denominada “Hapaikán”, cuya traducción es “la serpiente chupadora”. Este ser mítico estuvo relacionado con el ascenso al poder de un personaje que habría de influir en una etapa importante de la historia de las ciudades mayas prehispánicas. En el Templo de los Guerreros, situado en Chichén Itzá, existe un mural que parece aludir a esta etapa, pues muestra un sacrificio humano en presencia de una gran serpiente con elementos corporales semejando plumas. El autor induce que es una serpiente emplumada, lo que sugiere alguna relación con Kukulkán (ROYS; 1973: 179-1980).

5.- Distribución Geográfica del Mito

Por muy extraordinario que parezca un relato de una serpiente de grandes proporciones, que vive en las grutas y/o en los cuerpos de agua contenidos en ellas, por rigor metodológico fue necesario investigar en la mitología de otras partes del mundo y conocer la interpretación que se le han dado a esas narraciones. De esta manera es como se descubren los siguientes casos:

La serpiente Lou.- En uno de los linajes de origen Dinka, que vive en la región habitada por la tribu Leek (Sudán), tiene como tótem a la serpiente Luo. Se dice que esta enorme y mítica criatura gustaba de frecuentar las corrientes de agua y que su cabeza peluda se movía de un lado para otro conforme avanzaba por el agua. Los pertenecientes a este linaje aseguran que su antepasado principal recibió la visita nocturna de Lou, hecho que asustó mucho a la esposa de éste, al grado que se desmayó al verla. Al despertar el marido y ver a su mujer en estado de inconsciencia, prometió a Dios un buey para su restablecimiento. Desde entonces es muy respetada por todos sus descendientes (EVANS - PRITCHARD; 1980: 89-90).

La serpiente Kurreya.- Entre los australianos autóctonos se cree en la existencia de un monstruo de enormes dimensiones, semejante a una serpiente. Se le llama Kurreya y vive en las cuencas profundas y permanentes. Se le asocia con el elemento agua, el cual tiene una importancia vital para los habitantes de toda Australia. Cuando se le describe se dice que es un ser fantástico de grandes dimensiones semejante a una anguila o serpiente; que su cabeza es muy grande, con pelo rojo y fauces enormes. Además es peludo y de varios colores. Puede tragarse toda el agua en la que vive y también a sus víctimas (PROPP; 1979: 373-374).

Serpiente acuática de Galicia.- En la cultura popular gallega se habla de un ofidio mitológico. Se cree que es un animal totémico que vino del agua, como un genio protector del hogar y sus habitantes. Aun quedan reminiscencias de su culto en la en la provincia citada. Se cree que la serpiente está escondida en pozos y fuentes desde octubre hasta fines de abril, aproximadamente. Durante ese tiempo “es muy raro ver alguna”, dice la gente. Desde finales de abril hasta finales de septiembre las serpientes se dejan ver por todas partes y salen a alimentarse de sapos, pájaros, conejos y otros bichos que atrae con el aliento. Las serpientes no mueren; cuando son viejas les crecen alas y se van volando al río Jordán. (ANTON Y MANDIANES: 1995, 103-111).

Bachúe.- En la tradición oral de los muiscas, grupo humano perteneciente a la cultura chibcha de Colombia, hay un mito que trata de la creación de las cosas y se cree que en una gran laguna atrapada entre las heladas cumbres del paisaje, salió una mujer llamada Bachúe. De la laguna sacó a un niño que cuando creció se casó con ella y de cada parto tenía cuatro y cinco hijos. Como iban de un lugar a otro dejando a sus hijos, fueron poblando la tierra. Después de muchos años la tierra ya estaba llena de gente y ellos ya muy viejos. Entonces volvieron al mismo pueblo donde habían salido y se convirtieron en dos grandes culebras; ante toda la gente se metieron a las aguas de la laguna para nunca más aparecer. Sin embargo, la Bachúe se apareció muchas veces por otros lugares y los indios la contaron entre sus dioses, por los beneficios que de ella habían recibido

(RICKEBERG; 1991: 151-152).

La Madre de Agua.- En la tradición oral de Cuba hay un relato muy frecuente: se trata de la Madre de Agua, una serpiente mágica, muy poderosa que vive en cuevas lagunas y ríos. Un escritor cubano recolectó 50 relatos en las zonas rurales de ese país. En muchas de las versiones obtenidas la serpiente es descrita con cuernos que le crecen mientras envejece y con cuerpo de tronco de árbol, generalmente de palmera. Envejecen pero no perecen y nadie se atreve a agredirlas, porque quien lo haga morirá. A veces las Madres de Agua no atacan a nadie pero a las personas que las ven les da fiebre. Lo bueno que tienen, según los informantes, es que el río o laguna donde hay una Madre de Agua, nunca se seca (FEIJOO : 1986,186-187).

La lista de serpientes no se agota con estos casos. Lo que se quiere destacar es que en cada uno de estos ejemplos se percibe la presencia de tres elementos comunes: la serpiente, el agua y la cueva, mismos que se analizarán a la luz de la simbología universal.

6.- El Mito y sus Símbolos

La serpiente, la cueva y el agua, principales elementos simbólicos del mito estudiado fueron y son todavía de una gran importancia en la mayoría de las culturas del mundo. Un breve repaso sobre los contenidos de cada uno de los símbolos que conforman el mito de la Tsukan nos aproximará a su significado.

La serpiente. Animal simbólico en muchas culturas arcaicas es concebido como la representación del mundo subterráneo y del reino de los muertos, probablemente a causa de su manera de vivir en lo oculto y en agujeros de la tierra, pero al mismo tiempo por su capacidad de mudar de piel, parece rejuvenecer. La vida y la muerte se insinúan en la figura de este animal, de un modo tan singular, que apenas hay culturas en las que no se haya prestado atención a la serpiente (BIEDERMANN: 1999, 420-423).

En sus análisis de cuentos, Propp, señaló que la figura de la serpiente es la más complicada e indescifrada del folklore y la religión. El autor encontró que la serpiente está vinculada con el agua. Pero no es exclusiva del agua y se le puede asociar con otros tipos de medio natural como la montaña y las cuevas (PROPP: 1979, 317).

Otra de las funciones destacadas que las serpientes desempeñan es la de guardianes de los tesoros de la tierra. La serpiente cuida uno de esos tesoros más apreciados por todos los pueblos del mundo: el agua (BIEDERMANN: 1999, 420-423).

La cueva. Es el arquetipo del seno materno, simboliza el lugar de origen de muchos pueblos, fue la sede de los primeros oráculos, la entrada al mundo de los muertos y representa la región infernal donde habitan monstruos que guardan tesoros (CHEVALIER; 1995: 263-267). La mitología y la religión de Mesoamérica están impregnadas con el tema de las cavernas. El culto a las cuevas tuvo gran importancia en las prácticas religiosas antiguas y todavía la tiene en nuestros días. Representaciones de cuevas abundan en los códices indígenas de la época prehispánica (HEYDEN: 1989, 91).

El agua. En tanto que es masa informe e indiferenciada ya sea de río, de manantial, de lago o de mar, simboliza la plenitud de todas las posibilidades o el origen primitivo de todo lo existente, es decir, la materia prima. En ese sentido aparece en numerosos mitos de la creación. El agua es también símbolo de renovación física, psíquica y espiritual, así como de purificación, tanto en el islamismo, como en el budismo y el cristianismo. La relación simbólica del agua con la fecundidad y la vida es universal (BECKER: 1998, 13).

Con la interpretación combinada de estos símbolos se explica como es que la Tsukan corresponde a la manifestación local de la mitología universal, no sólo por la descripción de su apariencia, sino por su función como guardiana del agua, elemento indispensable para el surgimiento de la vida y el desarrollo de la civilización.

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Sítio Espeleológico Lincoln Magalhães

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Abstract

The Lincoln Magalhães Speleological Site is located in Jequitibá Township at 42 kilometer near Sete Lagoas City in Minas Gerais State. The area is part of the São Francisco Supergroup and the following rocks are represented on the base to the top by carbonates of Lagoa do Jacaré Formation and pelitics of Serra da Saudade Formation. The most evident structural pattern in the area is represented by a system of NS lineation marked by thrusts (reverse faults). Abundant kinematics hear sense indicators show tectonic transport towards E to W directions. Based on this study we determinate one speleological/arqueleological site that are comprised by small to medium caves that are controlled by these structures. In addition, these caves are well ornamented and some of them there are arqueological vestiges. This speleological site is comprised by 12 caves in which develop average is around 100m. The predominant development of these caves is NS and EW.

1 Introdução

O presente trabalho tem por objetivo apresentar os resultados de um levantamento geoespeleológico, realizado em área com cerca de 500ha, localizada no município Jequitibá-MG (*Figura 01*).

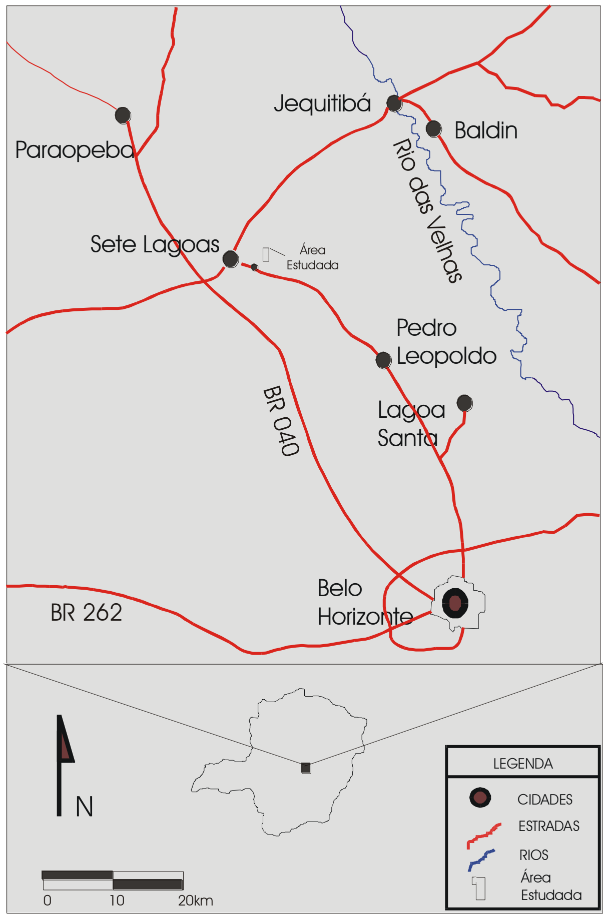


Figura 01 – Mapa de localização e vias de acesso modificado de Magalhães 1988

2 Localização e Acesso

A área estudada localiza-se no município de Jequitibá/MG distando cerca de 20 km a sudoeste dessa cidade (*Figura 01*).

3 Geologia Regional

3.1 Geomorfologia

Segundo Boaventura *et al* (1977), a área insere-se em uma “ilha” de planaltos residuais do São Francisco, bordejada por superfícies aplainadas da Depressão Periférica do São Francisco, que são as duas unidades geomorfológicas principais da região. As formas de relevo constituem-se de superfície tabular, no primeiro caso, e superfície aplainada e superfície ondulada em depressão, no segundo caso.

3.2 Estratigrafia

Segundo Magalhães (1988), o Grupo Bambuí pode ser dividido em três unidades principais: uma basal, predominantemente carbonática; uma intermediária, composta por clásticos finos e um segundo nível de carbonatos escuros intercalados com clásticos finos. Em concordância à denominação Formação Sete Lagoas, Formação Serra de Santa Helena e Formação Lagoa do Jacaré de Dardenne (1978).

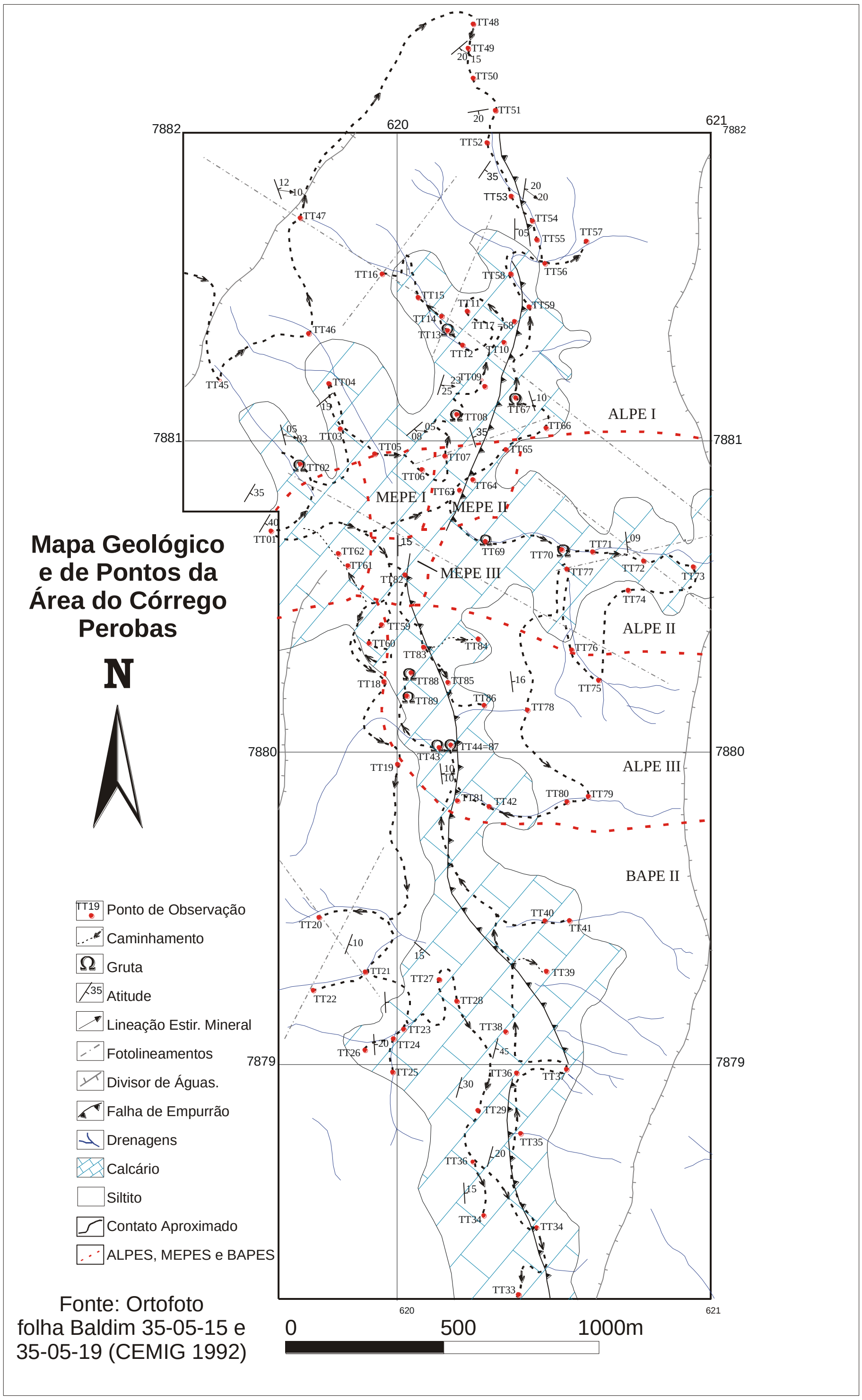
3.3 Geologia Estrutural

Magalhães (1988) mostra que as unidades do Supergrupo São Francisco têm sua ocorrência limitada a leste pelas frentes de empurrões presentes na Cordilheira do Espinhaço e ao sul, o limite faz-se com os gnaisses e migmatitos do embasamento cristalino. A caracterização estrutural, da porção sudeste da bacia do São Francisco, foi feita, também, por Magalhães (1988) que individualizou três domínios estruturais distintos representados por falhas de empurrão, rasgamento e pares conjugados de cisalhamento. Segundo Alkmim *et al.* (1989) este compartimento estrutural da bacia do São Francisco pode ser entendido como pertencente à área de influência da Faixa de Dobramentos Araçuaí, originada durante o Ciclo Brasiliano.

4 Geologia Local

De acordo com os estudos efetuados foi possível subdividir a área em duas unidades, a seguir: a base formada por rochas carbonáticas e o topo por rochas pelíticas (**Figura 02**). As rochas carbonáticas apresentam composição calcítica e dolomítica e as rochas pelíticas variam de siltitos a ardósias, em alguns pontos. As rochas carbonáticas apresentam coloração, em geral, cinza médio a cinza claro. São rochas cristalinas a laminadas. Em alguns pontos, como o TT 27, podem-se observar intraclastos, os quais encontram-se alongados segundo o S0//Sn. O siltito/lamito apresenta coloração cinza amarelado e é finamente laminado. Nos pontos onde se observa a ardósia (TT 53, 55), a rocha é finamente laminada e a coloração é cinza esverdeada. Em uma análise comparativa, aos estudos de Magalhães 1988, as rochas carbonáticas (base) podem ser correlacionadas àquelas da Formação Lagoa do Jacaré e as rochas pelíticas (topo) às da Formação Serra da Saudade, ambas pertencentes ao Grupo Bambuí.

O padrão geomorfológico pode ser subdividido em topo e base. O topo, de rochas pelíticas, apresenta um relevo tipo cuestas, sendo mais abaulados. A base, representada pelas rochas carbonáticas, predomina um relevo de *canyons* (vales cársticos), paredões, grandes escarpas e dolinamentos. Assim como a geomorfologia, a vegetação apresenta um padrão diferenciado, sendo que nos altos, ou seja, na cobertura, tem-se uma vegetação baixa do tipo campo, excetuando-se nas drenagens, onde a vegetação é de médio porte. Porém, nos domínios de rochas carbonáticas, a vegetação é constituída por matas fechadas, com árvores de pequeno a grande porte, de vários tipos. O controle hidrológico se faz pela serra dos Pires, onde partes das águas deságuam, para leste, no Córrego da Serra e tendo como destino o Rio Cipó, e partes das águas migram, para oeste, desembocando no Córrego das Perobas e por final atingindo o Rio das Velhas. A hidrogeologia é caracterizada por sumidouros, nascentes e dolinas. O padrão, das drenagens observadas, é dendrítico. São drenagens, em geral intermitentes. Algumas dessas drenagens, como a que passa pelo ponto TT 48, TT 56, observa-se a presença de água vindo do início da drenagem, em siltito, que deve ser contínua, tanto no período das chuvas quanto no período das secas. No ponto TT 58, observa-se que as águas, ao atingir as rochas carbonáticas, desaparecem em um sumidouro. O padrão, das drenagens principais, segue um controle estrutural, tendo como alinhamento principal a direção NS. O estilo estrutural da área é relativamente simples, tendo como grande precursor da deformação o Evento Tectonotermal Brasiliano. As estruturas caracterizadas são: uma foliação Sn//S0, uma lineação de estiramento mineral, sigmóides da foliação, dobras em "S" e em "M'', duas direções principais de fraturamento e "tension gashes". A foliação Sn//S0 apresenta mergulhos suaves de 10-20 graus e, em alguns pontos, pode atingir mergulhos moderados de até 45 graus. Contida, nos planos da foliação, observa-se uma lineação de estiramento mineral que, encontra-se "Dip" a ligeiramente oblíqua, indicando movimentos EW. Através da análise de alguns indicadores cinemáticos, tais como sigmóides, vergência das dobras, pequenos veios de quartzo e/ou calcita rotacionados, foi possível caracterizar cavalgamentos de E para W *(Figura 02*). Em alguns pontos (*e.g*. TT 23) observa-se uma inversão da estratigrafia colocando a rocha carbonática sobre o siltito, caracterizando movimentos reversos. A área estudada está inserida no domínio 1 de deformação de Magalhães (1988).



Fonte: Ortofoto
folha Baldim 35-05-15 e
35-05-19 (CEMIG 1992)

Figura 2 – Mapa Geológico da área estudada

5 Avaliação Espeleológica

A área analisada, de acordo com o que foi descrito anteriormente, pode ser dividida em dois domínios geológico – geomorfológicos distintos, a saber: um de cobertura metassedimentar pelítica (superior) e um outro de rochas carbonáticas (inferior). O primeiro controla os altos topográficos, onde predominam a vegetação de campo e gramíneas, de pastagens, em colinas suaves e com drenamegens superficiais. O segundo domínio é onde ocorrem as feições cársticas, como paredões, *canyons*, dolinas, sumidouros, ressurgências, lapiás e cavernas, onde a vegetação torna-se exuberante, com grandes espécimens de representantes da vegetação arbórea nativa, e com drenamento, de águas freáticas e subterrâneas (criptorréico). As características desse domínio cárstico, com cobertura de rochas pelíticas e com poucas, ou ausência de feições de dissolução superficiais (lapiezamento), permitem deduzir que essa área constitui-se de um "carste jovem" ou incipiente. Com relação ao potencial espeleológico, as áreas foram divididas de acordo com os critérios propostos por Teixeira da Silva & Costa Jr. (1997). Esses autores definiram os termos ALPE, MEPE e BAPE, para caracterizarem áreas com alto potencial espeleológico, áreas com médio potencial espeleológico e áreas com baixo potencial espeleológico, respectivamente. As áreas aqui definidas, de acordo com esses critérios podem ser visualizadas na **figura 02** onde estão delimitadas três áreas ALPE (I, II e III), três áreas MEPE (1, 2, e 3) e duas áreas BAPE (4 e 5). A avaliação, de cada área, foi feita através da aplicação, específica, de uma matriz de Fatores X Níveis de Valorização e de acordo com as características individuais de cada uma delas Brandt (1988). ***Área ALPE I*** Essa área abrange, praticamente, toda a parte norte (**Figura 02**). Ela contém três cavidades importantes: abrigo "Mandala" (Ponto TT 02), gruta "Tívoli" (TT 08) e gruta "Bocão" (TT 67), além do *canyon* NE (Nordeste). ***Área ALPE II*** Essa área compreende a porção centro - leste do local estudado (**Figura 02**) e abrange o *canyon* EW e três cavidades, a saber: gruta "Quatro Sapinhos" (TT 69), gruta da "Ressurgência Dobrada" (TT 70) e abrigo "Não Verificado" (TT 72). ***Área ALPEIII*** Essa área compreende a região centro – sul (**Figura 02**) e possui seis cavidades, são elas: gruta dos "Dois Sapos" (TT 43), gruta "Sumidouro Piramidal" (TT 44), gruta "Barulho D'água" (TT 84), abrigo "Será Que é Mesmo?" (TT 85), gruta "Entra e Sai" (TT 88) e gruta "Conduto Atolado" (TT 89). A***rea MEPE I, II e III*** Situam-se na região central e não apresentam um conjunto espeleológico considerável, a não ser pela proximidade das ALPES.

6 Considerações Finais

O local examinado constitui-se de rochas carbonáticas laminadas, correlacionáveis com as da Formação Lagoa do Jacaré e, superiormente, por siltitos, também, laminados que se correlacionam com a Formação Serra da Saudade. Estruturalmente, esses litotipos, estão inseridos no domínio 1 de Magalhães (1988), de maior intensidade de deformação, com ocorrência de cisalhamentos dúcteis-rúpteis, dobramentos com vergências para oeste, lineações de estiramento mineral e clivagens. A área estudada constitui-se de um "carste recente" devido à cobertura de rochas pelíticas superiores e ausência de lapiezamento intenso nas rochas carbonáticas. É um carste que está em processo de exumação, isto é, está em fase de desenterramento.

A partir dos dados de campo, foi possível subdividir a área estudada em domínios que podem ser explorados, áreas MEPE e áreas BAPE, e em domínios que devem ser preservados, áreas ALPE. Os estudos efetuados foram balizados, tanto no potencial espeleológico, quanto no arqueológico, no paisagístico, na presença de águas, na fauna e na flora.

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Cavidades Pseudokársticas en Rodeo, San Juan, Argentina

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Summary

Based on recollected data and archeological and biological material in a joint group campaign of C.E.R.M.A., G.E.Laj. and KARST, we inform about the possibilities of a scientific and topographic work in a number of caverns named "La Cañada", wich develop in the Precordillera dessert, near the Colola stream in the Northwest of San Juan.

Resumen

En base a datos y material arqueológico y biológico recolectado, en una campaña conjunta de los grupos C.E.R.M.A, G.E.Laj. y KARST, se informa sobre las posibilidades de trabajos científicos y topográficos en una serie de cavernas denominadas de "La Cañada", que se desarrollan en la aridez de la Precordillera cerca del arroyo Colola, en el Noroeste Sanjuanino.

Introducción

Dentro del programa de expediciones conjuntas que se vienen realizando desde 1999 entre distintas agrupaciones a las que pertenecen los integrantes de esta salida, se decidió hacer una prospección en la localidad de Rodeo, Iglesia, dado el potencial espeleológico existente en la zona del noroeste argentino según lo expresara GALAN en su trabajo de 1986.

Dada la escasez de publicaciones existentes desde el punto de vista espeleológico y a manera de trabajo documental presentamos este para señalar la importancia de conservar esta zona para estudios ulteriores.

Antecedentes

Diversas expediciones espeleológicas habían explorado la zona pero poco dejaron publicado sobre sus hallazgos. Tal es asi que todavia no hay acuerdos sobre cuales cavernas exploró cada una. Nosotros las hemos denominado con nombres que una vez determinados los definitivos para un catastro, quedarán como sinónimos toda vez que hayan sido exploradas con anterioridad.

Debemos resaltar que no todas han sido exploradas y en su totalidad; la mayoría de ellas por problemas tecnicos, generalmente de verticalidad y anclaje de los elementos de seguridad que presentan las simas de acceso.

Tambien las expediciones anteriores supieron ver el potencial espeleológico que presenta esta zona quedando plasmados proyectos futuros, muchos de ellos todavia en elaboración dado lo inhóspito del lugar y su difícil acceso.

Cronológicamente logramos establecer que la zona ya era conocida por el Profesor Mariano Gambier en la década de 70 donde inicia estudios arqueológicos. El Centro Argentino de Espeleología (C.A.E.) hace una prospección a principios de los 80 y en 1985 el lugar es visitado por el Centro Espeleológico Córdoba (C.E.C.) y el Grupo Argentino de Espeleología (G.E.A.). En 1987 el C.E.C. explora en conjunto con el grupo LISPEL de Francia y en ese año el C.A.E. realiza trabajos de topografía. El grupo Espelaion también topografía algunas de las cavernas en 1990.

Descripción de la zona

Dentro de territorio precordillerano al Norte de San Juan Capital a pocos kilómetros de la localidad de Rodeo, cabecera de Iglesia (donde tiene asiento la Municipalidad de Iglesia)) se halla el sitio "La Cañada" donde se desarrollan las cavernas exploradas. Esta zona está delimitada entre los 30º a 30º20´ de Lat. Sur y 69º a 69º 05´Long. Oeste.

En un paisaje de desierto Andino de Cordillera se destaca la estepa arbustiva casi xerófila que disminuye con la altura. En algunos bolsones, cuando la nieve se derrite o recibe aporte pluvial crecen extensas vegas de gramíneas. La vegetación siempre está limitada por la extrema aridez (Clima tipo continental desértico) y por una precipitación menor a 100 mm anuales.

Geológicamente la zona ha sido estudiada por diversos investigadores (BERCOWSKI, 1993) y el trabajo final de licenciatura de YACANTE (1992) que dedica exclusivamente al área "La Cañada", incluye a las cavernas como fenómenos pseudokársticos, que son objetivo de sus tesis, y dá interesantes apreciaciones. Este considerable trabajo incluye un análisis geomorfológico y una variada bibliografía del sitio.

Acá las cavernas se describen como manifestaciones "pseudokársticas", dado el terreno donde se desarrollan, término que nos parece con mayor propiedad que los de "karsticas o carsicas" a los que estamos acostumbrados a escuchar cuando se habla sobre el sistema de cavernas de Rodeo.

El terreno, afloramiento del terciario, formado por sedimentitas, compuestas por Halita, Yeso y Thenardita (SO4Na) y mezcladas en arcillas, es propicio para la formación de las cavernas cuando se disuelven las sales y que con el hinchamiento de las arcillas al hidratarse facilitan el arrastre mecánico que provoca la erosión formadora. YACANTE (1992) también describe un nivel cálcitico de poco espesor pero de gran continuidad.

Es en el pedemonte de la Precordillera Occidental y en este afloramiento donde se desarrollan las cavernas, precisamente en la Formación La Flores tanto en el miembro superior como en el inferior.

La zona continúa afectada a movimientos neotectónicos. Nosotros tuvimos la oportunidad de sentir movimientos sísmicos el 11 de Noviembre a las 21 hs. 50´ en el exterior.

Cavernas exploradas

Durante los dias 9 al 13 de Noviembre de 2000 exploramos las cavernas que denominamos: Cueva del Golpe, del Ascenso, del Bautismo, de los Desfederados, Caracol, de la Virgen y del Búho. En la del Bautismo, de los Desfederados y la Caracol debimos usar técnicas verticales de descenso dado los desniveles que en algunos casos superaron los 15 mts.

En todos los casos estas simas son sumideros. Los sectores horizontales de las cuevas tienen típicos diseños meandrosos que son recorridos por el agua de deshielo y lluvias (estivales torrenciales). Esta va dejando depósitos fluviales dentro de la caverna y no se acumula, ya que se trata de cursos temporarios que desagotan rápidamente pero dejan rastros de una importante circulación por las manifestaciones de erosión hídrica que observamos, a pesar de desconocerse sus caudales.

Los espeleotemas en este endopseudokarst están compuestos por estalactitas de arcillas y sales, cristalizaciones de yeso y recristalizaciones en el lecho seco del agua que recirculará en las épocas correspondientes.

En las fechas visitadas las cuevas se hallaban completamente secas, lo que denota una gran circulación aérea (por la ventilación apenas queda humedad). Esto provoca que se levante polvo (grandes cantidades) al explorar las cavernas.

Si bien se observaron telas de arañas y excrementos, dada la baja humedad relativa era de esperar una pobre recolección biológica: un arácnido en la cueva de La Virgen, que como predador es de aguardar más material (presas). Además es una caverna muy visitada por los pobladores que dejan restos orgánicos que servirán de sustrato a los primeros niveles tróficos. En la cueva del Búho se observó el ave que dio nombre a la misma. De la Cueva Caracol se recolectaron egagrópilas con restos de *Calomys musculinus*, *Akodon molinae*, *Graomys griseoflavus* (todos ellos de la Familia Muridae, ratones de campo) y de *Thylamys sp* (Familia Didelphidae, comadrejas). Estos micromamíferos son dieta usual de rapaces que encuentran el refugio ideal en estas cuevas. En la cueva de los Desfederados se avistaron quirópteros.

Arqueología

Esta zona fue un área de convivencia de distintos pueblos que supieron organizarse a las orillas de los ríos y arroyos que colectan el agua de los deshielos de los cerros circundantes aprovechando el recurso en un ámbito eminentemente desértico y agreste.

La ocupación existe desde antes de la llegada hispánica y es notable el amplio conocimiento que tenían de su entorno, ya que no solo tenían asentamientos fijos sino que utilizaban algunas cavernas como sus enterratorios.

Pertenecientes a las culturas de Angualasto o Sanagasta que tuvieron notable expansión en esa zona a partir de los años 1200 hasta 1490-1500 de nuestra era cuando se pusieron en contacto con la Cultura Inca. Cuando llegaron los españoles hacia el 1700 la zona ya estaba despoblada.

La Cultura Angualasto se caracterizó por una economía agrícola, espectaculares construcciones de canales y áreas cultivadas. También traficaban Llamas con el Norte de Chile (DAMIANI, com. Personal).

La expedición C.E.C. de 1985 halló restos humanos y tejidos en distintos sitios en las cuevas de cuyo análisis surgió que pertenecían a 5 individuos: un infante, 2 jóvenes y 2 adultos. Nuestro muestreo se limitó a la recolección de lo hallado en superficie, no excavaciones, de material desparramado en la pendiente exterior de la cueva del Choclo (en realidad un abrigo por carecer de oscuridad) la cual tenia evidentes signos de haber sido excavada (saqueada). Se recolectaron trozos de cerámica y marlos de maíz que se depositaron en el Museo Arqueológico La Laja, Albardón San Juan, que dirige el Dr. Mariano Gambier. Esperamos que estos elementos permitan aportar nuevos datos del pasado cultural de esta región y comprender el porqué del uso de las cuevas con fines funerarios y por que estos elementos, presuntos indicadores arqueológicos, han sido hallados dentro de ellas.

Conservacionismo

Uno de los aspectos abordados durante la exploración fue ver la posibilidad de proponerlas como áreas para visitas asociándolas a un turismo tipo ecológico y o científico y vincularlas con operadores controlados por el municipio para que sea una actividad responsable y sustentable.

La inquietud surgió dados los siguientes motivos:

1) Hallamos huellas de camionetas tipo 4x4 y de motocross que cruzaban sobre el desarrollo de las cavernas, que no solo arruinan un paisaje prístino sino que podrían provocar derrumbes destruyendo así un recurso que ayudaría al desarrollo cultural de la localidad.

2) Se sabe de algunos pobladores que se dedican a extraer restos arqueológicos cuando estos quedan al descubierto por las lluvias, algunas veces con fines conservacionistas pero sin el control de arqueólogos.

3)Visitas a la caverna de La Virgen que con objeto religioso los fieles dejan sus rastros, restos de velas y antorchas, vidrios, latas y alteran el frágil ecosistema que pudiera desarrollarse.

Por ello debiera aplicarse un plan de manejo por parte de las autoridades para lograr la preservación del recurso ademas de incentivar una actividad económica a parte de la población.

Incluir un "Turismo Minero" ampliará las posibilidades, ya que todo un nivel de pirquineos utilizados por mineros que explotaban el sulfato de sodio, dará interesantes datos históricos del lugar y área de influencia.

Conclusiones

Si bien la zona ha sido suficientemente explorada quedan todavia bastantes trabajos en topografía, biología, hidrogeología subterránea, etc. para los especialistas.

Si se contara con la vigilancia del Municipio, el sitio podría transformarse en un parque arqueológico y geológico y ser polo de referencia para más trabajos de espeleología en la provincia ya que como lo demuestra el interesante trabajo de WETTEN y DAMIANI (1999), donde se describe el cordón calcáreo que atraviesa a San Juan de Norte a Sur, las posibilidades para la espeleología están aseguradas.

Agradecimientos

Todo este trabajo contó con los auspicios de la Municipalidad de Iglesia a la cual agradecemos el apoyo brindado. Tambien colaboraron directamente: el Dr. Oscar Damiani del Centro Regional del Agua Subterránea de San Juan con los comentarios sobre la arqueología y las posibilidades espeleológicas en San Juan; los Sres. Rubén Vrech y Edgardo Avaca con la información inédita de las expediciones del C.E.C.; el Sr. Guillermo Paoli con su gestión logística a lo largo de toda la expedición; el Dr. Ulyses Pardiñas del Museo de La Plata, Depto. de Paleontología de Vertebrados, con las determinaciones del material hallado en egagrópilas y la Dra. Cristina Scioscia del Museo de Ciencias Nat. "B. Rivadavia" quien aporta con las determinaciones en artrópodos A todos ellos queremos dejar expreso reconocimiento y gratitud por su ayuda.

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The Middle-East Speleology 2001 Symposium: A Turning Point for the Speleology of the Middle-East

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Abstract

The Speleo-Club du Liban (SCL) and the Lebanese National Council for Scientific Research (LNCSR) organized, in April 2001, an international speleological meeting, where local and foreign cavers discussed the present situation of the Middle-East speleology. This event, which took the form of a three-day symposium, was done also with the collaboration of the "Groupe d'Etudes et de Recherches Souterraines du Liban (GERSL)" and the "Association Libanaise d'Etudes Spéléologiques (ALES)".

The symposium encompassed the three main perspectives of speleology: sport and leisure, science, and culture. During the first two days, 38 oral presentations and 20 posters were exposed. These presentations tackled different subjects that are grouped under five major topics: 1. cave rescue, 2. exploration, 3. hydrogeology and karstology, 4. protection of the karst environment, and 5. archeology. The presentations discussed various speleological features present in Lebanon, Syria, Egypt, Saudi Arabia, Turkey and Iran. The audience consisted of cavers and scientists from the Middle-East as well as from Europe, North America, and Japan. A spelemedia exhibition with more than 150 photo-posters also took place. In addition, several films were projected. Finally, a beautiful excursion through the Lebanese western mountain chain with a picnic-lunch marked the third day and the end of the symposium.

The significance of this event is not only due to the fact that it is the first of its kind, but also for providing a meeting point for local and foreign cavers and scientists who are interested in the speleology of the Middle-East. An important link between different caving entities was, hence, established, anticipating rewarding future cooperation. In addition, the symposium falls on the 50th anniversary of the Speleo-Club du Liban which was a pioneering speleological organization in the Middle-East and a founding member of the International Union of Speleology (UIS). As it has been broadly proposed, by the participants of the symposium, to establish an international speleological documentation center for the Middle-East in Lebanon, the Speleo-Club du Liban is honored to announce the opening of such a center by the beginning of the year 2002. The Club archives, which include invaluable information along a span of 50 years, as well as the contribution of the different speleological organizations will be stored in a modern well maintained library with a state-of-the-art internet facilities.

Key words: Middle-East Speleology Exploration Karst Hydrogeology

Spelemedia Spélé-Club du Liban

1. Introduction

The Middle-East region encompasses great prospects for speleological explorations. Local and foreign cavers have been recording momentous discoveries since the 1950s. The Spéléo-Club du Liban was established in 1951 and has pioneered the organized speleological activity not only in Lebanon but in the nearby countries as well. New discoveries coming from the East fascinate many cavers around the globe. For instance, the amazing photographs from the Saudi Arabia Geological Survey – John Pint and his colleagues, the Gypsum caves of Syria discovered and surveyed by a German team – Stefan Voigt and colleagues, and the list continues… As much as these discoveries are significant to the world of speleologists, information about them is very scattered. One can seldom find specific news about such explorations if luck is not involved. This led the Spéléo-Club du Liban, on the eve of its 50th anniversary of its founding, to throw an interesting initiative in the form of an international meeting dedicated for the Speleology of the Middle-East. The main objective of such an event is to create a "rendez-vous" for all local and foreign cavers who have interests in the Middle-East region. Future cooperation and the publishing of a symposium book featuring all the presented papers will be basic building bolcks for a new speleological era in this region.

This article is but a small report about the Middle-East Speleology 2001 Symposim (April 2001), which was organized by the Speleo-Club du Liban (SCL) and the Lebanese National Council for Scientific Research (LNCSR); with the collaboration of the “Groupe d’Etudes et de Recherches Souterraines du Liban (GERSL)” and the “Association Libanaise d’Etudes Spéléologiques (ALES)”. 38 oral presentations and 20 posters were exposed (five major topics: 1. cave rescue, 2. exploration, 3. hydrogeology and karstology, 4. protection of the karst environment, and 5. Archeology). A spelemedia exhibition with more than 150 photo-posters also took place.

The main post-symposium project, as proposed by many participants, will be the establishment of an international speleological documentation center for the Middle-East in Lebanon, the Speleo-Club du Liban is honored to announce the opening of such a center by the beginning of the year 2002.

2. Pre-Symposium

The first Lebanese national meeting for speleology was organized by the Spéléo-Club du Liban in 1996. This event brought together the four different caving entities in Lebanon (SCL, SC Ouadi Al Arayesh, GERSL, and ALES). The different presentations that were given are documented in Al-Ouat’Ouate N°10 (SCL Journal). The meeting was held on the occasion of the 50th anniversary of the first Lebanese caving activity and the first Lebanese cavers (e.g., Lionel Gorra, Louis Eid,…). The idea of an international meeting originated from this previous meeting. Basically, it was thought to organize an international meeting where the different national entities will be present as well as others from the Middle-East (namely Syria, Saudi Arabia, Egypt, and Turkey) and foreigners who often explore caves in this region.

The pre-symposium work consisted on the concept creation and the putting together of the organizing team. The Lebanese National Council for Scientific Research (LNCSR) was the first target as it is the sole governmental institution for scientific research in Lebanon. It was thought that having a scientific perspective is necessary since speleology is linked to earth sciences. Then, the different Lebanese caving associations and clubs were invited to collaborate with the organizers. The interior organization was designed as follows:

- an organizing committee (SCL and LNCSR), including a president, secretary, treasurer, public relation representative, and consultant
- and 12 commissions (SCL, GERSL and ALES), each of which has a coordinator and a secretary.

The 12 commissions are grouped into scientic (hydrogeology and karstology, protection of the karst environment, archeology, exploration and techniques, and cave-rescue) and non-scientific commissions (spelemedia, social and accommodations, field-trips, mailing and correspondence, media and press, publications, and sponsoring). About six months prior to the symposium date, the commissions started to meet and work independently. The organizing committee took the role of a connection between the various commissions. It is out of the patience and hard-work of the very few members who devoted their time that the success of the symposium was achieved.

Media and Press. The media coverage was aimed before and after the date of the symposium. A sort of a media ‘boom’ was needed in order to attract some sponsoring. Articles in many periodicals as well as radio and TV interviews were planned. In addition a press-release was made before the symposium and all media agencies were invited.

3. The Sympoium

The symposium was held at the ‘Université du Saint-Esprit Kaslik’ near the city of Jounieh about 15km to the north of Beirut (the capital of Lebanon; Fig. 1), from 20 to 22 April 2001. During the first day, the opening ceremony was held under the auspices of the minister of environement of the Lebanese government, the head of the Kaslik university, the general secretary of UIS (union international de spéléologie), and the chairman of the symposium (Fig. 2). After the opening ceremony, the different presentations started each of which having duration of 15 minutes plus 5 minutes for questions. First, the four Lebanese caving entities gave separate general presentations, and then cave-rescue and exploration presentations. On Saturday, the hydrogeology; karst protection and archeology presentations were given and the day ended with a momentous dinner preceded by a tour in the Jiita Grotto (the famous Lebanese show-cave). The third day included a field-trip in Mount-Lebanon with archeological and geological guiding. Eventually, some participants did some minor improvised caving as well.

In total, 38 oral presentations and 20 posters were exposed. The presentations discussed various breath-taking speleological features present in Lebanon, Syria, Egypt, Saudi Arabia, Turkey and Iran. The audience consisted of cavers and scientists from the Middle-East as well as from Europe (e.g., Belgium, Chek republic, France, Germany, Italy, Switzerland), North America (e.g., Mexico, USA), and Japan. A spelemedia exhibition with more than 150 photo-posters also took place. In addition, several films were projected. Information about all these is featured in the symposium book.

Accommodation. The foreign guests were accommodated in a '*cute*' small hotel nested on a hill just on the edge. A very beautiful sight of the valley and the horizons towards the Mediterranean Sea were the daily bonus as the spring weather is marvelous in Lebanon. The hotel was about 15 minutes by car from the symposium venue and a shuttle service was provided. Other type of accommodation was also provided upon request (e.g., camping, city-hotels).

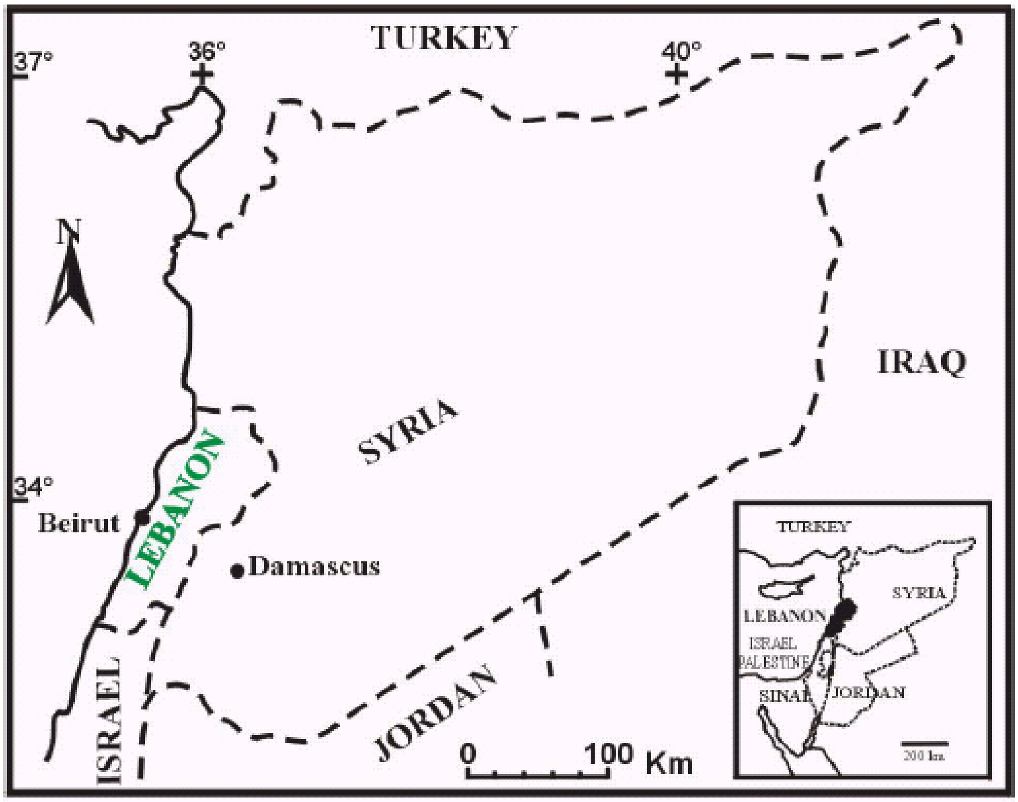

Fig. 1 – Location map of Lebanon and the neighboring countries. Tha MES2001 venue was in Kaslik abaut 15 Km north of Beirut city on the coast-line.

4. Post-Sympoium

Being a first of its kind does not grant the Middle-East Speleology Symposium success, and having a 3-day leisure vacation does not make out of this event more than souvenirs to discuss over a dinner. The most important goal is to provide a meeting point for local and foreign cavers and scientists. This was targeted and accomplished due to the broad audience. Links between different caving entities were, hence, established, anticipating rewarding future cooperation. Not only partnership was promoted but friendship and caving bounds were initiated.

The next important achievement is the symposium book, which will feature the immortal record of the symposium. All the presentations will be published within the framework of this book. It is a starting to point to reference and put together the various pieces of the speleological literature of the Middle-East. No more scattered information, but one single reference book is aimed. Here it is hoped that such a meeting will happen again in the future and the initiated work will be continuously evolved to match the significance of the new explorations and discoveries.

Last but not least, as it has been broadly proposed by the participants of the symposium, the Speleo-Club du Liban is honored to announce the opening of an international speleological documentation center for the

Middle-East in Lebanon. This is scheduled for the beginning of the year 2002. The Club archives, which include invaluable information along a span of 50 years, as well as the contribution of the different speleological organizations will be stored in a modern well maintained library with a state-of-the-art internet facilities. This project originates also from the quest of creating a 'meeting point' for the speleology of the Middle-East. SCL will be more than honored to offer its facilities (a big club-house and a library with documents wince the 1950s) for the benefit of cavers and speleology. The documentation center will be a useful link for cavers around the world and their colleagues in the Middle-East. A huge wealth of information is already stacked in the to-be-born center due to the long history of the Spéléo-Club du Liban and its known international connections. However, additional documents are welcome and asked for in order to work all together on such a huge project.

Fig. 2 – Photografh showing Dr Pavel Bosak giving his talk during the opening cerimony. From left to right, Mr. Michel Moussa Minister of the Environmentt (lebanese Government), and Mr. Jo Zgheib chairman of the symposium (SCL).

5. Conclusion

This article reports the Middle-East Speleology 2001 symposium that occurred in Lebanon, in April 2001. 38 oral presentations and 20 posters discussed various speleological features present in Lebanon, Syria, Egypt, Saudi Arabia, Turkey and Iran. Besides, more than 150 photo-posters were exhibited and several films were projected. The symposium also included a beautiful excursion through the Lebanese mountains with a picnic-lunch.

The results of this meeting were:

1- Initiation of future cooperation and friendship rather than only partnership between the participating groups,

2- Publication of a symposium book enclosing all the papers presented during the symposium,

3- Preparation for creating an international documentation center for the Speleology of the Middle-East in Lebanon.

Finally, it is important to stress on the resulting friendship that was launched between the various participants and the subsequent enlargement of the Spéléo-Club du Liban big family. In fact, just after the symposium, four participants honored SCL by asking to become members of this latter club. Such a special relationship anticipates rewarding future work and achievements.

Laboratório II: Uma Nova Cavidade no Bairro da Serra Iporanga/SP

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Abstract

In 1995 the GPME (Pierre Martin Speleology Group) undertook an exploratory job after the "Ressurgência das Areias" Cave siphon, better known as “Gruta do Laboratório" (Laboratory Cave), previously mentioned in R. Krone's researches by the end of the 19th century. After the crossing of the siphon, a topographical and exploratory undertaking took place which resulted in the discovery of the cave's continuity, reaching 920m (3,018 ft) in development and 72m (236 ft) in depth. Its morphological axis is parallel to the previously known segment and has been denominated "Laboratório II". It consists in a cavity characterized by large salons where the ground collapsed and galleries ornamented by both monumental speleothemes and extremely delicate formations, creating an environment of rare beauty. This work describes the cave's exploration and documentation historical, touristic and visiting issues, as well as its scientific research potential.

Sommaire

En 1995, le GPME (Groupe Pierre Martin de Spéleologie) a commencé a explorer le sifon de la Grotte de la Ressurgence des “Areias”, plus connue comme “Gruta do Laboratório”(Grotte du Laboratoire), déjà citée dans les recherches de R. Krone, à la fin du XIXème siècle. Après le passage du sifon, un travail de topographie et d’exploration a abouti à la découverte d’une continuité de la caverne, sur 920m de développement et 72m de profondeur. Son axe morphologique est parallèle a celui qui était déjà connu, et pour cette raison la caverne a été appelée « Laboratório II ». Il s’agît d’une cavité caractérisée par de grands salons d’eboulements et de galeries ornées par des spéléothèmes monumentaux ainsi que par des formations d’une grande délicatesse, créant un ensemble d’une rare beauté. Ce travail décrit l’historique de l’exploration de la cavité, la question de la fréquentation et de l’exploitation touristique, ainsi que le potentiel de recherches scientifiques.

Apresentação

Em 1995, o GPME (Grupo Pierre Martin de Espeleologia) iniciou um trabalho de exploração após o sifão da Gruta da Ressurgência das Areias, mais conhecida como Gruta do Laboratório (cadastro SBE SP-016).

Este artigo relata um breve histórico de exploração e as características básicas da cavidade, no trecho denominado Laboratório II, abordando aspectos de proteção, manejo turístico e potencial científico da cavidade.

Localização da Área de Estudo

A Gruta do Laboratório (SP-016) localiza-se no Bairro da Serra, município de Iporanga, sudoeste do Estado de São Paulo, nas coordenadas 24º33’42’’ S e 48º40’15’’ W. Constitui uma das ressurgências do Sistema Espeleológico da Areias, inserida na porção SW da faixa carbonática do Bloco do Lageado, pertencente ao Grupo Açungui (CAMPANHA, 1991).

A Exploração e as Características Gerais da Ressurgência das Areias (Laboratório II)

Antecedentes

A Gruta da Ressurgência das Areias já era conhecida pelo naturalista Ricardo Krone desde o final do séc. XIX. Na década de 60, Michel Le Bret realizou o primeiro mapeamento da caverna, já indicando sua provável conexão com a caverna Areias de Baixo (SP-019). Essa hipótese foi comprovada em fins da década de 70, por meio de coloração feita pelo grupo Opiliões, em trabalho coordenado por Pierre Martin.

Na década de 70, a caverna foi utilizada para a instalação do primeiro laboratório subterrâneo do Brasil, sob a coordenação do grupo Bagrus (Guy Collet, Nelson da Silva Jr. e outros). Essa foi a origem da denominação popular da cavidade. O objetivo desse laboratório era desenvolver estudos sobre a gênese e o desenvolvimento das cavidades em meio tropical e equatorial, sob os aspectos geológicos, físicos e químicos, além da observação "in loco" de Troglóbios. No entanto, carecendo de recursos para sua manutenção e assessoria científica, o laboratório subterrâneo foi desativado.

A primeira tentativa relatada de mergulho no sifão da Laboratório foi feito pelo CAP - Clube Alpino Paulista - em 1974 (SLAVEC, 1976). Nos anos 80 e 90 alguns espeleo-mergulhadores conseguiram transpor o sifão, destacando-se equipes coordenadas por Sérgio Beck e Ricardo Armelim - vinculados ao CEU (Centro Excursionista Universitário) - e Ezio Rubioli do GBPE (Grupo Bambuí de Pesquisas Espeleológicas); porém, não realizaram uma exploração sistemática da cavidade.

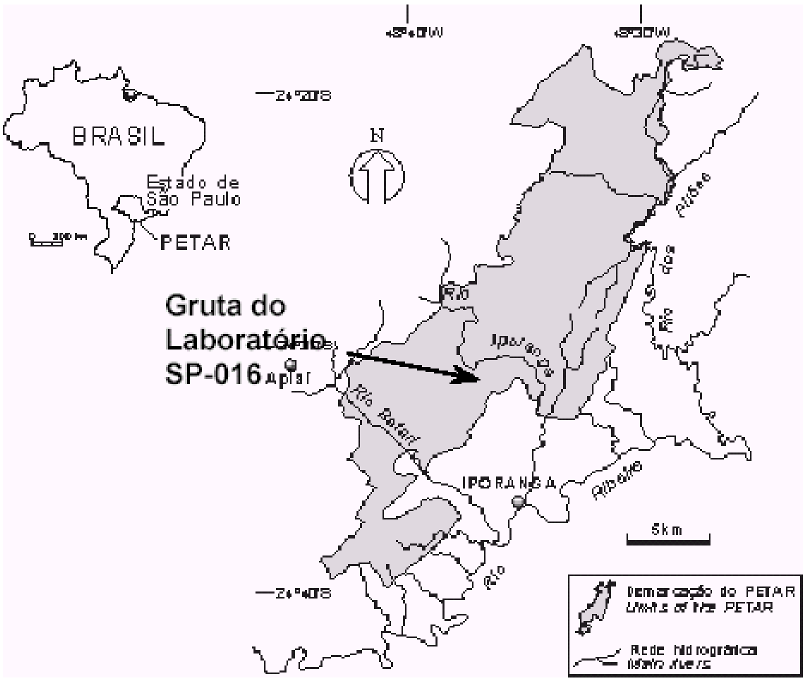

Figura 1 – Localização da Gruta do Laboratório (SP-016) em relação Parque Estadual Turístico do Alto Ribeira (adaptado de KARMANN & FERRARI, 1999)

O Espeleo-Mergulho e a Descoberta da Continuidade

Em 1994, uma equipe de espeleo-mergulhadores, composta por Matheus Sanchez e Roberto Baracho, convidou o GPME (Grupo Pierre Martin de Espeleologia) para juntos realizarem um trabalho mais técnico de exploração e documentação da cavidade.

O trabalho foi iniciado em 1995, após o treinamento intensivo de dois integrantes do GPME (Chico e Maurício). Neste ano foram realizadas três expedições que contaram com o apoio de moradores locais e da escola de mergulho SCUBASUL (Curitiba, PR).

O sifão compreende um conduto com cerca de 35 metros de extensão, profundidade média de três metros, algumas passagens estreitas e fundo com sedimentos finos. Dá acesso a Sala "Pata-do-Dino", um interessante espeleotema suspenso, evidenciando antigo nível de sedimentos da cavidade. Esta sala é formada, provavelmente, por duas drenagens com galerias distintas, uma de maior vazão (Ribeirão Areias), que percorre espaços confinados entre blocos e uma outra drenagem menor, relacionada a uma galeria à SE e cujo acesso é impedido.

Após a subida pela passagem do "Golfinho", chega-se ao salão do "Tobogã", com presença de blocos muito instáveis e um ressalto íngreme de onde se visualiza um grande salão superior.

Em 30 de abril de 1995, após subida perigosa por entre os blocos, os integrantes do GPME chegaram a um nível intermediário da cavidade e descobriram a passagem “Scubasul”, trecho labiríntico por entre blocos que possibilitou a descoberta do salão “Tá-no-Papo” e a continuidade da caverna.

Com 500 m^2 de área e pé direito alto, o salão “Tá-no-Papo” se caracteriza por grandes blocos ornamentados por diversas estalagmites e grande “chão de estrelas”. Destaque para uma grande coluna na área central medindo 11 metros de altura.

Após descer um ressalto com escorrimentos de calcita, a equipe chegou ao salão “Duplo-Abatimento”, cujo nome se deve à existência de dois grandes salões sobrepostos, unidos por um desmoronamento de blocos instáveis. Posteriormente foi descoberta uma outra passagem estreita que leva ao sifão, na parte inferior desse conjunto.

Numa segunda expedição, em julho de 1995, foi localizado a partir do salão “Duplo Abatimento, um percurso bastante estreito com muitas estalactites e uma fraca corrente de ar, dando acesso a uma galeria larga e ornamentada, denominada de galeria dos “Ritmitos”, devido a interessante depósito de sedimentos finos cobertos por crosta calcítica. Destacam-se duas cortinas laterais que se abrem para o majestoso salão do “Teatro”, com área aproximada de 1800 m^2..

A partir da galeria dos Ritmitos, a cavidade se desenvolve paralelamente ao alinhamento do trecho turístico da Gruta do Laboratório, rumando em direção ao Vale do Betari.

Caminhando em meio a blocos imensos, com presença de sedimentos e uma larga estalagmite na passagem, surge o “Lagolama”, interessante depósito argiloso, provavelmente associado a drenagem temporária.

De lá sai em linha reta, numa extensão de 80m, o conduto “249”, de padrão freático (seção elíptica) com “teto-baixo” e fundo argiloso. Uma leve corrente de ar e presença de depósitos de conchas de caramujo eram claros indícios de comunicação com o exterior.

Abre-se então o salão “Nhô Gusto”, com estalagmites, travertinos e chão-de-estrelas cristalinos. Por uma pequena fenda intransponível, a equipe pôde avistar a luz da lua que iluminava o bairro da Serra naquele momento. Próximo a esse local, foram deixados uma bandeira do GPME e um adesivo da SCUBASUL, para futura localização em prospecção externa.

A Redescoberta a Partir da Entrada Superior e a Invasão Turística

Em julho de 1997, Francisco e Hilda, do GPME, foram pedir permissão para os moradores, Sr. Augusto (Nhô Gusto) e Dona Isabel para entrar em suas terras a fim de localizar a possível entrada da “Laboratório II”.

Na ocasião a equipe do GPME soube que, em abril de 96, os filhos do casal, Antônio Marcos, Osmar e Adilson, estavam preparando o terreno para o plantio de uma roça de feijão, quando encontraram uma fenda estreita, escura entre afloramentos de calcário. Curiosos, os garotos alargaram aos poucos a fenda fazendo fogueiras sobre a rocha calcária e conseguiram, por fim, penetrar na cavidade.

Com criatividade, em agosto de 1996 os meninos improvisaram com um tronco um escorregador que os levou até a base do ressalto da entrada. Com garrafas de querosene, tampadas com gravetos de madeira, fizeram tochas para iluminar o caminho. Logo encontraram a bandeira do GPME e o adesivo da Scubasul e os trouxeram para fora da caverna.

Com a abertura do acesso superior (nova entrada) o trabalho de reconhecimento da cavidade foi bastante facilitado, permitindo novas incursões de estudo do GPME e também de visitantes.

Em uma conversa de bar, alguns moradores locais, relataram a descoberta da entrada superior e a existência de uma caverna magnífica no bairro da Serra. Em pouco tempo a notícia se espalhou e uma multidão de curiosos começou a visitar a caverna. Após o estabelecimento de acordos locais visando sua proteção, a caverna foi fechada com uma grade de ferro, e o GPME assumiu o compromisso de continuar o mapeamento da cavidade. Infelizmente, nesse curto espaço de tempo, a visitação desordenada provocou, impactos ambientais relevantes, principalmente quebra e pisoteio de espeleotemas.

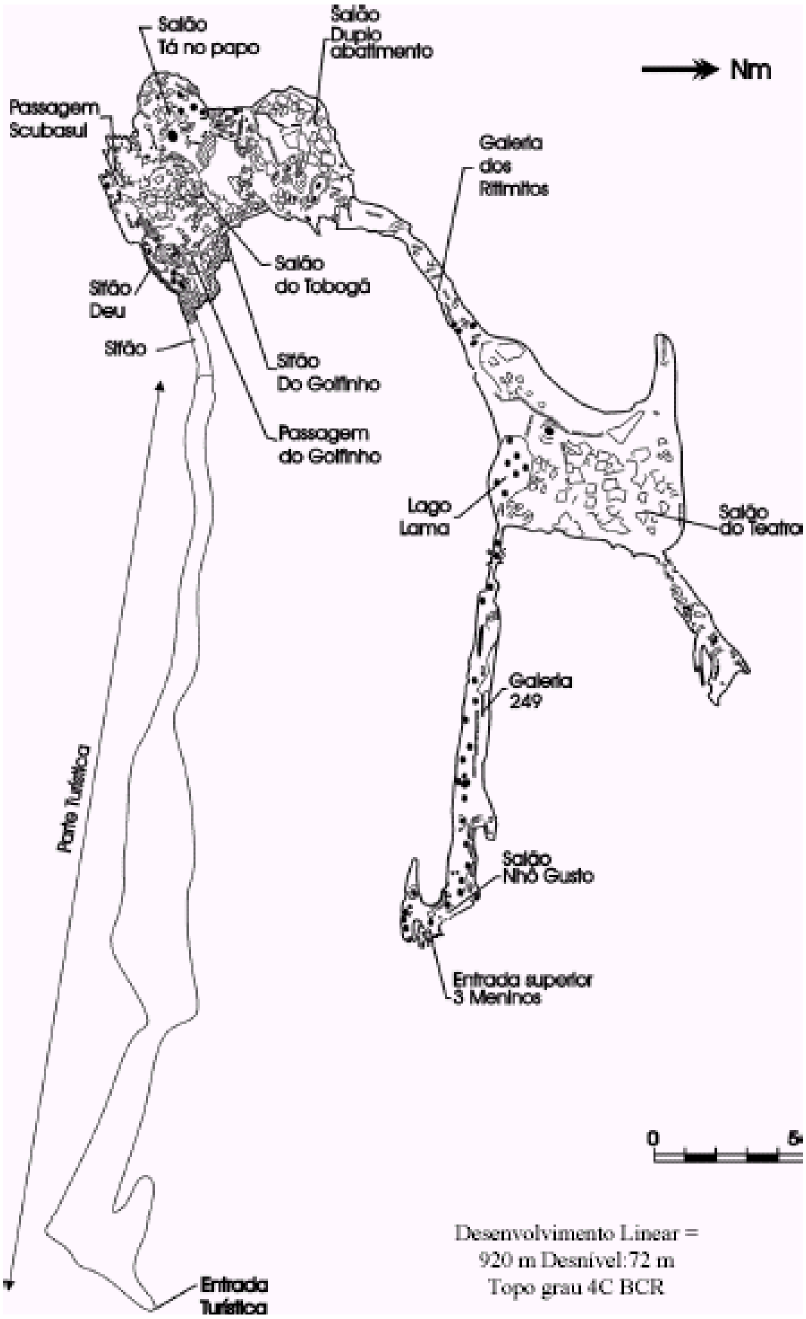

Figura 2 – Gruta do Laboratório – Trecho Laboratório II (Iporanga, SP) - Grupo Pierre Martin de Espeleologia (1995 – 1998)

Importância Científica e Medidas de Proteção

A cavidade denominada Laboratório II (trecho da SP-016) possui mapeados 920 metros de desenvolvimento e 72 metros de desnível. É caracterizada por grandes salões de abatimento e galerias ornamentadas tanto por espeleotemas monumentais como por formações extremamente delicadas, criando um conjunto de rara beleza. Representa a continuidade do sistema espeleológico das Areias, mais precisamente a Caverna Areias II (SP-019), cujo trecho final localiza-se há cerca de 3, 5 km em linha reta da cavidade em estudo.

Foi constatado, do outro lado do sifão (sala "Pata-do-Dino") a presença de bagres-cegos (*Pimelodella kronei*), espécies troglóbias, que implicam em uma proteção ambiental especial. Ressalta-se que a visitação é proibida nas cavernas do sistema Areais, conforme a resolução CONAMA de 5/8/97.

Ocorrem, ao longo do conjunto de salões e galerias da Laboratório II (trecho superior), a presença de depósitos de sedimentos, evidenciados na galeria dos "Ritmitos". Esses depósitos merecem um estudo mais detalhado, do ponto de vista sedimentológico e paleontológico. Também devem ser estudados os depósitos minerais secundários, extremamente delicados e raros, próximos ao Salão do “Teatro”.

Outro fator importante a ser considerado é a implementação de estudos topoclimáticos e hidrológicos que poderiam ser feitos de forma integrada com os estudos geológicos, biológicos e geomorfológicos, contribuindo para o plano de manejo da cavidade.

A Gruta do Laboratório – parte turística e o trecho denominado Laboratório II – foram incluídas na área proposta para criação de um Parque Municipal, em função de seu evidente potencial turístico. Trata-se área de influência do projeto Uniparque, coordenado pelo Instituto Physis e colaboradores, que objetiva a criação de um núcleo de ensino, pesquisa e educação ambiental, voltado às necessidades da região.

Ressalta-se a existência de pressão, por parte da atual gestão municipal, para promover a abertura da cavidade à visitação pública, e constante ameaça de invasão de visitantes curiosos.

O Manejo Ambiental e Turístico

Diante do exposto, considerando a existência de diferentes setores sociais envolvidos no destino da Laboratório II e seu potencial científico e ecoturístico, propomos a realização de um projeto integrado que busque a consulta a pesquisadores que atuam na região, estabelecendo-se um espaço de diálogo para a elaboração de um plano de ação visando definir o zoneamento ambiental, regulamentação e controle turístico da caverna.

Numa análise preliminar o GPME considera que o trecho da entrada superior até o Salão do Teatro possui potencial para visitação monitorada, de forma criteriosa, assegurando a proteção de locais mais frágeis. Não existe a necessidade de promover interferência física imediata na área. Apenas seria conveniente a instalação de uma escada com degraus no trecho de acesso a cavidade e delimitação de trilha de caminhamento.

É necessário se pensar em um estudo integrado com a parte turística da Gruta do Laboratório, trecho altamente impactado, e com as cavernas Areais I e II que continuam recebendo visitação apesar da restrição legal.

O GPME continua disposto a contribuir com tudo o que estiver ao seu alcance, nos estudos que vierem a ser feitos visando assegurar a proteção e o manejo adequado da Gruta do Laboratório.

A medida de proibição em si não garante proteção alguma. Essa meta só será atingida quando houver uma conscientização geral e a participação direta de todos os atores desse processo: autoridades, comunidade local e visitantes, incluindo turistas, espeleólogos e pesquisadores. O ideal do GPME é que essa atitude seja estendida a todo o Parque do PETAR e entorno. Sem isso, continuaremos correndo o risco eminente de que o rico patrimônio espeleológico da região seja comprometido definitivamente paras as futuras gerações.

Participantes

Exploração e Documentação

Alexandre Nakai, Blanche de Souza, Bosco, Edna Mithie, Erica Diogo, Francisco José Sarpa Lima, Hilda K. Itokawa, Hudson Adtiano, Julio Roncada, Leda Zogbi, Matheus Sanchez, Marcos O. Silverio, Maurício A. Marinho, Reinaldo Viedma da Silva, Roberto Baracho, Roberto Rodrigues, Ted (Eduardo) e Xisto (Luís Claudio) – GPME

Apoio

Integrantes do GPME - Carlos Maldaner, Claudia Beltrane, Ery Nagasawa, Geni Francis, João Rocha (Jota), Leda Zogbi, Liliane, Márcia, Marília C. Arruda e Marizete R. de Silva (GPME); monitores Ambientais da ASA - Agnaldo A. dos Santos, Anderson O. Monteiro, Bóris O. Monteiro, Cidão, Jurandir A. Santos; Moradores Locais - Adilson Macile de Godói, Antonio Marcos Godói, Osmar Marcos Godói, Marisa M. Godói, Paulo H. Monteiro, Sueli Maciel Godói e Terezinha M. Godói; Equipe PETAR: Dema, Modesto e Tadeu; Reserva da Biosfera da Mata Atlântica - Ana Maria Lopes e Clayton Ferreira lino e Prefeitura Municipal de Iporanga - Nilton Rosa

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The Longest and the Deepest Caves in Croati

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Abstract

Here is the list of the longest and the deepest caves and pits in Croatia. In cadaster of the Croatian speleological features (caves and pits) are more than 8650 caves and pits. It is important to say that this cadaster does not contents all the speleological and karst phenomena, but only the speleological features - caves and pits according to the internationally recognised classifications namely, in some speleological cadasters we can find bigger doline, the bigger fissures in the rocks, natural bridges, all the karst springs, under sea springs, and some where even the artificial speleological objects (tunnels, catacombs, old mines, etc.). Also here are conditions for organising speleological expeditions in Croatia proposed by Croatian Speleological Federation, which will help foreign cavers and speleologists in organising such expeditions.

Introduction

In almost 25 years of collecting and sorting the speleological data, with the help of the computers, we managed to make the cadaster of the Croatian speleological objects, that includes more than 8650 caves and pits. It is important to say that this cadaster does not contents all the speleological and karst phenomena, but only the speleological features - caves and pits according to the internationally recognised classifications namely, in some speleological cadasters we can find bigger doline, the bigger fissures in the rocks, natural bridges, all the karst springs, under sea springs, and some where even the artificial speleological objects (tunnels, catacombs, old mines, etc.). The rule of this cadaster is that only treated objects are those in which can be physically entered, in which diving's were done, and not those that are supposed to be connected with some speleological feature, with not enough evidence for that conclusion. Other objects must be added according to the degree of exploring (for example, springs and sinkholes, but only dived through and classificated in speleological objects, dolines only when are digged down the connection with some real speleological object, fissures enough widened for entering, etc.). According to geological and hydrogeological characteristics, it can be presumed that there are at least 20000 speleological objects in Croatia, most of them unknown and not explored yet.

There is a list of the 37 deepest and 45 longest caves in Croatia.

The Deepest Pits

In Croatia were explored about 6834 pits or 79 % of all speleological features in Croatian Dinaric Karst area. This means that vertical speleogenesis is more often than horisontal speleogenesis. Here is official list of 37 deepest pits deeper than 250 meters in Croatia (till 31.05.2001.):

1. Lukina jama - Trojama system	1392 m
2. Slovacka jama	1301 m
3. Stara skola	576 m
4. Vilimova jama (A - 2)	572 m
5. Patkov gust	553 m
6. Ledena (Ledenica) jama u Lomu	536m
7. Ponor na Bunjevcu (Bunovcu)	534 m
8. Jama Olimp I	531 m
9. Crveno jezero	528 m
10. Jama pod Kamenitim vratima	520 m
11. Amfora	515 m
12. Fantomska jama	477m
13. Munizaba	448 m
14. Stupina jama	413 m

15. Nova velika jama	380 m
16. Jama kod Raspora	361 m
17. Biokovka	359 m
18. Ponor Pepelarica	358 m
19. Punar u Luci	350 m
20. Klementina III	333 m
21. Podgracisce II (Titina jama)	329 m
22. Xantipa	323 m
23. Klanski ponor	320 m
24. Puhaljka	320 m
25. Zaboravna jama	311 m
26. Klementina IV	300 m
27. Burinka	290 m
28. Jama Kobiljak	286 m
29. Kicljeve jame (system)	285 m
30. Balinka	283 m
31. Ponor Bregi	273 m
32. Klementina I	269 m
33. Jama kod Matesic stana	260 m
34. Lokvarka	252 m
35. Pretnerova jama	252 m
37. Jama Marianna	250 m

The Longest Caves

In Croatian Karst area were explored and surveyed about 1718 of caves or 20 % of all known speleological features in this Karst region. This means that in Dinaric karst area, caves are more rare than pits. Also there are about 1 % of caves which have entrances like pits, or pits which have entrances like pits. Their characters are unknown - pits or caves. We called them complex speleological features.

Here is official list of the longest 45 caves (longer than 1 km) in Croatia (till 31.05.2001.):

1. Dulin ponor (Dula) - Medvedica system	16396 m
2. Muskinja - Panjkova spilja system	12385 m
3. Spilja u kamenolomu Tounj	8487 m
4. Veternica	7100 m
5. Jopiceva spilja - Bent system	6570 m
6. Vilinska jama - Ombla cave system	3063 m
7. Gospodska spilja	3060 m
8. Donja Cerovacka spilja	2682 m
9. Slovacka jama	2414 m
10. Klementina I	2403 m
11. Mandelaja	2326 m
12. Munizaba	2300 m
13. Ponorac - Suvaja (sustav)	2232 m
14. Spilja za Gromackom vlakom	2171 m
15. Izvor Gojacke Dobre	2160 m
16. Ponor Bregi	2055 m
17. Kotlusa	2015 m
18. Kaverna u tunelu "Plat"	1985 m
19. Provala	1802 m
20. Spilja Miljacka II	1750 m
21. Markov ponor	1650 m
22-Ponor Vele vode	1495 m
23. Kaverna u tunelu "Ucka"	1490 m
24. Punar u Luci	1478 m
25. Debela Ljut	1448 m
26. Strmotica ponor	1437 m

27. Sariceva spilja	1378 m
28. Gornja Cerovacka spilja	1295 m
29. Ponor Kolinasi	1278 m
30. Rudeliceva spilja	1252 m
31. Matesiceva spilja	1246 m
32. Babina jama	1230 m
33. Mijatova jama	1204 m
34. Gatica	1195 m
35. Hajdova hiza	1188 m
36. Horvatova (Bezdanjaca pod Vatinov.)	1176 m
37. Jama kod Raspora	1106 m
38. Tamnica	1093 m
39. Jankoviceva spilja mala (ponor Adios)	1087 m
40. Lukina jama - Trojama system	1078 m
41. Kicljeve jame system	1075 m
42. Rujnica	1052 m
43. Spilja Piskovica	1036 m
44. Kaverna u tunelu "Velebit"	1030 m
45. Rokina bezdana	1016 m

The Deepest and Longest Sumps

In the caves there are thousands of sumps, several hundreds of them were dived. Here is the list of deepest and longest sumps (deeper than 85 meters and longer than 400 meters) in Croatia.

1. Crveno jezero	(depth 281 m, dive wth heliox -181 m)
2. Glavas	(-115 m), dive with heliox
3. Sinac	(-103 m), dive with heliox,
4. Vruja Dubci	(-102,5 m), dive with air,
5. Majerovo vrelo	(depth-93 m, long 450 m), heliox
6. Izvor Kupe	(-86 m), with air

The Biggest Vertical (pitch)

Croatian Cvaes are rather vertical, and the deepest pitch in one step is 553 meters in Patkov gust pit on Velebit mountain Here is the list of biggest vertivals in caves and pits in Croatia (deeper than 200 meters)

1. Patkov gust	553 m
2. Lukina jama	320 m
3. Podgracisce II	237 m
4. Lukina jama	228 m
5. Balinka	218 m
6. Slovacka jama	213 m
7. Jama Marianna	210 m
8. Mamet	206 m
9. Munizaba	206 m
10. Stupina jama	205 m
11. Xantipa	200 m

Conditions for Organising Speleological Expeditions in Croatia

Croatian Speleological Federation, as national speleological association is proposing this terms that are following documents accepted by majority of UIS (Union Internationale de Speleologie) members at 12th International Speleological Congress, La Chaux-de-Fondes, Switzerland, 10th August 1997. For organising speleological explorations or visits (speleological expeditions) in Croatia, it is necessary to contact legitimate representative of UIS (association or individual) in the country from which the initiative comes. UIS representative from such country must send a letter of approval and support in the name of national speleological association (meaning also responsibility) to Croatian UIS representative. In the letter is needed to determine the expedition area, dates and time period, names of the expedition members, their associations, addresses, aims and objectives of the expedition, certifications about life insurance for all members, and certified document about paying eventual speleological rescue in Croatia. Letter must be sent no less than 6 month before expedition, and has to be addressed at:

CROATIAN SPELEOLOGICAL FEDERATION, Nova Ves 66 HR - 10000 Zagreb CROATIA, EUROPE fax/phone: **385 1 4666 586; **385 1 4668 475; GSM: **385 98 283 657; e-mail: mgarasic@public.srce.hr, URL: http://jagor.srce.hr/~mgarasic/speleo.html

Croatian Speleological Federation will take care for permissions (if such are needed for particular expedition) according to the Croatian Constitution and Laws, and will inform the organiser about it. Simultaneously Croatian Speleological Association will insure detail topographic and geological maps for expedition area. Submitting permissions and topographic (and geological) maps are to be paid by organiser. According to the number of participants, location, objective and other needs, Croatian Speleological Association can order the escort for particular foreign speleological expedition. In Croatia it is forbidden and treated as criminal act to bring out any biological, geological, archaeological or other material from speleological objects (caves, pits and mines). For scientific or other purposes special licence can be issued by authorised Ministries, but the requisition has to be made in advance.

A newly discovered caves and pits - speleological features (without previous names) should be named according to the local toponimes in researched area. Each new cave entrance will get identification number (from Central speleological Cadastre, Croatian Speleological Association) for registration. Organiser should suggest the name but it has to be approved by Croatian Speleological Association. Without such approval none can publish the data about new found caves in Croatia. The leader of the expedition has to inform the Croatian escort and Croatian Speleological Association about the results of expedition in short written report. No later than 6 months after expedition, organiser is obligated to submit complete and detail report (position of the cave or pit, detailed outline, description, photos, and other data) in 2 copies. The future possibilities for certain association to organise such expeditions in Croatia is determined by respectation of this terms. If foreign speleologists are participating in expedition organised by some Croatian speleological societies or clubs, and are invited by Croatian Speleological Federation, they need not apply to Croatian Speleological Federation in order to get permissions, because Croatian organiser will take care of that according to the Constitution and Laws**.**

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Exploraciones a Cuevas en Zona Kársticas de los Andes Venezolanos y en el Estado Falcón

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Resumen

En este trabajo se presentarán los detalles y planos topográficos de las cuevas exploradas en estas zonas y su proveccion a futuras exploraciones

Andes Venezolanos

El Páramo “El tamá” es un parque colombo-venezolano. La zona correspondiente a Venezuela está localizada en el noroeste del Estado Apure. Municipio Páez y el suroeste del Estado Táchira. Las cuevas están situadas en “La Linea”, area cercana al cauce del río Oirá, el cual marca la frontera entre los dos paises. A un promedio de 3000 metros sobre el nivel del mar están localizado 8 cuevas horizontales y es considerada una de las zonas kársticas más altas del país.

Se há reportado en esta zona comunidades de Guácharos (*esteatonis caripensus*).

La otra es una nueva zona de exploración que se encuentra al norte del estado Táchira en el municipio Samuel Dario Maldonado, próxima a las Pablaciones de San Simones y Hermandez y cerca del cause del río Escalante. En esta zona ha encontrado formaciones subterráneas en disposición horizontal originadas pro disolución de roca caliza com diversos espeleotemas y fauna. Asicomo también cavidades posiblemente producto de derrumbes en una falla geológica.

Estado Falcón

En este estado se encuentra nuestra principal zona de trabajo, especificamente en la Sierra de San Luis, dentro del Parque Nacional Juan Crisóstomo Falcón, delimitada por el triángulo formado por tres poblaciones: Cabure, San Luis y Curimagua. Esta zona es especialmente importante por la gran cantidad de simas desarrolladas en caliza que se encuentran, las cuales forman un gran sisitema de drenaje de la sierra.

Paramo del Tama

Parque Nacional el Tamá. Localización: Estados Táchira y Apure coordenadas: 07º 01 y 07º 38 Latitud Norte 71º y 72º 25 Longitud Oeste

Superficie actual: 139.000há

Clima: Lluvioso cálido de bosque húmedo tropófilo y sabanas

Temp. anual: entre 2000 y 4000 mm

Prec. anual: Premontano, Montano y Montano Bajo

Altitud: entre 320 y 3329 msnm

Vegetación: Bosques ombrófilos submontanos, montanos siempre verdes. Páramos andinos incluyendo páramos arbustivos, herbáceos y desérticos.

Zonas de Vida: Bosque muy húmedo, montano bajo. Bosque húmedo montano bajo.

El Parque Nacional El Tamá está localizado en la región montañosa de la Cordillera de los Andes. La de los Andes Colombianos, separada de la Sierra de Mérida pos la depresión del Táchira que hace más de 50 millones de años constituía un estrecho que comunicaba la Hoya de Maracaibo com la Cuenca del Orinoco.

La, Sierra El Tamá se caracteriza por presentar un conjunto de cadenas montañosas plegadas com una topografia sontamente escarpada donde destaca el **Páramos del Tamá** com una altitud de 3.320 m. En este páramos tienen su origen ríos como el Oirá. Por su hidrografía esta Sierra constituyen el recurso hídrico más importante que drena sus aguas hacia las cuencas del Orinoco y del Lago de Maracaibo.

La vegetación es característica de las selvas nubladas andinas, densas, con altura de media a alta, 2 ó 3 estratos arbóreos, sotobosque bien desarrollado y abundantes epífitas.

En las áreas de bosques destacan especies como Lagenanthus princeps que presenta flores cuyo colorido semeja el plumaje de las guacamayas, plantas con campanillas aterciopeladas o de flores en forma de trompeta, así como numerosos helechos arborescentes.

En el páramo prevalecen los frailejones y especies de los géneros Jamesonia, Oreobutus, Castilleja, Gentiana, Halenia, Pinguícula, Utricularia, Castratella y Veceinium.

De la fauna cabe mencionar especies de aves endémicas como el hormiguero tororoi tachirense, el carpintero barreteado barriga amarilla, el cabecicastaño y el atrapamoscas cerdoso; de los mamíferos el oso frontino, la danta, la lapa, el oso hormiguero y el cunaguaro. El Páramo del Tamá se caracteriza por su singular belleza y su poca accesibilidad.

En el año 2000, el Centro de Exploraciones Espeleológicas de la Universidad Nacional Experímental del Táchira (GEEXUNET) realizó una rápida expedición a esta zona y obtuvo como resultado el levantamiento topográfico de la cueva “La Ye” de 93,60m de desrrollo horizontal en arenisca.

El Instituto Nacional de Parques Nacionales (IMPARQUES) há contabilizado 9 cuevas en la zona.

La principal importancia de las cavidades de esta zona radica en que en algunas se puede conseguir restos de colonias de Guácharos (esteatornis caripensis), como la encontrada en dicha cueva La Ye, y colonias aún activas como es el caso de la colonia en la cueva “El Loto”, topografiada por la Sociedad Venezolana De Espeleología.

Esta zona no ha sido muy estudiada en el área de la espeleología. Esto se debe al difícil acceso a este páramo, ya que se encuentra rodeado por espesa selva nublada en las escarpadas laderas del Parque y a la fragilidad de todo el ecosistema, especialmente el del Páramo del Tamá.

El Páramo del Tamá es considerado como una joya dentro del Parque Nacional por su belleza y fragilidad. IMPARQUES es el organismo encargado de velar por el cumplimiento de las normas necesarias para acceder a este lugar, y gracias al esfuerzo de los guarda parques de este monumento natural, en especial aquellos que viven y conviven com él se há logrado la conservación de esta maravilla y por su entrega al trabajo han logrado un funcionamiento en cuanto a permisología y apoyo logístico a pesar de su poco presupuesto, que facilita la investigación cientifíca.

Zona Cárstica San Simón

Localización: Norte del Estado Táchira municipio Samuel Darío Maldonado

Clima: Lluvioso cálido de bosque húmedo tropo filo y sabanas

Temp anual: entre 13 y 26 ºC

Prec. Anual: entre 1000 y 2500 mm

Pisos Altitudinales: Premontano, Montano y Montano Bajo

Altitud: entre 800 y 1800 m

Vegetación: Bosques ombrófilos submontanos, montanos siempre verdes.

Zonas de Vida: Bosque muy húmedo montano bajo. Bosque húmedo montano bajo.

Esta zona se encuentra al borde de la depresión del Táchira y pertenece a la Sierra de Mérida, pertenece al período Cretáceo de la era Mesozoica. Esta zona es parte de una cadena montañosa que haciende com regularidad hasta los límites del Estado Mérida luego de la cual se hace más escarpada alcanzando los 4000 m en el Parque Nacional Sierra Nevada en el Estado Mérida.

Es una franja delimitada por el naciente del Río Escalante al suroeste, y la Población Hernández hacia el norte.

La vegetación característica es la selva tropical de altura muy similar a la del parque Nacional El Tamá.

De la fauna endémica podemos señalar a los mamíferos: la Lapa, Ardillas y Ratones silvestres, los lugareños aseguran que en otrora existían comunidades de primates.

Esta zona presenta medianos afloramientos de roca caliza, corrientes subterráneas y quebradas que son afluentes del Río Escalante, cuyo naciente se encuentra del extremo norte de la zona.

En abril de año 1999 comenzaron las prospecciones en el lugar y se hallaron 3 cuevas; La primera la cueva del Salado 1, es una formación horizontal por la que corre un río subterráneo com 40º de inclinación y de m en la que se halló gran cantidad de espeleotemas y una interesante leyenda; Cueva la Encantada. En año 2000 se realiza el levantamiento topográfico de una de estas cuevas y se descubre un gran afloramiento de caliza en donde se exploran diaclasas y grietas que aparentan una falla geológica. Lo que hace aún más interesante las formaciones halladas, son las evidencias que estas ofrecen acerca del pasado submarino de estas tierras.

Por todas estas características consideramos que esta nueva zona de trabajo es muy prometedora para nuestro trabajo espeleológico.

Futuro

El proyecto futuro en esta zona es usar las pequeñas formaciones como cuevas escuelas para ensenãr las nociones básicas de la espeleología a las recientes agrupaciones del estado Táchira, como lo es la sección de espeleología del GEXUNET, u así contribuir con el desarrollo de esta ciencia en la región.

Seguir descubriendo y explorando en conjunto con las agrupaciones de este estado, nuevas formaciones subterráneas de interés científico y pedagógico que serán muy útiles para los estudiantes y profesionales tachirenses dedicados a las materias relacionadas como geofísica, geología y minas, biología, etc.

Parque Nacional Sierra De San Luis

Localización: Estado Falcón

Coordenadas:11º 08 y 11º 19 Latitud Norte, 69º 29 y 69º 42 Longitud Oeste

Superficie actual: 20.000 Ha

Clima: Lluvioso cálido, Templado de altura tropical

Temp. **anual:** entre 15 y 25 ºC

Prec. anual: entre 1000 y 1400 mm

Pisos Altitudinales: Tropical y Premontano

Altitud: entre 200 y 1500 msnm

Vegetación: Bosques tropófilos basimontanos deciduos, Bosques ombrófilos submontanos siempre verdes

Zonas de vida: Bosque muy húmedo premontano, Bosque húmedo premontano

El Parque Nacional Sierra de San Luis está ubicado en el extremo sur del Estado Falcón, ocupando parte de la Sierra de San Luis. Este parque de belleza extraordinaria representa las áreas semidesérticas del Estado e incluye la microcuenca de Curimagua, donde se observan cuevas de grandes salas y galerias que tienen su origen en la acción de las aguas sobre las rocas calizas. Este fenómeno también ha originado la formación de grandes lagos subterráneos; el ejemplo más representativo lo constituye el lago formado en le cueva del Río Acarite, el mayor de Venezuela. Estas características y su importancia hidrológica determinaron la pretección y conservación del área bajo esta figura.

Un elemento importante constituye el hecho que dentro del parque se encuentran las nacientes de los más importantes ríos del Estado como lo son los rios Ricoa y Coro que aliementan las represas de Barrancos e Isiro; y el Mitare, Açarigua y Hueque.

Este último com el Ricoa tienen caídas de agua que poseen su mismo nombre.

Las variaciones topográficas están en el orden de las 200 y 1500 msnm en el Cerro Galicia. Outras alturas importantes son El Peñasco com 1470 msnm y el cerro El Candado com 1123m.

El parque tiene una vegetación diversa, pudiendose distinguir áreas de espinares y bosques tropófilos basimontanos y bosques ombrófilos submontanos siempre verdes. Los espinares están relacionados con el piedemonte de la Sierra, en los cuales destaca la presencia de especies como el cuji-vaque, el yabo y las tunas. En el bosque se encuentran especies arbóreas como el carcanapire, el yagrumo macho y el carnestolento. Hacia los sectores más altos específicamente en el Cerro Galicia se presenta los bosques nublados con especies endémicas, palmas y árboles como el ramón y el lechero.

El parque posee una rica avifauna y una gran diversidad de reptíles como las iguanas, lagartijos y culebras.

Este Parque Nacional es nuestra prinicipal zona de trabajo. Aquí, el Centro de exploraciones Espeleológicas de la Univerdidad Simón Bolívar lleva a coba la mayoria de sus expediciones, así mismo, esta es la zona predilecta para poner en practica los conocimientos adquiridos durante los cursos y talleres, gracias a la diversidad de formaciones subterráneas que en ella se encuentran.

Esta zona es muy rica en cuevas originarias de diactasas erosiondas, cuya exploración exige el uso de técnicas verticales.

Una de las características más resaltante es la alta densidad de cuevas, en mayoría verticales. La Zona de trabajo está delimitada por el triángulo formado por tres poblaciones importantes: Cabure, San Luis y Curimagua.

De acuerdo com las áreas prospectadas, se há obtenido un promedio de 50 cuevas por km2 lo cuál indica que cada 200 m que caminemos dentro de esta zona, nos encontraremos com una cueva. Por esto la llamamos “el Queso”.

Cabe destacar que dentro de esta zona se encuentra la sima más profunda desarrollada en caliza en Venezuela el: “Haitón del Guaratаro”.

Nuestra misión es realizar el levantamiento topográfico de todas las cuevas en la zona.

Futuro

En el Centro de Exploraciones Espeleológicas de la Universidad Simón Bolívar existe gran expectativa por las posibilidades de realizar expediciones en conjunto con grupos espeleológicos nacionales e internacionales, que nos darían el honor de recibirlos para así intercambiar experiencias y conocimientos.

Consideraciones Finales

El CEEUSB está dispuesto a colaborar com la preservación de estos ecosistemas tan especiales por su fragilidad, belleza y escasees como lo s Parque Nacional El Tamá para así conservar el legado natural de nuestros entepasados

Esperamos transmitir nuestros conocimentos a las nuevas generaciones de espeleólogia de la región tachirense y ofrecerles las herramientas necesarias para su buen desempeño como agrupaciones espeleológicas.

Todas estas zonas tienen una gran posibilidad de aportar al conocimiento humano algo más acerca de nuestro origen y es por esto que seguiremos trabajando con entusiasmo y con especial esmero en alcanzar la meta trazada por nuestro lema: **Hasta lo más profundo...**

Spedizione HUMALAJANTA'98

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Abstract

This work report the results of The Expedition Humajalanta'98 realized by AKAKOR GEOGRAPHICAL EXPLORING Onlus in Torotoro, Bolivia.

Twenty-two explorers from four different country Bolivia, Brazil, Italy and Spain, organized in 8 teams produced an absolutely importance experience that, through synergic interventions of multidisciplinary elements that, in addition to satisfy the legitime curiosity to explore of Homo Sapiens, permitted to develop studies that improve the concept of science like supreme human activity.

All of this with the purpose of synergic comparison between components with different technical and cultural experiences coming from different countries.

A lot of effort has been dedicated to involve local authority and/or local people with global international proposal doing technical stages, formation courses and technical meetings.

Relevant was the support of FEALC -Speleological Federation of American Latin Country-, of SOBESPE – Bolivian Society of Speleology and of ACT - Torotoro Preservation Association-. This have been fundamentals contact for the develop of the following researches in South-America area.

Riassunto

Il testo espone i risultati della Spedizione Humalajanta'98 realizzata da AKAKOR GEOGRAPHICAL EXPLORING Onlus, a Torotoro, Bolivia.

Ventidue esploratori provenienti da quattro diversi paesi Bolivia, Brasile, Italia e Spagna organizzati in otto squadre hanno prodotto un'esperienza d'assoluto rilievo, attraverso interventi sinergici d'elementi multidisciplinari che, oltre a soddisfare la legittima curiosità dell'uomo Sapiens di esplorare l'ignoto hanno permesso approfondimenti e sviluppi che amplificano il concetto della scienza come sovrana attività umana.

Il tutto nell'ottica di un confronto sinergico fra componenti con esperienze tecniche e culturali di diversi paesi partecipanti.

Particolare interesse è stato dedicato al coinvolgimento d'enti e/o elementi locali con proposte d'interazioni globali effettuando stage tecnici, corsi di formazione ed incontri.

Determinante è stato il supporto della FEALC, SOBESPE e ACT, appoggi decisivi per i successivi sviluppi di ricerca nei territori sudamericani.

Introduzione

"Un gruppo di dinosauri erbivori si muove ai margini di una palude, gli animali camminano uniti, sopra un terreno pantanoso, lasciando profonde impronte. Sono sei esemplari adulti e due giovani, è possibile che si stiano recando a bere e rinfrescarsi; improvvisamente qualcosa li spaventa. Un grande gruppo di carnivori appare all'orizzonte, sono animali più piccoli, bipedi, che corrono velocemente. Inizia il combattimento, i grandi erbivori scappano tumultuosamente, ma la loro fuga è breve, i carnivori li hanno già raggiunti. E' l'inizio del dramma per questi enormi animali…"

Questo è il sunto di un articolo dove si descrivono le ricerche di carattere paleontologico effettuate a Torotoro.

In questi territori è stata svolta la Spedizione Humajalanta'98 del progetto AKAKOR, che è stata realizzata dall'8 al 23 agosto 1998.

I risultati ottenuti nelle ricognizioni hanno evidenziato il potenziale di questi territori e le infrastrutture di supporto locali. Sono state effettuate immersioni nel lago Titicaca (3810 m. s.l.m.) e sul Chakaltaia (5150 m. s.l.m.), ricognizioni aeree, esplorazioni speleo subacquee ai piedi dell'Ilhampo (Ande boliviane). Infine è stato localizzato nei territori del Charcas il punto dove è stata realizzata la spedizione.

Perché Humajalanta'98?

La spedizione prende il nome dalla grotta più importante della Bolivia, situata nel territorio di Torotoro, e vuole essere la prima di una serie d'esplorazioni che saranno realizzate nella regione.

Si tratta della prima spedizione Italiana in Bolivia, e come per le precedenti la collaborazione Italo-Brasiliana verterà sugli stessi livelli tecnico-scientifici con l'inserimento dello staff Boliviano che presenta una storia più recente.

Parallelamente alla spedizione è stato realizzato dalla SOBESP e dall'Akakor Geographical Exploring il primo incontro Boliviano, Brasiliano e Italiano su tematiche speleologiche al quale hanno partecipato i rappresentanti del FEALC entità d'appoggio per entrambi gli eventi.

Localizzazione e Caratteristiche Fisiografiche dei Territori

La regione di Torotoro è localizzata nella provincia di Charcas dipartimento di Potosi in Bolivia e si estende approssimativamente su un'area di 165.700 chilometri quadrati.

In questo paesaggio, d'altipiani si sviluppano grandi canyon con altezze variabili da 60 a 300 metri; l'ambiente naturale è caratterizzato da una vegetazione di tipo alpino (Puna e Paramo) e da una tundra sub artica a cespugli e muschi. L'altitudine varia da 2000 a 3500 metri s.l.m. Il clima è semi arido.

Le formazioni carsiche (caverne, abissi, inghiottitoi, risorgenze, doline e lapiaz) si sono sviluppate nei calcari del cretaceo. Delle otto grotte conosciute in Bolivia cinque sono situate nel territorio di Torotoro, ma non dobbiamo dimenticare che la storia speleologica boliviana è recente, per tanto c'è molto da esplorare. Il maggiore e più importante sistema carsico è quello di Humajalanta e Chijflon-q'haq'ha.

La regione presenta un grande potenziale speleologico, paleontologico, archeologico ed antropologico, biologico e geologico.

Obiettivi

Entro gli innumerevoli obiettivi della **Spedizione Humajalanta'98** distinguiamo quelli di maggiore importanza.

01. Esplorare, catalogare e fotografare grotte, abissi, risorgenze, inghiottitoi, canyons e doline nell'area del parco di Torotoro e dei territori circostanti.
02. Studiare la geologia e l'idrogeologia dei sistemi carsici dell'area in oggetto.
03. Localizzare e studiare siti d'interesse paleontologico, archeologico ed antropologico.
04. Realizzare filmati e fotografie di carattere documentativo
05. Realizzare pubblicazioni documentative.
06. Sviluppare un sistema di comunicazioni che attraverso l'uso d'apparecchi subacquei collegati coi campi esterni e tramite ponti radio siano trasferiti in tempo reale ad un sistema informativo e trasmessi tramite Internet.
07. Confrontare esperienze tecniche e culturali fra i componenti di diversi paesi partecipanti durante la varie attività della spedizione.

Logistica

La logistica è stata realizzata tenendo conto di una serie di fattori nell'ottica di metodi applicativi gerarchici e sinergici per raggiungere gli obiettivi prefissati ed è stata strutturata in diverse squadre: documentazione, alimentazione, materiali, comunicazioni, immagini, medica, topografia, esplorazione, Speleologia, Geologia ed Archeologia.

Oltre ad un coordinatore generale sono state identificati dei coordinatori responsabili per ogni paese partecipante.

Stage pre-Spedizione

Allo scopo di uniformare la conoscenza basica dei componenti della spedizione in modo di produrre degli interventi omogenei d'affiancamento agli specialisti di settore sono stati realizzati degli stage condotti dagli stessi così strutturati: Paleontologia (Ivano Fabri), Tecnologia (Walter Triacchini), Topografia (Soraya Ayub), Tecniche di Soccorso (Alessandro Anghileri), Geologia (Soraya Ayub).

Prima Fase

Sono state effettuate delle riunioni dello staff brasiliano con i coordinatori allo scopo di attuare gli approfondimenti logistici e la preparazione dei materiali, successivamente i coordinatori si sono recati in Bolivia dieci giorni prima dei membri della spedizione per poter organizzare la logistica in Torotoro, Provincia di Charcas, il reperimento automezzi, il trasporto della prima parte dei materiali e dell'alimentazione, la verifica in loco delle strutture logistiche e la collaborazione con l'Alcandia, l'ospedale, le associazioni ed i gruppi locali d'appoggio

Sono stati inoltre definiti i dettagli d'appoggio ufficiale delle entità governative (Ambasciate Italiana e brasiliana) e non governative ACT e SOBESP.

Seconda Fase

La seconda fase inizia con l'arrivo della prima squadra brasiliana a La Paz che successivamente si trasferisce a Sorata località situata nella valle sovrastata dalle vette dell'Illampu (6362 msl) e dell'Anchuma (6427 msl) nella cordigliera Real del nord per effettuare le misurazioni fisico-chimiche dell'acqua del fiume sotterraneo della grotta San Pedro, ed il rilevamento delle coordinate geografiche della grotta per poi trasferirsi a Chacaltaya allo scopo di verificare la presenza di grotte nel ghiacciaio e testare gli strumenti TESTO (Strumentazione elettronica di misure di parametri fisico-chimici multifunzione per identificazione della velocità dell'aria, temperatura ed umidità) ed effettuare la seconda fase d'acclimatamento in altitudine nel rifugio campo base a 5300 msl.

Di seguito ha avuto luogo l'apertura ufficiale della Spedizione Humajalanta'98/Progetto AKAKOR presso l'Accademia Nazionale delle Scienze con conferenze stampa ed interviste radiotelevisive.

Terza Fase

Questa fase identifica l'arrivo degli altri componenti brasiliani, italiani e spagnoli con l'aggregazione dei componenti dello staff boliviano ed il successivo trasferimento a Torotoro (150 km di piste sterrate), e l'assemblamento del campo base

Vengono installati, il gruppo elettrogeno, le apparecchiature di comunicazione, i computers, ed i compressori subacquei.

Particolare attenzione viene dedicata alla Predisposizione della sala operativa, del magazzino materiali, della cucina e degli alloggiamenti.

Quarta Fase

Questa fase introduce l'aspetto operativo ed in sequenza vengono descritte le principali attività effettuate durante la spedizione: (1) studi dei materiali documentativi della regione (mappe, foto aerei, ecc.); (2) ricognizione aerea per prospezione geologica; (3) rilevamento delle pitture rupestri nel rio Torotoro e localizzazione e studio di altre nuove nella zona di Maguey-Mayu; (4) realizzazione di due stazioni idrogeologiche in Humajalanta in interno ed esterno grotta con 100 punti di rilievo; (5) rilevamento geologico in tre stazioni nei pressi di Chijflon-q'haq'ha; (6) Conferenza al Congresso Boliviano di Speleologia, da rilevare la numerosa presenza tra i partecipanti del Congresso d'indios quechua e Aymara; (7) rilievo e studi archeologici ed antropologici delle rovine di Llamaciachi; (8) rilevamento geologico e misurazione fisico-chimica delle acque dei fiumi sotterranei di Humajalanta; (9) esplorazione speleo subacquea di un nuovo sifone in Humajalanta con successiva scoperta di un salone post-sifone; (10) effettuato test d'attrezzature subacquee non convenzionali: maschere gran facciali con apparecchiature intercomunicanti, computers subacquei con rilievi multifunzione; (11) esplorazione e topografia delle grotte Huayllas, Chankarani, Wayq'ho Chinkasq'a, Huasarin Railp'a, Puyu Allpa, Chiliyusq'u e Yurajq'asa (la più profonda della Bolivia); (12) effettuato ricerche di carattere geologico, speleologico ed archeologico nella località Rincon; (13) effettuati rilievi fisico-chimici delle risorgenze locali con relativo rilevamento geologico; (14) localizzato ingresso di una tomba del periodo Chulpa contenente resti umani; (15) realizzato corso di tecniche verticali per speleologi alle guide del Parco Nazionale di Torotoro (venti persone); (16) localizzate e misurate nuove impronte di dinosauri (90 impronte in una linea di 60 metri); (17) elaborazione dati idrogeologici e realizzazione topografie computerizzate; (18) effettuata importante connessione fra i sistemi Chijflon-q'haq'ha.e Chijflon-q'haq'ha II, (la seconda grotta più estesa della Bolivia).

Conclusioni

La Spedizione Humajalanta'98, la prima realizzata dallo staff AKAKOR in Bolivia, è stata estremamente positiva ed ha concretizzato buona parte degli obbiettivi che ci eravamo preposti. Le difficoltà riscontrate durante questa esperienza sono state superate grazie ad un'ottima organizzazione logistica ben armonizzata, il supporto da parte delle autorità locali è stato eccezionale e le collaborazioni prodotte si sono rivelate proficue e fioriere di futuri sviluppi.

Ringraziamenti

Consolato Generale d'Italia in Bolivia, Consolato Brasiliano in Bolivia, SBE – Società Brasiliana di Speleologia, SOBESPE – Società Boliviana di Speleologia, SSI - Società Speleologica Italiana, ACT - Asociacion Conservacionista de Torotoro, FEALC - Federazione Speleologica dell'America Latina e Caraibi (Cuba, Venezuela, Messico, Brasile, Bolivia, Argentina, Porto Rico e Costa Rica), ANIS - Associazione Nazionale Istruttori Subacquei; PANGEA – Associazione Culturale di Faenza; IBAMA/CECAV/DIREC – Istituto Brasiliano dell'Ambiente; Corpo Nazionale Soccorso Alpino e Speleologico Italiano; The Explorer's Club, New York; TESTO – strumentazione elettronica di misura di precisione e ALITALIA.

Nome Caverna	N. Catasto	Mumicipio	Equipe Topografica
San Pedro	LA - SO - 01	Sorata	AKAKOR
Humajalanta	CH - PO - 01	Torotoro	Guyot e equipe/AKAKOR
Chijflon-q'haq'ha	CH - PO - 02	Torotoro	Guyot e equipe
Yurajq'asa	CH - PO - 03	Torotoro	AKAKOR
Chilijusq'u	CH - PO - 04	Torotoro	AKAKOR
Huayllas	CH - PO - 05	Torotoro	AKAKOR
Huaq'ha-senq'ha	CH - PO - 06	Torotoro	Guyot e equipe
Chankarani	CH - PO - 07	Torotoro	AKAKOR
Chijflon-q'haq'ha II	CH - PO - 08	Torotoro	AKAKOR
Wayq'ho Chinkasq'a	CH - PO - 09	Torotoro	AKAKOR
Huasarin Railp'a	CH - PO - 10	Torotoro	AKAKOR
Puyu allpa	CH - PO - 11	Torotoro	AKAKOR

Tabella semplificata del Primo Catasto delle grotte boliviane fatto dall' AKAKOR GEOGRAPHICAL EXPLORING Onlus ***e della*** *SOBESP* ***– Società Boliviana di Speleologia***

OBS1: i nomi delle grotte sono in lingua locale (quechua o aimara), molte volte scelto degli abitanti dei posti

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Exploração, Topografia e Manejo da Gruta do Jeremias - Iporanga - São Paulo

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Abstract

Jeremias Cave, located in the region of Cotia de Cima in the county of Iporanga in the state of São Paulo contains the gallery of Salão Duca, with some of the most spectacular speleothems in Brazil. It presents great difficulty for exploration due to the long passages with low roof, small siphons, and fallen rocks. Ever since its discovery and original mapping, few have visited the cave, and little of interest has been found beyond this gallery. The expeditions of the GPME were designed to map the river gallery and the Duca Room, as well as to reach the end of the cave and find new galleries, especially on the upper level. The use of relatively uncommon techniques for mapping and exploration of vertical expanses was necessary. After this exploration, however, the cave has been subjected to non-supervised visitation and its safety is at risk.

Resumo

A Gruta do Jeremias, localizada no bairro Cotia de Cima, apresenta uma galeria com um dos mais belos conjuntos de espeleotemas do Brasil, o Salão Duca, além de apresentar dificuldades de caminhamento por conter grandes extensões de galerias em teto baixo e pequenos sifões e desmoronamentos. Desde sua descoberta e primeira topografia, poucos se aventuraram em seu interior e pouco foi descoberto além do Salão Duca. Nas expedições do GPME o objetivo era, além de topografar a galeria do rio e o Salão Duca, explorar o final da caverna e procurar novas galerias, principalmente superiores. Para o quê foi necessário o uso de técnicas de topografia e exploração pouco usuais até o momento. Verificamos que após nossas investidas a Gruta foi alvo de turismo irregular o que coloca em risco sua preservação.

Introdução

Histórico

Pierre Martin ao saber de uma gruta, recém descoberta na região do Rio Cotia de Cima, procura o então prefeito de Iporanga, o Sr. Jeremias e propõe o seguinte acordo. Em troca do empréstimo de uma canoa com motor de popa por dois dias, para subir o Ribeira, ele daria a caverna, o nome do Prefeito.

A gruta do Jeremias está cadastrada na SBE com o número SP-053, esta cavidade fora explorada e topografada em 23 de junho de 1968, por Pierre Martin, Guy Collet, Luiz Carlos Marinho e Vandir de Andrade.

Na ocasião nossos precursores decidiram explorar e topografar o conduto principal do rio, dada as dimensões da nova caverna e o tempo disponível. Assim algumas galerias deixaram de ser exploradas e topografadas.

Localização

A Gruta do Jeremias localiza-se na região conhecida como Cotia de Cima no município de Iporanga – Sudeste do Estado de São Paulo, em terras particulares, próximo ao limite Sul do Parque Estadual Turístico do Alto Ribeira (PETAR). Suas coordenadas são Lat. 24º38’15”S e Long. 48º42’2”W e 335 s.n.m.

Acesso

A Gruta pode ser acessada de três maneiras, à pé pelo Bairro Bombas. De Carro até a Barra do Rio Pardo e o restante à pé e, de barco pelo Ribeira de Iguape e a pé até a ressurgência.

A Trilha

O trecho inicial da caminhada via Barra do Rio Pardo, às margens do ribeira de Iguape até a ressurgência da Caverna, atravesa um belo trecho de Mata Atlântica, sempre às margens do Córrego Cotia de Cima, atravessando-o diversas vezes e subindo e descendo montanhas. Esta trilha caminha em direção ao Bairro Bombas e a certa altura um desvio para uma região de mata mais preservada leva até a entrada da Gruta.

Características da Caverna

Descrição Geral

A entrada da Gruta se situa a cerca de 15 m acima da ressurgência, uma pequena boca com cerca de 0,70m de altura por 1,50m de largura, uma páleo ressurgência que dá acesso ao salão Vandir, de onde pode-se avançar através da páleo galeria a frente ou através de um desnível acentuado à direita alcançar uma galeria mais recente e com trechos estreitos até atingir o rio, que corre rápido. Neste ponto as duas galerias se unem e formam uma galeria mais larga e alta de onde avista-se os primeiros desmoronamentos, a cerca de 80m da entrada.

A partir deste ponto o deslocamento se dá pela galeria do rio, sempre com água pelos joelhos. Logo de alcança o primeiro sifão, conhecido como Passagem da Corda, facilmente ultrapassado por cima do lago profundo, os primeiros trechos de teto baixo começam logo após este sifão.

Após o primeiro trecho de teto-baixo chega-se à subida da Rede Mer, detalhada adiante, e depois do segundo trecho de teto-baixo a galeria se amplia e uma cascata de pedra e um magnífico chão-de-estrelas denunciam uma galeria superior, o Salão Ducano.

A galeria se desenvolve ampla até o chamado Pseudo-Sifão, um trecho de uma galeria-baixa onde é necessário entrar com o corpo inteiro na água profunda deixando apenas a cabeça de fora. Poucos metros adiante atinge-se o Sifão Guy, uma homenagem à Guy Collet que na primeira exploração da gruta, ultrapassou o sifão, uma galeria estreita e regular denuncia o sifão, que se estende por cerca de 1,5m e em épocas de seca, deixa uma faixa de 10cm de ar entre o teto e a água.

Após mais alguns trechos de tetos-baixos chega-se a subida do Salão Duca, seguindo-se adiante mais tetos-baixos e galerias emplas se alternam. Não foram descobertas galerias superiores até o final da gruta, apenas galerias mais amplas em dois ou mais níveis, como o Salão Piratininga ou a Rede Fria.

No segundo terço da gruta encontra-se dois pequenos afluentes do lado esquerdo do rio, pouco significantes. Próxima a estes o Sifão da Lama se mostra a frente, é necessário rastejar na lama e descer ‘de cara’ no rio adiante. Mais alguns passos e é necessário novamente se curvar para ultrapassar o Sifão Fú, local que em dias de chuva sifona o rio por um trecho de cerca de 4m, tornando bastante arriscado ultrapassá-lo nestas épocas.

Daí para frente as feições da galeria mudam bastante. Se tornam mais baixas e regulares, de seção quase quadrada, com blocos bastante fraturados principalmente no lado direito do rio, que corre por entre blocos abatidos e sob estalactites tipo canudo de refresco, das quais precisa-se desviar constantemente.

Um pouco à frente a galeria se abre e permite uma escalada de cerca de 10m do lado direito, de onde, mais abaixo, corre um afluente de água gelada e limpa e mais atrás deste abre-se um pequeno salão entre blocos e muita argila.

A gruta segue por uma longa galeria muito baixa, por onde é preciso ‘andar de joelhos’ até alcançar uma pequena cachoeira de cerca de 50cm, neste trecho torna-se necessário rastejar até que a galeria se aprofunde permitindo uma posição mais confortável. Um pequeno sifão se apresenta e cerca de 5 metros adiante chega-se a uma trecho muito baixo com paredes muito próximas uma da outra, é o final da gruta. Podemos perceber o rio invadindo a gruta através de pequenas e intransponíveis fendas abaixo do nível da água.

A Rede Mer

Na segunda expedição dedicamos bastante tempo para a exploração em busca de galerias superiores e salões. Após subir em divesos locais sem sucesso tentamos um pequeno desnível de 4m após um trecho de teto-baixo, para a nossa surpresa após um rastejamento de 5m sobre areia seca atingimos uma pequena rede de galerias com um modesto afluente. São dois salões se desenvolvendo hora sobre a galeria principal hora à leste.

O Salão Ducano

Desde a nossa primeira investida na Gruta percebemos a possibilidade de existência de uma galeria superior um pouco adiante da Rede Mer, um grande escorrimento de calcita na margem direita e um buraco no teto, a cerca de 7m acima do rio nos deixaram tentados. Mas somente após desenvolver um dispositivo para subir, já que a escalada e mesmo a laçada de algo lá em cima era impossível, conseguimos vencer e chegamos ao salão.

O dispositivo se compõe de um tubo de aço de 6 metros de comprimento cortado em pedaços de 1,5m com encaixes parafusados nas extremidades e vários pontos para amarração.

Com uma corda e uma escadinha-de-cabo-de-aço, mais o dispositivo, conseguimos alcançar a borda do buraco no teto e com uma pequena escalada chegamos a um patamar, de onde tivemos a certeza de uma grande descoberta, mais uma escalada de 4m e vislumbrávamos um belo salão largo e alto, com chão-de-estrelas por todo lado e com cascatas de calcita por onde escorre água em épocas de chuva. Algumas flores de calcita e pérolas aparecem em pontos isolados.

Continuamos a exploração e avançamos por desmoronamentos muito instáveis e uma fenda alta e muito estreita, até atingir novamente a galeria do rio através de um pequeno abismo num trecho mais adiante. A galeria ainda se desenvolve bastante, seguindo o mesmo rumo da galeria atual do rio, sempre por uma fenda hora estreita e profunda hora mais larga e tomada de blocos abatidos.

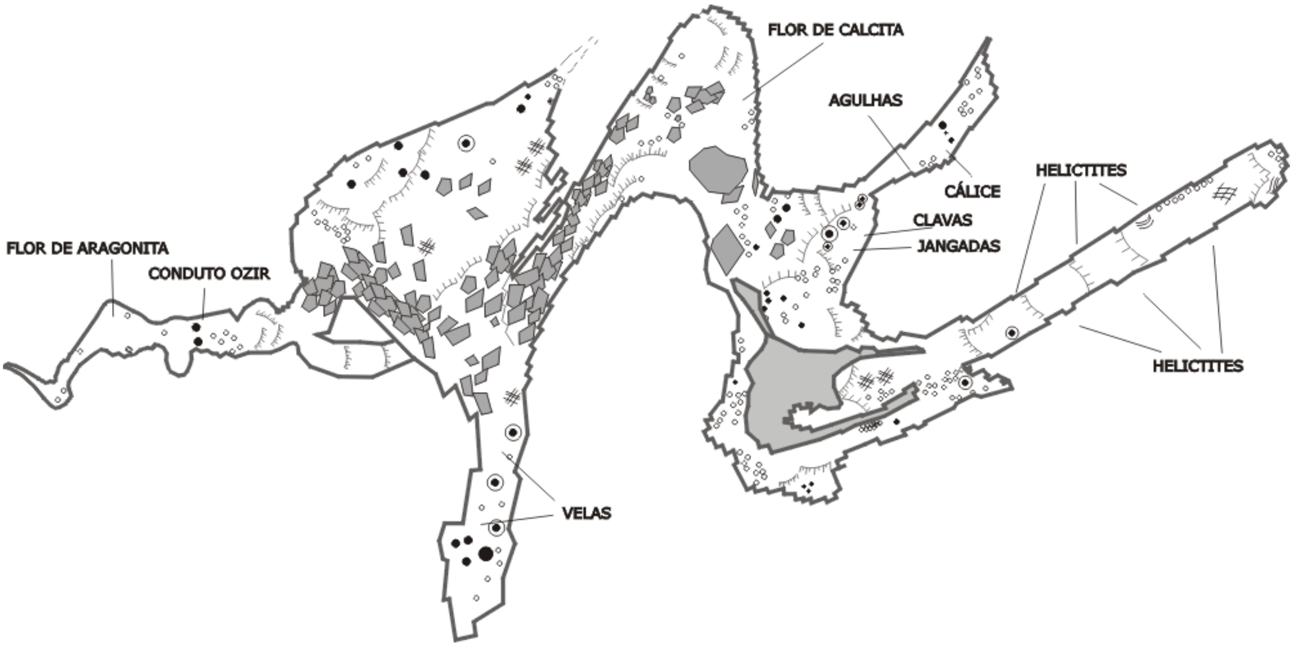
O Salão Duca

O Salão Duca foi descoberto durante uma viagem do Centro Excursionista Univesitário – CEU, mas desde então nunca havia sido topografado.

Conhecido pela sua beleza, apresenta espeleotemas raros e delicados, confinados em uma rede de galerias superiores, mostrando um sem número de formas e tons de ocre e branco.

No Duca encontramos helictites e heligmites espalhadas por todo o salão, agulhas de calcita e aragonita, pequenas flores de calcita, aragonita e gipsita e escorrimentos e estalactites brancas como a neve.

Também encontramos uma rara formação dentro de um travertino seco, que lembra um cálice, além de jangadas, clavas e dentes de cão em travertinos cheios.



Salão Duca – Localização dos principais espeleotemas

Cuidados

Os cuidados a serem tomados na galeria do rio, principalmente após o Salão Duca, são evitar as temporadas de chuvas pois o risco de inundação e iminente e proteger-se do frio caso vá permanecer muito tempo dentro d'água.

No Salão Duca, deve-se ter cuidado com a subida após o rio, com blocos soltos e principalmente com os espeleotemas, tendo o cuidado de não usar carbureteira e não tocar em nada.

Topografia

O levantamento topográfico da gruta foi realizado conforme a classificação da UIS e as Normas e Convenções Espeleométricas da SBE. Foram utilizadas bússolas, clinômetros e trenas além de cadernetas a prova d'água para as anotações.

Os dados foram digitalizados e foi gerado o alinhamento da caverna com programa específico, sobre o qual foi desenhado o contorno das galerias e o detalhamento das mesmas.

O mapa foi produzido na escala 1:1000 com detalhe do Salão Duca em 1:250, conveniente para o posicionamento dos espeleotemas.

Projeção da Gruta sobre Mapa do DAEE

Projeção da Gruta sobre Mapa do DAEE

Conclusões

A exploração e topografia nos revelaram três novos lugares, a rede Mer, o Salão Ducano e a galeria Ozir, esta que encontramos durante a topografia do Salão Duca, muito ornamentada com dentes de cão e muitas flores de aragonita que ainda não havia sido mencionada por nenhum grupo que fora ali. Além do final da caverna, não descrito anteriormente.

O Salão Duca, foi totalmente topografado, onde fizemos a localização exata dos espeleotemas mais notáveis.

Durante uma de nossas expedições realizamos uma limpeza dos espeleotemas do Duca. Usamos apenas água do rio, borrifada sobre os espeleotemas sujos. Nos menos delicados usamos escovas de dente com cerdas macias e água do rio a fim de retirar a sujeira.

Uma projeção horizontal do interior da gruta, foi produzido para plotagem em mapa do DAEE, folha X-12, escala 1:10.000, assim pudemos conhecer os limites da caverna na superfície do solo.

Pudemos supor que o sumidouro se encontra na região de Bombas, provavelmente nos lagos daquela região. Esta constatação necessitará de estudos posteriores com traçadores, já que é impossível continuar a exploração.

A gruta se desenvolve seguindo a orientação NE-SW, no contato entre os metacalcários e os filitos.

O mergulho da rocha, bastante acentuado, condicionou a morfologia dos condutos, geralmente estreitos e regulares, na sua seção transversal, como cannions e muitas vezes baixos ocorrendo a formação de tetos-baixos e sifões e o padrão planimétrico retilíneo e anguloso.

Pudemos identificar fendas e fraturas onde as galerias se tornam mais amplas ou há formação de salões superiores e abatimentos.

Notamos que nas épocas de chuvas as galerias baixas são parcial ou totalmente preenchidas durante as inundações, comuns na região. Numa delas ficamos presos durante mais de 12 horas no final da Caverna, num trecho que denominamos Rede Fria.

Documentamos a caverna em foto e vídeo, para conhecimento do potencial espeleológico da cavidade.

Manejo

Durante os dois anos em que duraram as nossas expedições a esta caverna, pudemos observar que ela esta sendo freqüentada por turistas ocasionais. Também observamos que existem algumas pichações em galerias mais próximas a entrada da caverna. Porém o que mais nos preocupou foi o grande número de espeleotemas sujos no “DUCA”.

Hoje a situação está fora de controle, guias locais e pseudo-espeleólogos têm levado turistas a caverna com o objetivo de visitar o Salão Duca, o que têm colocado em risco a vida dos turistas e a preservação da Gruta. Mesmo apesar das dificuldades de acesso e de deslocamento interno encontrados.

Nossa proposta é uma parceria entre o GPME, o CECAV, a SBE, o IF e a Prefeitura de Iporanga, para elaboração de algumas normas de visitação para todo tipo de expedição programada para esta caverna.

Nossa sugestão é o fechamento do Salão Duca, de maneira que restrinja o acesso a ele e ao mesmo tempo seja colocado em prática um plano de manejo que permita somente a visitação para pesquisas espeleológicas e para conhecimento dos monitores locais, não sendo permitido o acesso a turistas.

A equipe deverá ser composta de um pequeno número de pessoas, as quais deverão estar preparadas e instruídas para tal visita. Deverá haver um guia responsável e a visita deverá ser agendada com um período mínimo de antecedência e com um intervalo regular entre as visitas. Esta visita deverá ser documentada em forma de relatório.

Desta maneira poderemos ter o controle do acesso à Gruta e garantir a sua preservação.

Lembramos que este método já foi aplicado ao salão Taqueupa na caverna de Santana e se mostrou eficiente quanto a contenção da depredação do patrimônio espeleológico da caverna.

Agradecimentos

SBE – Sociedade Brasileira de Espeleologia

Prefeitura do Município de Iporanga

IF - Instituto Florestal – PETAR

CECAV - IBAMA

Reserva da Biosfera da Mata Atlântica

Le Spéléo-Secours au Liban: Derniers Développements

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Le premier club de spéléologie fut crée au Liban depuis près de 50 ans succédant à plus cent ans de spéléologie effective. Aucun accident mortel n'a été enregistré. Cependant, à plusieurs reprises des catastrophes furent évitées de justesse, engendrant une prise de conscience de la nécessité d'une formation d'une Equipe de Spéléo-Secours au Liban.

Les thèmes abordés dans cet exposé seront les suivants:

- Historique du Spéléo-Secours au Liban et le rôle pionnier du SCL.
- Explications détaillées des derniers développements du Spéléo-Secours au Liban au sein de l' ALES, avec des exercices en grotte, en gouffre et en canyon, suivis de stages régionaux et internationaux en France. Les techniques acquises à cette occasion, dont certaines sont toutes récentes, seront particulièrement évoquées.
- Intervention réelle à l'échelle nationale.
- Interactions avec les différents acteurs publics et privés libanais : Croix-Rouge, Armée, etc.… On parlera à cette occasion de la formation idéale d'un Spéléo-Secours à l'échelle nationale et des problèmes de financement.

Mots clés : Equipe Spéléo-Secours Liban, ALES, Spéléologie, Grottes, Gouffres, Canyon, Croix-Rouge, Armée Libanaise, Défense Civile.

Histoire du Spéléo-Secours au Liban

Le premier contact entre le Spéléo-Secours et le Liban eut lieu le 7-5-1983, suite à une correspondance envoyée par Pierre Rias directeur du Spéléo-Secours Français – SSF- et Ahmed Malek président du Spéléo Club du Liban - SCL.

En 1991, et suite à la demande du SCL auprès de la FFS, un stage de formation spéléologique se tint au Liban du 9 au 17 Août 1991. Le président du SSF Jean-Claude Frachon et cinq autres cadres eurent pour mission d'exécuter le programme de sept jours dont quatre étaient consacrés à la formation technique et trois autres aux techniques secours. (Al Ouat'ouate Nouvelle série Nº 6 – 1991).

En 1993, une manœuvre du SCL dans la grotte de Nabaa el Sakie.

En 1995, une manœuvre du SCL fut effectuée dans la grotte de Roueiss en collaboration avec la Croix Rouge Libanaise – CRL- pour la formation d'une équipe de la CRL.

En 1997, et dans le cadre du douzième Congrès International de la Spéléologie en Suisse, un Stage International de Spéléo-Secours fut organisé par Christian Dodelin président du SSF en Haute Savoie en Juillet-Août 1997. Trois spéléologues libanais y participèrent : deux membres de l'Association Libanaise

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[5] ALES – Association Libanaise d'Etudes Spéléologiques fondée en 1994, Dépôt légal (6-6-1994 A/D) a pour buts : L'Exploration et l'études des phénomènes karstiques souterrains (grottes, gouffres, etc.…); La Vulgarisation de la connaissance du monde souterrain : publications, conférences, expositions,…; La Collaboration avec les administrations officielles pour la protection et la valorisation des milieux karstiques; Le Spéléo-Secours

d'Etudes Spéléologiques – ALES- (Fadi Beayno et Badr Jabbour-Gédéon) ainsi qu'un membre du SCL (Fadi Aboujaoudé). (Spéléorient Nº 3, 1998).

Durant la même année, un programme étalé sur deux mois fut établi par Joseph Zeidan spéléologue du SCL et le Commandant Khalil Helou de l'Armée Libanaise. Deux manœuvres de sauvetage en cavité eurent lieu le 30 novembre 1997 dans la grotte de Roueiss à Aaqoura et le 20 décembre 1997 dans le gouffre el Habb à Tripoli. Au cours de l'exercice dans le gouffre el Habb, un coéquipier du SCL a glissé à l'entrée du puits et s'est trouvé immobiliser quelques mètres plus bas. Il subit une atteinte grave au niveau du cou et un tassement des vertèbres. (Al Ouat'ouate Nouvelle série Nº 11– 1997/1998).

Un an plus tard, en Août-Septembre 1998 deux membres de l'ALES (Dany Khalaf et Badr Jabbour-Gédéon) ont séjourné à Vienne au Sud de la France dans le cadre d'un stage de restauration des mosaïques avec le concours de l'Ambassade de France. Grâce aux contacts que l'ALES a réalisé avec l'Organisme du SSF présidé par Christian Dodelin et suite à la réunion qui a eu lieu le 15 août 1998, une correspondance électronique a été envoyée le 16 août 1998 par Christian Dodelin concernant l'organisation d'un stage secours au Liban entre le 27 août et le 5 septembre 1999. Une copie de la correspondance a été envoyée aux différents clubs libanais

En automne 1998 les deux spéléologues de L'ALES (Dany Khalaf et Badr Jabbour-Gédéon) ont participé à un exercice régional organisé par le SSF dans le gouffre du Libanais à Flaine. Le blessé fictif positionné à une profondeur de 200m est ressorti 'sain et sauf'. *La cuvette de Flaine est un des quatre bassins versants du désert de Platé qui se trouve dans les Hautes-Aples calcaires situées à cinquante kilomètres du Sud-Est de Genève. Ce gouffre, qui est à proximité de la station de ski, fut découvert en 1992 par Denis Favre. Son développement est approximativement de un kilomètre et sa profondeur est de 277m. C'est un beau gouffre alpin, qui se trouve à 2132m d'altitude, très froid jusqu'au point de la gélification. A l'occasion du stage un nettoyage de pierres et blocs a eu lieu au niveau des ressauts.* (Stalactite, 1/2000).

En juillet 1999 le SCL organise un exercice dans le gouffre Albert avec comme mission le dégagement d'un blessé à 65m de profondeur.

A la suite de chacun de ces exercices, la nécessité d'avoir une bonne formation en matière de secours devient évidente. C'est dans ce concept que, le premier Stage National de Spéléo-Secours eut lieu à Mnaitra-Liban du 26 Août au 5 septembre 1999. L'opportunité de travailler à l'échelle nationale a été offerte à tous les clubs libanais. Trente sept adhérants y ont participé, dix neuf spéléologues maîtrisant les techniques verticales de l'ALES, cinq spéléologues du Groupe Spéléo de Wadi el Arayech - GSWA, un spéléologue du SCL (à titre indépendant), un secouriste de la CRL, trois cadres de la réserve Afqa ainsi que sept membres et amis de L'ALES qui ont assuré la secrétariat et l'intendance. Ce stage nous a permis de perfectionner :

- Les astuces de la progression verticale,
- Le montage de différents ateliers en falaise : répartiteur de charge, palan, tyrolienne horizontale et oblique, frein de charge avec descendeur ainsi sur demi-nœud d'amarre, passage de nœud dans un palan et dans un frein de charge, poulie humaine, poulie largable, balancier.
- Les différentes méthodes de dégagement d'un coéquipier ; depuis le bas : technique de coupé de corde, de la pédale crollée (deux nouvelles techniques), croll to croll, la longue longe ; depuis le haut : par la technique du faux balancier.
- Les différentes notions sur le bilan médical, point chaud, mise en brancard et transport.
- La gestion d'une opération de secours au niveau du poste de commandement opérationnel.

Nos terrains de jeu étaient la grotte Ain Libné, gouffre Albert, Baloua Bala'a, pont Faqra, canyon Hedayné.

Le résultat du stage, permit à l'équipe constituée de savoir gérer une évacuation dans une cavité de 100 à 200m de profondeur. (Compte rendu d'activités Nº 8 – 1999, FFS)

Ce stage national a également jeté les premiers jalons d'un accord tacite entre, les autorités intéressées dans le domaine de secours, l'Armée Libanaise, la Défense Civile, la Croix Rouge Libanaise et la gendarmerie et l'Equipe du Spéléo-Secours Liban.

Du 7 au 14 novembre 1999, 5 spéléologues de l'Equipe Spéléo-Secours Liban ont participé au Stage International Spéléo-Secours, Arbas – Pyrénées, France organisé par Bernard Tourte (Buldo). Les pays participants au nombre de 7 comprenant le Liban, la France, l'Espagne, la Croatie, le Canada, la Bulgarie et la Belgique. Le stage s'est effectué dans le fameux Réseau de Trombe «la Coume » le plus grand développement de France de 100 km

Le contenu du stage était le suivant :

- Techniques de désobstruction : explication des techniques, exposition du matériel de désobstruction et démonstration en cavités des différentes techniques : éclateurs de roche, explosifs. Session donnée par Alain Lafarguette.
- Présentation de la civière plongée et de tout le matériel qui la compose. Session donnée par Jacques Michel (Benjamin).
- Présentation des différents moyens de communications sous terre :
    * principe de radio repérage avec Valade,
    * principe de téléphone par Jean Marc Gibelin (Gibus),
    * principe du système Nicola.
- Techniques de progression classiques.
- Techniques de Spéléo-Secours,
- Essai fait au dynamomètre en surface, présentation des derniers rapports et tests par le SSF qui justifient les techniques les plus actuelles.
- Application des techniques d'évacuation de blessé dans les gouffres de la Coume Ouranède.

L'exercice final dans la Henne Morte a rassemblé 160 spéléologues, c'est à ce moment là que le Poste de Commandement Opérationnel - PCO- de cet exercice s'est transformé en vrai PCO pour l'opération de secours à la grotte de Vitarelles, Lot. Il s'agissait d'évacuer avec beaucoup de difficultés 7 spéléologues de l'Association Culture et Loisirs de Gramat, Lot, qui s'étaient engagés dans la grotte le 11 novembre 1999, et qui avaient été bloqués par la montée des eaux de 12m à cause des conditions climatiques défavorables dans le département. (Compte rendu d'activités Nº 8 – 1999, FFS)

En 2000 le SCL a organisé une manœuvre en rivière à Nahr el Aassi.

Durant cette même année, les exercices techniques / secours au sein de l'Equipe Spéléo-Secours Liban ont été éffectués à un rythme bis-mensuel.

Du 24 au 27 Mai 2001, 3 spéléologues de l'Equipe Spéléo-Secours Liban ont participé au Stage National Assistance Victimes 2001 à Saint Alban en Ardèche –France. Ce stage fut organisé par Eric David, conseiller technique national – CTN- et cadre au SSF, avec la participation de 4 cadres du SSF et de 2 Docteurs de la Commission Médicale – COMED- et en même temps cadres au SSF. Au total douze participants français provenant de 9 départements et de trois participants libanais dont deux secouristes constituaient cette mission dont le contenu était :

- Concept et position de l'équipe A.S.V. en Spéléo-Secours
- Notions de secourisme et bilan primaire
- Déplacement primaire
- Point chaud, mille-feuille
- Typologie des accidents
- L'unité de conditionnement « point chaud »
- Préparation des kits
- Gestion du stress
- Organisation des secours
- Assistance aux médecins

. Connaissance de la terminologie médicale

. Lot matériel médical

. Gestes techniques

- Unité de conditionnement soins et nourriture

. Théorie et pratique, conditionnement opérationnel (logique de propreté)

- Simulation bilan et interprétation de la fiche de renseignement.

La politique que s'est fixée l'Equipe Spéléo-Secours est de prendre en considération toutes les mesures préventives, d'être prêt, de pouvoir intervenir n'importe où, comment, et dans toutes conditions. C'est ainsi que l'Equipe du Spéléo-Secours s'est présentée le Jour de l'An à la demande express de l'armée libanaise pour évacuer un cadavre d'un gouffre au Nord du Liban, ainsi qu'à d'autres appels qui nous mis en alerte. Un programme technique/ secours bis-mensuel, a été établi au sein de l'équipe ainsi que la participation aux stages internationaux ou régionaux à l'étranger à raison d'une fois par an minimum pour être à jour et pour acquérir plus d'expérience et suivre l'évolution des différentes méthodes et techniques.

Intervention réelle à l'échelle nationale

L'Equipe Spéléo-Secours Liban est intervenue lors des différents appels notamment dans le cas d'évacuations :

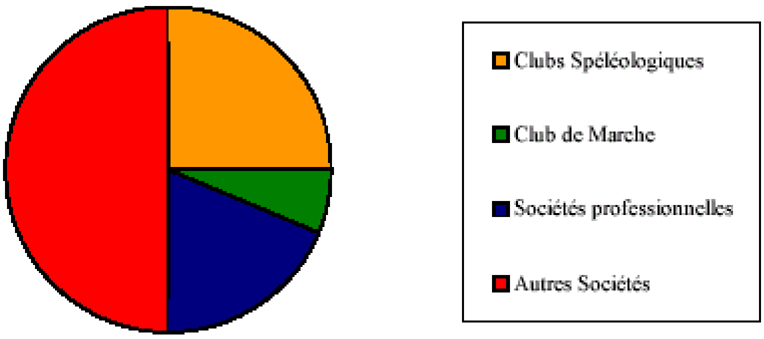
· Un cadavre au fond d'un puits au Nord Liban, le janvier 2001.

· Le secours d'une jeune fille qui s'est foulée la cheville à Wadi el Jamajem, le 25 mars 2001.

· Un homme tombé dans un puits artésien de 15 m. à Wata el Jaouze, le 31 mars 2001.

· L'évacuation du fils de l'ambassadeur de Jordanie qui s'est aventuré tout seul au fond du gouffre des trois ponts (-87m) à Tannourine, le 22 avril 2001.

Recensement des clubs et societes au Liban



	Nombre
Clubs Speleologiques	4
Club de Marche	1
Societes professionnelles	3
Autres Societes	8

Causes des accidents

A la suite du développement des sports de plein air, l'existence du matériel spéléologique et de montagne sur le marché libanais à la portée de jeunes aventuriers non-spéléologues, l'augmentation du nombre d'associations et clubs professionnels ainsi que des sociétés professionnelles ou non qui assurent toute initiation professionnelle ou

non au domaine souterrain et montagne, et la volonté des spéléologues professionnels de découvrir de nouveaux réseaux par l'utilisation de nouvelles méthodes plus compliquées et plus risquées, certains accidents ont eu lieu à cause :

Des chutes de pierres

Des blocages

Des crues

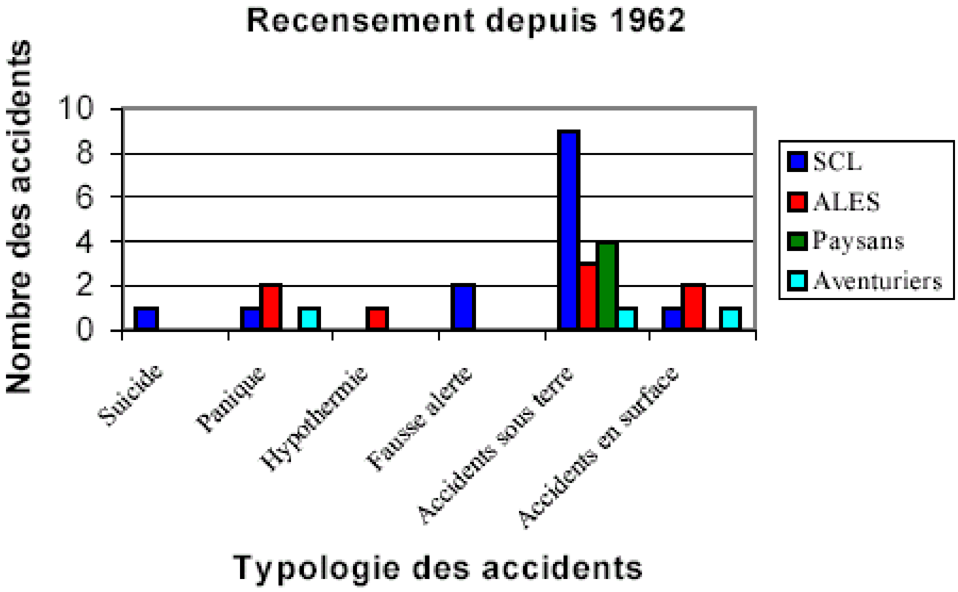
Des chutes d'éléments naturels

D'épuisement et d'hypothermie

De panique

De panne électrique, explosion de carbure, gaz carbonique, orientation, …

Accidents en spéléologie et en canyon



Formation idéale de l'Equipe de Spéléo-Secours au Liban

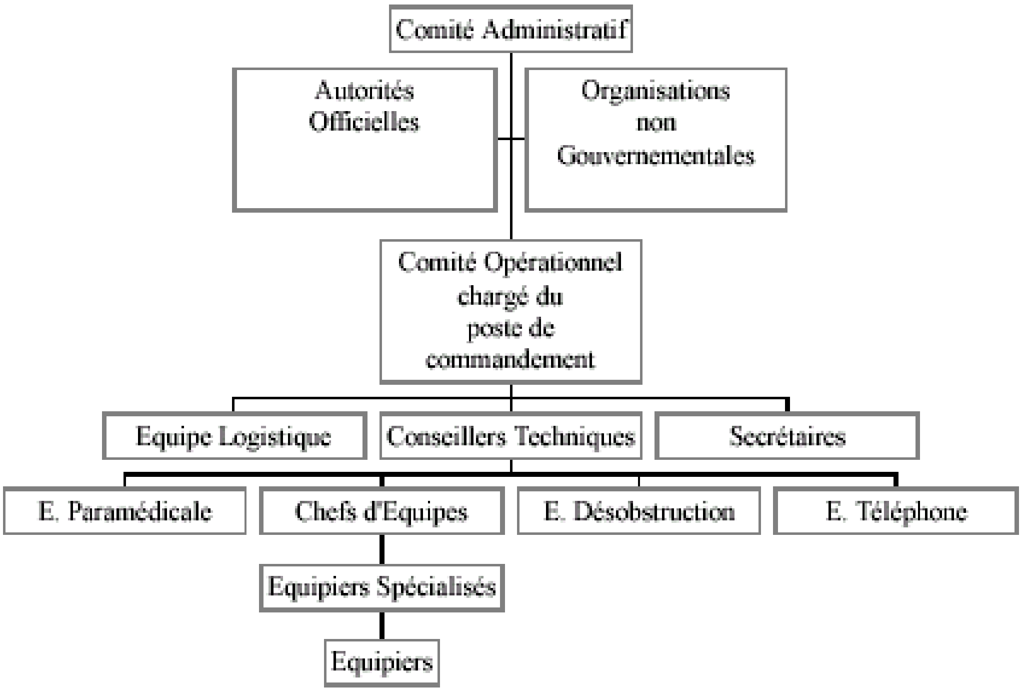
Le Spéléo-Secours est une équipe de spéléologues entraînés aux techniques de sauvetages sous terre et en canyon. C'est un organisme indépendant qui possède sa propre structure.

Le domaine de secours sous terre et en canyon devient une nécessité au Liban. Il ne peut être assuré que par des spéléologues qui ont acquis une formation de secours sous terre et en canyon, à travers des stages et des exercices perpétuels qui leurs permettent de rester à jour avec l'évolution des techniques et du matériel.

Problèmes de financement.

Le Spéléo-Secours a besoin d'un financement spécial qui n'est pas à la portée des clubs et associations de spéléologie officiels (puisqu'ils sont à but non lucratif). Ce qui nécessite la sensibilisation du public et du gouvernement ainsi que les secteurs privés pour soutenir pécuniairement tous les besoins du secours.

La gestion de l'opération secours ainsi que toute intervention sous terre ou en canyon est la responsabilité des seuls spéléologues qui maîtrisent les techniques spéciales de sauvetage. Toute aide pécuniaire qui sert au renouvellement du matériel ainsi que toute facilitation de participation aux stages locaux et internationaux est en soi un droit acquis aux spéléologues professionnels de secourisme.



Accords avec les ONG et l'Administration au Liban.

Le gouvernement et les ONG peuvent intervenir d'une façon directe ou indirecte :

- Par la création d'accords gouvernementaux et bi-gouvernementaux qui facilitent la participation des membres de l'organisme du Spéléo-Secours à des stages locaux ou à l'étranger.
- Par la création de conventions entre l'équipe de Spéléo-Secours et les autorités sensibilisées par le domaine de secours. Ces conventions préserveraient les responsabilités et les droits de chaque partie, (projet en cours).
- Par la sauvegarde des accords tacites entre l'équipe du Spéléo-Secours d'une part et l'Armée Libanaise, la Défense Civile, la Croix Rouge Libanaise et la gendarmerie d'autre part.
- Par l'affiliation d'une équipe paramédicale formée de médecins d'infirmiers et d'une équipe de désobstruction et de dynamitage de l'armée qui suivra un entraînement spécial, (projet en cours avec l'armée libanaise).

Pour toutes informations veuillez contacter l'adresse suivante :

Association Libanaise d'Études Spéléologiques (ALES)

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E.Mail: ales@alesliban.org

Estudio Preliminar de la Mitología Venezolana Asociada a las Cuevas

[Preliminary study of Venezuelan mythology associated to caves]

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Introducción

Las escasas referencias etnográficas venezolanas sobre cuevas se deben a cronistas y misioneros de la historia reciente. Nuestros antropoespeleólogos se han concentrado en el campo de la cultura material, los trabajos etnográficos ocasionalmente son consultados en función de intereses arqueológicos. Información de interés se halla dispersa entre numerosos temas aparentemente no-vinculados con la espeleología, como por ejemplo la literatura, textos que no suelen ser considerados en los estudios kársticos.

El presente trabajo tiene como objetivo revisar la data etnográfica para recopilar y sistematizar mitos y creencias relacionadas con cuevas venezolanas. Este sondeo preliminar abarca un universo de estudio multicultural constituido de manifestaciones indígenas y criollas. La fuente documental involucró 80 trabajos bibliográficos, anexando escasos datos recopilados en campo.

La información fue subdividida: 1)El mayor volumen de información seleccionó, en una base de datos, a seres del bestiario e integrantes de panteones regionales relacionados directa o indirectamente con el mundo subterráneo. Al caracterizarlos morfológica y actitudinalmente también se recopilaron los eventos argumentales protagonizados por ellos. 2)Se extrajeron algunos datos que describían espacios subterráneos imaginarios. Ambas entradas contienen: Etnia estudiada, filiación lingüística, descripción, localidad geopolítica y referencia bibliográfica. Debido a lo vasto del material estudiado, se omitieron los personajes, acontecimientos y descripciones ambientales no vinculadas al entorno hipógeo.

Resultados

Se encontró un total de 323 personajes asociados al subsuelo y la descripción de unos 30 espacios virtuales subyacentes, adicionalmente disponemos de un lote de más de 100 entradas del bestiario-panteón que aún no se procesaron sistemáticamente.

Se estudiaron 25 literaturas venezolanas. 8 culturas de la familia lingüística Caribe aportaron 122 personajes, 4 etnias Arawaks presentaron 36 entradas y otros 13 grupos ofrecieron 86 entes. Los personajes criollos ocupan 79 entradas.

Geográficamente el inventario incluye 19 de los 23 estados, el mayor aporte proviene de Zulia (77 personajes), Bolívar (72) y Amazonas (55), representando sectores de baja densidad demográfica.

Conclusiones

Por no basarse en información científica, sino en conocimientos tradicionales, el imaginario popular y aborigen evidencia una percepción animista del inframundo muy alejada de la formal cosmovisión de los citadinos modernos. La actitud ideológica más adecuada para investigadores habituados al proceso de las ciencias naturales, es adoptar una flexibilidad neutral valorando la heterodoxa retórica de los mitemas espelófilos.

Generalmente no encontramos descripciones que de manera explícita diserten sobre las cuevas, incluso la noción de “*cueva*” raramente está presente y el nivel inferior del cosmos puede sugerirse como un ámbito omnisciente. La imagen típica de la cueva oscura, vadosa y concrecionada que muchos espeleólogos visualizamos, frecuentemente está sustituida por un entorno abstracto que aparenta ser el reflejo del nivel terrenal. Es decir, muchos relatos no parecen referirse a subterráneos, lacónicamente se refieren al universo de abajo o al espacio interior. La población rural acostumbra emitir discursos que asocian hábitos subterráneos y subacuáticos, representando cierta ambigüedad si sólo se desea seleccionar los elementos intraterrenales. Las madrigueras se consideran parte del inframundo. La noción de un purgatorio infernal está poco arraigada.

Leyendo entre líneas se interpreta que los etnólogos nos ofrecen un bestiario que, en vez de ser estrictamente troglodita, parece estar más bien constituido por habitantes hemihedáficos de espacios intersticiales o por seres que incorpóreamente moran en el interior de rocas o montañas. En conjunto los seres del imaginario podrían subdividirse de manera similar al criterio bioespelológico: hay escasos troglobios míticos (escasos *ctónicos*), diversos troglófilos (diversos espeleófilos), y numerosos troglóxenos (numerosos personajes imaginarios pertenecientes a estratos intermedios o celestes que ingresan circunstancialmente al inframundo). El recurrente argumento de la rápida metamorfosis refleja una intuición que sintetizaría la lenta evolución biológica, esta coincidencia biológico/cultural evoca la herencia de conocimientos difusos propia de las teorías del inconsciente colectivo. Las comunidades *ctónicas* o subterráneas pueden adoptar quimérica o licantrópicamente apariencias zoo-antropomórficas permanentes o transitorias.

Los seres ctónicos suelen poseer rasgos antitéticos, en comparación a sus congéneres reales de la superficie terrestre. Demiurgos, ogros, protohumanos, difuntos y héroes culturales ctónicos poseen poderes sobrenaturales: Omnipotencia, invisibilidad selectiva, ubicuidad, antropofagia, control faunístico, dominio hidrológico, influencias mortales, gigantismo, enanismo, etc; ellos juegan roles de civilizadores, regidores o castigadores que proscriben el caos primigenio enunciado por Elíade. Entes como los *maware* y *encantos* son compartidos por diversas regiones y culturas.

Se empiezan a vislumbrar coincidencias con arquetipos universales reseñados por investigadores foráneos. Sin embargo, este estudio prevé compilar mayor cantidad de entradas de cada etnia para poder sustentar en el futuro tal afirmación y determinar la cosmovisión de nuestra diversidad cultural.

Los argumentos vinculados al submundo pueden estructurarse como mitos de origen, algunos con referencias diluvianas. Más que un recurso recreativo, series de fábulas totémicas cumplen funciones formativas que moralizan y transmiten nociones vinculadas a una compleja espiritualidad.

Las Serpientes Ctónicas de la Mitología Venezolana, su Apariencia Morfológica y su Ámbito Cósmico

[Ctonic Snakes of the Venezuelan Mythology, their Morphological Appearance and their Cosmic Environment]

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Introducción

Dentro de un amplio trabajo de antropoespeleológico se sondearon bibliográficamente cuentos folklóricos y mitos venezolanos para estudiar personajes del panteón y el bestiario de aborígenes y campesinos. El trabajo etnológico compiló un total de 323 entradas, de las cuales 42 entes son descritos como serpientes o seres de rasgos ofiomorfos. Este notable subgrupo constituye un 13 % del inventario general, notable proporción que ameritaba dedicar mayor atención. Al estar relacionadas directa o indirectamente con el entorno subterráneo, algunas de estas serpientes son calificables como entidades *ctónicas* , mientras que otras sólo ingresaron al subsuelo de manera casual sin que se pueda tipificarlas como habitantes permanentes del inframundo. Obviando las diferencias individuales de cada una de las entradas se detectaron los rasgos comunes a la mayoría de la muestra.

Resultados

El aspecto externo de muchos ofidios espeleófilos destaca como animales de talla muy grande, parecidos a las anacondas (Boidae: *Eunectes murinus gigas*). Ninguno de los mitos mencionó culebras minadoras diminutas, aunque en la vida real estas siempre son de pequeña talla. Durante el relato algunos ofidios eran capaces de metamorfosearse en forma humana o animal, proceso comparable al acto de vestir una piel escamada. Su habilidad mimética puede alcanzar la invisibilidad, pudiendo ser avistados selectivamente por curanderos o shamanes durante sus trances.

Muchas serpientes del inframundo cósmico suelen ser individuos aislados, pero en las narraciones a veces se menciona la presencia de varios congéneres agrupados en familias o sociedades imaginarias. Alguno individuos son machos, otras son hembras, existiendo un pequeño grupo de sexo ambivalente; hay que recordar que en la vida real ese aspecto anatómico no es discernible a primera vista, por lo que se trata de una caracterización libremente ofrecida por los relatores.

Ciertos ofidios ctónicos detentan poderes sobrenaturales como la ubicuidad y omnipotencia propias de los semidioses, ello hace sospechar que anteriormente desempeñaban un importante rol en creencias ancestrales que actualmente parecen estar parcialmente olvidadas. Algunas serpientes del subsuelo pueden presentarse como amos de la fauna, el clima, el agua y las inundaciones cataclismicas. Ello demuestra una hidrofilia dulceacuícola debido a que en los relatos usualmente emergen de ríos, lagunas, raudales o cascadas; rara vez aparecen en drenajes costeros potencialmente salobres. En muchos casos la presencia de estos entes es espiritual y su presencia física se manifiesta cuando ocasionan desgracias. Las serpientes imaginarias habitan en cuevas o subterráneos no-descritos por los informantes, ámbitos que pudieran constituir entornos vadosos o freáticos. No solo moran en hipogeos sino que tienen cierto enlace con el ámbito superficial y celeste logrando aparecer en forma de arco-iris, aunque esta forma no corresponde a una manifestación física de su ser.

Las narraciones no se restringen a terrenos kársticos, ya que se reportan en todo tipo de regiones. Por ejemplo 12 personajes son propios del estado Bolívar, siete serpientes provienen del estado Zulia y ocho son características de la cultura criolla centro-occidental.

En cuanto a las literaturas venezolanas que concibieron estos seres las 42 serpientes espeleófilas seleccionadas se originaron a partir de 11 culturas venezolanas. Cinco de las 42 entradas se refieren a personajes del bestiario Guajiro (familia lingüística Arawak), cuatro pertenecen a la cultura Pemón (familia Caribe), cuatro a la etnia Whótuha (familia Piaroa) y 10 entradas corresponden a otros grupos étnicos. El imaginario campesino participó en esta muestra con un bestiario de 19 seres ofiófilos.

Próximamente profundizaremos en un trabajo adicional que presentará rasgos del carácter, actitudes o habilidades de este arquetipo. Hay que acotar que las serpientes han inspirado numerosos relatos imaginarios que no solamente se restringen a individuos de hábitos subterráneos, por lo que su estudio no es de exclusivo interés espeleológico.

Invariablemente tienen dimensiones grandes, con forma de Anaconda
Pueden asumir la invisibilidad y transformarse en humano o animal
Tienen poderes sobrenaturales (ubicuidad fluvial, veneno, poseen tesoros)
Son individuos dominantes (pueden tener descendientes o acólitos)
Se presentan como seres ambiguos (a veces malignos, otras benefactores)
En su actitud adversa a la humanidad pueden ser entes secuestradores o asesinos
En su actitud de aliado ofrece conocimientos, abundancia alimentaria, fertilidad
Habitan el medio hipogeo (cuevas, cerros, piedras o un subsuelo no descrito)
Son padres o madres de vías dulceacuícolas (ríos, manantiales, lagunas, cascadas)
Se relacionan con elementos atmosféricos (precipitaciones, arco-iris, inundaciones)
Están vinculados al panteón mítico local (actuando en mitos de origen)
Ocasionalmente asumen el rol de regentes de animales o difuntos
Etiologicamente estos personajes buscan inculcar la conservación de las aguas
Los ofídios ctónicos son concebidos en toda Venezuela (indígenas y criollos)

Tabla: Resumen de características

Levantamento Preliminar das Cavernas do Estado do Rio Grande do Norte, Brasil

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Summary

The present study presents a speleological patrimony preliminary rising State of Rio Grande do Norte's. The work was fruit of a technical cooperation accomplished between National Center for the Study, Protection and Management of Caves (CECAV) in the state of Rio Grande do Norte and SEPARN (Society for the Development, Research and RN's Education). State owns an plenty heterogeneous geological structure, distinguish basically two portions: Potiguar Basin and the Crystalline Basement. In this work were going selected larger interest speleological areas, located in the portion karstic of Potiguar Basin and objectified arise a basic diagnosis which had allowed us know the most important caves in the state, as well as to detect the preservation status of each one their subsidizing posterior projects concerning the patrimony speleologic preservation. The fieldwork was going developed between July and December months 1999. They were going met caves concentrations in Lajedo de Jandaíra (Jandaíra's Municipal District), Lajedo Soledade (Apodi's Municipal District) and caves not yet nominated in Felipe Guerra's Municipal District. Beyond of these areas, found still isolated, important chambers by historical, geological and tourist factors. The methodology was going performed through photographic registrations, search *in locate,* in charts and their aspects, detected and described preservation importance and status.

Introdução

Embora o Estado do Rio Grande do Norte não apresente até o momento atual destaque no cenário espeleológico brasileiro, temos que evidenciar a importância das cavernas lá encontradas por seu conteúdo histórico, cultural, científico e turístico. No ano de 2000 haviam apenas 58 cavidades registradas segundo o Cadastro Nacional de Cavidades, sistematizado pela Sociedade Brasileira de Espeleologia(SBE,2000), cadastro este que tem sido realizado por grupos espeleológicos do próprio Estado. Os dados recentes mostram que um número muito maior de cavernas tem sido descoberto, e dados preliminares indicam que este número pode ser até triplicado.

Embora a comprovação deste potencial espeleológico do Estado, pouca coisa tem sido efetivamente feita para mudança deste quadro. Os grupos estão em fase de reorganização e trabalham com dificuldades inerentes a um trabalho não remunerado.

Com a criação da base do Centro Nacional de Estudo, Proteção e Manejo de Cavernas (CECAV) no Estado do RN, iniciou-se uma ação junto a estes grupos de espeleologia, firmando Termo de Cooperação Técnica com a SEPARN (Sociedade para o Desenvolvimento, Pesquisa e Educação do RN), grupo que já vinha desenvolvendo trabalhos na área de espeleologia.

Objetivos

Promover um levantamento preliminar das cavernas do estado, determinando onde encontram-se as principais concentrações cársticas;

Avaliar o status de conservação das cavernas do Estado para posterior ação nas áreas em que fossem detectados problemas;

Realizar trabalho informal de educação ambiental junto aos habitantes dos Municípios que apresentassem incidência de caverna.

Caracterização da Área de Estudo

A heterogeneidade da estrutura geológica do Estado do Rio Grande do Norte propicia a formação de diferentes feições cársticas. Ao norte, a Bacia Potiguar, formada durante o período Cretáceo e pré-Cambriano e na porção sul, o Embasamento Cristalino. A principal rocha que compõe as formações espeleológicas do Estado é o calcário.

Denominou-se Grupo Apodi ao grupo de sedimentos constituídos de arenitos e calcários aflorantes na bacia costeira do Rio Grande do Norte (OLIVEIRA & LEONARDOS, 1943). No entanto, alguns anos depois KREIDLER & ANDERY(1949) dividem o grupo Apodi em duas unidades, a porção superior ou “ calcário Jandaíra” e a porção inferior ou “arenito Açu” , terminologias mantidas por KEGEL (1957) BEURLEN (1967). Posteriormente foram propostas as denominações formação Açu e formação Jandaíra para designar as unidades acima relacionadas (SAMPAIO & SCHALLER, 1968) in Schobbenhaus(1984).

A Bacia Potiguar é composta por grandes extensões de lajedo de pedra calcária e corresponde a área de maior significância cárstica na região, podendo ser dividida fundamentalmente nos lajedos localizados nos seguintes Municípios: Jandaíra, Felipe Guerra/Apodi, Martins e Baraúnas.

Metodologia

A metodologia empregada no presente trabalho resumiu-se a realização de cinco viagens de campo com duração de 07 dias cada, aos Municípios de maior importância do ponto de vista espeleológico: Martins, Felipe Guerra, Jandaíra, João Câmara, Pedra Grande, Apodi, Mossoró, Açu, Patu, Baraúnas e Caicó. Em cada caverna visitada foram fotografadas suas entradas principais e secundárias, bem como formações consideradas importantes e significativas. Fichas cadastrais foram preenchidas onde constavam localização, vegetação de entorno, fauna detectada, aspectos geológicos gerais, tais como rocha encaixante e formações encontradas e ainda,aspectos fundiários da área. Posteriormente, estes pontos eram plotados em mapas do IBGE, além da utilização de aerofotocartas e fotografias de satélite que orientavam na localização das áreas calcárias de maior abrangência e significância. Além deste recurso, realizou-se entrevistas com habitantes da região para detectar cavidades ainda não conhecidas.

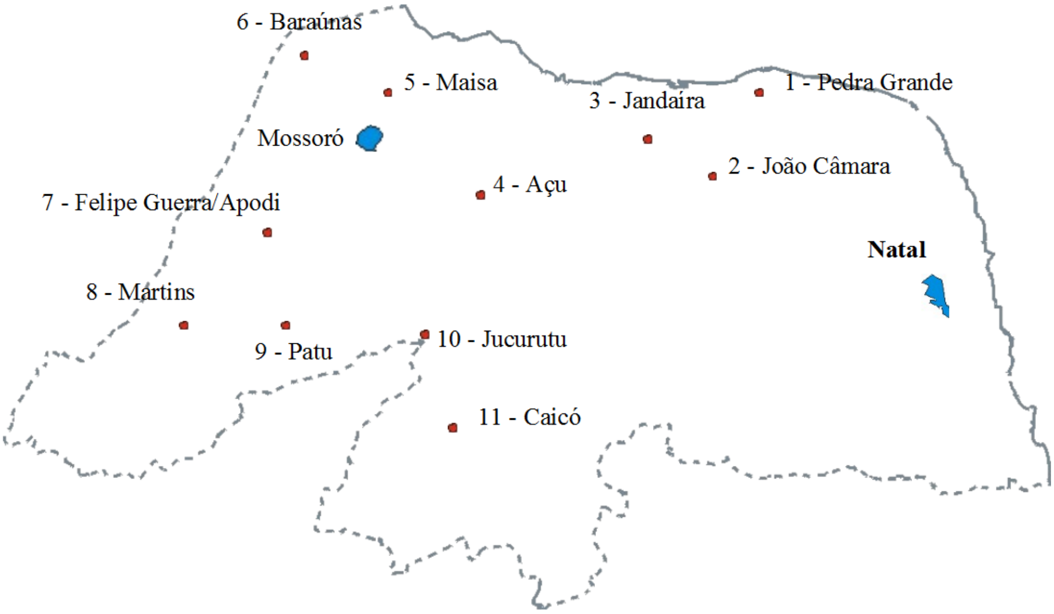

Figura 1: Mapa esquemático do Estado do Rio Grande do Norte mostrando os municípios de principal incidência de patrimônio espeleológico

Resultados

A tabela mostrada abaixo apresenta a porcentagem representada por cada Município no contexto estadual, destacando-se a Formação Jandaíra, o lajedo ainda praticamente inexplorado do Município de Felipe Guerra , a região de Martins e Baraúnas.

Queremos destacar ainda algumas cavernas encontradas no Estado. A variedade espeleológica já citada anteriormente possibilita a ocorrência de cavernas como a conhecida Casa de Pedra de Martins, no Município de Martins, formada em mármore e de uma beleza única em seu conjunto.

No município de Patu, ainda não cadastrada, encontra-se a Casa de Pedra de Patu, localizada no alto da Serra do Cajueiro, refúgio do ex-cangaceiro "Jesuíno Brilhante" que teria utilizado a referida gruta como ponto de fuga para si e seus companheiro.

Nº de Cavernas Cadastradas	**Município/**	**Localização no Mapa**	**%**
25	Jandaíra	3	43,10
11	Felipe Guerra/Apodi	7	18,96
05	Martins	8	8,62
04	Baraúnas	6	6,89
04	Governador Dixsept-Rosado	5	6,89
03	Pedra Grande	1	5,17
02	João Câmara	2	3,45
01	Caicó	11	1,73
01	Patu	9	1,73
01	Jucurutu	10	1,73
01	Açu	4	1,73
58			100%

Tabela 1 – Relação de cavernas cadastradas junto à SBE, com seus respectivos Municípios e a significância

Discussão

A formação Jandaíra caracteriza-se por extensa região de calcário, conhecido comumente por lajedo. Sendo de extrema representatividade, Jandaíra representa o pólo de abastecimento de cal para todo o Estado. A retirada é realizada de forma manual e ao longo dos últimos anos tem representado a única fonte de renda do Município de Jandaíra caracterizada por uma população de baixa renda. Esta atividade econômica não sustentável e degradadora, é gerada pelo total desconhecimento e decorrente do estado de extrema pobreza que assola o interior dos estados do Nordeste brasileiro. Os ecossistemas cavernícolas são destruídos antes mesmo de que se possa conhecê-los e de que tenhamos oportunidade de vislumbrar suas belezas.

Com quase 50% das cavernas cadastradas no Estado, Jandaíra é município importante no contexto espeleológico do Estado. Representa a área de maior representatividade e ainda a mais ameaçada pela ação do homem com o avanço das inúmeras caieiras que operam sem qualquer tipo de licença do DNPM.

Muitas das cavernas e abrigos sob rochas encontradas na maior exposição de rocha calcária da Bacia Potiguar, estão inseridos no Lajedo Soledade. É o mais rico sítio arqueológico do Rio Grande do Norte, localizado no Município de Apodi e apresenta 7 painéis de pinturas rupestres, das quais um deles está entre um dos maiores do Brasil, em extensão. Essa formação surgiu há 600 milhões de anos quando um mar superficial cobria a região. Foram as condições ideais que possibilitaram a formação de várias cavernas ali existentes, destacando-se algumas grutas importantes dentro do contexto turístico e educacional. O turismo e educação ambiental são realizados no Lajedo Soledade e organizado pela Associação Amigos do Lajedo de Soledade, que contou com a participação ativa da PETROBRÁS para efetivar a construção de um museu e a colocação de placas informativas e proteção das pinturas rupestres e cavernas existentes. Foram colocadas cercas e placas indicativas. As visitas são realizadas com guias mirins treinados que residem no Distrito do Município de Apodi, denominado Soledade. Segunda maior representatividade espeleológica, estão os dois Municípios limítrofes: Felipe Guerra e Apodi, sendo que Felipe Guerra apresenta ainda grandes extensões de áreas totalmente inexploradas.

Agradecimentos

Ao CECAV/IBAMA/SEDE, através da pessoa do Sr. Ricardo José Calembo Marra pelo apoio recebido, tanto financeiro como emocional, bem como toda a equipe que compõe o CECAV,

Aos integrantes da SEPARN, companheiros de campo que tornaram possível a realização deste trabalho,

Ao apoio dado pela representação Estadual do Rio Grande do Norte, através de seu Representante Francisco Pondofe Cavalcanti e funcionários do IBAMA.

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CNC – Cadastro Nacional de Cavernas – Brasil
(SBE – Sociedade Brasileira de Espeleologia)

Roberto RODRIGUES

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Histórico

A constituição de um acervo centralizado dos dados referentes às cavernas do Brasil é uma das obrigações estatutárias da S.B.E. (SOCIEDADE BRASILEIRA DE ESPELEOLOGIA), que desde a sua fundação mantém essas informações organizadas de forma que possam ser apresentadas quando solicitado.

Cabe ressaltar as grandes contribuições dos precursores da espeleologia como Peter W. Lund e Ricard Krone, grupos espeleológicos e órgãos governamentais, além de espeleólogos que muito se dedicaram na organização do Cadastro das Cavernas do Brasil.

Durante o IV Congresso Nacional de Espeleologia (1969) foi fundada a S.B.E. e logo no ano seguinte foi publicado por Pierre Albert Martin uma relação das maiores cavernas do Brasil, com dados de Novembro/69, num total de 12 cavidades. A numeração utilizada pelo então cadastro, correspondia ao município em que pertencia a caverna, precedido da sigla do estado. Por exemplo: BA.10.01 - O número 10 corresponde ao município Ituaçu e 01 à caverna, no caso, Mangabeira.

Em 1971 pela primeira vez no Brasil adota-se o sistema de numeração das cavidades em ordem cronológica de descoberta ou exploração, precedido da sigla do estado.

Após vários anos (1976) Pierre A. Martin publica uma lista das maiores cavernas brasileiras, incluindo também abismos mais profundos.

Em 1979 a Comissão de Cadastro da S.B.E. coordenada por Peter Slavec e Clayton Ferreira Lino, publica uma lista das cavernas brasileiras cadastradas, acrescentando data e autores dos levantamentos topográficos e tipo de rocha. Esse cadastro foi montado a partir da bibliografia existente e de informações colhidas diretamente com os autores dos trabalhos e como princípio, adotaram as definições e regras estabelecidas pelos próprios espeleólogos ao longo de diversos Congressos Nacionais e adotados oficialmente pela S.B.E.

No início de 1985 Pierre A. Martin então depositário do Arquivo Cadastral da Sociedade Brasileira de Espeleologia, decidiu dar continuidade ao trabalho de publicação de listagens sobre as cavernas brasileiras, optando pelo uso de computadores a partir de relatos sobre experiências similares na Europa. Decidiu então pela perspectiva de inserção e/ou alteração localizada de dados sem a necessidade de reorganização e datilografia de todo o conjunto, vislumbrando portanto redução acentuada de trabalho, como também a possibilidade de constante atualização das informações colocadas à disposição da Comunidade Espeleológica Brasileira.

Assessorado inicialmente por João Carlos Setubal e posteriormente por Roberto Rodrigues, estes independentemente definiram um mesmo software sobre o qual Roberto Rodrigues finalmente veio a desenvolver o programa Inventário das Cavernas Brasileiras, de acordo com a análise de Pierre A. Martin e de Rogério S. Chrysostomo sobre a real disponibilidade de informações no Arquivo Cadastral da S.B.E.

Ao final de 1986, o então Inventário passou por um longo processo de reavaliação crítica das propostas, concluindo finalmente os organizadores remanescentes, conjuntamente com o Presidente da S.B.E. João Allievi sobre a necessidade de criação de um sistema mais aperfeiçoado, totalmente subordinado aos arquivos desta sociedade e que possa ser eficientemente utilizado por várias décadas, sendo desejável tanto a agilização do circuito de alimentação, como também dentro de um princípio de prestação de serviços, ampla democratização do acesso ao conteúdo de informações armazenadas, servindo portanto como parâmetro habitual para as atividades de campo dos espeleólogos que hoje iniciam suas atividades.

Em setembro de 1988 a S.B.E. cria a C.C.E.P.E. - Comissão de Cadastro, Espeleometria e Províncias Espeleológicas. Formada por representantes de diversos grupos e sob a coordenação de Cláudia I. Parellada. Essa comissão tem tomado decisões importantes para a evolução técnica do Cadastro Brasileiro. Em maio de 1989 o índice de dados sobre as cavernas do Brasil passou novamente por profundas transformações que culminarão nesta edição comemorativa da MILÉSIMA caverna brasileira cadastrada.

O mérito desta conquista pertenceu à Comunidade Espeleológica Brasileira que de uma forma ou outra, contribuiu para a evolução do Cadastro Brasileiro.

Apresentação no XX Congresso Nacional de Espeleologia de uma proposta de participação ativa e integrada da Comunidade Espeleológica Brasileira, que produzem informações que possam realmente contribuir para a Preservação do Patrimônio Espeleológico Brasileiro.

Em 1994, Roberto Rodrigues entrega a administração e os dados do Cadastro. Rubens Hardt assume interinamente e escreve novo programa em Clipper para acessar os arquivos dBase. Neste período se iniciou a distribuição de dados na forma de arquivos em disquete, e mesmo de cópias da base inteira para os que dela necessitassem, aliviando um pouco a tarefa do operador do Cadastro no atendimento a consultas.

Nesta mesma época Mylène Berbert-Born, geóloga da CPRM de Belo Horizonte, desenvolve banco de dados usando o Access da Microsoft para registrar as informações sobre as cavernas pesquisadas no Projeto VIDA. Tal base de dados, batizada de CAVE, após vencer as resistências que havia na comunidade ao uso de um gerenciador comercial de banco de dados, é adotada como a ferramenta a ser usada no Cadastro SBE, assumindo a Mylène a coordenação e operação do mesmo.

Embora a operação do Cadastro tivesse continuado a ser centralizada, foi mantida a política de distribuir uma cópia para consulta dos grupos que dela necessitassem. Poucos foram os grupos que fizeram uso de tal prerrogativa, e menos ainda os que conseguiram realmente consultar a base, tal a complexidade do modelo de dados implementado na mesma. Tal complexidade também extraiu seu custo na ponta da inserção de informações na base: tamanho era o tempo necessário para inserir os dados de uma caverna que os dados das cavernas cadastradas antes de 1995 continuaram sendo mantidos no modelo antigo (o do Índice de 1989), com o acréscimo de campos para coordenadas UTM como principal inovação. Mesmo as grutas novas foram inseridas desta forma, sendo mantidas no modelo completo do CAVE apenas as grutas inseridas pela própria CPRM.

No primeiro semestre de 1997, após ter recebido uma das cópias para consulta do CAVE, Leandro Dybal Bertoni, aproveitando a experiência em Access adquirida na elaboração do cadastro de cavernas da UPE (União Paulista de Espeleologia) e ao longo de 5 anos trabalhando com modelagem de dados, procura Mylène com uma proposta de reformulação do funcionamento do CAVE, visando basicamente a divisão do trabalho de inserção de informações entre várias pessoas. Juntos, eles refazem o modelo de dados, dando origem ao modelo do CAVE97.

Um protótipo avançado da nova versão do banco foi apresentada à comunidade no XXIV Congresso Brasileiro de Espeleologia, em julho de 1997 em Ouro Preto, juntamente com a proposta de descentralização da operação do Cadastro. Não tendo tal proposta sofrido oposição de nenhum dos presentes, o protótipo apresentado foi complementado e um plano de ação apresentado à Diretoria e alguns membros do Conselho Deliberativo da SBE em agosto de 1997, quando foi aprovada a proposta de descentralização da operação do Cadastro, na forma de diversas Regionais, assumindo Leandro a coordenação geral do mesmo.

A nova versão do Cadastro Nacional, somente para consulta, foi instalada na sede da SBE no final de novembro de 1997. A primeira regional foi implantada em dezembro de 1997, em Curitiba, e a segunda em fevereiro de 1998, em São Paulo.

O trabalho no Cadastro SBE foi dividido em três fases, cada uma com suas ferramentas próprias.

A primeira fase é o preenchimento das informações da caverna por pessoas da comunidade, informações essas a serem enviadas ao Cadastro. Tradicionalmente esta fase era levada a cabo através de formulários em papel, estando amplamente difundido o formulário referente ao modelo de dados do Índice de 1989. O objetivo atualmente é obter esses dados tanto quanto possível na forma de arquivos em disco que não precisem ser redigitados na regional. Para tanto, foi elaborado uma versão do banco de dados, com o mesmo modelo de dados do Cadastro Nacional, chamado de Avulso. No banco Avulso é possível inserir os dados de uma caverna no mesmo formato que será usado no Cadastro SBE, trazendo para o autor das informações a decisão de como representar a caverna no cadastro, e fornecendo uma série de "ajudas" de "dicas" no preenchimento dos campos (por exemplo, não é mais necessário adivinhar que código foi usado para cada tipo de rocha: os nomes dos tipos de rocha mais comuns estão disponíveis ao se clicar no campo onde essa informação será inserida). Um dos trabalhos por fazer ainda no Cadastro é elaborar um formulário padrão, em papel, para uso em cadastramento daqueles que não possam usar o banco Avulso.

A segunda fase é a verificação das informações e inserção das mesmas no Cadastro. Esta fase é levada a cabo numa regional do Cadastro. Cada regional tem sob sua responsabilidade um certo número de Estados da Federação, e nenhum Estado está sob a responsabilidade de mais do que uma regional. A identificação de uma caverna no Cadastro é feita por duas informações: a sigla do Estado no qual ela se encontra e um número seqüencial, único, para cada caverna naquele Estado. O banco de dados de uma regional é composto de duas partes: o banco oficial e o banco de trabalho. Uma vez inserida a caverna no banco de trabalho e verificadas as informações, caso ela preencha os requisitos mínimos ela recebe um número dentro do seu Estado e passa para o banco oficial. Periodicamente os bancos oficiais das diversas regionais são coletados e a partir deles é gerada uma nova versão do Cadastro Nacional de Cavidades Naturais.

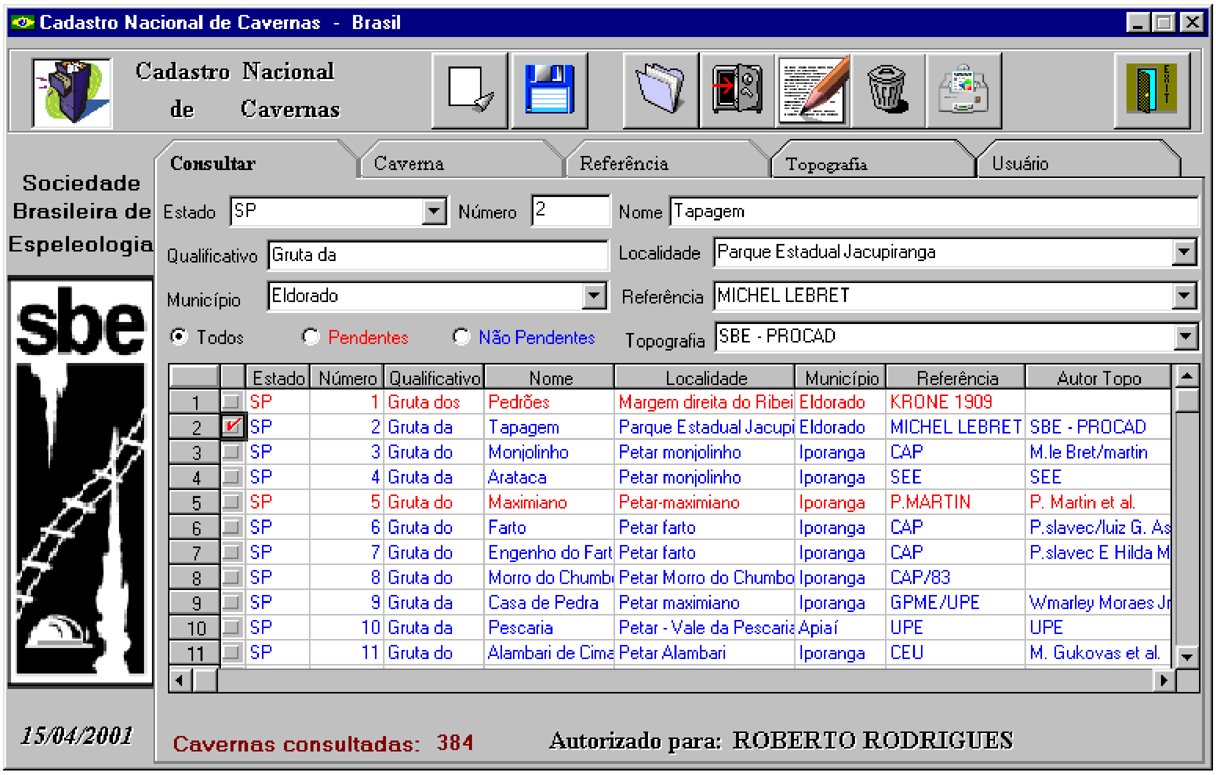
A terceira fase é a fase de consultas ao Cadastro. Há duas formas básicas de consulta: obter uma cópia do Cadastro com a SBE em Monte Sião e efetuar suas próprias consultas, ou especificar uma caverna e obter da SBE todos os dados da mesma. A primeira forma já está disponível (a versão atual do Cadastro, compactada, ocupa menos de 400Kb, cabendo num único disquete), mas para a segunda estar disponível ainda é necessário o desenvolvimento de ferramentas. Cabe aqui ressaltar que a versão do Cadastro sendo distribuída possui coordenadas aproximadas das cavernas, boas o suficiente para se pesquisar as cavernas existentes numa região, mas não o suficiente para se chegar na boca da caverna com um GPS (essa é uma informação considerada sensível e disponível apenas em casos especiais e nunca "ao atacado").

Após o XXV Congresso Brasileiro de Espeleologia realizado em Vinhedo-SP. , o cadastro inicia uma nova fase agora divulgado como CNC – Cadastro Nacional de Cavernas do Brasil.

Nesta nova fase o CNC passa por uma simplificação e divulgação via Internet, onde os sócios vão poder fazer o cadastramento via e-mail.

Em Março de 2000 o CNC é lançado oficialmente, trazendo esta nova formatação apresentada a seguir.

Tela de entrada do CNC



Estado: SP
Número: 2
Nome: Tapagem
Qualificativo: Gruta da
Localidade: Parque Estadual Jacupiranga
Município: Eldorado
Referência: MICHEL LEBRET
● Todos ○ Pendentes ○ Não Pendentes
Topografia: SBE - PROCAD

		Estado	Número	Qualificativo	Nome	Localidade	Município	Referência	Autor Topo
1	☐	SP	1	Gruta dos	Pedrões	Margem direita do Ribei	Eldorado	KRONE 1909	
2	☑	SP	2	Gruta da	Tapagem	Parque Estadual Jacupi	Eldorado	MICHEL LEBRET	SBE - PROCAD
3	☐	SP	3	Gruta do	Monjolinho	Petar monjolinho	Iporanga	CAP	M.le Bret/martin
4	☐	SP	4	Gruta da	Arataca	Petar monjolinho	Iporanga	SEE	SEE
5	☐	SP	5	Gruta do	Maximiano	Petar-maximiano	Iporanga	P.MARTIN	P. Martin et al.
6	☐	SP	6	Gruta do	Farto	Petar farto	Iporanga	CAP	P.slavec/luiz G. As
7	☐	SP	7	Gruta do	Engenho do Fart	Petar farto	Iporanga	CAP	P.slavec E Hilda M
8	☐	SP	8	Gruta do	Morro do Chumb	Petar Morro do Chumbo	Iporanga	CAP/83	
9	☐	SP	9	Gruta da	Casa de Pedra	Petar maximiano	Iporanga	GPME/UPE	Wmarley Moraes Jr
10	☐	SP	10	Gruta da	Pescaria	Petar - Vale da Pescaria	Apiaí	UPE	UPE
11	☐	SP	11	Gruta do	Alambari de Cima	Petar Alambari	Iporanga	CEU	M. Gukovas et al.

15/04/2001
Cavernas consultadas: 384
Autorizado para: ROBERTO RODRIGUES

Metodologia e Utilização

O **SOFTWARE** foi escrito em VB6 (Visual Basic versão 6) acessando um banco de dados Acess. Esta linguagem está muito voltada ao usuário final, assim podemos ter uma interface mais intuitiva, facilitando a operação do software. O novo software tem o nome de CNC.EXE.

O **BANCO DE DADOS** foi totalmente reformulado, mantendo porém os mesmos conceitos e campos do banco anterior. Alguns campos foram suprimidos, pois ao longo do tempo verificou-se que a comunidade espeleológica não os preenchiam devidamente ou simplesmente os ignorava. Os dados foram migrados do banco antigo para o novo, sem perda de informações. O novo banco de dados foi chamado de CNC.MDB.

O **MICRO COMPUTADOR** ideal para o uso do sistema é de pentium 233 para cima, recomenda-se 64MB de memória. Nos modelos inferiores, o sistema vai funcionar, porém pode ser observado uma certa lentidão nas consultas. Os relatórios gerados pelo sistema foram programados para impressoras Laser ou Jato de tinta, as matriciais não vão conseguir uma impressão satisfatória dos relatórios.

O banco de dados tem uma **SENHA** que não será revelada aos usuários, esta medida foi necessária para manter a integridade dos dados armazenados no banco. As atualizações do banco de dados serão informadas no site da SBE e estarão disponíveis para download.

O software também tem uma outra **SENHA COM VALIDADE,** isso significa que para utilizar o sistema CNC, o usuário precisa solicitar por escrito para a SBE. Cada novo usuário no momento da solicitação vai sugerir uma senha para seu acesso. Esta senha será de conhecimento apenas da SBE e do usuário.

O **SOLICITAÇÃO DE USO** do CNC, deve ser feita via site da SBE, www.sbe.com.br , após o preenchimento da solicitação, o usuário deverá aguardar a oficialização do pedido. Somente após este comunicado o usuário poderá fazer o Download do software e do banco de dados, que somente poderá ser acessado com sua senha.

O software só vai funcionar se for instalado através de um **PROGRAMA INSTALADOR,** que acompanha o pacote (**SETUP.EXE**). Somente copiar os arquivos e o banco de dados não vai fazer com que o sistema funcione.

Além da senha do usuário, o sistema trabalha com **NÍVEIS DE PRIVILÉGIO**. Estes níveis vão determinar o perfil do usuário, que através dele a SBE vai atribuir um nível maior ou menor para visualização das pastas de dados do CNC.

Os níveis de privilégios são 5 : 0 – Administrador do CNC; 1 – SBE; 2 – Grupos e sócios individuais da SBE; 3 – Sócios de Grupos associados a SBE e Entidades não associadas a SBE; 4 – Público.

Para operar o sistema o usuário deverá fazer uso dos botões de acesso, descritos a seguir :

O primeiro GIF (arquivo) a esquerda no canto superior do vídeo, ao ser clicado duas vezes, exibi este arquivo de Manual de Procedimentos.

Os outros GIFS na mesma linha são intuitivos e tem uma label que explica a sua ação ao ser clicado.

Retângulo em branco – Limpa a tela.

Disquete – Gravar as inclusões, alterações e exclusões.

Pasta aberta – Consulta as cavernas.

Cofre com seta vermelha – Abre um novo registro para inserção de novas cavernas.

Lápis - Altera os dados e volta o status do registro para normal se estiver pendente.

Lata de lixo – Marca a caverna como pendente.

Impressora – Abre tela para selecionar impressão.

Porta aberta – Sair do sistema.

Caso algum dos GIFS não apareça no software, é devido ao fato do seu nível de privilégio não dar acesso a estas funções.

Abaixo dos GIFS temos os **FILTROS PARA CONSULTAS** das cavernas. Estes filtros são compostos pelo campo e ao lado direto uma seta para baixo que chamamos de **COMBO.**

Para preenchimento de um ou mais filtros, podemos simplesmente digitar uma palavra ou conjunto de palavras. Outra forma de fazer busca com filtro é acionar a combo, clicando na seta e após o sistema mostrar a lista de possibilidades do filtro, basta escolher uma opção da lista e dar o enter para carregar o filtro. Para ambas as formas deve-se acionar o botão de consultar, o sistema vai trazer o resultado e carregar o **GRIDE** abaixo (espécie de grade matricial com as informações trazidas do banco de dados). Para limpar a tela clique no botão limpar.

Mais de um filtro poderá ser preenchido, o sistema vai entende-los como uma busca de operadores “ e “ , isto é, as cavernas que forem mostradas no gride, atende a um filtro e a outro e a outro, etc.

Todas os campos entre os botões de ação e a grade de consulta, podem receber valores para funcionarem com filtros de consulta.

As cavernas poderão ter a linha ***vermelha*** (**PENDENTE**) ou ***azul*** (**NORMAL**). Esta distinção existe para podermos dividir bem os dois grupos ou utilizarmos um terceiro que seria todas as cavernas cadastradas. Para conseguir este efeito, a pasta de consulta dispõe de 3 opções, pendente, não pendente e todas. Deverá ser escolhido somente uma opção. O sistema traz como default, todas.

Após o gride ser preenchido, podemos escolher uma caverna em específico para visualizarmos os dados das outras pastas, referencia e topografia. Para isso de um click em qualquer campo de linha da caverna escolhida. Aparecerá um **TIQUE VERMELHO** ao lado esquerdo da sigla do estado, isso significa que foi marcado com sucesso. Não é possível marcar mais de uma caverna.

As cavernas consultadas podem sofrer uma nova organização, para isso o usuário deve escolher uma coluna pela qual vai querer fazer a organização, dai basta posicionar o mouse sobre o título do cabeçalho que escolher e acionar o botão direito para ordenação ascendente ou o esquerdo para organização descendente. Ao acionar o botão no mouse, aguarde alguns segundos, a ordenação pode demorar um pouco.

As **PASTAS DE REFERÊNCIA E TOPOGRAFIA** vão ser carregadas ao clicar na linha da caverna. Para acessar qualquer uma das duas pastas basta clicar na aba superior da pasta. Os dados serão mostrados para conhecimento e consulta do usuário, não sendo permitido alterar ou excluir algum dado.

Caso algumas pastas não apareça no seu produto, é devido ao fato do seu privilégio não ter permissão para visualizar os dados mostrados nestas pastas. Também alguns níveis não tem privilégio para ver os **SEGUNDOS OU METROS DAS COORDENADAS.**

Para **ACIONAR AS IMPRESSÕES** em relatório, o usuário terá que dispor de uma impressora de jato de tinta ou lazer, matriciais não conseguiram imprimir o CNC. Para iniciar a impressão, acione o GIF com um desenho de impressora, fica na parte superior da tela e no canto direito. Ao clicar o sistema vai trazer uma tela para escolha da ordenação dos relatórios, basta dar um duplo click, nos campos para ordenação, que eles pularam para a direita, informando que foram selecionados, a volta pode ser feita da mesma forma. As colunas poder ser todas escolhidas o que vai valer é a seqüência que foram escolhidas.

Logo abaixo o sistema pede um **NOME PARA O RELATÓRIO**, este nome poder ser uma síntese do que foi filtrado na tela de consulta, pois será exatamente o que foi consultado que vai ser impresso nos relatórios.

O CNC dispõem de 3 tipos de relatórios :

1 – A consulta básica – que mostra apenas os dados básicos da caverna, são os dados que também podem ser visualizados na pasta de **CAVERNAS**.

2 – A consulta de Referencia – que mostra os dados colhidos pela pessoa ou grupo que realmente cadastrou a caverna. São os dados que aparecem na pasta de **REFERENCIA**.

3 – A consulta de Topografia – que mostra os dados topográficos colhidos pela equipe de topografia. São os dados que aparecem na pasta de **TOPOGRAFIA**.

Os relatórios podem ser solicitados aos mesmo tempo ou individualizados, bastando para isso marcar a sua opção na tela de impressão dos relatórios.

O tique vermelho não tem influência para a impressão, ele serve somente para escolher uma caverna para ser visualizada nas pastas.

Caso a **OPÇÕES DE IMPRESSÃO** dos dados topográficos ou das referencias não estejam disponíveis na tela de impressão, o fato deve-se ao seu nível de privilégio não dar acesso a estes dados.

O envio das fichas de inclusão, alteração ou exclusão de cavernas do CNC, somente poderá ser feita, por Sócios Individuais e/ou Grupos de Espeleologia associados à SBE. Outras entidades não associadas poderão fazer a solicitação, porém cabe à SBE avaliar o material enviado e decidir sobre o aceite dos dados.

As fichas de dados devem ser enviadas via e-mail (cadastro@sbe.com.br) para facilitar a digitação e leitura dos dados, também pela agilidade com que a informação vai chegar ao destino.

Ao enviar as fichas para a SBE, automaticamente uma cópia seguirá para **OS REGIONAIS** de cada estado que for referenciado na ficha de dados. Estes regionais vão avaliar as fichas e apontar qualquer irregularidade que por ventura encontrem nos dados enviados. (

A SBE está credenciando sócios que queiram atuar como representante regional em seu estado, para isso basta enviar a **FICHA DE SOLICITAÇÃO DE USO DO CNC** e nas observações informar que deseja **SER REPRESENTANTE REGIONAL** e de qual(is) estado(s) que atua na espeleologia. Para tanto a SBE solicita um breve resumo de seus feitos na área de Espeleometria para que possa avaliar o grau de conhecimento sobre o assunto.

FICHA DE SOLICITAÇÃO DE USO DO CNC

A – IDENTIFICAÇÃO CONVENCIONAL
01 – NOME COMPLETO :
02 – ENDEREÇO :
03 – CEP :
04 – CIDADE :
05 – ESTADO :
06 – DDD + TELEFONE :

B – IDENTIFICAÇÃO ELETRÔNICA
07 – E-MAIL :

C – IDENTIFICAÇÃO NA SBE
08 – NUMERO NA SBE :
09 – GRUPO ESPELEO :

D – IDENTIFICAÇÃO NO CNC
10 – TITULO PARA O SEU USUARIO :
(NO MÁXIMO 20 POSIÇÕES ALFA NUMÉRICAS)
11 – SENHA PARA O SEU USUARIO :
(NO MÁXIMO 10 POSIÇÕES ALFA NUMÉRICAS)

E – IDENTIFICAÇÃO REGIONAL
12 – DESEJA SER REPRESENTANTE REGIONAL DO CNC :
13 – PARA QUAL OU QUAIS ESTADOS :

AGUARDE UM RETORNO DA SBE, ANTES DE FAZER O DOWLOAD DO CNC.

As fichas de inclusão, alteração e exclusão podem ser visualizadas na Internet através do site da SBE, preferencialmente devem ser enviadas pela Internet.

FICHA DE DADOS DA CAVERNA

INCLUSÃO DE CAVERNA NOVA ( )	ALTERAÇÃO DE DADOS ( )	**EXCLUSÃO DE CAVERNA** ( )

IDENTIFICAÇÃO – Informe os seus dados.		
01 – Seu nome		Nome completo
02 – Número na SBE		Número de sócio na SBE
03 – Grupo Espeleo		Nome do Grupo Espeleológico
04 – e-mail		e-mail
05 – Telefone		DDD e telefone

CAVERNA – São informações básicas para inclusão, alteração ou exclusão de cavernas**.**		
06 – Estado		Nome ou sigla do estado onde encontra-se a entrada principal da caverna.
07 – Número		Número da caverna na SBE – somente para alteração e exclusão de dados.
08 - Município		Município onde encontra-se a caverna.
09 – Localidade		Região, Bairro, Serra, Parque ou Apa.
10 – Qualificativo		Acompanhamento do nome da caverna.
11 – Nome		Nome que a caverna é conhecida.
12 – Sinonimia		Apelido ou o outro nome da caverna.
13 – Observações		Qualquer outro tipo de informação.

REFERÊNCIA – São dados complementares fornecidos pela pessoa que fez o cadastro.		
14 – Referência		Nome do responsável pela autenticidade dos dados enviados.
15 – Hidrologia		Existência de qualquer tipo de água no interior da caverna.
16 – Litologia		Rocha principal formadora da caverna.
17 – Fragilidade		Existem formações ou formas de vidas frágeis na caverna.
18 – Mineração		Proximidade com mineradora.
19 – Acesso		Especifique o acesso a caverna.
20 – Arqueologia		Achados arqueológicos.
21 – Paleontologia		Achados paleontológicos.
22 – Dificuldades		Quais as dificuldade técnicas existentes na caverna.
23 – Mapa		Mapa utilizado para tirar as coordenadas.
24 – Latitude		Latitude – Norte ou Sul.
25 – Graus		Grau(s) da latitude.
26 – Minutos		Minuto(s) da latitude.
27 – Segundos		Segundo(s) da latitude.
28 – Longitude		Longitude – Leste ou Oeste
29 – Graus		Grau(s) da longitude.
30 – Minutos		Minuto(s) da longitude.
31 – Segundos		Segundo(s) da longitude.
32 – Altitude		Sobre o nível do mar.
33 – Zona UTM		Zona UTM
34 – East UTM		East UTM
35 – East UTM M		East UTM M
36 – North UTM		North UTM
37 – North UTM M		North UTM M
38 – Datum		Datum
39 – Observação		Qualquer outra informação.

TOPOGRAFIA – São informações espeleométricas da medição da caverna.		
40 – AUTOR		Autor(es) da topografia
41 – GRAU		Grau do trabalho

42 – SISTEMA		Sistema utilizado para graduação.
43 – DATA INICIO		Data de início da topografia.
44 – DATA FINAL		Data de término da topografia.
45 – PROHZ		Projeção Horizontal.
46 – DESLN		Desenvolvimento Linear.
47 – TIPO DESENVOLVIMENTO		Método usado para calcular o desenvolvimento.
48 – DESNÍVEL		Profundidade - Diferença entre o ponto mais alto e o mais alto topografado.
49 – TIPO DESNÍVEL		Método usado para calcular o desnível.
50 – OBSERVAÇÕES		Qualquer outra informação.

INFORME AQUI QUALQUER TIPO DE DÚVIDA OU QUESTIONAMENTO PARA O CNC - SBE
AQUARDE FUTUROS CONTATOS VIA E-MAIL, SOBRE OS TRAMITES DESTE CADASTRO

Considerações Finais

A SBE tem como obrigação estatutária manter um cadastro de todas as cavidades naturais subterrâneas do Brasil. Desde 1989 esta obrigação vem sem desenvolvida com uso da melhor tecnologia de bancos de dados disponíveis para a época. Ao longo dos anos a qualidade dos dados vem sendo melhorados constantemente pelos membros da comunidade espeleológica. Com este intuito estamos lançando uma nova versão do Cadastro Nacional de Cavernas Brasileiras, o CNC. Pretendemos nesta nova etapa, uma simplificação e divulgação geral dos dados colhidos durante mais de 10 anos de cadastro. Para isso disponibilizamos uma ferramenta ágil e segura, assim vamos poder garantir que as informações serão usadas pelas pessoas certas, evitando que os dados do cadastro da SBE sejam usados contra as cavernas e sim para auxiliar a proteção do Patrimônio Espeleológico Brasileiro.

Caves of Mt. Miroč (Danube Gorge, Eastern Serbia)

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Abstract

Mt. Miroč is located in Eastern Serbia, on the right bank of the Danube, in Djerdap (Iron Gates) gorge. The karst occupies approx. 120 sq. km, on a plateau with relatively low elevation (400 – 500 m a.s.l). Until 1990, when Student Speleologic and Alpinistic Club (ASAK) started its explorations, it was believed that Mt. Miroč lacks caves of considerable dimensions. However, several major caves have been explored on Miroč since then, including the deepest Serbian cave – Rakin ponor (-285 m). This paper presents the geological and hydrogeological characteristics of Mt. Miroč karst, and the results of the speleological explorations perfomed so far. The explorations set focus on some interesting questions concerning the caves of Mt. Miroč: 1) The deposition of manganese oxides at the lowest part of Buronov ponor cave, which indicates the past oscillations of water table; 2) The source of CO2 and the ciclicity in its concentracion in Nemački ponor cave, the only cave with significant CO2 ocurrence in Serbian karst; and 3) The speleogenesis of the caves in the area, and succession and mutual influence of events, viewed in conjunction with the uplift of Mt. Miroč and incision of Djerdap Gorge which drained the Panonian sea into the Dacian bassin.

Introduction

Mt. Miroč karst was only partially explored until 1990, when Student Speleologic and Alpinistic Club (ASAK) started the explorations of Mt. Miroč caves. After ten years of explorations, Mt. Miroč hosts four out of six deepest Serbian caves (including the deepest one, Rakin ponor), and also two out of ten longest caves. Compared with other karst areas in Eastern Serbia, Mt. Miroč apparently does not have outstanding features. However, favourable conditions led to a formation of numerous significant caves.

Geological and hydrogeological setting

On its path from the Panonnian basin towards the Black sea, the Danube flows across the Carpatho-Balkanides mountain range, through the Djerdap gorge. Mt. Miroč is located at the downstream part of the gorge, on its narrowest part (named Kazan), on the right river bank. Most of Mt. Miroč is located in the Djerdap National Park. Mt. Miroč karst is located on a plateau at 400-500 m a.s.l., with peaks overpassing 600-700 m. The karst occupies some 120 km^2 of a meridionally elongated area with well defined contact along the western and eastern boundary with surrounding non-karstic rocks.

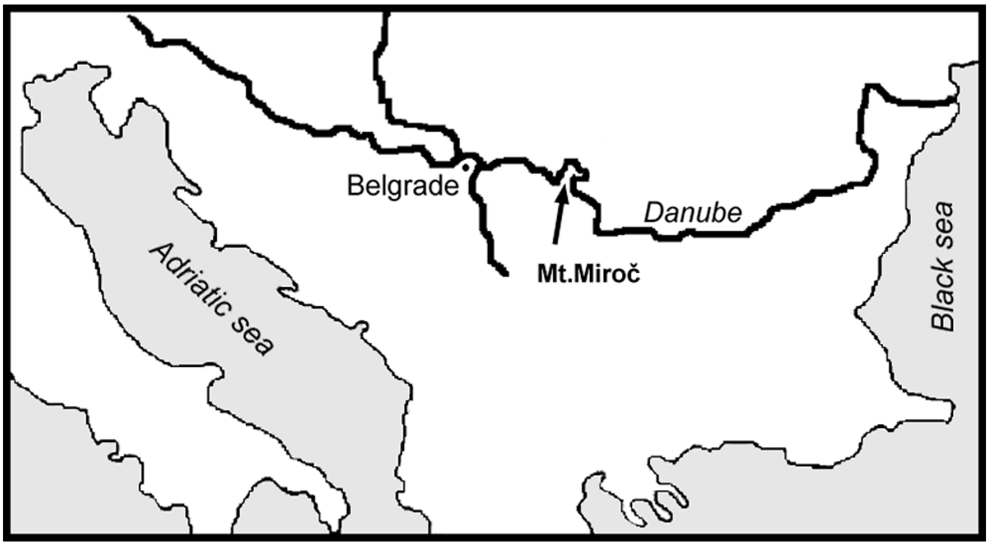

Figure 1 – Location of Mt. Miroč along Danube course

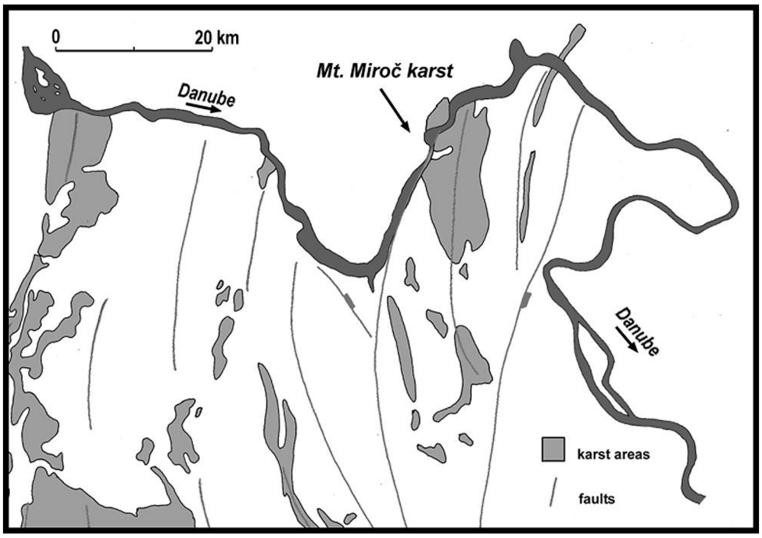

Figure 2 – Karst areas in the Djerdap gorge. Only small part of Miroč karst continues on the left river bank. (MENKOVIĆ 1995)

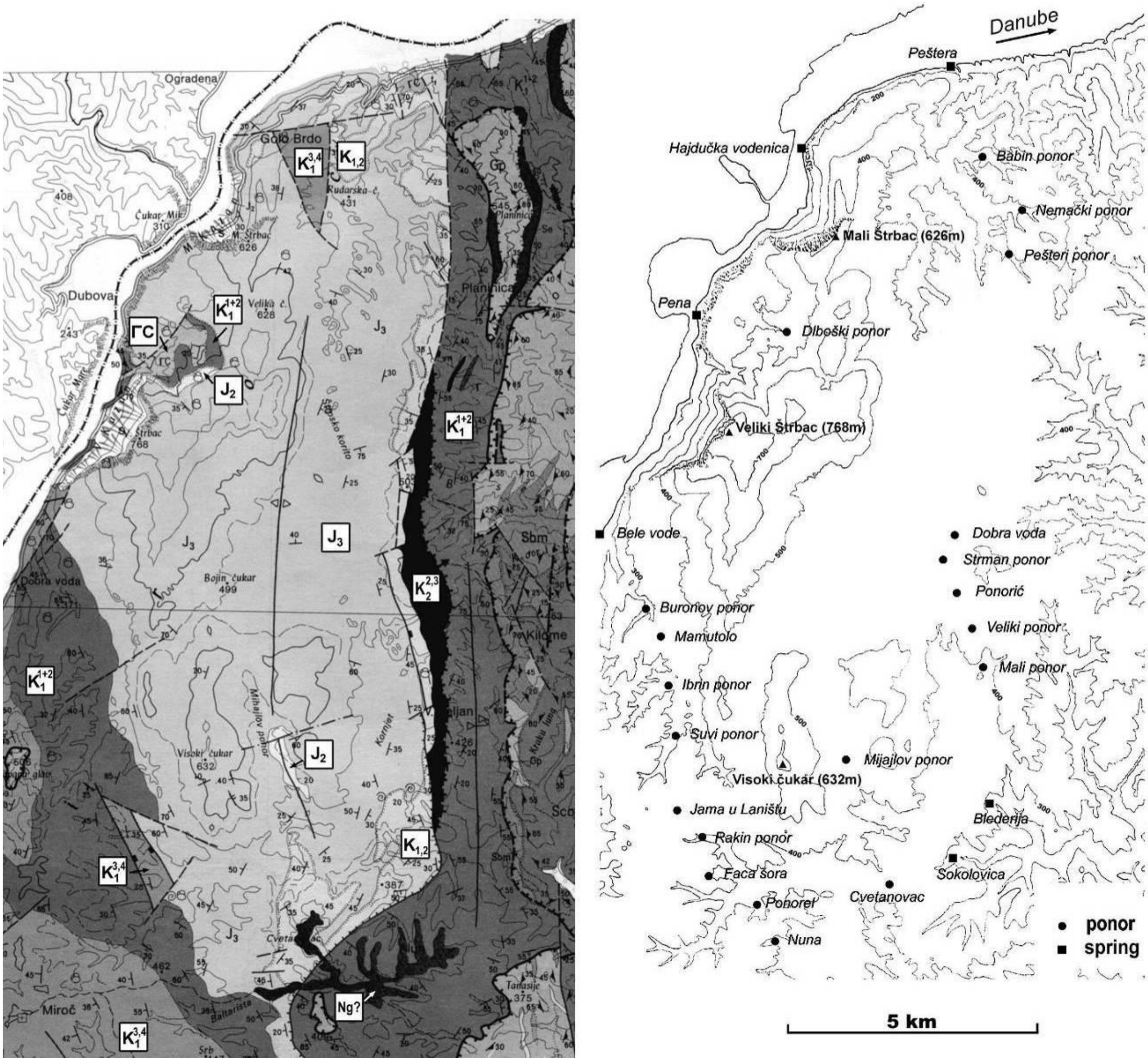

Figure 3 – Geological map of Mt. Miroč karst (left) and Situation map of ponors and springs (right)

As a structural unit, Mt. Miroč is a N-S oriented anticline plunging gently towards North, composed mainly of massive limestones (J_3) up to 300 m thick. Non-karstic rocks outcrop in a small extent, as Middle Jurassic conglomerates and sandstones at the central part, and also as Hercynian granites and chlorite-sericite schists exposed by erosion on NW part of Mt. Miroč. Lower and Upper Cretaceous limestones, marlstones, shales and sandstones lie conformably in succesion on the limbs of the anticline. The eastern limb is disrupted by a normal fault of N-S orientation, to the East of which there are Proterozoic schists of the Gethic nappe.

The non-karstic rocks surrounding Mt. Miroč karst lie on slightly higher elevation, and numerous short periodic streams flow from them sinking along the western and eastern contact, mostly in caves. Due to an artificial accumulation of Djerdap lake, the water level was risen for approx. 20 m (to 70-75 m a.s.l), submerging four springs which drain most of the aquifer towards the Danube (with minimum discharges 10-20 l/s and maximum ranging from 1 to 2 m^3/s). Unfortunately, tracing tests and detailed analyses have not been performed before the submersion of these springs. The SE part of Mt. Miroč karst is drained towards the springs Sokolovica and Blederija, the latter having both cold and sub-thermal waters (17.5^{o}C) with gas pulsations (STEVANOVIĆ, 1997).

The Caves

All of the major caves on Miroč are ponor caves, with both vertical and horizontal portions. Outflow caves are known only at the springs Sokolovica, Bele vode (partially submerged) and Peštera (totally submerged, known only from reports by CVIJIĆ, 1921). Few small fossil (dry) caves are known, but it must be noted that the central part of the plateau, where fossil caves are expected, is still unexplored.

Most of the ponor caves are lined along the western and eastern contacts, and can be viewed as parts of two drainage systems. The terminal caves along the contact zones (Buronov ponor, on the western, and Nemački ponor on the eastern contact zone) reach main horizontal conduits. Their assumed outflow caves are Bele vode, and Peštera, respectively. The ponor caves on Mt. Miroč can be identified as high-gradient vadose inlets (Ibrin ponor, Jama u Laništu, Rakin ponor, Faca šora) and low-gradient vadose inlets with perched sumps (Buronov ponor, Suvi ponor, Veliki ponor, Nemački ponor), as defined by WORTHINGTON (1991). Water table is reached only in two caves (Rakin ponor, with inundated steep phreatic passage at 124 m a.s.l, dived to 95 m a.s.l, and Buronov ponor, with active passages with sumps at 93 m a.s.l).

Cave	length (m)	depth (m)
Bele Vode	304	14
Buronov ponor	2.400	187
Mamutolo	80	-
Ibrin ponor	855	239
Suvi ponor	930	133
Jama u Laništu	710	272
Rakin ponor	684	285
Faca šora	-	approx. 150
Sokolovica	283	-
Veliki ponor	536	92
Pešteri ponor	59	-
Nemački ponor	3.422	210
Gaura Ra	185	-

Table 1 – Most important caves of Mt. Miroč karst

Rakin ponor is the deepest explored cave in Serbia. In September 2000 it was dived by speleodivers from SOB caving club to the current depth of 285 m. The level of the inundated phreatic passage at the bottom lies approx. 55 m above the Danube accumulation. Cave Jama u Laništu has the highest entrance of all the ponor caves on Mt. Miroč. It is a deeply incised vadose cave, cascading without distinctive horizontal tiers. Its bottom is 44 m above the water table reached in a nearby Rakin ponor.

Suvi ponor, the third longest cave on Mt. Miroč, ends in a perched sump in a horizontal gallery wich drains the smaller inlets along the stream bed above the cave. Adjacent Ibrin ponor cave has both vertical and horizontal parts and ends without reaching the water table.

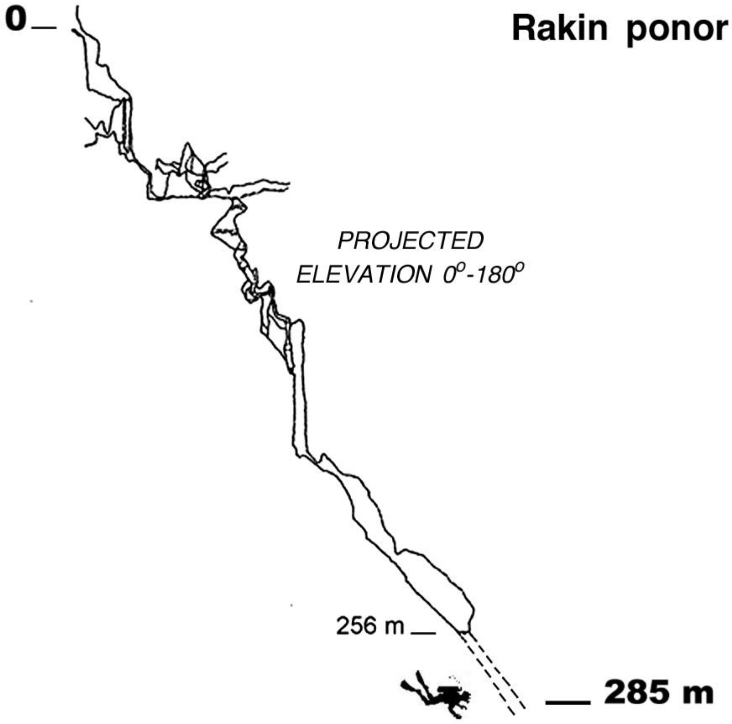

Figure 4 – Rakin ponor

Buronov ponor is the last of the ponor caves along the western contact. It has two distinctive horizontal tiers. The upper part (Elephant walk) is filled with sediment of unkown depth almost to the roof wich displays forms of phreatic origin (ZLOKOLICA-MANDIĆ & MANDIĆ, 1997). The Rio Bravo passage might be the fossil tributary connected with upstream ponors. The lower parts of the cave, Rio Negro and Mammoth gallery, show traces of periodic inundation. They lay 15 m above active conduits, visible at several parts interconnected by siphons. The observed stream is estimated at 0.5 m^3/s in the dry part of the year, and it is presumed that it feeds the springs at Bele Vode.

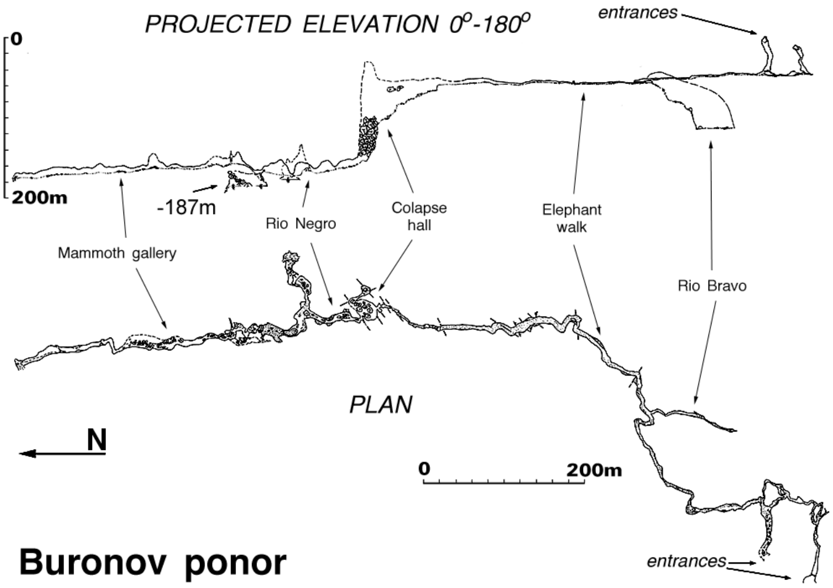

Figure 5 – Buronov ponor

The caves along the eastern contact are mostly impenetrable due to tectonic disruption. Nemački ponor, the last along the contact, is the longest cave on Mt. Miroč. It drains few adjacent ponors. At its bottom there is a horizontal passage 2400 m long, approx. 100 m above the Danube accumulation. It is covered with sediments of unknown depth, and ends in perched sumps. It is presumed that it drains towards now submerged Peštera outflow cave. According to CVIJIĆ (1921) allogenic schists exist in the Peštera cave, and they probably originate from the contact area of Nemački ponor (contact with Proterozoic schists).

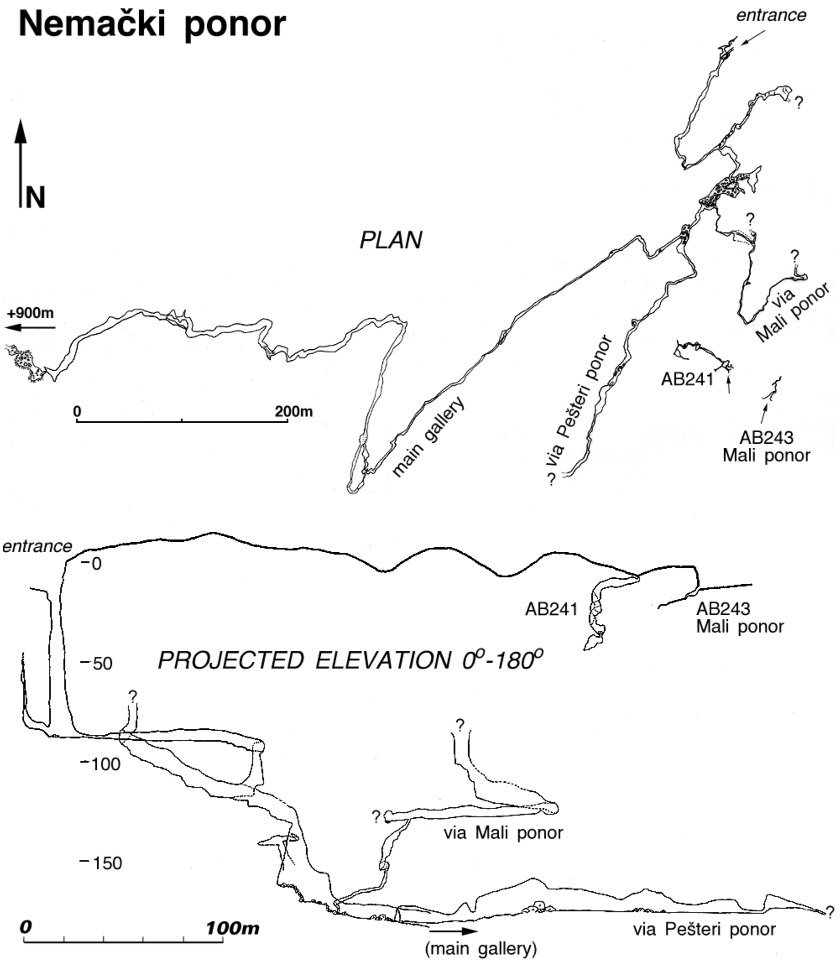

Figure 6 – Nemački ponor

Peculiarities

Some of the interesting questions wich have arisen after the explorations of Mt. Miroč caves are:

The passages in the lowest parts of Buronov ponor cave are completely covered with thin crust of Mn oxides. That indicates complete inundations of that part of the cave, since Mn oxides are deposited only at water-air interface level. Banded Mn layers on speleothem cross sections indicate the ciclicity in deposition. Dating of speleothems can explain the time and magnitude of events which caused such large and lasting oscillations of water level in the vicinity of a major river.

In Nemački ponor cave, CO_2 concentration is increased in the last 1000 m of the main gallery. In springtime (after snowmelt) the concentration drops. The analyses of air and water in the cave are yet to be performed, in order to determine the source of CO2. Is it originated by organic decay, or from (possibly sub-thermal) waters emerging in that par of the cave?

The speleogenesis of Mt. Miroč caves is of special interest, viewed in conjuction with the uplift of Mt. Miroč and incision of Djerdap Gorge. A final answer on the formation of Djerdap Gorge does not exist, so the solution of speleogenesis in the area might lighen up the problem of incision of Djerdap Gorge. Which was the sequence of events? Which paleoaquifer drained the area? Why the low-gradient passages in the caves show no correlation with river terraces?

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Use of the Caves as Mass Graveyards in Slovenia

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Abstract

Paper gives the brief account on use of caves for mass graveyards in the time of war from years 1941–1945. People were killed at the entrances and thrown into the caves. After that several entrances were undermined and intentionally filled. This hiding of the evidence lasted in some cases tens of years after the events.

In the cave register of Speleogical Association of Slovenia 86 caves with human remains are reported. In most caves are only few skeletons, but in some probably several thousand people were disposed. Exact number of the people killed from the remains in caves can not be established. Few identifications of the people were possible, small object found usually show their provenance only. People were mostly Slovene, but remains of people from Croatia, Serbia, Albania, Germany and Italy are there as well.

Introduction

During the second world war and some months after in Slovenia a great number of shafts were used for mass-graveyards for military and political opponents and prisoners of war that were liquidated without any trial. The phenomenon is documented by rich memoir literature that was published by emigrants abroad, but in Slovenia the discussion about that was forbidden up to the beginning of the last decade of the 20th century. The phenomenon is still burdened by political content and by questions of responsibility and this makes studies of it very difficult.

To understand the phenomenon we must shortly introduce the events in Slovenia during the World war II between the years 1941 to 1945: the actual Slovene territory belonged to the Monarchy of Yugoslavia and its western part to Italy. In spring 1941 it was occupied by German and Italian army and some time later resistance against the aggressors started. At first heterogeneous political movements have taken part in it, but the communist party soon prevailed and started with the revolution at the same time.

Already in the year 1942 (BAJT, 1999, 480), the caves were chosen to conceal the liquidation of prisoners of war or civil opponents of the communist party. However, the massacres culminated at the end of the war and after it, between May and July 1945, when partisans took over the power and when thousands of refugees (TOLSTOY, 1986) were returned to Yugoslavia from the British occupation zone.

The exact number of people that were thrown into the caves is not known. Various authors give different numbers; KOVAČ (1968) gives number of 14.000 for the caves of Kočevski Rog mountain only. For other karst areas and caves in Slovenia there are not even approximate estimations. Similar events may be traced in other parts of former Yugoslavia, on the Dinaric karst of Croatia, Bosnia and Herzegovina and in Montenegro (BOŽIČEVIČ, 1991; ŽANKO, 1990).

The regime that was established after the war have tried to keep this events and caves secret. Several caves were blasted or filled and all discussions about were forbidden. After the political change in 1991 and after the Slovene separation from the Yugoslavia there were some attempts to make a research of these caves, but because of the lack of the political will no official systematic research or even evidences have been done yet.

Visiting such a caves is not very pleasant, sometimes was also connected with troubles and the phenomenon had influence on the cave research in some karst areas. From speleological point of view we are mostly interested in a number of caves used for this purpose, number of victims in them and how the traces of the massacres were disguised. The data presented in this paper are basing on the Cave Register of the Speleological association of Slovenia and my own observations in which I tried to check the information from the different sources.

Caves with Human Remains

The first written information about throwing the people into the caves appeared already during the war time in some magazines and books. These information were at that time used as a political propaganda material against the communist guerrilla. Several caves mentioned and the first visit of such a cave, Krimska jama cave was described. In it several dead bodies were reported (ANONYMOUS, 1943).

In the karst areas above the city Trieste on the W side of Slovenia, in summer 1945 soldiers of British army researched several caves and abandoned mine shafts. From some of them bodies were extracted (KARAPANDZICH, 1980). In this areas the caves where people were thrown in, are in Italian literature known as foibas (PAPO, 1999), foiba is a local name used before for a shaft or deep doline.

In Slovenia, which was part of Yugoslavia people knew about mass executions and people being thrown into the caves but they were afraid to speak about openly. This is the reason why for several decades human remains in caves were not mentioned in Slovenia, but in the memorial literature of the political emigrants only (IŽANEC, 1970; KARAPANDZICH, 1980). These books were forbidden, but people smuggle them into the country. They described numerous caves, in some of them the bones may be seen still today, some shafts were later filled up by rubbish, and we can not check them, while many others cannot be identified due to either inaccurate locations or names.

In Slovenia the first descriptions of the executions and caves appeared in newspapers, periodical magazines at the end of eighties, just before the separation from Yugoslavia in 1991. Most of the information were from journalistic and political point of view, but among them there were also testimonies of the few people, which survived or were involved in the cave executions.

In speleo literature little is written about the phenomena. The first overview based on the data from the Cave Register of the Slovene speleological society was published in 1995 (MIHEVC). Later some shorter observations were published in Naše jame, magazine of the Slovene speleological society (MIHEVC, 1995; 1999). A special books was devoted to the events in one karst area (ŽAJDELA, 1990) and patients from some hospitals which ended in the caves (ŠTURM, 2000).

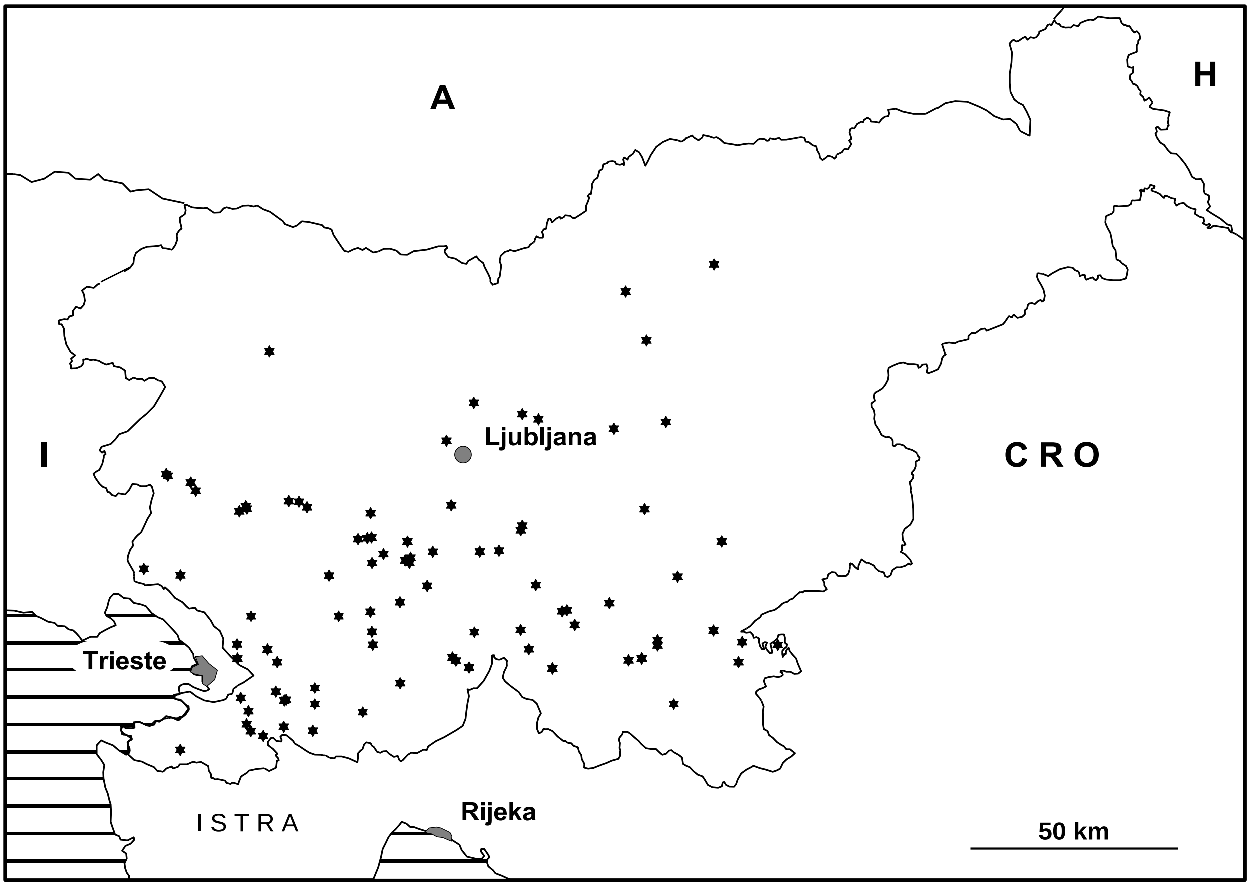

Fig 1: Position of the caves – mass graveyards in Slovenia. Source: Cave register of the Speleological association of Slovenia and Archive of the Karst research institute.

Data of the Cave Register

Cave register contains data of more than 7500 caves. Human remains, usually bones are mentioned in the files from 86 caves. The data from the register are not absolutely reliable. In first years after the war, cavers didn't dare to make notices about them, or they mask them with remarks of double meaning. Many human bones were also overlooked or are hidden by debris.

In several cases in the cave register it is mentioned that the people were thrown into the cave, but now no bones are visible in it. In such cases the data may be wrong, maybe the bones are covered by deposits or even removed. Such caves we can consider as the graveyards only when the source is reliable enough, or when we have several different sources, or when there are traces at the caves indicating that unusual activities that have taken place.

Such case is for example Brezarjevo Brezno. The record about the visit mentions rubbish in the cave and traces of blasting at the entrance only. KOVAČ (1968, 70) quotes that about 1000 people were thrown into this cave after the war, the entrance was later blown up and covered by concrete plate. Because of pollution of the nearby karst spring, the dead bodies were shortly afterwards drawn out and transported elsewhere. Similar case is cave Šemonovo brezno: comparing the before and after-war cave plan type of the gravel below the entrance one may conclude that on the bottom of the shaft some 10 m³ of allochthonous gravel was thrown in. In Dvojno brezno no bones can be seen, probably because of the gravel originating from blasting, traces of which are still visible at the shaft's entrance.

There are 7 reports about traces of the blasting at the entrance part of the caves. The blasting had dual purpose. The first one was to kill the survived people in the cave and the second one to camouflage the traces. At some cases, only one part of the entrance shows the traces of blasting; at Jama pod Krenom and at Jama pod Macesnovo gorico the entrances to the caves arc completely destroyed and the caves are closed. At 9 caves there are beside the bones the remains of unexploded ammunition reported.

The number of skeletons seen in the caves is usually not precisely defined. In 15 cases it is cited that in the cave there are many bones, in a sense, that there were many people thrown in. Most uncovered bones are still visible in the cave Zalesnika.

More frequent are remarks of buried human remains. In some cases the process is natural, but in many instances the covering was deliberate. In 13 caves the bones are partially covered by rubbish. In most cases this is not just the "usual" pollution, typical of caves of easy access near the roads and villages but intentional covering of the human remains. Such examples are Socerbska jama za Vrhom and Brezno v Debliških livadah (MIHEVC, 1999). Both caves are located far from the nearest settlement source of waste and access to them is difficult.

Not only human remains but also parts of clothes or shoes are found in the caves and they provide partial identification. In several cases the persons were German soldiers. The identification is easier because of discernible cloth of German military uniform. From three caves the identification tags of German soldiers are reported.

Some Examples of the Caves with Human Remains

Entrance to the cave Brezno v Mrzlih dolih lies in a remote beech forest, about 3 km distant from the nearest village. The cave is known to the few natives only but they do not know that people were thrown in it

During our visit we found shoes below 40 m deep entrance shaft. After examination we found among the leaves and rocks at the edge of talus cone and of the entrance chamber two skeletons. Nearby were some remainders of clothes and two rucksacks, with basic necessities of life: spoon, shaving and sewing outfits and rubber for mending the soles. Different clothes, shoes and rubber soles indicate that the two men were not soldiers of a regular army and not natives either.

Cave Brezno na Koševcu lies in the middle of a forest some 2 km from Logatec. The record from before war from the year 1934 does not mention any particularity. After the war the rumours appeared that several people were thrown into this cave. The first cavers after the war visited cave in the year 1962. They found out that the bottom of the entrance shaft was covered by skeletons. They notified the police.

Later nobody found the entrance to this cave; it was established that the entrance was covered by timbers and disguised. When the timber, years later, rotted the cover fall into the cave. Our visit evidenced that the skeletons on the bottom were covered by several cubic metres of allochthonous rocks, but the skeletons were still visible.

Jama pod Macesnovo Gorico lies in the middle of a forest, about 10 km from Kočevje. The shape and the depth of the shaft is not known as the entrance part was blown up and this changed the shaft into depression, 10 m in depth with vertical walls in some places. On them the traces of blasting are still visible. The bottom is entirely covered by under-mined material.

The location and the shape of the cave probably corresponds to the cave that is quoted in the memoirs of one of the three men that survived and saved himself out of the Slovene caves (IŽANEC, 1971, 191). The witness cites that the victims were transported by six lorries, each containing 50 people. He himself was shot but only wounded, and thrown into the cave on June 2. 1945. He escaped from the cave on June 5. 1945. Shooting and throwing the people, he witnessed lasted for two days and a half. In this time the edge of the entrance to the cave was blown up five times. When the blasting started the 16 survivors were hiding in a lateral passage. During the blasting a tree fall into the cave and by it the witness escaped. Today the cave is completely filled up and thus the passage where the survivor was hidden is inaccessible; we may infer that the cave was undermined still later. If the quotations are accurate, 2250 people ended in this single cave only.

The witness quotes that the victims in front of the cave had to give away all the objects they had and take off the clothes. We have checked these information and in the nearby doline we excavated a test trench of one square metre. In 15 cm thick superficial layer we found numerous objects that confirm the witness's statement. We found parts of clothes, buttons, belt-buckles, parts of shoes and personal objects as are spoons, pocket-knives, pieces of pocket-mirrors and combs. Also we found pieces of rosaries, Italian, German and also Serbian, Croatian and Albanian coins evidencing that also people of other nations died in that cave.

The cave was known to the people and they used to visit it in secret. Since 1989 a wooden cross was erected and the cave can be visited openly.

Conclusion

The data from the cave register, quotations in literature and field evidences indicate that the use of caves for mass-graveyards was very diffused in the time from 1941 to 1945. The caves were suitable, there are many, they are deep and it was relatively easy to hide the dead bodies in them.

Although this phenomenon is spread all over the Slovene karst there are some common properties. On the base of observations of how the burial was executed and number of victims and in particular in respect to traces the caves - mass-graveyards, may be divided into two types.

The caves where there are bones of some persons only, who were thrown dressed into a cave, probably became tombs during the revolution and guerrilla fighting. In these caves nobody disguised the traces later and the bones are found on the surface or they are covered by natural processes. These caves are usually less known and are located in remote woodlands.

The second type of the caves are places of mass executions. In them remains of great number of people are usually found. The executions were well organised and lasted longer time. This is why they could not be kept secret. The disguising of traces followed, blasting of entrances or filling up the entrance shafts, somewhere even tens of years after the war. Also the police was controlling the access to such caves and areas and people and cavers were avoiding them. The use of caves for such a purpose and in particular later camouflaging of the traces considerably changed the physiognomy of numerous entrance parts of the shafts. Some of them were completely filled up or even blown up and thus became inaccessible

So far no larger projects of research, excavation and identification of the victims in these caves were undertaken. But many the most important caves became the places visited by relatives of people that disappeared during the war and several crosses or monuments were erected at the entrances. Most of the terror victims were thrown into about 10 entrances.

After estimations in memoir literature there would be more than 10.000 people thrown into the caves but we do not have any official data. The precise number will never be found out and in the caves there are people of other nations and countries leke Serbs, Croats, Albanians, Germans and Italians present too.

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Polish Caving 1997-2000

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Abstract

Traditionally the most spectacular explorations were done in the Austrian Alps. In the Leoganger Steinberge PL-2 cave was joined to Lamprechtsofen and thus it became the world deepest cave. Other fruitful expeditions worked in the Höher Göll and the Tennengebirge.

Polish teams carried out exploration also in Spain (the Picos de Europa), Italy (the Julian Alps), Slovenia and Turkey. Other numerous outside expeditions, not only to European caves, were mainly the training activity.

Some interesting explorations were done in Poland too. The deepest and longest Polish cave - Wielka Œnie¿na reached 22 km in length, and now has five entrances.

Introduction

At present there are about 1000 cavers in clubs belonging to the national federation - the Polish Alpine Association. The Western Tatra Mountains - the limestone part of the Tatra range is practically the only region in Poland where large and deep caves are encountered. Because

of that the everyday activity of Polish cavers, both exploration and training, is concentrated in this area. In recent years there were also many expeditions abroad, not only the usual exploration of various karst massifs of the world, but also numerous training trips. All the more significant successes, both at home and abroad, were the outcome of long, sometimes lasting for many years, conceptual and field work.

All the activities were described in Polish caving quarterly journal Jaskinie (The Caves) which is systematically published.

Expeditions abroad

The Austrian Alps were traditionally the goal of numerous Polish expeditions. Some of them yielded spectacular exploration results. The activity in this region was possible thanks to the friendly attitude of the Austrian hosts who provided our cavers with invaluable assistance.

Four expeditions (in 1997, 1998, 1999 and 2000) to the Leoganger Steinberge were led, as almost always in the past, by Andrzej Ciszewski. Their goal was the linking of PL-2 (situated in the Nebelsbergkar) with Lamprechtsofen. In 1998 more than 1200 of a new series of meanders and pitches were discovered. The series lead to PL-2 cave, to the series called Wielkie Galerie (Huge Galleries) situated at the depth of about -400 m. The first team which achieved PL-2 did not realize this. Later, on 19 August the next team recognized Wielkie Galerie. The new depth of Lamprechtsofen is 1632 m (figure 1). Thus, Lamprechtsofen became the deepest cave in the world. This achievement crowns the 24 years of Polish exploration in the Leoganger Steinebrge massif. Further works, carried out by the same and next expeditions, were aimed to link other caves, situated higher than PL-2, to Lamprechtsofen. The main explored object has been Cl-3 cave. The linking of this cave to Lamprechtsofen would result in a vertical extent of about 1690 m.

The prolonged and systematic exploration of Höher Göll by KKS (Speleoclub Katowice) and WKTJ (Speleoclub Poznañ) expe ditions (leaders Zbigniew Rysiecki and Piotr Tambor) concentrated in 1997-2000 around the eastern branch of the massif. The most interesting achievement was the discoveries in Kammerschartenhöhle, where more than 2 km of new passages were found. A possible link with the long known nearby Gruberhornhöhle would create a system

deeper than 1000 m but dozen of meters still separate both caves.

Several smaller caves were discovered too. Jaskinia Gadaj¹cych Kamieni (more than 300 m deep) seems to be the most significant of them.

Expeditions organized by SG KW Wroc³aw and SKTJ (Speleoclub Sopot) led by Marek Wierzbowski explored the eastern part of the Höher Göll in 1997 and 2000. Their main target was Ogrschacht (discovered in 1995). Besides, the Schnee Höhle was deepened about 40 m.

The Tennengebirge massif was the target of the expeditions organized jointly by Speleoklub ¯agañ and Speleoklub Gorzów led by Rajmund Kondratowicz, Halina Zyzañska and Daniel Oleksy.

The former teams visited the eastern part of the massif. In August 1997 Bleikogelhöhle (discovered in 1988) was deepended from - 1011 m to -1021 m, and in 1999 the cave P-77 (-440 m) was discovered. Besides in P-19 and and the cave Pod Œnie¿nymi Korkami long hotizontal galleries were explored. The team of AKG Kraków (leader Marcin Krajewski) explored the southern part of the Tennengebirge massif in 1997. They concentrated their activity in Schnee Maria Höhle and Ariadna Höhle. The former cave was pushed down from -817 to -935. They also discovered some smaller caves. The Poles (team of STJ KW Kraków) explored also the Steinernes Meer massif in 1997.

A new area of speleological exploration was opened in 1998.

The team from Kraków led by Andrzej Ciszewski went to Kitzste inhorn massif (the Höhe Tauern). The massif is built of metamorphic rocks - marbles and calcareous shcists. The main goal of the expedi tion was Feichtnerschahthöhle, which had been previously explored by an Austrian caver to -520 m. In 1998 the cave was deeepened to -623 m, in 2000 to -698 m and in 2001 to -1025 m. The exploration was carried out only in winter due to high water level within the cave in summer.

In recent years the expeditions of Speleoclub Wroc³aw (leader Marek Jêdrzejczak) continued exploration of El Cornion massif of the Picos de Europa Mts. in Spain. In 1998 a cave named Pozu del Porru de las Garapozales was discovered and pushed down to –432 m. The expeditions in 1999 also carried out a series of water dying tests.

The Poles also explored the Canin massif (Italy/Slovenia).

Several expeditions, in summer and winter seasons, organized by Speleoclub Aven and led by Marek Kozio³ explored the Compelsso del Foran del Muss. They concentrated in the new discoverd cave called Point 5 which was jointed to the Complesso in 1998 and in Abisso Carlo Seppenhofer. In 1999 and 2000 the expeditions organized by STJ KW Kraków led by Maciej Tomaszek went to the Slovenian part of the massif. They explored several small caves in the southern slopes of Kanin. In 2000 a team from ¯agañ and Gorzów carried out exploration in the Velebit massif (Croatia). The cave Lubuska Jama (-330 m) was the deepest one. Several expeditions visited various karst areas of Romania. They explored some small caves. The diving exploration were conducted too.

There was also some activity outside Europe. The cavers of Speleoklub Czêstochowa visited the Bolkar Mountain in Turkey in summer 1997. They deepened caves Pl-5 to -160 m, and Pl3 to -235 m. Both caves were discovered by Poles in 1995. A Polish team explored several small caves in Java island in 1999.

The cavers from Speleoclub ¯agañ and Speleoclub Gorzów, collect” the deepest pitches of the world. They visited Sotano del Barro (Mexico) in 1997, Vrtglavica (Slovenia) in 1998, Brezno pod Velbom (Slovenia) in 1999 and 2000 as well as Patkov Gušt (Croatia) in 1999.

Many small groups went to large cave systems for training. In 1998 Gouffre Berger was visited in cooperation with some French cavers. Besides, numerous teams chose as their target some caves in Slovakia, the Czech Republik, Hungary, Romania, the Ukraine as well as Sardinia and the Canary Islands.

Exploration in Poland

The most spectacular exploration activities in Poland were concentrated in Wielka Œnie¿na - the Polish deepest cave (vertical extent 814 m). The length of the system reached 22 km. It was the final results of long work carried out mainly by the cavers from Wroc³aw, led by Marek Wierzbowski and Rafa³ Mateja, from Sopot led by Darek Bartoszewski and from Warszawa led by Marcin Gala and Stefan Stefañski. The most spectacular achievements in the cave was the discovery of the new, the fifth, entrance. It was found in 1999 by joining Wielka Œnie¿na, with the small cave called Wilcza.

Several houndred meters of vertical series (Partie Animatorów, Partie Amoku) was climbed up in the cave too. A small exploration was also conducted in other Tatra caves (e.g., Œnie¿na Studnia).

The intensification of diving activity in the caves of the Tatra Mts. should also be mentioned. Wiktor Bolek dived the 70 m deep sump situtated at the bottom of Ciasne Kominy series in Miêtusia Cave. Thus, the vertical extent of the cave was 305 m. Another sump was dived through in the same cave by Krzysztof Starnawski who discovered a small series beyond. Other sumps in Bystra, Zimna, Wielka Œnie¿na and Mokra Dziura (the Slovakian Tatras) were the aim of diving activity too.

Numerous discoveries were also made in other karst regions of Poland. Some caves of the length of more than 500 m were explored in Cracow-Wieluñ Upland (Brzozowa Cave) and Œwiêtokrzyskie Mts. (Pajêcza Cave).

Table 1 : The longest caves in Poland (all situated in the Western Tatra Mts.)

1. Wielka Œnie¿na	22 000 m
2. Wysoka za Siedmiu-Progami	11 660 m
3. Miêtusia ca.	
4. Bañdzich Kominiarski	9 550 m
5. Œnie¿na Studnia ca.	8 166 m

Table 2 : The deepest caves in Poland (all situated in the Western Tatra Mts.)

1. Wielka Œnie¿na	814 m	(-807; + 7)
2. Œnie¿na Studnia	763 m	(-726; + 37)
3. Bañdzicho Kominiarski	562 m	(-546; +16)
4. Wysoka za Siedmiu Progami	435 m	(-288;+147)
5. Kozia	389 m	(-376; + 13)

The New Crystal Caves in Hungary at Beremend and Nagyharsány

Szabolcs LEÉL-ŐSSY; Tamás VIGASSY
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Two crystal caves, extremely rich in formations, became known in the southernmost part of Hungary in the last decades.

On November 12, 1984, during an explosion, a 1 m cave mouth opened in the upper level 116 of the Beremend limestone quarry, on the NE front, at the foot of the wall, which led into a hall full of debris. It is a great result, that this cave did not share the fortune of its about two dozens fellows, which were demolished on the spot. The discovery was reported to the Ministry of Environmental Protection and Nature Conservation, which immediately delegated a research team under the guidance of Katalin Takács-Bolner. They explored only the first hall of the cave and realised that there is a passage leading further. Still in this year, on December 6, there was a second field survey. In this occasion, more helping hands were invited – supposing it may be carry out demolition work. Thus, among others, I myself also took part in this survey on behalf of the Rózsadomb (Rose Hill) "Kinizsi" Speleological Society together with Péter Adamkó, when we discovered the back parts. At the beginning of 1985, the team of József Kárpát explored also the other branch of the cave, which ends in an active lake filled by 18^{o}C water.

Shortly after the discovery of the cave, its scientific elaboration also began. The mineralogical research was led by László Bognár, and the fossils collected by the team of Katalin Takács-Bolner were determined by Dénes Jánossy and György Topál.

Today, the length of the cave exceeds 700 m, and its vertical extension has reached 53 m. By the end of the ‘90-ies, the final entrance had been completed. The original entrance hall has been partly filled up due to safety reasons. The visitors can get from the entrance into the hall under the fill in a wide iron tube. From the bottom of the rocky wall, a long concrete tube leads to the present-day, final entrance under the area of the subsequent collapse. In the environs of the entrance, explosion and mining have been stopped.

The Nagyharsány crystal cave was discovered “officially” in April 1994. According to unverifiable gossips, however, the discovery took place already a decade before, but this fact was kept quiet and the entrance was filled up.

This version is supported by the facts, that not far away from the present-day entrance, light filters in the cave for a relatively significant length at the foot of the quarry wall, and in this section well-sorted debris of undoubtedly anthropogeneous origin poured in. The crushed rock material of 1–2 cm size could not have absolutely got into the cave in a natural way.

After its discovery in 1994, the cave was surveyed also by the team of Katalin Takács-Bolner. In addition, on behalf of the Speleological Department Kinga Székely and at the same time Sándor Kraus, Gábor Salamon and Zsolt Végh examined the cave. As a result, the map of the cave was compiled, which is unpublished up to this day. According to this map, the length of the cave exceeds 550 m, and its vertical extension is 60 m. The end point does not reach the karst water level, but there is no possibility to get lower down in the narrow passage due to the fantastic richness of the formations.

No official presentation of the cave has been published. In order to protect it, its existence has been almost kept secret. The only lecture about the cave was delivered by Katalin Takács-Bolner at a conference in Jósvafő, in 1995. Though sampling has taken place, the analyses have not been carried out yet. This is the reason why we have received permission from Ildikó Lendvay and Ildikó Havas in the name of the Danube–Drava National Park to survey the caves under the guidance of Tibor Parragh several times and examine the formations collected during limited sampling.

The work was carried out in the frame of a diploma project – under my supervision – by Tamás Vigassy. As he has obtained a foreign scholarship, it is my task now to give a summary of his work

Development of the cave has begun, the entrance section has been made accessible by rust-proof steel sidewalk and ladders under the guidance of Pál Berczik. In order to protect the formations, no permission is given to descend into the cave until the construction works will not be finished.

From geomorphological point of view, there is a noticeable similarity between the positions of the two caves, situated little more than 5 km from each other.

The Nagyharsány crystal cave is situated under the highly karstified, extensive surface of Mt. Szársomlyó, which is considered a significant gathering ground. The bottom of its eastern part, formed between two steep bedding planes, can be found 10–15 m higher than the thermal water level of the Beremend crystal cave.

Above the Beremend crystal cave, surface water can ooze in only from a limited area due to the small extension of the Beremend block.

On the basis of the map of Alföldy and others from 1977, no separate karst water flow directions and systems must be taken into consideration between the Nagyharsány and Beremend slivers. Karst water levels of the two blocks is nearly the same according to the well data, as well.

As to its features, the Beremend crystal cave is a typical thermal karst cave. Its passage structure is characterised by several storeys and labyrinths. There is not at all fluviatile sediment in it. The passages of the cave have no connection with the topography of the surface, and it is characterised by extremely rich mineral precipitations, which can be related to the presence of warm water. And finally, still there is in the cave the lake, which is warmer than its environment…

The case of the Nagyharsány crystal cave is already not so unambiguous. The different character and height above sea level of the passages indicate clearly two cave levels. The upper level is represented by an extensive hall system on the western side, covered by large flowstones and stalagmites. The lower level is represented by a much smaller, narrow, steeply sloping passage system on the eastern side, richly ornamented by mineral precipitations, related to the warm water, and stalactites.

To sum up these observations, it can be established, that the Beremend crystal cave is dominated by thermal water character, following the tectonic preformation, while in the case of the Nagyharsány crystal cave, the passage system of tectonic origin was later formed by thermal water processes.

Though the forming processes were similar in the case of both caves, the host rock of $CaCO_3$ of 99.5% pureness and the Nagyharsány Limestone, formed in the Cretaceous, are the same – there are some differences in the mineral assemblages. The minerals were examined macroscopically, in thin section by cathode luminescence microscope, derivatograph and spectrograph as well as by means of X-ray powder diffraction and stable isotopes.

Besides the carbonate minerals, quartz, sericite/illite, chlorite, smectite, ankerite and anorthite could be detected at the western end point of the Nagyharsány crystal cave. This mineral assemblage is not the insoluble residue of the Nagyharsány Limestone. The great amount of bone material, found in the environs of the sample, refers also to transport from outside. This bone assemblage was determined by László Kordos as of Pleistocene–Holocene age on the basis of the collection of Piroska Pazonyi. Here – presumably due to E–W-ward strike-slip faults – an opening may have formed in the ceiling of the hall (roots hang down even today).

In the Eastern Branch, on a surface little more than 1–2 m^2, gypsum material of a snow-white 1–2 mm thick crust could be detected.

Quartz appears also in several samples from the Beremend crystal cave as pollutant. In the bauxite-like sample, collected at the entrance, gibbsite, goethite and kaolinite occur.

In both caves, precipitations of calcite material are predominant in great diversity. On the basis of the optic emission investigations, the carbonates in the samples are of high pureness and poor in trace elements.

In the Beremend crystal cave, dripstone occurs only at the lake in a smaller quantity and it is covered by peastone. On the contrary, the Nagyharsány crystal cave is very rich in dripstones. It is interesting, that in the hall system of the western side mainly large sized, sometimes human waist thick stalagmites and huge, locally 10 m long flowstones occur, while the sloping, narrow passage system of the eastern side is characterised by only maximum 10 cm thick stalactites. The reason for the difference may be the fact, that on the western side a very thin, altogether 10 m thick heading with steep layers can be found. On its planed surface, the soil mantle is insignificant and the vegetation is scattered, which does not provide continuous dripping. Seasonally variable respiration of the hanging roots probably increases the CO_2 concentration. Besides the young, one metre long, extremely thin stalactites, it is also remarkable, that the stalagmites were frequently broken to several pieces.

The peastone is snow-white in the Beremend crystal cave. It covers richly the walls and ceilings almost everywhere, and the rocks can be observed only at a few places. Distribution boundary of the common peastone is terminated frequently by a sharp line. In the inner parts of the cave, angular peastone, bounded by rhombohedral faces with an edge length less than 0.5 cm, also appears. During the exploration, even a nice specimen of coral peastone was observed, but it disappeared from the cave in a short time.

Peastones of the Nagyharsány crystal cave are not so white. They have a brownish colour, and resemble the common peastone of the caves in the Buda Mts. However, it is remarkable, that the peastone precipitations alternate with dripstone layers, mainly in the Western Branch. At least, three generations of dripstones can be distinguished! Examined in thin sections, the peastone precipitations are concentrically zoned. They do not luminesce.

The glass ball peastone is relatively widespread in the cave. It is a yellowish brown, globular formation, translucent like glass, which is saturated with $CaCO_3$, and gets precipitated from cold water solutions, flowing down, due to mechanical effects.

In the central, collapse zone of the Western Branch, in a dripstone environment, the dripstone peastone, consisting of unusually big, 2.5 cm diameter grains appears.

The absolute number one speciality of the Nagyharsány crystal cave is the peastone column, which occurs at several places in the Eastern Branch. It is an about 20–30 cm high, 4–8 cm diameter formation of dripstone habitus. It has a net structure, radial build-up and hole in the middle. The inner grains are usually smaller. Probably, the developed peastone agglomeration was at least partly redissolved by aggressive dripping waters.

Multigeneration calcite crusts occur barely in the Beremend crystal cave, and mainly in a redissolved state. In the Nagyharsány crystal cave, first of all in the Western Branch, however, they are one of the most frequent precipitation types. Some specimens may reach 10–20 cm thickness. Usually, their surface is strongly corroded.

The vein calcites are characteristic of both caves, probably they are older than the cave system. At many places, the spherical niches were corroded into this formation. At the spot of the corrosions, the surfaces break up fibrously, like needles. Some veins may be 1–1.5 m thick, and their colours range in bands from snow-white to red.

Agglomerations of aragonite crystalline needles occur in both caves. However, while in the Nagyharsány crystal cave they can be found only at a few places, in the Beremend crystal cave they are common. The locally whitish, glass-like crystalline needles, which are nearly 1 cm long, stick out from the almost 1 cm diameter peastone grains most frequently, resembling a pincushion. In the Washing Powder (Mosóporos) Branch, redissolution of the needles, which hang down and stand in dripping water, can be also observed. Here, according to X-ray powder diffraction investigations, aragonite is a component also of the powder, covering the bottom of the passage.

Dolomite and ferriferous dolomite occur in the powder-like samples of both caves.

Magnesite and ferriferous magnesite were detected in the Washing Powder Branch of the Beremend crystal cave.

Huntite could be detected first in Hungary in the Beremend crystal cave. The massive whitish material on the surface of the peastones is nearly pure huntite. The same could be detected the first time also in the Nagyharsány crystal cave, under similar conditions of occurrence.

The formations were subject to stable isotope investigations several times. The $D^{13}C$ and $D^{18}O$ investigations partly have not been finished yet, partly their evaluation needs to be the topic of a separate lecture.

Antarctica 2000

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Abstract

During 2000 a fist speleological expedition to Antarctica was organised by La Venta exploring team together with Etsim of Madrid Polytechnics and the Institute of Geography of the Russian Academy of Sciences. The aim this expedition was to search for glacial karst phenomena, which resulted to exist even at a small scale due to the very scarce melting and high acclivity of the glaciers.

Keywords: Glaciokarst, Ice caves, King George Island

Introduction

In the last few years the “La Venta Exploring team” is carrying explorations in the largest glaciers of the world in order to characterise their glacial karst phenomena (Badino 1994, 1995,1999; Badino & Piccini, 1995). Therefore La Venta members made expeditions to Central and Southern Asia, Patagonia, Iceland and Tierra del Fuego.

These explorations evidenced that just 2° southward were enough to transform the “glacial hypercast” found in Patagonia to a scarce “glacial karst” in the Tierra del Fuego. In fact the limit of the late summer snow, which is over 1500 m a.s.l. in the Hielo Continental Patagonico, is lowered to about 500 m a.s.l. in the Sierra Darwin of the Tierra del Fuego.

Therefore it was extremely important to see if any glacial karst still exists some 10° southward.

The map of the annual mean temperatures put in evidence that rather all Antarctica is far below 0°. The single area slightly over that temperature, which has proved to be the limit for glacial karst in the Alps, is the occidental part of the peninsula together with its archipelagos. Therefore this is the single region of Antarctica in which ice pits and caves should develop.

In order to organise the first true speleological expedition to Antarctica, La Venta joined the Etsim of the Polytechnic of Madrid and the Institute of Geography of the Russian Academy of Science: the selected area being King George island.

Previous Karst Observations in Antarctica

A long and hard bibliographical research allowed to discover that during expeditions with different targets someone went inside some Antarctic caves in the past.

The Rumanian Emile Racovitza, who is the founder of biospeleology, was the first caver reaching Antarctica in 1898 with the tragic Belgian expedition, world-wide renown due to the presence of Amunsen. Anyway in the long period spent there Racovitza made no one caving exploration.

The first news about a cave in Antarctica was found in the report of the Scott 1911 expedition: a photo with the title “The boat Terra Nova in the Ross sea”, now property of the Royal Geographical Society, was taken from the interior of an ice cave, which is reasonably to think as a sea cave on the border of a tabular iceberg. Now that photo has been chosen as the logos of the U.I.S. Commission on glaciokarst.

The first true cave exploration was made by Mr Werner during the scientific expedition lead by Tazieff on Mt Erebus, an active volcano not far from Mc Murdo base. Fumarolic vents melts the overlying ice thus allowing the evolution of rooms large enough to be explored between the rock and the ice. These cavities, which are well known and documented in Iceland, are called sub-glacial caves and in reality they cannot be considered true glacier caves.

Anyway practically nothing is known on this fist cave exploration in Antarctica: in fact, in his “Erebus”, Tazieff printed just a photo of scarce quality together with the following caption “*Werner avait exploré un système de grottes*”.

During the ’80, a true glacial karst (developed by the water action over ice) has been observed by East Germany scientists inside a dry valley in the part of Antarctica facing the Indian Ocean, close to the important Russian base of Novolazarevskaya. They reported (AA.VV. 1993) that during summer a rather large river springs from the gralcier and gave the photos of the cave entrances but no further speleological details are supplied because they were not cavers.

A further speleological exploration was carried out by an Italian team on Melbourne Mt, a volcano close to the Terranova base. In 1985, during the first PMRA expedition M. Spezzotti bacame the first italian caver in Antarctica exploring a fumarole vent on top of the volcano. Five years later the same exploration was made for a second time in order to do volcanological observations (gas analyses).

Galcial mills have been seen by helicopters flying over the glaciers of the peninsula and in the King George island. Anyway the scarcity in the information (glaciologists have no real interest in ablation zones) was perhaps the main reason for organising this speleological expedition.

The Expedition

The meeting point with the other members of the “Antarctica 2000” expedition (Dominguez and Eraso from Etsim of Madrid and Moskalevsky from IG of Moscow) was in Punta Arenas in the extreme South of Chile from where the King George island was reached by plane.

The two Spanish cavers started their research in a different area, while the members of La Venta with the aid of a small track reached the Collins glacier which covers rather all the 1300 km^2 of the island. The champ was settled up at 235 m a.s.l. where the Russian glaciologists detected the presence of liquid water some 50-80 m below the surface with aid of a radar. The area is completely covered by snow: it is not a usual ablation zone but an accumulation one without any water flow. The area corresponds to a wide crest protruding into the sea in which icebergs are present.

In the first days the research was directed toward the sea, looking for water flows. Moving was extremely hard and dangerous due to the presence of wide areas with crevasses, which were often evident but sometimes completely masked, being always covered by a thin layer of snow.

In the whole Antarctica the ice ablation is not controlled, as in the temperate zones, by its melting and consequent water flow, which may in turn give rise to karst phenomena if the environmental condition are favourable. Here ablation is mainly induced to wind erosion and, at a smaller extent, to calving (ice breakdown into the sea from the final part of the glacier).

In King George island the last process is by far the predominant: in fact the structure of the its ice cap, steep in its external parts, hinder the rilling and therefore the possibility to drill caves.

The exploration in the surface were very long and dangerous but allowed to confirm that these conditions are efficient to avoid the evolution of glacio-karst forms. Moreover the ice temperature is always a few below 0°C and the snow cover ends about at 100 m a.s.l.: therefore the possibility to find a cave seems to be rather impossible.

Only during the third exploration day it was possible to detect that close to the main drains discharging into the sea along steep slopes some low acclivity areas develops in which small and short freshets exists. The gentle slope allows the evolution of a drainage network thus causing an increase of kinetic energy, and, in the mean time, avoids the sliding of the ice and, consequently, the karst systems may develops over the years (Fig. 1).

In one of this zone the La Venta team discovered and explored 4 caves from 15 to 55 m a.s.l.

It is an ablation area of about 400x200 m^2 with a regular dip of 16-18° toward East, developing from about 80 m a.s.l. and the seashore (Fig. 2).

The area is cossed by small flreshets with main N-S direction in the upper part and along the maximun dip in the lower one. The whole drainage network consists of small water flows inside scarcely downcut “bediere”, the characteristic flow of which is of few l/s.

The acclivity of the area is normally to high to allow the drilling of glacial mills (sinkholes) thus most of the freshets evolves into waterfalls reaching the beach and, after few meters, the sea.

The only exception is represented by 4 freshets which have the possibility to drill their mill just where the acclivity is a minimum (about 10°).

Following a tradition of the "La Venta" these first ice caves of Antarctica were named after famous Italian wines, which were chosen on the basis of origin of the different members of the team.

The Caves

the highest cave was named Brunello AN1 (Fig. 3-1): it has an entrance at 48 m a.s.l. and consists of a rather large pit 28 m high: a waterfall makes difficult its exploration from 10 m down. At the base of this pit the cave develops in fissure rather filled by the flowing water and too narrow to be explored. Most probably this sinkhole is directly linked to the wide spring-hole Frascati AN5 (Fig. 3-4), just below Brunello AN1, developing where the ice glacier enter the sea. This cave has a total length of 30 meters and shows the classical morphology of a subglacial cavity.

Cabernet AN2 (Fig. 3-2) is the deepest glacial cave of Antarctica (37 m). It is very close to AN1, the entrance of which is only 3 meters higher. The river sinking inside is smaller and consequently the cave size is lower: it structure consists of a sequence of two pits reaching the basement.

Barbera AN3 is a very small vertical cave, consisting of a pit of 13 m and a relatively large room inclined along the slope of the rock. All the cave is interested by a scarce water flow.

AN4, is close to Barbera and represents the active flow of the same system: the waterfall sinking inside avoided the possibility of its exploration and therefore no name was given to this cavity.

There is an aspect of these caves that is really terrific: they are sufficiently wide and with an inlet pit of some tens of meters but this, except for the first cave, is perfectly masked by a thin layer of snow. The wind, powerful ally of fogs and of very wet snows, flatters all the surface…. Thus it is very difficult to detect the presence of a killer pit under a one of the very frequent spots of snow only due to the presence of a scarce water flow enters the snow but never exists. These caves are really far worse traps the worst crevasse!

Final Remarks

The last day of the expedition was dedicated to the exploration of the crevasses as rear as possible to the camp. The aim is to test the hypothesis of the existence of groundwater in the ice body: the results seems to confirm the absence of such a water level.

The following few days were used to make a preliminary survey in another area of lateral flow, in order to improve the knowledge on the karst phenomena of this strange site.

In conclusion, even if it is evident that this expedition, due to is shortness, had not the possibility to allow a detailed observation of the karst phenomena of the King George island, was useful to put in evidence that even at this low latitude glacial karst systems may by hydrologically active.

Acknowledgement

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Figure Captions

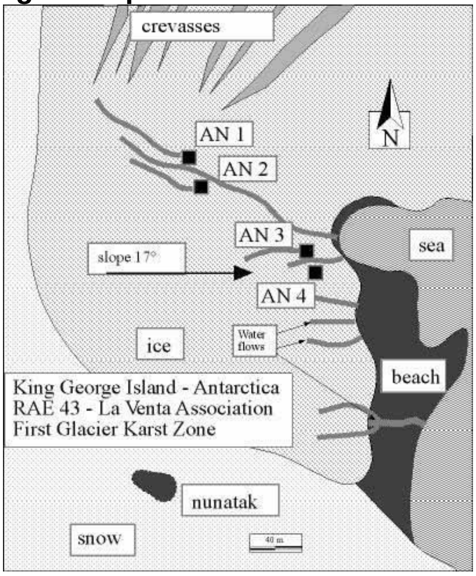

Fig.1 – Sketch of the explored area

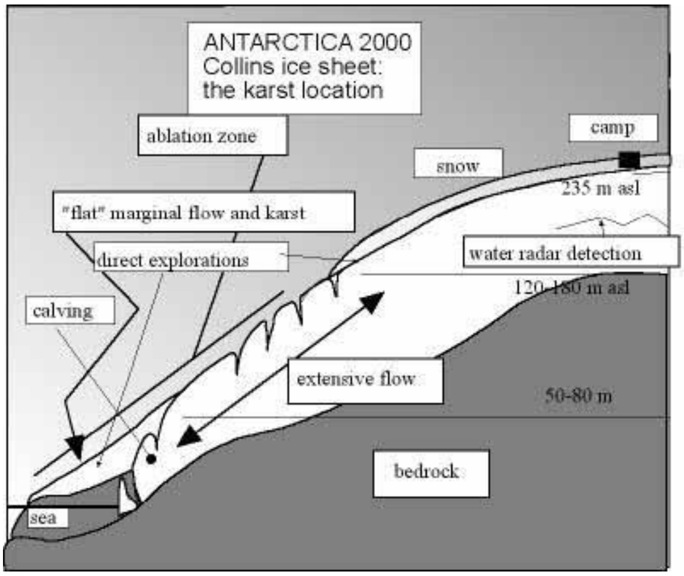

Fig.2 – Cross section of the explored area

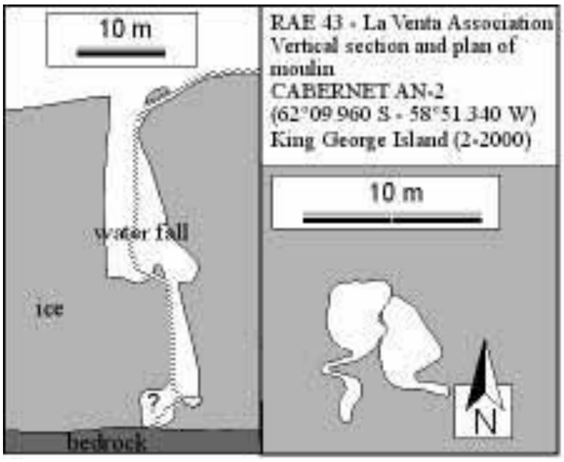

Fig. 3.1 - Map of the explored cave

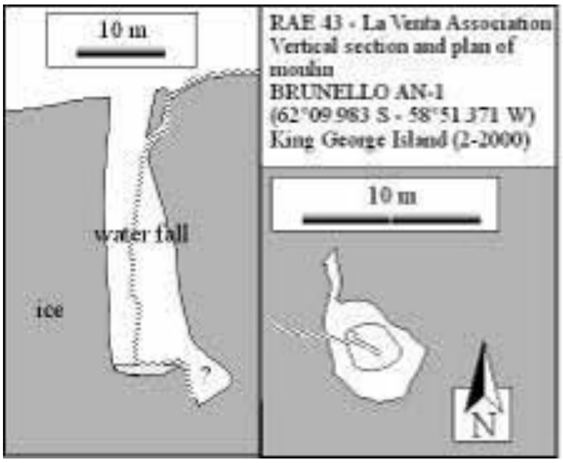

Fig. 3.2 - Map of the explored cave

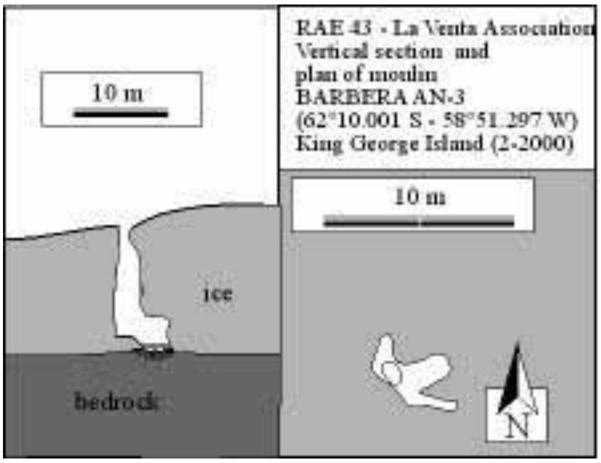

Fig. 3.3 - Map of the explored cave

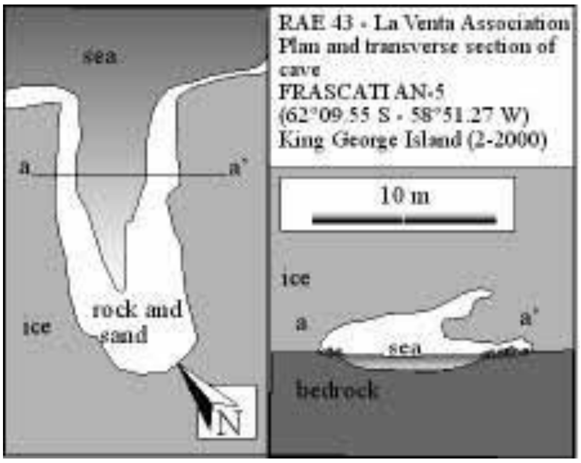

Fig. 3.4 - Map of the explored cave

About the Name Kras (Karst) in Slovenia

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Abstract

The term karst derived from the name of the karst plateau called Kras in Slovene, Carso in Italian, and Karst in German. In the antiquity it was called Carsus, Carusadus, Mons Carusad, etc., which came from the root *kar/gar, kara/gara*, meaning rock, stone. In the literature there are known numerous examples of names derived the base *kar(r)a/gar(r)a.* Furthermore the word of the regional name Kras in the Slovene language has also a common meaning, that is a rocky, stony, no good or useful (for cultivation or pasture) part of land. In Slovenia it is possible to find many names derived from kras. When we are talking about the term "karst" we are usually considering only the direct link **kar(a)/gar(a)* ->Carusadus -> Kras (Karst, Carso). But beside the regional name there are numerous names, as toponyms, names of geographical and morphological features, of settlements, and of waters derived from this root.

The international term karst derived from the name of the karst plateau in the background of Trieste bay (Adriatic sea), on the Slovene-Italian border, called Kras in Slovene, Carso in Italian and Karst in German language. It covers about 440 km2 (40 km long and 13 km wide) and lies at 450 45' N and 140 E. The altitude is between 200 – 500 m. To the SW it is bounded by Trieste bay, a low lying flysch coast; to the NW lies alluvial Friuli (river Soča – Isonzo) plain; to the NE is low lying alluvial and flysch valley of the Vipava river; to the E and SE there is higher flysch terrain (Brkini hills) crossed by the Reka river, and limestone country continues towards SE, through Istria and along the Adriatic coast. The plateau itself consists of Cretaceous and Tertiary carbonate rocks (KRANJC, 1997).

From the 15th century on, for the travellers coming from the Central Europe (specially from Vienna) towards Trieste, the only possible route passed the country Kras. And between Postojna and Trieste they passed the only "authentic" karst landscape. The traffic intensified specially after 1719 when Trieste got the status of "free port". The geographers, cartographers, cosmographers, and topographers (Aistingerus, Cluverius, Mercator, Merian, Münster, Ortelius), scientists of the epoch (Agricola, Baucer, Faber, Kircher) and travellers (Brown), published the descriptions of Kras and its phenomena and thus being the predecessors of modern scientists. Most of the descriptions were published in German language, using German version of the name, which is Karst. At the same time travellers were observing similar phenomena in other limestone countries and compared them with features of the Kras. Knowledge attained so far shows that F. J. HOHENWART (1830) was the first who explicitly wrote in the preface of his guide-book to Postojnska jama cave that Karst stretches from Udine province over the whole of Dalmatia, Dubrovnik, Albania, and a part of Bosnia. In the middle and the second half of the 19th century specially geographers and geologists began to write about Karst and karst phenomena in a larger sense, as for example A. MORLOT (1848) of karst limestone (Karstkalk). Finally at the end of the 19th and the beginning of the 20th centuries term karst became general term as showed by the titles of the then published main works: 1895 - Das Karstphänomen (CVIJIĆ, 1893), Karsthydrographie (GRUND, 1903), Die Seen des Karstes (GAVAZZI, 1904), and Das Karstphänomen ... (PENCK, 1904). In the antiquity the country, which was in Roman times a part of "Regio X – Venetia et Histria", was called Carsus, Carusadus, Mons Carusad, Karusad and similar. Predecessors of modern Slovenes who started to settle nowadays territory of Slovenia in the second half of the 6th century, turned *kar* according to the early metathesis in the Slovene language (family of Slavic languages) into *kra* and thus we got the name Kras (RAMOVŠ, 1995). The first written name of Kras is recorded in a document from 1177, in the form of Grast. Italian form Carso and the German Karst are nearer to the original form, while Slovene name Kras changed slightly more. Most of linguists dealing with this problem agree that the name Carsus, Karst and Kras has the pre-Indo-European or Indo-European root *kar(r)a/gar(r)a*, meaning rock, stone. From the literature there are known numerous examples of the names derived from the pre-Indo-European base *kar(r)a/gar(r)a* in the large regions of Europe. This base was first seriously studied in 1935 by M. G. ALESSIO. The same base covers different forms **kal-, *gal-, *kar-, *gar-*, also **al-, *ar-* after the fall of the first consonant, and even like in Greek **l-* or **r-.* The same radical can be in the full form **kal-* or in the reduced one **kl-.* To the mentioned eight forms for the same base **kl-, *gl-, *kr-, *gr-* can be added. From this it can be seen what perspectives are given by this system to the field of toponymic research.

Initially **kal-* meant stone, later shelter made of stone, and finally house, fortress or village. There are numerous examples in France: Chelles, Challes, Chalo, Chalou, Caille, Challans, etc. Typical form of karstified French coast are small bays called calanques, calanco in Provençal and calanche in the language of the Corse. The prototype was **kal-anc-us*. Also the name of the karst plateaux in France, Causses, has his origin in **kal-*. **Kar-* appears in composition in the name of the town Carcassone. For us are more interesting La Cra and La Crai in Burgundy, and specially the toponym La Cras in the same region. Well known rocky plane in the delta of Rhone the Crau came from the form **kr-* (ROSTAING, 1974). Not only the toponyms, from the same base derived also the names of other phenomena important for karst: karren from **kar-*, and the French expression for the same, clapier, from **kl-*. While garrigue (typical vegetation association on the karst of the Southern France) came from **gar-*. Base ***kr-app-** is known also from Slavic languages, Albanian and “Piemontian”. Slovene expression for **kar**ren and clapier is š**krap**lje. Is it the same base, **kr-app-*? In Croatian language, the word *krš* means karst. The same (*krš-)* is the root in an old Indian language for the verb to plough, to till, the original meaning being to scrape, to scratch (VREČAR, 1984).

In the Slovene language the most of the study of this base was carried out by BEZLAJ and published in “Etymological Vocabulary of the Slovene Language” (1976, 1982, 1995). The words like kal, kar (limestone rock), karati, Karavanke Mts., Koroška (Carinthia), Kranj, Kras, skala (rock), etc. are treated there.

The name Kras and its connection to the root meaning rock, is not problematic. As mentioned already, besides the regional name Kras the word in the Slovene language has also a common meaning, that is a rocky, stony, no good or useless (for cultivation or pasture) part of the land. In nowadays Slovenia as well as on the whole territory which was settled by the Slavic tribes between the 6th and 8th centuries, it is possible to find a lot of names containing “kras”. That is in that part of the Eastern Alps as far as the springs of the rivers Drava and Mura, where the border with the Bavarians has been stabilised on the main ridges of the Central Alps. These are either names of small regions (plateaux, ridges, etc.), or plots of land, different smaller settlements (villages, hamlets, farms), etc.

Just browsing the main lists of names such as Encyclopaedia of Slovene place names (SAVNIK, 1968; 1971; 1976; 1980), Atlas of Slovenia (1: 50.000), Field terminology (BADJURA, 1953), Terminology of Julian Alps (TUMA, 1929), and Toponyms of Istria (TITL, 1998; 2000) a lot of names which are linked with *kras* can be found. Besides *kras* as a general term there are words in Slovene language linked to *kras,* that is to **kar-,* which means rock or rocky, barren land: *krasica, krasina, krašce, krašèina, krašica,* and *krašnja* (BADJURA, 1953). These words are often the base for toponyms too. In the north-western Istria (TITL, 1998) only there are 35 geographical names called *Kras.* In the same region besides the name *Kras* there are also 51 toponyms linked to this word: *Kras* (21 examples), *Krasiè* (3), *Krasica, Krasnice*, *Krašca*, *Krašèe* (4), *Krašèica*, *Krašèiè*, *Krašna*, *Kršiè*, *Kršin* (5), *Kršini*, *Kraška njiva*, *Laniški kras*, *Nad kršinom*, *Na krasu*, *Na kršini*, *Pod kršinom*, and *Spodnji kras* (TITL, 2000). The word *kras* is also the base for forming toponyms in the Julian Alps belonging to the Southern Limestone Alps consisting mainly of carbonate rocks (Mesozoic limestones and dolomites) such as *Kras, Krase, Kras(i)ce, Krasje, Krasji vrh, Na kras, Ostri kras, Vodenièni kras* (TUMA, 1929). In the whole Slovenia there are 10 names of settlements (villages and hamlets) connected with the word *kras: Krasce, Krasinec, Krasna, Krasno, Krašèi, Kraška vas, Krašnja, Krašnji vrh, Krsinji vrh,* and *Kršiè* (SAVNIK, 1968; 1971; 1976; 1980). In the Eastern Alps, where there are no more Slovenes, isolated farms can be found, and their names are based on the word *kras* as well*: Kras, Krass, Krassbach, Krasswald,* and *Krastal* (BADJURA, 1953). Looking the modern Atlas of Slovenia (KOS, 1996), including parts of Southern Carinthia (where Slovenes are living too) and parts of Istria, belonging to the state of Croatia, there are 40 names connected to *kras*. The most numerous are the names of settlements, hamlets and isolated farms (*Kras, Krashitz, Krasica, Krasinec, Krasna, Krasnica, Krasnig, Krasnik, Krasno, Kraßnitz, Krast, Krastiæi, Krašce, Krašèi, Krašèiæi, Kraševec, Krašine, Kraška vas, Kraški Vrh, Krašnja, Krašnji Vrh*) followed by names of geomorphological features *(Kras, Krasca, Krasiæ, Krasine, Krasje, Krasji vrh),* toponyms *(Kras, Krasca, Kraškašija),* and only in one case of streams *(Krašiæevica)*. Very interesting but relatively long lasting task would be the search through the toponyms on the maps of small scales (1:25.000, 1: 10.000 or 1:5.000) existing for the territory of Slovenia.

When we are talking about the term “karst” we are usually considering only the direct link **kar(a)/gar(a)* › Carusadus › Kras (Karst, Carso). But in fact it is only one of the regions, which got the name from stone, regarding its stony character. There are other regions too, bearing the names from the same root. And beside the regional names there are numerous names, as toponyms, names of geographical and morphological features, settlements (from towns to hamlets and isolated farms), and waters. On the Slovenian territory there are tens, maybe hundreds of them. It is proved that such names are covering the territory of the best developed karst in Europe: from Dinaric Mountains through the Alps to the karst of Provence and Southern France. The word for stone is used in many languages in the form very near to the root, such as *ker, èer* in the Slovene language, *kar, karren* in German, *cairn* in Irish etc.

Is it possible that one of the first known ethnic groups living also on the territory of nowadays karst in Slovenia named Carni, got its name from the "rock" because they lived in Carnia – Rocky country? Although the science of karstology is very young, its name is old, deriving from one of the first known languages in Europe.

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Expedition Atahuallpa'2000

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Abstract

The **Project Atahuallpa** is the result of three years of research in which many data were collected and continuous exchange of scientific publications took place. The target was the Sole and Koa Island situated at e Titicaca Lake. The main objectives were first the choice of a selected bibliography and documents, hen the personal meeting with the local staff and finally the geographic exploration. During the research many disciplines such as Geology, Hydrogeology, Archeology and Hyperbaric Medicine were employed.

The **EXPEDITION ATAHUALPA 2000** was very successful and the staff from ***AKAKOR GEOGRAPHICAL EXPLORING SOCIETY*** had synthesize modern concept of exploration involving 26 researches and technicians from three different countries: Italy (10) Brazil (10), Bolivia (6) who during the twenty working days did 250 scientific dives, botton measurement, physical and chemical water analyses, topography, archaeology survey, geography, geology, underwater and land chemistry, forty five hours of film and four thousands of photos. It was also realized medical studies related to the divers behave in relation to the high altitudes.

It was discovered in a broad area at the depth from ten to thirty meters deep the remains of a temple, a road and some terrace provably related to each other. During the exploration was recuperated from the lake three vases, ceramics and many handworks from the Inca period showing that the theory we based was right, the level of the lake was much higher and the coast line quite different.

The AKAKOR GEOGRAPHICAL EXPLORING Association

The ***AKAKOR GEOGRAPHICAL EXPLORING*** Cultural Association is a research team born in 1992 with the purpose of carrying out technical-scientific expeditions, developing projects and cultural exchanges within many accomplishment areas. The old exploration concept searching to discover new lands, now on the verge of the third millennium, takes a new global form doing depth analysis and multipurpose developments.

There's a lot still to discover. In the more remote regions of the earth there are unexplored places that keep extraordinary secrets and offer the opportunity to write new pages of human and natural history allowing important experiences relating at numerous possible interactions between well-known sciences.

Why Carry out Studies on Titicaca Lake

The ***Atahuallpa Project*** takes its starting point from data collected during three years of search and reconnaissance.The constant exchange of scientific publications provoked considerable interest in our staff to undertake several sistematic research.The area in this Expedition is the Sun and Koa Islands situated in Titicaca Lake at the foot of the Real Cordigliera and connected to a series of mystic events. There are also the hypothesis of a lost city in the depths of the lake.

Now the Titicaca lake is what remains of the ancient inland sea known as Ballivan lake. A long time ago this lake covered most of Altopiano before the lowering water level which was provoked by thrusts and evaporations. The principal objectives were chosen first among sellected bibliographies and documentations and then to the direct and personal meeting with the local people and the geographical reconnaissance.The results obtained were satisfactory thanks to collaboration of Italian Consulate in Bolivia and Bolivian Cultural Department that put at our disposition three archaeologists from National Archaeology and Anthropology Institute- areas which had been identified and were object of our search. The collected data were compared and processed with synergic viewpoint to produce a global completely integrated target. Division of labour was an operative approach that allowed the choice of the partecipants, the citizen contact, the requests and permits, the partnership and the structural logistic.

Atahuallpa Project – Pianification

The previous research and contacts had a positive outcome then the possibility of undertaking the expedition of ***Atahuallpa Project*** became reality. In the first phase had been planned five expeditions to be realized in a period of 4 years. The waiting time between each phase would depend on the results of each one.

1 .December 1995 Duration: 30 days
Objective: territory understanding – physiographic investigation, contact with local entity and authority.

2 .December 1997 Duration: 16 days
Objective: advanced reconnaissance – First logistic planning, territory investigation

3 .August 1998 Duration: 6 days
Objective: to collect rock specimens for geological studies - Hydro-geology investigation.

4 .July 1999 Duration: 10 days
Objective: underwater reconnaissance, territory understanding, agreements with entity and authority.

5 .Decembre 1999 and January 2000 Duration: 25 days
Objective: final check for organization and determination of logistic planning.

Development

The research work of the expeditions involved different disciplines to achieve targets in the following fields:

- Geology
- Hydro-geology
- Archaeology
- Hyperbaric medicine

A series of activities was planned keeping in mind the principal areas of difficulty, namely the inaccessibility of the area, the difficulty of travelling and moving within the territory itself, the vast area of research, the problems of diving at high altitudes, etc. Work groups were formed based on the research programmes decided upon, which would operate separately in the first phase, coming together in a global multidisciplinary structure afterwards.

first phase, coming together in a global multidisciplinary structure afterwards.

Targets

The objectives of the ***Atahuallpa 2000*** Expedition are the following:

- To locate and to study sites of archeological i nterest, using land-based and underwater research
- To study the geology and hydro-geology of the area in question
- To collect rock specimens for geological studies following predetermined technical indications
- To realize medical studies related to the dives at high quota
- To realize film and photographs of a documentary nature
- To realize documentative publications
- To effect communications using underwater apparatus linked to a satellite system able to transfer data live directly on-line
- To realize three stages of technical dives - underwater archeology, dives at high altitude and scientific dives
- To collect data to aid the development of 'green tourism' in the area
- To compare the technical and cultural experiences of the team members from the different participating countries during the various activities of the expedition.

Location

The ***Atahuallpa 2000*** Expedition took place in Bolivia on the shores of Lake Titicaca, roughly 150 kms from La Paz, in the region of Copacabana in the Islands of the Sun and the Moon and the Straits of Tiquina. Three base camps were planned:

Principal Base Camp: Copacabana

First Advanced Camp: Island of the Sun

Second Advanced Camp: Island of the Khoa

Third Advanced Camp: Island of Pallalla

Fourth Advanced Camp: Peninsula of Yampupata

Titicaca Lake	
Altitude	3812 metri
Surface Area	8400 km²
Maximum Depth	283 metri
Maximum Length	176 km
Maximum Width	70 km

Logistics

- Documentation: team responsible for the organisation, filing and use of all the documentation relative to the expedition (maps, aerial photos, satellite pictures, books, magazines, Web sites, etc.), from the preparatory phase to the publication of the results.

- Nutrition: a nutritional programme has been studied exclusively for the team members for the time spent at the camps, based on the need for vitamins and energy .

- Materials: team responsible for the availability, maintenance and distribution of the collective resources in use during the expedition (climbing equipment, underwater equipment, instruments for geographical locating - GPS, topography, etc.)

·- Communications: team responsible for the setting-up of communication channels between base camp and the external teams, and the maintenance of international connections both vocal and of data (portable receiver/transmitters [walkie-talkies] and radio-telephone links, both land-lines and satellite, specific systems for use in caves and experimental underwater communicators, use of Web pages).

- Didactics: team responsible for the specialised underwater training stages.

- Topography: team responsible for topography and the surveys of the areas and sites explored and studied.- Exploration: team responsible for the job of carrying out explorations and precise geographical identifications, submitting daily reports to transmit to the topography and underwater exploration teams, and for specific studies.

- Subaqua: team responsible for underwater exploration, topography, archeology, realization of images and collection of targeted samples.- Geology and Hydrogeology: team responsible for geological surveys of the caves and the area.

- Archeology and Anthropology: team responsible for surveys and studies of the sites.

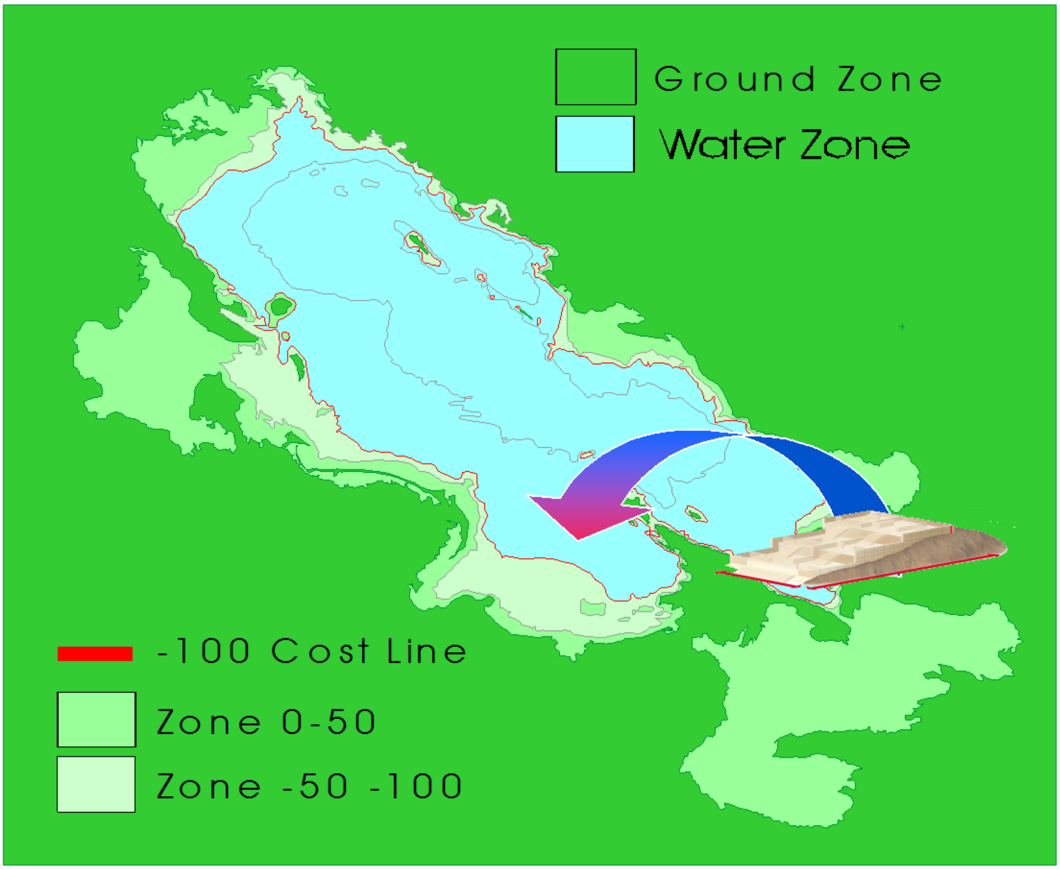
- Medicine: team responsible for the study of the physiological reactions of the team members and medical assistance to the members of the expedition.

Preliminary Relation

THE AKAKOR GEOGRAPHICAL EXPLORING Onlus with the Expedition Atahuallpa 2000 resumed the modern exploration idea, involving 26 researchers and technicians coming from different nations (10 from Italy, 10 from Brazil, 6 from Bolivia), that have produced very important geographical and scientific ideas about one of the unknown areas of our Planet, especially related to the lakebed of Titicaca Lake, Bolivia.

The ***AKAKOR GEOGRAPHICAL EXPLORING*** team, composed of explorors and researchers with several specializations, realized many of the proposed objectives Project by the way of explorations and high-tech researches, experimenting new methods and unconventional technologies, carried out by long multidisciplinary experiences, aerial recognitions, immersions in rarified atmosphere, travelling on tableland and unknown land exploration.

During the 20 operative days, 250 explorative dives have been made, seabed survey, chemical-physical water analysis, topography, archaeological geographic and geological relief (underwater and terrestrial), carring out movies and more than 4000 photographs.



Water Level Variation at TITICACA Lake

Some Results

The results broady superated all the expectatives and the most striking results took place.

The discoveries which certainly comprise the ruins of a vast cerimonial area are at ten to thirty meters deep.

It was also found a 700 meters long road, some terraces and protection walls, probably related each other, ceramics and lhama bones which were used for religious purposes.

Conclusions

The interaction developed during the expedition showed that we fulfil the main objectives of the expedition, which were not only the use of the most advanced exploration and research among the most developed in the world employing methods and non-conventional technics but also the social objectives using the different experiences of its members in the multi-disciplinary fields due also to a broad differences in ages.

Aknowlegments

Atahuallpa 2000 Expedition's collaborators are: Italian consulate in Bolivia, SBE - Brazilian Speleological Society, SOBESP - Bolivian Speleological Society, SSI - Italian Speleological Society, FEALC - Latin America and Caribbean Speleological Federation, CIRSS - Italian Committee for Underwater Studying and Research, CMAS - Confederation Mondiale des Activites Subaquatique, IBAMA/CECAV/DIREC - Instituto Brasileiro do Meio Ambiente, DINAAR - National Archaeology and Anthropology Institut, Bolivia, ALT - Titikaka Lake Binational Authority (Perù and Bolivia), Bolivian Naval Force by Naval Command in Tiquina, ACT - Torotoro Preservation Association; TESTO; EBM; ARISTON; ENTEL; SCUBASUL; LLOYD AEREO BOLIVIANO; ICEMEN; WINTER & SUMMER; BIOTRIP; NUTRIMENTAL; PRAXAIR; VIAGGI MENTASTI; MEDILAND; MARES; OCEAN REEF and all the bolivian friends who helped us to realize this research.

Entre o Sagrado e o Profano:
A Romaria da Gruta de Terra Ronca (GO)

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Summary

Between the sacred and the profane: The “Terra Ronca” Pilgrimage Cave (Goiás, Brazil)

This work relates how the “Terra Ronca” cave, the best known of the São Domingos (Goiás, Brazil) speleological complex, has been transformed into a pilgrimage site. This works deals also with how the transformation of this complex into a conservation unit is endangering the cultural inheritance of Bom Jesus da Lapa.

1 - O Espaço do Sagrado em Terra Ronca

Todos os anos nos dias 5 e 6 de agosto, na Lapa da gruta de Terra Ronca I ocorre uma expressão da fé católica, a manifestação cultural-religiosa, denominada de a Romaria do Bom Jesus da Lapa. Este acontecimento, constitui-se como maior patrimônio cultural do Parque Estadual de Terra Ronca – PETeR, uma unidade de conservação localizada no município de São Domingos, no Estado de Goiás, criada para preservar um complexo espeleológico.

A realização da romaria do Bom Jesus da Lapa em Terra Ronca, tem seu início perdido na memória dos que ainda vivem e contam sua história. Não existem escritos que relatem seu surgimento ou que façam menção sobre esse evento, exceto os livros da Igreja Católica, única fonte de informação escrita conhecida.

Os moradores do município relatam que na época do início da romaria, a comunidade de São Domingos era assistida por padres missionários que percorriam as cidades e povoados da região celebrando missas, casamentos, batizados e ouvindo confissões em uma atividade da Igreja conhecida como desobriga. Estes missionários eram conhecidos por padres viajantes e pertenciam a congregação dos padres claretianos. As primeiras celebrações em Terra Ronca foram realizadas por esses padres viajantes e, ainda de acordo com os relatos de moradores e antigos romeiros, um padre viajante por nome Luís foi quem incentivou os fiéis a pagarem seus votos e promessas na Lapa de Terra Ronca I, ao invés de fazê-lo na Bahia, sendo também esse o motivo pelo qual a romaria é realizada nos dias 5 e 6 de agosto, período no qual se realiza a romaria em Bom Jesus da Lapa, na Bahia e que no calendário católico corresponde ao dia da transfiguração do Senhor (06 de agosto). O padre em questão chamava-se Luís Olabarrieta e foi designado para a paróquia de São Domingos no ano de 1935.

2 - Histórico

Há relatos de que a gruta serviu de refúgio para algumas famílias que fugiam da violência dos “revoltosos”, denominação que a coluna Prestes recebeu quando esteve no município de São Domingos, no ano de 1925. Na “Era de 25”, como dizem os habitantes de São Domingos ao se referirem a esse fato histórico. Por esse motivo, pode-se concluir que por esse período a gruta da Terra Ronca ainda era um local de difícil acesso e desconhecido por muitos e não um ponto de concentração de pessoas, como o seria se lá ocorressem celebrações religiosas. Também não foram encontrados relatos de celebrações no local durante esse período.

De acordo com o Livro de Tombo da Paróquia de São Domingos, aberto em sete de julho de 1928, no qual o padre José Maria Marti, nas páginas 14 e 15, relata sua desobriga do ano de 1929, o local já era de romaria mas não sistematizada. Dele foi extraído o seguinte trecho dos escritos do referido páraco:

Em Terra Ronca visitei a importante e celebre Lapa, onde entra misterioso o Rio de igual nome. Vai gente a fazer e deixar promessas ou ex-votos, principalmente ao Bom Jesus da Lapa e tem conseguido graças, como atestam os ex-votos que ali achei.[6]

Fui no dia vinte e três de abril, de tarde, acompanhado dumas quinze pessoas.

Deixei um pequeno crucifixo de metal, que me ofereceram o dito crucifixo na Capital da Bahia faz anos, perante ele celebrei muitas vezes nas desobrigas.

Perante ele rezei 3 padres nossos ao Bom Jesus da Lapa e cantei um bendito com os circundantes, pedindo que anunciassem e espalhassem a voz que tinha sido por mim colocado, para que ninguém tirasse.

Perante o dito crucifixo ascendi também velas e coloquei em volta dele as promessas que achei.

Prometi, com o auxílio do divino, dar missas lá este mesmo ano.

Fiz tudo isso para não virar lugar de superstição e possa no futuro ser centro de piedade e devoção.

Na página 19 desse mesmo livro, o Padre José Maria relata como ocorreram as primeiras celebrações em Terra Ronca:

Nos dias vinte e seis e vinte e sete de setembro de1929 houve missas na Lapa de Terra Ronca e terço nos dias vinte e cinco e vinte e seis.

Em frente da Lapa, foi levantado um artístico cruzeiro com as datas do dia da colocação da imagem do Senhor Bom Jesus na Lapa, do dia da primeira missa nela celebrada e do dia do erguimento do cruzeiro; fazendo a benção o Padre Benedicto.

Houve muita afluência de povo, eu não pude ir por causa de moléstia na véspera da viagem.

(...)O Reverendíssimo Vigário da Posse salvou a situação. A romaria pegou graças ao Bom Jesus.

O local dessas primeiras celebrações é uma várzea, um tipo de vegetação que recebe a denominação local de vargem, localizada a aproximadamente 500 m a frente da boca da caverna. Ao pé do cruzeiro eram então realizadas as missas, sendo celebradas pelos padres viajantes em desobrigas. No local ainda hoje são encontrados partes desse cruzeiro e dois túmulos onde foram sepultados duas crianças, irmãs, como era costume na região. Os túmulos erguidos pela mãe das crianças, próximos do cruzeiro, facilitam a identificação do local, já que do cruzeiro só resta parte do pedestal.

Outro marco identificador utilizado para se encontrar o local da primeira celebração do Bom Jesus da Lapa em Terra Ronca é um agrupamento de jatobás que se destaca na várzea e se interpõe entre o que resta do cruzeiro e a boca da caverna.

Relatam os antigos romeiros que o acesso à gruta era impedido por uma mata densa, com muitos cipós, além do que para se chegar à gruta era preciso não só atravessar a várzea e a mata mas também o Rio Lapa, já que não existiam as pontes, hoje presentes.

Após a primeira celebração, o padre Leopoldo Ripa passou a visitar sistematicamente a Lapa da Terra Ronca e a partir de 1941 o padre José de Oliveira passa a marcar pouso naquele local.

Em um livro de casamentos e batizados da Paróquia de São Domingos de Gusmão, Diocese Imaculado Coração, do município de Formosa em Goiás, foram encontrados as seguintes anotações de celebrações em Terra Ronca: no dia 23 de abril de 1929, 21 batizados e 03 casamentos; em 18 de agosto de 1929, 01 batizado e vários casamentos; no dia 19 de agosto de 1929, 15 batizados e vários casamentos e em 26 de setembro de 1929, vários batizados e casamentos, sendo essas as informações possíveis de se obter sobre as primeiras celebrações na Lapa da Terra Ronca.

3 - As Primeiras Romarias

Pelos relatos colhidos, a romaria foi iniciada pelo padre José de Oliveira, no ano de 1948. (Tombo, pag. 91) A princípio era um acontecimento apenas religioso, restrito a gruta, considerada um local sagrado, de veneração.

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[6] Uma clara referência ao fato de já ser um local freqüentado com fins religiosos.

À página 91 do Livro de Tombo encontra-se um Resumo Ministerial de 1948 que diz: *Iniciou a Romaria da Lapa de Terra Ronca. O povo tem devoção ao Bom Jesus. Se os vigários futuros a cultivarem terá movimento avassalador.*

A majestade da abertura da gruta, a mistura entre a vegetação e as pedras, a sensação de amplitude, tudo colaborava e colabora para tornar místico o local. O rio ladeado por uma mata, penetrando gruta a dentro, sob a cúpula formada pela projeção da boca da caverna em sua forma de ogiva, transmite uma sensação de plenitude, manifestada por muitos dos romeiros.

O movimento crescia, *a cada ano tinha mais gente no interior, notando-se grande devoção e confiança do povo no Bom Jesus* (Tombo, pag. 91).

Com o passar das anos começaram a aparecer os comerciantes e, conseqüentemente, as manifestações festivas. A festa pagã, que se realizava do lado de fora, caracterizava-se por um intenso comércio de comidas, bebidas, roupas, calçados e os mais diferentes produtos. Era a oportunidade das pessoas da região adquirirem mercadorias apenas disponíveis nas cidades, que se faziam distantes para serem alcançadas em lombo de cavalos ou carros de boi em estradas cavaleiras.

O transporte dos produtos era feito em carros de bois e os pastos das redondezas ficavam ocupados pelas montarias dos romeiros. Tanto no aspecto da peregrinação religiosa quanto pelo caráter pagão de diversão e comércio, a cada ano ocorria o aumento do número de romeiros,. Mas, sob o ponto de vista religioso esse crescimento não era bem recebido pela igreja, pois, a página 101 encontra-se a seguinte observação feita pelo pároco do município:

O senso espiritual que deveria cunhar uma Romaria religiosa fica muito aquém da realidade. O número de confissões e comunhões: deficientíssimo. O diabólico meretrício tem sua nesgazinha. Os bailes desrespeitam a solenidade. A franquia em venda de bebidas alcólatras, tem acarretado não poucas conseqüências desagradáveis, deixando cair tonalidades a fortes comentários desairosos, a tais iniciativas católicas.

O movimento de pessoas era considerável, em 1958 foram contabilizadas 3.500 de acordo com as anotações do padre Geraldo Ferracioli, pároco de São Domingos.[7]

Os romeiro eram oriundos dos mais diferentes lugares mas, principalmente, da região de São Domingos e municípios próximos: *Em sua totalidade absoluta goianos de vários municípios. Cumprir votos, já aportaram alguns baianos e mineiros.*

Esse mesmo padre, em um outro trecho, faz referência à magnitude da caverna, quando afirma que a Lapa da Terra Ronca *pode agasalhar, em seu corpo, uma boiada de mais de duas mil cabeças.*

Os romeiros vinham para permanecer por vários dias. Acampavam próximo a gruta ou nos quintais das fazendas próximas.

De acordo com o depoimento de Maria Aparecida dos Santos (35 anos), o pagamento das promessas era acompanhado por queima de fogos de artifícios. Os romeiros soltavam foguetes, tanto no interior quanto no exterior da caverna, e a queima de fogos provocou a completa destruição das estalactites que adornavam o salão que abriga a romaria.

4 - A Construção do Altar

Como conseqüência da romaria não foram realizadas quaisquer outras alterações no interior da gruta, além da construção do altar onde eram e são celebradas as missas, casamentos e batizados.

Segundo relatos de D. Isabel Maria Barbosa dos Santos (80 anos), proprietária, moradora da Fazenda Lapa, em cujas terras se localiza a Lapa de Terra Ronca I e viúva do senhor Antônio Hilário dos Santos, conhecido como Antoninho da Lapa, foi seu esposo quem construiu o altar junto com o viajante Pe. Jesus que veio de Formosa. Ele, Seu Antoninho e seus filhos carregaram pedras para erigirem o altar, inclusive pequenos seixos para dar acabamento e ornamentá-lo.

Ainda de acordo com depoimentos de D. Isabel, antes da construção do altar já eram celebradas missas e casamentos e, diz ela, que quando menina, morando em São Desidério, na Bahia, ela ouvia as pessoas

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[7] Página 101 do livro de Tombo.

falarem e saírem em rumo a Terra Ronca para pagarem promessas. Dona Isabel nasceu em 1920 e mora em Terra Ronca na fazenda Lapa desde 1936.

Os relatos dessa senhora condizem com as anotações do livro de Tombo, página 101, onde está anotado que em 1953 o altar foi construído pelo padre Jesus Osés contando com o auxílio de seis operários.

O altar é o único sinal da realização da romaria. Ele, hoje como no passado, mantém a simplicidade de sua origem, com as imagem que o ornamenta acompanhando esta simplicidade. Sobre ele são depositados votos, fotografias e acesas velas.

Como no passado, as celebrações são realizadas com a maioria dos fiéis romeiros de pé, em um semi-círculo de frente para o altar. Os demais se espalham por sobre as inúmeras pedras que circundam o altar ou que se espalham no interior da gruta ou participam das celebrações por sobre a ponte do Rio Lapa, no interior da gruta.

Uma reentrância natural da caverna, localizada na lateral direita do altar, apesar de ser de pequena dimensão funcionou como sacristia durante o período inicial da romaria. Na atualidade encontra-se parcialmente desativada, sendo denominada de Salão dos Milagres e é onde estão depositados alguns dos votos dos romeiros.

Um sino trazido de São Paulo e inaugurado em 1952 pelo Padre Geraldo Feracioli desapareceu.

Lapa é o lugar do nascimento do Cristo, no entanto, no altar de Terra Ronca está o Cristo Crucificado, o Bom Jesus da Lapa.

5 - A Romaria nos Dias Atuais

Com o passar dos anos a romaria tornou-se tradição entre os dominicanos e moradores dos municípios próximos. Milhares de pessoas, por ocasião do festejo, se deslocavam até a gruta para cumprirem a tradição, pagarem votos, casarem, batizarem seus filhos ou a si próprio e, de uma maneira ou de outra, participar daquilo que se transformou na maior manifestação popular da região, a Romaria do Bom Jesus da Lapa, ou mesmo apenas para se divertir, participando da festa pagã ou ainda, apenas para fazer suas compras nos mascates.

Porém, a romaria encontra-se ameaçada por dois fenômenos próprios à modernidade.

A construção da rodovia GO-108, em substituição da estrada cavaleira e a criação do Parque Estadual de Terra Ronca são instrumentos de mudança da forma dessa manifestação popular de fé. A cada ano que passa o número de romeiros torna-se menor, fato que pode, entre outros, ser, sobretudo, creditado a estes dois fatores.

A facilidade de acesso reduz o número daqueles que acampam próximo à gruta. Como a maioria deles são provenientes de São Domingos, ou de municípios vizinhos, com a estrada, mesmo não sendo pavimentada, é possível rápidos deslocamentos. Assim, os romeiros passam a se dirigir a caverna apenas nos dois dias das celebrações ou até mesmo tão somente no dia da romaria, 06 de agosto. A rodovia e os meios de transporte agilizam o deslocamento, permitindo, inclusive, que a pessoa vá, retorne para pernoitar, voltando no dia seguinte.

Outro aspecto a ser considerado, relacionado a redução do número de pessoas na romaria, é que a construção da estrada GO-108, também facilitou o acesso ao comércio das cidades para aqueles que residiam nas zonas rurais e que deixavam para adquirir o que necessitavam durante a realização da romaria, comprando dos mascates que montavam e ainda montam barracas próximas a abertura da gruta. Essa necessidade tornou-se menor com a rodovia porque, junto com ela, veio o transporte intermunicipal e uma maior facilidade de deslocamento para essas pessoas. Uma linha diária passou a ligar todos os moradores das redondezas com a sede do município e com municípios vizinhos, onde podem se abastecer do que necessitam como roupas, calçados, utensílios domésticos, entre outros produtos.

A criação do parque, no entanto, pode ser o fator que mais contribuiu para a redução do número de romeiros.

Quando Furnas enviou o montante de recursos referente a compensação ambiental pela construção da usina hidrelétrica de Serra da Mesa, da linha de transmissão Serra da Mesa-Samambaia II e da interligação Norte-Sul, parte das verbas oriundas do ajuste destes três convênios foram alocadas para a implantação do PETeR. Foi feito um contrato com uma organização não governamental de Brasília, a Gea – Brasil, para a elaboração do plano de manejo do parque.

Demonstrando desconhecimento do que seja o patrimônio cultural de uma unidade de conservação, desconhecendo princípios e objetivos da educação ambiental, como também que não só exemplares da fauna e flora se extinguem mas também elementos da cultura, os membros dessa organização, com a aquiescência do órgão ambiental responsável pelo parque, promoveram, em nome do princípio de áreas protegidas com a exclusão do homem - o mito da natureza intocada - um verdadeiro ataque a esta manifestação cultural.

Estabeleceram um rol de proibições relacionadas a maneira como o povo manifestava sua fé, que por medo à repressão imposta por esta organização, com o aval do órgão ambiental, os romeiros deixaram de comparecer. De acordo com relato de muitos deles, a tal ponto chegou a pressão contrária que muitos romeiros interpretaram e propalaram, que estava proibida a realização da romaria. Esse equívoco reduziu em muito o número de participantes.

Mesmo considerando a pressão exercida por milhares de romeiros transitando no interior da gruta, é fácil perceber que as alterações do patrimônio natural foram ocasionadas pelos foguetes soltados como parte da tradição. Dessa maneira, para a preservação do patrimônio natural, era suficiente a proibição de foguetes e o ordenamento do comércio da festa profana.

Assim, dois distintos fenômenos da modernidade. Distintos e opostos. Um, em sua face reconhecidamente perversa pelos ambientalistas - as estradas e o outro, em sua face propalada como positiva, a preservação ambiental, se somam para expulsar do horizonte cultural dos habitantes da região uma de suas mais longas tradições. Componente essencial à sua história e intrínseco á sua identidade.

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Livro de casamentos e batizados da Paróquia de São Domingos, 1928.

Depoimentos

Sr. Herculano Antônio de Lima (80 anos), pessoa que, junto com outros membros da igreja, carregou o cruzeiro e paramentos para a primeira missa na Lapa da gruta de Terra Ronca em 1948.

Sr. Biá (80 anos), residente no povoado de São João Evangelista, contíguo ao PETeR.

D. Isabel Maria Barbosa dos Santos (80 anos), proprietária e moradora da Fazenda Lapa.

D. Maria Aparecida dos Santos (35 anos), moradora de Terra Ronca.

Physical and Speleological Characterization of the Lauráceas State Park – PR / Brazil[8]

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Abstract

From October 1999 until October 2000 a physical environment research (geomorphology, speleology and hydric resources) was undertaken in the Lauráceas State Park (PEL). The PEL was created in 1979, having 27.000 ha (270 km^2) and it is the largest state conservation unit in the state of Paraná. After 20 years, since its creation, the park had not been studied. For this reason a Rapid Ecological Evaluation (AER) was chosen since data acquisition for large areas is faster. One of the main purposes of this AER was a study of the physical environment of the park to support the execution of a management plan. With the results of this research some basic guidelines could be established concernig the use and vocation for the park related to its physical characteristics.

Resumo

No período de outubro de 1999 a outubro de 2000 efetuou-se um levantamento do meio físico (geomorfologia, espeleologia e recursos hídricos) do Parque Estadual das Lauráceas (PEL). Criado em 1979, com cerca de 27.000 ha (270km^2), o PEL é a maior unidade de conservação do estado do Paraná. No entanto, até o presente, nenhum estudo referente ao meio físico havia sido realizado. Em virtude disso, optou-se pela execução de uma Avaliação Ecológica Rápida (AER), principalmente pela rapidez na aquisição de dados em áreas mais extensas. Um dos objetivos básicos desta AER, foi o de realizar um diagnóstico do meio físico do Parque, visando embasar a execução e implementação de um Plano de Manejo para a unidade de conservação. Através dos resultados obtidos, determinou-se algumas diretrizes básicas relacionados ao uso e à vocação do Parque em relação ao meio físico.

Localização

A região de estudo localiza-se no estado do Paraná (PR) próximo à divisa com o estado de São Paulo, compreendendo os municípios de Adrianópolis e Tunas do Paraná (Figura 01).

Objetivos

A presente AER teve como objetivos principais identificar as unidades geomorfológicas, bacias hidrográficas e feições cársticas da área do PEL. Além disso, realizou-se uma avaliação ambiental do meio físico verificando as possibilidades de uso e indicando alternativas para o manejo e proteção. Adicionalmente foram realizados levantametos topográficos e fotográficos das cavidades localizadas pelo trabalho.

Métodos

Para a execução desta AER tomou-se como base algumas informações preliminares existentes sobre a região, obtidas pelo GEEP-Açungui, principalmente no que diz respeito à espeleologia. O levantamento do meio físico foi desenvolvido em duas etapas, nas quais foram empregadas diversas técnicas e métodos:

a) Atividades de Escritório

pesquisa bibliográfica;

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[8] Artigo viabilizado pelo Programa Proteção da Floresta Atlântica-PR, cooperação financeira Bilateral Brasil/Alemanha, Governo do estado do Paraná (SEMA) – Governo Federal da Alemanha (Kreditanstalt für Wiederaufbau/KFW).

interpretação de fotos aéreas na escala 1:35.000, datadas de dez./1997, com a finalidade de identificar a rede hidrográfica, os divisores de águas, os padrões estruturais e geomorfológicos e os indícios espeleológicos;

análise comparativa entre os dados obtidos sobre as bases cartográficas, mapas geológicos e fotos aéreas, a fim de pré-delimitar as áreas de interesse;

os indícios espeleológicos e/ou acidentes geográficos relevantes, localizados a partir da fotointerpretação, foram plotados em bases cartográficas para uma correlação imediata com estas;

confecção de mapas, croquis e relatórios com os dados levantados na fase de campo;

b) Atividades de Campo

prospecção dos dados organizados em escritório e informações junto à população local;

obtenção de coordenadas geográficas com auxílio do G.P.S., para localização das cavidades, elementos cársticos e/ou acidentes geográficos relevantes de cada região;

coleta de dados dos pontos de interesse observados em campo para preenchimento das fichas da AER;

levantamento fotográfico das cavidades e elementos de interesse localizados durante a fase de campo;

análise da situação ambiental atual de cada ponto individualmente. Esses dados ambientais observados foram utilizados para a posterior confecção do SIG;

topografia das cavidades localizadas durante as atividades de campo.

O método para o levantamento topográfico das cavidades descobertas pelo trabalho foi o usualmente utilizado pelo GEEP-Açungui em levantamentos espeleológicos em conformidade com a classificação da União Internacional de Espeleologia (UIS).

Para execução das atividades de campo foram realizadas 4 saídas, perfazendo um total de 35 dias de esforço ou ainda, 10,5 dias por técnico envolvido nesta fase.

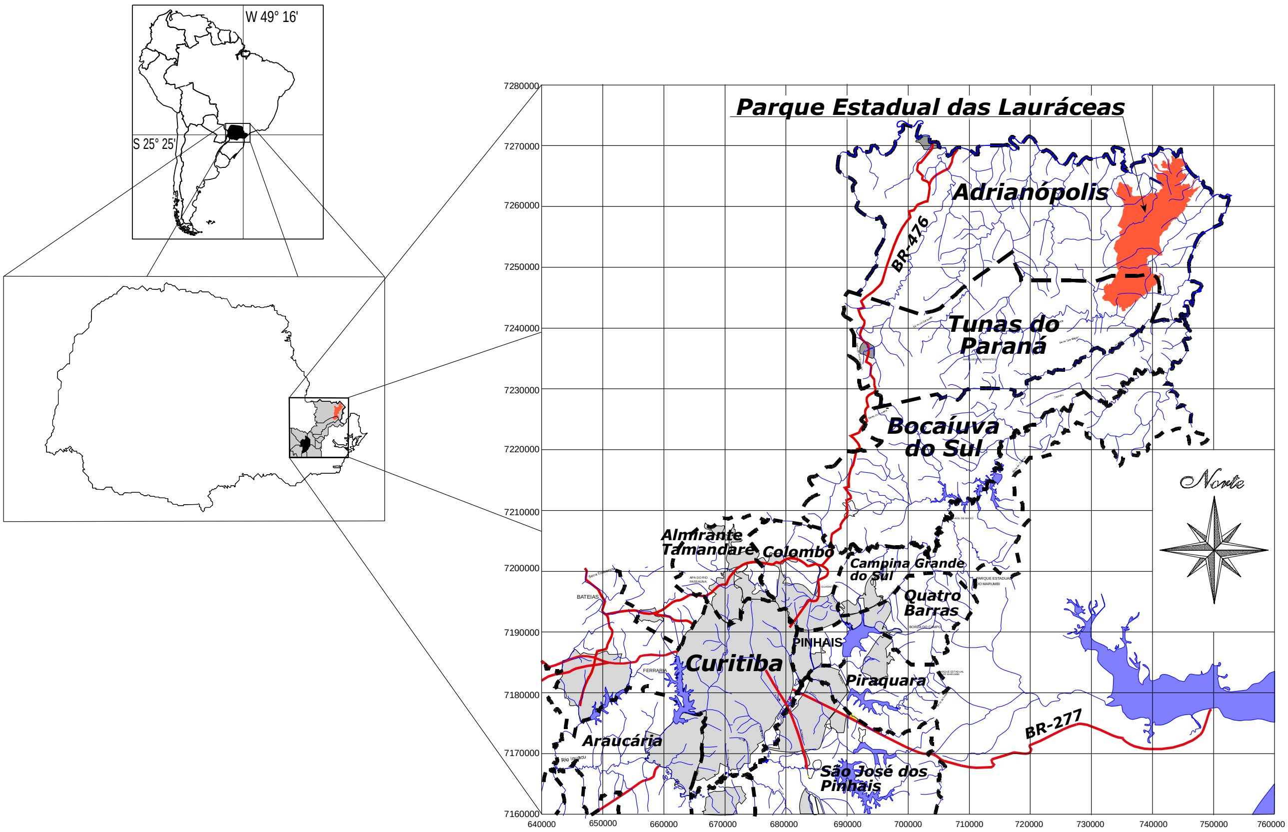

Figura 1 – Localização do Parque Estadual das Lauráceas no estado do Paraná

Resultados

Contexto Hidrológico / Clmático

Segundo a Carta Climática do Estado do Paraná (GODOY e CORREIA, 1976) e a Divisão Climática do Estado do Paraná proposta por MAACK (1981), ambas baseadas em Köeppen, o Parque Estadual das Lauráceas enquadra-se em uma zona de clima quente temperado subtropical e é caracterizado pela predominância do tipo climático Cfb, com índices pluviométricos de 1.300 a 1.500 mm/ano. O trimestre mais chuvoso do ano (janeiro a março) apresenta valores de 500 a 550 mm, enquanto que nos meses de menores índices pluviométricos (junho a agosto), os valores são da ordem de 300 a 350 mm. A umidade relativa do ar gira em torno de 78 % enquanto que a temperatura média anual é de 17,7º C.

O PEL está inserido na porção leste da Bacia Hidrográfica do Ribeira, cujo nível de base de erosão regional apresenta uma cota média inferior a 330 m. O Parque é drenado quase na sua totalidade pelos afluentes da margem esquerda do rio Pardo. As drenagens são caracterizadas pelo padrão geral dendrítico, de densidade média a alta, perfis convexos a retilíneos, vales fechados a abertos, planícies aluvionares interiores restritas e com muitos vales apresentando-se secos e na forma de V.

O rio Ribeira adapta-se às principais linhas estruturais da geologia, entalhando profundamente a paisagem. Seus afluentes apresentam saltos e corredeiras, bem como setores de aluvionamento.

A maior porção do território do Parque é abrangida por três sub-bacias hidrográficas principais, sendo elas:

Sub-bacia Hidrográfica do rio Uberaba (7º ordem);

Sub-bacia Hidrográfica do rio João Surrá (5º ordem);

Sub-bacia Hidrográfica do rio São João (5º ordem);

Dentro dos seus limites podem ainda ser encontradas porções menores de outras sub-bacias de drenagem, como: Sub-bacias do Guaracuí, Pimentas, Veados e do Poço Grande, além de pequenos afluentes que deságuam diretamente no rio Pardo, ao norte do parque. Na tabela 01, constam os dados dos canais principais das bacias hidrográficas identificadas no interior do Parque Estadual das Lauráceas.

De modo geral, as bacias hidrográficas encontradas na região do Parque apresentam características semelhantes. Estas podem ser classificadas como sendo superimpostas, dendrítico ou arborescente e exorreicas, segundo a classificação proposta por DAVIS *apud* SUGUIO e BIGARELLLA (1979). Localmente ocorrem ainda padrões retilíneos e paralelos, evidenciando um forte condicionamento das drenagens aos elementos estruturais. Este padrão também é observado em áreas onde há presença de vertentes com declividade acentuada.

Tabela 01 – Dados dos canais principais das Bacias Hidrográficas do PEL.

Rio	Cota Nascente*	Cota Foz*	Desnível*	Extensão*	Gradiente Médio	Ordem	Área 1**	Área 2***
Uberaba	1.350	190	1.160	63.000	1º	7º	7,58	48,07
São Miguel	1.144	270	864	77.000	0,64º	6º	6,02	24,77
Putunã	1.350	270	1.080	49.000	1,26º	6º	1,57	18,57
São João	1100	120	980	28.000	2º	5º	5,91	8,34
João Surrá	1.035	100	935	31.000	1,72º	5º	7,98	10,34
Guaracuí	800	100	700	12.500	3,2º	5º	1,25	3,83
Pimentas	1.020	175	845	17.000	2,84º	4º	1,67	5,15
Veados	800	120	680	9.700	4,01º	3º	1,27	1,80
Poço Grande	900	100	800	9.800	4,66º	2º	0,76	1,12

**** em metros; ** Área da Bacia Hidrográfica dentro da U.C. (em quilômetros quadrados); *** Área total da Bacia Hidrográfica(em quilômetros quadrados)***

Contexto Morfológico

Segundo a divisão clássica do relevo paranaense (MAACK 1947), a área do PEL, encaixa-se no Primeiro Planalto Paranaense, localizada entre a Serra do Mar e a escarpa formada pelos sedimentos paleozóicos da Bacia do Paraná. Constitui-se em uma superfície esculpida abaixo do *paleo-plano* desta que se encontra hoje em processo de erosão causada pela drenagem bastante ativa da bacia do rio Ribeira, criando uma imagem de planalto dissecado.

O relevo da região é montanhoso, justificado pela grande variedade de litologias, com diferentes graus de resistência à erosão. Exibe vales profundos, interflúvios estreitos, uma série de cristas alongadas de orientação preferencial NE, além de um rígido controle tectônico-estrutural das drenagens, adquirindo localmente um padrão retangular e subordinadamente paralelo. No geral as cotas altimétricas variam entre 800 e 900 m, sendo que a cota máxima observada é de 1.226 m, localizada na porção centro-leste do parque, enquanto que a cota mínima é de aproximadamente 100 m.

Observam-se áreas com muitas cicatrizes de deslizamentos recentes em função da fragilidade do substrato rochoso associada à alta pluviosidade concentrada em curtos períodos de tempo e à interferência humana sobre a cobertura florestal. Quanto à morfologia das regiões onde ocorrem as rochas carbonáticas, observam-se esporádicas feições cársticas como as depressões em forma de dolinas, colmatadas na maioria dos casos por sedimentos, e algumas grutas isoladas em meia encosta.

O modelado fluvial é caracterizado por vales abruptos e profundamente encaixados em zonas de falhas ou fraturas, em meio a paredes verticalizadas ou sub-verticais, criando-se formas de pequenos *canyons* por onde escoam os córregos em cursos rápidos ou encachoeirados.

Na área do PEL foram identificados dois grandes domínios geomorfológicos:

Domínio dos Metassedimentos: ocupando uma grande porção do Parque localizada a NW e representado predominantemente por litologias como xistos, calco-xistos, filitos, quartzitos, metarenitos, epicalcários e raros diques de rocha básica que aparecem formando morros alongados de direção NW.

Domínio das Rochas do Complexo Gnáissico-Migmatítico: ocorre em uma pequena porção a SE do parque, apresentando uma grande uniformidade em quase toda a sua extensão, com exceção de poucas faixas acidentadas.

Contexto Geológico

A região estudada situa-se na margem sudeste da Plataforma Continental Sul-americana e engloba unidades geológicas do Cinturão Móvel Ribeira (BRITO NEVES e CORDANI, 1991).

No Paraná, este cinturão é composto principalmente por rochas deformadas, de diferentes graus metamórficos, pertencentes ao Grupo Açungui, Complexo Setuva, Complexo Pré-Setuva e ainda por intrusões graníticas diversas (FIORI *et al.,* 1987), sendo o embasamento deste cinturão constituído pelas rochas do Complexo Costeiro.

Na região do PEL a geologia é dividida em dois blocos tectônicos separados pela zona de cisalhamento Lancinha-Itapeúna (CAMPANHA, 1991). O Bloco Costeiro inclui as unidades do Complexo Gnáissico-Migmatítico, a Formação Setuva e a Formação Capirú, enquanto que no Bloco Andorinhas foi identificado apenas unidades representantes da Formação Setuva.

As coberturas sedimentares acham-se dispostas de forma localizada, descontínua e pouco freqüente, em geral associadas às calhas da drenagem atual. Apresentam composição variando entre conglomerática e argilo-arenosas.

Contexto Espeleológico

O carste do Parque Estadual das Lauráceas está inserido na Província Espeleológica Alto Ribeira (KARMANN e SANCHEZ, 1979), caracterizada por abranger a região do rio Ribeira e seus tributários.

No estado do Paraná esta província é caracterizada por três faixas calcárias dispostas no sentido NE-SW, constituindo grandes conjuntos diferenciados litologicamente e estruturalmente. Segundo FIORI (1991), estas três faixas estão sempre obedecendo a alinhamentos tectônicos, segundo as falhas a que são condicionadas, respectivamente a Falha da Lancinha, Morro Agudo e Itapirapuã.

O carste do PEL encontra-se situado predominantemente nos calcários da Faixa Leste, constituídos basicamente por dolomitos metamorfizados, na Formação Capirú do Grupo Açungui.

Cavidades Localizadas

Consultando-se o Cadastro de Cavidades Naturais do Paraná (GEEP-AÇUNGUI, 1996), até o início do projeto apenas duas cavidades encontravam-se oficialmente cadastradas: Grutas do Leão (PR-0220) e Filho do Darci (PR-0221).

Ao longo do levantamento descobriram-se seis novas cavidades e executou-se seu cadastramento, mapeamento e análise ambiental, entre outros aspectos. Quanto às grutas anteriormente cadastradas, executou-se todas as atividades, incluindo-se a revisão dos dados pré-existentes. Um resumo dos dados produzidos neste levantamento, que acabou por englobar seis cavidades além de duas feições espeleológicas, pode ser visualizado na tabela 02.

Tabela 02 – Cavidades levantadas durante a execução da AER.

Nº DE CADASTRO	Nome e Qualificativo	LATITUDE	Longitude	ALTITUDE	P.Hz (M)	D.L. (M)	Desn. (M)
PR-0220	Gruta do Leão	7249620	730480	823	318	334	17
PR-0221	Gruta Filho do Darci	7249962	731980	826	46	65	18
PR-0244	Gruta do João Surrá	7262283	740396	374	70	71	5
PR-0245	Abismo do João Surrá	7261884	740796	324	74	89	18
PR-0246	Gruta do Saboroso	7261793	748163	386	90	112	14
PR-0247	Gruta do Pimentas	7245570	736840	558	138	145	10,5
*	Caverna do Africano	7260546	740215	310	5	5	1
*	Buraco do Larguinho	7253155	738626	725	3	5	1,5

Não cadastrável

Cartografia

Durante a execução das atividades da AER, foram geradas pela equipe do meio físico, cartas temáticas e mapas topográficos, como forma de apoio aos levantamentos e conclusões dos trabalhos, são eles:

Cartas Topográficas da Unidade (correções), 1:20.000;

Carta Morfológica, 1:50.000;

Carta das Bacias Hidrográficas, 1:50.000;

Carta de Domínios Geomorfológicos, 1:50.000;

Carta de Altimetria, 1:50.000;

Carta de Declividade, 1:50.000;

Carta Níveis de Restrição de Uso (meio físico), 1:50.000;

Carta Compartimentação Tectônica (adaptado), 1:100.000;

Carta Principais Unidades Geológicas (adaptado), 1:100.000;

Mapas Topográficos das cavidades identificadas pela AER.

Foram gerados ainda uma série de perfis geomorfológicos do PEL e perfis esquemáticos dos principais canais de drenagem identificados nas bacias hidrográficas.

Conclusões

Com base nos estudos efetuados verificou-se que o Parque, situa-se em uma zona montanhosa, com grandes desníveis e declividades acentuadas. Poucas são as regiões planas e, em geral, as poucas trilhas que percorrem seu interior situam-se próximas aos seus limites. Estas trilhas, estão posicionadas de forma inadequada, em áreas de alta fragilidade do solo e em muitos pontos cortando trechos de alta declividade.

Devido a essa escassez de acesso ao interior do Parque, os caminhos naturais acabam sendo os rios existentes e/ou as margens destes, por apresentarem sempre inclinações mais suaves que as encostas e cristas da região montanhosa do entorno. Deve-se dissociar os caminhos da drenagem devido à rápida elevação dos níveis dos rios quando ocorrem chuvas intensas, devido principalmente aos padrões morfológicos. Este fenômeno ocorre principalmente no verão e foi vivenciado na execução do levantamento.

Todos os possíveis atrativos em relação ao meio físico, em termos cênico/turísticos situam-se em áreas de difícil acesso, à exceção das grutas localizadas próximas à base do Caratuval. Excetuando-se alguns rios principais (João Surrá, Larguinho, Poço Grande, Veados e Guaracuí), nenhum dos acidentes geográficos localizados no PEL possui uma trilha de acesso e mesmo para que se consiga adentrar ao Parque, em muitos pontos, é necessária uma caminhada pesada. Esse fato faz com que os possíveis atrativos turísticos tornem-se inviáveis para o uso de um visitante comum.

Mesmo assim, em quase todos os pontos visitados durante a execução da AER, constatou-se o uso antrópico, das mais variadas formas (retirada da vegetação, pegadas e fezes de animais domésticos, restos inorgânicos, queimadas, entre outros). Das cavidades identificadas na região a gruta do Pimentas (PR-0247), era a única que não apresentava sinais de visitação anterior. Em todas as outras encontraram-se sinais mais variados de uso pela população local, (pegadas, pichações, quebra de espeleotemas, entre outros).

Por estes fatos, pode-se afirmar que a Unidade em questão não possui uma vocação para o turismo de massa e também pouco para o ecoturismo e/ou turismo-aventura. Pois, além da dificuldade dos seus acessos, existe a questão da proximidade de outras Unidades de Conservação (PETAR, P.E. Carlos Botelho, P.E. Faz. Intervales, P.E. do Jacupiranga e outras áreas menores) que já exploram todas estas variáveis do turismo e que, além de já consagradas como tal, possuem uma boa infra-estrutura de apoio ao visitante, além de acessos muito mais simples e rápidos.

O P.E. das Lauráceas, apesar de inúmeras áreas degradadas, protege inúmeras nascentes. Assim num contexto global, possui uma importante função de interligação ambiental com as unidades anteriormente citadas. Por isso, sob o ponto de vista do meio físico, o turismo no P.E. das Lauráceas deve ser direcionado para o turismo técnico-científico.

Visando compatibilizar o uso do patrimônio natural do Parque Estadual das Lauráceas com a sua efetiva conservação, algumas sugestões são elencadas a seguir:

as trilhas criadas e/ou as existentes no interior e arredores do PEL devem, na medida do possível, ter seus traçados remodelados, evitando-se pontos de alta declividade e proximidade de drenagens de elevado gradiente e posicionadas em vales encaixados;

as áreas de deslizamento e/ou acomodações de massas, devem estar em zonas classificadas como Zonas de Recuperação dentro da Unidade;

toda e qualquer visitação, que venha a ocorrer no interior do Parque, deve impreterivelmente ser monitorada, visando a integridade do visitante e do ambiente;

deve-se estabelecer uma política efetiva de fiscalização no interior e nos arredores do Parque, dando maior ênfase as áreas que sofrem maior pressão;

as cavidades que encontram-se próximas às divisas do Parque também devem sofrer estudos complementares, para que se verificar a importância delas num contexto regional e a partir daí, optar-se ou não pela ampliação dos limites do Parque, visando englobar estas cavernas.

recomenda-se a ampliação dos limites do Parque na região do Caratuval, para que este passe a englobar a gruta do Leão (PR-0220), por ser esta, sob o ponto de vista físico, a mais importante (junto com a gruta do Pimentas) das levantadas pela AER e localmente a maior dentre todas;

deve-se estabelecer um programa de educação ambiental junto às comunidades existentes no entorno do Parque, esclarecendo sobre a necessidade de conservação dos recursos naturais, além de enfocar as cavernas, principalmente nas proximidades onde estas ocorrem, para que se possa com isso sanar os problemas de depredação verificados em várias das cavidades estudadas por esta AER;

finalmente, deve-se incentivar a pesquisa nos vários campos das ciências naturais e sociais, para a implementação de um Plano de Manejo, que seja dinâmico e que possa, dessa forma, evoluir junto com o grau de conhecimento que venha a ser adquirido a cerca do P.E. das Lauráceas.

Homenagem Póstuma

Ao geólogo Luciano Rabelo, nosso respeito e homenagem pela sua dedicação, espírito de equipe e companheirismo, durante todos os momentos em que esteve entre nós. Profissional competente e amante da natureza, Rabelo perdeu a vida fazendo aquilo que gostava, compartilhando com seus amigos os bons e maus momentos. Ao amigo que não pode ver a sua tarefa finalizada, mas que ainda assim continua presente entre nós, dedicamos esse trabalho como forma de reconhecimento, por sua amizade que sempre permanecerá.

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Speleological Characterization of the Casa de Pedra Karst System, Doutor Ulysses – PR / Brazil[9]

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Abstract

The Doutor Ulysses county has a great speleological potencial related to the presence of Proterozoic limestones (Açungui Group) and to the evidence of important karst features. This area was selected by GEEP-Açungui in 1997 to undertake a project about the protection and management of caves, due to the fact of this region is little explored and undamaged by tourism and mining activities, if compared to other areas in the Metropolitan Region of Curitiba-Parana. The main objective of this project was the physical and biotic characterization of caves located in this county, aiming to define methods for protection and management. This paper shows the results for the Casa de Pedra Karst System, one of the karst systems surveyed by this project, and the characterization of the Da a Volta Cave, the longest cave in Parana State with 2,49 Km.

Resumo

O município de Doutor Ulysses possui um grande potencial espeleológico devido à ocorrência de rochas carbonáticas e à presença de importantes feições cársticas na área. Por tratar-se de uma região ainda pouco explorada, onde a degradação pelo turismo e pela atividade minerária ainda é pequena, comparada a outras regiões da Região Metropolitana de Curitiba, em 1997 o GEEP-Açungui realizou o projeto: “Levantamento, proteção e manejo das cavernas de Doutor Ulysses-PR”, financiado pelo Fundo Nacional do Meio Ambiente (FNMA). Este projeto teve como objetivo realizar a caracterização das cavidades localizadas no município, definindo medidas para sua proteção e manejo. No presente trabalho serão apresentados os resultados relativos ao Sistema Cárstico Casa de Pedra, (uma das áreas abrangidas pelo projeto), no qual descobriu-se a Gruta Dá a Volta (PR-0239), maior caverna identificada até o momento no estado do Paraná.

Localização e Fisiografia

A região estudada localiza-se no município de Dr. Ulysses, na Região Metropolitana de Curitiba (PR), próximo à divisa com o estado de São Paulo (figura 1).

Introdução

As cavidades ocorrem junto à Serra de Paranapiacaba, em sua porção oeste, inseridas na bacia do ribeirão Feital, afluente do rio Itapirapuã, na bacia hidrográfica do rio Ribeira. A área enquadra-se na compartimentação geomorfológica do primeiro planalto paranaense, no setor conhecido como Planalto de Maracanã, caracterizado por altitudes que variam de 330 a 1200 m, com relevos bem diferenciados, associados aos tipos litológicos, ao clima e à evolução estrutural da região (EMBRAPA, 1981).

Contexto Geológico

A região situa-se na margem sudeste da Plataforma Continental Sul-Americana, nas unidades geológicas do Cinturão Móvel Ribeira (BRITO NEVES e CORDANI, 1991). No município, essas unidades são caracterizadas pela ocorrência de rochas metassedimentares dispostas em faixas, intrusões graníticas (Complexos Graníticos Três Córregos e Cunhaporanga e Granito Francisco Simas), intrusões de rochas ígneas básicas, alcalinas e sedimentos aluvionares recentes.

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[9] Componente do Projeto “Levantamento, conservação e manejo do patrimônio espeleológico do município de Dr. Ulysses, Pr. Convênio Ministério do Meio Ambiente/Fundo Nacional do Meio Ambiente 055/97.

O sistema cárstico estudado está associado às rochas metassedimentares pertencentes a Formação Itaiacoca do Grupo Açungui (Mesoproterozóico a Neoproterozóico), constituída exclusivamente por metassedimentos carbonáticos dolomíticos, metassedimentos pelíticos e psamíticos intercalados por metavulcânicas. Estes metassedimentos foram afetados por metamorfismo dinamotermal na fácies xisto-verde, zona da clorita, associado à intensa deformação de caráter dúctil e rúptil (FIORI *et al*., 1985)

As rochas carbonáticas estão inseridas na Província Espeleológica Alto Ribeira (KARMANN e SANCHEZ, 1979), que no Paraná é caracterizada por três faixas calcárias dispostas no sentido NE-SW. As cavidades do presente estudo ocorrem na faixa noroeste, composta preferencialmente por calcários dolomíticos.

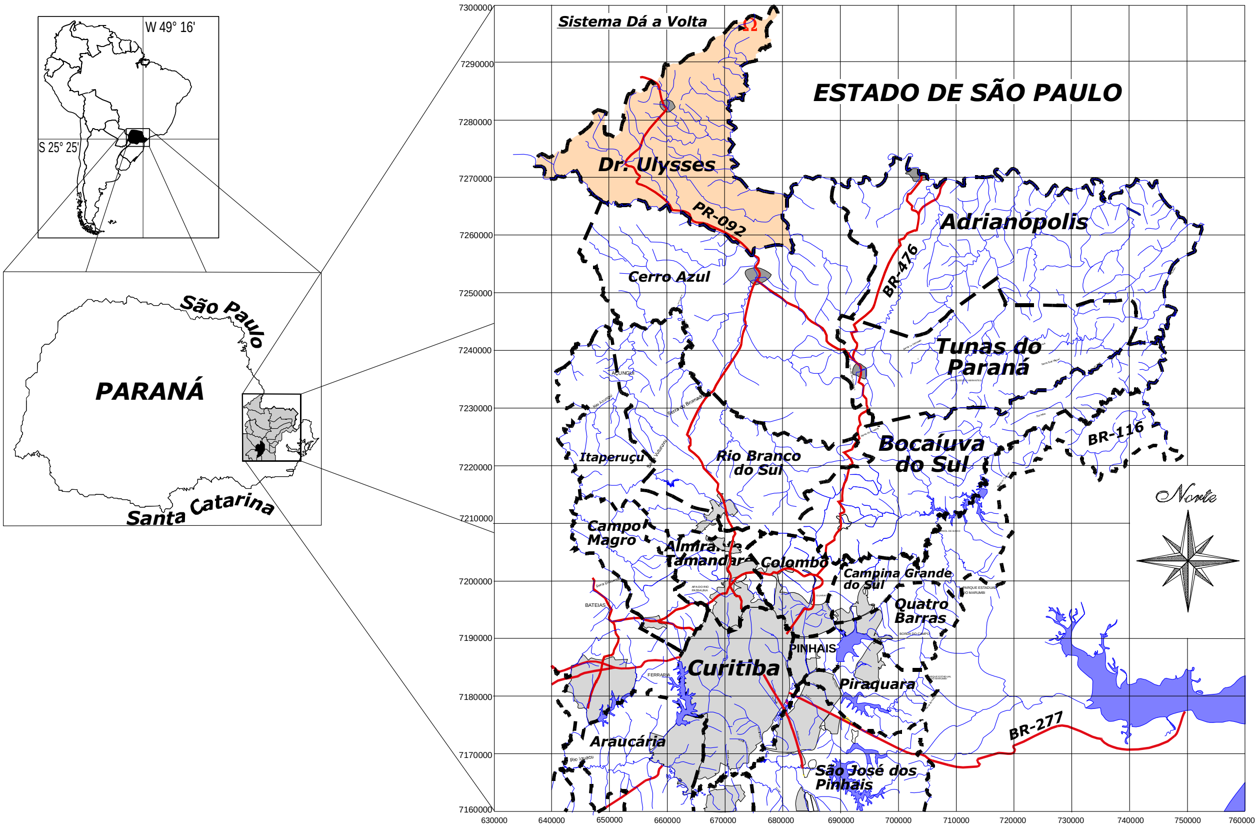

Figura 1: Localização do município e do Sistema Casa de Pedra

Trabalhos Anteriores

O primeiro estudo realizado na região de Casa de Pedra foi realizado pelo geógrafo Darci P. Zakrzewski, em agosto de 1987, resultando num mapa topográfico de grau ”1A” da Gruta de Pocinho e da Gruta Casa de Pedra. O registro oficial da Gruta Casa de Pedra e Gruta do Buraco do Vento somente ocorreu em 20/04/89 (SBE, 1989).

Somente alguns anos após o Museu Paranaense, com apoio da Fundação O Boticário de Proteção à Natureza, realizou estudos de pesquisa ambiental e arqueológica nos municípios de Cerro Azul, Sengés e Doutor Ulysses (PARELLADA *et al.,*1993).

PILATI (1997) efetuou um trabalho na região e adjacências, verificando alguns impactos da ação antrópica na Gruta de Pocinho.

Materiais e Métodos

A prospeção de cavidades foi desenvolvida em duas etapas:

a) Atividades de Escritório

pesquisa bibliográfica visando avaliar o conhecimento existente;

caracterização da rede hidrográfica, e feições cársticas existentes, tais como sumidouros, ressurgências e dolinas a partir das Fotos aéreas n^{os}: 23194 – 23197 e 23189 – 23190 (ITC, 1980), escala 1:25.000; Mapa Geológico da Comissão da Carta (1970) 1:50.000 Folha: Serra das Antas e Carta Topográfica 1:50.000 Folha: SG-22-X-B-I-3 Folha Ouro Verde (IBGE, 1975). Com base nos resultados delimitou-se previamente o sistema, indicando os principais elementos cársticos associados.

b) Atividades de Campo

prospeção de cavidades com base nos dados organizados em escritório e em informações obtidas junto à população local;

obtenção das coordenadas geográficas com auxílio do G.P.S., para localização das cavidades e das feições cársticas de cada sistema;

levantamento topográfico, fotográfico e avaliação ambiental do sistema estudado;

atualização e coleta de dados das novas cavernas e abismos para um posterior cadastramento junto à Sociedade Brasileira de Espeleologia.

O método utilizado para o levantamento topográfico das cavidades identificadas no estudo foi o usualmente utilizado pelo GEEP-Açungui em levantamentos espeleológicos e adequado à classificação da União Internacional de Espeleologia (UIS).

Resultados

Durante a realização deste projeto foram identificadas cinco novas cavidades na área na área de abrangência do sistema (Tabela 01). Após o levantamento topográfico realizou-se a amarração das entradas através de uma topografia externa, resultando no mapa do Sistema Casa de Pedra (Figura 02).

Tabela 01 – Cavidades do Sistema Casa de Pedra, Dr. Ulysses – PR

Nº de Cad.	Nome e Qualificativo	Latitude	Longitude	Altitude**	PHZ**	D.LIN.**	DESN.**
PR-0070	Gruta de Pocinho	24º26'28"S	49º18'26"W	905	590	625	25
PR-0071	Gruta Casa de Pedra	24º26'55"S	49º18'53"W	895	70	72	10
PR-0072	Gruta Buraco do Vento	24º26'57"S	49º18'57"W	893	67	71	14
PR-0238*	Buraco do Claudio	24º27'01"S	49º18'52"W	890	30	32	4
PR-0239*	Gruta Dá a Volta	24º27'07"S	49º19'08"W	900	2490	2675	55
PR-0240*	Gruta da Caverninha	24º27'03"S	49º19'10"W	898	20	23	12
PR-0241*	Gruta da Ressurgência do Feital	24º27'21"S	49º19'08"W	870	284	327	28
PR-0242*	Gruta Cão Paraná	24º27'13"S	49º19'08"W	880	125	130	16
PR-0243*	Gruta Arco do Pé	24º27'13"S	49º18'53"W	875	122	175	37

* Cavernas descobertas; **Em metros

O Sistema Casa de Pedra é formado pelas nascentes do ribeirão Feital, que atravessa as seguintes cavidades: Gruta Casa de Pedra, Gruta Buraco do Vento, Buraco do Claudio, Gruta Dá a Volta, Gruta Arco do Pé e Gruta Ressurgência do Feital. A Gruta Cão Paraná foi caracterizada como sendo um antigo ponto de injeção do sistema estudado, atualmente inativo. A Gruta de Pocinho, foi considerada como parte deste sistema por encontrar-se na mesma bacia, à montante das demais cavidades.

Destaca-se neste trabalho a descoberta da Gruta Dá a Volta (Figura 3), tratando-se atualmente da maior caverna cadastrada no estado do Paraná. Apresenta uma projeção horizontal total de 2490 m, um desenvolvimento linear total de 2675 m (obtidos pelo método da descontinuidade) e um desnível total de 55 m (obtido pelo método da continuidade). Este mapeamento alcançou um grau de precisão/detalhamento "4C" segundo a classificação da UIS (SBE, 1989).

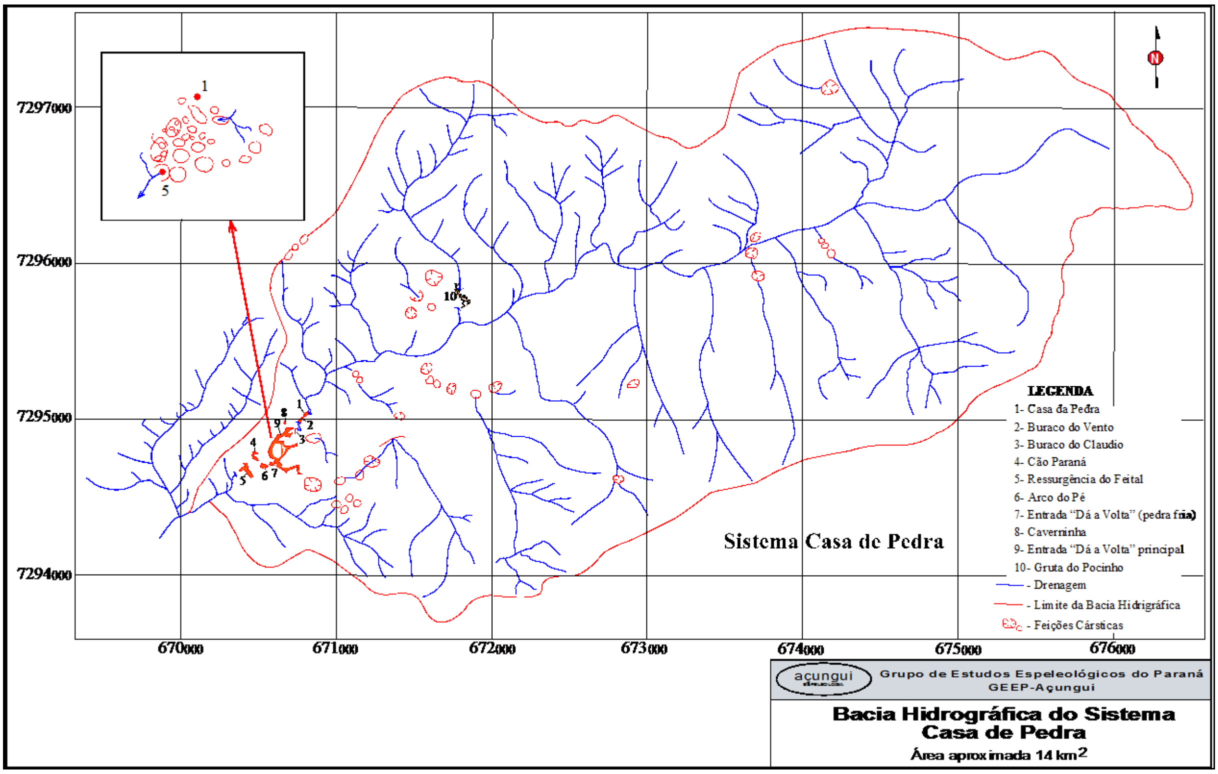

Figura 2 – Bacia Hidrográfica do Sistema Cárstico Casa de Pedra

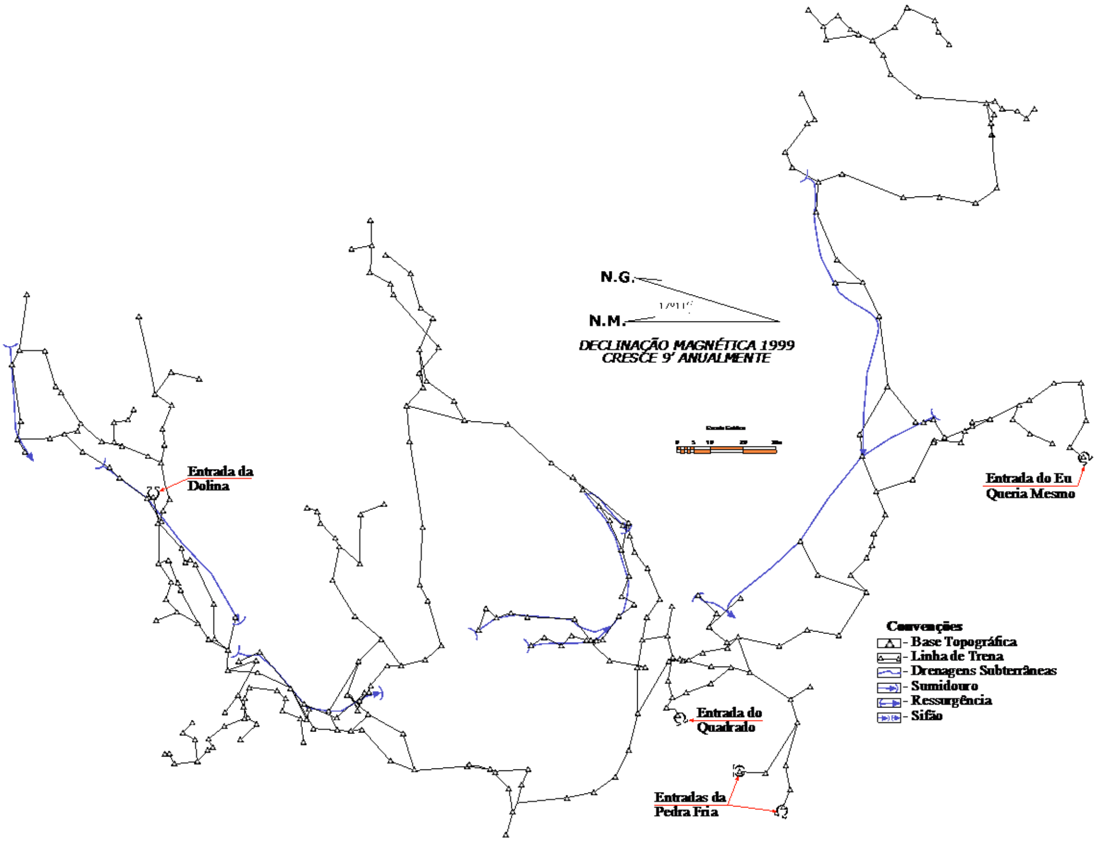

Figura 3: Linha topográfica (projeção horizontal) da Gruta Dá a Volta (PR-0239)

A Gruta Dá a Volta localiza-se nas coordenadas 24º27'07"S e 49º19'08"W. A cavidade apresenta quatro entradas conhecidas, a primeira descoberta localiza-se nas encostas de uma dolina próxima ao Buraco do Claudio e a Segunda é conhecida como Gruta da Pedra Fria e localiza-se próximo à Gruta do Arco do Pé. As galerias principais desta cavidade são formadas por três drenagens subterrâneas distintas que apresentam-se condicionadas segundo fraturas de direção NE-SW. O rio Feital corresponde à drenagem principal e é responsável pela formação da galeria principal, localizada na porção NW do mapa. Já na porção SW deste mapa, observa-se que as estruturas NE-SW são cortadas por uma fratura de direção NW-SE, sendo esta responsável pela união destas drenagens e pela definição da galeria de mesmo sentido.

Observou-se que tanto a drenagem da porção NW quanto SE convergem para um ponto central no qual localiza-se a entrada da Pedra Fria, sugerindo que estruturalmente a cavidade está associada a uma dobra sinforme.

Em perfil a cavidade é caracterizada por dois níveis. O nível superior é definido por uma galeria ampla, seca e pouco ornamentada, que é melhor identificada no trecho entre a entrada da dolina até a Gruta da Pedra Fria. O nível inferior é caracterizado pela galeria do rio Feital e seus afluentes subterrâneos. Esta galeria não é contínua, apresentando-se interrompida em diversos pontos por blocos, sifões e estrangulamentos. O acesso a este nível se dá em diversos pontos da galeria do nível superior, através de abismos e declividades acentuadas. Em última análise a cavidade apresenta um padrão labiríntico, muitos abismos e espeleotemas pouco expressivos.

Por sobre a Gruta Casa de Pedra e o sistema correlacionado, verificam-se capoeirinha, capoeira e agricultura de subsistência que utiliza o sistema de pousio. O mesmo quadro se apresenta à montante, próximo à Gruta de Pocinho, onde verifica-se a existência de um maior número de residências rurais junto ao ribeirão. Na metade da bacia, à montante, há um povoamento de pinus, em fase de exploração, com a abertura de estradas, circulação de caminhões pesados e tratores.

PILATI (1997) realizou coleta de água na gruta de Pocinho, visando realizar análise bacteriológica. Apesar da aparente limpidez da água, a amostra apresentou teores de coliformes totais e fecais acima dos permissíveis.

Conclui-se que a atividade antrópica tem alterado significativamente a região, causando vários impactos dentro e fora das cavidades. Indícios de visitação (garrafas quebradas, embalagens diversas) relativamente freqüente, foram verificados na Gruta de Pocinho e Casa de Pedra.

Conclusão

O Sistema Casa de Pedra engloba a maior caverna localizada no Estado até o momento, além de outras cavidades de importância regional. Apesar disso vários problemas de usos indevidos (resíduos, quebra de espeleotemas e pichações) das cavidades foram verificados, assim como problemas ambientais relacionados ao ambiente externo do sistema (bacia hidrográfica e uso do solo).

Em vista disso, visando proteger este sistema de grande interesse regional, sugeriu-se a criação de um Monumento Natural, possibilitando, desta forma, a conservação do mesmo. Recomenda-se ainda a continuidade e a efetivação de novos estudos e levantamentos na região (bioespeleologia, geoespeleologia, entre outros), para uma perfeita compreenssão deste sistema cárstico.

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Capacitação de Monitores Ambientais em Áreas Espeleológicas com Potencial Ecoturístico

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O Programa de Ecoturismo do Conselho Nacional da Reserva da Biosfera serviu para aprimorar a formação de Monitores Ambientais que trabalhem em Municípios do entorno de Unidades de Conservação com potencial espeleológico, reforçando o papel fundamental dos cidadãos e entidades envolvidas na busca do desenvolvimento sustentável, ordenando as atividades de ecoturismo, atuando como educadores ambientais e criando novos mercados de trabalho/fonte de rendimentos para estas comunidades, obtendo subsídios para futuras ações em áreas distintas desta.

Baseados em práticas pedagógicas e experiências realizadas no princípio da década de noventa, o projeto piloto propôs, para o curso base, uma nova grade curricular, nova carga horária e principalmente, uma visão holística e interdisciplinar da Educação Ambiental que obrigatoriamente teriam que se incorporar às capacitações nesta área.

Foram executados, também, cursos de especialização, segundo a escolha e aptidão dos monitores, para melhor adequar o atendimento da monitoria aos serviços de turismo e preservação do ambiente cavernícola.

No aprimoramento das soluções locais, um programa de intercâmbio entre áreas que apresentam serviços de monitoria em áreas cársticas vem sendo executado, buscando aperfeiçoar a formação do monitor.

O Conselho Nacional da Reserva da Biosfera da Mata Atlântica pretendendo criar subsídios à efetiva capacitação dos monitores ambientais nas áreas remanescentes de mata atlântica por todo o país, criou um projeto piloto para servir como laboratório. Este projeto foi implementado na região do Alto Ribeira - SP, capacitando cerca de 120 monitores ambientais em todas as suas fases: um curso básico em 1998 e outra especialização em 1999, culminando com o terceiro curso, 2000.

O ecoturismo vêm se apresentando como alternativa para algumas áreas de preservação e com riquíssimo patrimônio espeleológico, como é o caso do Alto Ribeira, e para a inclusão das comunidades locais no mercado do ecoturismo. Porém essa alternativa acarreta uma degeneração da cultura e pressão sobre as áreas protegidas, exigindo ações que venham garantir a nova fonte de renda e um baixo impacto sobre a cultura e costumes.

A região envolvida abriga extensa área de Mata Atlântica, com riquíssimo potencial espeleológico, ao mesmo tempo que estas extensões protegidas garantem a manutenção da biodiversidade, representam para as comunidades residentes em seu entorno um fator restritivo de desenvolvimento, em função das diversas limitações impostas pela condição de Áreas de Proteção Integral.

A região está na parte alta do curso do rio Ribeira de Iguape , onde a Serra de Paranapiacaba faz um recuo ao interior do continente, em direção sudoeste, considerada a maior área contínua de mata atlântica preservada do Brasil. A sua importância foi realçada já em 1991, quando de sua incorporação pela UNESCO como área-piloto da Reserva da Biosfera da Mata Atlântica, portanto, patrimônio da humanidade.

No Alto Ribeira estão concentradas uma das maiores áreas de Unidades de Conservação do Estado de São Paulo, formando o grande conjunto de interesse preservacionista da mata atlântica e sua biodiversidade que ainda restam do patrimônio natural. Na área de atuação do projeto piloto podemos citar os Parques Estaduais de Jacupiranga, Parque Estadual Turístico do Alto Ribeira e Intervales que, somados em suas áreas teremos um total de 231.970 hectares e 250 cavernas cadastradas.

Nos três parques onde os monitores podem atuar há um grande número de cavernas. Já em 1976, Lino elaborou uma proposta de roteiro para as cavernas, visionando a alternativa de sustentabilidade que só nesta década se configurou mais claramente.

O projeto constou de: curso básico, especialização e intercâmbio. O curso básico planejou em sua grade um módulo para a compreensão do Karst, cavidades naturais, cartografia e biomas locais, além de turismo, condução de grupos, suporte básico de vida e saúde preventiva, entre outros. A carga horária, que em portaria do IF-São Paulo é de 120 horas, foi estendida para 200 horas, já que em diagnóstico avaliativo do curso de 1998, ficou claro que não atende à demanda de mudança dos valores e atitudes que se pretende alcançar com uma capacitação desta envergadura.

A especialização foi oferecida de acordo com as necessidades de aperfeiçoamento da prática de monitoria, para melhor atender ao binômio turismo – preservação, onde, após diagnosticar as habilidades dos alunos e suas preferências, escolheu-se as especializações que deveriam ser executadas. Realizaram-se módulos de técnicas verticais, botânica, fauna cavernícola, pronto socorrismo, educação ambiental, topografia dentre outros. Cada curso teve a duração de quarenta horas com a carga horária dando realce às aulas práticas, sem deixar de lado o embasamento teórico.

O intercâmbio, num primeiro momento, levou monitores do alto Ribeira a outras localidades que apresentam turismo em áreas cársticas, como Bonito-MS, trazendo também, outros para esta região. A troca de experiências foi relatada e repassada aos monitores de cada local, garantindo o aperfeiçoamento da atividade, buscando solução às perguntas e questões que se impõem ao trabalho de monitoria. O programa de intercâmbio busca incentivar a iniciativa de formação de núcleos gestores na própria comunidade, assegurando assim, a reflexão dos agentes locais sobre os caminhos que possam seguir. A especialização está em fase final de avaliação, devendo ser encerrado com um seminário onde as trocas de experiências sejam apresentadas e publicadas em anais.

A realização de cursos básicos e de especialização busca aprofundar a práxis de estruturação de capacitação em monitoria ambiental que deu seus primeiros passos no início dos anos 90 na Fazenda Intervales, passando pelo I Curso em Iporanga -1995 (Marinho, 1997) e posteriormente em 1998 com o II Curso (relatório do II curso de monitores ambientais). Foi importante a incorporação dos fundamentos para a capacitação de moradores locais através da Educação Ambiental, partindo da realidade regional local, diagnosticando as necessidades dos conteúdos do curso e adequando-os ao tempo necessário de amadurecimento e a forma de se refletir a realidade, tornado todos os envolvidos em co-autores do processo.

Monitores Ambientais: Participação e Realização de Trabalhos Espeleológicos em Iporanga (Vale do Ribeira – São Paulo)

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Monitores Ambientais da AMAIR - Associação de Monitores Ambientais de Iporanga e Região

Introdução

Durante os anos de 1999 e 2000, os Monitores Ambientais (Condutores Locais de ecoturismo) do Município de Iporanga, Vale do Ribeira, realizaram vários trabalhos espeleológicos nos terrenos cársticos da região. Trabalharam no interior do PETAR (Parque Estadual Turístico do Alto Ribeira) e em seu entorno, onde se localiza hoje, a maior concentração de cavidades subterrâneas do Brasil. Nesses trabalhos, encontraram e reencontraram várias cavidades, nas quais exploraram, fotografaram e relizaram levantamentos espeleométricos. Participaram de trabalhos com outros grupos de espeleologia e em programas intergrupais como PROCAD (Projeto Caverna do Diabo), de seminários e encontros espeleológicos.

O presente trabalho pretende apresentar uma síntese dos resultados abtidos nessas atividades e destacar a importância da ação de grupos locais para o estudo espeleológico, a conservação ambiental e do desenvolvimento do ecoturismo naquela região do Vale do Ribeira.

Monitores Ambientais no PETAR

O Monitores Ambientais são capacitados para conduzir grupos de pessoas em atrativos turístico do PETAR (Parque Estadual Turístico do Alto Ribeira), recebendo uma bagagem de vários temas como Introdução ao Turismo, Ocupação Histórica Regional, Botânica, Primeiros Socorros, Espeleo Resgate, Espeleologia e outros. No tema Espeleologia, abordam- se assuntos relacionados com a área, como Topografia em Cavernas, Fotografia em Cavernas, Espeleo Vertical, Arqueologia e as Cavernas, Manejo Turístico de Cavernas, Morfogeologia Cárstica e Técnicas de Exploração. Com estes conhecimentos e a experiência já adquirida pelos Monitores Ambientais Locais ao longo da vida, estes realizaram trabalhos espeleológicos no interior e entorno do PETAR reencontrando e encontrando cavidades de pequeno médio porte.

Expedições e Prospecções

Gruta do Tatu (Exploração, Trabalho Fotográfico e Levantamento Espeleométrico)

Abismo Doriana e Gruta Gastãozinho

Sumidouro da Lição Nº 1

Exploração da Serra do Manduri

Exploração da Serra Camargo de Cima

Exploração na Região do Bairro Bombas de Baixo e de Cima

Gruta do Tatu (Exploração, Trabalho Fotográfico e Levantamento Espeleométrico)

Situada aos arredores do Bairro Betary fica a mais ou menos 1,5 Km da estrada Iporanga- Apiaí, esta cavidade foi encontrada no ano de 1999 por moradores locais que faziam atividade de caça perto da desconhecida gruta. Gastão o morador local, encontrou a cavidade quando acoava um tatu e este pressionado por ele caiu dentro de um buraco que ainda tinha uma pequena passagem. No outro dia convidou Elisângela Monitora Ambiental, para entrarem na cavidade foi preciso a retirada de alguns blocos calcários que obstruiam a passagem, com uma pequena corda de cinco metros aproximadamente desceram a queda de 4 metros de altura da entrada e com um simples equipamento de iluminação adentraram a caverna. Depois foi contatado mais Monitores e outros espeleólogos que fizeram exploração, fotografia e um primeiro levantamento espeleométrico da gruta que possui vários espeleotemas como helectites pérolas e várias cortinas. O seu desenvolvimento é de 200 metros com pequenas galerias laterais, sua entrada possui uma queda vertical de 4 metros e mais 17 metros de diagonal, depois a sua continuação é com uma galeria ornamentada de helectites, chão de estrelas, estalactites e cortinas, grande parte possui blocos caídos, um pequeno córrego aparece apenas em pequeno trecho da gruta que foi encoberto com a queda de blocos que criou no final da caverna passagens difíceis com vários trechos de quebra- corpo.

No ano de 1999 foi realizado um primeiro levantamento espeleológico realizado por Monitores Ambientais, GPME (Grupo Pierre Martin de Espeleologia) e CAV (Corpo de Ação Voluntária). Foram colocados cordões de isolamento em áreas de formações frágeis da gruta, como chão de estrelas e ninho de pérolas. Com outros trabalhos de exploração foi encontrado com uma árdua tarefa uma pequena galeria onde se chega até o pequeno córrego da caverna e se encontra também grande quantidade de seixos de rio. Em janeiro de 2001 uma equipe de três Monitores Ambientais realizaram um trabalho fotográfico e croqui. Devido a falta de controle de visitação na Gruta que não é turística e pela falta de consciência espeleológica de alguns Monitores Ambientais, está sendo estudada instalação de um portão na entrada da gruta.

Abismo Doriana e Gruta Gastãozinho

Situadas também na região do Bairro Betary as duas cavidades foram encontradas por moradores locais e exploradas por Monitores e alguns espeleólogos.

O Abismo Doriana se localiza no alto da Serra do Betary com uma profundidade de 100 metros de altura, foi encontrado no ano de 1999 e explorado por uma equipe de 4 pessoas, um abismo com médio grau de dificuldade, sua entrada é bem estreita e depois de certo ponto fica com diâmetro de mais ou menos 5 metros, suas paredes tem vários lapiás e em certo ponto é coberto por fina camada de argila, a cavidade é pouco ornamentada, foi encontrado no fundo do abismo uma ossada de paca que caira ali cerca de algum tempo, o abismo possui continuação horizontal.

A Gruta Gastãozinho situa- se próximo da Gruta do Tatu sendo também ornamentada e de pequeno desenvolvimento, nesta cavidade foi realizado apenas trabalhos de exploração.

Exploração da Serra do Manduri: Descoberta do Sumidouro da Lição Nº 1

Durante o ano 2000 foram realizadas várias propecções na Serra do Manduri localizada cerca de 9 Km da cidade de Iporanga, possui um dos mais profundos abismos do Brasil, o Abismo do Manduri que não foi explorado totalmente. Anos atrás alguns espeleólogos desceram os primeiros 150 metros do abismo permanecendo até hoje como um mistério para a espeleologia, há também cerca de 4 abismos no alto da serra que foram encontrados recentemente, alguns foram explorados até certo ponto e outros ainda continuam inexplorados.

A Gruta Lição Nº 1 foi explorada na década de 80, é de pequeno porte e possui algumas ornamentações, o córrego do Bernardo atravessa a cavidade mas é inacessível a travessia para outra entrada que foi encontrada no ano de 2000 por uma equipe de monitores ambientais, nesta entrada o acesso é difícil sendo um pequeno abismo mas de difícil acesso e onde o córrego fez um depósito de seixos dificultando muito o acesso dentro desta cavidade. Para a realização de uma melhor prospecção é necessário um grupo maior e bem equipada para dar continuação ao trabalho.

Exploração da Serra Camargo de Cima

A Serra do Camargo de Cima fica entre o Bairro Serra e Serra do Manduri, mesmo complexo que se localiza a gruta Alambari de cima e Abismo Gurutuva é uma grande região calcária com altos paredões. As águas que descem da Serra do Manduri penetram na rocha calcária da região, no pé dos paredões encontram- se vários buracos de difícil acesso que foram obstruidos por material orgânico e blocos rochosos. No alto da Serra encontram- se inúmeros abismo de pequeno porte surgindo a possibilidade destes contactarem com cavidades formadas pelas águas que penetram na montanha. Ainda é necessário um grande trabalho de exploração espeleológica para desvendar as cavidades daquela região.

Exploração na Região do Bairro Bombas de Baixo e Bombas de Cima

Os Moniotres Ambientais realizaram trabalhos na região dos Bairros Bombas I e II dando enfoque para a exploração de grutas e abismos. No Bairro Bombas II reexploraram cavidades já conhecidas por outros espeleólogos e encontraram novas cavidades com grande quantidade de abismos e dolinas. Várias explorações foram feitas na região da gruta de Bombas com intuito de encontrar uma entrada que desse acesso ao interior da cavidade. Na maioria dos abismos explorados na região de Bombas de Cima o seu final era em água dando grande possibilidade da existência de um grande Lençol freático que divide às águas da região. Em Bombas I exploramos uma cavidade já conhecidas e cadastradas. Algumas locas também foram encontradas mas sem terem muita continuidade.

PROCAD 2000 (Projeto Caverna do Diabo)

Os Monitores Ambientais participaram do PROCAD 2000 sendo responsáveis pela equipe de limpeza. Fizeram um grande trabalho retirando todo o lixo encontrado ao longo da travessia da caverna como latinhas de bebidas, plásticos, pedaços de ferro, objetos religiosos, papelão e outros. A maioria do lixo encontrado foi ao longo do rio das ostras. A equipe atuou durante 8 horas no interior da gruta tendo como resultado final algumas mochilas de lixo. Este material foi fotografado e documentado pelos organizadores do evento.

Outras Participações

Moradores Locais e outros Espeleólogos

Medical consideracions about diving in expeditions in high altitudes

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Abstract

The main problem in high altitude diving expeditions is the decompression and its calculation and operational aspects. All the divers must know the tables currently used.

A plan to be used in an emergency situation including situations outside the water is a must. The amount of available oxygen, the quality of medical services near the exploration site and the possibility of transporting medical equipments and victims by air are crucial issues. The influence of the hyperbaric inspired oxygen in the human beings must also be explored.

During the Expedition Atahuallpa 2000 we tried to find if there were the incidence of mountain sickness in the diving group and specific date was collected. The psychological changes in humans during this kind of activity are still in study and the need of further medical researches must be always considered.

Diving in the high altitudes

Nowadays with the new technics and the development of the diving industry became possible explorations in remote areas with high risk conditions. Explorations underwater realized in high altitudes is a special chapter. The atmospheric pressure which is diminuished in relation to the see level affects in many important ways the many aspects of the decompression disease (Van & Thalmann, 1993; Edmonds et al., 1997)

One of the most important problems which can occur in such an expedition is the possibility to contract the Decompression Disease (DD), also called Bents. Although the tables are well calculated, they were made for diving up to 700 m above the see level. When transposed to higher altitudes they became theoretical and turns to a complex mathematical calculation. A calculation table was generally made at the diving places just before going in the water. But today even with the development of diving computers which calculates up to 4000 m. (UWATEC AG, 1999) it is not possible to eliminate all the risks to contract the Decompression Disease.

It is then extremely important the development of specific technics in a way to obtain the maximal security since the medical treatment in a remote place can be difficult and even impossible. In this sense during the Expedition Atahuallpa 2000 was realized many divings at the 3800 m when we utilized special procedures in order to obtain the calculation of the decompression in each diving. We used a portable eccodoppler, an instrument which allows to perceive the gas bubbles in the veins very soon. In this way it became possible to accompany the reactions of each diver after each diving (Nishi, 1998).

An important point in expeditions of this kind is an emergency plan including also situations which are not diving related (Arrington, 1994). In this sense was considered the following aspects: the amount of medical and portable oxygen available, the quality of the medical facilities at the local and the possibility to obtain air or ground transportation.

In the specific case of the Expedition Atahuallpa 2000 which took place in the Bolivian part of the Titicaca Lake, the amount of portable medical oxygen was satisfactory, although we had some problems in acquiring it. There was only one industry in the whole country. The system was the same we find in hospitals (System DIN) which is not adequate to the use of more specialized and modern equipments (System YOKE) In regard to the quality of the medical assistance next to the diving sites we considered that the better way was to keep a medical doctor ready to act in emergency situations not only inside but also outside the water. Unfortunately our area of exploration was economically and socially underdeveloped, what was reflected in the scarce resources found in the nearest city, N. S. Copacabana. There would also be a problem in paying the local medical services in case we needed them, what proves the necessity of having a medical doctor among the members of such an expedition. Finally the possibility of transportation was restrict to a ground transportation since there were no possibility of using any kind of airplanes.qs Hospitals were previously contacted in order to avoid bad surprises in case of a major emergency.

The medical control with a eccodoppler

The realization of such an underwater exploration allows also that many important points related to human physiological alterations to be studied. Not many things are known about the level of the oxygen at 100% during the period of acclimatization in elevated altitudes but without doubts the exposure at high quantity of oxygen during divings are a chapter to be studied.

After the first 72 hours of expositore in an altitude over 3800 meters. We realized divings almost every day. We used two types of mixtures: air (21% oxygen) and Nitrox (33% oxygen). We noticed that even in the shallow divings the partial pressure went fast to values above 0,4 absolute atmospheres (ATA) showing pressures higher than those at the see level. In this way, it was as if each diver after the diving were brought to levels under the see level for many days. A question remains still without an answer: would this hyperbaric exposure influences the daily acclimatization?

Basically our work consisted of a daily data about the conditions of each member of the group, regardless if they were or not a diver. This data consisted of a questionary where we tried to observed the possibility of having the signs and symptoms of the Mountain Sickness (Hultgren, 1997) This condition is related directly to the continuos exposure to high altitudes and can be observed right in the first days (Hall et al., 1965; Hackett &Rennie, 1976). In this case we had two groups, one with only divers the other without and each group with seven people.

Although his data didn't show differences between the two groups and we didn't notice any occurrence of this disease, further studies must be done. At this moment we feel that it is still too soon to reach a final conclusion. Many other aspects need to be studied and I propose that the future expeditions make further studies of eventual changes in the breathing as a reaction to the hypoxia during the sleep time and the level of the breathing reflection during apnea I would propose also technics more precise than questionaries in order to evaluate the study of these important subjects.

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13th International Congress of Speleology
4th Speleological Congress of Latin América and Caribbean
26th Brazilian Congress of Speleology

Brasília DF, 15-22 de julho de 2001

New Speleohydrogeological Research of Crveno jezero (Red Lake) near Imotski in Dinaric Karst Area (Croatia, Europe) - International speleodiving expedition “Crveno jezero 98”

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Abstract

The new speleohydrogeological research recently conducted in Crveno jezero (Red Lake) provided valuable information about the depth, volume and morphology of this karst phenomenon. This is a much larger speleological system than could have been gathered from previous research, and the volume of the submerged portion of the system amounts to approximately 16 million cubic meters of water. The total difference in height between the highest and the presently known lowest point amounts to 528 meters, and is located at 6 meters below sea level. The lowermost depth of lake water as registered during the research (Autumn, 1998) was 281 meters. Several hundreds meters of speleological structures (caves) within the lake were also investigated. An overview of the Crveno jezero speleogenesis is presented, as it is in fact a speleological feature (pit).

Introduction

The Red Lake is a karst phenomenon known throughout the world for its size and specific features. In the course of the 1950's, some hydrological measurements were made on the surface of the lake, including depth measurement at 39 points (academician M. Petrik and his associates). The information about the maximum depth of 254 meters actually originates from that research (PETRIK, 1960). This depth has been "attracting" geologists, hydrogeologists and speleologists for many years now. On numerous occasions, people descended to the surface of the lake but, in the period prior to speleohydrogeological research conducted in 1998, no attempt had been made to dive underwater and document the lake depth, nor to investigate by other methods the interior of the lake and give a scientifically documented representation of this karst phenomenon from the speleohydrogeological aspect (GARAŠIĆ, 2000).

The Red Lake, located one kilometer to the west of Imotski, is the biggest of all lakes situated in the area (featuring 18 big or small dry or water-filled depressions) and this by both its visible (superficial) and invisible (submerged) portions. Its name originates from red rocks perched on cliffs extending to more than 250 meters in height. The lake color is dark blue, and it measures about 150 x 180 meters, depending on water level, i.e. on the time of the year. The easiest way to reach the lake (belay, descend and ascend with ropes) is to approach it from the east side. Here we have a vertical cliff about 60 meters in height, followed by 300 meters of a very steep soil creep zone, after which there is yet another vertical cliff of at least ten meters in height (depending on lake water level).

In other words, a special descending technique must be used to access any point along the lake perimeter in summer months. Vertical and overhanging cliffs rising above the surface of the lake range from 160 to 250 meters in height. However, the depth of the lake is even more fascinating and has been measured on a number of occasions.

Brief overview of previous investigations

To this date, many authors including Ph. Ballif, A. Gavazzi, J. Daneš, O. Opitz, A. Ujević, J. Roglić, M. Petrik, S. Božičević, L. Bojanić, D. Ivičić, V. Batić, S. Bahun (KOVAČEVIĆ, 1999) have published papers about various scientific aspects of the Red Lake. The first systematic research of the lake morphology was made by Dr. Josip Roglić in 1937, but the data obtained by these measurements are not very accurate (ROGLIĆ, 1938). Data characterized by a higher level of accuracy were obtained during hydrologic measurements conducted by academician Milivoj Petrik in the period from 1955 to 1958. While Roglić claims that the bottom of the lake is at 19 meters above sea level, Petrik has found it to be at 4 meters a.s.l. (PETRIK, 1960).

The morphological character of the red Lake is described by BOŽIČEVIĆ (1971). The hydrogeology of Imotsko polje and the Red Lake area is depicted by BOJANIĆ, IVIČIĆ & BATIĆ (1981). The author of the most significant paper about formation of the Red Lake claims that it is in fact a ponor that has lost its water due to neotectonic uplifts (BAHUN, 1991).

However, no paper was published at that time about speleological structures within the Red Lake "crater" although it is known that several speleological teams inspected the surface of this lake, but did not investigate speleological structures above or under the water level.

Recent Speleohydrogeological Research

Valuable and interesting data about the lake depth, as presented by academician Milivoj Petrik in 1955, show that the lake is about 250 meters deep, which discouraged any attempts to dive to the bottom of the lake.

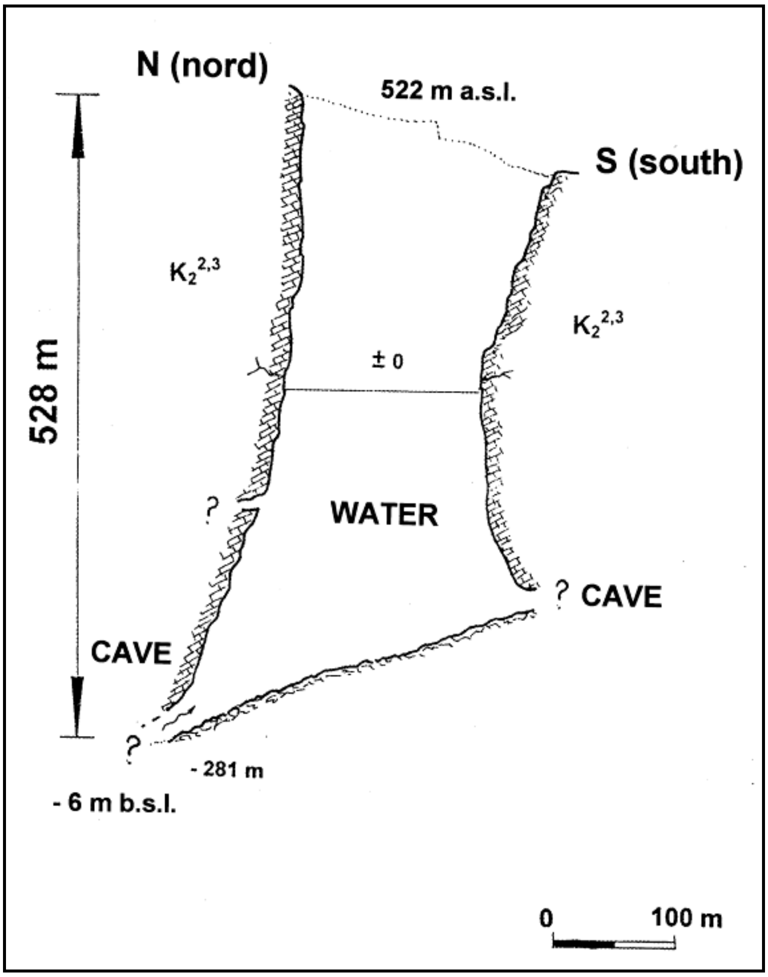

Figure 1 - Cross section (Nord - South) of Crveno jezero (Red Lake in Croatian Dinaric Karst (Imotski, Croatia), Cat. no. HSS 4729

During the 5th International Congress of Speleology held in Stuttgart in Germany, Croatian cavers and speleologists have tried to add the Red Lake to the list of deepest pits in the world, as its real depth amounted to 518 meters at the time. However, the response of the documentation committee was that the depth had not been duly documented, that no man has been at such depth etc., although in reality it is a real pit one half of which is filled with water.

In late 1970's and early 1980's the speleodiving activities rapidly gathered momentum in all parts of the world and it is in this period that deepest dives were made at the source called Fontaine de Vaucluse. At that time, a special underwater vehicle, the so called "Speleonaut", attained (without crew) the depth of 315 meters. Similar vehicle called Hyball descended down to the depth of 165 meters in Hranicke propasti in Czech

Republic. These speleological structures are therefore considered as sufficiently documented and, as such, they have been added to the list of the world's deepest water structures.

In 1980's speleodiving has became an increasingly popular cave exploration method in Croatia. Thus, the decision was made to contact the world's best speleodivers and invite them to investigate the Red Lake. In 1981, during their stay in the USA, Dr. Mladen Garašić and Tihomir Kovačević BSc contacted Mr. Jochan Hassenmayer who was at that time the best speleodiver of the world. However, because of political climate that prevailed in that period, Mr. Hassenmayer finally decided not to come to our country. In an unfortunate turn of events, this diver was later affected with a permanent disability. In the course of 1989 and 1990, Dr. Garašić established contact with Mr. Sheck Exley (from Florida , USA) who is considered to be the best speleodiver of all times. At the time, it was agreed that he and his team would come to Croatia during the summer of 1991 and that they will, in the course of this visit, investigate the Red Lake. Unfortunately, due to the outbreak of war, this has been postponed and, in 1994, this outstanding diver had a fatal accident while diving at the depth of about 300 meters. This accident has remained unexplained to this date. In the course of 1996, French speleodivers recommended German speleodivers that would be interested in the underwater exploration of deep speleological structures. In this respect, the contact was established in early 1997 with the German Caving Group from Hanover the members of which had by that time been diving at about 200 m below the water surface (ASPACHER, B.& all, 2000).

This team visited the Red Lake on several occasions in 1997 and 1998 and, during these visits, the lake depth was measured (using an echo sounder and highly-accurate depth measuring devices) at the total of 454 points, while previous measurements conducted in 1955 were performed at 39 points only. The maximum depth registered during our measurements was 276.35 meters, which exceeds the depth determined in previous measurements by approximately twenty meters.

The main objective of the "Red Lake 98" expedition was to obtain new data about the speleogenesis of this structure, about its morphology, hydrogeology, tectonics and biospeleology, and to produce an appropriate documentation (video recordings, structural-tectonics and speleological maps). This was a Croatian speleodiving expedition with international participation and was sponsored by the UIS members from Germany, Austria and Switzerland (GARAŠIĆ, 1999). Sedimentologic studies were conducted in cooperation with colleagues from Tubingen-based Max Planc Institute and with those from the Technical Faculty in Munich, while biospeleological studies were performed together with colleagues from Salzburg. Highly accurate topographic instruments were borrowed from the University of Zürich.

Results and Final Considerations

The development of speleological, speleo-hydrogeological and speleodiving methods encouraged new investigations and, in that respect, new exploration was carried out in the Red Lake during the summer of 1998. The depth of the lake was measured at 454 points, topographic measurements of underwater parts of the lake were made, and several hundred meters of cave canals (dry and submerged), within the area delineated by the lake's vertical cliffs, were investigated. The maximum depth of the lake (-281 meters) was measured and recorded by means of a special autonomous underwater vehicle, the quantity of water flowing into the lake through a cave canal was established, and the quantity of water contained in the lake was determined (approx. 16 million of cubic meters). Recent studies provided information that is highly useful for better understanding of this karst phenomenon. The inverse karstification was dominant in the genesis, while gravity karstification had an accessory role only (GARAŠIĆ & KOVAČEVIĆ, 2000). The bottom of the lake is inclined towards the west, and the lowest point lies 6 meters below sea level. At the time of these investigations, strong water currents in the direction of southwest were observed at the depths ranging from -206 to -281 meters. The total difference in height is 528 meters (from the highest point at lake periphery to the lowest point registered at the bottom of the lake). The bottom of the lake is deeper down but, due to technical difficulties, the camera was unable to penetrate any further. This extension is in fact a large cave canal spreading obliquely in the southwest direction.

The International speleodiving expedition "Crveno jezero 98" resulted in numerous new findings some of which are listed below (GARAŠIĆ, 2000; GARAŠIĆ & KOVAČEVIĆ, 2001):

- a fully documented material (photographs, topographic maps, video recordings) about the previously unknown parts of the lake was established,
- an inflow cave-shaped canal (measuring 30 x 30 meters) was discovered in the eastern part of the lake, at the depth of approximately 175 meters,

- new assumptions were made about ground water circulation in this area,

- it was concluded that principal karstification processes develop in the interior and spread towards the surface, i.e. that this is the zone dominated by an inverse karstification; a room measuring 400 x 300 x 500 meters has been created in the interior, which is quite amazing,

- some new species of cave fish, crabs, frogs and insects were discovered and determined within the lake and in speleological structures,

- all speleohydrogeological features, as well as most significant tectonic elements, were determined down to 90 m in depth,

-sedimentological and petrological testing of the lake bottom was conducted (at four locations),

- more than 800 meters of cave canals were discovered within the lake "crater",

- more than 22 hours of video material was recorded,

the deepest point registered by ROV (Remotely Operated Vehicle) is 236 meters,

- the deepest point measured in the lake is 281 meters, i.e. 6 meters below sea level,

- the constant water temperature is +7.9°C (50 m below the surface),

- (westward) movement of ground water was registered at the bottom of the lake,

- the total of 454 points were measured,

- heliox was used to dive to the depth of 181 m, which is one of the deepest cave dives ever performed in the world (ASPACHER & BEHREND, 1999),

- vertical difference between the highest and lowest points in the lake is - 528 meters,

- the size of the lake bottom was established (about 300 x 300 m) while on its surface the lake measures approximately 180 x 200 meters,

- as many as 43 members have participated in the expedition /22 from Croatia, 18 from Germany, 2 from Austria and 1 from Switzerland)

- more than 20 tons of equipment and material were transported to the site., etc.

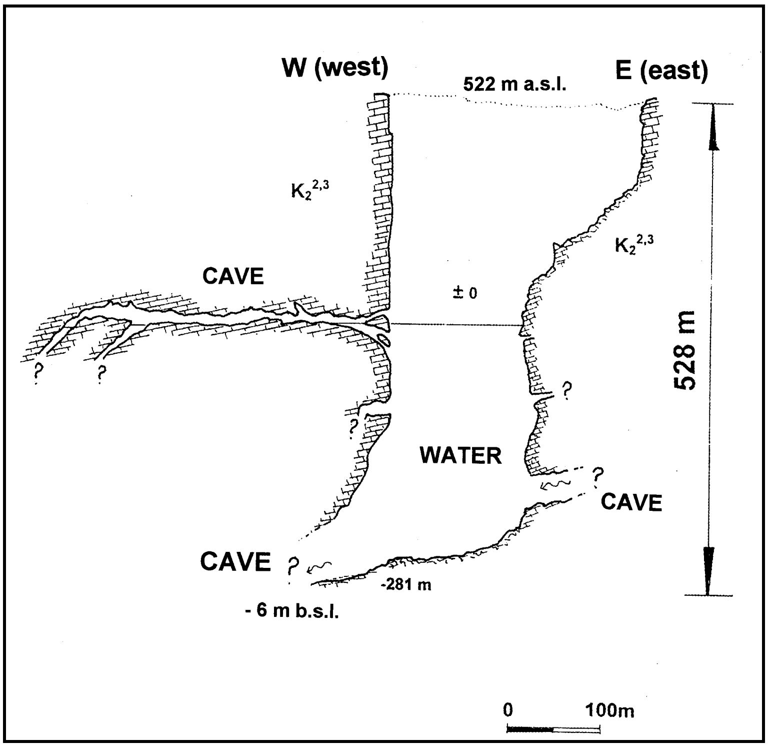

Figure 2 - Cross section (West - East) of Crveno jezero (Red Lake) in Croatian Dinaric Karst (Imotski, Croatia), Cat. no. HSS 4729

As the Red Lake is a geological monument of high significance to natural environment, and its morphology is a proof that such status is well deserved, special environmental protection measures had to be undertaken in the course of the expedition. After the expedition, all equipment and previously accumulated waste was extracted by cableway to the surface.

This expedition has brought Croatia and its karst closer to the rest of the international community, and the Red Lake has obtained its rightful status as a worldwide phenomenon so that it now figures on all lists of the world's deepest speleodiving structures.

The Red Lake is ONE OF THE DEEPEST KARST (CAVE) LAKES IN THE WORLD and its deepest measured level of -281 METERS is still not the deepest point of the lake! It is a water storage containing more than 16,000,000 cubic meters of water.

More accurate figures will be obtained in the course of future explorations to be undertaken by a special kind of bathyscaph. The Red Lake is the world's largest documented and surveyed ground water storage in karst, and deserves to be appreciated as such.

The study of the Red Lake speleogenesis has contributed to better understanding of the creation of many similar occurrences in neighboring areas, and has confirmed the assumption about existence of a large recent system, and of an even greater paleospeleological system, which is currently being formed and can be situated between the principal phase (II) and fossil phase (III) of the speleogenesis.

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Spedizione ICELAND '99 - Esplorazione subacquea degli abissi glaciali…

[Expedição Islandia'99 – Exploração subaquática dos abismos glaciais …]

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Abstract

In this work report technical and scientific results of Iceland'99 Expedition. The expedition was organized by "International Commission Glacier Caves and Karst in Polar Regions" and performed by AKAKOR GEOGRAPHICAL EXPLORING staff with the target to extend our competence about geographical exploring and research in hostile environment where the concepts of socialization and synergic implementation of multidisciplinary and well over ten years experiences, are extended Iceland'99 expedition summarize the modern concept of exploration, involving 9 researchers from 4 different countries: Italy, Brazil, Spain and Iceland and some representing of FEALC - Speleological Federation of American Latin Country. During the 40 days of the expedition they produced geographical technical a scientific study, of absolute importance, in an area less know of the Earth. Particularly the studies are carry over in the bigger glacier of Europe, the Vatnajokül (8410 km2).

In detail the study covers:

Dives and exploration under ice carried out with non conventional methods

Exploration and survey of 23 ponores (glacial abyss) carried out with specific techniques

Use of last generation multifunctional electronic instruments to analyze chemical and phisical parameters of different glacier waters

Realization of reportage, photographic journalistic documentation.

Riassunto

Nel documento prodotto vengono presentati i risultati tecnico/scientifici della spedizione – ISLANDA 99 - organizzata dall'International Commission Glacier Caves and Karst in Polar Regions ed interpretata dallo staff dell'AKAKOR GEOGRAPHICAL EXPLORING allo scopo di estendere le proprie competenze in tema d'esplorazioni geografiche e ricerche in aree ostili e confinate in cui si amplificano i concetti di socializzazione e sinergie implementate da esperienze pluridisciplinari e ultradecennali.

La Spedizione Iceland'99 ha sintetizzato il concetto moderno d'esplorazione coinvolgendo 9 ricercatori di 4 differenti paesi: Italia, Brasile, Spagna e Islanda, alcuni membri e rappresentanti della FEALC – Federazione Speleologica dei paesi dell'America Latina, che in 40 giorni di Spedizione hanno prodotto approfondimenti geografici, tecnici e scientifici di rilievo assoluto in una delle aree meno note della Terra, in particolare nel ghiacciaio più esteso dell'Europa, il Vatnajokül (8410 km2).

In particolare gli approfondimenti riguardano:

Immersioni ed esplorazione subacquee endoglaciali effettuate con metodi non convenzionali

Esplorazioni e rilevamenti di 23 ponores (abissi glaciali) con tecniche specifiche

Utilizzo di strumenti elettronici multifunzione delle ultime generazioni per analisi dei parametri fisico-chimici delle diverse acque del ghiacciaio

Realizzazione filmati, documentazione fotografica e giornalistica.

Introduzione

Il concetto d'esplorazione dei secoli passati finalizzata alla scoperta di nuove terre alle soglie del terzo millennio assume aspetti globali producendo approfondimenti e sviluppi pluridisciplinari.

C'è ancora molto da scoprire, nelle regioni più remote della Terra e negli abissi marini, esistono aree ed anfratti ancora sconosciuti che custodiscono straordinari segreti ed offrono l'opportunità di scrivere nuove pagine della storia dell'uomo e della natura permettendo esperienze morali di rilievo assoluto coniugando le mille interazioni possibili tra le scienze conosciute.

In questo contesto si sviluppano le attività dell'Associazione Culturale AKAKOR GEOGRAPHICAL EXPLORING ONLUS, nata nel 1992, con lo scopo di effettuare esplorazioni, condurre studi tecnici scientifici e realizzare progetti ed interscambi culturali in diverse aree d'attuazione, ed in quest'ottica si è sviluppata la spedizione scientifica ISLANDA'99 durante la quale sono state praticate e messe a punto tecniche di Glaciospeleologia subacquea, ovvero esplorazioni subacquee di sistemi che si sviluppano nei ghiacciai.

Il famoso romanzo di Jules Verne – Viaggio al Centro della Terra – narra la folle impresa di un professore di Hamburgo e di suo titubante nipote. Ed è proprio in Islanda che tutto ha inizio. Dopo avere decifrato un misterioso manoscritto che svelava la via per raggiungere il centro della Terra, la strana coppia decidere di seguire le orme e di scendere nel cratere di un vulcano all'estremità occidentale del paese. Nelle viscere della Terra troveranno mari e fiumi, tempeste magnetiche, piante e animali preistorici.

In questa geografia fantascientifica è stata realizzata la Spedizione Islanda'99 – Viaggio al Centro della Terra, organizzata dal "International Commission Glacier Caves and karst in Polar Regions" in collaborazione con il team di ricerca dell'AKAKOR con l'obiettivo di condurre studi al fine di determinare i parametri fisici e chimici nel tempo del ghiacciaio più esteso dell'Europa, il Vatnajoküll con (8410 kmq).

Alle ricerche hanno partecipato nove ricercatori di quattro differenti paesi: Italia (3), Brasile (2), Spagna (3), Islanda (1).

Localizzazione e aspetti fisiografici

Sola nel mezzo dell'Oceano, attraversata negli abissi del sottosuolo dal solco incandescente della Dorsale medioatlantica e sfiorata a nord dal Circolo Polare Artico, l'Islanda è una terra estrema, contesa dal gelo dei ghiacciai e dal calore dei vulcani. L'opera immane delle ere geologiche ha scolpito il suo volto in un grandioso scenario di fiordi, torrenti, cascate, montagne lunari e nere falesie, erte come muraglie sul mare con le loro fantastiche colonne di basalto.

La mappa dell'Islanda è dipinta da grandi macchie bianche che coprono complessivamente l'undici per cento dell'intera superficie dell'isola. Sono gli jökull, i grandi ghiacciai islandesi, le calotte tondeggianti di Drangajökull, Mýrdalsjökull, Langjökull, Vatnajökull, il Padre delle Acque. Quest'ultimo, Vatnajökull, copre da solo 8.410 kmq, ed è in assoluto il ghiacciaio più grande d'Europa. La calotta raggiunge una quota massima di 2.119 metri, con una corazza di ghiaccio spessa oltre la metà.

La logistica della spedizione

Lo staff AKAKOR: ha prodotto in 2000 ore di ricerca dei considerevoli risultati: sono stati ed esplorati e studiati 23 ponores (abissi glaciali) con tecniche specifiche praticando immersioni ed esplorazioni subacquee endoglaciali effettuate con metodi non convenzionali; in oltre è stata realizzata una ricerca idrogeologica di un bacino idrografico glaciale ed un monitoraggio climatico continuo tramite una stazione meteorologica e strumenti multifunzione dell'ultima generazione.

Quaranta giorni passati sul più grande ghiacciaio dell'Europa con l'obiettivo di carpire all'impressionante massa bianca del Vatnajökull i segreti del clima terrestre. La missione in Islanda ha avuto un grande successo. Sono stati esplorati in profondità le grotte e gli anfratti sotto l'immenso ghiacciaio immergendosi per decine di metri nelle acque che scorrono nelle sue viscere.

Da metà luglio a fine agosto i nove ricercatori hanno sfidato le insidie dei ponores, gli abissi glaciali, per verificare i cambiamenti del clima e suoi effetti sullo scorrimento del ghiacciaio. Sono stati applicate le più sofisticate tecniche di Speleologia Subacquea, utilizzando attrezzature subacquee high-tec progettate e realizzate per potere effettuare una serie d'immersioni in ambienti estremi con l'obiettivo di esplorare e studiare dei sistemi endoglaciali.

Sono stati percorsi 8.000 km e trasportati 4000 kg di materiali (attrezzature subacquee, fotografiche e video, apparecchi di radio comunicazione, strumenti di rilevamento, ecc.).

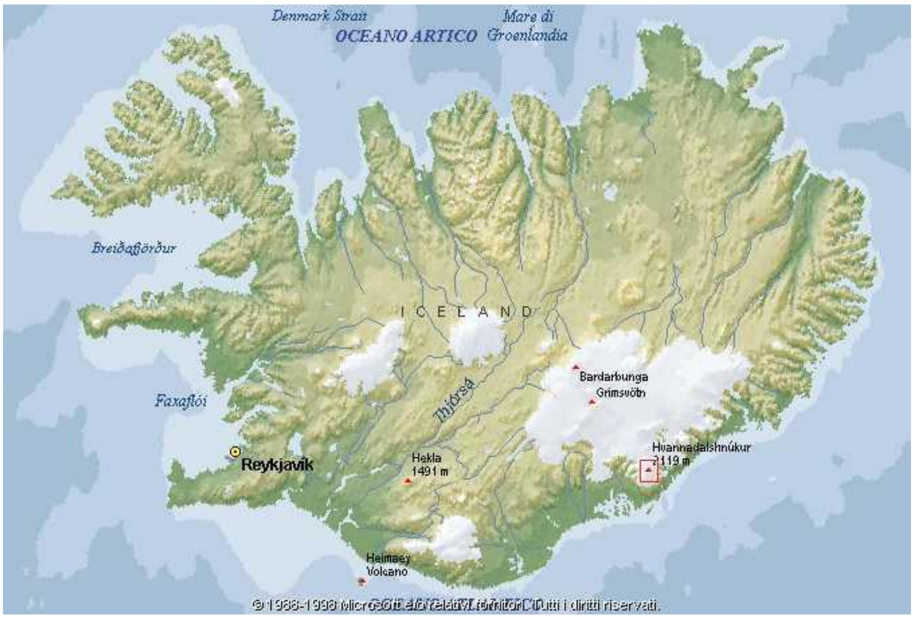

Figura 1 - Mappa dell'Islanda

Figura 2 – Discesa in un ponore (foto Lorenzo Epis)

La Glacio Speleologia Subacquea

In Spedizioni come questa il lavoro di squadra è fondamentale. Occorre installare un campo base estremamente organizzato che permetta di ospitare gli uomini e le attrezzature in modo tale di garantire il massimo grado di conforto logistico per potere pianificare e sviluppare al meglio tutte le attività tecnico esplorative collegate alla Glacio Speleologia Subacquea.

Le immersione endoglaciali rappresentano una grossa incognita e vengono effettuate in condizioni di rischio elevato ma offrono paesaggi di bellezza incredibile, esplorando mondi del tutto sconosciuti effettuando punte esplorative che offrono allo speleosub momenti eccezionali, intensi per magia, bellezza, paura ed angoscia.

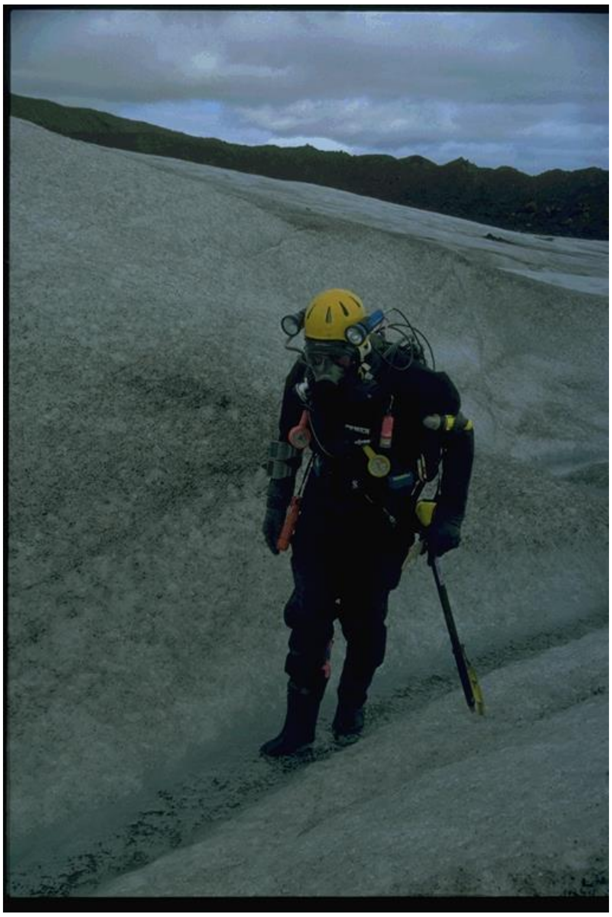

Figura 3 – Trasferimento difficoltoso verso il ponore (foto Soraya Ayub)

La preparazione ad un'immersione endoglaciale è estremamente complessa e laboriosa, nulla deve essere lasciato al caso: un'improvvisa avaria alla attrezzatura subacquea potrebbe avere conseguenze drammatiche. Le condizioni ambientali e le temperature dell'acqua costantemente intorno a zero gradi rendono oltre modo ardua un'immersione in queste condizione mettendo a dura prova il fisico dei subacquei e i loro equipaggiamenti.

La buona riuscita delle immersioni sia quelle esplorative che operative dipende da diversi fattori ma è essenziale la pianificazione e l'autocontrollo, è fondamentale comportarsi in tutte le fasi dell'immersione come da programma prestabilito e non esporsi a rischi aggiuntivi che possono produrre conseguenze tragiche e mettere in discussione tutta l'organizzazione.

Imperativo è il controllo psico-fisico delle proprie condizioni che permette di percepire immediatamente l'insorgere di stati d'ansia o problemi di altra natura che, anche se non ben identificati vanno affrontati e risolti, e, nel caso non sia possibile, l'interruzione dell'immersione deve essere automatica e non condizionata da pressioni di qualsiasi natura.

Le squadre esplorative vengono composte di volta in volta tenendo conto dei compiti da effettuare considerando le caratteristiche di ogni componente, la conoscenza specifica delle tecniche da adottare, unita all'autocontrollo ed all'affiatamento con lo staff contribuiscono alla riuscita dell'operazione in considerazione del fatto che portare a termine un esplorazione è sempre il risultato di un lavoro di gruppo in cui ognuno riveste un ruolo essenziale, il componente che effettua le punte esplorative può farlo grazie a doti personali che non sarebbero sufficienti senza l'apporto fidato di elementi altrettanto validi.

Inoltre è stata effettuata una rigorosa selezione dei materiali da impiegare nelle immersioni, da cui dipendeva non solo il successo delle ricerche ma anche l'integrità fisica.

Coerenti con il principio di utilizzare in Spedizione solo attrezzature strettamente di serie ma assolutamente valide l'AKAKOR si è rivolta a Winter & Summer, by Longoni che ha messo a disposizione il meglio della sua produzione, con il supporto diretto dei responsabili dei materiali che ci hanno permesso di conoscerne i particolari e le caratteristiche principali La scelta si è rivelata più che mai azzeccata: ogni elemento dell'equipaggiamento collaudato in condizioni estreme ha dimostrato di unire all'alta tecnologia il più elevato grado di affidabilità, anche in relazione al fatto che ben pochi costruttori realizzano materiali che possono funzionare con temperature dell'acqua di zero gradi.

La Spedizione Islanda'99 ha rappresentato un'esperienza di assoluto rilievo attraverso interventi sinergici che oltre a soddisfare la legittima curiosità del Homo sapiens di esplorare l'ignoto ha permesso approfondimenti e sviluppi che amplificano il concetto della scienza come sovrana attività umana, producendo azioni concrete in favore delle comprensioni dei fenomeni e delle conservazioni delle aree oggetto di studio.

Figura 4 – Immersione fra gli Icebergs (foto Lorenzo Epis)

Figura 5 – Lo staff AKAKOR (Italia e Brasile) e la squadra spagnola della Spedizione Islanda'99 (foto archivio AKAKOR)

Ringraziamenti

Si ringraziano per la collaborazione: "International Commission Glacier Caves and Karst in Polar Regions" nella persona del Dottor Adolfo Eraso Romero; FEALC – Federazione Speleologica dei paesi della America Latina e Caraib; SSI – Società Italiana di Speleologia; SBE – Società Brasiliana di Speleologia; The Explorer's Club, New York; TESTO – istrumenti multifunzioni, Italia; Winter & Summer by LONGONI and ICEMEN dry suit, Italia.

Figura 6 – Topografia aerea di un ponore (Foto Alessandro Anghileri)

Stress and Control Techniques for Cave Divers Activity

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Abstract

What's Stress? Which implication does it have for an activity that take place in an hostile environment with life support equipment to manage? Can we control it? How could we manage it?

This work give an indication in order to provide an answer to this questions; it analyzes the behavior of the man during the dive in confined space and suggests some methods to improve the sensorial perception and performances during that activity where the Stress is a fundamental parameter.

The following arguments are analyzed: Developing Stress Causes in a cave diver; Effects of the Stress, The spiral Stress/Panic. Also are discussed: Technique to prevent manage and control of Stress, Personal capability improvement, Training, Concentration and control of the mind, Control of breathing, Positive visualization, Psychological self training methods, Perceptive capability improvement.

Abstract

Che cosa è lo Stress? Quali implicazioni ha in una attività svolta in un ambiente ostile, con attrezzature vitali da gestire? Lo Stress è controllabile? Come?

Il presente lavoro vuole fornire indicazioni utili a formulare una risposta alle domande di cui sopra, analizzando il comportamento degli individui durante le immersioni in ambienti confinati e suggerisce alcuni metodi per migliorare la percezione sensoriale e le performance in una attività dove lo stress è un parametro fondamentale.

Sono trattati i seguenti argomenti: sviluppo delle cause dello stress nello speleosubacqueo, effetti dello stress, la spirale stress/panico. Sono inoltre discussi: tecniche di prevenzione gestione e controllo dello stress, incremento delle capacità personali, allenamento, concentrazione e controllo della mente, controllo della respirazione, visualizzazioni positive, Training Autogeno, incremento delle capacità percettive.

Lo stress e la speleosubacquea

Stress

Nel linguaggio comune la parola Stress viene comunemente utilizzata per definire uno stato psicofisico di un soggetto sottoposto a stimoli nocivi, fisici e sociali, che agiscono con una elevata intensità e per un lungo periodo di tempo. Assume poi il significato di "strapazzo fisico e mentale" o di "prolungata tensione nervosa. Con il termine Stress, si vuole indicare uno "stato di tensione o di resistenza di un soggetto o di un oggetto che si oppone a forze che agiscono su di lui." Le seguenti definizioni di Stress aiutano a delinearne le caratteristiche: "Risultato dello squilibrio tra le richieste poste su di un individuo e la capacità dell'individuo di rispondere a quelle richieste" (Mc GRATH 1970) oppure "… perché una situazione risulti Stressante è necessario che l'individuo percepisca come gravi le conseguenze di un eventuale errore" (SELLS 1970).

Due fattori caratterizzano una situazione di Stress: la differenza tra richieste e possibilità di soddisfarle nonché la gravità delle conseguenze di questa incapacità. Questa differenza tra richieste e capacità di soddisfarle assume la connotazione di una forza motrice per l'adattamento ad una nuova situazione caratterizzata da nuove richieste. Lo Stress è quindi indispensabile per garantire l'adattamento. Quando però le risorse psichiche necessarie non sono sufficienti a garantire questo adattamento l'organismo reagisce in modo anomalo dando origine in alcuni casi, a situazioni patologiche.

Gli stimoli esterni a cui siamo sottoposti hanno quindi azione diretta non solo sul sistema psicologico ma anche su quello biologico. Il sistema nervoso autonomo funziona da tramite con tutti gli organi coinvolti nelle reazioni da Stress.

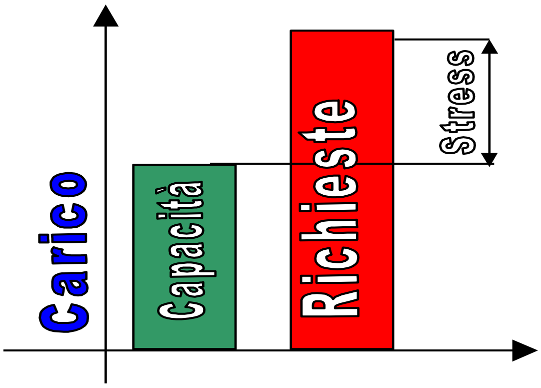

Figura 1: Lo stress si concretizza come differenza tra Capacità e Richieste

Il livello di queste reazioni determina il modo in cui il soggetto reagisce, correttamente o non correttamente, alle richieste a cui è sottoposto (Fig. 2) . L'accuratezza delle risposte è strettamente legata al livello di eccitazione, e quindi di Stress, a cui il soggetto è sottoposto. Il livello più basso di eccitazione corrisponde al sonno profondo. Al crescere dell'eccitazione si passa al risveglio e quindi ad un aumento delle capacità d'attenzione, delle capacità percettive, sensoriali e di sintesi fino ad arrivare ad un livello massimo corrispondente al livello ottimale di eccitazione. Superato questo livello ottimale l'aumento dell'eccitazione (dello Stress) provoca l'insorgere di turbe emotive che possono condurre velocemente alla completa disorganizzazione. Il livello di eccitazione ottimale, corrispondente alla massima accuratezza dell'esecuzione, è intermedio tra i due estremi relativi ad uno stato di sonno profondo e ad uno stato di disorganizzazione.

Figura 2: Curva Eccitazione Accuratezza: il livello ottimale di Stress, corrispondente alla massima accuratezza dell'esecuzione, è intermedio tra sonno profondo e disorganizzazione

In condizioni "normali" lo Stress è una risposta positiva dell'organismo che stimola l'adattamento alle nuove richieste. Se questo adattamento non avviene, o se la continuazione degli stimoli inducono in un eccesso di Stress (chiamato anche "Distress" in gergo tecnico) questo si trasforma in una condizione negativa che comporta risposte anomale da parte dell'organismo.

Le *capacità*, le *richieste* e le *conseguenze* sono soggette a variazioni soggettive e ambientali. L'individuo può intervenire sia sui primi due fattori (capacità e richieste) al fine di diminuire l'ampiezza del divario, sia sul terzo fattore (conseguenza) modificando il risultato di un eventuale errore.

La speleosubacquea è un'attività dalle diverse connotazioni, con notevoli coinvolgimenti psicologici ed emozionali che nella maggioranza dei casi portano ad agire in condizioni di stress.

La necessità di conoscerlo, e controllarlo rientra tra le fondamentali tecniche dell'immersione speleosubacquea

Cause determinanti Stress

Prima, durante e dopo l'immersione lo speleosub è sottoposto ad una serie di stimoli di natura fisica e psicologica che intervengono pesantemente sulle decisioni da prendere o sul comportamento durante l'immersione. Questi stimoli possono essere raggruppati in: compiti e stimoli esterni, interazione con l'ambiente, stimoli interni (autosuggestione).

Il soggetto deve agire in un ambiente diverso in cui, per sopravvivere, è necessario utilizzare e sapere gestire una complessa e pesante mole di attrezzature. E' necessario avere fiducia nell'attrezzatura e saperla utilizzare senza commettere errori. Oltre a ciò, durante l'immersione, il subacqueo deve svolgere una serie di compiti, fisicamente ed emotivamente impegnativi.

L'obiettivo della immersione deve essere raggiunto nello stretto rispetto dei tempi imposti durante la pianificazione e pertanto strettamente correlati con l'autonomia che l'attrezzatura e le scorte di gas impongono. Molto spesso questi compiti devono essere svolti in condizione di freddo e di scarsa visibilità. L'ambiente circostante, con cui il subacqueo interagisce, può essere fonte di ulteriori pressioni causate dallo stesso subacqueo (sollevamento di sospensione, perdita di orientamento).

Ognuno di questi fattori determina una pressione psicologica e fisica a cui il soggetto deve fare fronte.

Suggestione: l'ambiente e gli stimoli a cui il subacqueo è sottoposto, unitamente al retaggio culturale, suggestionano il soggetto spingendo la sua mente ad immaginare scenari fantastici, spesso catastrofici ed il più delle volte ingiustificati. La suggestione derivante dall'ambiente si integra con l'autosuggestione derivante dal subacqueo.

Stress da equipaggiamento: è da attribuirsi a: scelta dell'equipaggiamento ottimale in termini di sicurezza/ridondanza, non perfetta conoscenza e fiducia dell'equipaggiamento.

La scelta, la ridondanza, la qualità sono spesso caratteristiche che non dipendono solamente da valutazioni tecniche. La non completa fiducia può sembrare irrilevante al momento dell'immersione ma poi, in profondità, magari durante un'emergenza, affiora dal subconscio aggravando ulteriormente il carico psicologico da gestire in quella situazione. L'oggetto che inconsciamente si pensa non essere adatto all'immersione sarà il primo pensiero nel caso di un sovraccarico di Stress, spostando l'attenzione del soggetto dalle effettive cause da considerare.

Pressione sull'orgoglio: voler dimostrare a se stessi o agli altri di poter fare cose per cui non si ha la certezza di poter riuscire, andare oltre a quelle che sono le nostre reali capacità per sfida personale o per pressioni esterne costituiscono grossi fattori incidentali. La maturità, richiesta ad ogni speleosubacqueo, porterà il soggetto a non accettare sfide per cui non è preparato o per cui non è disposto ad accettare il rischio.

Sovraccarico di compiti e pressione sul tempo: nelle attività speleosubacquee, l'accuratezza è di fondamentale importanza; per la maggior parte delle azioni non è ammesso nessun margine di errore. Il sovraccarico di compiti e la pressione sul tempo agiscono generando divario tra richieste e possibilità di soddisfarle generando una situazione di Stress.

Il Compagno: la presenza di un compagno è fonte di sicurezza. Da sempre l'uomo ha tentato di domare le proprie paure attraverso il conforto e la sicurezza derivante dall'appartenenza ad un gruppo. A questi retaggi storici si deve aggiungere che tutte le didattiche commerciali inculcano negli allievi il concetto di sicurezza legato all'immersione in coppia. In molti casi, nell'immersione in grotta è però richiesto un intervento solitario e, questa sicurezza viene a mancare.

Ma che cosa succede quando, dovendoci immergere con un compagno, siamo consapevoli della sua "incompetenza"? La necessità di dovere intervenire in suo aiuto o la difficoltà derivante dalla mancanza di feeling tra gli elemento del gruppo comporta un sovraccarico di compiti negli elementi "competenti" generando in questi una situazione di Stress. Al compagno "incompetente" che cosa succede? Se è inconsapevole della sua "incompetenza" o se questa incompetenza è "istituzionale" (allievo o cliente di una guida), non subirà pressioni alcune da questo stato ma se, viceversa, né è consapevole, subirà una duplice pressione derivante da : sovraccarico di compiti, dettata dalla volontà di essere allo stesso livello degli altri elementi e pressione sull'orgoglio generata dalla paura di non potervi riuscire.

Effetti dello Stress

Piccoli livelli di Stress possono non dare segnali percettibili ma, quando il carico comincia a diventare consistente il soggetto manifesta una serie di comportamenti che possono essere individuati dal soggetto stesso o da un compagno di immersione che osservi con attenzione.

I segnali di Stress individuabili dal soggetto stesso possono essere: aumento del ritmo respiratorio, necessità di tenersi fortemente ad una cima, contatto con il compagno, necessità di fuga (dall'acqua, da una grotta, dalla barca); mentre tra i segnali di Stress individuabili dai/dal compagni/o abbiamo: risposte ritardate o scorrette, occhi sbarrati, movimenti confusi e scoordinati, alterazioni comportamentali (Loquacità, Silenzio), eccessivo controllo dell'attrezzatura.

Compromissione delle percezioni: il soggetto percepisce solamente l'elemento più immediato o più evidente di un problema senza considerare le ulteriori informazioni a disposizione che porterebbero ad una soluzione razionale. E' necessario allenare le capacità percettive imparando a "sentire" tutti i segnali che provengono dall'interno o dall'esterno del nostro corpo. Solamente la selezione razionale dovrà dirci quali segnali considerare e quali ignorare.

Compromissione Cognitiva e Analitica: il soggetto, pur avendo a disposizione tutte le informazioni necessarie per arrivare ad una decisione, non è in grado si sintetizzare la conclusione o non è in grado di agire di conseguenza, oppure agisce in modo differente dalla decisione presa.

Compromissione delle capacità di reazione: il soggetto non agisce in modo coerente o non agisce assolutamente, a seguito di stimoli esterni, pur avendo sintetizzato una azione coerente dalle informazioni in suo possesso.

Panico: è l'ultimo stadio della compromissione mentale: il soggetto agisce in modo inconsulto e disordinato senza alcuna connessione razionale; tende solamente a soddisfare in modo istintivo una richiesta che in quel momento giudica primaria.

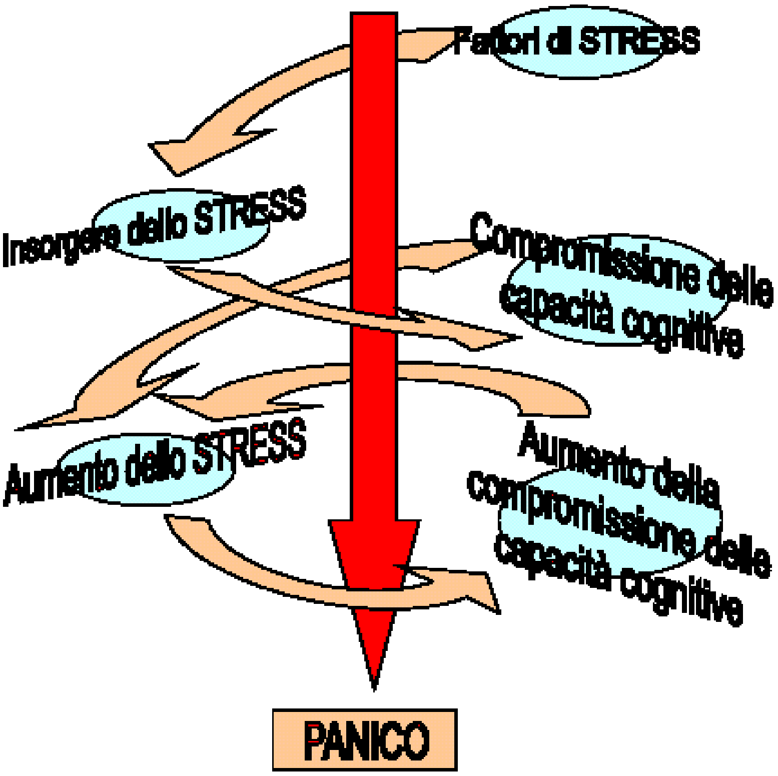

Figura 3: Spirale Stress-Panico. Se non fermato in tempo, lo Stress genera una spirale causa effetto che conduce al Panico

La spirale STRESS / PANICO

Quando lo Stress aumenta, diminuisce nel soggetto la sensibilità ad individuarlo e ad agire di conseguenza. Si innesca in questo modo una reazione a catena, una spirale di azioni e reazioni che, se non interrotta tempestivamente, avrà come ultima ed inevitabile conseguenza il panico, uno stato di disorganizzazione totale.

E' necessario interrompere questa excalation intervenendo al più presto possibile; più l'intervento sarà intrapreso all'inizio della spirale, tanto più facile sarà porvi rimedio adeguatamente.

Prevenzione Controllo e Gestione

Durante lo svolgimento di un'immersione la differenza tra richieste (stimoli da soddisfare e controllare) e le capacità proprie del subacqueo in quel momento, causerà nel soggetto un determinato grado di Stress che, se mantenuto entro livelli normali (Fig.4(1)) svilupperà un adattamento, una sorta di allenamento psicologico, migliorando le sue capacità e riducendo quindi nel tempo lo Stress generato fino ad annullarlo. (Fig.4(2))

Abbiamo visto che esiste un livello ottimale di eccitazione, di Stress, che comporta il massimo di risposte corrette nel soggetto. Il processo di adattamento comporta la diminuzione dello Stress e quindi uno spostamento nella curva Eccitazione/Accuratezza verso sinistra in una zona in cui la non correttezza delle risposte è dovuta ad una sotto eccitazione, ad uno stato di torpore. Il soggetto è ben preparato per affrontare le richieste a cui è sottoposto ma il suo livello di attenzione è spento, insufficiente. A questo punto devono intervenire dei meccanismi coscienti, razionali, che impongano al soggetto la massima vigilanza anche in assenza di stimoli esterni che inducono Stress. Questi meccanismi si possono ricercare nelle tecniche di concentrazione e di controllo della mente.

Contrariamente può succedere che un'emergenza causi un grosso ed improvviso aumento delle richieste. Questo, in un soggetto in via di adattamento (Fig.4(1)) o in un soggetto adattato alla normale routine di immersione (Fig.4(2)) causa un immediato insorgere di uno stato di Stress maggiore di quello compromettendo le sue capacità di gestire l'emergenza. (Fig.4(3)) Questa situazione fa scaturire due diversi problemi riguardanti la gestione dell'emergenza e la sua prevenzione. Durante la gestione dell'emergenza il subacqueo deve controllare la situazione per evitare di cadere nella disorganizzazione e nel panico. Deve sviluppare la capacità di agire razionalmente anche sotto un forte carico di Stress e deve sviluppare un adattamento tale che, anche in condizione di emergenza, gli permetta di essere in una condizione di eccitamento ottimale tale da poter gestire l'imprevisto (Fig.4(4)). Questo comporta allenamento alla gestione delle emergenze, adattamento all'ambiente, preparazione fisica e tecnica. Come prevenzione il subacqueo deve programmare l'immersione in modo da evitare emergenze di ampiezza tale da non essere gestite. Questo comporta un'accurata scelta dell'immersione, del compagno, dell'attrezzatura, delle procedure di emergenza.

La situazione di immersione ottimale sarebbe quella in cui il soggetto ha sviluppato un adattamento all'emergenza. Durante la normale attività, l'individuo è quindi in condizioni tali da essere in assenza di Stress (capacità superiori alle richieste) ed inoltre con una capacità di concentrazione tale da permettergli, anche in questa situazione, una massima vigilanza attiva e quindi un livello di eccitazione percezionale indotto che implichi un'accuratezza dell'esecuzione simile a quella derivante da un livello ottimale di Stress. Nel caso di un'emergenza il soggetto si troverà sottoposto ad un livello di Stress prossimo al livello ottimale. Le capacità di concentrazione devono intervenire anche per individuare, nel caso di una emergenza di dimensioni maggiori, quei segnali che avvisano il soggetto della presenza di un eccessivo livello di Stress e che quindi ne impongono una gestione, una interruzione della spirale, prima che questa conduca al panico.

Non essendo determinabile a priori il livello delle richieste derivanti da un'emergenza, il soggetto deve avere la possibilità di dedicare ad essa tutte le energie disponibili evitando di impegnare energie in attività che possono essere svolte in modo automatico o riflesso.

La capacità di agire sotto Stress implica la necessità di intraprendere azioni senza dover applicare una procedura di problem solving. E' pertanto necessario, per ridurre le richieste rivolte al soggetto durante un emergenza, che tutte le procedure e tutte le azioni da esse imposte siano sovraimparate. In questo modo ogni azione avviene in modo riflesso e non ragionato. In questo modo molte più energie sono disponibili per analizzare gli altri fattori derivanti dall'emergenza.

Il subacqueo deve essere cosciente delle proprie effettive capacità e dell'ampiezza delle emergenze che si possono verificare durante l'immersione. La consapevolezza di questi due fattori determina la consapevolezza del livello di rischio a cui il soggetto si sottopone e che è disposto ad accettare. Qualora invece il soggetto pensi di poter affrontare una situazione a cui non è preparato, si sottopone ad una situazione estremamente rischiosa poiché, in questa circostanza di inconsapevolezza, mancheranno i segnali di allarme derivanti da Stress che avviseranno il soggetto della inadeguatezza della sua preparazione. Solo in caso di necessità il soggetto si rende conto di non essere all'altezza, quando l'ampiezza delle richieste ha già superato le capacità del soggetto. Qualora, d'altro canto, un soggetto affronti una situazione consapevole di non esserne all'altezza, il suo livello di Stress iniziale sarà già tale da portarlo ad agire nella zona 2 della curva Eccitazione/Accuratezza.

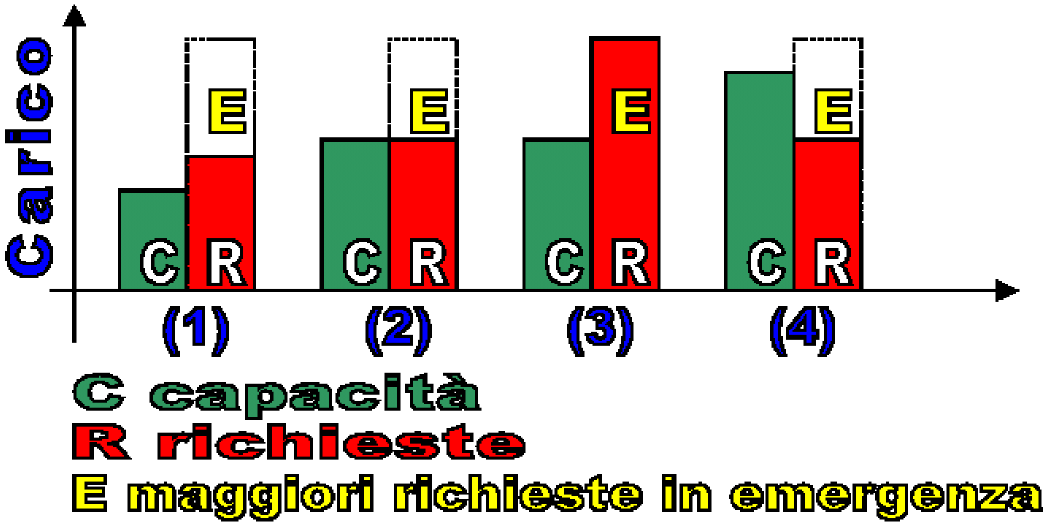

Figura 4: Aumento delle richieste in caso di emergenza: è necessario essere preparati a sopportare questo carico.

Aumento delle Capacità Personali

Preparazione Fisica, allenamento e controllo della forma, alimentazione, preparazione tecnica (teorica e pratica), sovraimparare le procedure sono tutti argomenti da considerare per aumentare e proprie capacità personali.

Le tecniche di controllo comprendono: visualizzazione positiva (Suggestione), Training Autogeno, Tecniche di controllo della respirazione, tecniche di controllo della mente, miglioramento e sensibilizzazione alle percezioni sensoriali.

Valutazione dei soggetti inadatti

La valutazione dei soggetti deve essere effettuata sia per soggetti che si avvicinano all'attività (eventualmente scoraggiandone la prosecuzione) sia, cosa ancora più importante, per la scelta del compagno di immersione o per la formazione di team che devono svolgere assieme determinate attività nell'ambito dell'immersione non sportiva.

Preparazione Fisica

Capacità di trasportare e gestire l'attrezzatura fuori dall'acqua durante la vestizione, durate gli spostamenti, su di una barca che rolla a seguito di mare grosso. Una buona preparazione fisica generale è indispensabile; le caratteristiche da curare maggiormente sia per quanto riguarda l'apparato locomotore e il tronco sono: capacità e resistenza aerobica, forza generale. Non è richiesta potenza e resistenza lattacida in quanto questo campo di produzione di lavoro deve essere evitato dal subacqueo in immersione. Un'alta soglia lattacida è comunque una caratteristica fondamentale. Per alcuni tipi di immersione la corporatura fisica è pure di aiuto. Le caratteristiche richieste sono: capacità aerobica, potenza aerobica, forza fisica generale, alta soglia aerobica.

Apnea

E' il miglior esercizio di allenamento per tutte le immersioni non sportive. Serve a migliorare il controllo della respirazione, insegna ad agire in condizione di pressione sul tempo, insegna a controllare fino a che punto spingersi, a non superare il limite imposto.

Concentrazione e controllo della mente

Le tecniche di concentrazione e di controllo della mente insegnano ad affilare lo strumento, a diventare padroni della mente, a concentrare le sue energie in un punto, con precisione, con efficienza. Attraverso le tecniche di concentrazione è possibile comandare la mente e non farsi comandare da essa.

L'importanza di tutto ciò per l'attività subacquea è innegabile. Il mantenimento della concentrazione, focalizzando tutte le nostre energie sulla esatta percezione degli stimoli esterni ed interni a cui siamo sottoposti, senza inutili divagazioni, senza inutili attività mentali parallele, pongono il subacqueo in una condizione mentale ottimale, di massima efficienza, in cui la corretta applicazione delle tecniche di immersione apprese e lo svolgimento dei compiti richiesti rappresentano l'obiettivo principale della nostra mente.

Divagazioni e disordine mentale ci spingono verso la distrazione, verso la mancata lettura dei segnali percettivi, verso l'autosuggestione; questo, in uno scenario di immersione speleosubacquea, porta irrimediabilmente ad un ingigantimento dei pericoli a cui il soggetto è sottoposto.

Controllo della respirazione

Il controllo della respirazione mira a due importanti traguardi: la diminuzione dei consumi di gas e l'influenza sui processi psichici. Normalmente, durante i corsi subacquei, si sente ripetere che in acqua si deve semplicemente respirare in modo normale, come durante una qualunque attività di superficie. Questo è totalmente sbagliato. E' necessario adottare un ritmo respiratorio che diminuisca i consumi comportando un aumento dell'autonomia in immersione. Il subacqueo deve adattare il carico di lavoro al ritmo respiratorio e non viceversa. Un corretto ritmo respiratorio facilita anche il rilassamento e l'autocontrollo agendo direttamente sui nostri processi psichici e, riducendo la pressione psicologica nei momenti di Stress.

Visualizzazioni Positive

La tecnica delle visualizzazioni positive, attraverso il coinvolgimento del sistema nervoso emozionale, consente al soggetto di porsi in condizioni psicofisiche ottimali per affrontare una immersione. Il subacqueo, nei momenti precedenti una attività, deve immaginare lo svolgersi dell'immersione in modo positivo, ripercorrendo mentalmente le attività da svolgere pensandole condotte con esito favorevole, senza incidenti, in un ambiente amichevole e conosciuto.

Training Autogeno

Il T.A. è una tecnica di rilassamento e cambiamento che produce nel praticante delle reali modificazioni psicologiche e fisiologiche. Attraverso una serie di esercizi da apprendere e ripetere in modo autonomo, il T.A. insegna ad un individuo a separare e distinguere le azioni dei sistemi simpatico e parasimpatico permettendogli di creare un giusto equilibrio psicofisico e di controllare in modo volontario reazioni fisiche che normalmente non sono sotto il suo controllo.

Miglioramento delle capacità percettive

Un essere umano è in contatto con il mondo esterno attraverso i cinque sensi: egli ascolta, vede, tocca, annusa e assapora. Questi sensi gli permettono di percepire le sensazioni, di percepire ciò che l'ambiente esterno comunica. L'improvviso annullamento di uno dei sensi può provocare in un soggetto reazioni diverse, variabili da individuo a individuo, che possono arrivare fino al panico.

La mancanza o la menomazione di uno dei sensi spinge normalmente un soggetto all'adattamento sviluppando maggiormente i sensi rimanenti o il senso che può supplire maggiormente alla mancanza. Il subacqueo in immersione si trova in una situazione particolare in cui due dei cinque sensi non sono assolutamente usati (olfatto e gusto) mentre gli altri sono obbligati a lavorare in una condizione particolare.

The Underwater Topography in Expedition Atahualllpa 2000: The connection with archaeology and Geology Sciences

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Abstract

With the Atahuallpa Expedition in August 2000, the cultural association AKAKOR GEOGRAPHICAL EXPLORING Onlus realised a multidisciplinary project in the waters of Lake Titicaca (Bolivia), in which underwater topography played an important role, serving the explorers.

The extreme conditions in which the work was carried out (3812m altitude) combined with the technical difficulties due to the nature of the project, forced the divers to adapt to the Bolivian physical-social system, using simple but efficient instruments and work techniques. In this article the author wishes to highlight the technical-operative aspects adopted during the expedition which brought concrete results over a short time scale and with limited costs.

Geographical localisation and physical characteristics of the work area

Lake Titicaca in South America extends along the heart of the high plain divided between Peru and Bolivia at an alitude of 3812m, at the feet of the western front of the Cordigliera Andina whose peaks stand at over 6000m.

The lake is 176m long in the northwestern-southeastern plane, 70km wide and has a surface area of 8400km2, with a maximum depth of 283m in Bolivia.

Characteristics of the Lakewater

The average monthly temperatures of the surface water of Lake Mayor between 1977 and 1979 (Carmouze et al. 1983) vary between 11.25 and 14.35°C, the minimum in August and the maximum in March. The average annual temperature (1977-79) is 13.0°C.

Occasional measurements taken in Lake Mayor (Gibson 1964, ILTIS 1987) demonstrate a minimum of 10.9°C at the end of July and a maximum of 17°C in February, whilst Lake Minor shows extremes of 8.5°C in July and 18.5°C in February.

In Lake Menor, the transparency of the water varies between a minimum of 4.5m and a maximum of 10.5m (Richerson 1977). Observations taken in 1982 show a maximum of 13.3m visibility which increased to 15.7m in 1984-85 (Alfaro and Roncal). In the Bolivian area of Lake Mayor five series of measurements taken at nineteen stations, show average visibility of 11.8m in June 1985, 11.9m in December 1985, 13.2m in April 1986, 12.4m in October 1986 and 13.9m in February 1987 with values between 7.5m and 18.5m (ILTIS 1987).

The Theory of Akakor Geographical Exploring

Recent studies have shown that 10,000 years ago Lake Titicaca had a smaller surface area due to an arid climate and the influx of alluvial deposits carried by the numerous torrents. The level of the lake dropped almost to drought levels, giving the possibility to new civilisations, however, to expand along its fertile banks. Successive natural events have brought the lake to today’s levels submerging centuries of history.

Akakor’s archaeologists believe that civilisations grew up on the now-flooded shores of the antique lake, and that interesting ruins remain on the lakebed near to several islands. It was around these islands - Island of the Sun, Island of the Moon, Koa Island and Pallalla Island - that the research of the Atahuallpa 2000 Expedition was concentrated.

Aim of the topographical survey

The topographical surveys of the archaeological sites identified in Lake Titicaca had the following aims:

- to draw up sufficiently detailed maps of the lakebed explored to allow the elaboration of geological and archaeological studies and theories of the Atahuallpa project;

- to construct a basic network in which the minor samples and eventual findings on the lakebed can be fitted.

Working methods applied

The choice of the working methods applied was heavily influenced by the difficult work conditions:

- the high altitude of the lake (3812m);

- the difficult access to the underwater work areas caused by the long distances and the complex morphology of the terrain.

The altitude of the lake led to specific immersion techniques and consequently limited the productivity. The difficulties in reaching the work areas also compromised the transport and use of technically advanced equipment, due to their size or fragile nature.

Simple yet reliable topographical techniques and instruments were therefore employed, easy to use in stressful or difficult conditions.

The first topographical operations conducted were the localisation of several points, limited in number yet precisely localised, which serve as reference points for the successive operations. These points made up the horizontal support network. The operations were carried out using triangulation and polygonation techniques due to the nature of the sites and the kind of information required for the archaeologists.

The geometric plan of triangulation is made up of a large number of triangles placed side by side with one side in common, obtaining between them the points to read; polygonation on the other hand, consists of measuring directly all the angles and sides of a polygon obtained by joining the points two by two.

Due to the difficult terrain, the problems connected with repetitive dives at high altitude and the extreme conditions linked to the work areas, these techniques were adopted because they don’t require sophisticated or heavy, cumbersome equipment.

Triangulation Method: to begin with we carried out an inspection of the lakebed to ascertain its morphological characteristics, the types of vegetation and the level of visibility: elements which, together with the expanse of the area, led to the choice of the points to read, called trigonometric vertices. The lines of sight linking these points formed the sides of the triangles. One side of the first triangle was measured, called the triangulation base, from which the other sides were calculated based on the measured angles, after applying the sine theorem. Having established the direction of one side, the direction of the others were then established and the relative positions of all the vertices could be calculated in cartesian co-ordinates.

This method needed only basic underwater topographical instruments; a lanyard measurement reel, a diving suit compass, depth guage and a tape measure.

Polygonation Method: The conditions of the lakebed and the precision required limited the choice of the points to distances between five and thirty metres. When the polygon touched two trigonometric vertices, it was done so that it had a flattish plane, or in other words, so that the angles were almost flat. When the lakebed to measure was quite spread out, several polygons were created in three distinct levels of importance: the primary polygon, the secondary and then detail polygons.

Often, for several smaller areas, one polygon was enough without using triangulation: in these cases the points were chosen specifically to obtain a closed polygon so having the possibility to carry out checks and compensation of the measurements.

The “Squaring” or Grill Method: This is the most practical method to survey a site of archaeological interest. Some of the sites identified by the archaeologists of Atahuallpa were covered by a fixed geometric grid made up of a series of orthogonal co-ordinates extended between two perimeter points, to form a mesh with dimensions relative to the size of the area.

To avoid distortions due to the flexing of the lines under water, this technique required the use of a non-extending flexible cable or, where possible, the use of a rigid quadrant: a modular framework constructed using any available materials, such as plastic tubes (PVC) filled with sand or metal tubes with a cross-section of 30mm, distributed in quadrants of two by two, three by three or four by four metres, with vertical support legs regulated according to the lakebed morphology.

Topographic survey and design

The topographic design and survey consists of determining the form and dimensions of the natural characteristics (rocks, pits, algae, etc.) and artificial characteristics (habitat, ruins, general finds, etc.) of the lakebed and to represent these characteristics on a map using conventional symbols, in a clear and precise manner.

The planimetric position and the depth of the various points chosen in the area to map, must be sufficiently numerous to allow a faithful reproduction of the lakebed characteristics on the final design. The distances and angles measured are cross-referenced to already known points and directions, and are generally executed using simple and quick instruments and equipment such as a tape measure, a compass and depth measure.

The correct choice of the points to map was very important for the project: for the sites containing archaeological finds or human remains under the sand (discovered in the waters of Titicaca by the Akakor divers) important vertices from a scientific point of view were chosen, whilst for the natural lakebed locations cardinal points such as large masses, notable depth variations or artificial stakes appropriately placed were chosen. The choice of the points for the depth readings was more delicate, as it was necessary to take note of all the points in which there was any notable variation in the slope or in the direction of the level curve. Fortunately Lake Titicaca has a relatively regular lakebed, with fairly consistent variations in its level, which follow the profile of the surrounding hills.

The scale of the map was chosen according to its eventual purpose (archaeological, geological, hydrological), whilst the distance between the level curves was fixed at 1/1000th of the scale denominator.

For the Atahuallpa project the scientists had requested scales such as 1:1000, 1:1500, 1:2000 as these could be traced on a normal field table whilst the morphological and archaeological details of the lakebed could be shown with sufficient precision.

The reference points were surveyed with great precision, to limit the errors in the location of the detail points which in turn would be compounded by the map scale. Therefore, on a map with a scale of 1:2000 with a graphical precision of +/- 0.25mm, realised with a normal field instrument (a sharp pencil), this meant a lakebed error of +/- 0.50m.

The data and information recorded was then transferred to graphical form on a map, clearly noting the depth next to each point. With the help of the notes taken and the sketches made, the points were joined up to obtain the planimetry. To obtain all the depth points through which the level curves pass, linear lines were drawn up between the measured points. In a few cases, the level curves were obtained using the sections method, measuring various vertical sections of the lakebed from the noted points: after having drawn up the vertical sections in scale, the positions of all the depth points were drawn up and then transferred to the map.

The map was completed by the use of symbols and inscriptions to identify particular characteristics on the lakebed, such as sandy areas, the presence of algae, stones and rocks, or archaeological finds.

In the map's margins the scale, the distance of the depth lines and geographic and magnetic north were indicated. To help the passage from the graphic measurements to the real ones, the graphic scale was also shown: from left to right along a straight line, segments were drawn up representing, in scale, 1m, 2m, 5m, 10m, 100m, etc. Starting from the same initial point on the straight line but to the left, a one metre segment divided in ten equal numbered parts was shown. Using only field instruments (a compass) it was quick and easy to obtain real lengths and distances without using calculations, which greatly helps those who have to work in difficult conditions or a hostile environment.

The designs and drawings of the structures discovered during the digs were also very relevant. One may believe that photography could replace traditional designs, but this isn't true. The archaeological design presents the inequivocable advantage of combining an objective representation with subjective selection and interpretation of reality. The Akakor divers had to try during the dives to represent in a scientific-documentative way, tablets and structures of historical interest. The designs were then immediately copied on paper and were then studied to draw up sections and plans of possible ancient constructions.

Instruments and tools

The following is a list of the instruments used during the topographical surveys in the underwater archaeological work areas of Lake Titicaca. They are terrestrial tools modified to make them lighter, less bulky and safer. Some of these modifications were carried out in the work camps using available materials and according to the required needs.

Tape Measure: a normal rewindable tape measure normally used for terrestrial topography. The tape measures available for the use of the expedition's underwater divers were of 20m, 30m or 50m depending on the area to be measured. Important characteristics to obtain the maximum efficiency were:

- stainless steel construction;
- winding handle to speed up the rewinding of the tape;
- security attachment ring.

Lanyard Measuring Reel:_the reels used during the expedition are made up of a reel on which is wound a plaited white nylon cord of 3mm thickness and at least 100/150m long. Every five metres, the cord has a reference knot with a white band of reinforced tape on which is written in indelible ink the progressive distance in metres from zero. The precision depends on the elasticity of the material (test elasticity of approximately 20-25cm every 10m). , The cord, working in water, will eventually show a physical shortening variable depending on use, but averaging approximately 5% after 2-3 years.

Signal Strips: these are strips formed of white and red stripes normally used to mark out work areas in terrestrial sites. In underwater work sites they are used in the same way to indicate the extremes of the area to map or survey.

Underwater Compass: the divers have used commercial high quality instruments.

Depth Meter: use of the computer has been consolidated due to the levels of reliability reached, both in terms of use and of the precision of the data.

During the topography of the archaeological sites in Lake Titicaca, Aladin computers were used which proved themselves to be efficient even at such high altitudes (3812m), at low temperatures and for numerous consecutive dives.

To obtain a correct reading, the depth meters were basically rested on the lakebed at the point where the depth reading was to be taken.

Full Face Mask: during long work operations in cold water, requiring high levels of concentration such as for underwater topography, the divers needed thermal operation, comfort, the possibility of communication and good visibility. The use of full face masks avoids the need for an uncomfortable mouthpiece, and permits the nasal breathing of filtered air, facial protection, and improvements in the work conditions increasing performance.

The use of the full face mask became extremely important, above all for underwater topographical techniques involving more than one element. Co-ordinating six divers distributed over a front of ten metres, involved in a carpet rake of the lakebed with a visibility of one metre, would have been particularly difficult and wouldn't have given the same results in terms of speed and efficiency without the use of communications systems.

Equally, for drawing up of grids for the vast and morphologically complex archaeological sites where visible contact between the operators is often difficult or impossible, the use of full face masks proved essential.

The detailed planning of the operations is fundamental, but obviously cannot foresee problems that may emerge during the dive. Vocal communication in real time between the operators allows, for example, to verify dubious measurements, to correct the positions of the instruments, and to signal problems without the need for visual contact.

It is also beyond discussion that this equipment greatly aids the security of the work dives. The possibility to notify problems or uneasiness during difficult dives allows one to work with greater tranquillity and attention.

The Atahuallpa expedition used Ocean Reef equipment, appreciated for its light weight, robust construction, ample visual field, ease of fit, stability at low temperature, and reliability.

Blackboard: essential for underwater topographical work. Large blackboards with fine writing were used to record the data collected and to realise designs underwater. The sizes used were: 15x20cm for explorative sketches; 20x30cm for instrumental surveys.

Survey Team

The personnel for the underwater topographical team of the Atahuallpa project was made up of an underwater survey technician and three expert support divers.

The teams of two were chosen according to the difficulty of the work to be carried out, the necessary immersion time for the survey and the underwater visibility conditions.

The cost factor is also an element that cannot be overlooked in an expedition of this nature.

For this reason underwater topography must be carrried out with great precision (relative to the work environment) and in the minimum possible time, having by necessity limited autonomy. This means providing the necessary data for the scientists in the shortest possible time to leave more time for analysis, which is notoriously long and laborious.

Perfect harmony in the survey team is necessary to guarantee the above. The underwater operators must have knowledge and command of the techniques adopted and a notable understanding with each other.

The organisation of the expedition allowed the perfection of underwater communication, above all through the use of the specialist equipment such as the masks which allow direct communication. This allowed us to increase the precision of the work whilst at the same time reducing the immersion times by 30%.

We cannot neglect the importance in the context of underwater topography in a scientific expedition of the transcription of the survey data during the day. This should be done, if possible, immediately after the dive, or at the latest in the evening after the completion of the work operations, to avoid losing the significance of the notes or the sketches, often recorded during difficult dives with little time available.

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Evaluation of the Tourist Impact in the Kartchner Caverns (Arizona, Usa)

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Abstract

Kartchner Caverns opened to the public in November 1999. Some preliminary studies have been performed in the cave in its natural status. Arizona Conservation Projects, Inc. (ACPI) established 22 monitoring stations, from these specific areas, measurements of air, water, soil, temperature's were taken. Humidity and carbon dioxide concentrations were also measured.

An evaluation of the impact assessment was obtained and suggestions to improve the present situation were proposed.

Introduction

This cave was discovered in 1974 on the property of Kartchner Family; fourteen years later a bill of the State of Arizona was passed and the creation of James and Lois Kartchner Cavern State Park authorised. After a long and detailed study of the cave, the first section of Kartchner Caverns was opened to the public in November 1999.

The results of a multidisciplinary investigation were published in the Journal of Cave and Karst Studies, vol. 61, No. 2, August 1999, where maps of the cave with indication of the stations are reported. A paper concerning the development and management of the Kartchner Caverns is included in the proceedings of this congress (TRAVOUS & REAM, 2001).

Measurements

Temperature

According to the actual data, the information was transformed from the original °F into °C. Digital thermometers were used and calibrated monthly with the same standard mercury thermometer over the time interval considered here. The accuracy of a single measurement may be assumed to be ± 0.1°C. The distribution of the stations in the cave is reported in Fig. 1.

For this study, 10 stations with the most complete data record in the period from 1996 to 2000 were considered. A sinusoidal best fit was calculated for each station with the FitSin Programme (GIORCELLI, 1998).

The generic equation of a sinusoid being:

y = A+B*sin(2□□x+□)/T)

where y is the temperature (°C), A is the average temperature, B is a coefficient equivalent to one half the amplitude of the sinusoid, x is the time (days), □ is the phase delay with respect to x = 0 (1st January 1996) and T is the period (= 365 days).

Obviously the temperature wave, originated outside by the seasonal variation, propagates into the cave through different mechanisms (air, rock, tourists) with a delay and attenuation depending on the mechanisms involved for each station. In Fig. 2 two typical diagrams have been reported..

In Table 1 some parameters obtained from the equations calculated for each station are reported. The average temperature is given by the coefficient A; the wave amplitude is given by the double of coefficient B; the attenuation is reported as percent of the outside amplitude; the date of the "summer" peak and the delay with respect to the outside peak are finally given. The stations have been listed according the increasing values of the delay.

A first examination of these data shows that the delay in Rotunda is the shortest (about one month). Then, in a second group of stations (Cul-de-Sac, Main Corridor, Grand Central, Lower Throne, Big Room Overlook) the delay is of two months. Another group of stations (Kartchner Towers, Jack Rabbit, Sharon Saddle) have a delay around three months and, finally, the last station (Start of Echo Passage) is characterised by the longest delay (about 8 months).

The attenuation of the temperature wave reported here, is calculated with reference to the ratio between the coefficient B of the respective best fit equations and not to the original values. According this procedure the disturbance of local temporary effects is avoided because smoothed functions are compared.

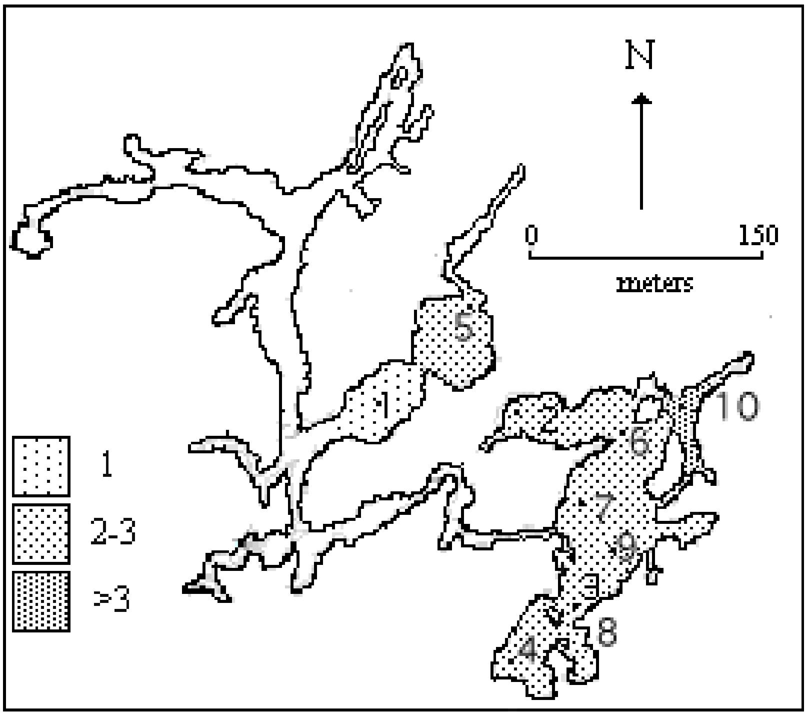

Fig. 1 Monitoring network. 1-Rotunda: 2-Cuk-de-Sac; 3-Main corridor; 4-Grand Central; 5-Lower Throne; 6-Big Room Overlook; 7-Kartchner Towers; 8-Jack Rabbit; 9- Sharon's Saddle; 10-Echo. The zones with the same delay (1, 2-3, and > 3 months) of the temperature wave propagation are also indicated.

Table 1 - Parameters of the temperature wave obtained from the sinusoidal best fit for the stations investigated.

Station	Average Temp. (°C)	Wave Amplitude (°C)	% of Outside	Date of max	Delay (days)
Outside	18.85	17.42	100	1-Aug	0
Rotunda	20.52	0.36	2.1	5-Sep	35
Cul-de-Sac	20.78	0.14	0.8	30-Sep	60
Main Corridor	20.21	0.54	3.1	30-Sep	60
Grand Central	18.68	0.90	5.2	30-Sep	60
Lower Throne	20.20	0.14	0.8	30-Sep	60
Big Room Overlook	21.11	0.04	0.2	30-Sep	60
Kartchner Towers	20.85	0.14	0.8	16-Oct	76
Jack Rabbit	20.26	0.04	1.1	22-Oct	82
Sharon's Saddle	20.99	0.34	**2.0**	15-Nov	105
Echo Pass. (Start)	20.64	0.10	0.6	28-Mar	238

Relative Humidity

In most cases, also the relative humidity was measured at the same time and place with air temperature. The very largest majority of values range between 95 and 100%. A few values, only, reach 90% but the natural equilibrium area close to 100%.

In this paper the relative humidity was not considered because it does not contribute any further to the knowledge of the cave climatology when temperature alone is investigated.

Obviously the relative humidity could be the object of future researches.

CO_2 concentration

Spot measurements of the CO_2 concentration were carried out by mean of a Draeger Pump from the end of 1997 and the results are reported in Fig. 3. The standard error associated to each value may be assumed to be around 100 ppm.

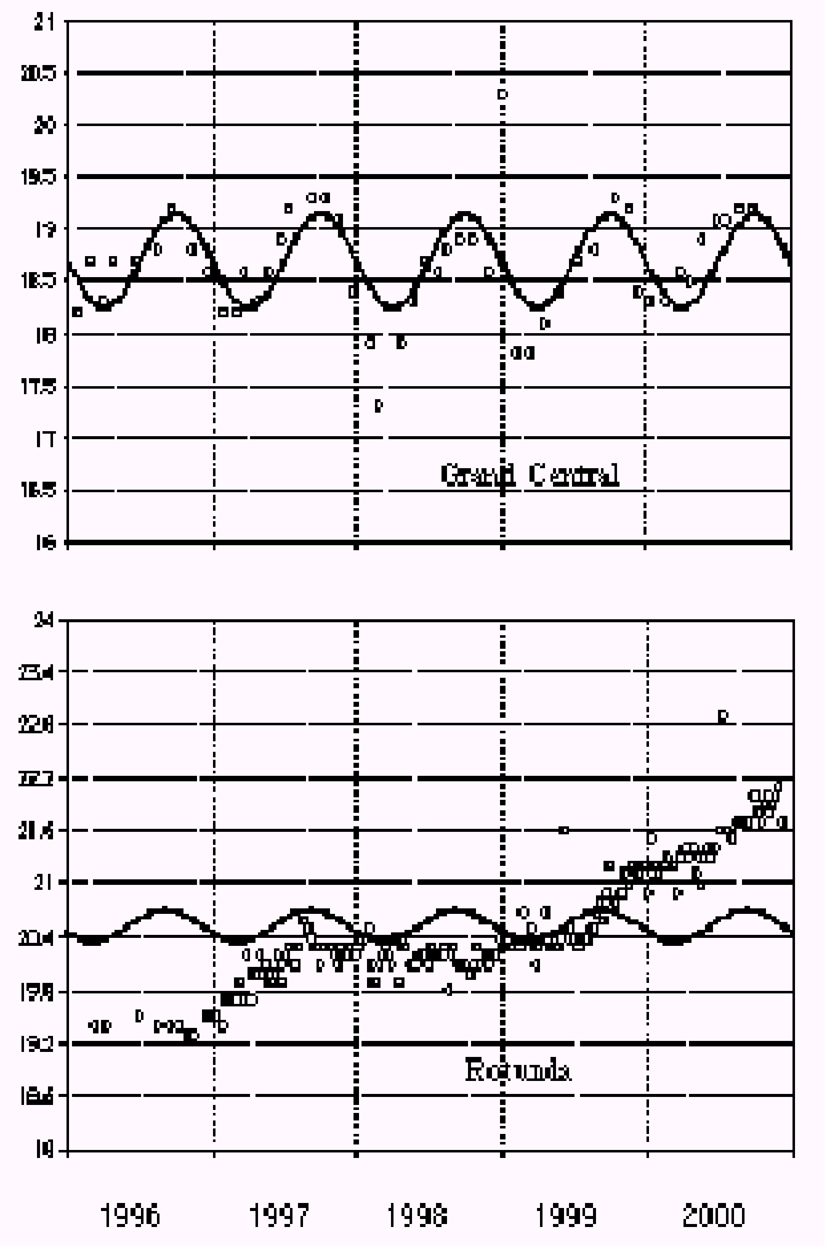

Fig. 2 - Data interpolation for Grand Central and Rotunda. Temperatures are in °C.

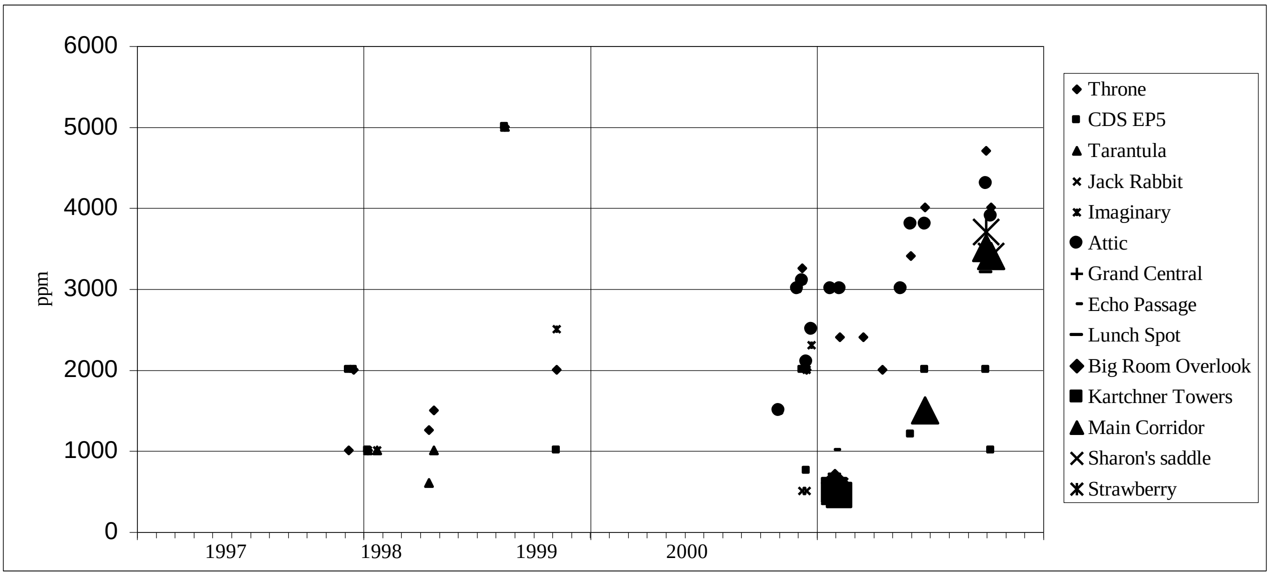

Fig. 3 - CO_2 concentrations in Kartchner Caverns from December 1997 to September 2000.

Discussion

Temperatures

Only a couple of stations (Rotunda and Lower Throne) show an increase of 1°C from 1996 to present, superimposed to the usual seasonal variation. In order to investigate this behaviour the sinusoidal best fit was also tentatively applied to the values measured in these stations after subtraction of the steady increase quoted above.

Unfortunately, the correlation coefficient of the best fit was very low, on account of the rather large spread of the values yet for the original series of values; when the steady increase was subtracted, the correlation coefficient decreased to a point that the fit has a rather scarce meaning.

Following the distribution of the delay of the temperature wave in the different stations (Fig. 1), three main areas have been identified:

About one month: Rotunda

About two-three months: Cul-de-Sac, Main Corridor, Grand Central, Lower Throne, Big Room Overlook, Kartchner Towers, Jack Rabbit, Sharon's Saddle

Longer than three months: Start of Echo Passage

The delay of one month is in good agreement with the fact that the Rotunda is the closest station to the entrance to the tourist cave. This means that the propagation through the entrance tunnel is prevalent above any other possibility.

The delay of two months correspond to a kind of "average delay" for most of the cave, and the longer delays (up to 8 months for the Start of the Echo Passage) may be due to local conditions.

In particular, such a long delay of 8 months could perhaps be due to an air circulation reaching the cave from the Echo Passage and opposing to the propagation of the temperature wave. If this is the case, it would be worthwhile to explore with great attention any possible connection through the Echo Passage to another branch still unknown.

CO_2 concentration

From Fig. 2 an apparent correlation with opening to the public could be found at first, but it must be stressed that the main source of CO_2 in the cave environment is from a natural process of oxidation of the organic matter in the percolation water (BOURGES et al., 1998).

In fact many high values were obtained in the section of the cave not yet open to the public where there are no artificial sources of CO_2 (TRAVOUS & REAM, 2001). In addition a closer examination of the distribution of values during each year shows a tendency to find higher values in the summer months, when the natural oxidation process is enhanced. The values found in Kartchner Caverns show no difference from those obtained in other caves, e.g. Cango cave (South Africa) (CIGNA, 2001) from a region with similar amount of precipitation.

Conclusions

Temperatures

The evaluation of the temperature measurements has shown that a temperature wave is present everywhere in the cave with different delay time and attenuation with respect to outside.

While in most parts of the cave the average temperature is essentially constant, in two places (Rotunda and Throne) an increase, not very large (0.2°C/year) but steady, was detected. Such an impact could be due to the visitors, the lighting and the influence from outside.

CO_2 concentration

Since the main source of CO_2 in the cave is natural and the surface above it has not be influenced by the buildings and the other facilities, it may be assumed that such a source is totally independent from the development of the show cave.

By taking into account that the CO_2 released by the visitors is a very minor fraction of the natural one, it may be concluded that the CO_2 is far from being a limiting factor in the development of the cave.

Final remarks

The small increase of the temperature found in two stations, as reported above, requires a further investigation to identify its causes.

A series of frequent temperature measurements (e.g. every 15 min) for about a couple of months, in some places around the stations concerned, possibly at different heights, could contribute to clarify the origin of the perturbation. In fact a detailed correlation both with the flux of visitors and the lights on could be studied. In order to distinguish between these two sources (visitors and lights) the lamps could sometimes be switched on during a few nights when visitors are absent and look for any possible impact.

Once the mechanism of the cave climate is fully understood, an automatic monitoring system could be installed to keep under control air and water temperature, relative humidity and airflows. Obviously these parameters would not necessarily be measured in every stations, but only in critical points which the simple preliminary network has pointed out.

The operation of the misting system should be limited to avoid the dispersion of dust arising from the trail construction. On the long run, the misting system could result in a negative balance between risks and benefits because it releases water, which in principle is not karst water. On the other hand, the relative humidity is a self-adjusting parameter (obviously within a limited range, which is not exceeded in this case) and no intervention is required.

When lamps are replaced, a special care should be assured in order use the most efficient kind available at the moment. In this way any improvement resulting from the lamp technology will be automatically transferred in the cave light system.

Finally, an air curtain system could be installed in each entrance tunnel. This simple device would result in a double advantage because it would "wash" the visitors and transfer into a suitable filter a good amount of the dust (lint, etc.) brought in by each person. In addition, if the systems were placed in proximity of the door leading into the cave, it would reduce greatly the air exchange between the tunnel and the cave.

To further reduce the impact of the tunnel on the cave, an air conditioning of the "conservation chambers" regulated to a temperature of 18-19°C and a relative humidity of 100% could be installed. Since the volume of such chambers is relatively limited the power requested would not be large.

It must be emphasised that Kartchner Caverns have been developed according the best standard, because each particular solution adopted in the most advanced show caves in the world have been implemented. This is one of the greatest successes ever obtained in this field and should be taken as an example for any further development of a tourist cave.

Acknowledgements

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Results of the Preliminary Monitoring Network of Cango Caves (Outdshoorn, South Africa)

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Abstract

Cango Cave is the most important show cave in Africa with some hundreds of thousand visitors per year, and is presently monitored to ascertain its visitors' capacity. A simple monitoring network has been installed in September 2000 to be operated for one year. It consists of 15 rugged data loggers distributed along the cave. Air and water temperature, carbon dioxide concentration, and relative humidity are measured and the values are transferred periodically by a shuttle into a computer outside the cave. The first results are here reported. Later, a totally automatic monitoring network will be installed after the results of the first simple network are achieved. In addition to the parameters measured by the first simple network, also air current and water level will be included in the automatic one.

Introduction

Cango Cave was discovered in 1780 by a Hottentot herd-boy working in Van Zyl's farm. During the XVIII century no records of the number of visitors are available but, on account of the travel difficulties, the figure should be of the order of hundreds. In 1914 it was 1352, in 1930 11,457; around 50.000 in 1955; around 100,000 in the '60s; 228,600 in 1990 (CRAVEN, 1994) and around 250,000 from 1995 to present. The cave was the object of a long series of regulations for its preservation, which were more or less successful. Finally, on 31 August 1938 the cave was proclaimed a Historical Monument because of its natural and scientific value. A rather complete descriptions of the cave and its surroundings was published recently by Martini (2000).

The section normally visited by tourists is known as Cango I and extends about 600 m from the entrance; another section follows, Cango II, for about 400 m. The whole cave morphology is essentially horizontal and the cave develops at the same fossil level. To proceed any further than the end of Cango II it is necessary to reach a lower level (about 20 m below) still active with a streamlet (the Sump). Normally this level is totally flooded and the access to Cango III is possible only after lowering the water level by a pump. The flooded part is 179 m long and the Cango III can be reached by climbing up to the same level of the previous sections of the cave (Fig. 1).

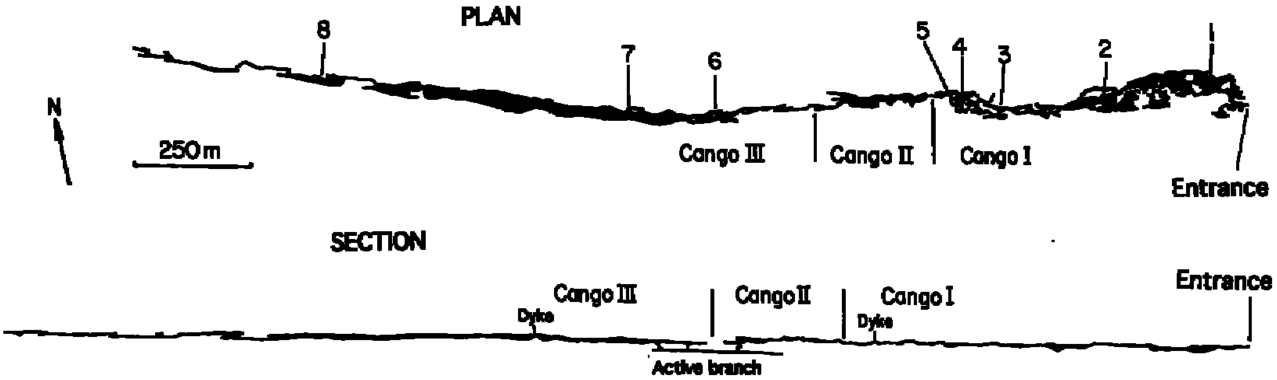

Fig. 1 - The Cango Cave: 1) Van Zyl's Hall, 2) Grand Hall, 3) Japanese Umbrella, 4) Devil's Workshop, 5) Banqueting Hall, 6) Krakatoa Chamber, 7) Stonehenge, 8) Isolation Chamber (After Crombie et al., 1978).

In 1995 the University of the Free State, Bloemfontein, carried out a scientific study which resulted in a report (GROBBELAAR et al., 1996). Such a report covers different issues both on the external environment and on the cave itself. Data on average CO_2 concentration, air temperature and relative humidity for some months are given.

In April 2000 a series of spot measurements of air temperature and relative humidity along the whole cave, from the entrance to "Isolation Chamber" in Cango III (some 1700 m from the entrance) were obtained. Since the last days of August 2000 a preliminary monitoring network was installed.

Measurements

Spot measurements

From 3 to 7 April 2000 a number of measurements of air temperature and relative humidity have been carried out along the cave. Obviously such measurements were assumed only to have an idea of the distribution of these parameters. A good agreement within 0.1°C was found between measurements performed with different portable instruments (i.e. Airflow and Thermo). The results are reported in Table 1.

Table 1 - Spot measurements (3-7 April 2000)

POSITION	DISTANCE FROM THE ENTRANCE (m)	TEMPERATURE (°C)	RELATIVE HUMIDITY (%)
Outside	0	13.3	59.8
Entrance	5	18.4	75.1
"Museum"	30	19.7	74.2
Fern garden	40	19.9	78.2
"	63	19.5	77.6
Van Zyl's Hall	84	19.2	81.6
Botha's Hall	170	19.2	84.5
Devil's face	194	19.3	86.7
Bridal chamber	220	19.7	88.6
Fairy palace	255	19.3	88.2
	265	20.5	88.7
Drum Room	280	19.9	88.7
Entr. Grand Hall	294	19.3	88.8
Lot's chamber	350	19.2	89.6
Nylon stockings	396	18.5	89.8
Gen. Smythe's ladder	440	18.1	90.0
Crystal chamber	473	18.3	90.0
Lumbago Walk	485	18.6	90.6
Crystal palace	520	19.6	90.1
King Salomon's mine	550	19.6	90.0
Above Iron ladder	558	20.3	89.9
Ice chamber	576	20.0	89.7
Devil's workshop	635	19.5	85.7
"Transformers"	640	18.5	85.7
Sump	1040	18.4	-
Alpine room	1730	18.2	87.4

The peaks of air temperature may be due to both local perturbations by tourists and an air circulation cell originated by some unknown passages of the cave. The data obtained by the monitoring network over an extended time interval will confirm or exclude such a hypothesis.

In Cango 1, in addition to the data obtained along the walkways, other relative humidity measurements were carried out in some passages far from such walkways and confirmed that the relative humidity was always less than 100%. A measurement of the water temperature of the stream at the end of Cango 2 gave a value of 18.2°C, i.e. 0.2°C below the corresponding air temperature.

When the water level in the Sump between Cango II and III was lowered in order to negotiate the flooded passage, a distinct noise, due to the air blowing from Cango III, was heard for some minutes, confirming that this section of the cave is normally sealed with respect to Cango II.

Preliminary Monitoring Network

A simple monitoring network was designed to be operated for one year. It is constituted by 15 data loggers distributed along the cave, which record temperature (T) at 6:00, 12:00, 18:00 and 24:00 of every day. Some of them record also the relative humidity (RH) and one the water temperature. Sensors for CO_2 were installed in fours stations and their outputs are transmitted to a data logger in the entrance for easy data retrieval.

Data are transferred periodically by a shuttle into a computer outside the cave. The layout of this network is summarised in the Table 2.

On 25 August 2000 this preliminary monitoring network was set into operation. Unfortunately the humidity sensors did not perform correctly because of the saturation of the capacitive sensor when some condensation occurred on them notwithstanding the result of the spot measurements were always below 100%. For this reason only Station 2 (Van Zyl's Hall) recorded acceptable relative humidity values for a couple of months before moving out of range for about one month; successively acceptable values were recorded again. This inconvenience, due to condensation, must be taken into account when automatic monitoring networks are operated.

Table 2 - Layout of the preliminary monitoring network.

POSITION	PARAMETERS	FrEquency of discharge
0-Outside	T, RH, Atm. Press.	One month
1-“Washrooms”	T	1 month
2-Van Zyl’s Hall	T, CO_2	1 month
3-Botha Hall	T, RH	1 month
4-The Vestry	T, RH	1 month
5-Drums Room	T, RH, CO_2	1 month
6-Lot’s Chamber	T	1 month
7-Gen. Smythe's Ladder	T, RH	1 month
8-Crystal Palace	T	1 month
9-Ice Chamber	T	1 month
10-“Transformers”	T	1 month
11-Cango 2: Broken stalagmite	T, RH	1 month
12-Cango 2: Sump	T + T water, CO_2	1 month
13-Cango 3: Base Camp	T, CO_2	3 months
14-Cango 3: Alpine Room	T	3 months
15-Cango 3: Isolation Chamber	T, RH	3 months

First Results of the Preliminary Monitoring Network

Presently, the temperature recorded from August 25, 2000 to January. 30, 2001 is available. There are a few gaps, only, due to temporary problems of some sensors. The data are reported in Fig. 2. The range of air temperature within the cave is about 2°C, by increasing steadily from 18 °C in Cango 3 to about 20°C at the entrance with three exceptions.

Station 7 "Gen. Smythe's Ladder" and 6 "Lot’s Chamber" have an average temperature which is from 0.1 to 0.2 °C less than the expected value according the steady increase quoted above; station 4 " The Vestry", which is rather close to Station 3 "Botha's Hall", has a value 0.26 °C lower than the latter.

In this last case the difference could be due to the evaporation latent heat because in the Vestry there are some small ponds while the area close by is drier. The explanation of the difference observed in Stations 6 and 7 is less evident because it could be due both to the same mechanism of Station 4 and to some hypothetical air flow from inner passages still unknown. When the data, recorded during at least one year, will be available, a more founded explanation would probably be obtained.

The abnormal fluctuation of Station 12 "Sump" is an artefact due to some local disturbance (works, heat released by instruments) in a rather small volume.

CO_2 concentrations are available from December 5, 2000 to January. 30, 2001.

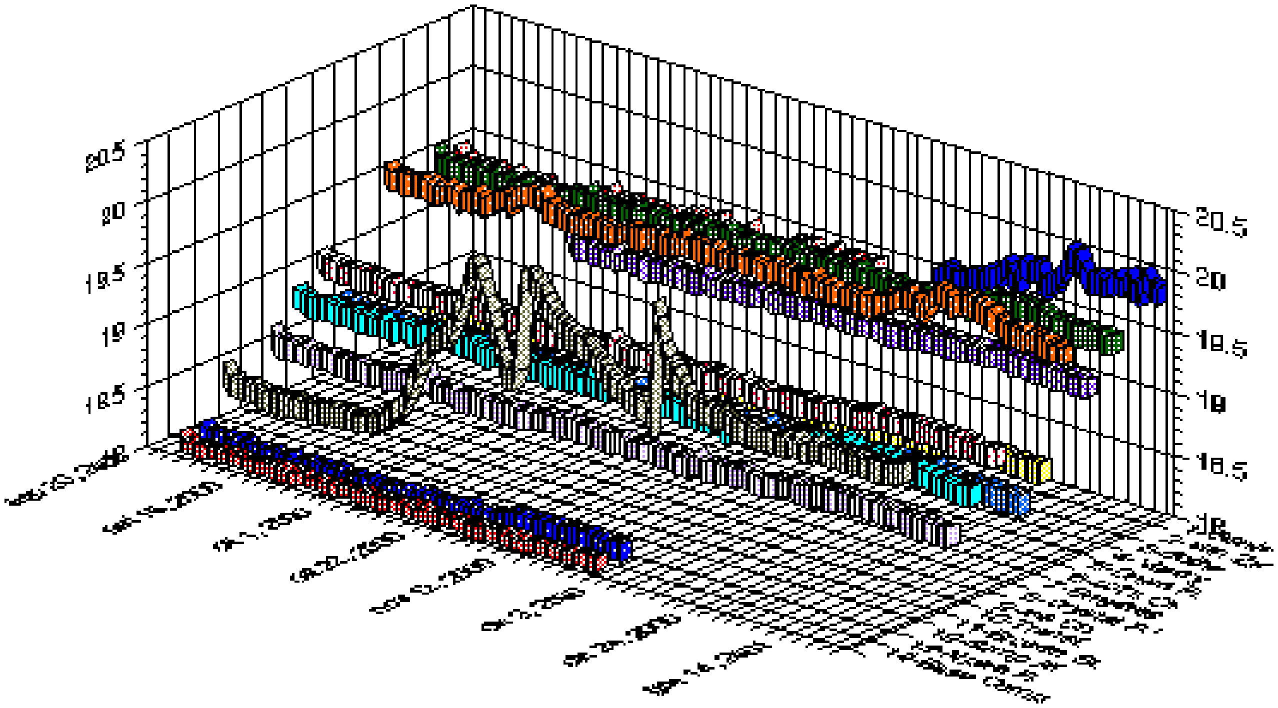

Fig. 2 - Air temperature distribution in Cango Cave from August 25. 2000 to January 30. 2001.

Discussion

Temperatures

In addition to the data reported in the previous section, an additional set is available. From September 1 to 3, 1956 the Cave Research Sub-Committee of the Cape Section of the South African Spelaeological Association made some meteorological observation at the Cango Cave (DU PLESSIS, 1958a).

The readings were obtained by the following unstandardised instruments:

Max and Min thermometers, accuracy approximately 0.6°C;

Wet and dry-bulb thermometers, accuracy approximately 0.3°C;

Soil thermometers, accuracy approximately 0.2°C.

In Table 3 a comparison between these measurements and those obtained by the monitoring network operating at present, are reported. This comparison is obviously indicative only, because the stations are not really identical but refer to sites very close by. By taking into account the accuracy of the thermometers it can be assumed that the increase of temperature in the stations here considered, if any, is not greater than some tenth of °C in about half a century.

It is noteworthy to recall here that in March 1896 air temperatures ranging "from 65 to 66°F" (18.3 to 18.9°C) were recorded in Cango cave. Since values are given as a whole number of °F, it may be attributed an approximation of about ± 0.5°C (CORSTORPHINE G.S., 1897).

Table 3 - Air temperature measurements in 1956 and 2000.

STATION	°C (Sept. 1956) (± 0.3)	°C (Sept. 2000) (± 0.2)
5/6 - Drum Room /Lot's Chamber	18.7	18.6 ÷ 19.6
10 - Transformers	17.8 ÷ 18.6	18.6

CO_2 concentration

As it was reported above, fours sensors for CO_2 were installed in stations: 2-Van Zyl's Hall; 5-Drums Room; 12-Cango 2: Sump and 13-Cango 3: Base Camp. Unfortunately the sensor of station 12 did not worked properly due to a power supply problem. The values of CO_2 concentration are plotted in Fig. 3 together with the daily number of visitors.

The values measured in Van Zyl's Hall started from around 3000 ppm in the first part of December, increasing to nearly 5000 ppm at the beginning of January and decreasing slowly to 4000 ppm successively. In the Drum Room the behaviour is similar with a starting value around 4500 ppm and a maximum around 8000 ppm about one week later than that observed in Van Zyl's Hall. In Cango 3, Base Camp, i.e. just after the sump that divides Cango 3 from Cango 2, the values are constantly around 9500 ppm. Such a constant value over the whole period is an artefact due to values out of range (0-10,000 ppm) in agreement with the values ranging from 12,500 to 16,300 reported by Maxwell (1980). In the future the sensor in Cango 3 will be substituted in order to cover a wider range.

The measurements carried out in 1995 by the University of the Free State, (GROBBELAAR et al., 1996) reported values in good agreement with those reported above. In particular the daily fluctuation due to the presence of visitors is identical with a range of few hundreds of ppm.

The peak of the number of visitors, around 2500 persons per day, is nearly one week before the maximum of CO_2 concentration observed in Van Zyl's Hall.

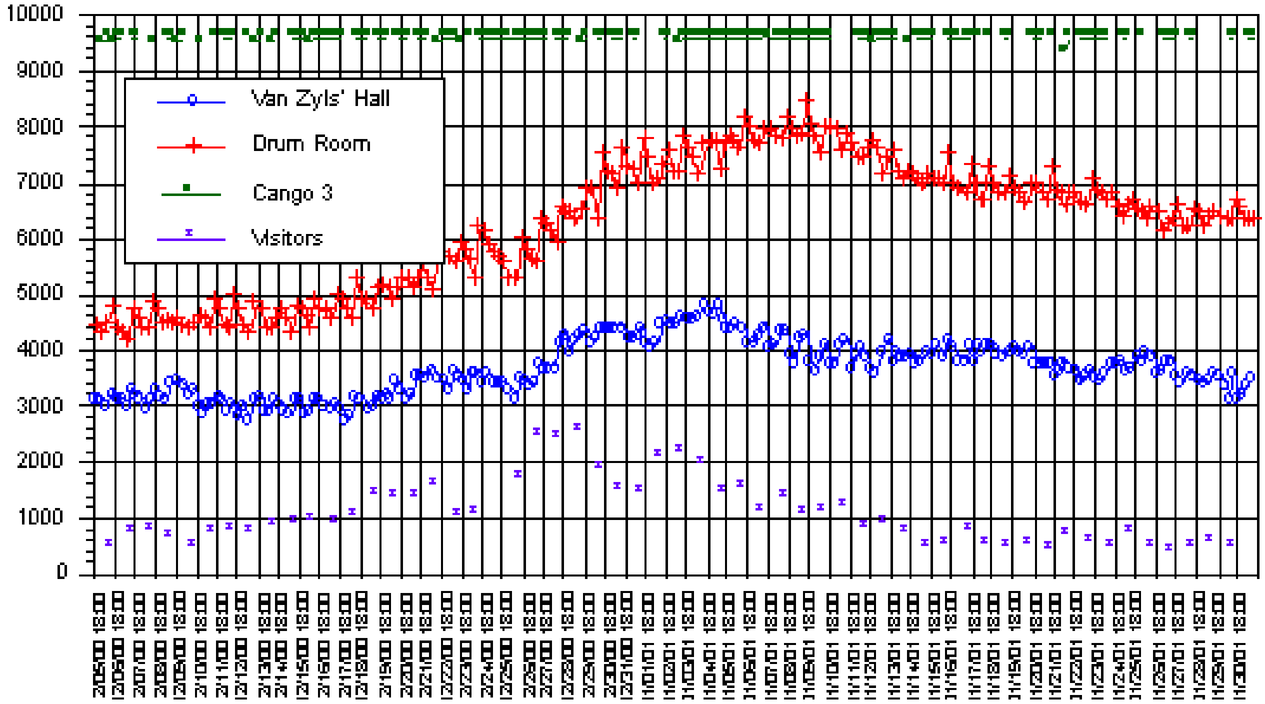

Fig. 3 - CO2 concentrations (ppm) Cango Cave from December 5. 2000 to January 30. 2001. The daily number of visitors is also report

Conclusions

The data obtained up to now allow drawing some preliminary conclusions, which should be confirmed or modified when a whole set of data ranging over at least one year interval will be available.

Temperatures

The first measurements were recorded in Cango Cave in 1896 (CORSTORPHINE G.S., 1896) when the global number of visitors from its development as a show cave was around few thousands people. Same values were obtained when the South African Spelaeological Association carried out some measurements in 1956 (DU PLESSIS, 1958a) and the visitors reached about 900,000; from that time to now other 7 millions people visited the cave. As it was reported above, the increase of air temperature during this time interval, if any, is not greater than some tenth of °C.

This fact means that the visitors capacity (CIGNA & FORTI, 1989) of Cango Cave was reasonably not exceeded notwithstanding management criteria (light, entertainment, etc.) not optimised from the point of view of the environmental impact.

The temperature measured in Cango 3, where the impact of visitors is absolutely negligible (few tenth of persons since its discovery) may be assumed as an undisturbed value not affected by any external influence (seasonal variation, visitors).

The average increase observed by moving from the inner stations to the entrance is probably due mainly to the influence of the seasonal variation from outside. The exceptions to such an increase found in stations 7-Gen. Smythe's Ladder, 6-Lot’s Chamber and 4-The Vestry, could be due to either the evaporation latent heat or some hypothetical air flow from inner passages still unknown, as it was reported above.

When data sets ranging over one year will be available, the propagation velocity of the seasonal heat wave inside the cave could be evaluated and provide some more information on the real cause of such exceptions.

CO_2 concentration

The evaluation of the data shows that the main source of CO_2 in the cave is the natural process of oxidation of the organic matter in the percolation water (BOURGES et al., 1998) while the amount of CO_2 released by visitors is at least one order of magnitude lower. This fact is confirmed by the measurements carried out by GROBBELAAR et al. (1998) when the increase due to the visitors was around some hundreds of ppm against a background of some thousands. In addition the CO_2 concentration increases in the inner part of the cave reaching a value above 10,000 ppm in the confined section of Cango 3 where the visitors have no influence at all.

Final remarks

The different appearance between the first halls of the Cango Cave and the inner parts is quite evident because the formations and the rock surface of the former are somewhat corroded while in the inner parts the formations are still growing.

Such a difference has been attributed to the use of the cave as a show cave. The results obtained in the first months of operation of the preliminary monitoring network do not support the conclusion that the CO_2 released by tourists could affect the chemical equilibrium concerning the formations. In fact the CO_2 released by natural oxidation process of organic matter in the percolation water is much larger than the CO_2 released by visitors.

In any case, it must be pointed out that, if the corrosion of the formations and the rock surface would be recent, the rock painting discovered by the Abbé Breuil in 1929 (CRAVEN, 1988) would have totally disappeared notwithstanding any possible restoration occurred in the meantime. The corrosion of formations must therefore be attributed mainly to natural causes as the decomposition of guano (CRAVEN, 1994). In fact the "dirty yellowish brown colour" observed by a visitor in the XIX century (DU PLESSIS, 1958b) was due to such a corrosion and was already present when the number of visitors was absolutely too small to produce any impact.

On the other hand, the plastic closure of the cave entrance installed on the gate might have modified the air circulation; the first halls could now act as a "warm trap" with a consequent increase of thetemperature in this section. When more data from the preliminary monitoring network will be available a firmer conclusion concerning this point could be drawn.

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26th Brazilian Congress of Speleology

Brasília DF, 15-22 de julho de 2001

Human Use of Caves in Perigord, Dordogne, France

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Abstract

All significant human uses of caves in Périgord are reviewed: by Prehistoric Man, as burial places, as shelters for people, domestic animals and food, religious purposes, water collect, etc. Man sometimes suffered in caves, or made illicit practices in them. Harm to the Environment exists. Tourism and speleology are very developed. The latter leads to the thorough study of hundred of caves and to their good protection.

Résumé

Les nombreuses grottes du Périgord ont souvent connu une longue utilisation par l'Homme: représentations préhistoriques, sépultures de toutes époques, abris (personnes, animaux et nourriture), captages d'eau, usage religieux, etc. L'Homme y a parfois souffert; des pratiques illicites y ont été parfois conduites; les atteintes à l'Environnement y sont visibles. Le tourisme est très développé et la spéléologie aussi. Celle-ci s'attache à étudier toutes les grottes et à les protéger avec leur Environnement.

Périgord is a world-famous area in the South-Central part of France, for its ornated prehistoric caves (Lascaux…), numerous chateaus, fascinating landscapes (and for its delicate food). Many foreigners, British and Dutch mainly, have settled there.

Périgord has been the land of Man for long. It is also an extensive karst area, with hundreds of caves. Such favourable factors have resulted in a long inhabitancy in the caves and in many activities related to them. Speleology is very active in the area and has led to the acquisition of a wide knowledge, available in around 150 issues of speleological magazines, the most famous being "Spéléo-Dordogne", and in many papers.

This brief paper is only an outline of the topic. It is based on authors' knowledge and bibliographic review.

Cave use During Prehistoric Times

Needless to say that Périgord caves were largely used by Prehistoric Man. Both Neandertal Man and Cro-Magnon Man inhabited the area, which is rich in eponym locations of prehistoric cultures. Ornated caves are numerous, no less than 40 of them, and encompass painted walls, carved walls or both. Lascaux is world-wide famous. Others have names such as Rouffignac, Font-de-Gaume, Villars, Bara-Bahau, La Mouthe, Comarque, etc. The topic is specially rich and we are here forced to consider it extremely briefly. A large part of the cave paintings and carvings was discovered by speleologists, such as Rouffignac, Villars, Bara-Bahau, Jovelle, Fronsac, Cadoin (in 2000), among others.

Many caves have been excavated, with numerous discoveries of industries and burials.

Archeological Remains

Such remains are not rare and cover almost the whole time span from Palaeolithic to present day. They encompass abundant prehistoric materials, such as stone tools, ceramic fragments, pottery of different styles, but also remains from the Gallic and Gallo-Roman periods, the Middle-Ages and younger periods, for instance:

Ceramic fragments of the Bronze Age at grotte de Jovelle and 4 nice bracelets of the same age in grotte de la Calévie.

Protohistoric ceramic fragments and other remains in a cave near the Fronsac castle.

abundant remains from Palaeolithic to the older Middle Ages including pottery, tools, bones, etc. in grotte de La Martine.

a 18 cm long bronze statue of the Roman god Apollo, discovered a few years ago by a speleologist who was digging a choked passage in a small cave near Saint-Amand-de-Coly.

Medieval ceramic fragments have been commonly uncovered, e.g. at grotte de Peyreblanque.

Coins, as old as the 14th Century in some cases: grottes de Pradellas, La Martine, Pech Curret, Péchialet. Coins of Gallic period in Rouffignac.

Underground Shelters

Caves were used as shelters quite a long time in Périgord, because of the frequent invasions and troubles during historic times, at least until the end of "Guerre de Cent Ans" in the 15th Century, a long and terrible war during which inhabitants were forced to live under frequently precarious conditions. Subsequent religious wars between Christians brought their own lot of trouble. For these reasons, caves were a good place where to find some safety. Man-made underground tunnels and chambers called "*cluzeaux*" were also largely dug out and widely used. Caves were commonly used after some specific organisation work was made, sometimes including a significant reshaping based on the *cluzeaux* digging techniques.

Some caves were inhabited for long periods, such as grotte du Péchialet, or grotte des Maquisards where were found flint tools (Palaeolithic), ceramic from Gallic period, and from the Middle-Ages. This cave was also used as a shelter during World War II.

At grotte du Poirier, the entrance was closed with a wall of juxtaposed large flagstones, which was likely hidden from the outside by the depressed landscape and likely earth covering. The cave itself is quite large and shows a number of man-dug holes in the cave walls which were used to support beams. Stone walls form the three sides of two large enclosures along the cave wall may have been used either as the bottom part of a covered shelter for people, or to shed and hide domestic animals, to prevent them from robbery.

The goule de Jean du Noir shows remains of a closing system of the entrance. This cave was a good place where to stay, with a narrow entrance corridor followed by spacious passages with dormant water. Another cave near the old castle at Fronsac also shows the remains of a closing system at the entrance, and it also shows numerous prehistoric engravings.

The Grange des Putes Cave also shows man-made holes in the walls, which were used during medieval times to support parting walls and perhaps blockades. In the trou du Huguenot, a thick wall was built and a carved eye was made on the cave wall. In the trou des Martres, a wall was erected to support a scree cone. A chamber located a little deeper in the cave was made accessible by a man-made passage following an initial karstified fracture. At grotte de Rouchatoux, cave walls were adapted to support wooden beams. At grotte des Bernoux de la Ferrassie, holes in both walls of the gallery indicate that a wooden floor was existing, likely during the Middle Ages. Grotte du Roc shows a chamber dedicated to area watching. At the grotte de la Font-Bargeix, the part near the entrance was largely reshaped by man, on the troglodyte way. In this cave, as in a number of others, the use during the Middle ages followed other uses, specially during the prehistoric times, the Magdalenian in the present case.

Grotte du Déroc was used not only at the Chalcolithic but also, at an unclear period, as a shelter.

Small caves in travertines in Sourzac were re-shaped and used as shelters during the Middle-Ages. Traces of use during the same period were found in grotte des Cluzeloux. In the 18th Century, grotte de Bara-Bahau was closed by a wall with a locked door, perhaps to store the equipment necessary to cultivate a nearby vineyard.

Modern use is present for instance at grotte de Haut-La-Maison: a house is built in the entrance and the rest of the cave is used as the cellar; medieval pottery was discovered in it.

Graffiti are plenty and of different types:

Dates and names: grotte du Poirier (dates around 1880 and names); grotte de La Martine (date of 1669); grotte du Cluzeau (graffiti more frequent in the proximal part, including some "modern" ones near the entrance, dated among others 1687).

Drawings and carvings: grotte du Cluzeau (geometric patterns); grotte de Gaussen (crossbow-like engravings probably medieval); grotte des Fadettes (cross and modern animal engraving, among others; plus more ancient graffiti which are not clearly dated); cave near La Chapelle-Faucher (unclearly dated engravings); grotte de Larzac ("recently" made engravings, stairs in the rock, closing system and re-shaping).

Pencil portraits in grotte du Péchialet (1847).

Shelter for Domestic Animals

Ancient use of caves as animal shelters has been recognised: for cattle, pigs, sheep. This use has been perpetuated up to present times in some cases.

A very interesting cave, the grotte du Pigeonnier de Laussel, has been walled at the entrance to make a dovecote, with hundreds of places for pigeons and a nice architectural look. Grottes du Pigeonnier (West and East) at Saint-Front-de-Domme are beautiful dovecotes as well.

Grotte de la Sudrie shed chicken, after its cave fill removal in the 19th Century and grotte des Combarelles entrance had a cowshed (and a house).

Food Storage and Food Production

In grotte de la Millette, no less than 40 silos were dug out of the moderately regular cave floor fill over some 400 m long. The passage is no much larger than the silos and one has to step across them to move in it. Silos are not exactly similar in shape and size, as each was dug out with no care for being regular, just being useful and convenient. Commonly are silo walls overhanging and the narrower upper opening is convenient to place the protecting cover. The depth is up to 1.5 m and the width at the base up to 1 m.

Grotte du Cheyrat also shows silos, in the shaly floor near the entrance. A cave near La Rochebeaucourt bears a possible silo or a partially dug water well. Other silos are known in Périgord, as in *cluzeaux.*

Silos were used for cereal storage. According to Savinien d'Alguié, cited by CARCAUZON (1991), they were used at least up to the end of the 18th Century.

Some caves were used to store wine and occasionally other drinks: grotte du Rajol, which is closed by a wall with a door, was used at the beginning of the 20th Century by a wine merchant to store his goods. One cave shows an oven to cook bread, at some distance from the entrance. Mushrooms were grown some 20 years ago in grotte des Crozes.

Uses Related to Religion

Caves were used by Prehistoric Man and their nice art may have had a religious significance. This has been largely debated, but it is still a matter of controversy.

2000 years ago, Gauls used some circular natural wells for offerings: characteristic ceramic fragments were discovered at the base. In Trou du Merle was found a Gallic goddess head (2nd Century AD).

More recently, churches have occasionally been built under cliff overhangs, such at La Madeleine, or at Caudon. Indeed, in La Madeleine, a whole cliff-hanged village is located on either sides of the church, which reflects a need for defence during troubled periods.

Crosses and cross-like features have been drawn in several caves, such as grottes de Rouffignac and du Serpent and aven de Caudon.

Grotte de l'Eglise, near Excideuil, was used as a hidden church during the French Revolution (XVIIIth Century). Statues of the Virgin Mary have been placed in the entrance at: grottes de Sourzac, de Prunier, etc.

Burial Grounds

Burial has been frequent in Périgord caves since the Palaeolithic times. The Neandertal Man buried at La Ferrassie some 60000 years ago is at the origin of the recognition of such burials by the scientific community. In subsequent times, burial cave sites are known for nearly every period. At grotte de la Croix, Neolithic burials were made, but the cave was also rich in ceramic fragments of the Iron Age. At trou de la Louve, archaeological remains of the Iron Age or the Bronze Age were possibly associated to burials.

Grottes des Ormes (Tene III), de Rouffignac and de la Fontanguillère (Bronze and Iron), grottes du Déroc and de Campniac (Chalcolithic and Late Neolithic) and so many others have borne burial places.

Grotte de Présillac, which entrance is a small reshaped shaft, shed Roman burials.

War-Related Facts and Crimes

Caves were used during World War II, in relation with resistance to invaders. For instance, grenades were stored in grotte de la Fontanguillère and other caves sheltered warriors hiding from invaders. War crimes were dissimulated in caves. At the trou de la Chèvre near Coulaures, collaborators to invaders were shot dead and thrown into the entrance shaft; their remains were recovered only after the war. Also, in a narrow vertical shaft, from which filling stones were being removed by cavers, the remains of a man who was likely buried alive were found some 20 years ago.

During difficult circumstances of former centuries, some natural shafts were used to hide murdered people or to push down some unpleasant people, as for instance gouffre de Proumeyssac.

Illicit Man Activity in Caves

Illicit activities occurred in Périgord caves as in many others. Forgery existed in grottes de Rouffignac and in Croze à Gontran. Cannabis stored in a cave was incidentally found by cavers some years ago. Sects meetings were pointed out a few years ago in caves located in southern Périgord.

In the 19th Century, fills were removed from several caves, Campniac specially, with very rich Neolithic artefacts and burials, and La Mouthe, to fertilize fields around. This practice destroyed major prehistoric places. Very damageable was in the early days of prehistoric research the too quick search for prehistoric, noble, layers in caves: overlying ones, proto-historic, Gallo-Roman, medieval, etc. were neglected and left in disorder, and so lost for science.

Younger Man activity in caves has often resulted in the destruction of older remains: medieval re-shaping of grotte du Pigeonnier Est partly destroyed prehistoric engravings. In grotte du Mammouth, the prehistoric ground was subsequently levelled. This also happened in Lascaux ! Names were written centuries ago on top of prehistoric paintings in grotte de Rouffignac, and graffiti cover other paintings in Font-de-Gaume. In croze de Salvetou, recent graffiti made by children from a vacation centre have largely destroyed older man-made lines on the walls, possibly prehistoric.

Mysterious destruction of palaeontological remains happened in grotte de Sarconnat, where skulls of cave bears were partly destroyed.

Uses Harming the Environment

Despite the prohibition by law, and despite strong and regular actions and information by speleologists, a number of caves and more specially shafts are still being used as wild garbage deposits or even as a convenient place where to throw animals dead from diseases. The “eydge” d’Ajat, the aven de Rouchatoux or the trou des Martres are good examples of this. The trou du Vent de Bouzic suffered similar problems for long, due to its 18 m deep entrance shaft. The gouffre de la Peytelie was nearly filled up with a variety of domestic waste, including animal corpses, cars, old washing machines, etc., despite its 15 m diameter and its depth. The gouffre (shaft) des Pénassoux was fully filled with domestic waste and was used to inject domestic effluents.

A few sinking streams bring some garbage and detritus into the underground realm. For instance, the pertes de l’Auvézère play such a role, despite repeated actions of polluting matter removal by Dordogne cavers. Faecal pollution entered grotte des Charreaux from the surface through karst fissures, as it was observed and denounced by speleologists.

Faecal pollution was also present in grotte de La Martine, which originated from the overlying city of Domme. Another infamous case was given by CARCAUZON (1991) who met with a sudden flood in the narrow grotte de la Javanelle during a sunny day. It appeared later on that this virgin cave was connected to a small sinkhole, into which waters from a treatment station were injected into the karst!

A re-shaped cave with stairs dug out of the rock (grotte des Canquilloux) receives waste water and animal slurry from a farm yard. It was discovered while digging foundations to build a large shed in the farm and 14th Century pottery fragments were discovered in it. At perte d’Aubas, the landowner used to direct run-off water into a small hole in the ground. A land collapse resulted and a large shaft devastated the nearby area.

Another harm to the environment is the gassing of animals such as badgers or foxes in their burrows. In a number of cases, burrows were indeed narrow cave entrances and it even happened that speleologists were in these caves when so-called hunters came to inject their deadly gases (chloropicrine or others)!

Finally, The walls of a small cave near Montignac were entirely tagged by unknown people.

Search for Water and Water Mills

On the karst plateaus where water is scarce , wells have been dug out, usually on the basis of divination. Several of them are the only access to caves:

Grotte de la Plansonnie: 27 m deep well; the underground stream is very regular and flows in a nice gallery broadly 2m wide and high.

Grotte de Beauronne (11 m deep well) and underground stream at Crabanac (9 m).

Grotte du Queyla, (5 m well, stream pumped by a hydraulic ram).

La Borie Well, cased down to 65 m depth, though the water table stands at -18 m; cave at -38 m.

Other wells are not the only access to the cave they reach: grotte de La Reille (stream), grotte de Patissou (stream, 4 m deep well), grotte de Queyssac (lake), grotte de Fonroque (stream reached at 100 m from the natural outlet; a small dam gathers the water below the well, as in La Plansonnie).

Karst springs are used to collect water for domestic purpose, after treatment: résurgence des Moulinauds (a spring with one in the biggest flows in Périgord), source du Toulon, source de Glane, résurgence des Fonts, grotte du Plancat, the outlet of the underground stream at Sourzac, source de la Clautre, fontaine de Bouzic (a spring derived from the trou du Vent, a formerly polluted cave), source de Sarconnat (despite it collects the polluted stream in grotte des Charreaux).

At grotte de la Grèzelie, a cave on a hill slope, the entrance is walled and the catchment has led to the elevation of the water level. In grotte de Bridoire, the water is pumped to the outside by a hydraulic ram.

A lot of springs fill open tanks where women used to wash clothes (wash houses = lavoirs): fontaine du lavoir de Beaussac, a karst spring at La Bachellerie (formerly used for domestic purpose), etc. At Fonroque, collected water also ensured cattle drinking.

Karst springs moved water mill (“moulins”) wheels: grotte droite des Douymes, Doux de Coly (the longest dived sump in the world, more than 4,2 km long one way, end not reached), résurgence de Bezan. The “moulin de Soucy” is located along a sinking stream from Auvézère River.

Mineral and other Resources

No real mining activity is known to have occurred in Périgord caves. Nevertheless, calcite exploitation was going on for some time, at least at the end of the XVIIIth Century. Calcite vases were made of calcite from grotte du Poirier (grotte d’Azerat), in which large stalagmites are re-shaped as parallelepipeds. Extraction took place largely in grotte de Roffy.

Guano was collected during XIXth Century to fertilise poor soils around the grotte de Vezac. A trial was done after two priests killed almost all of the bats.

Caves are sometimes supposed to hide treasures, as is grotte de La Mole : the owner spent several years digging out the cave fill, searching for the “golden calf” of an old legend.

In Villars area, several paleokarst fills are presently extracted to make tiling tint and for silicium industry.

Caves and Public Works

Several caves were discovered during public works activity, such as railroad construction, road reshaping, telephone posts emplacement, quarrying and house building. One opened suddenly in the tarmac of a road and was plugged. Near Saint-Germain-des-Prés, a cave is accessible only from a bedroom!

Tourism

Tourism is a major activity in Périgord caves. No less than 30 of them are widely opened to visitors, without including troglodyte sites. Many are related to prehistoric art, such as Rouffignac, Font-de-Gaume, Les Combarelles, Bara-Bahau, Villars or to cave sites, such as Proumeyssac, Domme, Carpe Diem, or the exceptional geode of the Grand Roc, which is full of calcite speleothems, including spectacular helictites.

Underground tourism in the area has a quite old origin. Not taking into account questionable pleasure trips by the Prehistoric Man, famous visits with local guides were made to grotte de Rouffignac, and recorded since around 1570 (GUICHARD, 1993). Similar visits to other caves have been reported during the 18th Century.

Visits with local guides still exist, but these are highly qualified speleologists with a National diploma.

Science and Culture

Périgord caves have been widely used by prehistorians and other archaeologists, specially since the 19th Century until now.

At present, one cave, called grotte de La Faurie, is used for scientific research: speleothem growth is studied in detail in it by a specialist of carbonate deposition. Other measurements are made in Villars.

Ground stability is currently studied at gouffre des Fraux, a gravity-related cave made up of high, narrow passages which are the result of a gentle hill slide towards the adjacent valley: indicators of rock motion have been placed at critical locations and monitored. This cave is located below a nice castle and its surrounding village!

Vertebrae palaeontology was studied, but to a moderate extent. Usually, remains were studied when they were found associated with prehistoric human remains and/or artefacts. Purely palaeontological sites were not really studied, despite some nice discoveries by speleologists, such as the grotte des Borderies (Carcauzon, 1991), with cave bear, hyena coproliths, bison, auroch, horse, cervidae, capridae, etc. Cave bear remains were also discovered by speleologists in fossil passages of the Sarconnat Cave. Remains discovered in the entrance scree of the gouffre de Taille-Petit were dated in Lyon with the C14 method. Bison was unearthed from a cave near Meyrals.

Traces of life of cave bears are relatively common in Périgord caves, but they have not been studied for themselves. Bear footprints are not uncommon and wall scratches left by their claws are familiar to speleologists. Their oval pan-shaped places for hibernation (wallows) are also well known, in grotte de Rouffignac specially. Several biospeological studies have shown a rich troglobite fauna. For instance, Niphargus and Caecospheroma (troglobite Crustaceans) are found in numerous cave streams.

Of course, legends exist about caves in Périgord. Some movies and novels relate to them.

Speleology, Cave and Karst Protection

Extensive speleology has existed in Périgord for half a century, after a long period with less activity, and mainly prehistoric research in caves since the 19th Century. Thorough exploration, including digging and diving, cave mapping, study and reporting is very well advanced.

Protection has always been a major concern to speleologists, with good reasons. Doors were installed at a number of cave entrances, in order to protect them: Crobique (giant calcite crystals), La Roffy and Orliac (speleothems), Journiac (safety), Doline du Lavoir de Bussac (owner’s request), Les Borderies (speleothems and paleontological remains), Sarconnat (water catchment protection), prehistoric and tourist caves, etc. placing doors is not a target but it is occasionally necessary.

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Gruta Tamboril: Domínios Espeleogenéticos

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Abstract

The purpose of this work is to make a presentation of the conservation status of the Tamboril Cave, which is an important speleological patrimony due to its scenic beauty and tourist, potential. The Tamboril Cave is situated in the northwestern part of Minas Gerais, Brazil.

The description of observation points, which are plotted in maps at scale 1:500, in addition to photographs of those sites, have allowed to establish four domains according to their particular features. A detailed description of these features constitutes the body of this work.

The Tamboril Cave, generally speaking, is well preserved. However, some of its points display the effects of the anthropic action: broken speleothemes, tarnished walls, etc. Other damages, due to the surrounding mining activities, were not observed. Such activities are supervised by the Brazilian environmental protection agency (FEAM).

Resumo

Através de caminhamentos, descrições de pontos de observações e tomadas de fotografias, plotados em planta baixa dessa caverna, escala 1:500, pode-se caracterizar e compartimentar essa gruta em quatro domínios espeleológicos, cada um deles com feições particulares e típicas.

A Gruta Tamboril encontra-se em bom estado de preservação, salvo alguns pontos, os quais encontram-se pichados e alguns espeleotemas quebrados por ação antrópica, devidos a eventuais visitantes ou “turistas”. Não foram observados danos a integridade física da gruta, por ação do empreendimento mineiro, assim a continuação da lavra fica condicionada ao atendimento das solicitações da FEAM (Fundação Estadual do Meio Ambiente).

1 Introdução

Este trabalho refere-se à apresentação dos resultados advindos de uma avaliação espeleológica realizada no interior da Gruta Tamboril, situada no município de Unaí – MG.

1.1 Objetivos

O objetivo principal deste foi a realização de uma vistoria técnica, especializada, no interior da Gruta Tamboril, com o propósito de se detectar prováveis danos físicos causados à mesma, devidos às detonações, com explosivos, realizadas pela atividade mineira, no maciço calcário onde se encontra inserida essa caverna.

1.2 Localização e vias de acesso.

A Gruta Tamboril localiza-se a cerca de 10 Km, para noroeste, da cidade de Unaí, que por sua vez dista 600 Km da capital do estado, Belo Horizonte.
O acesso à caverna faz-se, a partir de Belo Horizonte, através da BR 040. Percorrendo-se cerca de 490 Km, por essa rodovia, chega-se ao trevo da cidade de Paracatu. Nesse ponto entra-se à esquerda, na rodovia MG 188, e percorrem-se mais 110 Km até a cidade de Unaí. Depois, na mesma rodovia, percorrem-se mais 10 Km, até a entrada, da estrada de terra à esquerda (oeste), que permite o acesso à gruta (Figura 01).

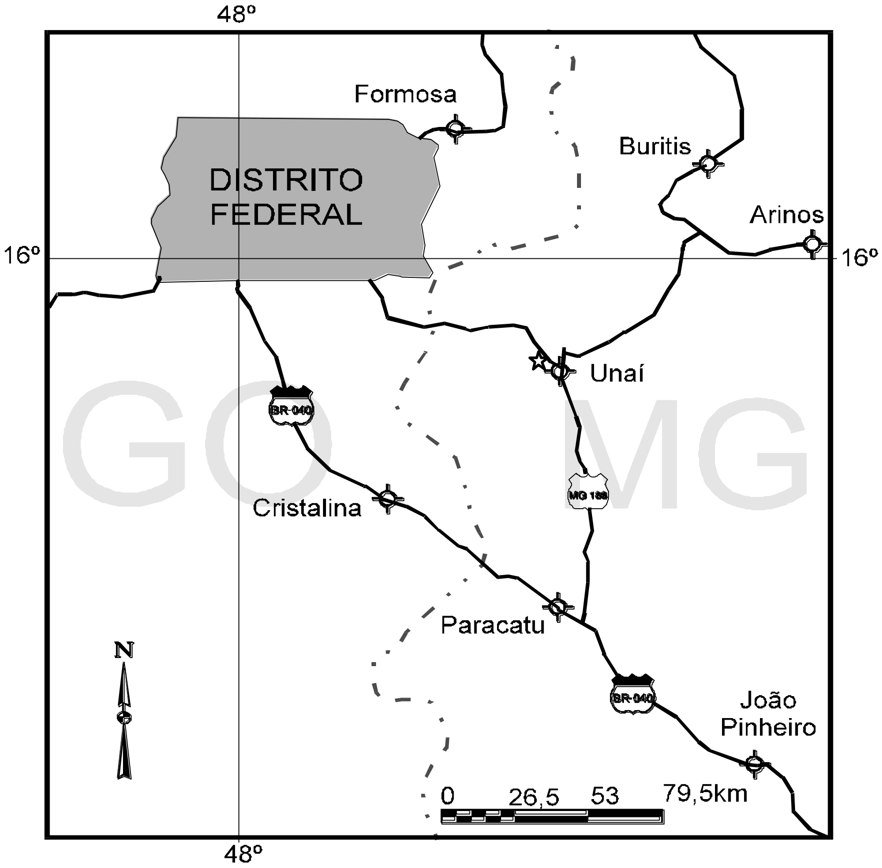

*Figura 01: Mapa de localização e acesso à cidade de Unaí e ao local da Mineração Britacal - * Gruta Tamboril*

2 Geologia Regional

2.1 Geomorfologia

A Geomorfologia da região noroeste do estado de Minas Gerais consiste de escarpas erosivas e formas de relevo originadas por processos fluviais de dissecação e/ou acumulação, e aplainamento. As principais unidades geomorfológicas são: Planalto do São Francisco, Depressão Sanfranciscana e Cristas de Unaí (BOAVENTURA *et al*. 1982).

2.2 Estratigrafia

A seqüência estratigráfica regional consiste de rochas metamórficas do Grupo Canastra e rochas metassedimentares da Formação Vazante e do Grupo Bambuí, predominantemente. Ocorrem, também, rochas sedimentares cretáceas e rochas ígneas alcalinas.

A região de Lagamar-Vazante-Paracatu-Unaí, situada na parte oeste do estado de Minas Gerais, é constituída por unidades geológicas, orientadas grosseiramente na direção norte-sul, compostas por filitos, ardósias, quartzitos, metassiltitos, raros calcários e abundantes dolomitos de origem algálicas. Tradicionalmente, essas unidades são correlacionadas ao Grupo Bambuí, mas a seqüência litoestratigráfica levantada por DARDENNE (1974, 1978 e 1979) não permitiu uma correlação segura com a estratigrafia clássica desse grupo. Como existe a possibilidade dela ser mais antiga que o Grupo Bambuí ela foi individualizada sob a denominação de “Formação Vazante” (DARDENNE 1978 e 1981).

2.3 Estrutural

Estruturalmente a região faz parte da faixa de dobramentos Brasília, que bordeja o Cráton de São Francisco (ALMEIDA 1977), no seu limite oeste.

Essa faixa caracteriza-se pela presença de grandes dobramentos assimétricos, formando anticlinais e sinclinais, com vergência das dobras para leste, e falhas inversas, ou de empurrão, de direções regionais norte-sul e caimento para oeste (LARANJEIRA & DARDENNE 1990).

3 Geologia da Gruta

3.1 Generalidades

A Gruta Tamboril (Figura 02) é, predominantemente, do tipo linear curvilínea, em planta, e horizontal-ondulada, com aclives e declives suaves, em perfil. As suas seções transversais apresentam configurações quadradas, retangulares e elipsoidais, em sua grande maioria.

O seu desenvolvimento linear, medido em planta, atinge cerca de 950m. Podendo essa dimensão dobrar de tamanho se forem computados suas ramificações e apêndices. A sua largura máxima atinge 55m e a altura, 30m.

O lago existente em seu interior divide a gruta em dois segmentos principais. De sua entrada até o lago, ela tem direção praticamente norte-sul, depois do lago, até o seu final, ela tem direção sudoeste.

A água que aflora no interior da cavidade, e que forma “o lago”, representa o afloramento do lençol freático regional, que se comunica ao interior da gruta, pelo princípio dos “vasos comunicantes”, através de zona de falha geológica.

A caverna apresenta uma ornamentação exuberante, principalmente no segmento que vai desde a sua entrada até ao “Salão do Lago”. Essa ornamentação torna-se muito significativa devido à grande quantidade volumétrica de espeleotemas, à sua grande variedade de formas e, também, devido às grandes dimensões de alguns desses espeleotemas. Existem colunas que chegam a ter 15m de diâmetro (estação T 20) e 20m de altura, estalagmites e estalactites podem atingir 10m de altura e escorrimentos, em forma de cascatas, chegam a 20m de altura (corte na estação T 25).

3.2 Estratigrafia e Geologia Estrutural

Os diversos aspectos geológicos, do entorno da cavidade e do seu interior, foram, respectivamente, caracterizados na década de 90 por LARANJEIRA & DARDENNE (1990) e, pela equipe da S.E.E., por TEIXEIRA da SILVA *et al*. (1991) e CAVALCANTI *et al.* (1993).

LARANJEIRA & DARDENNE (1990) mostraram que as rochas que hospedam a gruta (Fotografia 01) pertencem às formações Paranoá e Sete Lagoas, que se encontram em contato tectônico, por falhamento de empurrão (*thrust).*

TEIXEIRA da SILVA *et al.* (1991) executaram o mapeamento geoespeleológico da cavidade definindo litofácies e caracterizando os diversos elementos estruturais, planares, lineares e tectônicos, e estabelecendo um modelo espeleogenético, para origem dessa cavidade.

CAVALCANTI *et al.*(1993) apresentam uma compilação e atualização desses diversos dados.

3.3 Considerações Espeleogenéticas

Como conseqüência desses estudos, citados no item anterior, as seguintes considerações podem ser feitas:

a caverna possui um “nítido controle estrutural e estratigráfico” no seu desenvolvimento;

a mudança no sentido do desenvolvimento da caverna, a partir do “Salão do Lago”, deve-se a falhamento associado à mudança de direção das camadas;

a gruta apresenta diferentes estágios de maturidade: 1) *estágio maduro*, da boca ao “Salão do Lago”, 2) *estágio juvenil*, do “Grande Salão” ao “Salão dos Travertinos” e 3) *estágio infantil ou inicial,* na sua parte labiríntica final;

foram caracterizadas duas fases distintas de abatimentos (mudanças estruturais) na caverna. Uma, mais antiga, caracterizada por abatimentos de grandes espeleotemas e blocos, que foram recobertos, posteriormente, pela precipitação e deposição de novos espeleotemas. Essa fase foi acompanhada por variações no nível do lençol freático, pretérito, e sua área de ocorrência vai desde a entrada até o lago. A segunda fase está caracterizada por novos abatimentos de blocos e rebaixamento do nível do lençol freático, provavelmente devido à reativação tectônica da cavidade. Essa fase está bem representada no segmento sudoeste da caverna.

4 Domínios Espeleogenéticos

Entende-se por domínio espeleogenético uma área da caverna que possui determinadas características físicas peculiares (contexto geológico, espeleotemas e volume) que definem uma diferenciada fase evolutiva da mesma.

Para facilitar a avaliação, subdividiu-se a caverna em 4 domínios espeleogenéticos, a saber:

Domínio 1 – Esse domínio vai desde o “Salão da Entrada” até o “Salão do Lago”, tem direção preferencial norte-sul e constitui-se de um grande conduto com dimensões de cerca de 455m de comprimento, por 45m de largura máxima e 25m de altura máxima. Caracteriza-se por espeleotemas formados a partir da dissolução e precipitação de carbonato de cálcio. Os espeleotemas são de grande porte (dimensões métricas a decimétricas), apresentam coloração fortemente esverdeada (devido à presença de fungos). Pode-se observar grande quantidade de espeleotemas abatidos, comumente “soldados” por uma matriz carbonática e com crescimento de estalagmites sobre os mesmos, em resposta ao crescimento natural da caverna. Entre os espeleotemas que mais se destacam, estão as colunas com diâmetro médio de 10 metros, formas botrioidais que recobrem estalagmites e formas coraloidais (CAVALCANTI & TEIXEIRA da SILVA 1997) que recobrem vários espeleotemas e demarcam, sobre as estalactites, os níveis de inundação freáticas. Encontram-se, também, travertinos de dimensões milimétricas a centimétricas, sobre escorrimentos no chão. Geralmente, os espeleotemas do teto estão ornamentados por helictites. Próximo ao final, desse primeiro domínio, ocorre um salão, tendo sua maior área recoberta por areia, apresentando formações cônicas (“Salão das Cônicas”). Raros espeleotemas, do tipo estalagmites, foram quebrados devido, principalmente, à ação antrópica isolada, no próprio interior da caverna. Provavelmente algum visitante desavisado usou as estalagmites como apoio, durante o deslocamento, ou como “teste de força”, e quebrou as mesmas. A grande maioria dos espeleotemas encontra-se, no entanto, em excelente estado de conservação.

Domínio 2 – Este domínio vai desde o final do “Salão do Lago” até o “Salão Inclinado”. Compreende um “salão” de grandes dimensões, 165mX55mX30m, (“Grande Salão”), que é constituído de inúmeros blocos abatidos e represas de travertinos de dimensões métricas, que se encontram em franca atividade. Ao final deste “salão”, tem-se uma bifurcação para a esquerda e outra para a direita. No conduto da esquerda, ocorrem dois níveis, que se unem em um único salão (“Salão Inclinado”), ornamentado por escorrimentos e travertinos, que indicam a orientação do fluxo da água de SW para NE, estalactites, estalagmites e colunas adornadas por helictites e flores de calcita (“antodites”). No conduto à direita (“Conduto do Encontro”) inicia-se o terceiro domínio da caverna. No Domínio 2 encontram-se pequenos estalactites (“tites” com máximo de 10cm de comprimento) quebrados em uma represa de travertinos e uma estalagmite de médio porte (cerca de 20cm de diâmetro e 2m de comprimento) abatida e quebrada, nas proximidades da estação R 223. Essa parte da cavidade (“Grande Salão”) aparenta ser a mais frágil e instável de todas, devido à presença de falha e litofácies que se desplaca com facilidade. A grande quantidade de blocos abatidos atestam este fato. Ficaram dúvidas, no entanto, se esses espeleotemas foram “quebrados” por ação antrópica isolada ou por detonações de explosivos na frente de lavra. Observações futuras feitas durante os “fogos” mineiros e *in loco* poderão elucidar este fato. A instabilidade deste local pode ser constada, ao longo do tempo, pelas diversas “gerações" de fragmentos de pequenos “tites” abatidos. Alguns encontram-se “fossilizados” pelos escorrimentos carbonáticos, outros estão sujos pela poeira do tempo e outros estão limpos, indicando que “caíram” recentemente. De qualquer maneira este é um local recomendado a futuras e cuidadosas observações.

As principais depredações deste domínio foram causadas por ações antrópicas isoladas, com “pisoteio” e quebramento de casca fina, pichações com tintas vermelhas e cortina avariada “criminosamente” .

Domínio 3 – Começa no “Conduto do Encontro” e vai até o final do “Conduto dos Travertinos”. Este domínio está representado por vários condutos e salões, sendo que estes podem ser caracterizados por apresentarem diferentes tipos de espeleotemas. Há um salão onde se desenvolvem represas de travertinos, de dimensões métricas (“Salão dos Travertinos”), essas represas recobrem sua maior área e indicam direção de fluxo de SW para NE, escorrimentos de calcita e flores de aragonita podem ser observados, nesse salão. Um outro salão tem seu teto recoberto por eflorescências carbonáticas, denominadas “antodites” (“Salão das Flores”). De um modo geral, esta parte da caverna apresenta espeleotemas muito distintos, sendo os mais freqüentes os travertinos, as flores de aragonita, as pequenas colunas, estalactites, estalagmites e helictites. Este domínio está totalmente preservado.

Domínio 4 – Constituído pela extremidade final, sudoeste, da caverna. Este domínio é caracterizado por condutos, em geral, de pequenas dimensões e pouco ornamentados. Os espeleotemas observados são de pequenas dimensões (centimétricos). O chão é recoberto por blocos abatidos e grande quantidade de argila. Sob os depósitos de argilas observam-se a presença de raízes de árvores, esse fato pode caracterizar a proximidade com a parte externa da caverna. Este domínio está, também, totalmente preservado.

5 Conclusões

Com base nas observações de épocas anteriores e nas observações atuais, pode-se dizer que o patrimônio espeleogenético da cavidade está, no seu todo, preservado. Com raras exceções, os espeleotemas estão intactos e a cavidade está limpa, principalmente no Domínio 1. Algumas "pichações" aparecem no "Salão da Entrada" e no "Salão das Cônicas". Restos de lixos, como partes de garrafas plásticas, saco plástico, pilhas velhas, restos de carbureto, fragmentos de espelhos, meias e sola de calçado, foram recolhidos no Domínio 2. Devido à dificuldade de transposição do "Conduto do Encontro" o restante da cavidade apresenta-se bastante conservado.

Não foram observados danos a integridade física da gruta, por ação do empreendimento mineiro, assim a continuação da lavra fica condicionada às solicitações da FEAM (Fundação Estadual do Meio Ambiente).

O domínio 1 apresenta um estágio de evolução maduro, onde os condutos e salões acham-se em fase de fossilização. Os abatimentos pretéritos dos grandes espeleotemas podem ser devidos a "terremotos" locais, como o que recentemente atingiu a região do Distrito Federal. Os domínios 2 e 3 encontram numa fase juvenil de desenvolvimento da caverna, enquanto o domínio 4 encontra-se na fase inicial, ou recente.

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Espeleología y Educación Ambiental.
Un Abordaje desde la Pedagogía de la Complejidad

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Abstract

Speleology and Environmental Education. A way from the pedagogy of the complexity.

It is considered by the author that nowadays the contents of speleology should be thought from the point of view of an environmental education by means of a Pedagogy of the Complexity.

The increase of problems regarding the protection of caves has resulted in action in many different groups towards how to act and with which tools. In fact, what kind of knowledge is required.

Specific knowledge on geology, biology, topography and archaeology is not enough to solve these issues.

The pedagogy of the complexity proposes rethinking the relationship of ecological, economical, social, cultural and political processes.

Resumen

La autora considera que los contenidos de la espeleología deberían hoy pensarse desde la educación ambiental, aplicando una pedagogía de la complejidad.

El aumento de conflictivas en relación a la protección de las cavernas, ha generado una movilización en los distintos grupos sobre el cómo actuar, con qué elementos, en definitiva, con qué saberes.

Los conocimientos específicos sobre la geología, la biología, la topografía, la arqueología de las cavernas, no son suficientes por sí solos para resolver estas conflictivas.

La pedagogía de la complejidad propone repensar las relaciones entre los procesos ecológicos, económicos, sociales, culturales y políticos.

Introducción

Varios son los conceptos que hoy circulan en el mundo sobre la educación ambiental. El presente trabajo está enmarcado dentro del paradigma de la complejidad, concepto al cual adhiero y que está signado por un cambio en la concepción de mundo, por pensar que lo impensable pueda empezar a ser pensado.

A partir de aquí, intentaré abordar la espeleología desde los tres principios que convergen en la educación ambiental: la complejidad, la interdisciplinariedad y la sustentabilidad.

Pensar la espeleología dentro de este marco posibilitará la construcción de una nueva matriz de aprendizaje, un nuevo sistema de relaciones sociales y de producción, una nueva ética ecológica y una nueva percepción de la realidad espeleológica.

Este enfoque llevará a una comprensión del objeto de estudio, las cavernas, como un sistema complejo, donde convergen múltiples procesos y actores sociales, donde lo importante no es lo heterogéneo y lo cuantitativo de los elementos que componen al sistema, sino la trama de interrelaciones y la mutua dependencia de las funciones que cumplen dichos elementos dentro del sistema total.

Tomar a este objeto de conocimiento como sistema complejo, que en nuestro caso sería un sistema ambiental, implicará que la metodología de trabajo sea necesariamente interdisciplinaria, como forma de organizar el conocimiento e integrar los elementos de análisis.

El desafío será hacer uso de estos conceptos, ya sea desde la prevención primaria como desde las conflictivas ya instaladas, y poder construir estrategias de acción sustentables para la convivencia del hombre con el medio ambiente.

La educación ambiental

La Educación ambiental es un proceso de formación y concientización dirigido a todos los niveles y estratos sociales sobre los problemas del medio ambiente" (SEFERCHE, 1991). Al decir de LEFF (1999) la educación ambiental "se inscribe en esta transición histórica que va del cuestionamiento de los modelos sociales dominantes, hacia la emergencia de una nueva sociedad, orientada por los valores de la democracia y los principios del ambientalismo".

Esto implica la necesidad de replantear los conocimientos, saberes y valores con los que se analizan las complejas relaciones entre procesos naturales y sociales, para actuar en el ambiente con una perspectiva holística.

Es aquí donde la pedagogía de la complejidad se hace imprescindible para promover:

- valores, actitudes y competencias necesarios para actuar en sistemas socioambientales complejos.
- la investigación de los sistemas socioambientales desde la visión de la multicausalidad y desde un enfoque sistémico.
- un pensamiento crítico, creativo y trasgresor.
- la investigación-acción.
- estrategias de acción sustentables frente a las conflictivas espeleológicas ambientales.
- La construcción de un saber espeleológico ambiental.

La espeleología es una interdisciplina que se nutre y se significa a través del aporte de diversas disciplinas, principalmente técnicas y científicas. Esta característica le confiere un amplio abanico de contenidos, que pueden ser atravesados desde los tres principios ambientalistas: la complejidad, la interdisciplinariedad y la sustentabilidad.

Trabajar en espeleología desde la interdisciplinariedad posibilitará abordar problemáticas complejas mediante la convergencia y la combinación de los diferentes puntos de vista que cada disciplina aporte. Las investigaciones de los ecosistemas cavernarios y la búsqueda de estrategias socio-político-ambientales para preservarlos son procesos donde intervienen múltiples factores, actores sociales y acciones. Además, éstos se dan en una interacción contínua influyéndose recíprocamente. Desde esta perspectiva, la realidad espeleológica puede pensarse como un sistema circular, cuyos elementos se organizan dinámica e interactivamente.

El principio de sustentabilidad surge de pensar un nuevo modelo de desarrollo humano "fundado en bases ecológicas, de equidad social, diversidad cultural y democracia participativa"(LEFF, E. ,1999). Su aplicación llevará a establecer límites a la racionalidad económica, a la intervención desmedida y egoísta del hombre sobre el ambiente y a construir una nueva ética, la ética ambiental, donde el hombre no esté disociado de la naturaleza sino que forme parte de ella y donde la solidaridad y la justicia social dejen de ser meros enunciados.

El aumento de las conflictivas espeleológicas en estos últimos años nos dan cuenta de un manejo no sustentable del hombre en relación a su ambiente natural y cultural. Pensar el quehacer de la espeleología desde un marco ambientalista nos hará replantear tanto la sustentabilidad de la actividad turística dentro de las cavernas y de la actividad minera o industrial cercana a las cavidades, como también la participación activa y comprometida de la comunidad espeleológica frente al deterioro progresivo de dicho recurso. En definitiva, nos promoverá replanteos tanto internos como externos, tanto desde los subjetivo y axiológico como desde lo político-económico respectivamente. Inclusive podríamos preguntarnos si la transición hacia un mundo sostenible es técnica y económicamente posible, pero a su vez es psicológica y políticamente intimidatoria, por cuanto hemos puesto demasiada autocomplacencia en la reducción de nuestro horizonte, encandilados por la premisa del perpetuo crecimiento material.

Un abordaje pedagógico de la espeleología

Visto desde el conjunto de ideas desarrolladas anteriormente, el objeto de estudio de la espeleología es un sistema complejo, que no se reduce a la simple adición de situaciones o fenómenos que pertenezcan al dominio exclusivo de una disciplina.

El abordaje de dicha complejidad debe basarse en los principios ambientales, en una nueva ética y en líneas teóricas como el constructivismo, el cognitivismo y la teoría sistémica, dando origen a la pedagogía de la complejidad. Ésta enseña a pensar la realidad socioambiental como un proceso de construcción social, orientado a producir una fractura en el pensamiento reduccionista de los conocimientos, propiciando una visión integradora del mundo. A su vez promueve el desarrollo de capacidades para comprender la multicausalidad de los hechos de la realidad, incentiva la conciencia ambiental y estimula la acción social en las transformaciones del mundo actual.

La espeleología no debería quedar fuera de este proceso de transformación. Es allí donde la educación ambiental juega un rol preponderante e ineludible.

Un primer paso es construir desde las instituciones espeleológicas espacios pedagógicos. Estos tendrán como objetivo difundir los contenidos de la espeleología atravesados por los valores de la educación ambiental. El lugar más propicio serán las escuelas de espeleología, cuyo fin debe ser informar y formar no solo en los contenidos científicos y deportivos, sino también en los aspectos que hacen a la relación entre el hombre y los sistemas cavernarios.

También dentro de los ámbitos de formación debe estar presente el tratamiento de las conflictivas espeleológicas ambientales para la búsqueda de estrategias de intervención que sean sustentables.

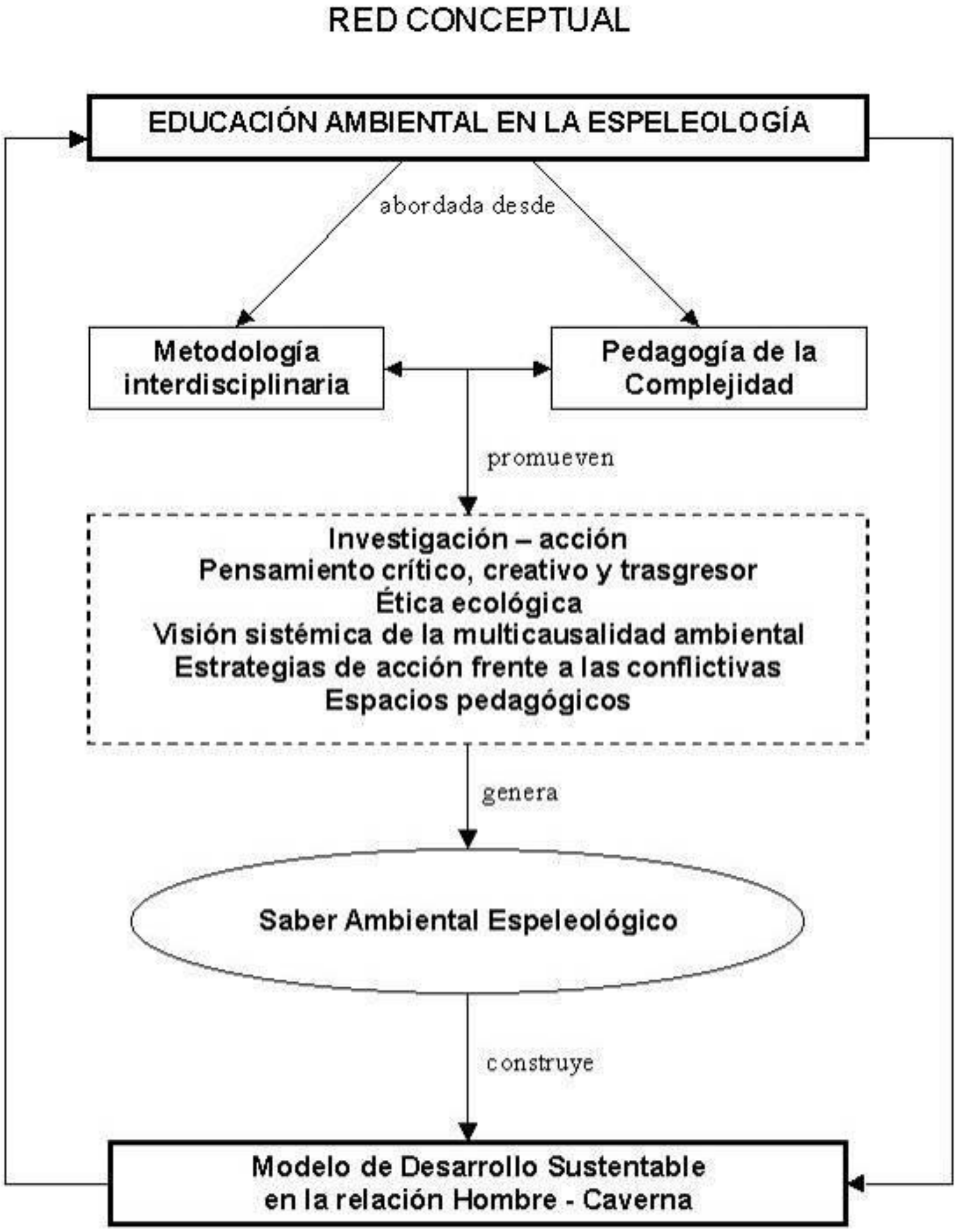

Figura 1 – Espeleología y Educación Ambiental, Red Conceptual.

Conclusiones

Aperturas, más que conclusiones, resultan del presente trabajo al apuntar la educación ambiental a establecer un nuevo sistema de valores. Es imposible proteger y conservar el medio ambiente de manera comprometida y responsable si los conocimientos que se tienen del mismo son parcializados.

Un desarrollo sustentable debe tener como meta transformar las relaciones del hombre con su medio ambiente y con sus semejantes. La educación es la vía principal para esta transformación. Desde el quehacer espeleológico, los espacios pedagógicos existentes dentro de las asociaciones son los ámbitos mas “ricos”, desde donde considero puede comenzar a gestarse ese cambio. Esta nueva percepción desde el modelo de desarrollo sustentable no es una cuestión que se de abruptamente, sino que es un proceso de cambio que se va construyendo desde la subjetivo y desde la relación con los otros y los objetos.

La pedagogía de la complejidad propone analizar los ecosistemas cavernarios como totalidades, como un sistema abierto en el cual interactúan diferentes fenómenos bio-físicos-culturales, diferentes actores sociales y diferentes acciones antrópicas. Esta nueva pedagogía tendrá como metodología los trabajos interdisciplinarios, y promoverá debates, que nos harán enfrentarnos con nuestro pensamiento antropocentrista omnipotente, con nuestro conformismo intelectualizado y con nuestra incómoda comodidad frente a la crisis ambiental que en definitiva es una crisis de nuestra civilización. Afortunadamente también nos posibilitará reencontrarnos con nuestras potencialidades y estimulará el lenguaje de las ideas.

La construcción de espacios pedagógicos en la espeleología desde los principios de la educación ambiental, constituyen una estrategia conducente a generar un modelo de desarrollo sustentable en la relación hombre – caverna. Desde éstos espacios pueden originarse distintos proyectos educativos, a través de las escuelas de espeleología ya existentes, proyectos museográficos, proyectos turísticos-educativos en áreas protegidas, etc.

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Environment Threats in Romanian Karst

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Abstract

Human impact on Romanian karst generated numerous environment threats, among which we mention habitation, agriculture, forestry, industry and tourism - induced threats.

Human presence and households in karst areas determine habitation threats. The construction of households and annexes, access roads, fences is based on the quarrying of limestones. Habitats also involve karst water pollution with domestic runoff and residual waste.

Agriculture and pastoral threats are manifested on soils karst microlandscapes, which are modified or destroyed by plant cultures or pastures.

Forestry threats derive from forest exploitation and modification of their componence and of local topoclimates, with chain effects on landscape dynamics.

Industrial risks are caused by quarrying of limestones, fire clays and bauxites. They determine landscape modifications, including the disappearance of various landscapes (gorges, caves).

Touristic threats consist of erosion acceleration, endangering of rare plant and animal species, speleothem breaking, graphic pollution of the cave walls, karst water pollution, etc.

Karst landscape occupies in Romania cca 4.600 km^2, which represent only 1,94 % from the total surface of the country. Besides its restricted territorial extension, karst areas are extremely fragmented (Fig. 1). Even if the extent of karstified areas is limited and they are highly dissipated, their karstification index is high. The Romanian karst inscribes, by its number of forms, variety and by the amplitude of exo- and endokarstic forms, in the category of karst typical for the temperate areas (Cocean, 2000). It suffices to mention the abundance of closed basins (dolines, uvalas, karst catchment depressions), but especially of the approximately 12.000 caves and potholes (cca 2.8 caves/km^2) frequently disposed in multi-leveled systems (with 2 or 3 levels). Exploration activities continue, especially in the flooded endokarst networks.

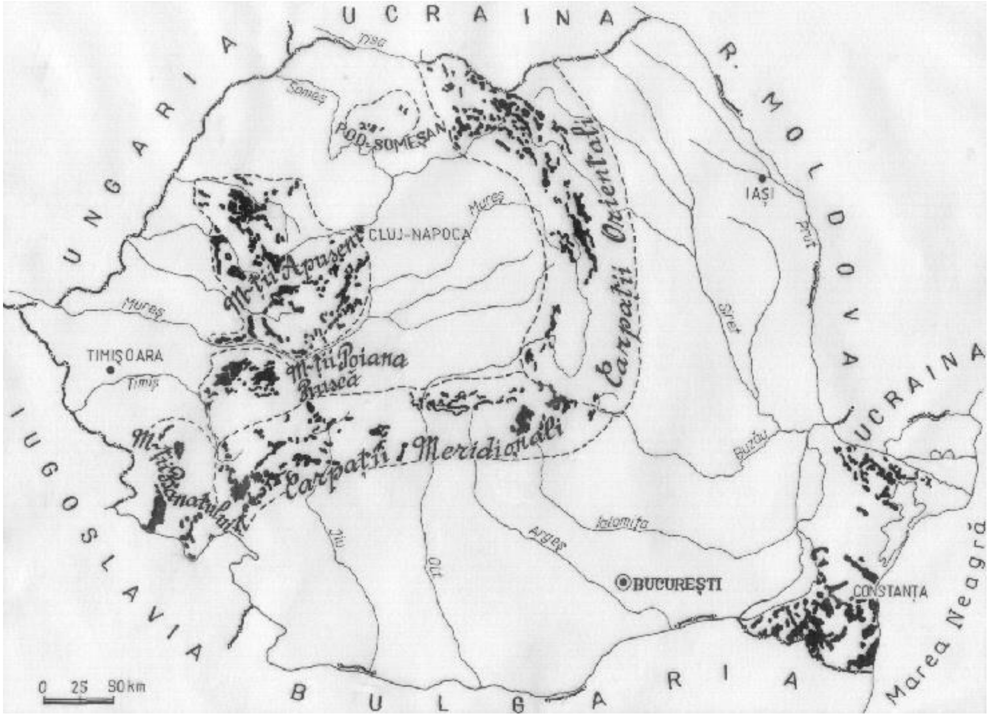

Fig. 1. Karst areas of Romania (from Bleahu M. et al., 1976)

Human impact on karst has a long history and a varied action which, corroborated with its complex natural evolution, have shown a series of ecologic risks, frequently succeeding in perturbing the dynamics of the karst systems and their natural feedback. Such risks are determined by human habitation, agriculture, forestry, industry and tourism.

1. Risks determined by human habitation appear from the degree of habitation of areas with limestones, respectively of constitution of settlements and groups of permanent households. The relatively low altitude of Romanian karst (250 m in South Dobrogea Plateau – 1400 m in Padis area, Apuseni Mountains), together with its preponderant disposition as large plateaus, intensely flattened - veritable karstoplenes - determined an early and very intense settling. There should be mentioned the footprint discoveries from Ciur-Izbuc Cave, Vîrtop Glacier Cave, as well as of the prehistoric paintings from Cuciulat Cave, whose age was estimated at over .000 years.

Karst plateaus from Apuseni Mountains (fig. 2), Banat Mountains, Poiana Ruscã Mountains, Mehedinţi Plateau, South Dobrogea Plateau, Someşan Plateau, are densely populated, with small and medium, villages, spread or concentrated especially along plateau valley passages (Ponoare, Mniera, Ocoale) or on the smooth water divide between them. The construction of households, annexes and fences is frequently based on using the calcareous rock in masonry. Limestones are quarried from the abrupt sectors of the slopes or from karren (Poieni Plateau). These have as result changes in the mechanic equilibrium of rock beds, of the topographic angles of the slope surfaces, generating landslides and erosional processes. When houses are built on inclined slopes, there are leveled platforms, which induce the same phenomena.

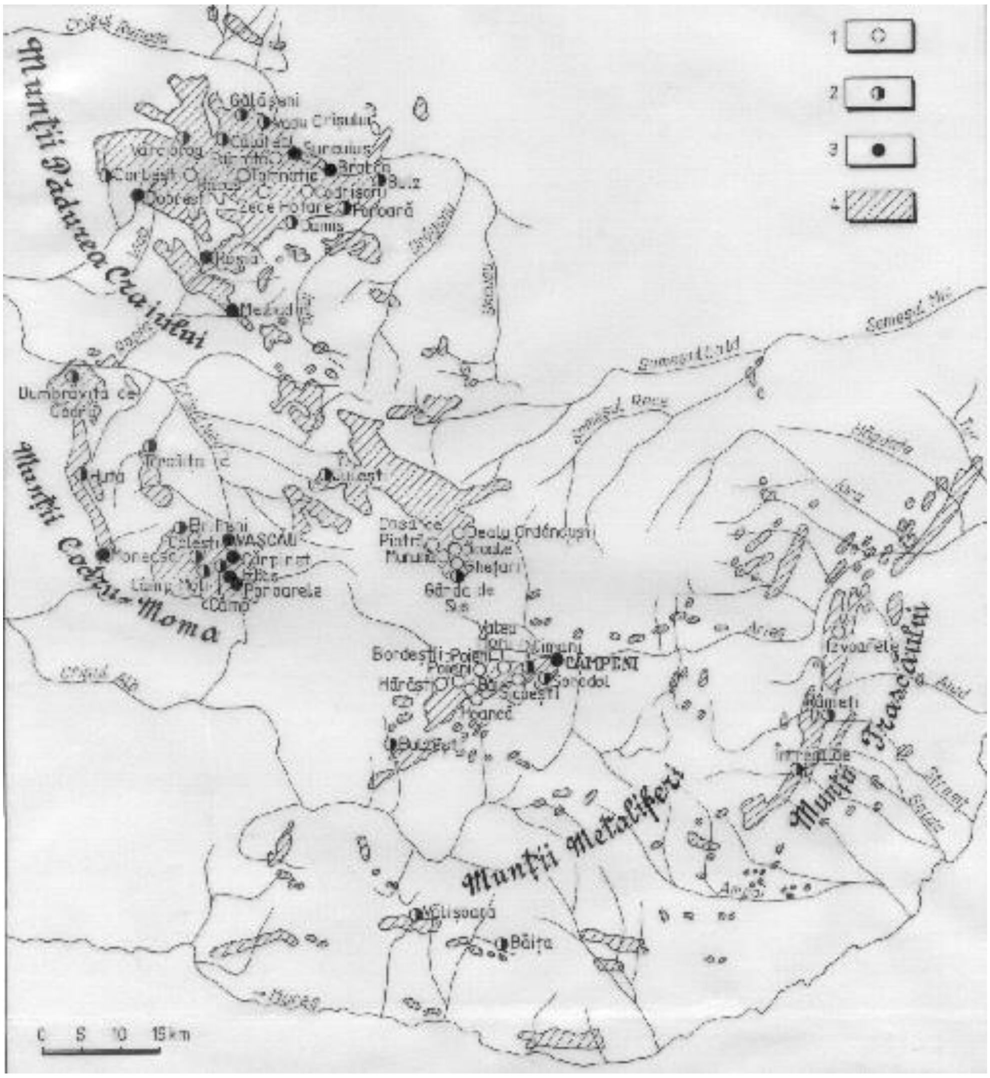

Fig. 2. Settlements in the karst of Apuseni Mountains. 1.Scattered settlements; 2.Spreaded settlements; 3.Gathered settlements;4.Karstic zones.

On the other hand, habitats generate a diverse contribution of residual products (domestic and animal waste) which are frequently discarded in karst waters or deposited in negative landscapes (especially dolines and potholes), affecting chemical composition or generating local pollution. The archaic habit of disposing dead animal in ponors or potholes may have ill-fated sanitary repercussions, in the context of polluting groundwater with an unknown direction, whose outlets serve as water source for other inhabited areas.

Inhabited areas, directly linked with their extent and degree of development, presume a technical territorial infrastructure necessary for an optimal functionality. This includes access roads, power lines, water pipes etc. The material support of the elements mentioned is karst landscape, more or less affected. Road construction implies the most consistent impact, especially on slopes, where landscape modifications are most visible (blasting, terrace construction, leveling, excavations). These can be seen along gorge sectors, such as those of Ordâncuşa, Vida, Gârdişoara, Olteţ, Galbena, Bicaz rivers, but also on karst plateaus from Anina, Pădurea Craiului, Codru-Moma Mountains, Mehedinţi Plateau, etc.

2. *Agriculture and pastoral risks* derive from agricultural exploitation of karst areas. The increased pressure over soil levels has as consequences the degradation of soil horizons, their compaction or removal through erosion stimulated by uncontrolled use. The economic profile of most inhabited areas in Romanian karst is agricultural or agriculture and forestry-based, so the pressure over the lands progressively increased with population growth. The maximum value was reached in the 6th –7th decades of the XXth century, when the Romanian rural demographic boom was at its peak. Since then, rural population migration towards cities, in the period of forced communist industrialization, respectively the drastic fall of the demographic growth from after 1990, led to a decrease of the agricultural impact on karst, where depopulation has reached alarming levels for the existence of many inhabited areas.

The forms of manifestation of the agro-pastoral threats include the replacements of natural, spontaneous vegetation, with cultures; the threat of the phytogeographic stock through intensive pasture; erosion acceleration and the increase of the rock outcrop surfaces (especially in the areas with preexistent karren fields). Such phenomena can be seen in plateau areas from Padurea Craiului, Codru Moma, Bihor, and Aninei Mountains, and Mehedinti Plateau. In South Dobrogea Plateau, the incipiently karstified Sarmatian limestones are covered with a thick layer of loess, which provoked intense solification; the limestones are less affected from this point of view.

Locally, groundwater is polluted with animal runoff. Springs and wells used as water sources are centers for such phenomena. The neighboring areas are strongly affected by erosion due to the destruction of the vegetal layer resulted from animal movements.

3. *Risks induced by forest exploitation* in karst areas concern strong landscape modifications determined by total deforestation. They involve changes of floristic composition, or definitive removal of vegetation on slopes with high declivity. After the removal of tree cover, erosional processes are installed, determining the wash-away of soils and therefore the removal of the germinal substratum necessary for plant growth.

The most frequent aspects in the studied karst areas are those linked to the development of derivative vegetation in areas where deforestation was not immediately followed by immediate replanting. This derivative vegetation consists of varios bush species with low economic value. Their only function is the one of fixation of the soil cover. Typical examples of these are Bedeleu slopes or karst areas of Metaliferi and Aninei Mountains, but also extended plateau surfaces (Vascau, Racas, Poieni).

Forest exploitations presume constructions of access roads that frequent are randomly traced at, without an adequate landscape protection. These access roads are the starting points for intense and profound streaming and ravination of slope that become unbalanced due to landslides and crumbling. In turn these phenomenon is affecting gorges, defiles, abrupt slopes or even slope caves (Vida, Gârdisoara, Ribicioara, Oltet, Galbena Gorges etc).

The changes of the natural vegetal composition determine cumulative modifications of solar radiation and in turn, of local topoclimates, reflected in more pronounced drought, accelerated surface flow and the increase of the hydric deficit in soils. As a consequence, there appear the conditions for the extension of the uncovered karst, together with the gradual removal of the soil cover previously protected by forest vegetal associations. In the same time there appears the migration and disappearance of the specific fauna; the brown bears, once frequent in the forests from Apuseni Mountains are now rarely present and only in areas unaffected by strong deforestation.

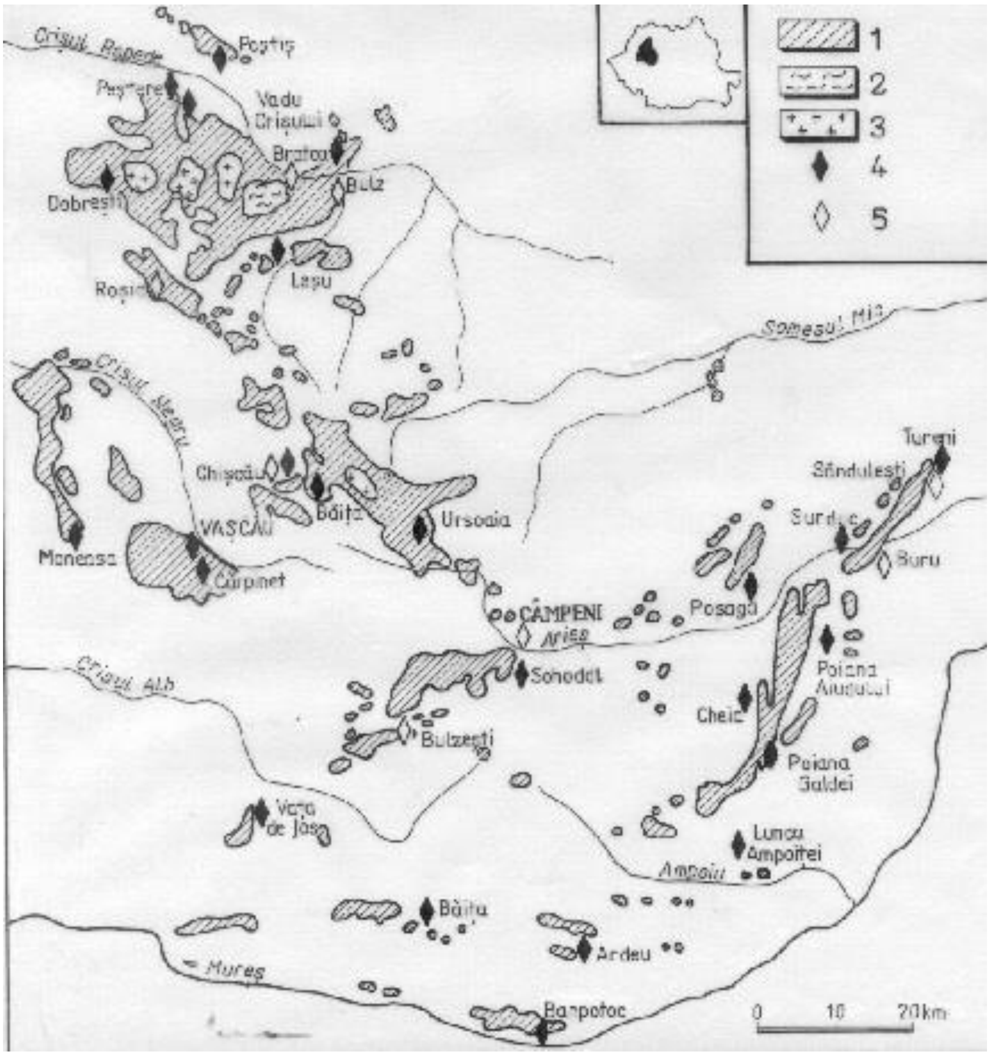

Fig. 3. Forms of industrial exploitation of karst from Apuseni Mountains. 1.Karstic zones; 2.Fire-clay exploitations; 3.Bauxite exploitations; 4.Biuld materials exploitations; 5.Abandoned quarries.

4. *Industrial threats* are the most numerous and the most important, frequently affecting the structure of the dissolution landscape. They are derived from quarrying or mining of limestones and marbles, fireclays, and bauxites.

Limestone exploitation as construction rock (including crystalline limestones, quarried for monuments and works of art), but also for lime, is extremely old on Romanian territory. It was primarily attested by archeological discoveries; the Roman city of Ulpia Traiana Sarmisegetuza, built in the centuries II-III A.C., is mainly constructed with marble extracted from the Poiana Ruscã Mountains. Limestone exploitation did not stop, on contrary it was intensified nowadays. The presence of high-efficiency cement factories intensified the exploitation of this raw material, the quarries visibly affecting the slopes of most calcareous massifs. Limestones are also used in other industrial processes (steel industry, chemical industry), and by rural population to build foundations, fences, roads etc. Fig. 3 illustrates the main limestone quarries from Apuseni Mountains, where the exploitation has reached its peak.

The limestone quarrying effects over the environment are numerous: destruction or threatening of the structure and aspect of some landscapes (gorges, caves, cliffs, klippes or olistoliths); changes in slope declivity and creation of new landscapes with unstable equilibrium – quarry terraces and steps, gradients, overhangs resulted through explosion, waste rock; the removal of the neighboring vegetation; migration of the terrestrial and subterranean fauna from the threatened area etc. The remodeling of the relief so created needs rapid and consistent interventions, which was not realized in the Romanian karst.

Exploitation of Hettangian fireclays from Padurea Craiului Mountains was done in shallow mine galleries in the Suncuius-Balnaca area. Acces roads to the galleries, raw material charge and discharge stations, cable ways, have a negative impact over the landscape whose components (soil, vegetation) are threatened.

The Neocomian bauxites exploitations started in 1914 and reached a high intensity in Padurea Craiului and Bihor Mountains (where are the biggest reserves in Romania). Their accumulation mode, in the Lower Cretaceous paleokarst features (mainly dolines), determined the formation of lens-like bodies. Exploiting such bodies caused the landscape to be come completely modified. Alongside landscape inversions created by lenses excavation these also resulted in intense minor fragmentation with excavation holes, waste rock disposals, access roads to each particular lens, etc. On a minor scale, karst landscape of Racas, Zece Hotare, Padis plateaus was unstructured, its natural evolution being completely modified through the destruction of karren, dolines, uvalas, filling of ponors, caves and potholes with material belonging to uncoverings. Evidently, the vegetation in the respective areas is completely removed, the erosion installing rapidly through sillon and ravines.

5. *Touristically derived threats* are, in their turn, extremely varied. The attractions of karst areas, trough their variety and consistency, make them more interesting than other landscapes. Therefore touristic impacts have a large development and various intensities.

A first form derives from unorganized tourism. Gorges and caves are primarily affected, as they are standards for most karst areas. The choice of accessing paths and campsites, collecting endemic or relict plants within biotopes located in the ecologic niches from gorges, destruction of speleothems, pollution of the underground landscape, waste disposal etc., are only a few of the numerous negative impacts conditioned by the uncontrolled groups of tourists in karst areas.

Possible threats may be induced by the actions of arrangement and tourist exploitation of karst attractions. We include here especially ice caves (such as Scarisoara Glacier Cave) where tourist access on the surface of the ice block has a strong influence over the caloric balance of the cave, with negative influences on the conservation of the fossil glacier. In such cases, show cave arrangements must be realized only after rigorous studies, and the intensity of tourist exploitation must be correlated with the conservation capacity of the tourist resource.

Circumstantial show cave arrangements such as the ones in Vadu Crisului, Meziad, Huda lui Papara caves etc, where the absence of electricity and of some construction works determined the degradation of the underground landscape in some sectors, not to mention the doubty safety and easiness of the access.

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Impactos Ambientais e o Planejamento Turístico em Áreas Cársticas

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Abstract

The caves constitute a particularly rich space of the point of view so much scientific as tourist and it comes waking up interest every larger time for the agents promoters of the regional development seeking dinamical the man's economic activities. However, in the search of her to try to offer good time options and recreation some misunderstandings is made generating serious environmental problems and that of right sets up they can become irreversible. The environmental impacts in caves provoked by the lack of technical approaches and planning, for many times it has been taking to experiences.

KEY WORDS: Caves, Environmental Impacts, Turistic.

Introdução

A caverna foi a morada segura que abrigou os primeiros hominídeos na face da terra, e são nelas, que encontramos a maior quantidade de registros fossilizados de seus hábitos e costumes, na forma de restos de fogueira e utensílios de pedra e cerâmica, além de inúmeras figuras pintadas em suas paredes nos mais variados aspectos, desde os geométricos, passando pelos zoomorficos e chegando até os antropomorficos, o que por si só, já caracteriza uma grande fonte de estudo e pesquisa. São vários destes registros em muitas cavernas ao redor de todo o mundo inclusive no Brasil, onde são comuns registros de agrupamentos humanos nas paredes, teto e mesmo no chão das cavernas, sendo um dos motivos que atrai pesquisadores e curiosos até o local, o que inclusive, tem estimulado o surgimento de atividades turísticas neste tipo de ambiente, muitas vezes sem qualquer infra-estrutura, ou pior, uma estrutura degradante deste meio. Qualquer atividade desenvolvida pelo homem dentro e nos arredores de qualquer caverna tem efeitos secundários adversos para o ambiente hipógeo. Obviamente, que para se preservar este tipo de sistema tem que se impor restrições e critérios de preservação ambiental no processo de planejamento e uso de áreas cársticas. Segundo Lino & Allievi (1984), "Conservar uma caverna é manter suas características próprias inalteradas, de modo a modificar o menos possível o ambiente", ou seja, seria o uso ótimo continuado desse recurso natural. Esta definição choca-se com o uso e a conservação, que são critérios basicamente antagônicos, uma vez que não estamos falando de recursos renováveis. Em alguns casos, quando a preservação da caverna é um objetivo mais importante que seu uso turístico (tal como acontece em alguns Parques, Reservas e Áreas de Proteção Nacionais), a caverna é aberta ao público em sua forma natural, sem facilidades de nenhum tipo. É possível adentra-las com lanternas portáteis, calçados leves e pequenos lampiões, onde se objetiva atingir um mínimo de impacto negativo sobre o sistema da caverna, para que a presença humana ocasional nesta, provoque um mínimo de modificações em seus atributos físicos. O problema com esta alternativa de baixo nível de interferência e que só atrai a uma pequena fração de turistas, pois que a maioria das pessoas preferem caminhar facilmente por um caminho preestabelecido, com iluminação adequada, o que acaba por gerar uma pressão para a abertura de cavernas visitáveis (com maior infra-estrutura interna e externa). Esta, por sua vez, tem sido a experiência "fácil" e pouco ponderada, principalmente por aqueles que só visam o lucro obtido pela exploração de tal atividade. O alto custo de investimento que requer a preparação da infra-estrutura de uma caverna, para finalidades turísticas, é compensado na medida em que se pode perceber como os estudos de impactos ambientais feitos previamente, podem ajudar a preservação da mesma, zoneando áreas que podem ou não absorver estes impactos. Entretanto, o que se percebe atualmente a nível mundial é que existe um uso excessivo de cavernas acondicionadas de forma inadequada gerando problemas sérios de ordem ambiental, infelizmente o Brasil vem a reboque nesta onda turística. Na maioria das cavernas, os impactos dos visitantes são ignorados e os promotores dos projetos não parecem vislumbrar limite algum para o número de visitantes que a caverna possa acomodar. Esta idéia de *recreação ilimitada em um ambiente limitado*, que no caso das cavernas chega ao extremo, não é mais do que outro aspecto da quase universal falta de respeito do homem pela preservação do ambiente em que vive. No caso do ambiente hipógeo, os efeito desta forma de pensar são particularmente daninhos para as cavernas, e potencialmente perigoso para o homem, se não forem tomadas algumas precauções. Os encarregados de abrir cavernas para o uso turístico (principalmente os proprietários das terras onde estas se encontram), deveriam compreender que o atrativo da visita ao mundo subterrâneo depende da preservação das características da caverna, e segurança de quem por ela transita, e isto só é possível através da definição da capacidade de carga de visitantes baseadas em limites particulares relativos a cada caverna, dado este que será revelado através de elaboração do EIA e RIMA por equipe interdisciplinar de espeleologos e pesquisadores. Muito pouco se tem investigado a esse respeito, e não existe consenso geral sobre o que constituiria um limite aceitável para o uso de uma caverna ou parte desta. Há a proposta do Serviço de Parques Nacionais dos Estados Unidos para estabelecer estações de controle tanto em galerias acondicionadas como em galerias naturais do mesmo sistema de cavernas, o que também já começou a ser feito no Brasil no Vale do Ribeira(São Paulo e Paraná).Este é um passo importante para a compreensão das mudanças induzidas pelo homem no sistema. No caso americano, estas estações forneceriam periodicamente dados instrumentais e observações diretas de "...qualidade e temperatura do ar e da água (quando esta ocorrer), umidade relativa, e taxa de evaporação, incremento de calor por visitante, iluminação e informações associadas". (Informativo SBE, 1988). Comparando dados de galerias ocupadas, com galerias sem visitantes, se poderia chegar a ter uma idéia mais próxima da realidade e da magnitude das mudanças introduzidas, e desta maneira fixar limites seguros para seu uso. O mesmo Serviço de Parques Nacionais tem dividido as galerias de Mamoth, Cave em seis categorias de acordo ao seu nível de uso, e a importância de suas caracteristicas. Com este sistema de zonificação, os usos da caverna variam desde áreas de uso intensivo, até passagens em estado natural totalmente protegidos, e de acesso restrito apenas a espeleologos e pesquisadores autorizados. Este constitui um guia útil para determinar critérios de uso das passagens de acordo a sua classificação. No entanto este sistema falha ao não levar em conta nenhum critério de impacto ambiental, ao por limite de uso de diferentes passagens, que no caso das de uso intensivo, e galerias completamente acondicionadas, é de 650 pessoas por hora. Apesar do dito anteriormente, se pode dizer que atualmente existe um processo crescente face a adoção de critérios cujos objetivos são a preservação da caverna e não só o êxito econômico e funcional do projeto, como infelizmente tem ocorrido na maioria das cavernas acondicionadas para este fim.

As instalações subterrâneas

O nível de uso que uma caverna tenha, é importante para a conservação de suas características ambientais, pois a natureza das mudanças que se introduzam nela, produto de como as instalações subterrâneas e de superfície foram projetadas e construídas, é fundamental para definir o futuro da cavidade natural. Por norma estabelecida pelo CONAMA (Conselho Nacional do Meio Ambiente), antes de começar um projeto de acondicionamento de uma caverna, deveria se completar um estudo ambiental de seus aspectos mais relevantes, a fim de precisar os componentes críticos no funcionamento deste sistema hipógeo. Este tipo de estudo assume a forma de um Estudo de Impactos Ambientais, e deveria cobrir os principais aspectos hidrológicos, microclimáticos, geográficos, arqueológicos, paleotológicos, antropológicos, bióticos, geológicos, químicos e a interação destes, e qualquer outro aspecto importante para a caverna em estudo e a região circundante. Estudos de Impactos Ambientais que incluem varias cavernas, tem sido "concluídos" nos Estados Unidos, porém estes foram desenvolvidos para áreas maiores e só contém aspectos do meio hipógeo. Estudos centrados nas interrelações entre o ambiente interno e externo ainda não tinham sido completados, aliás, este erro também tem sido cometido em outros países e o Brasil não é exceção. Um ponto de vista interessante foi expressado por Gurnee(1971), segundo ele, o vandalismo desproporcionado e as visitas as cavernas por turistas, vão ser responsáveis, em poucos anos, pela completa destruição e desaparecimento das cavernas selvagens, e a única maneira de proteger estas cavernas é através do seu acondicionamento turístico. É verdade que no acondicionamento turístico de uma caverna, se preservam certas características de sua completa destruição, mas para um espeleologo experimentado, este conceito de "virgindade das cavernas " não pode ser menos que decepcionante além de limitado. É deprimente, pois cremos que Gurnee leva grande parte de razão, se pensarmos que em poucos anos não haverá cavernas intactas para visitar. Em um projeto de acondicionamento de uma caverna, existem alguns aspectos que devem ser levados em consideração para efeito de preservação ambiental levando em consideração as observações relatadas no estudo de Impactos Ambientais realizado previamente:

1-O processo de construção das estruturas

O processo de construção poderia parecer a princípio pouco importante para a conservação da caverna, porém, o impacto do processo construtivo que não tome conta da fragilidade do meio hipógeo, pode ser o causador de danos irreparáveis a caverna. É necessário considerar não só a maneira como as estruturas vão ser construídas, mas também como os materiais vão ser transportados e armazenados dentro da caverna, como dispor do lixo gerado na obra, como minimizar o ruído das máquinas e possíveis liberação de gases que podem gerar, e como se fará o transporte de técnicos e operários envolvidos na execução da obra. A perfuração e desobstrução de galerias para o transporte de materiais tem sido feita, mas tem que se lembrar que esta solução pode causar mais problemas do que resolver, se o fechamento destes túneis artificiais não é efetuado depois do processo de construção. Sobretudo, se requer uma supervisão permanente de um corpo técnico que possa tomar decisões, a medida que surjam problemas, sem que se gerem conflitos desnecessários devido à ignorância e desconhecimento do assunto por parte dos operários envolvidos na obra.

2-Os Tipos de Materiais

A atmosfera das cavernas em geral é mais úmida que o ambiente externo a ela associado, o que faz com que o uso de madeira e metais oxidáveis não seja recomendado a não ser por curto período de tempo. Devem ser utilizados materiais que ofereçam maior resistência e durabilidade como: alumínio, aço inoxidável, polímeros plásticos, concreto, madeira tratada ou outros. Alguns destes não precisam de coberturas protetoras com periodicidade. A aparência das superfícies destes materiais, deve estar de acordo com o aspecto dos materiais naturais da caverna, e não se diferenciar muito em textura, cor, ou mesmo das formas. Isto faz com que as construções executadas na caverna possuam um aspecto mais próximo do natural, do que se estiver cheia de cabos de aço, de nylon, ou “trilhos de trem”, o que daria uma feição artificial constante.

3-Construção das Estruturas

A construção e características das estruturas tais como: caminhos, portas, pontes e escadarias são importantes, pois podem alterar o fluxo de animais ou aporte de água e ar que poderiam ser maléficos aos componentes abióticos e bióticos, provocados pela alteração do *input* e *output* (Bertandt,1977) do sistema hipógeo. Os caminhos turísticos projetados, devem sempre que possível, evitar galerias onde morcegos abriguem-se, assim como qualquer área de valor orgânico como pilhas de guano ou acumulo de galhos em decomposição, de outra maneira, os animais que dependem destas fontes de energia para sobreviver, serão incomodados por luzes e barulho provocados por turistas. De igual maneira, os caminhos devem ser projetados de forma que permitam ao visitante a observação dos espeleotemas importantes ou conjunto destes, sem dar-lhes a oportunidade de quebrá-los ou danificá-los pelo contato continuo. Os caminhos devem desenvolver-se com sensibilidade, como as flutuações naturais da caverna, tais como as formas das galerias e sinuosidades das correntes de água. As portas estanques, devem ser evitadas ao máximo, já que estas dificultam a livre interação entre a caverna e o meio exterior, ou entre diferentes galerias. Por esta razão a melhor porta nesses casos, é aquela que permite a interação entre o *input* e o *output* do sistema como por exemplo, as feitas com barras metálicas.

4-A Conservação

Um aspecto muito importante relacionado com o mínimo impacto, é a conservação das estruturas e dos serviços instalados, que devem ser projetados para requerer um mínimo de manutenção, portanto, a escolha prévia do material a ser utilizado, se faz de máxima importância como visto anteriormente. A instalação de partes móveis e/ou desmontáveis, devem ser particularmente estudadas, para evitar sua colocação em locais de difícil acesso, tais como topos de clarabóias, fundo de abismos, e outros do gênero. Para minimizar o impacto das instalações na caverna tem que se seguir um princípio geral: reduzir a introdução de instalações e materiais a um mínimo possível alterando o que for apenas estritamente necessário.

5-O Sistema de iluminação

Os problemas derivados da introdução de um sistema de iluminação dentro do meio hipógeo foram estudados em detalhes por Temperine (1976). O impacto da iluminação artificial variará logicamente, de acordo as características desta, a sua utilização e intensidade. Um problema sério criado por luzes artificiais instaladas em ambientes hipógeos é o desenvolvimento de vegetais em suas proximidades, e seu controle pode ser efetuado por vários métodos. Normalmente os espeleotemas atacados por algas podem ser limpos com soluções de formaldeido, cloro ou similares, contudo, alguns desses compostos podem danificar e corroer os espeleotemas, mudar-lhes a coloração original, além de introduzir odores desagradáveis e estranhos ao ambiente cavernícola. Na Alemanha, foram feitas experiências para determinar os efeitos da luz ultra violeta sobre a microflora, e a possibilidade de seu controle com exposições periódicas a tais lâmpadas (Bauer,1971).Tambem sugere, a *desumidificação* artificial do ar ao redor das luzes, para impedir o crescimento das plantas, porém, é de se imaginar o que aconteceria com o microclima cavernícola. Os efeitos que tal prática produz, com toda certeza provocaria mais danos do que qualquer beneficio visível. Existem dois tipos de lâmpadas atualmente usados em cavernas: As incandescentes e as fluorescentes. Destas, a incandescente possui a maior perda de energia, que é convertida em calor residual, elevando significativamente a temperatura ao redor da lâmpada, e portanto, alterando a umidade do ar. Apesar das lâmpadas incandescentes consumirem maior energia, e aumentarem os custos de manutenção do sistema de iluminação, ainda sim são as mais utilizadas em cavernas turísticas, provavelmente porque oferecem um máximo de possibilidades de efeitos “cênicos” e controle direcional. Temos no Brasil três belos exemplos do que não se deve fazer a nível de iluminação em cavernas, que são as grutas de Maquiné e Rei de Mato em Minas Gerais e a Gruta da Mangabeira na Bahia. Em todas elas, é possível observar o desenvolvimento acelerado de formas vegetais que descaracterizam o ambiente, além de corroerem os espeleotemas próximos, o que denota a super utilização do equipamento de iluminação pela passagem frequente e não programada de visitantes, já que o sistema é acionado toda vez que passa um grupo humano. Na gruta da Mangabeira, (Athayde,1987) em períodos de romaria, o sistema chega a ficar ligado horas a fio initerruptamente, o que eleva a temperatura interna em vários graus em questão de poucas horas, sendo extremamente danoso para o ambiente hipogeo. Também deve-se ter em mente, que a presença de alta umidade característica dos ambientes hipógeos, representa um sério problema para as instalações elétricas. Estas, que preferencialmente devem ser de baixa voltagem, para minimizar os riscos de acidentes por choques elétricos, o que não seria muito improvável em uma atmosfera tão úmida e condutiva. Os compartimentos de luzes e refletores devem ser completamente selados, para assegurar sua durabilidade em condições adversas sem provocar acidentes.

6-O projeto de instalações de superfície

Um dos elementos de superfície mais importante nas instalações turísticas é geralmente o estacionamento para veículos. Não deverá estar próximo da entrada da caverna nem tão pouco em terrenos sobre as galerias da mesma. Se o estacionamento estiver posicionado próximo a entrada da caverna, o ruído, as luzes, e a contaminação pelas descargas dos gases, podem penetrar o interior da caverna diretamente, principalmente se não forem respeitadas as orientações fornecidas pelo Estudo de Impactos Ambientais, realizado previamente, quanto a situação e direcionamento das correntes de ar e ventos dominantes do local. Se o estacionamento for sobre a caverna, o solo pode ficar impermeabilizado pelo efeito de compactação, impedindo a percolação da água de superfície e consequente diminuição desse importante *input* ao sistema, além de poder causar alguma forma de desmoronamento, quer sejam blocos ou material terrígeno. Infelizmente, estas duas situações são os erros mais comuns encontrados em projetos de desenvolvimento turístico de cavernas. A água recolhida do estacionamento e outras superfícies pavimentadas, deveria ser dirigida a canaletas e despejadas em tanques de sedimentação, a fim de se coletar os diversos contaminantes produzidos por veículos, e posteriormente retira-los para evitar a contaminação das águas subterrâneas, quando poderia ser tarde demais para uma ação reparadora, afinal, prevenir é melhor do que reparar, alem de ser mais barato, sem falar que em algumas situações, pode não haver condições humanas para reparo. Igual ao estacionamento, todo o restante das instalações de superfície devem ser cuidadosamente projetados em relação a caverna/superfície. Esta deve ser uma relação em que a paisagem seja mantida o mais original possível, para que a caverna seja percebida a medida em que se aproxima da mesma. A cobertura vegetal que rodeia a entrada deverá ser conservada da forma mais natural possível, pois sem árvores e outras plantas que são removidas para instalação de equipamentos, serviços, e deixar a mostra sua entrada, a quantidade de luz que chega ao interior da caverna aumentaria, fazendo com que o fluxo de ar, a umidade, a temperatura e evaporação originais fossem alterados desestabilizando todo o sistema. Por estas razões, a cobertura vegetal deverá ser preservada prioritariamente. Além das mudanças microclimáticas que se produzem no interior da caverna, pelo efeito das alterações na área próximo a sua entrada, os animais trogloxenos que habitam a mesma, sofrem diretamente as consequências destas modificações em cada viagem ao exterior que como sabemos realizam periodicamente.

Planejamento em Áreas Carsticas

De nada adianta ser extremamente cuidadoso no desenho interno das instalações de uma caverna para fins turísticos, se não se tomam as medidas necessárias para preservar as condições originais do sistema de superfície, do qual a caverna depende a todo momento. Existe uma portaria do IBAMA de 15 de julho de 1987 que fala detalhadamente sobre a questão. A melhor maneira de preservar uma caverna, é deixar a área em que se encontra em estado natural, sem alterações ou modificações que alterem as condições ambientais originais. Isto é, na maioria dos casos, uma solução utópica já que o homem necessita dessas terras para a expansão de suas múltiplas atividades. A preservação em escala regional, somente é possível em poucas situações, geralmente em Parques Nacionais ou reservas de vários tipos, e mais especificamente em distritos espeleológicos. Mais realista é, a preservação de pequenas unidades ambientais, necessárias para a sobrevivência das cavernas que dependem delas. Existem duas unidades Geográficas importantes para a conservação das cavernas: A bacia hidrográfica e a depressão hidrográfica. A bacia hidrográfica é a área que coleta a água da chuva e a conduz à caverna, e como todo geossistema (Tricart,1977), sua preservação é importante, já que atividade que se desenvolva nela terá impacto direto sobre a caverna. A cobertura vegetal da bacia, deverá ser conservada, e não seria permitido utilizações urbanas, muito menos industriais. Se não se pretende preservar a bacia em estado natural, deveria ser utilizada para atividades agrícolas, visto que, são menos danosas que as urbanas nestes casos. Os efeitos nocivos da agricultura são a contaminação da cadeia trófica subterrânea pelos pesticidas e fertilizantes químicos, assim como, o incremento de sedimentos via correntes subterrâneas pelo efeito da erosão acelerada nas vertentes da bacia. A depressão hidrográfica é uma unidade menor em extensão que a bacia, e que geralmente possui um sumidouro ou grupo destes em seu fundo, pelo qual a água da chuva penetra diretamente no espaço subterrâneo. As depressões via de regra, são pequenas mas constituem um elemento valioso para o estudo ambiental das cavernas, particularmente de suas características hidrológicas e microclimáticas. A conservação das depressões é vital para a sobrevivência dos sistemas subterrâneos associados a elas, e qualquer uso que não seja o natural, é potencialmente danoso para a caverna abaixo. Não se deve permitir desenvolvimento de nenhum tipo, seja caminho, muito menos estradas já que estas são fontes constantes de contaminação e erosão. O uso de depressões e dolinas em agricultura, muito difundido em varias partes do mundo, deve evitar-se por completo, pois constitui-se a causa primordial de contaminação de águas subterrâneas. Temos um triste exemplo aqui mesmo no estado da Bahia, onde a área imediatamente acima da gruta da Torrinha, além de ter parte da cobertura vegetal retirada para implementação de cultivos, também está sendo irrigada, podendo a qualquer momento provocar desmoronamentos pela aceleração do processo de dissolução da rocha carbonática, o que seria desastroso para o patrimônio espeleológico ali existente. As atividades gerais da bacia devem ser estudadas em detalhe, a fim de evitar problemas derivados do pastoreio, desmatamento, cultivos em vertentes muito inclinadas, e solos com horizontes muito estreitos e rasos. As estradas também deve ser planejadas de acordo com a posição das cavernas que existem na bacia, e a ocupação urbana devem manter-se com baixa densidade, para minimizar os impactos sobre as cavernas, o que pode ser obtido com planejamento integrado a uma visão geossitêmica do ambiente. Igualmente o sistema de fossas sépticas, devem ser projetados para não contaminar as águas subterrâneas e muito menos superficiais.

Conclusões

Uma conclusão geral do assunto, é que a presença do homem nas cavernas está inerentemente associada às mudanças ambientais que estas sofrem, e não existem alternativas para evitar tais modificações, salvo eliminar por completo o fluxo humano. Como isto não é possível, cabe a nós, pesquisadores a tarefa de resolver esta equação, onde ocupação humana, desenvolvimento sustentável e finitude de recursos, alinhem-se da melhor maneira possível. O desenvolvimento horizontalizado da maioria das cavernas nacionais, causa a primeira sensação, de que é muito fácil se implementar qualquer atividade, principalmente, as de cunho turístico, o que só ajuda a aumentar a gama de equívocos no planejamento de tais atividades. O planejamento descuidado, é responsável por mudanças drásticas nas interrelações dos elementos da caverna, e o impacto produzido pela presença humana constante de turistas, é muito mais significativo na destruição do equilíbrio hipógeo. Não é um problema meramente técnico, de como colocar ou desenhar as estruturas e serviços de forma ótima, sendo o homem, um estranho em um ambiente demasiadamente frágil, para suportar sua persistente presença em números elevados. Um exemplo clássico deste fato, é o conhecido caso da caverna de Lascaux, na França, onde a tecnologia tem sido capaz de restaurar as condições originais da pequena caverna, para assim preservar as valiosas pinturas rupestres que contém e que ilustram diversos livros do ensino médio, contando a história e hábitos de seus primeiros habitantes, porém, a caverna não pode ser reaberta ao público, porque, isso significaria alterar novamente as condições ambientais da mesma. O homem pode planejar e projetar os caminhos em cavernas com o objetivo de mínimas modificações, porém, tem que recordar, que só o efeito de sua visita representa um importante impacto adverso para a caverna. Uma postura mais promissora se apresenta, a partir da possibilidade de criação de reservas naturais subterrâneas, que englobem as porções do ambiente superficial, visando assegurar um mínimo de mudanças e modificações danosas, parece ser a melhor possibilidade existente. O desenvolvimento de políticas efetivas de proteção do meio hipogeo, e provavelmente, o futuro de algumas cavernas selecionadas, depende exclusivamente da aplicação deste princípio. Uma ultima conclusão, se baseia no fato em que o processo de planejamento ambiental, que leve em conta as características ambientais de uma região cárstica, é muito mais importante do que se creia no princípio. As condições ambientais externas, são inseparáveis das condições hipógeas, e a única maneira de preservar ambas é através de processo de limitação na ocupação humana de tais áreas, paralelo a formação de agentes multiplicadores de opinião, tanto na vertente institucional, como, principalmente, na vertente comunitária. A existência de pesquisadores realmente envolvidos com a questão ambiental, e menos com a promoção pessoal, será decisiva a partir do momento em que grupos interdisciplinares de estudo e pesquisa, transcendam os vocábulos específicos de suas ciências, e procurem o verdadeiro sentido do desenvolvimento sustentável, sem as contaminações inerentes do lucro fácil e do positivismo, com os quais, estaremos definitivamente condenados a vermos as cavernas como um labirinto de galerias estáticas e sem vida, sem dinamismo algum e completamente dissociado do meio ambiente exterior. De outra maneira, a preservação do meio cavernícola, ou de qual quer outra porção do geossistema não tem sentido.

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El Impacto Antrópico en las Cavernas Argentinas. Estrategias para un Desarrollo Sustentable

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Abstract

Anthropic Impact on Argentinean caverns. Strategies for sustainable development. The Argentinean areas of bigger speleological interest are placed in the mountain range of Los Andes. They were explored partially by local speleologists and inventoried some 200 caves in different litologies. Many are visited by the adventure tourism.

Provincial Reservation of Las Brujas Cavern in Malargüe, Mendoza is one of the few places enabled to the tourism. Its operation began without previous studies nor handling plan, taking place negative impacts.

The mining activity affects to dozens of caves. A national law exists that forces to the companies to carry out an study of environmental impact. In few cases it is applied correctly.

The Argentinean Speleological Federation, promotes protectionist laws and the creation of protected areas to conserve the threatened sites. It impels an education process and awareness to all the levels and social layers about the problems of conservation of the cave environment.

Resumen

Las áreas de mayor interés espeleológico de la Argentina se localizan en la cordillera de Los Andes. Fueron exploradas parcialmente por espeleólogos locales, catastrándose unas 200 cuevas en diferentes litologías. Muchas son frecuentadas por el turismo de aventura.

Uno de los pocos sitios habilitados al turismo es la Reserva Provincial Caverna de Las Brujas en Malargüe, Mendoza. Su explotación se inició sin estudios previos ni plan de manejo, produciéndose impactos negativos.

La actividad minera afecta a decenas de cuevas. Existe una ley nacional que obliga a las empresas a efectuar un estudio de impacto ambiental previo a la explotación. Lamentablemente, en pocos casos se aplica correctamente.

La Federación Argentina de Espeleología, promueve leyes proteccionistas y la creación de áreas protegidas para conservar los sitios amenazados. Impulsa un proceso de educación y concientización dirigido a todos los niveles y estratos sociales sobre los problemas de conservación del medio ambiente cavernario.

Introducción

El área continental de la República Argentina tiene 2.791.810 km^2 de superficie. Este territorio posee áreas kársticas poco exploradas por los espeleólogos, principalmente en la Cordillera de Los Andes.

Las exploraciones de áreas kársticas en calizas han sido pocas, parciales y centradas en sitios como: Las Brujas (Malargüe, Mendoza), Cuchillo Cura (Las Lajas, Neuquén), Punilla (Valle de Punilla, Córdoba) y Cienaguita (Pedernal-Los Berros, San Juan).

Son extensas las áreas kársticas en yeso, la mayoría inexploradas. Algunos sitios estudiados son: La Yesera del Tromen, Pampa del Salado y Curymil, las tres en la provincia del Neuquén, y Las Leñas y Poti Malal en Malargüe, provincia de Mendoza.

Existen áreas con morfología kársticas en yeso y arcillas en Rodeo en la provincia de San Juan y en dolomitas en Sierras Bayas provincia de Buenos Aires.

También se han relevado cuevas volcánicas en las provincias de Mendoza, Neuquen, La Pampa, Río Negro y Santa Cruz.

En Tandil (Buenos Aires) existen muchas pequeñas cuevas prospectadas en rocas cuarcíticas y se conocen otras en granitos en la Provincia de Córdoba.

En los glaciares Perito Moreno y Viedma, en la provincia de Santa Cruz, espeleólogos italianos de la Asociación La Venta han relevado cavidades en hielo entre las cuales se destaca la Cueva Perito Meccanico con 1040 m de extensión que resultaría ser la mas larga galería endoglacial del mundo.

Unas 200 cuevas de diferente tipo han sido catastradas por los espeleólogos argentinos pero pocas superan los 1000 m de relevamiento topográfico (figura 1).

Los Impactos antrópicos en las cuevas

La mayoría de las cuevas prospectadas se encuentran en su estado natural y son frecuentadas por turistas en busca de aventuras con poco o ningún conocimiento de cómo obrar responsablemente en una caverna, por lo que es común observar destrucción de espeleotemas, abandono de basura, grabados y graffiti en paredes y techos. Solo unas pocas poseen control de visitantes o adecuaciones para un uso turístico.

Otra actividad humana que incide en nuestras cuevas es la minería. La explotación de recursos mineros ha causado la destrucción total o parcial de numerosas cuevas.

En este título mencionaremos distintos ejemplos de estos dos tipos de impactos ambientales.

Desarrollo / Development / Développement:

1.	Sistema de Cuchillo Cura (Neuquén)	3.432,86 m (*)
2.	Caverna de Las Brujas (Mendoza)	1.343,24 m (*)
3.	Caverna de La Liebre (San Juan)	1.225,00 m
4.	Caverna Perito Meccanico (Santa Cruz)	1.040 m
5.	Caverna del Arenal (Neuquén)	1.008,75 m (*)
6.	Caverna del León (Neuquén)	852,55 m
7.	Caverna de Doña Otilia(Mendoza)	838,00 m
8.	Sistema de La Cañada (San Juan)	668,23 m (*)
9.	Caverna Salado III (Neuquén)	577,00 m
10.	Caverna Pichi Neuquén (Neuquén)	515,00 m

(*) levantamientos topográficos parciales

Desnivel / Slope / Dénivelation:

1.	Caverna de Las Brujas (Mendoza)	68,49 m
2.	Caverna del León (Neuquén)	63,33 m
3.	Sima de Huitrín (Neuquén)	55 m
4.	Caverna Mercedes (Neuquén)	54 m
5.	Caverna Los Gatos (Neuquén)	36,71 m

Fuente: Comisión de Catastro y Cartografía de la Federación Argentina de Espeleología (F.A.d.E.)

Figura 1. Listado Espeleométrico

El impacto turístico

Solo se conocen cuatro cavidades con algún tipo de manejo turístico: La caverna de Las Brujas (Malargüe, Mendoza), las cuevas del Cerro Los Leones (Bariloche, Río Negro), la cueva del Walichu (Calafate, Santa Cruz) y las cuevas de Las Manos (Río Pinturas, Santa Cruz). Solo la primera es una caverna de origen kárstico en calizas; las otras son pequeñas cavidades de interés arqueológico. El manejo en cada uno de estos sitios es diferente pero hay dos puntos en común: en ninguno se ha consultado o considerado la opinión de espeleólogos y en ninguno se ha hecho un estudio previo del impacto turístico sobre las cuevas. Los resultados hoy están a la vista, y han sido principalmente negativos en la caverna de Las Brujas.

El turismo en la caverna de Las Brujas

La caverna de Las Brujas se encuentra en Bardas Blancas, departamento Malargüe, provincia de Mendoza. Está formada en calizas de edad Jurásica, su desarrollo supera los 2,5 km. Posee una boca principal donde se ha instalado una reja que da acceso a una pequeña antesala donde los turistas pueden munirse de un casco y linterna de mano. Allí comienzan el recorrido turístico visitando la "Sala de La Virgen" que es la más grande de la caverna y de donde parten las distintas galerías. Desde hace unos años se ha habilitado un circuito turístico con escaleras y puentes metálicos para facilitar el transito de los turistas. Inicialmente esas instalaciones se construyeron en hierro y se iluminó este recorrido con luz candente. La energía era abastecida mediante cables sujetos con clavos que colgaban a la vista sin ninguna protección especial conectados a un generador electrógeno situado en la entrada. Luego de años de desoír los reclamos de los espeleólogos, al hacerse visible el óxido de las escaleras, el deterioro del cableado y la rotura de espeleotemas, debieron reemplazarse esas instalaciones por otras más costosas realizadas en materiales inoxidables y eliminar la luz artificial. Estas mejoras parciales no contemplaron el impacto paisajístico de las nuevas instalaciones ni se modificó el recorrido, que es de un solo sentido, por lo cual los grupos de visitantes se cruzan produciéndose atascamientos y manoseo de espeleotemas.

En reiteradas oportunidades los espeleólogos, autores y/o generadores de la gran mayoría de la información científica disponible sobre este patrimonio espeleológico, han reclamado a las autoridades por la escasa o inadecuada información que reciben los visitantes, la falta de capacitación adecuada de los guías, la seguridad y otros temas que hacen a un deficiente manejo de este recurso, sin recibir respuestas.

El impacto minero

Varias cuevas de nuestro país presentan algún grado de alteración producto de la actividad minera. El alcance y gravedad del impacto depende del método minero aplicado (SCHALAMUK I., et.al., 1992.) y es diferente para las distintas fases (prospección, preparación, explotación, etc.). Existen distintos tipos de impacto: atmosférico, sónico y por vibraciones, sobre los suelos y su estabilidad, sobre las aguas superficiales y subterráneas, sobre la vegetación y la fauna, paisajístico, sobre valores culturales y sociales, etc.

La Federación Argentina de Espeleología (F.A.d.E.) lleva adelante gestiones para evitar la destrucción de cuevas amenazadas por actividad minera en las provincias de Buenos Aires, Córdoba, Mendoza y San Juan. Mencionaremos aquí dos casos.

El impacto minero en Cuchillo Cura

Las cavernas de Cuchillo Cura, en Las Lajas, provincia del Neuquén, fueron estudiadas desde 1982 por el Grupo Espeleológico Argentino (GEA) en el marco de un proyecto de investigación y conservación con la participación de grupos neuquinos. Este sistema es al presente uno de los principales cavernamientos de Argentina por su desarrollo que supera los 3 km, por su interés antropológico y por poseer la mayor comunidad de fauna cavernícola conocida en el país (REDONTE,G., 1997).

Las cavernas se encuentran en calizas del Período Jurásico Superior. En el sitio se han detectado siete bancos carbonáticos (ELZEARD L., 1987) dos de los cuales son los explotados como "mármol". El sistema de cavernas posee un desarrollo predominantemente horizontal y en muchos pasajes la distancia entre la superficie y el techo de las salas es menor a los 10 m, motivo por el cual el mayor aporte de energía al medio subterráneo lo constituyen las raíces y el material orgánico que ingresa por las diaclasas que se comunican con la superficie.

Los espeleólogos iniciaron en 1988 gestiones proteccionistas para el sitio logrando que en 1989 el Gobernador del Neuquén firme un Decreto restringiendo la explotación minera y declarando de "Interés Público" el cavernamiento. La Dirección Provincial de Minería, determinó una "zona de exclusión" insuficiente por lo cual el GEA realizó un estudio pidiendo su corrección (GRUPO ESPELEOLOGICO ARGENTINO, 1990) y posteriormente una propuesta de Área de Reserva Natural (GRUPO ESPELEOLÓGICO ARGENTINO, 1992). Las autoridades competentes se desentendieron del problema durante algunos años.

En 1996 la empresa minera abrió una nueva huella sobre la Caverna del Templo eliminando buena parte de la cubierta vegetal e hizo nuevos laboreos sin un estudio del impacto ambiental.

Los espeleólogos los denunciaron ante las autoridades y la prensa. Relevamientos simultáneos de la Dirección Provincial de Minería y del GEA permitieron verificar el riesgo y los impactos causados por las nuevas labores mineras. A partir de este trabajo, la Dirección Provincial de Minería elaboró un informe, proponiendo ampliar el área de exclusión minera (DANIELI, J.C. 1996). El gobernador suspendió los trabajos mineros hasta que no exista plena seguridad de que el cavernamiento no se verá afectado por los mismos.

En 1997 el III Congreso de la Federación Espeleológica de América Latina y el Caribe (F.E.A.L.C.) realizado en Malargüe se pronunció sobre el tema reclamando la protección del área.

En 1998 la Dirección de Bosques, Fauna y Áreas Protegidas de la Provincia emitió un informe técnico contrario a la propuesta de la Dirección de Minería y elaboró, con participación de los espeleólogos, un proyecto de Área Protegida que está siendo estudiado por las autoridades provinciales.

El impacto minero en las cuevas de Sierras Bayas

En Sierras Bayas, provincia de Buenos Aires, se encuentran cuevas en rocas dolomíticas. En el sitio también se hallan canteras de mármol. Se conocía desde 1971 la existencia de una cueva llamada Matilde Catriel. En 1996 el GEA acudió al sitio por pedido de la Comisión de Turismo y Cultura local y relevó otras cuevas descubiertas al avanzar la extracción de bloques en la cantera. Los trabajos alentaron la hipótesis de un paleokarst (BARREDO, S. 1997) y el GEA planteó un proyecto de investigación que fue declarado de “interés parlamentario” por la Cámara de Diputados del Congreso de la Nación. Pero el conjunto de canteristas inició una fuerte oposición a estos estudios y a la preservación del sitio. Los trabajos se realizaron espaciadamente hasta diciembre 2000 cuando se observó la destrucción de dos cuevas y la voladura y oclusión de la boca de entrada de la cueva Matilde Catriel.

Los espeleólogos denunciaron públicamente la destrucción e iniciaron acciones ante las autoridades mineras y ambientales provinciales. Lamentablemente, las mismas no han tomado medida efectiva alguna hasta el presente y se han limitado a cumplir formalidades burocráticas sin aplicar la legislación ambiental minera. El GEA con apoyo de la F.A.d.E. y de algunos legisladores continúa accionando ante las autoridades.

Legislación ambiental y minera

La última reforma a la Constitución Nacional en 1994 incorporó el derecho de todo habitante a gozar de un ambiente sano. En su Artículo 41 enuncia que las actividades productivas deben satisfacer las necesidades presentes sin comprometer a las generaciones futuras, agregando, que las autoridades se comprometerán a este derecho, a la utilización racional de los recursos naturales, a la preservación del patrimonio natural y cultural, de la biodiversidad, y a la información y educación ambientales.

La mayoría de las constituciones provinciales han agregado el derecho ambiental en sus textos. Cada provincia posee sus leyes ambientales y de protección del patrimonio natural y cultural, pero muchas no están reglamentadas, razón por la cual no se aplican.

La actividad minera se rige a través de un Código de Minería. La Ley 24.585 introduce en dicho Código un título complementario denominado “De la Protección Ambiental para la Actividad Minera”. Las autoridades de aplicación son las mismas Direcciones de Minería por lo cual en muchos casos prevalecen compromisos e intereses preexistentes con los productores mineros cuando se produce algún tipo de conflicto ambiental.

Legislación espeleológica

La legislación espeleológica en Argentina es poca y se aplica de modo parcial o distorsionada. No hay legislación nacional, pero sí leyes provinciales en Mendoza y Neuquén. En este título nos proponemos analizar cada una de ellas.

La legislación espeleológica en Mendoza

La Ley 5978/93 de la provincia de Mendoza fue propiciada desde 1992 por un grupo de legisladores, que previamente consultaron a las asociaciones espeleológicas de todo el país. La ley consta de una fundamentación breve y declara que todas las cavernas forman parte del patrimonio de la provincia y por ello sujetas a expropiación; también establece que las muestras mineralógicas, biológicas o arqueológicas de cavernas no pueden ser sacadas de la provincia sin permiso ni fiscalización de las autoridades, que se comprometen a llevar un registro de espeleólogos. La Ley designa a la dirección de Recursos Naturales Renovables (DRNR) de la Provincia para ser la autoridad de aplicación, y establece también las responsabilidades y atribuciones de la misma.

La Ley 5978/93 requiere de un decreto reglamentario para su aplicación, y el mismo fue insistentemente reclamado por los espeleólogos a lo largo de estos últimos años. Incluso el III Congreso de la F.E.A.L.C. (Malargüe, 1997) hizo un pronunciamiento explícito sobre este tema. Pero al día de la fecha las autoridades no reglamentaron esa ley, y no parecen tener interés en hacerlo. Creemos que ello debe entenderse de acuerdo con los acontecimientos en torno a la Caverna de Las Brujas, y que han generado diferencias entre las autoridades y los espeleólogos.

La Caverna de Las Brujas fue convertida, en 1996, en una reserva natural a cargo de la DRNR de Mendoza, y actualmente custodiada por guardaparques. La Caverna fue estudiada por espeleólogos entre 1968 y 1996. Fue expropiada y entregada para su explotación turística al Municipio de Malargüe, el cual procedió a prohibir el ingreso de los espeleólogos, apoyándose exclusivamente en guías de turismo y guardaparques, sin conocimientos de espeleología. Se da el caso de personas que son guardaparques y guías de turismo a la vez y se han dado situaciones de no cumplimiento de las normas de seguridad en cavernas. Los guías de turismo han sido designados, no por su capacidad, sino por razones de “amistad”. La exclusión de los espeleólogos es absoluta y en todo sentido. El registro de espeleólogos nunca fue creado. Esto ha sido permanentemente denunciado por las distintas asociaciones espeleológicas argentinas ante organismos de Estado, ante la prensa, ante la opinión pública internacional, etc., sin que hasta la fecha las autoridades hayan hecho nada para revertir la situación.

La legislación espeleológica en Neuquén

La Ley 2213 se fundamenta en un anteproyecto de Ley Nacional de Espeleología, que el Instituto Argentino de Investigaciones Espeleológicas (INAE) propuso a la Cámara de Diputados de la Nación en 1990, y cuyo trámite no prosperó. Con algunas modificaciones al proyecto original efectuadas por espeleólogos de Neuquen, fue analizado y sancionado por la Legislatura de Neuquén. La ley es extensa y contiene artículos con detalles sobre normas proteccionistas específicas, como asimismo capítulos dedicados a la promoción de las actividades espeleológicas en la Provincia. Se establece también la necesidad de estudios previos de impacto ambiental para las zonas kársticas que vayan a ser afectadas por actividades turísticas o mineras, entre otras disposiciones de importancia.

El Gobierno del Neuquén creó en 1999 un Área de Investigaciones Espeleológicas (A.I.E.), en el seno de la Dirección Provincial de Cultura, con el objetivo de hacer cumplir las disposiciones de esa Ley, y designó a su frente a un espeleólogo. El A.I.E. no ha producido aun resultados significativos, limitándose a aconsejar a las autoridades la prohibición de ingreso a todas las cavidades, incluyendo a los mismos espeleólogos, hasta que se efectúen “estudios de estabilidad” que permitan un uso futuro de cavernas turísticas, pero nada ha dicho ni hecho para llevar a cabo estudios de impacto ambiental en las cavernas en peligro. Tampoco ha dado pasos concretos para atender al reclamo de los espeleólogos sobre la necesidad de que el Sistema Cavernario Cuchillo Cura sea convertido en un Área Protegida. También el III Congreso de la F.E.A.L.C. hizo un reclamo concreto al respecto. Sin embargo, las autoridades neuquinas nada han hecho al respecto.

Estrategias para el desarrollo sustentable

La creación de la F.A.d.E. ha posibilitado intercambiar experiencias de las distintas asociaciones y planificar acciones conjuntas. Una Comisión para la Protección de Cavidades a comenzado a relevar las cuevas amenazadas por impacto antrópico en todo el país y a diseñar distintas estrategias de acción apoyadas en buscar fórmulas que compatibilicen la conservación y el desarrollo mediante un uso inteligente de los recursos espeleológicos de una región. La demanda de un turismo con mayor responsabilidad ecológica es creciente. Ese interés puede contribuir a la valorización y conservación de los recursos naturales y culturales que constituyen las cavernas y su entorno.

Para que tales emprendimientos sean sostenibles de acuerdo a las actuales tendencias ambientales-económicas deben integrarse intereses que habitualmente aparecen disociados: el de los investigadores, el de los administradores de las Áreas Protegidas o Reservas y el de la industria turística. Consideramos que es imposible hallar una solución al creciente deterioro de nuestras cavernas si no se aborda el problema en toda su complejidad. Por ello proponemos compatibilizar la actividad turística con la conservación y protección de la naturaleza permitiendo disfrutar y conocer el paisaje cavernario, su ecosistema, sus valores culturales así como su entorno, con un mínimo impacto ambiental. Este ecoturismo o turismo de Áreas Protegidas que se propone busca que las autoridades vean la necesidad de proteger las cavernas no como un fenómeno geológico, sino como un patrimonio natural y cultural cuya conservación y adecuado manejo turístico pueden hacer económica y ambientalmente sostenibles tanto los proyectos de exploración e investigación, como el mantenimiento turístico y control de un parque.

La estrategia se orientará a proponerle a las autoridades la creación de áreas protegidas y reservas espeleológicas donde se participe a los espeleólogos en el diseño y monitoreo de los planes de manejo, incluyendo la adecuada capacitación de los guías de caverna.

Las zonas de acceso al público deben convertirse en centros de educación y esparcimiento donde los guías de turismo entrenados sean divulgadores del conocimiento generado por los investigadores.

En aquellos sitios o cuevas amenazadas por actividad minera, creemos que la estrategia de sustentabilidad ambiental debe orientarse en dos sentidos: uno educativo y otro legal.

El educativo apunta a concientizar a productores y autoridades mineras sobre el valor de estos ambientes y la necesidad de minimizar los impactos. En muchos casos, es la ignorancia la que habilita la destrucción de las cuevas. Una frase usualmente repetida por canteristas y autoridades mineras es: “para nosotros solo es un agujero sin valor”. Son lamentablemente muchos los funcionarios ambientalistas de la Argentina que tiene esa errónea concepción, de manera que la educación espeleológica debe llegar hasta ellos si deseamos que luego actúen con eficacia.

La estrategia desde el plano legal debe fundarse en la denuncia de toda amenaza de destrucción parcial o total de cuevas y su entorno. Todos los proyectos mineros deben contemplar la prevención de los efectos nocivos al medio y la restauración del área una vez cumplida la fase de explotación, así como realizar un Estudio de Impacto Ambiental previo a la realización de actividades. Nuestra legislación ambiental minera es una buena herramienta para evitar la destrucción de cuevas, pero en la práctica las disposiciones ambientales pocas veces se aplican, sea por desconocimiento del valor de las cuevas o porque los funcionarios priorizan económicos de corto plazo. Por ello, en esta parte del mundo, se hace necesario para los espeleólogos, como ciudadanos responsables, exigir a los funcionarios que hagan cumplir las leyes.

Conclusiones

En los últimos años el deterioro de los ambientes subterráneos y kársticos de la Argentina se ha incrementado. La inexistencia de políticas ambientales eficientes, el grado de corrupción e impunidad imperante en la administración pública y la falta de legislación específica o reticente aplicación de las leyes ambientales contribuye, en gran medida, a profundizar este deterioro. Las políticas economicistas que rigen el mundo globalizado y el creciente poder de manipulación que los grupos económicos y corporaciones tienen sobre los funcionarios en esta región del mundo, hacen que muchas gestiones de conservación de cuevas naufraguen al enfrentar intereses económicos, aunque estos sean de muy corto plazo y perjudiciales (incluso económicamente) a futuro. Estos factores hacen que en nuestra región se manifieste una cultura del “salvese quien pueda” y se releguen intereses comunitarios o se comprometa la calidad de vida futura de la población. Las cavernas no escapan a esta situación.

La actividad minera junto con la actividad turística, desarrolladas de modo ambientalmente irresponsable, son los principales factores de riesgo para las cuevas argentinas. Los espeleólogos argentinos nos hemos propuesto desarrollar conjuntamente estrategias de acción directa que permitan revertir o detener el impacto antrópico negativo en aquellas cuevas hoy afectadas, trabajando desde la educación ambiental en la formación de una conciencia del valor de las cuevas y ambientes kársticos e impulsando leyes que procuren la conservación de cuevas y la creación de Áreas Protegidas que no se restrinjan a lo turístico-comercial ni excluyan a los espeleólogos de su manejo.

En síntesis, iniciamos estrategias de conservación enmarcadas en una estrategia prioritaria para nuestra región: el desarrollo sustentable.

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Estudo de Impacto em Cavernas com Interesse Turístico com uso de Carbureto para Iluminação

[Study of Impact on Caves Caused by Intensive Tourist Visitation Using Carbide-based Illumination]

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Abstract

This paper provides an analysis for the determination of the most adequate use of limestone caves, which are a source of mineral resources utilized in civil construction and agriculture. Caves are also exploited for their tourist potential and for the conduction of scientific research. The present research was designed to offer a basis for the legal regulation of the use of caves, thus contributing to the protection of natural cavities in Brazil. The research will involve the measurement of the temperature, atmospheric humidity, and carbon dioxide and oxygen content of the air, using sensitive equipment developed and operated in partnership with the National Institute of Information Technology (ITI) of Campinas. The results will be correlated with the number of individuals present at that location during the four months of the study. Studies will be made of two caves: Santana and Laboratório II, both located in the Valley of the Ribeira River in the south of the state of São Paulo. The former is located within the boundaries of the State Tourist Park of the Upper Ribeira (PETAR), while the latter is located some 2 km outside these boundaries, although well within its area of influence.

Introdição

Segundo FORTI (1999), o ambiente cárstico é um dos mais vulneráveis e a transformação de uma caverna natural em uma caverna turística deve ser projetada, implementada e manejada com grande atenção para os problemas de proteção ambiental, o que justifica a contribuição da Geologia de Engenharia nessas interferências.

Impactos externos ou de superfície são aqueles que resultam das alterações no entorno da caverna para instalação de toda infraestrutura necessária à atividade, como o desmatamento, a pavimentação do solo, a construção de estacionamentos, banheiros, hotéis, centros de informações, demarcação das trilhas, etc..

A impermeabilização do solo na superfície, com cobertura de cimento ou asfalto, produzem impactos nas cavernas e no carste, que foram identificados por pesquisadores como Willimas, Forti, Cigna, Menichetti, Tosti, Pierini, etc..

Os possíveis impactos são: mudanças na hidrologia, como desvio do curso d'água provocado pela construção de passarelas; mudanças na atmosfera da cavernas; interferência na permeabilidade natural do carste, provocando alterações no crescimento dos espeleotemas (redução ou até eliminação); crescimento de plantas verdes ocasionado pela iluminação contínua (algas, musgos e samambaias); o aumento prolongado na concentração de CO2 pode afetar o equilíbrio químico dos espeleotemas, etc. As pesquisas de Kermode em Nova Zelândia apontaram um decréscimo superficial em espeleotemas como resultado da visitação de cerca de 500 visitantes por dia.

Sobre as condições de um ambiente cárstico suportar ou não um determinado número de turistas, CIGNA (1989); CIGNA & FORTI (1989, 1990) mencionam: "Capacidade de carga de visitantes pode ser definida como o número máximo aceitável de visitantes em uma unidade de tempo sob condições definidas, as quais não podem implicar em uma modificação permanente de um relevante parâmetro ambiental da caverna".

Esta definição é baseada nas seguintes suposições: variações naturais dos parâmetros ambientais não prejudicam a integridade do ambientese o número de visitantes em uma caverna por unidade de tempo é gradativamente aumentado, isso fará o parâmetro ambiental exceder seu limite de variação natural, passando para outros parâmetros.

A capacidade de carga de visitante corresponde ao fluxo máximo de turistas na caverna que eleva os parâmetros para o limite de sua variação natural a classificação de parâmetros ambientais maiores ou menores é arbitrária. Se classificarmos a temperatura do ar, a concentração de dióxido de carbono e a qualidade da água como parâmetros maiores, a classificação de outros parâmetros requer estudos detalhados. A importância dos parâmentros varia amplamente de uma caverna para outra.

Para subsidiar os estudos sobre capacidade de carga de visitantes, pode-se lançar mão da revisão do conceito de NÍVEIS DE ENERGIA feita por HEATON (1986). Ele classificou as cavernas dentro de três categorias:

NÍVEL DE ENERGIA ALTO - normalmente abrigam eventos de alta energia.

Ex.: cavernas que sofrem inundações periódicas. De acordo com esta classificação, galerias ou salões em cavernas de ENERGIA ALTA pouco são afetados pelas atividades turísticas. Isto porque há uma reorganização do espaço interior da caverna por fenômenos naturais, como queda de rochas ou inundações.

NÍVEL DE ENERGIA MODERADO - abrigam eventos mais fracos.

Ex.: as mais significativas forças devem ser águas de chuva, vento constante ou mesmo perturbações de animais. Em cavernas ou trechos de ENERGIA MODERADA, que geralmente possuem muita ornamentação, a presença de visitantes é muito mais prejudicial. A energia liberada pelos turistas em um curto período de tempo pode ser da mesma magnitude que a liberada por processos naturais, que demoram mais tempo para ocorrer. Isto pode levar a um dano irreversível.

NÍVEL DE ENERGIA BAIXO - abrigam eventos de magnitude menor ainda

Ex.: o evento de mais alta energia pode ser uma queda d’água. Uma visita a uma caverna de ENERGIA BAIXA tem implicações mais sérias. Isto por que em um intervalo de tempo muito curto mais energia pode ser liberada pelos turistas do que aquela que a caverna já recebeu em centenas de anos. O dano causado por um grupo turistas é muito grande e os espeleotemas são rapidamente destruídos.

Ainda segundo o autor (HEATON, 1986), as cavernas turísticas mais comuns são as de ENERGIA BAIXA e ENERGIA MODERADA. Isto se deve à dificuldade e o alto custo para desenvolvimento e manutenção de cavernas turísticas que sejam de ENERGIA ALTA.

Em campo a situação é muito mais complexa que os exemplos acima, pois uma mesma caverna pode ter os três níveis de energia quando observada em diferentes trechos.

Coleta e Análise de Gases

A coleta de gases realizada teve como objetivo identificar os índices mínimo e máximo da concentração de CO^2 em alguns pontos da caverna correlacionando com quantidade de pessoas presentes no momento da coleta e com uso de carbureteira

Justificativa da Coleta

É imprescindível para identificar mudanças as quais indicarão alterações entre o estado natural para um outro com presença humana.

Índices Coletados

Locais, períodos e resultados das medições estão relacionados a seguir.

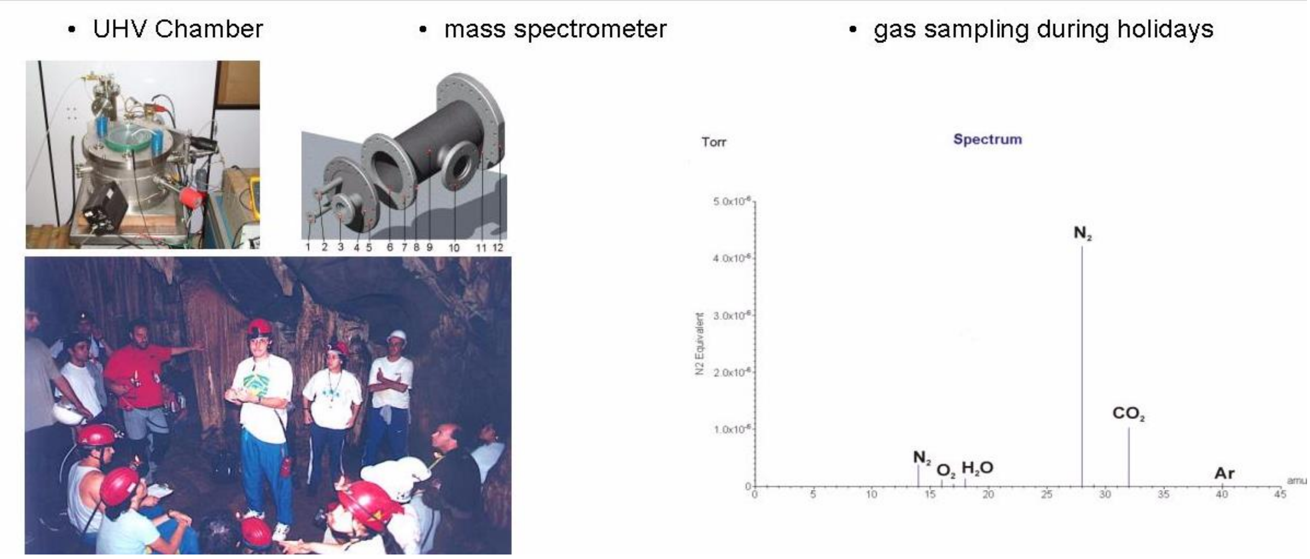
Coleta externa próximo à boca da caverna de Santana

12:00h	480ppm

Salão do Desencontro na Caverna de Santana

No início da coleta o equipamento estava acoplado à parte superior de uma estalagmite com 60cm. de altura:

Horário	nº de pessoas	PPM
13:45	04	1400
13:47	04	1361
13:55	17 sendo 2 carb	1362
14:07	10	1410 - a foto apresentada foi tirada nesse momento



- UHV Chamber
- mass spectrometer
- gas sampling during holidays

Nas medidas seguintes, o equipamento foi acondicionado no piso do salão próximo à mesma estalagmite. Entre o final da coleta anterior e o início desta, permanecemos em 4 pessoas no salão até a chegada de um novo grupo de pessoas, conforme os dados abaixo:

14:58	04	1360
15:00	07	1361
15:15	13	1354 menor valor
15:25	16 a partir desse momento,	1356
15:32	23 até 15:48, o local estava	1375
15:36	49 com 8 carbureteiras	1383
15:37	49 para iluminação	1400
15:38	49	1415
15:40	50	1540 momento em que o grupo de pessoas entrou no local da coleta
15:43	50	1600
15:44	50	1545 início da saída do grupo de pessoas
15:45	25	1540 grupo de pessoas ainda saindo
15:48	04	1415 última medição nesse local

Salão do Cristo (parte superior e parte inferior)

Na parte superior do salão, o aparelho foi instalado em uma rocha próxima ao conduto do Cristo, à altura de 50cm. do piso:

15:58	40	1732 neste momento as pessoas já estavam no local

As próximas coletas foram realizadas no salão inferior ao do Cristo, logo após a descida da escada. O aparelho foi instalado sobre uma rocha localizada no piso, com 20cm. de altura:

16:00	30	2315 maior valor
16:02	15	1615 neste momento as pessoas estavam saindo tanto do salão inferior como do superior.

Resultado Final

Constatamos que o menor valor coletado dentro da caverna foi 1354ppm e maior foi 2315ppm. Portanto o menor índice interno está com 182% a mais do que o resultado da coleta externa.

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Exploitation Durable des Grottes Touristiques et Protection D'un Patrimoine Commun

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Abstract

The appeal for the show caves is more and more emphasized. Constituting a millennium patrimony fragile and irreplaceable, their protection must therefore come before the economical interests. An imperative sensibilisation of the public before the visit will guarantee their respect.

The standardisation of the adapted signalling (pictograms) will make easier its comprehension by all the visitors.

Introduction

Le congrès UIS de Brasilia est le premier du nouveau millénaire mais en terme d'évolution, ce changement de siècle n'apporte aucune solution aux défis qui nous confrontent tous les jours à des choix économiques lourds de conséquences pour la planète. Qu'il s'agisse de l'air, de l'eau, de la faune, de la flore ou des grottes, tout ce qui fait l'équilibre de notre terre est toujours plus menacé aujourd'hui.

Les pessimistes se diront impuissants. Nous pouvons néanmoins "pensez globalement et agir localement", c'est à dire à notre échelle et avec nos moyens poser des actes modestes pour modifier les mentalités en faveur de la sauvegarde du milieu souterrain et continuer à véhiculer l'idée énoncée, dès 1963, par Gandhi : "c'est en le respectant que nous laisserons le monde viable et beau à nos descendants".

De plus, la spécificité du milieu souterrain et des grottes, ce patrimoine communautaire dont l'intérêt de la préservation a été reconnu et affirmé par la Déclaration internationale des droits de la mémoire de la Terre (13.06.1991), fait qu'il ne peut plus rester sans textes légaux précis et contraignants pour le protéger.

Protection et gestion scientifique - surfréquentation et intérêts économiques

Vu la rapidité de son expansion, qui sera encore trois fois plus importante d'ici 2020, le tourisme est considéré comme hautement prioritaire par les institutions financières.

Il est donc, depuis peu, devenu une préoccupation importante de bon nombre d'organisations internationales. Ainsi, la Commission du développement durable de l'UNESCO élabore, depuis sa septième session, des programmes de travail sur le tourisme durable, la Convention sur la diversité biologique génère aussi des programmes relatifs au tourisme, l'Organisation des Nations Unies a proclamé 2002 Année Internationale de l'éco-tourisme et enfin, l'Organisation Mondiale du Tourisme (OMT) a adopté le 01.10.99 un code universel de conduite touristique.

Il serait donc de bon ton que l'Union Internationale de Spéléologie par le biais de sa Commission de Protection du Karst et des Grottes se préoccupe, elle aussi, de deux importants volets du tourisme souterrain -celui des grottes touristiques et celui des tours-opérateurs- afin de prendre les devant pour que ce milieu d'exception soit exploité, sur le plan du tourisme, de manière durable. Cette commission devrait à l'avenir développer des stratégies pour devenir un groupe de pression efficace.

On constate que l'intérêt premier des lieux de destinations touristiques les plus prisés est sans équivoque le "milieu naturel" et que la condition primordiale pour attirer le visiteur est la "beauté naturelle". L' "intérêt historique" du lieu visité reste après le paysage et le milieu naturel le deuxième critère de choix des Européens.

Tous ces critères de choix ne se trouvent-ils pas réunis dans les éléments essentiels et constitutifs des grottes ? Le milieu souterrain et les grottes touristiques en particulier n'échappent pas à cet engouement pour le tourisme. Leurs gestionnaires sont dès lors aussi confrontés aux problèmes générés par cette expansion du tourisme et l'intérêt porté par les visiteurs pour des sites dont la nature elle-même en a limité la capacité d'accueil !

Ce qui précède met en évidence l'importante nécessité de protéger et de sauvegarder les grottes touristiques face aux enjeux purement économiques qui pourraient amener certains gestionnaires peu scrupuleux à une exploitation non respectueuse de ce patrimoine millénaire irremplaçable dont ils sont les garants.

Ces cavités doivent être considérées comme de réelles et véritables vitrines d'un patrimoine souterrain très fragile et plus que sensible. Leur qualité se veut et doit rester irréprochable au fil du temps.

Cette notion de vitrine se justifie déjà pleinement en Belgique et à coup sûr très bientôt dans les pays limitrophes comme la France, la Suisse… En effet, suite à une surfréquentation, un véritable “tourisme souterrain” des réseaux "sauvages", organisé depuis 1990 par des tours opérateurs pour des consommateurs avides d'aventures et d'activités de dépaysement, une série de grottes ont déjà dû être fermées pour éviter la destruction pure et simple de ces sites et par là-même préserver et sauvegarder leurs intérêts scientifiques (biologique, géologique, morphologique, hydrogéologique, cristallographique…) ou paysager.

Dans cette optique, pourquoi ne pas lancer une "Année Internationale des Grottes Aménagées pour le Tourisme". Cette idée se justifie dans la mesure où l'ouverture des joyaux du milieu souterrain karstique au grand public, à monsieur Tout-le-Monde devrait, lors de la visite d'un de ces sites exceptionnels, lui permettre de comprendre les raisons de la fermeture de certaines grottes ; raisons que l'on pourrait comparer à celles avancées pour l'équilibre et la protection de l'écosystème des "réserves naturelles". Une fois comprises, ces motivations contribueront à ce que la beauté et l'intégrité de ce patrimoine communautaire millénaire soient respectées au fil des générations.

De leur côté les responsables des grottes touristiques se doivent également de gérer ce patrimoine de manière scientifique tant du point de vue des aménagements que de la fréquentation, voire de la surfréquentation touristique de ces sites.

En effet, les aménagements touristiques des grottes peuvent entraîner des dommages irréversibles au milieu souterrain. Citons par exemple les modifications topographiques (percées de galeries nouvelles, lacs artificiels, sorties et entrées nouvelles, aménagements d'escaliers, de passerelles…) qui, réalisées sans une étude préalable d'incidence sur l'écosystème karstique, peuvent conduire une grotte à la mort "biologique" et au dessèchement des concrétions.

Ces modifications sont définitives, irrémédiables et altèrent la cavité sans qu'il ne soit jamais possible de les restaurer pour retrouver leur état d'origine. Outre leur aspect souvent inesthétique, elles provoquent fréquemment des modifications profondes du climat souterrain. Les échanges chimiques entre différentes parties de la cavité ainsi qu'avec l'extérieur sont ainsi perturbés alors qu'il s'agit d'un équilibre très fragile et propre à chaque grotte.

Au niveau biologique, ces modifications ont pour conséquence la suppression de certains habitats propices aux animaux cavernicoles : disparition des flaques et des zones humides, colmatage des fissures, réduction et tassement des parois et planchers argileux…

Une autre atteinte, trop peu souvent prise en considération, résulte de l'élévation de la température dans les cavités touristiques. Cette élévation, surtout sensible au niveau des plafonds, est à la fois provoquée par la chaleur corporelle des touristes et par le rayonnement calorifique des différentes sources lumineuses de la cavité. Cette élévation de la température entraîne un dessèchement de certains plafonds ou de parois pouvant provoquer décollements de strates et chutes de pierres ainsi qu'un arrêt d'activité de certaines concrétions. Il modifie aussi les conditions de vie des chiroptères accrochés dans les anfractuosités des voûtes.

Par ailleurs, cette augmentation de la température, cumulée aux effets de l'éclairage et à l'apport de spores et semences transportées par les visiteurs, entraîne aussi l'apparition d'une végétation chlorophyllienne dans la grotte, allant de la mousse à la fougère : la Lamp Flora. Celle-ci se fixe aussi bien sur les dépôts meubles que sur la roche en place. Tout le monde se rappelle la "maladie verte" provoquée par des algues et des moisissures qui a entraîné la fermeture de la Grotte de Lascaux. La grotte et les fresques préhistoriques ont dû subir un long traitement et certaines traces du mal sont malheureusement restées irréparables.

La plupart des grottes touristiques connaissent ce phénomène de "Lamp Flora". La prolifération de la flore, qui tire son énergie de la lumière, envahit les parois et concrétions de la grotte et les détruit petit à petit par dégradation biochimique. Les particules organiques déposées sur les parois de calcite se dégradent dans les gouttes d'eau de condensation et provoquent, par l'activité bactérienne réductrice, une corrosion des concrétions. Cette corrosion biochimique ponctuelle peut s'étendre par répétition et aboutir à la désagrégation totale des concrétions, devenues friables et poreuses. Les cavités touristiques, sans être le réceptacle d'eaux usées ou d'immondices, sont menacées par cette lèpre. Les déchets organiques, même ténus, apportés par les touristes peuvent suffire dans certaines conditions microclimatiques à déclencher ces processus destructeurs, favorisés souvent par la présence de la végétation indésirable (mousses, fougères, algues,...) se développant autour des sources de lumière.

D'autres perturbations viennent s'ajouter à la liste.

A partir de la surface, une variation du régime des eaux de ruissellement (superficielle et d'infiltration) due à des drainages ou à des changements brusques de flore en surface (abattage à blanc des arbres, créations de parkings et infrastructures touristiques, etc.) et l'usage immodéré d'engrais et de pesticides sur les prairies à l'aplomb agissent sur l'équilibre chimique du concrétionnement et sur les espèces cavernicoles.

D'une manière générale, le tourisme de masse dans les grottes engendre des modifications profondes de leur écosystème et irrémédiables pour leur avenir. Les apports en CO2 et vapeur d'eau (transpiration et respiration) et l'élévation de la température sont autant d'éléments perturbateurs d'un milieu physique particulièrement stable. De plus, le bruit, les déchets, les graffitis sur les parois, la destruction de concrétions perturbent également l'écosystème souterrain et souvent abîment à tout jamais le site.

Pour toutes ces raisons, il est urgent et indispensable de gérer de manière scientifique (étude d'incidence préalable à tout aménagement et suivi écologique) les grottes touristiques, patrimoine naturel communautaire, afin de les maintenir durablement dans un état le plus proche possible de leur état originel.

Chaque grotte aménagée ne devrait-elle pas s'entourer d'un comité d'accompagnement qui serait consulté avant chaque nouvel aménagement et où siègerait un spéléo?

Communiquer avec les visiteurs

Ce second point d'ordre beaucoup plus pratique touche à la communication.

Chaque grotte aménagée pour le tourisme se doit d'avoir une mission éducative (consignes pour la visite) et pédagogique (explications simples sur la formation des grottes, la fragilité du milieu karstique et son extrême sensibilité aux pollutions). Le respect du visiteur pour la cavité visitée n'en sera que plus grand et tout bénéfice pour l'exploitant.

Le passage obligé, avant même que le touriste ne pénètre dans la cavité, devant quelques panneaux didactiques identiques pour toutes les grottes mais à chaque fois bien illustrés de photos locales et dont le contenu sera rappelé par le guide au moment opportun de la visite, me semble être une démarche adéquate en matière de sensibilisation et d'éducation.

Il ne faut pas hésiter à interdire de fumer et de manger durant la durée de la visite, à sanctionner sévèrement les contrevenants. Si les consignes sont clairement énoncées, elles seront d'autant mieux respectées. Rappelons aux "clients" qu'ils ne sont pas dans une simple salle de musée où sont exposés des fac-similés de décors millénaires mais au sein même de la Terre, au cœur d'un milieu vivant, fragile, d'un écosystème très sensible aux incursions de l'homme. La visite de sites aussi prestigieux que les grottes ornées ou concrétionnées… cela se mérite !

Cet effort de sensibilisation et d'éducation ne relève pas uniquement des exploitants de grottes aménagées mais aussi de l'enseignement. C'est ce qu'il ressort de séminaires internationaux de formation des enseignants à la protection des géotopes qui se tiennent depuis 1997. Ainsi, le projet GRECEL, lancé dans le cadre des projets Comenius de la Commission européenne, prévoit la mise au point de méthodes et de moyens d'enseignement ainsi que de moyens pédagogiques pour la formation des enseignants qualifiés, qualification indispensable pour former et sensibiliser une population à l'environnement.

Les visites de grottes que j'ai effectuées m'ont amené à poser un autre constat : outre, le manque de panneaux didactiques informatifs, on retrouve quasi partout les mêmes injonctions explicites à l'attention du public. Nous pouvons estimer qu'environ la moitié des visiteurs ne comprend pas et donc ne respecte pas les consignes de protection.

Les exploitants auraient intérêt à ce qu'une réflexion soit menée sur la manière de faire passer clairement les messages et injonctions aux visiteurs par l'utilisation de pictogrammes pourquoi pas leur standardisation pour qu'ils soient identiques partout.

Un exemple : plutôt que d'écrire : "ne pas toucher" - "don't touch" – "non tocare" - "niet aanraken" - "**nedotykat se"** et … la même interdiction en chinois, en grec ou en japonais, ce que je ne peux écrire avec les caractères de ce traitement de texte européen, ne serait-il pas judicieux, à l'instar de la signalisation routière, de matérialiser cette volonté en insérant, en blanc sur fond rouge, l'ensemble du graphisme du doigt d'une main pointé vers la goutte d'un "macaroni", le tout simplement barré ?

N'est-ce pas là un moyen de communication simple, clair et universel?

Il me semble que ce principe peut s'appliquer à bien d'autres messages.

Voilà quelques piste de réflexion sur lesquelles devraient plancher les associations de grottes aménagées au niveau national et international.

Conclusion

Le tourisme souterrain ne peut être durable que si l'intégrité écologique et l'environnement sont sauvegardés. "Plus de tourisme risque de tuer le tourisme" dit Manfred Pils, secrétaire général de l'Internationale des Amis de la Nature. Et c'est bien vrai. Pouvez-vous imaginer dans quel état seraient les grottes, dont les espaces et volumes naturels ne sont pas extensibles, si on élargit sans scrupule les chemins pour absorber, comme l'annoncent les prévisions, une quantité de visiteurs trois fois plus importante ? Le triste état auquel vont être réduites les concrétions vu l'importante augmentation de la température et l'éclairage permanent, aura pour conséquence que les grottes aménagées ne répondront plus aux principaux critères de choix qui créent l'intérêt des foules et les font se déplacer.

La protection et le respect du patrimoine naturel et de géotopes tels que les grottes passe par l'éducation à tous les niveaux.

Developing and Managing an Environmentally Responsible Tourist Cave

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Abstract

In November 1999, Kartchner Caverns in Arizona, USA was opened to the public. Arizona State Parks took 11 years and spent $30 million preparing the cave for viewing while protecting it from the impacts that the tourists would have on the resource. Because the cave is a wet cave (99% humidity) just below the arid Arizona desert, extreme precautions were necessary to ensure that the cave would not dry out when opened to the public.

This paper will explore the sciences used in the planning of the development, the techniques used to protect the cave during development and to mitigate anticipated tourist impacts, and the management constraints imposed in the operation. It will also highlight the eco-tourism niche that was developed due to the extreme care given to this resource.

Sciences

Before any excavation for entrances or even the design of a tourist trail was attempted, an extensive scientific study of Kartchner Caverns was initiated. Because the cave is a wet cave just below the Arizona desert, any interference with the natural phenomena of the resource could have devastating impacts.

The discoverers had already recruited a cadre of cave scientists prior to the state purchase in 1988, and although much work had begun, it was constrained by the fact that the existence of the cave was a tightly-guarded secret. While there is no science known as "secretology", it can not be overstated that this secrecy (from 1974 to 1988) was perhaps the most important tool employed to protect the cave in that it prevented vandalism and inadvertent damage from recreational cavers. Moreover, it set the tone that Kartchner Caverns was a special place and needed to be treated with extraordinary care.

After the secret was lifted, Arizona State Parks spent the next four years continuing baseline studies on humidity, temperature, evaporation rates, rainfall, and a small colony of bats. In addition scientists were employed to study the geology, hydrology, sedimentology, mineralogy, vertebrates, invertebrates, speleothem dating, and geophysics among others. The discovery of bones from a ground sloth (~80 Ka) and a horse and bear (~20 Ka) required the services of a paleontologist.

The results of many of these scientific studies can be obtained through the National Speleological Society. They have been published in the *Journal of Cave and Karst Studies*, August 1999. Taken as a whole, the studies reveal a complicated system where geology, hydrology and biology intersect interplay creating a sophisticated and intriguing cave resource. This last statement could be made of any cave in the world. The challenge comes with the knowledge that the cave will be opened to tourists and the application of those sciences in the development and management of the resources in such a way that they will remain unimpaired for future generations . . . a difficult task in any case . . . particularly so in a wet cave just underneath the desert. Development Protection Techniques Masterplanning The first step in the development of the cave was to create a generalized master plan for the above-ground development. The visitor center, Park Manager housing, campground, restrooms, sewage treatment plant, utilities and roads were all located to prevent inadvertent contamination of the cave system and to avoid interference with the hydrological systems that provide water to the resource. With that plan in place, excavation sites (tunnels) were selected that met a variety of the same criteria. Workforce Training Over 90% of the cave floor were never touched by the explorers. Trails were marked and followed carefully. If this was to be maintained, the workers would have to go through rigorous orientation and training. Personnel were trained outside of the cave in trail construction that did not allow them to get off of the trail they were working on. All off-trail steps required approval by the supervisor. Gloves were mandatory to prevent the transfer of skin oils. Each worker signed an agreement that they would not touch any of the features unless it was necessary for the work at hand and approved. Over the course of construction of five years by more than 100 workers, only one worker deliberately disobeyed those rules. He was not only fired for breaking a stalactite, he was prosecuted successfully in the local courts. Newspapers around the state carried the story showing everyone how seriously we were taking this issue. Materials, Tools and Techniques The cave environment dictated that particular thought had to be given to the materials, tools and techniques used in the development. During the tunneling, for instance, standard mining techniques (blasting) were used. Extensiometers were placed in the cave to measure the acceleration of the shock wave for each blast to determine the charge for the next round. The final 1.8 m to 2.4 m of each tunnel was removed through hydraulic splitters and manual labor. Hydraulic, electrical, and muscle-powered equipment were the only tools allowed inside the cave because they did not emit fumes. The most sophisticated tools used were electric drills, hydraulic drills and splitters, a hydraulic diamond bit chainsaw, and a welder adapted with a charcoal-filtered vacuum. Beyond that, rock was moved by bucket or wheelbarrow.

Cement was mixed with an electric mixer in the tunnel to prevent dust from entering the cave. All handrails are stainless steel to avoid corrosion, and all of the re-bar used in construction was epoxy coated to prevent oxidation and eventual contamination by rust.

A special caution regarding materials is in order. State Parks had purchased some large rolls of black opaque plastic sheeting in order to seal off a part of the cave during the tunneling process. Park personnel were fearful that a sudden entrance to the cave without a temporary way to seal the airflow could quickly dry out that chamber. Three or four days after erection of these walls, large (15 cm. dia.) mold blooms had begun to grow in the dark. The process for making these sheets includes a micro-thin layer of oil to allow the sheets to unroll. The plastic was replaced with another type of sheeting, and from that point forward materials such as plastic, wood, and rubber were cleaned prior to being brought into the cave.

Dust Control

Cave development inevitably involves dust, and the more that dust is controlled or contained, the less clean-up is needed at the end of construction. Less contamination means less disturbance of cave features.

Development personnel used two techniques to help control dust. would soak an ordinary paint brush with water and apply it to the drill bit during operation. This would prevent much of the dust from occurring.

On larger scale projects, and eventually throughout the development, large walls were created on either side of the trail to contain the dust on the trail.

As soon as possible these walls were erected and maintained throughout the development process. Not only was post development clean-up minimal but the walls had the added effect of concentrating the focus of the work at hand and also provided a visual (and physical) barrier to cave features within arm’s length. It should be noted here that the cave trails was designed to keep people far enough away from the features that they could not be reached, but that it was not always possible.

There were times when construction required overhead protection from contamination. When the ceiling drew close or when using a hydraulic tool such as the chainsaw which could spew water, the plastic wall technique discussed previously included a tent-like plastic ceiling.

Moisture and Algae Control

Overarching issues in the development process included ways to keep the moisture in the cave and algae out of the cave. Airlock doors were installed in a series to minimize air exchange and a misting system was installed to add moisture.

In order to control algae, the trail was designed to catch most of the lint from the visitor and the lights (computer-controlled) are only on when being viewed by the visitor. Each evening the trail is washed down to low points and the dirty water is pumped out of the cave.

Management Constraints

There are several aspects of management to be considered. Setting a carrying capacity is perhaps the most critical. Management direction not to exceed that capacity under any circumstances is critical. All tours should have a lead guide to interpret and a tailing guide to add security.

Under the current management at Kartchner Caverns, the reservation system was set up with a limit of 20 people per tour, with the additional limit of 25 tours per day. This limit was created not only to control the number of people also to ensure a quality experience for each visitor. The cave size and developed visitor trail also provide constraints to group size. These are important factors that will keep future managers of the resources from increasing these numbers. The park has operated at capacity since opening day in November 1999.

Management includes perpetual monitoring of the cave conditions by the Cave Management Unit. This group of employees monitors temperature, humidity, evaporation and air chemistry. This data is interpreted to determine if management can adjust operational factors to counteract the changes. As an example managers have the ability to lower lighting levels reducing the amount of heat generated in any specific area.

Guides are trained to not only give tours but also to respond to a variety of emergencies. Cave guides are trained to respond to inadvertent or flagrant touching of cave formations. Guides mark formations touched and the cave unit cleans the area after tours are finished for the day. At that time all cave trails are washed down and the wash water is pumped out of the cave and released away form the cave.

The Eco-Tourism Niche

There is a definite eco-tourism niche for caves that are developed and managed with care. Reservations at Kartchner Caverns have consistently been full three months in advance. Tour group operators purchase $40,000 of tickets at a time. It is not uncommon for people to be at the park entrance 3 hours prior to opening seeking the daily issue of unreserved tickets. This also has an economic benefit to the surrounding community. The Arizona State Parks Research and Marketing section randomly surveys park visitors for feedback regarding their experience at all of our parks. It has been determined that each group visiting a park spends $150-$200 at local shops and restaurants. Visitation in the first year at Kartchner Caverns State Park was held to the cap of 180,000. While the financial success is remarkable, perhaps a greater indication of the niche is the feedback we are getting from the visitors. They indicate that they are glad we took the time to do it right, that the care we displayed in the development and management is obvious, and, because of that, they feel a visit is a privilege. Finally the environmental stewardship message has generated by far the most publicity for Kartchner Caverns State Park. Media around the world have headlined this environmentally-responsible tourist cave. Through these media, the nature resource stewardship message has been received by more than 100 million people.

Prise en Compte des Contraintes Physiques Liées au Karst: Une Approche Cartographique au Service de L'aménagement du Territoire en Belgique (Région Wallonne)

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Résumé

La Direction de l'Aménagement du Territoire de la Région Wallonne (DGATLP), a confié la réalisation d'une cartographie numérique des contraintes physiques inhérentes au karst à l'Université de Liège, à la Faculté Polytechnique de Mons et la Commission Wallonne d'Etude et de Protection des Sites Souterrains (CWEPSS).

Pour mettre l'accent sur les problèmes que peut poser le karst par rapport aux équipements, aux constructions et aux entreprises existantes et en projet et d'en tenir compte lors des permis d'urbanisme, l'étude s'est limitée, à la détermination des contraintes karstiques situées en zones urbanisables.

Pour que cette contrainte physique particulière puisse être prise en compte au moment de délivrer un permis d'urbanisme comme le prescrit l'article 136 du Code Wallon pour l'Aménagement du Territoire, de l'Urbanisme et du Patrimoine (CWATUP), une cartographie des zones de contraintes a été établie à l'échelle du 1/10.000. Celle-ci a été réalisée sur le logiciel de cartographie ArcView sur base de l'Atlas du Karst Wallon, inventaire des sites karstiques et des rivières souterraines de Wallonie, réalisé par la CWEPSS.

Summary

To take in account the effects and possible impacts of karst on land use management, the Wallonian government has ordered a scientific inquiry to evaluate and represent these physical restrains in urbanised areas. This study was conducted by the University of Liège, the Polytechnic Faculty of Mons and the « Commission Wallonne d'Etude et de Protection des Sites Souterrains (CWEPSS) between 1998 and 2000.

The three teams have mapped on a 1/10.000 scale all the area's where the probability of a karstic risk occurred. Each of those areas has been described and a list of recommendations was proposed to reduce the risk and possible impact of a karstic accident.

This cartographic survey was done with ArcView (GIS software) on the basis of the « Atlas du Karst Wallon », which is a cartographic inventory of all karstic sites and underground rivers of Wallonia, organised as a geo-referenced database.

Those maps will be a tool for land use management and will help to take in account the karstic dimension in an integrated approach of the environment.

1. Qu'est-ce qu'une contrainte karstique?

En Wallonie, les roches carbonatées sont nettement influencées par les phénomènes de dissolution. C'est dans les calcaires dévoniens (givétiens et frasniens) et carbonifères (tournaisiens et dinantiens), que se concentrent les cavités et les autres phénomènes karstiques résultant de l'effet des eaux agressives sur la roche carbonatée et en particulier des circulations d'eaux souterraines.

Ces processus karstiques sont à la fois responsables de phénomènes souterrains (grottes et rivières souterraines) et de sites visibles en surface (dolines, points de pertes, effondrements…). La présence de ces phénomènes karstiques et leur évolution continuelle peut poser de graves problèmes de stabilité du sol et peut nécessiter une grande prudence en matière d'urbanisation.

Les zones de contraintes karstiques se limitent donc aux affleurements calcaires présentant une dissolution et des risques de tassement ou d'effondrement. La présente étude délimite dans ces massifs calcaires karstifiés un ensemble de périmètres dans lesquels les prescriptions suivantes devraient être appliquées :

- *l'urbanisation devrait être interdite dans la zone de contrainte forte ;*
- *tout nouveau programme d'urbanisation devrait faire l'objet d'études complémentaires pour s'assurer de la stabilité du sous-sol dans la zone de contrainte faible.*

La délimitation des zones de contraintes ainsi que l'intensité forte ou faible de celles-ci est directement liée à la présence de phénomènes karstiques connus, à leur densité, à la vitesse de leur développement et au cadre géologique et géomorphologique général dans lequel ils se développent. Parmi les phénomènes karstiques dont la présence est un critère pour définir les zones de contraintes physiques liées au karst, il faut citer en particulier les suivants:

1.1. Incidence des dolines sur les zones urbanisables

Elles constituent les formes karstiques de surface les plus courantes ; elles sont la conséquence d'une intense dissolution de la roche calcaire en profondeur. Les dolines se forment dans les zones de faible résistance (fissures, failles), à la verticale de réseaux de galeries souterraines (grottes), sur l'axe de rivières souterraines et dans les vallées sèches. Les dolines d'effondrement (*sinkholes ou puits naturels*) se forment brutalement par effondrement du sol ou du sous-sol, parfois sur plusieurs mètres de profondeur.

1.2. Incidence des chantoirs et des rivières souterraines sur les zones urbanisables

Les chantoirs ou pertes du réseau hydrographique dans le massif calcaire induisent des contraintes particulières vis-à-vis de l'aménagement du territoire :

Celles liées à *l'évolution hydrogéologique de certaines régions karstiques*. On observe au cours du temps un recul des points de pertes vers l'amont, pouvant aller jusqu'au point de contact entre le substrat imperméable et l'affleurement calcaire. Les inventaires successifs de phénomènes karstiques démontrent que ce déplacement peut atteindre plusieurs centaines de mètres en un siècle et qu'il faut tenir compte de la mobilité des pertes dans la gestion rationnelle du territoire.

Les chantoirs sont des *têtes de réseaux d'écoulements souterrains* qui se poursuivent jusqu'aux points de résurgences. Les eaux dans leur parcours souterrain continuent à dissoudre le calcaire, provoquant un sapement de la roche pouvant entraîner l'effondrement de la voûte calcaire. On observe de nombreux cas d'effondrements qui s'alignent sur le parcours de ces rivières souterraines. Il faut tenir compte de ces axes sensibles du point de vue des contraintes karstiques dans la gestion du territoire.

Enfin, des augmentations du débit d'amenée d'eau peuvent provoquer l'engorgement et la *saturation de certains points de pertes*, induisant le débordement du chantoir et l'inondation des terrains environnants. Ce phénomène peut avoir un caractère catastrophique en zone urbaine où le sol, imperméabilisé par le bitume, provoque un afflux d'eau de ruissellement dans les chantoirs, ce qui nécessite des travaux importants de génie civil pour évacuer le trop-plein des chantoirs lors des orages.

1.3. Incidence de la pollution sur l'hydrologie karstique

Les nappes aquifères karstiques sont très sensibles aux pollutions. Cela résulte de la très grande perméabilité (porosité de fissures) du substratum calcaire et de la transmissivité observée dans les nappes karstiques, favorisant la propagation de la pollution sur de très grandes distances. Cette caractéristique physique et hydrogéologique est également une contrainte très importante pour l'aménagement du territoire. En effet la gestion et l'épuration des eaux usées doivent être prioritaires dans les zones karstiques, vu les conséquences que peuvent avoir ces rejets sur la qualité des eaux souterraines. Les nappes aquifères carbonatées constituent les réserves d'eaux potabilisables les plus importantes de Wallonie.

1.4. Pourquoi parler de contrainte karstique plutôt que de risque lié au karst ?

La cartographie réalisée permet de localiser *les zones des contraintes karstiques, mais elle ne peut être considérée comme une carte des zones à risques karstiques.* Dans cette étude, il s'agissait de déterminer des zones dans lesquelles des indices physiques doivent inciter les autorités à une certaine prudence quand il s'agit de délivrer un permis. La nature karstique de ces zones rend l'urbanisation classique sans mesure de stabilité du sol ou de renforcement des fondations, hasardeuses. Cette étude délimite ces zones, mais c'est aux dirigeants de définir les mesures à prendre pour atténuer les contraintes.

2. Gradation des contraintes liées au karst

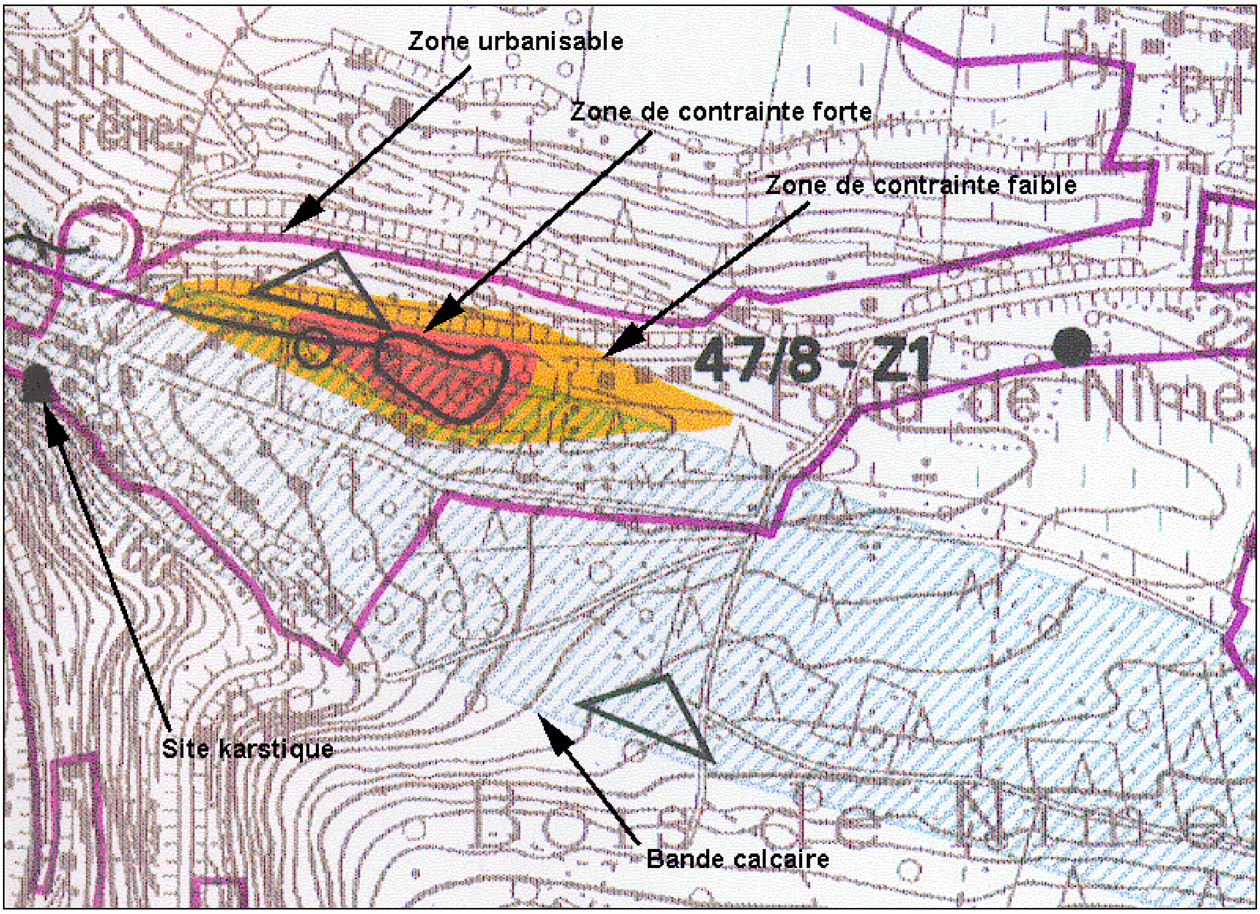
Suivant la proximité avec les phénomènes karstiques, la taille, l'importance et la dynamique de ceux-ci, leur densité sur le terrain et la présence d'éléments favorables à la réactivation des réseaux souterrains par des écoulements d'eaux, différentes classes quant à l'intensité des contraintes ont été définies sur les cartes.

2.1. Interdiction de construction sur les sites karstiques (représentés en noir)

Cette interdiction veut rencontrer deux buts:

1/ protéger les constructions elles-mêmes [les phénomènes karstiques, tant souterrains (cavités et circulations d'eaux souterraines) que de surface (dolines, résurgences, chantoirs…), peuvent rejouer et s'effondrer, causant ainsi des dégâts importants aux constructions].

2/ Eviter qu'une construction ne détruise un phénomène karstique de grande valeur et qui fait partie du patrimoine de la Région. Il s'agit donc aussi d'une mesure de préservation pour le karst.



Les différents types de contraintes karstiques tels que représentés dans cette l'étude (extrait de la carte 47/8 sud, vallon du Fond de Nîmes) – Province de Namur

2.2. Les zones de contraintes fortes (en rouge sur la carte)

Une zone de contrainte dépassant le simple diamètre du phénomène karstique a été définie lorsque :

- plusieurs phénomènes karstiques proches justifiaient la coalescence de leurs aires de contraintes, formant ainsi une zone pouvant par endroit être très étendue (ex : les champs de dolines regroupés formant une zone de contrainte plutôt qu'un ensemble de cercles de 30m où la construction est interdite);
- les indices observés sur le terrain, indiquent la présence d'une zone active où la formation de nouveaux phénomènes karstiques présente une forte probabilité (ex : un vallon sec sous lequel le soutirage et la dissolution liée à la circulation d'eau souterraine peuvent induire des effondrements);
- les phénomènes karstiques étudiés sont réactivés (cfr. Tournaisis suite au dénoyage du calcaire carbonifère) et que l'on peut prévoir la manière dont ils risquent d'évoluer (ex : la tendance naturelle au recul des chantoirs vers l'amont, le rejeu et l'approfondissement de certaines dolines…).

La *contrainte forte* s'appliquent aux zones où toute construction est à éviter, voire interdire, car les risques sont importants. Sont pris en compte dans la délimitation des zones de contraintes fortes :

- les superficies où la densité des phénomènes karstiques est la plus forte ;
- les zones très actives du point de vue karstique (celles où de nouveaux phénomènes sont apparus) ;
- la présence de circulations d'eaux souterraines et notamment les vallons secs ;
- la densité de la fissuration et de la fracturation du calcaire que constitue le substrat rocheux ;
- tout autre indice de terrain confirmant l'activité karstique en cet endroit.

2.3. Les zones de contraintes faibles (en orange sur la carte)

Les zones de contraintes faibles concernent des périmètres comprenant des sites karstiques, mais dont la dimension, la densité et l'inactivité (pas de rejeu connu ni de formation de nouveaux phénomènes à proximité) impliquent des risques inférieurs à ceux en zone de contrainte forte. Des zones de contraintes faibles ont été souvent définies autour des zones de contraintes forte comme «périmètre de sécurité ».

Dans ces zones, les constructions ne doivent pas être formellement interdites mais elles feront l'objet *d'investigations complémentaires* en vue de vérifier et de garantir la stabilité du sol et des fondations. Suivant la nature du sous-sol, un renforcement des fondations est à suggérer pour les constructions surtout si elles sont de grande dimension (comme par exemple pour les équipements collectifs et les industries).

Des *prescriptions strictes* concernant *l'égoutage* et la gestion des eaux usées doivent y être imposées. Un rejet direct des eaux peut avoir des conséquences graves sur les nappes aquifères calcaires. Par ailleurs, les rejets d'eaux peuvent également réactiver le karst et engendrer de nouveaux effondrements.

2.4. L'ensemble des affleurements calcaires en Wallonie (hachures bleues sur la carte)

Toutes les roches calcaires peuvent être corrodées par les eaux acides qui s'écoulent à leur contact. L'ensemble des zones urbanisables sur ce type d'affleurement peuvent potentiellement présenter des risques d'apparition de phénomènes karstiques à même d'entraîner une contrainte pour l'habitat.

Le risque n'est donc pas nul sur substrat calcaire et c'est la raison pour laquelle sur la carte ont été repris tous les affleurements calcaires afin d'attirer l'attention des gestionnaires sur la particularité du sous-sol de ces zones lorsqu'il s'agit de prévoir le développement urbain et au moment de délivrer les permis de bâtir.

3. Conclusions

L'objectif de cette étude était de contribuer à la mise en œuvre du Code Wallon de l'Aménagement du Territoire de l'Urbanisme et du Patrimoine (CWATUP) et du Schéma de Développement de l'Espace Régional, adopté par le Gouvernement wallon le 27 mai 1999.

L'étude porte sur les contraintes naturelles pouvant affecter les zones urbanisables, en l'occurrence celles relatives aux phénomènes karstiques : risques d'enfouissement des cours d'eau, de tassement ou d'effondrement du sol, d'inondation, etc. Vu l'ampleur de la tâche, ces contraintes physiques n'ont été cartographiées que dans les zones urbanisables. Mais il est prévu d'étudier d'autres zones limitrophes aux terrains urbanisables et par rapport auxquelles le karst peut présenter une contrainte physique majeure.

L'étude poursuit le double objectif de protéger les bâtiments et les ouvrages des risques karstiques, mais aussi de protéger le patrimoine karstique, là où cela s'impose, des dégradations liées à certaines activités humaines. Les dommages susceptibles d'être faits aux constructions peuvent être extrêmement coûteux, tout comme ceux que les activités humaines peuvent provoquer à l'égard du patrimoine naturel. L'investissement fait dans cette étude évitera bien des déboires et des frais liés à des accidents prévisibles.

Le produit final du travail vise la cartographie numérique des contraintes karstiques situées dans les zones urbanisables inscrites aux plans de secteur de la Région wallonne.

La cartographie a été harmonisée en vue de pouvoir être présentée sous une légende applicable à toute la Région Wallonne. La réalisation s'est concrétisée à partir d'un Système d'Information Géographique (SIG), traité par le logiciel ArcView. Outre les cartes imprimées (à 1/10.000 pour toute la Wallonie) et le texte correspondant sous forme d'une fiche descriptive (qui constitue en fait une véritable petite monographie de chaque demi-planchette), le travail sera également consultable sur CD-ROM.

On notera que pour la première fois, les contraintes inhérentes au sous-sol sont prises en compte dans l'aménagement du territoire d'une Région.

Le degré de contrainte a été précisé : trois classes ont été établies qui catégorisent l'importance du danger et représentent une proposition de gradation dans les prescriptions des mesures à prendre en vue d'un aménagement rationnel intégré. Les mesures de précaution proposées ne prétendent pas à une valeur légale. Il reste aux responsables de l'aménagement de la Région Wallonne à réaliser les arbitrages avant d'inscrire les périmètres de contraintes physiques aux plans de secteur.

Enfin, ce travail comporte trois principaux centres d'intérêt. Il correspond à la situation existante de fait en 1999 ; il a un caractère prospectif et sa version informatique offre une grande souplesse d'usage.

Le caractère d'actualité provient de ce que la cartographie intègre l'analyse de la situation existante et se base sur de multiples sources bibliographiques mais aussi sur un minutieux travail de terrain.

La valeur prospective du travail résulte des informations connues à ce jour auxquelles nous avons appliqué des modèles tenant compte de l'évolution probable des phénomènes karstiques.

La souplesse d'utilisation et la rapidité de consultation des documents, cartes, fiches descriptives et illustrations est assurée par la disponibilité de cette étude sous la forme de CD-ROM consultables à l'aide d'un logiciel ArcView.

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Conservation Issues in the Cockpit Country, Jamaica

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Abstract

The Jamaican Cockpit Country is one of the most spectacular karst landscapes in the World, and is the premier “type-example” of the cockpit style of polygonal karst. Despite this and the area’s hydrological and biological significance, effective conservation of the Cockpit Country is minimal and laissez-faire. While much of the Cockpit Country was designated as a Forest Reserve in 1950, enforcement of this legislation has been erratic, and human encroachment has been limited only by the remoteness and the difficulty of access to the karst. Karst areas surrounding the Cockpit Country are exploited for bauxite mining, agriculture and other purposes; logging and agricultural activities have extended into the Forest Reserve. Although previous studies have stressed the importance of effective conservation in the Cockpit Country, and the area has long been mooted as a national park, government attitudes towards conservation have been inconsistent. Recently, it has been suggested that the Cockpit Country should be nominated as a U.N. Natural World Heritage Site, and organizations including the World Bank and national NGOs have become involved in developing potential conservation strategies. Designation as a Heritage Site is hampered by the lack of appropriate government legislation and by the unresolved issue of land tenure of the resident Maroon community. Such designation may not ultimately be in the best interests of conservation if it draws public attention to the area before adequate protection measures are in place.

Introduction

The Cockpit Country, centered on Trelawny Parish, Jamaica, represents the type example of the cockpit style of polygonal karst (Figure 1). The 600km^2 area is a significant habitat for many endemic species and its future conservation is a matter of increasing concern both in Jamaica and internationally. Although much of the karst remains forested, some 10,000 people live in the immediate vicinity, and agricultural, domestic and industrial pressures are mounting. There have been several previous discussions of the status of existing conservation measures (EYRE, 1995; SMITH, 1995; BARKER & MILLER, 1995; MILLER, 1998) but no coherent strategy has yet been implemented and the area retains its largely ineffective 1950 designation as a Forest Reserve, which permits multiple uses of the forest. In 1994, the Jamaican Conservation and Development Trust recommended the Cockpit Country as a national park, but this has yet to be accomplished despite the support of national and international organizations as disparate as BirdLife Jamaica and the World Bank.

Fig. 1. IKONOS image in the near infrared band taken just south of Windsor (left) and an aerial view of a portion of the Cockpit Country (right). Notice the house in the lower right hand corner for scale.

The Cockpit Country Landscape

The Cockpit Country is developed in the White Limestone Group of Eocene to Miocene carbonates. The cockpits are steep-sided, enclosed depressions surrounded by residual hills or ridges (SWEETING, 1958; AUB, 1969; SMITH *et al.*, 1972; MILLER, 1998). The convex floors generally have a regolith or soil cover and some contain relict, debris-choked vertical shafts. Drainage is centripetal, although dominantly vertical (DAY, 1979). Some cockpits are elongated, reflecting structural influences or inheritance from abandoned surface drainage courses. The residual hills and ridges are notched by saddles and separated by corridors. Drainage is largely autogenic and northward, although there are some allogenic inputs on the southern periphery. Underground drainage emerges at springs, which support rivers draining to the north coast (DAY, 1985). Caves are numerous and are hydrologically active during wet seasons (FINCHAM, 1997).

The tropical wet climate varies both spatially and temporally. Rainfall increases from the periphery to the interior and also with higher elevation. May, September, and October account for 46% of the annual precipitation, which ranges between 1700 and 3800mm (BARKER & MILLER, 1995). Temperature and humidity vary too, with a wide array of microclimates, especially where the forest cover has been removed (BARKER & MILLER, 1995).

Most soils are thin and patchy except in depression bases, where they may be over 1m thick. Derived essentially from weathering of the limestone, they are mostly yellow or red brown clays, and some are bauxitic.

Undisturbed vegetation in the interior is classified as wet limestone forest, in which there is considerable topographic variability and floristic diversity (PROCTOR, 1986; KELLY *et al*., 1988) and BINNEY *et al*. (1991:68) emphasizes that "…no two hills are exactly alike in their vegetation." The Cockpit Country boasts the highest rate of West Indian plant endemism per unit area, and the karst is the only remaining refuge for many threatened species. There are at least 100 endemic plant species (PROCTOR, 1986) and more fern species, relative to the area, than in any other rain forest in the tropics (EYRE, 1995).

Threatened fauna also depend on the Cockpit Country karst for their survival. In addition to significant bat populations, several species of herpetofauna are restricted to the area, , including two species of Eleutherodactylus frogs (CROMBIE 1977, 1986) and one galliwasp (*Celestus fowleri*) (SCHWARTZ 1971). There is a distinctive and significant avifauna (FAIRBAIRN, 1986) including all but one of Jamaica's 28 endemic bird species (RAFFAELE *et al*., 1998). The Cockpit Country is the stronghold for many of the island's vulnerable species such as Black-billed Parrots (*Amazona agilis*) and Yellow-billed Parrots (*A. collaria*), the Jamaican boa (*Epicrates subflavus*), and the Giant Swallowtail butterfly (*Pterourus homerus*) (WINDSOR RESEARCH CENTRE, 2000).

Anthropogenic Influences

Its historical inaccessibility and lack of surface water has limited large-scale clearing and permanent dwellings within the Cockpit Country. Human alterations, however, are evident in an extensive trail system and clearing of cockpits for agriculture. In the 1700s, the Maroons used the area as a refuge and base for military campaigns against the British army. Treaties ending the Maroon Wars gave the Maroons a degree of autonomy, and resulted in permanent settlements such as Accompong, which are still Maroon strongholds. Relationships between the Jamaican government and the Maroons have not always been harmonious, and the Maroons maintain a recognized claim to much of the Cockpit Country (JAMAICAN CONSERVATION & DEVELOPMENT TRUST, 1994).

Colonial logging focused on hardwood species, principally mahogany and, in this context, the Cockpit Country was declared a forest reserve in 1950. Peripheral forests were cleared for sugar plantations and other agricultural endeavors, and there was a post-independence marginal settlement by people displaced by bauxite mining. The peripheral population currently numbers about 10,000, including the populations of Accompong, Maroon Town, Troy, Quickstep, and Windsor.

Contemporary Conservation Issues

The forested area of the Cockpit Country decreased by 15.9% between 1981 and 1987, a deforestation rate of 2.8% per annum leaving intact only 446km^2 of contiguous forest (EYRE, 1989). Small-scale agriculture is the primary contributor, with cockpits, glades and other accessible sites planted with yams, corn, dasheen, banana, plantain and sugar cane, and cattle and goats pastured locally (BARKER & MILLER, 1995).

Unauthorized logging occurs too, and saplings of certain species are in demand particularly to support yam vines (BARKER & MILLER, 1995; MILLER, 1998). Enforcement of the 1950 Forest Preservation Act is minimal (WCMC, 1992). Peripheral karstlands have been devastated by bauxite mining, and are heavily used for agriculture.

Improved accessibility via roads and trails poses a major threat to the integrity of the Cockpit Country (BARKER & MILLER, 1995), and this would be a serious adverse impact of the creation of a national park and the subsequent ingress of visitors. Not only does the creation of trails lead to increased soil erosion (WALLIN & HARDIN, 1996) and drying of microclimates, but it also facilitates the spread of non-native invasive species. Bauxite mining also remains a potential threat, particularly as reserves become exhausted elsewhere in the karst.

Karstland Conservation in Jamaica

By Caribbean standards, designation of karstlands in Jamaica as protected areas is negligible, with only 524km^2, seven percent of the total karst, so designated (KUENY & DAY, 1998; KUENY, 2000). The Montego Bay Marine Park was the first national park in Jamaica (1992) and, in 1997, six forest reserves, including 223km^2 of the Cockpit Country, were added to the WCMC list of protected areas, although these provide no real protection for the karst (EYRE, 1995; BARKER & MILLER, 1995; BARKER, 1998). Some karst is protected within the 780 km^2 Blue and John Crow National Mountains Park, although this is not included in the 1997 UN List of Protected Areas (WCMC, 1997).

The Cockpit Country has been under consideration for designation as a national park for more than 20 years (EYRE, 1990; SMITH, 1995), but declaration has been prevented by several difficulties. Conflicting land use potentials remain problematic, with future wholesale logging and bauxite mining not having been discounted. Differing tourism scenarios also exist, with various potentials for both income generation and environmental degradation. Economic considerations continue to receive undue emphasis, and agreement with the Maroons has not been reached.

In 1989, a Protected Areas Resource Conservation (PARC) project was instituted by the Jamaican government as a preliminary formal step towards establishing a national parks system in Jamaica (NRCA, 1995; SMITH, 1995). The Planning Institute of Jamaica is charged with operating the PARC, and the Jamaica Conservation Development Trust (JCDT), an NGO, operates the national parks under a delegation agreement with the Natural Resources Conservation Authority (NRCA), which oversees policy for the national parks (SMITH, 1995). Funding for PARC is through the US Agency for International Development, with technical assistance from the Nature Conservancy.

BirdLife Jamaica (BLJ) is working with local residents and overseas scientists to study the endemic Black-billed and Yellow-billed parrots in the Cockpit Country. Habitat loss and degradation are the greatest threats, followed by illegal collecting for the pet trade. In 2001, BLJ will be implementing an Important Bird Areas (IBA) Programme, in collaboration with international efforts lead by BirdLife International, to develop long-term monitoring projects in critical habitats such as the Cockpit Country.. The Windsor Research Centre is also involved in local conservation efforts (WRC, 2000) and the JCDT (with WRC) is investigating a conservation strategy for Windsor Great Cave.

In 1999, responding to mounting environmental pressures, the World Bank proposed a Cockpit Country Conservation Project (CCCP) in an effort to "…develop a sustainable funding strategy within the framework of the existing Jamaica National Parks Trust Fund to help finance long-term management of the Cockpit Country Protected Area" (WORLD BANK, 1999: 2). The project will address conservation issues through: (1) implementing resource management systems to conserve biodiversity, (2) improving forest management practices to improve forest quality and promote sustainable uses of forest resources, (3) improving land management practices in the buffer zone to prevent soil erosion and reduce river sediment levels, and (4) promoting sustainable use of resources by local residents.

The costs of the CCCP are estimated to be US$6million, to be funded by the World Bank, the Jamaican and foreign governments and participating NGOs. Community involvement at all levels is considered paramount, but the proposal provides no clear framework for the role of the local Maroon communities. The proposal remains under consideration.

EYRE (1995) contends that the Cockpit Country would be a strong candidate for designation as a UNESCO World Heritage Site, although he acknowledges that this would not be without difficulty. Problems include the following: (1) The current protected area status is inadequate, both in terms of demarcation and enforcement, (2) Natural resource inventories need yet to be completed, (3) National government commitment is unconfirmed, (4) Land tenure issues remain unresolved, in particular the claims of the Maroon community, (5) The role and impacts of tourism have yet to be adequately addressed.

Conclusion

Presently, conservation of the internationally recognized Cockpit Country karst is accomplished largely by virtue of inaccessibility and benign neglect, with the only official protective mechanism being the 1950 designation as a forest reserve. Enforcement of existing regulations is minimal and of limited efficacy. Economic and staffing restrictions are compounded by the lack of institutional commitment. At the same time, there are increasing pressures from diverse development interests.

There have been several well-intentioned proposals to change this situation through various legislative mechanisms, but these have not been implemented, nor is it certain that they ever will be. Moreover, it is unclear whether such recommendations are necessarily in the best interests of conservation and protection. Creation of a Cockpit Country National Park will not in itself promote more effective and ecologically sensitive management, although it would appear to be a necessary prerequisite to designation as an UNESCO World Heritage site. The Jamaican government needs to play a central and transparent role here, since nothing substantive can be accomplished without a clear affirmation of government commitment to environmental protection. The interests of other stakeholders, such as the Maroons, NGOs, residents and the various parish councils and commercial interests need to be addressed within the context of a consistent conservation vision.

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Proposta e Estudos para Implantação do Plano de Manejo Turístico da Caverna Torrinha. Iraquara-Ba

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Introdução

O Brasil é um país de muitos recursos naturais e com enorme potencial para todas as modalidades de turismo, porém, muitos de seus ecossistemas estão ameaçados. A prática de um ecoturismo irresponsável em nosso meio-ambiente poderá agravar esta situação.

Considerando que o ecoturismo é uma tendência em termos de turismo mundial que aponta para o uso sustentável de atrativos no meio ambiente e nas manifestações culturais, devemos ter em conta que somente teremos condições de sustentabilidade caso haja harmonia e equilíbrio no "diálogo" entre os seguintes fatores: resultado econômico, mínimos impactos ambientais e culturais, satisfação do ecoturista e da comunidade.

O mundo subterrâneo guarda ainda alguns dos últimos espaços intocados pelo homem em nosso planeta. Ano após ano novas cavernas são descobertas e exploradas e mesmo as já existentes nos proporcionam novas e belas descobertas abrindo ao turismo, esporte e as ciências um mundo novo para as pesquisas e novos conhecimentos.

No Brasil e em todo o resto do mundo, a consciência da preservação, desse patrimônio vem aumentando e novas orientações técnicas legais e educacionais tem sido criadas e utilizadas para esse fim, surgindo ai o "espeleoturismo", que apesar do planejamento as vezes inadequado e da infra-estrutura geralmente carente, vem surgindo como um importante e excelente meio de se divulgar a espeleologia e de se garantir a preservação do patrimônio espeleológico em geral. É sabido que o turismo em cavernas "orientado de forma apropriada e criteriosa", apresenta-se como uma das atividades econômicas mais promissoras para as regiões em que se inserem, gerando aumento na oferta de trabalho, dignidade e vitalizando as economias locais regionais, alem de auxiliar no desenvolvimento da indústria nacional.

Descrição Regional

A área de estudo está localizada na região da Chapada Diamantina, porção centro-norte do Estado da Bahia e abrange parte do Município de Iraquara.

O acesso a Iraquara, que dista cerca de 450km de Salvador, é feito pela BR-242, saindo de Salvador no sentido Brasília, até o entroncamento desta rodovia com a BR-330, no sul da área. Percorre-se 21Km a partir do entroncamento até a cidade de Iraquara.

A região de Iraquara possui atualmente um posicionamento de destaque no quadro espeleológico brasileiro. Nesta área merece destaque a existência de uma das maiores concentrações de cavernas do Brasil. Além de sua importância numérica e a inclusão de algumas dessas cavidades entre as maiores do nosso país, com vários quilômetros de desenvolvimento, o patrimônio da área se destaca igualmente pela riqueza geológica, biológica, arqueológica e paleontológica a ela associada.

A beleza dessas cavernas abre igualmente um grande potencial turístico para a região, que começa a ser explorado, ainda que de forma incipiente.

Todo esse patrimônio, todavia, está ameaçado pela falta de planejamento e controle da ocupação do solo, pela agricultura, pela urbanização e pelo turismo não organizado. Atualmente dentre todas as atividades econômicas, o turismo se constitui como a de maior potencial para o desenvolvimento sustentável de toda a região inserida na APA Marimbus/Iraquara, na Chapada Diamantina.

Aspectos Ambientais

"O crescente nível de informações e conscientização sobre a importância dos recursos naturais e do meio ambiente como fatores de produção, geração de amenidades e de equilíbrio ecológico, vem demonstrando a necessidade de um planejamento global de sua utilização, condição sem a qual nenhuma sociedade alcançará um padrão sustentável de desenvolvimento” (Carvalho.1994).

Dentro da Área de Proteção Ambiental, vários são os problemas que geram conflitos de interesse. Entre eles podemos citar alguns:

> -A utilização do fogo em muitas localidades com a finalidade de limpar áreas de cultivos agrícolas, tais como milho, feijão, cana de açúcar, palma, mandioca dentre outros.
>
> -Visitação de turistas em larga escala e muitas vezes sem critérios de preservação, incluindo-se aí as cavernas muitas vezes levando pedaços de estalactites como “lembranças”, ou ainda riscando seus nomes nas cavernas.
>
> -Desmatamento de áreas de ecossistemas naturais e utilização em larga escala pela população local, de lenha para combustível ou para dar lugar às atividades agrícolas, comprometendo a vegetação e,no caso da existência de grutas no subsolo,comprometendo a própria gruta.
>
> -Infra-estrutura urbana (sistema de esgotamento sanitário, abastecimento de água e coleta de lixo),muito deficiente ou inexistente.
>
> -Ausência de uma política preservacionista e fiscalização, principalmente com relação às belezas naturais da área: grutas e cavernas, cachoeiras e trilhas entre muitas outras que poderiam ser citadas.

Vimos que a batalha é difícil, porém não é impossível. É necessário adotar atitudes essencialmente positivas, no sentido de não se contrapor às alternativas de sobrevivência encontradas pelas suas populações,que precisam ser integradas em processos de desenvolvimento.

Potencial Turístico

A Chapada Diamantina tem um imenso potencial turístico e uma crescente necessidade de estruturar o ecoturismo em bases sólidas para que assim as gerações futuras possam desfrutar do que se tem atualmente na área. (STANNARD,1994), reforça a idéia e admite que o “ecoturismo é hoje um importante fator da economia da região, expondo a beleza natural da região, sua fauna e flora, isto tem gerado uma demanda muito grande de turistas pelos recursos naturais da região. Diz ainda que: “é impressionante o interesse da população local sobre a preservação dos recursos locais” .

O interesse da população em acompanhar o processo desse mercado econômico que é o turismo, já é um grande passo. Entretanto, é preciso esclarecê-la e alertá-la sobre uma grande variedade de questões ambientais que possam surgir. Uma forma de tornar isso viável é enriquecer os conhecimentos ambientais sobre a área, capacitar os professores da região com relação a proteção dos recursos naturais e assim, multiplicar o sentido da preservação do ambiente para a qualidade de vida da região. A APA Marimbus-Iraquara abriga um dos mais importantes acervos espeleológicos e arqueológicos do Brasil. Sua importância mundial vem sendo reconhecida, como comprova a sua inclusão na área da Reserva da Biosfera da Mata Atlântica declarada pela Unesco.

Importância Ambiental da Caverna Alvo

O conjunto da caverna está construído segundo duas direções de fraturas, N-S e L-O. Ele desenvolve-se sobre dois níveis horizontais superpostos a menos de uma centena de metros abaixo da superfície do planalto.

A morfologia das galerias e a configuração da ramificação implicam em uma formação e um funcionamento em regime freático. A importância do aterro e a ausência de vestígios de escoamento livre confirmam essa hipótese e ressaltam a lentidão das circulações. Ficamos sobretudo impressionados pela grandiosidade das salas e pela amplitude dos desmoronamentos que nelas ocorreram. Os vãos das abóbadas atingem, às vezes, uma centena de metros e a evolução no sentido de um perfil de equilíbrio foi favorecida pela falta de coerência da rocha encaixada. O material caído permaneceu em sua posição. A ramificação é inteiramente fóssil. É a tradução de fases climáticas muito mais úmidas. Alguns afloramentos d’água nos pontos baixos da caverna assinalam o nível atual do lençol freático. A alternância dos períodos secos e úmidos é posta em evidência pela presença, dentro do aterro, de leitos de depósitos que mostram em sua face superior fendas de retenção características dos períodos secos. A multidão de cristalizações e formas de concreção, muitas vezes raras, dão à caverna da Torrinha um caráter excepcional que conviria proteger.

Viabilidade Turística da Caverna

Na década de 1980 é que surgiram os primeiros espeleólogos e grupos interessados em pesquisas mais detalhadas. Conhecia-se então 600 metros de caverna. Já na década de 1990, o Grupo espeleológico Francês "Meandres", descobriu por entre os blocos abatidos, nova galeria, dando novas opções de descoberta. Com isso mapeando na época 8.300 metros, posicionando a Caverna Torrinha como uma das maiores cavernas do Brasil.Vale ressaltar que desde criança o Sr. Eduardo (morador,zelador e guia), reside no local e mantém a caverna em perfeito estado de conservação.Acompanhou a maioria dos grupos espeleológicos que por ali apareceu e passou a adquirir seus conhecimentos espeleológicos. No início do ano de 1997, sentiu-se obrigado a criar roteiros turísticos a fim de manter-se com a família no local e arrumar um modo de subsistência. Colocou parentes seus como guias para acompanhar as pessoas que por ali apareciam para conhecer o local e passou a explorar turisticamente a caverna. O trabalho realizado pelo Sr. Eduardo, apesar de pouca orientação, é excelente conforme vários relatos encontrados em diversos trabalhos já realizados na área. (Relatório Sr. Clayton Lino, para o Prodetur-Ba, para implantação do manejo da APA) (Revista da UPE-União Paulista de Espeleologia), (Reportagem Revista da Folha de São Paulo), (Revista Gulliver-Italiana).

Com o advento do Ecoturismo e o grande fluxo de turistas a região da Chapada Diamantina na Bahia o fluxo turístico da caverna também aumentou e a tendência a procura por novos paraísos espeleológicos vem aumentando a cada dia. Nossas pesquisas mostraram não existir nenhum trabalho referente a manejo turístico na área, apesar de haver vários trabalhos realizados na área inclusive na caverna Torrinha. Surgiu daí a necessidade básica de levantamentos de dados de controle de visitação entre outros. Tais parâmetros estão mostrando um aumento significativo de visitantes o que justifica por si só a realização deste trabalho.

O local denominado Baixa Funda da Torrinha apresenta outras opções de recreação aos seus visitantes desde que haja um planejamento adequado as condições do local; podemos citar trilhas interpretativas como a "Pedra da Torrinha", passando por mata nativa, margeando o paredão até ao sopé da rocha onde se observa algumas pinturas rupestres e intenciona-se implantarmos uma via de escalada, surgindo ai mais uma opção de lazer entre outros. As possibilidades de novas opções de lazer no local abrangem várias categorias de idades desde os mais jovens com espírito aventureiro como os mais velhos que buscam tranqüilidade e momentos de descontração e contemplação.

No que se refere à infra-estrutura social, os pontos mais críticos observados residem no precário serviço de saneamento básico destas populações; não possuem abastecimento de água com canalização interna,precárias instalações sanitárias e não tem o lixo coletado. A água que abastece o povoado é retirada da caverna por meio de bomba movida a motor diesel. A rede elétrica está a cerca de 300 metros da casa e até então não atendia aos moradores. Agora recentemente, depois de muito esforço, junto as autoridades municipais a energia elétrica estará sendo instalada no povoado, melhorando assim em muito a vida das populações locais trazendo um novo alento àqueles moradores. Para um aproveitamento turístico da caverna Torrinha é fundamental um planejamento detalhado, um rígido estudo e controle de capacidade de carga, e a melhoria de alguns acessos externos próximos à entrada. As pequenas casas centenárias existentes e o cemitério antigo existente no povoado merecem proteção e restauração.

A Chapada Diamantina, como um todo, apresenta graves problemas sócio-econômicos. A exclusão social é crítica, sendo relativamente grande o numero de famílias que padecem de pobreza e indigência.

A expressividade das considerações levantadas não pode ser desconsiderada na implementação do Plano de Manejo da caverna. O grande desafio do projeto está, portanto em, ao mesmo tempo proteger o Patrimônio espeleológico e promover a melhoria na qualidade de vida dessas pessoas. Certamente o turismo em cavernas pode ser um desses caminhos de desenvolvimento sustentável.

Objetivos e Considerações do Manejo

Objetivo Geral

Implantar o manejo adequado na caverna Torrinha e seu entorno, de forma a viabilizar a compatibilização da conservação dos recursos naturais com atividades de Lazer, Pesquisas e Ecoturismo.

Objetivos Específicos

Definir as bases para o Manejo da caverna e seu entorno.

Elaborar a implantação de Infra-estrutura – turística adequada, conforme definido no manejo.

Adaptar a infra estrutura de apoio interno (fitas reflexivas para demarcação de proximidade, escadas de madeira, corrimão entre outras), conforme definido no plano de manejo.

Edificar obras de apoio externo (centro administrativo, almoxarifado dos guias, centro de apoio espeleológico com biblioteca, videoteca entre outras, trilhas interpretativas com identificação das espécies nativas da região, educação ambiental (projeto que poderá ser entendido a toda a população da região), reflorestamento de toda a área de entorno da caverna (mudas das espécies nativas da região que serão fornecidas pelo viveiro mantido pela Prefeitura Municipal de Iraquara).

Restauração da moradia do administrador da caverna (já realizada) e cemitério centenário existente no caminho de acesso a recepção da caverna.

Realização de cursos de formação de guias locais em espeleologia e educação ambiental com os moradores locais.

Elaboração de material de divulgação turística sobre a caverna Torrinha.

Elaboração de material técnico de apoio espeleológico para formação dos guias da caverna Torrinha.

Capacidade de Suporte – Estudos

Visitação Anterior

Era feita sem controle algum. Não se sabia a quantidade de pessoas que visitavam a caverna. Não havia controle dos roteiros visitados, nem do numero de visitantes que adentravam a caverna num mesmo grupo, porém a visitação sempre foi monitorada pelos guias do local.

Visitação Atual

Atualmente a caverna é visitada preferencialmente nos finais de semana e feriados.No ano de 1999, passaram pela Torrinha, cerca de 2.300 pessoas que deixaram seus registros em nossos livros.

A partir do inicio dos trabalhos referentes a levantamento de dados para subsídio dos mesmos, a visitação passou a ser ordenada por roteiros/numero de pessoas do grupo, o que determina a quantidade de guias a acompanhá-los.

Atualmente, para acompanhamento de um grupo de 10 pessoas/01 guia. Em caso de maior numero de pessoas a visitar o roteiro 01, o grupo será desmembrado em 02 grupos e deslocado mais 01 guia para acompanhamento, com intervalo de 15 minutos para o acesso do segundo grupo.

Para o 2'roteiro, o numero de pessoas do grupo não deverá ser maior que 08 pessoas e terá o acompanhamento de 01 guia, com intervalo de 15 minutos para o acesso do segundo grupo.

Para o 3'roteiro, o numero de pessoas do grupo não deverá ultrapassar o numero de 05 pessoas e terá o acompanhamento de 01 guia,com intervalo de 15 minutos para o acesso do segundo grupo.

Passou a ser estabelecido horários de visitação a caverna para melhor organização dos grupos. O horário de visitação estabelecido para visitas compreende das 09:00/17:00hs.

Metodologia dos Trabalhos para Estudo do Suporte

Iniciamos na Segunda quinzena do mês de Novembro/98, o controle de visitação turística através da implantação de um livro de controle com dados básicos de informações. Como os roteiros de visitação já estavam definidos com base em segurança do turista/espeleotemas, instalamos termômetros em vários pontos dos roteiros turísticos, bem como também 01 aparelho termohigrógrafo para monitoração e medição de umidade relativa do ar e temperatura no salão branco, local de maior procura para visitação. Os dados coletados mostram que não houve alterações nos locais visitados. Instalamos fitas reflexivas nas áreas de maior proximidade e vulnerabilidade dos espeleotemas isolando-os e protegendo-os de qualquer vandalismo. Cabe ai ressaltar que desde o início de visitação da caverna, o Sr. Eduardo e/ou seus guias vem acompanhando os grupos conduzindo-os pela já bem demarcada trilha interna evitando assim maiores impactos laterais, mesmo nos grandes salões onde poderia haver maior dispersão das pessoas. Não foram localizados estudos que definam a capacidade de carga para a caverna. Observações práticas de guias na caverna Torrinha indicam a dificuldade de trabalhar com grupos maiores de 10 pessoas. Uma vez existindo 10 guias para acompanhamento dos turistas,possibilita-se a visitação de até 100 pessoas/dia,considerando-se o tempo médio dos roteiros. O numero máximo de 100 visitantes por dia foi definido apenas na logística da visitação, não tendo sido ainda definido a capacidade de suporte de visitação com base em parâmetros físico-químicos e biológicos. Podemos afirmar que a iluminação é entre todas as interferências da abertura de uma caverna ao turismo, aquela que causa o maior e mais diversificado impacto no ambiente cavernícola, estes poderão ser os mais variados: estéticos/climáticos entre outros. Por essas e outras razões a escolha de um sistema de iluminação turística requer conhecimentos científicos da caverna inexistentes até o momento no local mas que poderá vir num futuro ser estudado mais profundamente.

Avaliação do Impacto Ambiental da Visitação Turística

Tendo como exemplo a semana de 26/12/99 a 02/01/2000, onde a visitação foi intensificada na Chapada Diamantina, devido a grande quantidade de turistas que passaram as festividades de final de ano,cerca de 48 pessoas visitaram a caverna Torrinha no período que compreendia entre 09:00/17:00hs, e que permaneceram cerca de 3:30hs em média no interior da caverna.Nestes dias não foram notadas variações na temperatura interna da caverna bem como na umidade relativa do ar registradas em gráfico,permanecendo respectivamente entre 23'C e 90,9% rH. A temperatura externa a caverna variou entre 22 e 26,4'C. A umidade permaneceu constante e igual a 90,9%rH no salão branco onde encontrava-se instalado o aparelho termohigrógrafo e as temperaturas também não se alteraram nas várias bases onde estavam instalados os termômetros individuais.

Devido à variação natural relativamente grande da temperatura e umidade na caverna Torrinha a identificação da influência da visitação na mudança da T e H é dificultada, ainda mais devido ao fato do horário da visitação coincidir com o horário em que naturalmente a atmosfera da caverna sofre aumento da temperatura devido ao aumento da temperatura externa. Mesmo se considerarmos que se houvesse qualquer variação mesmo que mínima na temperatura interna da caverna e que essa tenha sido resultante do calor das pessoas que visitaram a caverna,este aumento seria pouco impactante frente às variações pela qual a caverna sofre ao longo do ano.

Os dados obtidos, apesar de serem ainda preliminares, corroboram a hipótese de que, devido às dimensões da caverna Torrinha sua abertura principal de grandes dimensões e suas duas outras entradas (que recomendamos, sejam excluídas de qualquer outra tentativa de acesso devido ao grande risco de desabamento de grandes blocos que estão a bloquear suas entradas) é uma caverna com grande troca de energia com o ambiente externo. Portanto na caverna Torrinha, o impacto da visitação sobre a mudança da temperatura e umidade da atmosfera pode ser considerado quase que nulo mesmo que a visitação diária seja de 100 pessoas. A visitação pode estar influenciando no aumento do teor de gás carbônico e contribuindo com a introdução de novas espécies de fungos e bactérias, parâmetros estes que também deverão ser analisados assim que conseguirmos a parceria com a empresa que cedeu o aparelho termohigrógrafo e que agora recentemente disponibilizou mais 02 aparelhos que auxiliarão a estender a outras áreas da caverna. Provavelmente, o impacto seja mais acentuado sobre a fauna que utiliza a gruta como abrigo (morcego, pássaros).

Provavelmente, o monitoramento do teor do gás carbônico no interior da caverna também não mostrará que a visitação provoque mudanças consideráveis. Esta hipótese tem como base a dimensão de seus condutos, galerias, salões e a grande abertura da caverna, aliado à presença de vegetação e solo na entrada da mesma, além de matéria orgânica que é carreada para seu interior.

Se a visitação a caverna Torrinha atingisse o numero máximo de visitantes em todos os dias, no total de um ano seria visitada por 36.000 pessoas. Analisando os quadros de visitação, nota-se que a visitação vem ocorrendo em números muito inferiores à metade do que seria permitido.

O problema observado é que a freqüência da visitação é muito irregular e concentrada em determinados períodos, como em feriados e nos meses de férias escolares. Nossa proposta é que para que seja testada e discutida, que o número máximo de visitantes por dia seja definido com base na logística de visitação da caverna pelo atual caminhamento, ou seja, o número deverá ser definido com base na capacidade máxima de pessoas transitando pelo caminhamento sem congestionamentos internos.

Uma possível solução para os dias de maior demanda de visitação seria colocar pessoal de apoio aos grupos de visitação. Este pessoal de apoio daria melhor orientação aos visitantes e serviria para acompanhar o visitante que resolve retornar a parte externa ou ficar parado em um determinado ponto.

Deveremos levar em consideração que poderemos estar contribuindo para a nova formação de guias para o local e região.

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Planejamento e a Prática do Turismo em Cavernas

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Abstract

This paper discusses the strategies adopted for the implementation of Agenda 21 and focuses on caves as ecosystems, with focuses on tourism and its relationship with the environment, showing the consequences of speleotourism and how caves have been used, managed and materials utilized. The proposal consists in identifies and explains the terminology of the different kinds of plans of management which exist. It argues in favor of a plan for speleological management and presents the objectives for the execution of such a plan, as well as suggesting procedures for its implementation, with focuses on the requirements for the establishment of the visitation capacity of each cave and discusses the impact of the basic infrastructure required on this capacity. The proposal consists too proposes guidelines for the elaboration of Speloelogical Management plans. This study aims to facilitate the evaluation of procedures and criteria utilized in speleological management, with an emphasis on execution, management and monitoring. It presents specific examples of the touristic use of caves, identifying harmful practices and suggesting more adequate procedures. It also suggests alternatives to avoid the impact of pollution, whether thermal, visual (either internal and external), chemical, and biological, as well as outlining the steps and procedures necessary for the establishment of speleological visitation capacity with reference to the guidelines proposed for the elaboration of plans for spelological management.

Introdução

Espeleologia é a ciência que tem por principal finalidade procurar, explorar, observar e interpretar as cavernas, tendo como critério de análise o conhecimento de seu processo de formação, o meio que se insere e o ambiente propriamente dito. Proveniente da expressão grega “spelaion” (cavernas) e “logos” (estudo), a espeleologia objetiva o uso sustentável do ambiente cavernícola através de mecanismos que efetivamente contribuam para a conservação das mesmas.

Segundo (Géze; 1968 apud Lino; 1989), surgiram inúmeras definições sobre espeleologia mais aprimoradas. O autor cita que uma das mais abrangentes e sintéticas definições, a qual ganhou grande aceitação internacional resume-se no aspecto de ser "a disciplina consagrada ao estudo das cavernas, sua gênese e evolução, do meio físico que elas representam, de seu povoamento biológico atual ou passado, bem como dos meios ou técnicas que são próprias ao seu estudo."

Entretanto, o ato de explorar cavernas vem de muito tempo atras. Desde o século XIX, muitas das cavidades naturais subterrâneas existentes no Brasil, receberam empenho de inúmeros europeus, viajantes que aqui estiveram, especialistas em história natural, para reconhecerem na importância do vasto e rico patrimônio espeleológico do território brasileiro, o motivo ideal para realizarem suas expedições.

O marco para a espeleologia brasileira veio por intermédio de dois pesquisadores - os naturalistas PETER W. LUND e RICARDO KRONE. Através das inúmeras e inéditas pesquisas desenvolvidas nas cavernas de Lagoa Santa/MG e Iporanga/SP, os mesmos foram paulatinamente sendo reconhecidos com destaque por autoridades no assunto pelas gerações atuais de cientistas espeleólogos, em função de serem os precursores da espeleologia nacional.

Lund (1871) realizou a primeira referência sobre caverna no Brasil, referindo-se a Lapa Nova do Maquiné, hoje a Gruta de Maquiné - Cordisburgo - Estado de Minas Gerais, que encaminhando um testamento enfocou: "*Recomendo à alta proteção do ilustrado Governo a mencionada Lapa que no estado virgem em que se achou a sua parte pitoresca na ocasião de sua visita (1834) era talvez sem rival no continente americano* ✍".

✍ Trecho do testamento de Peter Lund, escrito em 21 de Junho de 1871 a corte de Governo.

Meio abiótico - externo

Toda caverna esta inserida dentro de uma extensão de terreno cuja área esta obrigatoriamente relacionada com os recursos bióticos e abióticos, superficiais e subterrâneos deste específico ecossistema, conhecido como carste. Nenhuma caverna esta isolada. O meio abiótico em volta da ocorrência espeleológica, reuni todos os recursos essenciais para o equilíbrio do ambiente e "colabora" com a proteção da integridade física de um determinado espaço rochoso. O planejamento do turismo deve considerar tal premissa, sob o risco da multiplicação de nocivos ambientais sem proporções, uma vez que uma cavidade natural subterrânea provavelmente estará numa interconexão que permita a drenagem numa movimentação do volume de águas superficiais e de subsolo, de forma a não ser possível reverter o dano causado pela atividade turística. O planejador deve conhecer bem o funcionamento do carste, e das peculiaridades existentes visando atender as demandas ambientais existentes e que permitam o uso turístico deste tipo de ambiente.

Infra-estrutura externa

Atualmente todas as cavernas implantas para o turismo possuem um conjunto de infra-estruturas, os quais servem para atender os serviços turísticos necessários. Tais infra-estruturas são constituídas de rodoviária, aeroporto, estradas, posteamento, energia elétrica, hotel, estacionamento, restaurante, banheiros, ambulatório, centro de visitantes, lojas de souvenirs, livrarias, bilheterias, etc, todos habitualmente implantadas sobre o carste, o que é desaconselhavel e inadequado.

Infra-estrutura interna

Dependendo da categoria e da modalidade do turismo, normalmente as cavernas preparadas dentro desta finalidade, são dotadas de infra-estruturas internas, umas mais outras menos, mas sempre atribuídas da instalação de alguns materiais do tipo, ferro, alvenaria, madeira, acrílico, fios, lâmpadas, reatores, cabos, etc, visando preparação, aplicação e montagem do sistema de iluminação, portão, grade, passarelas, elevadores, pontes, corrimão, escadas, lixeiras e anteparos de proteção, os quais são barbaramente visíveis, chegando em muitos casos a dificultar a observação das formações espeleológicas. O extremismo de tal situação deve ser evitado a todo custo, sob o risco de ser necessário refazer uma obra qualquer de infra-estrutura interna.

Diversas experiências nos tem mostrado que a melhor maneira de implantar algum tipo de infra-estrutura interna como p.ex. escadas, é identificar e aproveitar os materiais existentes no local para a construção desses equipamentos, de forma que os elementos básicos estejam integrados ao meio, evitando que madeira, pedras, tijolos e outros materiais sejam agregados de fora à caverna, para novas construções de alvenaria ou similares. Além de esteticamente desagradável, torna-se mais uma razão para descaracterizar o ambiente com a obra e com o impacto diante do trânsito de pessoas, agravando ainda mais o seu aquecimento interno.

Infra-estrutura interna de sinalização

A informação dentro de uma caverna visa instruir os visitantes sobre as características principais do ambiente do tipo, extensão, peculiaridades do ambiente, tipos de espeleotemas, processo de formação, ensinando e procurando sensibilizar sobre a importância e necessidade de preservação.

Teoricamente esta informação visa reduzir o grau de incertezas, sobre o estado daquele meio que esta sendo visitado, que por intermédio de mensagens estampadas em placas, plantas, etc., oferecem um sentido educativo, lógico e agradável à visitação. A informação deve obrigatoriamente proporcionar segurança ao visitante, evitando que sua ausência resulte em inquietação ou maiores sobressaltos ao grupo.

A linguagem de uma placa deve ser direta, objetiva, explicativa, clara, para no mínimo ser entendida por alunos de 4ª série, com palavras chaves grifadas e explicadas. Seu conteúdo deve ser o mínimo possível. Implantada mais próximo ao chão, evitando seu posicionamento no sentido vertical que poderia prejudicar a visibilidade de um espeleotema, ou de uma pintura rupestre. Sua composição deve ser constituída de material para uso prolongado - tipo resistente à umidade - ex: acrílico, plástico durável, seguindo a uma padronização de símbolos, cor e textos.

As características e as condições para turismo em cavernas

A maioria dos problemas surgidos em função da má utilização e das ações antrópicas incompatíveis, são originados pela prática de visitas freqüentes sem limites de tempo e pessoas, razão pela qual justifica-se realizar os estudos para elaboração do Plano de Manejo Espeleológico.

A importância para preservação e conservação das cavernas, sítios espeleológicas e suas respectivas áreas de influências, refletem na necessidade de haver a consciência sobre em que aspectos e condições estes ambientes sofrerão intervenção.

Partindo do princípio que o ecossistema das cavernas encontra-se em equilíbrio, com temperatura e umidade constante, com a fauna espeleológica adaptada ao meio ambiente cavernícola e portanto preservada, é evidente que qualquer alteração significativa poderá quebrar o equilíbrio estabelecido, se não forem observadas medidas mitigadoras para a manutenção das relações ecológicas.

Muitas das cavernas turísticas no Brasil e no mundo foram adaptadas em função da realidade estabelecida de acesso e uso. Essas adaptações ocorreram em desrespeito ao ambiente cavernícola, ou em desacordo com a legislação vigente.

O turismo espeleológico mau planejado ou descontrolado, torna-se perigoso ao usuário visitante e de gravidade considerável ao ecossistema. Pensar em manejar uma área turística, é antes de tudo levantar e considerar a capacidade do recurso suportável e aceitável pelo ambiente. Diversas pesquisas demonstram que existem sérios problemas diante da inexistência de dados sobre a capacidade de suporte e como implementar ações protetoras formais baseado em tal avaliação.

Em outras instâncias, o problema pode ser a inabilidade do gerente para resistir às pressões políticas em favor da permissão da visitação excessiva, com o argumento de auferir ganhos diante arrecadação de ingressos vendidos.

As pessoas que residem próximas a caverna, possuem uma relação de intimidade e afetividade com estes atrativos naturais. O fato de manterem contato diário, nasceram, e conviverem diariamente com o ambiente de caverna, constitui-se um fato de extrema importância a ser considerado. Deve-se ter a idéia de fazer a comunidade ser participada e sentir envolvida com a preservação da mesma. Este procedimentos poderá ser mais vantajoso ao invés de se manter espeleólogos e vigias de forma constante em fiscalização diária. O que não impede ou não seja necessário que este procedimento seja atendido devido a fatores justificados.

As usuais e conhecidas formas tradicionais de lucro, voltadas ao benefício de uma pequena parte em detrimento ao prejuízo ou a pouca atenção às necessidades da grande maioria devem ser abandonadas. O treinamento de guias, venda de produtos artezanais, bem como a promoção de serviços e produtos necessários a prática do turismo sustentável (ecoturismo espeleológico), são alguns dos exemplos possíveis de serem previstos no Plano de Manejo Espeleológico.

A abrangência do Plano de Manejo Espeleológico procurará explicitar os procedimentos, métodos e desígnios do relacionamento entre preservação da caverna-alvo e o acesso e uso pretendido.

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Inventory of Important Karst Geological Monuments as Part of the Census of Geosites Deserving Protection in the Region of Abruzzo

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Abstract

The Region of Abruzzo has often recognized, in its planning reports, the importance of karst areas and caves, and a specific Regional Law concerning speleology has been in effect since 1972. Nevertheless, effective and direct environmental protection of the karst areas and caves must be still achieved. A first concrete attempt to protect a cave, and its external environmental context, was made by means of Regional Law no. 32, which established the Regional Natural Reserve of the Pietrasecca Caves. A new opportunity is offered by the Census of Geological Monuments (Geosites) requested by the Region of Abruzzo. Within this context, all the natural cavities worthy of interest (morphological, hydrological, archaeological) will be censused, by means of a special form to be illustrated in this contribution. On the basis of this survey, a global legislative decree will subsequently be issued that will provide for their integral and specific protection.

1.0 - Introduction

In the legislative decrees establishing the National Parks, Regional Reserves and many of the protected areas of Italy, particular emphasis has always been placed on the biological importance that motivated their creation. Thus the lists of "environmental elements" of the territories included mostly animal or plant species while there was little or nothing about the geomorphological aspect or the elements contained in it. Moreover, it was generally considered merely as a landscape containing the ecosystem to be protected.

However, this attitude has rapidly and radically changed in recent times. For example, in Italy, particular attention has also been given to the morphological context even in mainly biological censuses (Bioitaly, Sites of Community Interest). Following indications of the IUCN, increasing attention has been devoted to "environmental elements of morphological interest", a phrase later summarized by the term "geosites", at both the international and national level[10]. In this regard, a number of censuses have already been conducted: Geomorphological outcrops of the Marche Region (Nanni, 1991); Lazio Region (Casto & Zarlenga, 1992, 1996, 1997); Province of Cagliari (Barca & Di Gregorio, 1999); Province of Modena (Panizza et Al., 1999).

2.0 - Abruzzo Region Geosites Inventory

In the past, the Region of Abruzzo has issued decrees of environmental protection (in fact it is the Italian Region with the largest extension of protected areas) and has performed censuses of its biological and monumental patrimony. It also established the Cadastre of Natural Caves (the second region in Italy to do so) and has subdivided mountain areas with carbonate outcrops into Karst Morphology Units. Now it has also instituted the Abruzzo Region Geosites Inventory[11]. Previous international and national experience, including completed censuses, proposed forms for censusing and discussions of the elements to consider, has been analyzed in order to formulate a model-form for the census of geological monuments of Abruzzo. This census has led to the identification and classification of more than 250 sites of varying interest, morphology and extension.

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[10] For the specific reference bibliography: AA.VV, 1999. Geositi Testimoni del Tempo. Regione Emilia Romagna, 258 p.

[11] The census was performed by Ezio Burri, Raniero Massoli-Novelli and Marco Petitta, Department of Environmental Sciences, University of L'Aquila, with the collaboration of the Italian Speleological Society and the Abruzzo Speleology Federation.

2.1 - The model-form used for Abruzzo

As mentioned, the form[12] is based on national and international analyses of relevant material. Moreover, similar experience in the biological sector was taken into account (Bioitaly, Nature 2000, etc.), as well as the experience of the Abruzzo Region in the conservation and protection of the territory and its cultural and environmental patrimony (Propedeutic Analysis for the Regional Land Plan). The inclusion of some items and information were agreed upon with the offices of regional planning, so as to render the model-form not only consistent with previous inventories but also with the types of recording of environmentally important sites conducted by the Abruzzo Region in the past.

The form has 4 sections, marked A, B, C, D:

Section A contains the data identifying the geosite, i.e. that characterize the locality and magnitude of the geological monument.

Section B concerns the geological data justifying inclusion in the census, including information about the conservation status and risk of deterioration. A numerical value summarizes the degree of importance of the geosite.

Section C refers to the supporting data, i.e. information about relationships with other environmental-cultural contexts, protected areas and territorial jurisdictions, as well as proposals for the protection and public use of the site, as a guide to future interventions in the territory.

Section D includes the appendices, i.e. the bibliography, maps, geological scheme and photographic documentation; the maps are considered essential, while the other appendices are strongly recommended.

Section A: identifying data.

The geosite is identified mainly by a code (A1), represented by the monogram of the province in which it is located, a progressive three-figure number and the monogram of the geological typology.

Supplementary information is given by the class of importance (A1.1), a code that separates all the censused geosites into large groups of increasing importance.

The name of the geosite (A2) is expressed by a generally known place name (e.g. based on the topography) which allows immediate recognition of the area and the type of geosite (e.g. Sorgenti del Vera, Grotta del Cervo, etc.).

The A3 codes identify the province, municipality (with relative code) and the locality where the geosite is situated.

The subsequent information (A4) concerns the exact location, with an indication of the IGM table (more than one if the geosite extends over a broad territory), the latitude and longitude (reported at the center of the geosite if it extends over a broad area), the altitude (with an indication of the maximum and minimum values in the case of an extensive geosite) and the size (in m^2 or even km^2) or length (in m or km) if it is a linear element (e.g. a fault or a river).

A last observation concerns the possible continuation of the geosite outside the region (A5).

Section B: geological data.

This is the most important section, since it contains the elements that justify inclusion in the catalog.

First, the category of the site (B1) is indicated by a reference monogram, according to the type of geological monument (geomorphological, geological, mineralogical-petrographic, hydrogeological or hydrological, paleontological, pedological), and the subtype (B1.1) is specified according to the phenomenon involved (e.g. the geomorphological type includes erosion phenomena, canyons, karst, glacial morphologies and landslides).

Next, the lithology of the rock associated with the geosite is indicated, along with its stratigraphic age (B2).

The following information (B3) identifies the type of geological interest of the area, i.e. it briefly illustrates the reasons why the area is considered a geosite. Among the numerous types of interest described in the literature, seven items were selected, covering all facets of the geosite: its representativeness, scientific value, rarity, landscape, educational value, public usability, possible economic value. The presence of any of these items is recorded.

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[12] The model-forms is reproduced as enclosed document.

The geological situation is described in detail in the subsequent field (B4), concerning the description of the geological characteristics of the site.

However, the single geosite could be directly related to another geosite; this possibility is indicated in field B5, with a list of the related geosites.

Field B6 expresses a qualitative judgment about the current conservation status of the geosite.

A similar judgment is given for the risk of deterioration of the site (field B7), with a description of the possible type of risk (B7.1).

Next there is a semiquantitative judgment (expressed in terms of weighting) of the geological data in the preceding fields. This allows one to summarize (by means of a number) the judgment of the importance of the geosite in the regional context, albeit not in a totally objective manner since the weight assigned to the single elements could vary according to the operator.

Section C: supporting data.

This section includes some supplementary information about the site. It reports on the degree of knowledge about the site (C1), the presence of other possible geological interests (C2), but especially non-geological interests (C3), distinguishing between historical-cultural, architectural-archeological, vegetational and faunal values.

Field C4 expresses the possible relationship with other nature conservation programs, obviously based on the presence of non-geological values.

It also indicates if the site is already within a protected area (C5) and, if so, which agency manages it (C5.1), as well as the possible presence of territorial jurisdiction (C6). If not, it provides a judgment about the need to establish specific protection of the site (C7), along with indications of the proposal for its protection (C8) and its use by the public (C9).

The last field is reserved for various annotations that might be made (C10).

Section D: appendices.

The following types of auxiliary documentation should appended to the form: bibliography (D1), including bibliographical references concerning the site, with mainly geological information; a topographical map (scale 1/25,000) (D2), which is essential for identification of the site; a geological reference scheme (D3), both a map and profile, to better illustrate the geological characteristics of the site, where this is considered useful and possible; photographic documentation (D4), specifying the type of material (prints, slides, files).

3.0 - Census of the geosites and environmental protection of caves and karst areas

In Abruzzo, more than one-third of the territory is composed of lithological outcrops with karst morphology. Thus about half the geosites that have been identified and censused are constituted by karst-related typologies: caves, dolines, polje and springs. A high percentage of these geosites are located in protected areas; indeed, as mentioned previously, much of the territory of Abruzzo is under protection in the form of National and Regional Natural Parks, Regional Nature Reserves, and Regional Protected Areas. Therefore, there is no risk of their deterioration, although their identification will reinforce any type of protection and will control their use. The other sites will be protected by specific legislation which, in the case of caves, pertains only to the entrance area. Under Italian law, this allows for protection of the entire cave environment without significantly increasing the “quota” of protected territory, which by law cannot exceed a certain percentage of the regional territory. As mentioned above, in Abruzzo this percentage has reached its upper limit[13].

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A Espeleologia como Instrumento de Educação Ambiental: Parceria Escotismo X IBAMA/CECAV-GO, Um Estudo de Caso

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Abstract

This paper reports the results from the activities which were carried out by IBAMA/CECAV-GO, working in partnership with the 8th Rudyard Kipling Scouting Group, which is associated to the Brazilian Scout Union. This work proves that the partnership between official environmental institutions and other organisations that make use of cave's environments in their work programs, can be of great profit to both partners.

Introdução

O Escotismo é um Movimento Educativo, fundado na Inglaterra em 1907 estando difundido em praticamente todo o mundo. Trabalhando com jovens na faixa etária de sete a vinte e um anos, tem como objetivo "contribuir para que os jovens assumam seu próprio desenvolvimento, especialmente do caráter, ajudando-os a realizar suas plenas potencialidades físicas, intelectuais, sociais , afetivas e espirituais, como cidadãos responsáveis, participantes e úteis em suas comunidades" (POR 2000).

Para atingir os objetivos propostos o Método Escoteiro, entre outros pontos, enfatiza uma vida ao ar livre em contato com a natureza. Desta forma, seu Programa encontra-se repleto de atividades junto à natureza tais como, "camping", "trecking", montanhismo, rapel, e mesmo a espeleologia.(BSA, 1987; UEB,2000 ; UEB,1998, UEB,1998).

Embora atualmente muito se fale em educação ambiental, grande parte das ações propostas neste campo limitam-se apenas a colocar o cidadão em contato com natureza, em geral em áreas protegidas. O conceito de educação ambiental envolve uma postura bem mais complexa do que simples visitas monitoradas aos ambientes naturais. "Ele envolve a formação do indivíduo: seu caráter, cidadania, comportamento na sociedade, respeito aos direitos e deveres de cada pessoa, respeito ao ambiente e respeito a vida (AYUB,S.1997), o que torna o escotismo, face aos objetivos anteriormente citados, um parceiro em potencial das atividades ligadas à educação ambiental promovidas pelas instituições governamentais incumbidas da defesa do patrimônio espeleológico nacional. Por outro lado, o ambiente natural subterrâneo por propiciar aos envolvidos o contato com um ambiente desconhecido, com situações adversas a serem vencidas e toda uma aura de mistério onde audição e tato falam mais alto que a visão, o elevam a categoria de local ideal para desenvolvimento de valores básicos relativos à formação da personalidade como a paciência , o espírito de aventura, a solidariedade, e principalmente o respeito aos demais membros do grupo (AYUB 1997). Por reunir exatamente a situação ideal para a prática do escotismo diversas associações ligadas à Região Escoteira de Goiás já vem se utilizando destes ambientes para a prática de seus propósitos, mesmo que sem um acompanhamento de profissionais da área.

Parceria Institucional

Em 1996, travou-se um primeiro contato entre a base do IBAMA/CECAV em Goiás e o Grupo Escoteiro Rudyard Kipling 8º GO, que embora sem acompanhamento técnico, já realizava esporadicamente expedições em cavernas. Num primeiro momento foi efetuada a revisão e atualização da "Especialidade de Espeleologista" [14].

Como resultado foram propostas doze tarefas. Aqueles que cumprirem na íntegra os doze itens propostos conquistarão a especialidade em seu nível máximo (Nível 03), em seu Nível 02 aqueles que cumprirem oito

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[14] Dentro do Programa Escoteiro, especialidades são artifícios pedagógicos que resultam em acréscimos de informação a que os associados ao escotismo se submetem de modo voluntário, podendo, aqueles que cumprirem satisfatoriamente as atividades propostas usarem em seus uniformes, distintivo alusivo a área de conhecimento escolhida.

dos requisitos, a sua escolha, e finalmente, aqueles que cumprirem o mínimo de quatro tarefas farão jus ao Nível 01 da especialidade. As tarefas propostas são:

Saber o significado dos termos: trogloxenos, troglóbios, troglófilos,espeleotemas, e represas de travertino.;

Saber identificar estalagmites, estalactites, colunas, cortinas e conhecer seu processo de formação;

Conhecer os equipamentos necessários à exploração subterrânea;

Saber como se formam as cavernas calcárias, e mostrar no mapa do Brasil onde se situam as principais províncias espeleológicas;

Conhecer e interpretar o lema internacional do espeleólogo;

Apresentar em sua seção um trabalho de pesquisa mostrando as principais ameaças de degradação ambiental a que estão sujeitas as cavernas, e demonstrar conhecimentos sobre a legislação de proteção às cavidades naturais subterrâneas;

Demonstrar como se utiliza um sistema de iluminação à carbureto e efetuar sua limpeza e manutenção;

Efetuar troca de correspondência com 2 entidades voltadas à exploração e conservação de cavernas, levando à sua seção as informações e conhecimentos obtidos;

Identificar por ocasião de uma visita à caverna as zonas ambientais existentes baseadas na interação umidade/luminosidade/temperatura (Zona de penumbra, Zona I e Zona II);

Demonstrar a importância ecológica dos morcegos;

Tomar parte, acompanhado de guia experiente, em explorações de 4 cavernas diferentes, devendo duas delas apresentar desenvolvimento linear superior à 300 metros, e saber interpretar um mapa topográfico de uma caverna;

Identificar 5 animais habitantes das cavernas de sua região.

Atividades Realizadas e Resultados Alcançados

Um total de dez palestras envolvendo cerca de duzentos jovens e seis visitas a ambientes cársticos foram realizadas no período de 1996 a 2000. As palestras, aplicadas com a utilização de equipamentos multimídia, abordaram aspectos da formação de cavernas, comportamento ético em visitas às cavernas, prospecção de cavidades naturais subterrâneas, bioespelologia, equipamentos, orientação, segurança, técnicas de exploração, e necessidade de conservação dos ambientes subterrâneos, sendo que a participação nas etapas teóricas foi pré-requisito para participação nas visitas a campo. Estas obedeceram a seguinte dinâmica:

A visita tem o formato de gincana, ou seja competição entre equipes;

Cada equipe conta com a presença de um “monitor” do IBAMA/CECAV, cuja função é prestar informações sobre aspectos da caverna, zelar pela segurança dos participantes e pela integridade da caverna, não interferindo nas atividades da competição;

Cada equipe recebe um radio comunicador tipo “hand talk”, uma bússola e uma mapa da caverna;

As equipes receberão por radio os azimutes que deverão percorrer ate a boca da caverna, saindo a intervalos regulares de 10 minutos;

Na caverna deverão percorrer um roteiro previamente delimitado no mapa de modo a atingir determinados pontos da caverna onde foram escondidos objetos com trechos de mensagens.

Durante o percurso o monitor explica aos visitantes aspectos de interesse espeleológico pelos quais se depararam;

Ao final do roteiro as equipes deverão ler a integra do texto, montado com as mensagens localizadas;

A equipe com a melhor performance será a vencedora, recebendo brindes, geralmente camisetas e bonés institucionais como forma de valorização da conquista;

Finalmente ressaltamos que o objetivo da atividade não é chegar em primeiro lugar, o que está em jogo é a regularidade da equipe. De que forma ela se orientou com a bússola até a boca de caverna, como utilizaram o mapa, os aspectos ambientais observados, os cuidados com a conservação de espeleotemas, o companheirismo da equipe, etc..

Em julho de 2000 efetuamos mais uma atividade nesses moldes porém um pouco mais ambiciosa. Objetivando associar educação ambiental e cidadania propusemos aos escoteiros um trabalho comunitário com a população do entorno das cavernas. Foram recolhidos seiscentos quilos de roupas, brinquedos e calçados durante seis meses. Este material foi distribuído pessoalmente pelos escoteiros à famílias previamente cadastradas pelos servidores do IBAMA/CECAV. A atividade apresentou aos jovens uma realidade social diferente daquela vivenciada em seu dia a dia, tornando-os mais conscientes, além de ter contribuído com a formação de uma mentalidade conservacionista em cada um deles. Com relação ao IBAMA investiu-se na imagem institucional do Órgão, geralmente associada pela população rural a ações fiscalizarias e repressivas.

Conclusão

Cavernas há muito tempo vem sendo visitadas por escoteiros, muitas vezes sem o devido acompanhamento técnico. A parceria firmada em 1996 tem se mostrado produtiva no sentido de inserir no Programa Escoteiro, elementos de preservação do meio cavernícola, fazendo com que atividades ligadas a espeleologia sejam acompanhadas por profissionais da área. A experiência vivenciada pelo GE Rudyard Kipling 8º GO pode e deve ser estendida aos demais Grupos Escoteiros da Região Escoteira de Goiás, a fim de ampliar a consciência ambiental relativa a utilização dos ecossistemas naturais subterrâneos.

Agradecimentos

Nossos agradecimentos aos espeleotopógrafos Emílio Manoel Calvo e Vilmone Manoel Ferreira, cuja atuação se mostrou imprescindível ao sucesso dos trabalhos realizados.

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Mata de Pains e Cabeceiras do São Francisco: Ecossistemas sob Tensão Antrópica - Porque a Criação de Unidades de Conservação pode Levar ao Desenvolvimento Sustentável

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“... Um dos corredores, que se estendem em abóbada cerca de 60 passos, é fechado por uma massa de estalagmites... O outro corredor, de 50 passos de comprimento, se fecha em gruta.”

Eschwege, sobre a gruta da Cazanga, 1833.

Abstract

The present project have how objective the criation of the Parque Estadual da Mata de Pains, with continual area including three municipalities borders, and foresight of superior area 5 000 hectares. Another forms of environment permanent preservation is “special areas” denomined APAs with 7 628 km2 and RPPNs are foreseen in continuous borders of project, but whithout detail or relate. The implantation of project and sub-projects to give best benefit and the life quality and environment preservation enclosed ground to 20% of Mata de Pains (Pains Forest), that have superior area of 500 km^2 or 50 000 hectares.

So, enclosed ground 10 000 hectares what will be preservated in class 8 areas for not agriculture use. Parallel will have increase and development process environmental foreseen in Agenda 21/Rio 92. This to produce kindness for population of 50 275 inhabitants (IBGE Instictut 2000 cense) in three municipalities and total number of 117 264 inhabitants (idem), in adjacent region. The preservation of rare ecossystem for future generations with greatest potential bio-genetic and ecotouristic to amount to aspects also with specials caracteristics of geology, pedology, speleology, hidrics and wild life and forest rain in dead process, are essentials atributes today in somebody planning projection and economic development. In present plant is foressen the increase of rural economy, so the new and modern development of industry and urban areas towns, villages and old farms of region across ecological turism how *trekking*, *horse-cross*, bike-cross, mountain bike, canoeing, caving, and... speleology!

Introdução

Este pequeno e rápido estudo tem como meta propor a criação do Parque Estadual da Mata de Pains – PEMP, uma região com um rico e raro ecossistema em vias de extinção, cuja área de abrangência ocupará terras dos municípios de Pains, Iguatama e Arcos, em área contígua limítrofe. Na esteira do parque está prevista a criação da Área de Proteção Ambiental - APA das Sete Cidades-Mãe do São Francisco ou das Cabeceiras, que é contígua e está a montante da Mata de Pains, que ocupará a superfície total dos três municípios acima citados, mais Córrego Fundo, Doresópolis, Piumhi, Vargem Bonita, São Roque de Minas, Medeiros e Bambuí. Nesses dez municípios estão as nascentes do São Francisco e seus primeiros afluentes que são os rios Samburá, Santo Antônio, Piumhi, Ribeirão dos Patos, São Miguel, Bambuí e Ajudas. Prevê ainda o incentivo aos proprietários rurais para destinarem matas ciliares e de topo para Reservas Particulares do Patrimônio Natural - RPPNs.

Em junho de 1998 o documento foi encaminhado ao Secretário de Estado do Meio Ambiente e Desenvolvimento Sustentável de Minas Gerais- SEMAD, José Carlos Carvalho, que em entrevista a imprensa à época mostrou-se favorável à idéia, afirmando que “para viabilizar a proteção da Mata de Pains poderão ser utilizados recursos originários de taxas de utilização de recursos florestais e parcerias com a iniciativa privada”. Mais recentemente afirmou que caso continuasse no governo de Minas Gerais, as unidades de conservação seriam implantadas. Em setembro daquele ano sobrevoamos em helicóptero junto com o IEF – Instituto Estadual de Florestas-MG, toda a região proposta. Estudos de biodiversidade foram realizados pelo setor de zoneamento/unidades de conservação daquele instituto. Continuamos empenhados no projeto até a solução final. Informações e ações posteriores ao ano de 1998 estão inseridas no escopo do trabalho.

Objetivo

Criação do Parque Estadual da Mata de Pains, com área contígua abrangendo três municípios limítrofes com previsão de uma área superior a 5.000 (cinco mil) hectares. Outras formas de proteção ambiental permanentes como APA e RPPNs são previstas no projeto, devendo a APA abranger a área total dos municípios citados. A implantação dos projetos beneficiarão a qualidade de vida da população e a preservação ambiental de cerca de 20% da Mata de Pains que tem área superior a 500 km2 (50 000 hectares) e das cabeceiras do rio São Francisco. Isto representa cerca de 10 000 hectares que estarão preservados em áreas de classe-8, não agricultáveis, constituídos de maciços calcários. Se se considerar os municípios do parque proposto e a APA das Sete Cidades-Mãe ou das Cabeceiras, estarão interligados dois parques, um estadual com outro nacional, o da Canastra., incluindo o canyon do São Leão no rio São Francisco e daí à Casca d'Anta, onde tem início o parque nacional. A área total será contínua, interligando tudo ao parque Nacional da Serra da Canastra que situa-se no topo ou platô. Em paralelo haverá o crescimento e desenvolvimento sustentado previsto na Agenda 21/Rio 92. Isto trará benefícios diretos a uma população de 50 275 habitantes segundo o censo 2000/IBGE nos três municípios e um total de 117 264 habitantes, idem, na microrregião contígua da APA das Sete Cidades-Mãe. A preservação de um raro ecossistema para as atuais e futuras gerações, com grande potencial bio-fármaco-ecoturístico somados a aspectos também peculiares geológicos, pedológicos, espeleológicos, arqueológicos, hídricos e da flora e fauna em extinção, são fatores adicionais e indispensáveis hoje em qualquer agenda de planejamento e crescimento econômico. Prevê-se ainda o soerguimento da economia rural, assim como o redirecionamento industrial e urbano de cidades, distritos e vilas, além de incentivos fiscais para proteção das velhas fazendas da região, incorporando-as ao turismo ecológico. Um programa desta natureza existe em Portugal e Espanha, onde o governo adquire, restaura e adapta velhos castelos e casarões para hospedagem ecoturística no estilo da época, os paradores.

Justificativa

Uma proposta de desenvolvimento é sustentável quando a velocidade da agressão ambiental é menor do que a velocidade com que a natureza consegue reagir para compensar esses danos. Como convém à criação de um parque, o projeto fala de riquezas, de lendas e de destruição. Na região é possível ver coisas tão feias como apagar para sempre com talhadeiras arte rupestre de 4.000 anos atrás, como no Corumbá em Arcos, e a quase detonação com dinamite de grutas como a do Éden em Pains. Inúmeras cavernas foram destruídas para sempre para o fabrico de cimento, cal e carbureto de cálcio.

Com a implantação do projeto e sub-projetos, haverá um repensar e o conseqüente redirecionamento do modelo de crescimento econômico tradicional arraigado na região, seja o industrial ou o rural. O primeiro está em franca expansão, seguindo um modelo exportador globalizado, desconsiderando as mais elementares normas e critérios ambientais e sociais. Existem exceções, naturalmente. A isto soma-se a automação crescente que gera o desemprego.

Espera-se, na esteira dos projeto ambiental em tela: i. por fim à exploração industrial predatória; ii. soerguimento da economia e produção agrícola e pecuária de leite, através da diversificação; iii. introdução e incentivo do chamado ecoturismo e turismo rural orientados, como fonte de renda adicional aos fazendeiros; iv. fim do lançamento a céu aberto de lixo e esgotos, sejam urbanos ou industriais, além de emissões atmosféricas e ruídos / detonações de dinamites.

Se a região está inserida e é dotada das melhores infraestruturas do país, espera-se, em contrapartida, que a população local tenha acesso aos ganhos da riqueza gerada e desfrute de melhores condições de vida e ambientais. É apenas uma questão de redirecionamento e introdução de planos e projetos específicos rurais, industriais, ambientais e ecoturísticos.

Parques semelhantes foram recentemente implantados pelo governo federal e estadual como o Parque Nacional Cavernas do Peruaçu, em área de intensa ocupação entre Januária e Itacarambi (56.800 hectares); o Parque Estadual do Itambé nas cabeceiras do sofrido e degradado vale do Jequitinhonha. (4.700 hectares de parque e área total do entorno de 76.310 hectares, incluída a APA) e o Parque Estadual da Serra das Araras, no município de Chapada Gaúcha, com 11.360 ha de área, no noroeste do Estado, região de cultivo de soja e culturas irrigadas por pivô central.

Localização, clima e acessos.

A Mata de Pains situa-se na parte sul da região do Alto São Francisco, no sudoeste do Estado. Ao sul da área confronta-se com a represa de Furnas, e ao norte é banhada pelo rio São Francisco ainda estreito. Grosso modo, localiza-se entre as coordenadas 20º 10` e 20º 25` LS a 45º 35` e 45º 55` WG. É definido que em latitudes acima de 20º LS ocorrem geadas e elas ocorrem anualmente na região. A altitude máxima atinge 965 metros próximo a Córrego Fundo. Arcos está a 746 m.; Iguatama, a 715 m. e Pains a 695 m., sendo circundada por altitudes superiores a 800 m. O pico do Fundão, na divisa Iguatama e Pains atinge 878 m. (nascente do córrego Fundão na Pedra Grande), sendo o pico da Bocaina na fazenda do Doce, com 848 m a altitude máxima de Iguatama. Seio de Abraão atinge 800 m.; o monte Jatobá atinge 778 m. e Jatobazinho, 738 m. No Corumbá, em Arcos, onde parte das pinturas rupestres foram obliteradas para sempre, atinge altitudes de 816 m. Segundo a classificação climática de Köeppen o clima é definido como tropical úmido com inverno seco e verão chuvoso. A temperatura média anual é de 21º C, com meses mais frios de abril a agosto, com a temperatura caindo abaixo de 5º C em junho-julho, quando ocorrem geadas. A precipitação pluviométrica anual é de 1 500 mm em média conforme dados climáticos da estação agro-meteorológica de Bambuí 40 km a oeste da região, de Lavras a sul e Araxá a oeste, ambas a 170 km. de distância.

A Mata de Pains localiza-se a 220 km da capital, sendo cortada pela MG-050, Belo Horizonte - São Sebastião do Paraíso, e BR-354, Perdões-Estalagem (BR-262), no Alto Paranaíba.

Definição e caracterização do problema. Porque um parque e uma APA em toda a região

O grande problema que se depara é a avassaladora forma de exploração das jazidas de calcário somado ao empobrecimento sistemático do meio rural. O projeto visa promover o desenvolvimento sustentado da Mata, através do gerenciamento e da conservação dos seus recursos naturais de forma sustentada e incentivando atividades que sejam econômica e ambientalmente compatíveis com o ecossistema local. Visa também promover melhores condições de vida à população. O projeto tem três componentes básicos: i. assuntos vinculados ao meio ambiente urbano e industrial (ar, água, esgotos, ruídos / detonações etc); ii. promoção e diversificação de atividades econômicas no meio rural; iii. áreas de conservação mais gerenciamento de bacia e sub-bacias na área de influência.

Degradação no meio rural:

i. depauperamento advindo do fim das lavouras tradicionais de cereais: policultura do milho, feijão, arroz, mandioca, cana, amendoim, etc., café, em tempos mais remotos;

ii. sedes de fazendas e rico acervo arquitetônico peculiar em ruínas; muitas foram e estão sendo demolidas;

iii. desmatamento e destoca contínua irresponsável de matas ciliares e de topo remanescentes da Mata Atlântica em reconstituição, para pastagens de braquiária e criação extensiva de gado de corte nelore;

iv. existe conluio ente os proprietários e as firmas de desmatamento, que atuam à revelia da licença florestal;

v. para evitar este fato deve haver licenciamento tanto por parte do desmatante (proprietário) quanto do desmatador (patrulha), como é feito para a moto-serra;

vi. a sucessão familiar entre herdeiros retalha e subdivide a propriedade, e com ela as reservas nativas sem nenhum critério jurídico para outorga de escrituras. Nas comarcas de Arcos e de Iguatama existe uma figura tão estapafúrdia como o ‘licenciado precário agrimensor’, que emite laudos e faz croquis como se fossem plantas, sem nenhum critério técnico e ao bel prazer. É tão viciada e arcaica a estrutura jurídica–agrária, que laudos e estudos de profissionais reconhecidos são preteridos em processos de inventários e outros. É uma questão ética a ser resolvida pelo CREA e SMEA;

vii. esses fatores levam o pequeno e médio proprietários a um beco sem saída, obrigando-o a vender suas terras a pecuaristas alienígenas e absenteístas, que põem abaixo o que restou;

viii. nessa sucessão venal não há introdução de tecnologia conservacionista, e a erosão laminar, as vossorocas, o sobrepastoreio e outros fazem surgir focos dispersos de pré-desertificação nos solos que se tornam altamente erodidos, além do assoreamento dos rios, lagoas e baixadas.

Degradação dos maciços cársticos, matas de topo e ciliares:

i.destruição de grutas, cavernas, locas, abrigos, com detonação total por mineradoras, muitas clandestinas e sem alvará;

ii. idem, vandalismo com destruição de estalactites, estalagmites e outros espeleotemas por pessoas da região em comum com terceiros há indícios de comércio e tráfico;

iii. isso ocorre por falta de mapeamento, e quando ele existe, não é levado ao público local, gerando um abismo entre a ciência (espeleologia) e os autóctones (que ignoram o rico acervo que lá deve permanecer intocável);

iv. obliteração com 'talhadeiras' __ pasmem __ de figuras rupestres por megaempresas. Fato comprovado e documentado por membros que ora assinam este projeto, a imprensa representada pelo jornal "Estado de Minas" e técnicos do IEF. Corumbá será atração por dois motivos: pelas pinturas rupestres milenares e pelo que sobrou das mesmas pinturas rupestres;

v. orquídeas raras e maravilhosas, em extinção de espécies autóctones, por vandalismo e deseducação ambiental;

vi. idem madeiras de lei, que são serradas nos maciços e retiradas por "tifós", para comercialização, e com elas as orquídeas e outras epífitas ;

vii. é prática comum os fazendeiros roçarem a vegetação arbustiva sob as copas das reservas florestais legais e ciliares, para que aí permaneça o gado: onde se esconderão os animais silvestres?

Degradação nas cidades :

As várias formas de lixo não são tratadas, acumulando-se em lixões, nos terrenos baldios, margens de rios, etc.

ii. esgotos urbanos não sofrem o devido tratamento, sendo lançados nos rios São Francisco, São Miguel, dos Arcos e Córrego Fundo;

iii. a poluição atmosférica é grave em Pains, gerando doenças crônicas; ela existe também em Arcos, Córrego Fundo, Formiga e Iguatama;

iv - com exceção de Arcos (reserva do Corumbá) não existem áreas ou parques de preservação ambiental e lazer para a população.

v. o êxodo rural expande as cidades e é com tristeza que se vê o surgimento de favelas nessas cidades, aparentemente sem maiores problemas;

vi. cresce o sub-emprego nas cidades e no meio rural a escassez da mão de obra é crescente.

Com relação à cidade de Pains: bem próximo à cidade, o lixo urbano de Pimenta é despejado em um lixão nas cabeceiras do Ribeirão dos Patos, vertente oposta do divisor de águas do Rio Grande / Furnas, demonstrando que a pressão e conscientização em Furnas já se faz sentir. Também a água consumida em Pains pode estar contaminada uma vez que recebe efluentes industriais e "chorume" de lixão lançado sobre dolinas, no trecho em que o Rio São Miguel se torna subterrâneo, fazendo parte de extensa rede de lençóis freáticos e rios subterrâneos existentes no sub-solo de Pains e região. A água consumida na cidade é aí captada, à jusante deste ponto.

A poluição sonora e do ar é grave em Pains, causada por moagem e queima de pedras calcárias empregando-se como combustível pneus, retalhos de pneus de fábrica, pellets e sacos plásticos, cuja fumaça de ácido clorídrico e dioxina causam chuva ácida que é cancerígena. Detonações de dinamite são feitas sem proteção para os operadores e a população, causando rachaduras em casas e edificações com barulho infernal.

Poluição e degradação pelas indústrias e mineradoras

i. praticamente todas as indústrias em cinco municípios causam poluição atmosférica;

ii. idem poluição hídrica e sonora em maior ou menor grau;

iii. poucas indústrias adotam estudos de impacto ambiental - EIAs / RIMAs;

iv. poucas indústrias e mineradoras adotam os critérios e normas de segurança no trabalho, sendo comum a ocorrência de mortes em acidentes e mutilações com suas seqüelas;

v. por desconhecer e desconsiderar os critérios ambientais, muitos burlam a fiscalização, pagam as multas e voltam a operar como se nada tivesse acontecido. O sítio arqueólogico do Timboré, com registro no Iphan, está prestes a ser minerado, isto é, uma maravilha natural será detonada e mutilada, caso receba licença de operação(LO) da Feam e Ibama;

vi. Desrespeito total por sítios arqueológicos, a flora e a fauna da região: indústrias e mineradoras que se dizem do primeiro mundo, cometem atos do chamado quarto mundo, destruindo e obliterando, isto é, cortando com talhadeiras as pinturas rupestres de 4 000 anos. Isto pode ser visto nos paredões calcários da CSN – Companhia Siderúrgica Nacional de Volta Redonda, RJ, no Corumbá, entre Arcos e Pains.

O empirismo trás resultados apenas no curto prazo; é preciso haver critérios, bom censo, ciência e tecnologia na exploração dos recursos naturais. Esta situação mostra que a fiscalização e a liberação são deficientes e que a liberação deve ocorrer através de vistoria técnica e ambiental com emissão do respectivo laudo de licença ambiental. A Lei de Crimes Ambientais deve ser cumprida com rigor frente as denúncias de irregularidades. Isto é válido para as novas e as que já estão sendo liberadas. As que estão em situação irregular devem ser fechadas imediatamente. A Lei de Crimes Ambientais deve ser cumprida com rigor frente as denúncias de irregularidades ambientais. A equipe multidisciplinar deve ser permanente e composta por espeleólogos, arqueólogos, engenheiros agrônomos e florestais, biólogos, geólogos, etc com membros do governo e ONGs da região. Caso não se adotem estas medidas tudo continuará na mesma; tememos pelo futuro da região e então terá sido tarde demais.

Outros, mais degradação

Iguatama tem elaborados projetos executivos para o tratamento do esgoto e do lixo. Enquanto isto o esgoto urbano e do matadouro é lançado diretamente no Rio São Francisco. Idem, carcaças e ossadas de animais lançadas nas pontes da carranca e ao longo do rio.

Um breve histórico da Mata de Pains

Os primeiros exploradores foram os bandeirantes e mais tarde os naturalistas europeus. Incursões e passagens de bandeirantes vindos de São Paulo, para Goiás e Mato Grosso, através dos contrafortes da Mantiqueira, Campos das Vertentes e daí rumo ao Rio São Francisco e Triângulo Mineiro, ocorreram desde a segunda metade do século XVII, mais precisamente em 1.673. Augustin François Cesar Provensal de Saint Hilaire - Auguste de Saint Hilaire (1779 - 1853), botânico francês, sucedeu a Lamarck na Academia de Ciências de Paris. Percorreu o Brasil de 1816 a 1833, interpretando as relações entre o meio físico e as plantas observadas, os costumes e usos, a realidade do país. A primeira descrição científica da região se fez por St. Hilaire que cruzou a mata de Pains de Formiga à Canastra. Os primeiros achados fósseis de Pains foram encontrados e descritos por ele em 1816. O austríaco Johan Emmanuel Pohl percorreu o Brasil de 1817 a 1821. Em outubro de 1817 chegou a Formiga, vindo do Rio de Janeiro. Foi descrevendo o que via, como bom botânico, anotando os nomes comuns e científicos, as famílias, etc. Em uma venda deparou-se com o couro de uma sucuriu (Boa constritor) na parede. Vem daí, ou antes, o extermínio. Formiga, ele a descreve como um arraial com cerca de cem choupanas de barro e sapé/colmos. Daí parte em direção ao Rio São Francisco em Porto Real (Iguatama), cruzando o rio São Miguel e toda a Mata de Pains. Porto Real ele a descreve com seis choupanas. O século XIX assistiu a uma afluência de naturalistas estrangeiros no Brasil. “Spix e Martius, St. Hilaire, Pohl, Eschwege e Walsh visitaram cavernas no primeiro quarto do século. Em 1816 Eschwege visitou uma caverna no sul de Minas Gerais, provavelmente a gruta da Cazanga ou Loca Grande, no município de Arcos. Ele relata (1833) em pormenor o percurso efetuado dentro dessa cavidade: ‘Sua altura e largura variam de 15 a 20 palmos; e seu comprimento, 286 passos. A gruta, como um longo corredor, alarga-se no fim, dando lugar a um amplo salão de 40 palmos. A gruta se divide ... em 2 corredores principais ....um dos corredores, que se estende em abóbada cerca de 60 passos, é fechado por uma massa de estalagmites ... O outro corredor, de 50 passos de comprimento, se fecha em gruta ...’” (Eschwege, W.L. 1833, in Revista Espeleo-tema, vol.18, SBE, 1997). O militar, engenheiro e naturalista alemão Wilhelm Ludwig von Eschwege chegou ao Brasil em 1808 com D.João VI. Como mineralogista fez viagens e explorações científicas em Minas Gerais e São Paulo. Sobreviverá a gruta metodicamente descrita pelo naturalista que mal tinha a mão uma trena, à exploração das mineradoras que a cercam como anéis de fogo, anéis de dinamite? Sinal dos tempos, a mineradora ao redor tem o mesmo nome da gruta. Mais recentemente, ainda se ouve na região, as narrativas sobre o mastodonte descoberto em março de

1998 na gruta do Angá em Pains. Elas parecem não ter fim. As ossadas indicam tratar-se de um mastodonte, um tipo de elefante gigante peludo e grandes presas recurvas, ancestral do atual elefante. O paleontólogo Castor Cartele da PUC/MG resgatou e descreveu este fóssil.

O que é o Carst

Técnica e genericamente as formações calcárias são chamadas de karst, carst ou carste. A ação química de águas ácidas sobre rochas de conteúdo calcário, calcítico e dolomítico, está intimamente ligada ao ciclo geomorfológico que controla a erosão das rochas solúveis. Tal tipo de erosão denomina-se erosão cárstica. A palavra deriva da região Karst, província da Dalmácia, na Sérvia-Bósnia. Inúmeros termos internacionalmente utilizados na descrição e identificação de fenômenos cársticos são também dessa origem. A etimologia vem de kras, pedra, de onde deriva a palavra Carso que em latim, dá nome à região padrão localizada em ambos os lados do mar Adriático (Rolff, P.A.M. de Almeida), in Espeleologia nº 5, 1973 (2).

Os custos de implantação do parque

Acreditamos que através de negociações, os grandes grupos que têm propriedades ociosas na região cederão as terras, seja por meio de desapropriações por interesse público com indenizações, permutas e isenções fiscais ou mesmo por livre e espontânea vontade através de doações.

Eles participarão dessa nova era, a do crescimento sustentado, com níveis superiores de qualidade de vida para as comunidades que, direta ou indiretamente se encontram em sua área de influência. Para evitar especulações, essas áreas não serão aqui definidas. No momento oportuno e quando convocados, os proponentes apresentarão os mapas e cartas topográficos, descrições e outros dados. Cada município terá a sua sede ambiental no Parque observando-se entretanto a legislação ambiental. Cada município deverá arcar com contrapartidas de acordo com as leis orgânicas locais e estaduais. Em função do exposto, não é possível ser avaliado com segurança, o que só ocorrerá no decorrer e andamento das negociações e caracterização física efetiva, como dimensões, localização, etc. Estima-se um valor total de R$6.500.000,00 para o projeto. Recursos estaduais alocados pela lei Robin Hood / ICMS Ecológico serão repassados a cada município do PEMP e da APA das Sete Cidades-Mãe. Desapropriações e indenizações competem exclusivamente ao Governo Estadual. A operação, a manutenção e fiscalização do parque, APA e RPPNs ficarão a cargo dos municípios e proprietários particulares, em convênio com os órgãos ambientais estaduais, federais e ONGs de acordo com a legislação. Recursos externos, seja de governos, agências ou ONGs ambientalistas são benvindos, e estamos abertos para sugestões e propostas.

Considerações finais

Esperamos que este projeto da criação de um parque estadual e da APA contribua para criar novas condições para a elevação da riqueza e produção regional dentro de parâmetros ambientais. A nós, ele se revela de um grande alcance sócio-econômico-ambiental. Nossa intenção não foi propor ou fazer recomendações, mas antes de tudo, através do conhecimento dos problemas apresentar soluções que só o Poder Público, o Estado, é capaz de resolvê-los em consonância com os anseios e a participação das comunidades envolvidas. A idéia básica é o Estado implantar o Parque, etc e no seu bojo a iniciativa privada se encarregará de implantar os mais diversos projetos atrás delineados. No momento a região não apresenta fluxo turístico, mas poderá vir a tê-lo, unindo o potencial existente com as ações necessárias. Aí então entra a Faculdade de Turismo de Formiga, o SEBRAE, a AMO-TE e AMETUR e um pool de outros interessados do segmento produtivo, industrial e agropecuário como cooperativas, Emater, Ruralminas, Ima, IEF, IGAM, além do Mercosul. As Organizações Não Governamentais - ONGs, que elaboraram este projeto, desde já e de antemão, esperam e acompanham o desenrolar e os encaminhamentos necessários, que, sabemos, terão solução favorável dentro das proposições nele contidas. Para os proponentes que assinam este documento, é uma forma de contribuir para a análise da situação atual e o seu significado. Estamos ao inteiro dispor para as informações e maiores dados, indispensáveis para a implantação do projeto.

Siglas citadas

AMDA – Associação Mineira de Defesa do Meio Ambiente

AMETUR – Associação Mineira de Turismo Rural

AMO TE – Associação Mineira de Ecoturismo

APA – Área de Proteção Ambiental

CREA – Conselho Regional de Engenharia, Arquitetura e Agronomia

EIA – Estudo de Impacto Ambiental

FEAM = Fundação Estadual do Meio Ambiente

IBGE – Instituto Brasileiro de Geografia e Estatística

ICMS – Imposto sobre Circulação de Mercadorias e Serviços

IEF – Instituto Estadual de Florestas

IPHAN – Instituto do Patrimônio e Histórico e Artístico Nacional

ONG – Organização Não Governamental

PEMP – Parque Estadual da Mapa de Pains

PUCMG – Pontifícia Universidade Católica de Minas Gerais

RIMA – Relatório de Impacto mo Meio Ambiente

RPPN – Reserva Particular do Patrimônio Natural

SBE – Sociedade Brasileira de Espeleologia

SEBRAI – Serviço Brasileiro de Apreendizagem

SEMAD – Secretaria de Estado e Desenvolvimento Sustentável

SMEA – Sociedade Mineira dos Engenheiros Agrônomos

UFMG – Universidade Federal de Minas Gerais

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PS. Referências e respectivos autores foram citados no texto.

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“Mais vale o otimismo das ações do que o pessimismo das idéias.”
Greenpeace

“A natureza pode ser conservada não tanto pela ciência, mas sobretudo pelo amor dos homens. Esse carinho deve ser infundido continuamente.”

Kotliakov, V. M. geólogo, in: En los Glaciares del Pamir.

Brasília, 12 de abril de 2001

As Consequências do Mal Planejamento na Delimitação de uma Unidade de Conservação: O Complexo de Cavernas de São Domingos - Um Estudo de Caso

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Abstract

The Terra Ronca State Park is an environmental conservation area localized in the São Domingos municipality, Goiás State, in the central plateau of Brazil. The park was created to protect a unique cave complex. The geodesic criteria used to define park limits did not localized 10 springs that originate the caves. This research diagnoses problems that will influence the demarcation of the area and the management plan as well as recommends geodesic and cartographic criteria for phisical delimitation of environmental important areas.

Introdução

Criado pela lei 10.879 de 7 de julho de 1989 e regulamentado através do decreto n° 4.700 de 21 de agosto de 1996, o Parque Estadual de Terra Ronca-PETeR tem por objetivo proteger um complexo de cavernas, localizado no Município de São Domingos, região nordeste do Estado de Goiás, a 350 km de Brasília e 550 km de Goiânia (Figura 1).

Figura 1 – Localização do PETeR

No texto do documento oficial de criação, consta que o mesmo possui uma área aproximada de 50.000 hectares, tendo sido delimitado empregando-se folhas topográficas do Instituto Brasileiro de Geografia e Estatística - IBGE, constituídas a partir de fotografias aéreas oriundas do Projeto BAGOMAPI e de onde foram utilizados elementos como curva de nível, pontos de cotas não comprovadas, hidrografia e rodovias

O projeto BAGOMAPI apresenta a realidade regional do ano de 1967, isso significa quando da regulamentação do parque, na existência de uma defasagem multitemporal da ordem de 29 anos em alguns temas como malha rodoviária, uso da terra e cadastro das fazendas.

A referida defasagem sugeria uma maior atenção por parte da equipe técnica quando da delimitação do parque, no sentido de observar se nos trechos eleitos para divisas utilizando as rodovias locais, se estas não teriam sofrido nenhuma alteração no seu greide, capaz de induzir a um erro de locação nos vértices-limites da unidade de conservação em abordagem.

Outra particularidade, diz respeito ao uso de geodados tipo curvas de nível e pontos cotados não comprovados como elementos demarcatórios dos limites físicos do parque. Opções como estas implicam em conseqüências desfavoráveis a integridade do PETeR sob vários aspectos.

Considerando essas observações, o objetivo do trabalho foi um diagnóstico reportando os problemas de natureza técnico-operacional que influenciarão no plano de manejo e na materialização dos limites geográficos do PETeR, como conseqüência dos critérios geodésicos utilizados como referencial para delimitação do referido parque.

Metodologia

Para a elaboração deste trabalho foram utilizadas as mesmas cartas topográficas do IBGE folhas SD-23-V-D-I e SD-23-V-D-IV na escala de 1:100.000 que deram suporte ao planejamento da delimitação do PETeR, além de GPS de navegação GARMIN 12XL, Imagem digital do satélite Landsat 7, Software SPRING 3.4 (INPE), CorelDraw 8.0 e mesa digitalizadora A-0 (Digigraf) e cópia do Diário Oficial, contendo a Lei Nº 10.879 de 7 de julho de 1989, estabelecendo a área e os limites do PETeR.

As atividades foram desenvolvidas contemplando as seguintes fases:

Digitalização da base cartográfica da área de estudos, envolvendo os seguintes geotemas: malha hidrográfica, altimetria (curvas de nível e pontos cotados) e malha geodésica.

Utilização do Diário Oficial supra citado (Memorial Descritivo), para plotagem dos vértices que determinam os limites físicos do parque em abordagem;

Plotagem do conjunto de bocas de cavernas existentes na área de estudos, utilizando os dados da Sociedade Brasileira de Espeleologia;

Levantamento em campo do conjunto de bocas de cavernas.

Em seguida os geodados produzidos no SPRING 3.4, foram exportadas em formato DXF, para o aplicativo CorelDraw 9.0, onde foram editadas em layers distintos.

O Objeto de Estudo

O PETeR foi criado para preservar, em particular, as áreas de ocorrência de cavidades naturais subterrâneas e seu entorno protegendo sítios naturais de relevância ecológica e reconhecida importância turística.

O complexo de cavernas que este parque preserva contempla grandes sistemas do Brasil como o Angélica – Bezerra, o sistema Terra Ronca – Malhada e o sistema São Mateus – Imbira.

Na lista das trinta maiores cavernas do Brasil o parque possuí sete: a Lapa da Angélica, a Lapa de São Vicente, a Lapa São Mateus III, a Lapa do Bezerra, o Sistema Terra Ronca II/Malhada, a Lapa de São Vicente II e a Lapa do São Mateus II/Imbira (BAMBUÍ, 2001).

Também fazem parte do complexo espeleológico do parque, além das cavernas já relacionadas, a Lapa do São Bernardo (GO-2), a Lapa do Oco (GO-13) e a Lapa do Passa-Três (GO-14), entre inúmeras outras, todas cadastradas pela Sociedade Brasileira de Espeleologia-SBE (Mapa 2).

Terra Ronca é a mais conhecida das cavernas do parque, possuindo uma das maiores entradas de caverna do país com 100 m de largura por 84 de altura e lhe empresta o nome.

A vegetação dominante é caracterizada por cerrados, campos cerrado, campos sujos, matas de galeria, floresta tropical caducifólia e veredas (IBGE, 1995).

A flora é bastante diversificada com inúmeras plantas medicinais, frutíferas, árvores de grande porte e fornecedoras de madeira e inúmeras palmeiras (Braga, 1976; Goodland & Ferri, 1979 e Lorenzi, 1998).

Sua fauna é rica em espécies.

O parque está localizado em uma região que compreende o divisor de água das bacias hidrográficas dos rios São Francisco e Tocantins. Sendo atravessado por uma rica e piscosa rede hidrográfica com rios como Rio São Mateus, Ribeirão Angélica, Rio da Lapa, o Rio São Vicente, Ribeirão Palmeiras, Rio São Bernardo, dentre outros, que possuem suas nascentes no sopé da Serra Geral de Goiás (IBGE, 1995).

Resultados

Na avaliação dos inconvenientes gerados pela forma como a equipe técnica responsável pela condução do projeto de regulamentação do parque, escolheu elementos naturais e artificiais que definiram os limites geográficos daquela unidade de conservação, foram observadas incorreções inaceitáveis.

A primeira delas diz respeito a escolha da cota de 950m, curva de nível extremamente sinuosa, eleita como limite do parque por uma extensão de aproximadamente 25 km, definindo os vértices-divisas 8 a 18. Essa opção demonstra pouca eficácia técnica pois deixaram de considerar que uma atividade demarcatória nestes moldes representa um elevado custo para os cofres públicos e nenhuma praticidade de campo para a equipe responsável pela implantação dos marcos geodésicos nos limites do parque.

Outro inconveniente que diz respeito a escolha desta curva de nível é a exclusão de 10 (dez) nascentes, a saber: do Ribeirão Angélica, (2) duas; do Ribeirão São Vicente, 6 (seis) e do Córrego do Macaco, (2) duas. (Figuras 2, 3 e 4).

Figura 2 – Carta IBGE – folha SD-23-V-D-I, apresentando detalhe da nascente do Ribeirão Angélica excluída do PETeR

Se observado em tempo poder–se-ia verificar que havendo um avanço de no máximo 200m na horizontal, todas as nascentes deste conjunto hidrográfico, estariam contempladas como sendo área do parque.

Com relação a utilização de pontos de cotas não comprovadas, para definir os limites do parque (Figura 2), sob a ótica da cartografia não haveria inconveniente técnico para locação e materialização dos mesmo, pois em se tratando de planimetria, não apresentam possibilidade da existência de erros (2D) se realizado com um GPS topográfico ou geodésico, auxiliado por um link de rádio.

Entretanto na altimetria, diante da postura cartográfica que vem sendo discutida e em vias de implantação por parte dos órgãos oficiais nacionais, responsáveis por estas adequações de referencial geodésicos para os trabalhos de medição de glebas, certamente será necessário retificar o valor destes pontos (altitude).

Esta necessidade é fruto da forma como estes pontos cotados foram plotados em carta topográfica através de restituidores aerofotogramétricos. Mesmo considerando uma acurada orientação absoluta e relativa sobre os modelos estereofotogramétrico que deram origem aos dados cartográficos em abordagem, deve-se levar em consideração que a altura de vôo preconizada para esta missão aerofotogramétrica que deu origem ao projeto BAGOMAPI, foi da ordem de 7.000 metros.

Desta forma, um ponto destes pode apresentar um erro de altimetria na ordem de meia dezena de metros, a depender de uma série de fatores tais como escala do modelo, acuidade visual do fotointerprete, precisão do estereorestituidor que em sua maioria eram mecânicos na época da restituição, dentre outros.

Portanto, é possível que para alguns destes pontos sequer exista a cota escrita na carta topográfica do IBGE utilizada.

O que se pode afirmar com isto é que, pelo fato de ser cota aproximada, ela(s) pode(m) numa situação de verificação, apresentar seus valores inferiores ou superiores aos prescritos na referida carta e assim sendo na primeira hipótese, rigorosamente não existir e no segundo caso ser corrigida para seu valor real mensurado.

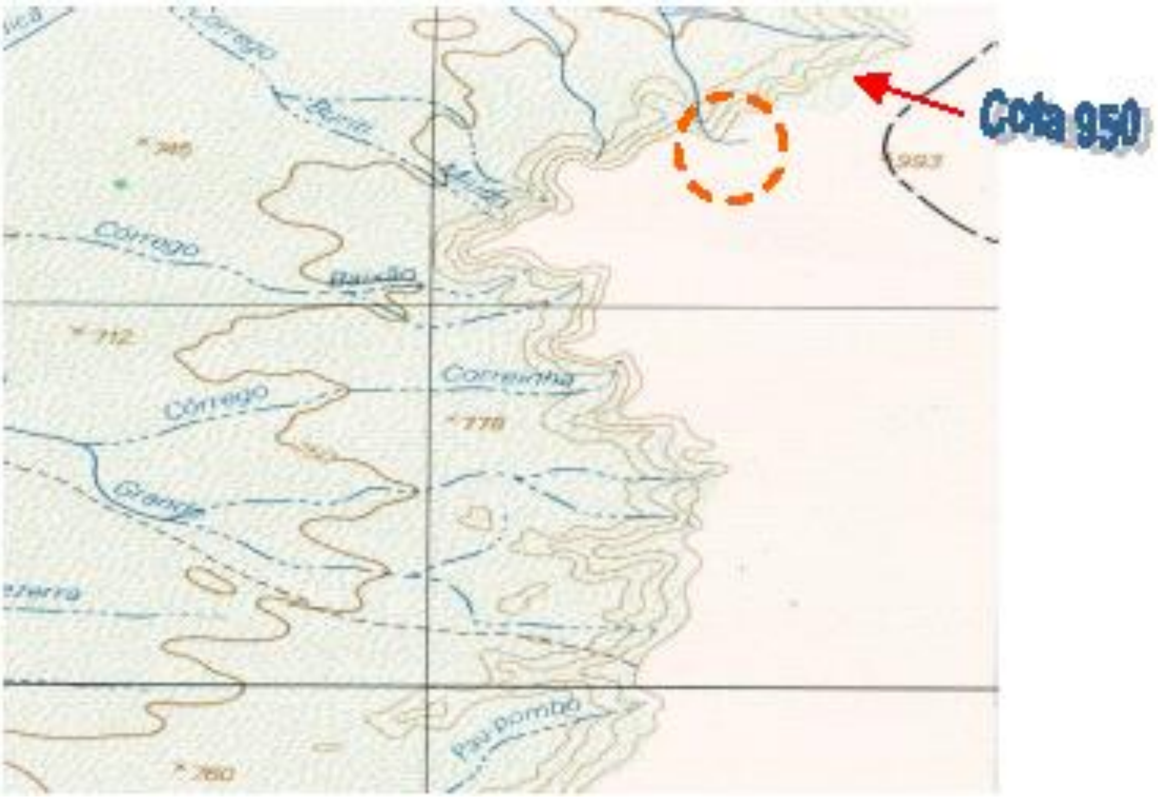

Figura 3 – Carta IBGE – folha SD 23-V-D-IV,apresentando detalhe da nascente do Ribeirão Angélica excluída do PeteR

Com relação a área do PETeR, ao invés de 50.000 hectares prescritos no documento de regulamentação do parque, foram encontrados 56.912,9923 hectares, um valor em muito superior ao descrito com um termo como aproximadamente.

E num país cuja topografia e geodesia encontram-se altamente tecnificadas acerca de duas décadas, não existe justificativa técnico-científica para um órgão governamental aprovar a criação de uma área de forma aproximada e com um erro dessa magnitude.

Mesmo porque a cartografia nacional vem ao longo dos anos se reestruturando no sentido de unificar seus documentos cartográficos, uma vez que a grande maioria destes encontram-se georreferenciados nos *Datum* Córrego Alegre e South American Datum-SAD69, como parte do Sistema Geodésico Brasileiro (IBGE, 1996) e num futuro próximo o Brasil terá seu referencial cartográfico num *Datum* geocêntrico "Sistema de Referência Geocêntrico para a América do Sul-SIRGAS", criado em 1993 numa conferência internacional.

Conclusão

Os critérios que a equipe técnica de implantação do parque utilizou, além de dificultar a materialização da demarcação do parque, deixou de contemplar 10 (dez) nascentes que são responsáveis pela formação de rios que originam cavernas no complexo do PETeR.

Também foi responsável por um erro da ordem de mais de 6.000 hectares quando da delimitação da área do parque.

Portanto, é chegado momento de um repensar urgente, no sentido de melhorar o planejamento e elaboração de projetos que tratam da delimitações das áreas que ficarão preservadas como patrimônio da humanidade.

No caso em questão se avançando mais um pouco, nesta questão de fórum técnico, verifica-se que a escolha da referida cota 950 como um dos limites do parque, deixou de envolver num mesmo projeto um trecho caracterizado por área de preservação permanente, situadas nas bordas das chapadas da Serra Geral de Goiás

Enfim, é de extrema importância a observância de regras básicas teóricas e práticas para o sucesso de um planejamento na criação de uma unidade de conservação, pois a dificuldades para construção de cercas obedecendo a uma curva de nível altamente sinuosa demanda pessoal especializado, equipamento e o pior, numa caso similar a este em abordagem, um tempo 20 (vinte) vezes maior do que o convencional e isto representa um custo.

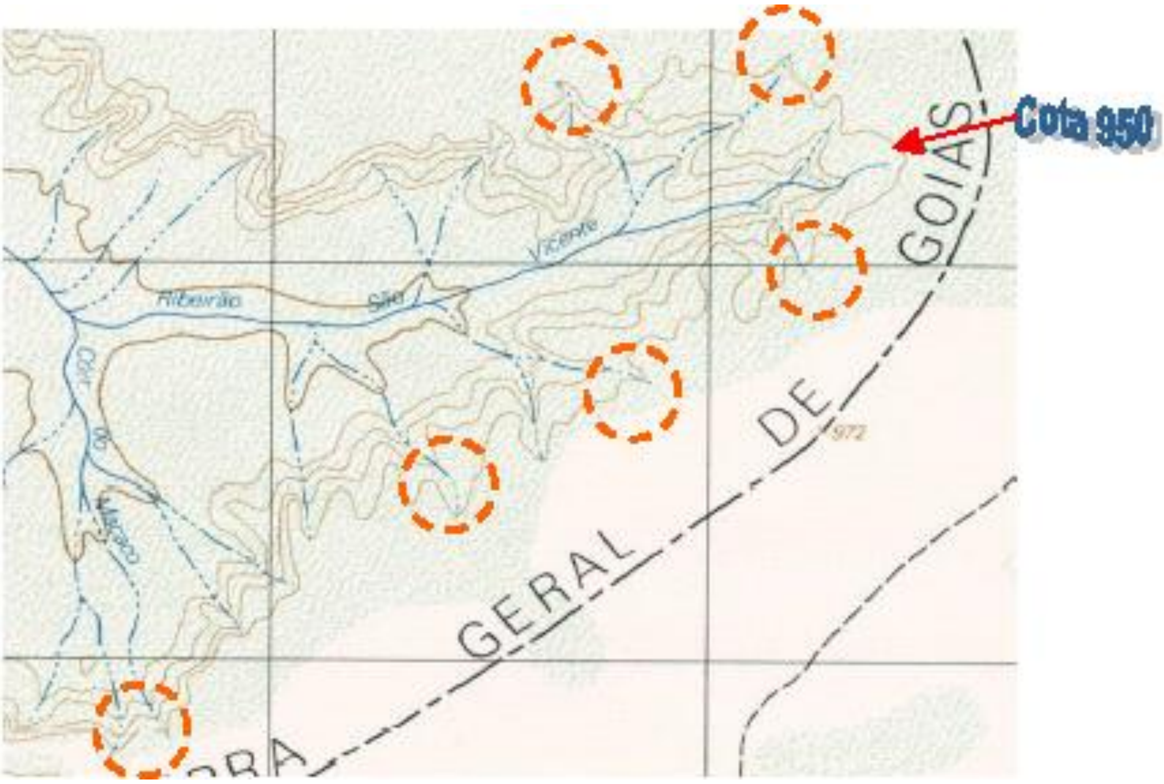

Figura 4 – Carta IBGE folha SD 23-V-D-IV, apresentando detalhe das nascentes do Ribeirão São Vicente e Córrego do Macaco, excluídas do PETeR

Recomendações

É imprescindível solicitar ajuda de profissionais que comprovadamente, apresentem conhecimentos sobre o assunto em questão;

Evitar sempre que possível pontos com cotas não comprovados para vértice de determinas áreas;

Recomendar curvas de nível para limite, apenas no caso de delimitar áreas remanescentes após a construção de lago artificial ou represa;

Ter ciência de que os erros cometidos por um mal planejamento, nem sempre podem ser corrigidos através de geotecnologias de última geração;

Usar sempre que possível hidrografia ou pontos hidrográficos bem definidos e estradas atuais como limites físicos destas áreas;

No momento do planejamento, deverá ser realizado um Cadastro Técnico Rural, reportando no mínimo com os limites e uso do solo de cada propriedade rural existente na área que será desapropriada.

Agradecimentos

Maria Célia Luiz da Silva, presidente da ACAN - São Domingos/GO e Jackson Ferreira Passos, pela orientação nos trabalhos de campo.

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Mapa e Roteiro Ecoturístico do Complexo de Cavernas do Parque Estadual de Terra Ronca - PEteR

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Summary

The objective was to define an ecotouristic itinerary for the Terra Ronca State Park caves, in the municipality of São Domingos, Goiás. It was drawn a map using ground survey, topographical charts, sattelite Landsat 7 images, and GPS equipment. The map localizes caves, park limits, roads, hydrography, and the São João Batista village. The information obtained is intended for ecotourism development and the Terra Ronca Park management plan.

1. Introdução

Criado em 1989 o Parque Estadual de Terra Ronca é uma unidade de conservação de proteção integral, localizado no Município de São Domingos na região nordeste do Estado de Goiás, entre o retângulo envolvente descrito pelas coordenadas geográficas de Latitude Sul 13º 28’ 28” e 13º 50’09” e de Longitude Oeste 46º 08’ 47” e 46º 28’ 45”, estando distante aproximadamente 550 km de Goiânia e 350 km de Brasília.

Com área de 56.912,9923 hectares, oferece um ambiente apropriado a prática de ecoturismo ou turismo de aventura. No contexto paisagístico o parque apresenta muitas atrações como sua vegetação típica do cerrado, a fauna, os cursos d’água mas o destaque é o complexo de cavernas e deste as grutas de Terra Ronca e a Lapa da Angélica, considerando apenas a vocação turística. Com relação ao patrimônio cultural, a Romaria do Bom Jesus da Lapa realizada na Lapa de Terra Ronca I é a principal atração turística.

Com o propósito de favorecer o desenvolvimento do ecoturismo no complexo de cavernas do PETeR e fornecer subsídios para o plano de manejo, o trabalho teve como objetivo traçar um mapa com os limites do parque, a localização das cavernas, as estradas, a hidrografia e indicar um roteiro de deslocamento para o ecoturista dentro do parque, haja visto que a seqüência dos componentes da paisagem durante o trajeto para as cavernas já estão definidos, em função da existência de um rodovia estadual, a GO-108, que atravessa o parque e cujo traçado está voltado apenas para o tráfego comercial.

2. Metodologia

Para a elaboração deste trabalho foram utilizados: cartas topográficas do Instituto Brasileiro de Geografia e Estatística – IBGE, folhas SD-23-V-D-I e SD-23-V-D-IV na escala de 1:100.000; GPS de navegação GARMIN 12XL, imagem digital do satélite Landsat 7, software SPRING 3.4 (INPE); mesa digitalizadora A-0 (Digigraf) e cópia do Diário Oficial do Estado de Goiás, de 27 de agosto de 1996, que publica o Decreto n° 4.700 de 21 de agosto de 1996, que regulamenta o PETeR. As atividades foram assim desenvolvidas: 1. Digitalização da base cartográfica da área de estudos, envolvendo os seguintes geotemas: malha hidrográfica; altimetria, curvas de nível e pontos cotados e malha geodésica. 2. Utilização do Diário Oficial supra citado, para plotagem dos vértices que determinam os limites físicos do parque, através de coordenadas geográficas, nele descritas. 3. Levantamento em campo do conjunto de bocas de cavernas existentes na área de estudos e do traçado da trilha ecoturística, considerando os seguintes parâmetros: beleza cênica, fauna e flora local, malha rodoviária, infraestrutura de apoio ao ecoturista e facilidade de acesso as cavernas (GRIFFTH.& VALENTE, 1979).

3. O Parque

Parque Estadual de Terra Ronca foi criado pela lei estadual n° 10.879 de 07 de julho de 1989, publicada em 19 de julho de 1989, para preservar a flora, a fauna, os mananciais e, em particular, as áreas de ocorrência de cavidades naturais subterrâneas e seu entorno protegendo sítios naturais de relevância ecológica e reconhecida importância turística.

3.1 - As cavernas do parque

No complexo estão grandes sistemas de cavernas do Brasil como o sistema Angélica – Bezerra, o sistema Terra Ronca – Malhada e o sistema São Mateus – Imbira. Na distribuição em províncias espeleológicas está localizado na Província Espeleológica do Bambuí, considerado o maior conjunto de ocorrência de calcários favoráveis a presença de cavernas no Brasil. As rochas deste grupo pertencem ao período Pré-Cambriano superior, com 500 a 600 milhões de anos. A província se divide em cinco distritos espeleológicos, com o complexo de cavernas do parque pertencendo ao Distrito de São Domingos (LINO & ALLIEVI, 1980), que é composto pelos municípios de Aurora do Norte (TO), Campos Belos (GO), São Domingos (GO), Guarani de Goiás (GO) e Posse (GO). São limites ao norte a cidade de Dianópolis (TO), ao sul a cidade de Formosa (GO), a leste a Serra Geral de Goiás (GO/BA) e a oeste a Serra Geral do Paranã (GO/TO) (DUTRA, 1996. p.15).

Na lista das trinta maiores cavernas do Brasil o parque possuí sete: a Lapa da Angélica com 14.100m de extensão, sendo considerada a 4a mais longa caverna do Brasil; a Lapa de São Vicente, a 6a mais longa do Brasil com 13.555m de extensão; a Lapa São Mateus III em 8o lugar com 10.828m de extensão; a Lapa do Bezerra com 8.250m de extensão classificada em 13a lugar; o Sistema Terra Ronca II/Malhada com 7.500m de extensão sendo a 16a classificada; a Lapa de São Vicente II a 24a em extensão com 4.550m e a Lapa do São Mateus II/Imbira com 4.106m de extensão a 28 a mais longa caverna no Brasil (BAMBUÍ, 2001).

Também fazem parte do complexo espeleológico do parque, além das cavernas já relacionadas, a Lapa do São Bernardo (GO-2) com 1.730m de desenvolvimento; a Lapa do Oco (GO-13) com 920m de desenvolvimento e a Lapa do Passa-Três (GO-14) também com 920m de desenvolvimento, entre inúmeras outras, todas cadastradas na Sociedade Brasileira de Espeleologia-SBE (Mapa roteiro).

3.2 A Lapa da Terra Ronca e a da Angélica

Terra Ronca era e ainda é a mais conhecida das cavernas do parque, sobretudo pela tradicional festa religiosa e manifestação popular da Romaria do Bom Jesus, que acontece todos os anos nos dias 5 e 6 do mês de agosto.

A principal entrada de Terra Ronca é denominada de Lapa da Terra Ronca I, sendo atravessada pelo Rio Lapa e possuindo uma das maiores entradas de caverna do país com 100 m de largura por 84 de altura.

De acordo com relatos de moradores locais e a tradição dos romeiros, Terra Ronca possuí poderes terapêuticos alcançados ou através da ingestão de água do Rio Lapa, ou por permanência em seu interior no salão denominado Hospital.

Para a realização da romaria, no interior da entrada principal de Terra Ronca foi construído um altar onde são celebradas missas, casamentos e batizados.

No conjunto de cavernas do PETeR, a Lapa da Angélica é a mais extensa , entretanto, o que a torna atrativa para o ecoturismo é a grande quantidade de salões e cortinas, com variedades de espeleotemas que podem ser visitados em uma área reduzida e de fácil acesso.

A Lapa da Angélica recebeu o nome do rio que lhe deu origem, sendo também muito visitada por estar próxima da sede do município de São Domingos, a 22 km por rodovia não pavimentada.

4. A Vegetação Do Parque

A vegetação é caracterizada por cerrados, campos cerrado, campos sujos, matas de galeria, floresta tropical caducifólia e veredas (IBGE, 1995).

4.1 Cerrado

Cerrado é o termo genérico para nomear um grupo de formas de vegetação que se apresenta segundo um gradiente de biomassa, cuja menor estratificação é denominada de campo limpo, sendo seguindo pelo campo sujo de cerrado, campo cerrado, o cerrado *stricto sensu* e o cerradão, esse último uma formação florestal (floresta seca) e os demais campestres. As formações campestres possuem um estrato contínuo de herbáceas revestindo o solo e um descontínuo de arbustos e árvores. Não existe a distinção exata entre os gradientes que vão das formas campestre à florestal (RIZZINI, 1962; (FERRI,1977) RIBEIRO & WALTER,1998; HERINGER *et al*, 1977)

4.2 Flora

Com vistas a interpretação ambiental no PETeR, foi realizado um levantamento florístico que constatou que a flora do parque é bastante diversificada com inúmeras plantas medicinais como a quina (Strychnos pseudo-quina St. Hil.), a sucupira (*Pterodon pubescens*), a faveira *(Dimorphandra mollis* Benth.), o barbatimão (*Stryphnodendron adstringens*), a emburana (*Amburana cearensis* (Fr. All.) A. C. Smith) e outras. Frutíferas como o caju (*Anacardium giganteum* Hanc. Ex. Engl.) , a cagaita (*Eugenia dysenterica* DC.), o puçá (Mouriri elliptica, a mangaba (*Hancornia speciosa* Gomez), o pequi (*Caryocar brasiliense* Camb.), o baru (*Dipteryx alata* Vog.) e outros. Árvores de grande porte e fornecedoras de madeira como: aroeira (*Lithraea molleoides* (Vell.) Engl.), ipês roxo, amarelo e branco (*Tabebuia* spp.), peroba (*Aspidosperma pyrifolium* Mart.), jequetibá (*Cariniana estrellensis* (Raddi) Kuntze), pau d'oleo (*Copaifera langsdorffii* Desf.), brauna (*Schinopsis brasiliensis Engl*.), cedro (*Cedrela fissilis* Vell.) e muitas outras. Palmeiras como buriti(*Mauritia flexuosa*), babaçu (*Orbignya speciosa*), guariroba (*Syagrus oleraceae*) e outras. (Braga, 1976; GOODLAND & FERRI, 1979 e LORENZI, 1998).

5. FAUNA

São encontrados inúmeros animais como anta (*Tapirus terrestris*), veados de diversas espécies, onça preta e a pintada, (Panthera onca); a vermelha, (*Felis concolor*), macaco-prego (Cebus apella), micos (*Callithrix* sp), lobo guará (*Chrysocyon brachyurus*), raposas (*Dusicyon vetulus*) entre outros. Entre as aves o pica-pau-do-campo (*Colaptes campestris*), a alma-de-gato (*Piaya cayana*), a curicaca (*Theristicus caudatus*), a coruja buraqueira (*Athene cunicularia*), a ema (*Rhea americana*), a perdiz (*Rhynchotus rufescens*), a maracanã (*Arara nobilis*), várias espécies de psitacídeos, beija-flores de várias espécies, a seriema (*Cariama cristata*), a codorna (*Nothura maculosa*) e muitas outras mais (ANTAS & CAVALCANTI, 1988 e ROCHA *et at* 1990).

6. A Hidrografia

De acordo com o Zoneamento Geoambiental e Agroecológico do IBGE, 1995, o parque está localizado em uma região que compreende o divisor de água das bacias hidrográficas dos rios São Francisco e Tocantins. A extensa Serra Calcária onde se encontram as cavernas, que compõem o principal patrimônio natural do parque, é atravessada por uma rica rede hidrográfica, Rio São Mateus, Ribeirão Angélica,Rio da Lapa, o Ribeirão São Vicente, Ribeirão Palmeiras, Rio São Bernardo, dentre outros, que possuem suas nascentes no sopé da Serra Geral de Goiás.

Os rios correm no sentido leste-oeste indo desaguar no Rio Paranã, integrante da bacia do rio Tocantins.

Exceto Terra Ronca que é atravessada pelo Rio da Lapa, via de regra as demais cavernas recebem o nome do rio que as atravessa.

7. Roteiro Ecoturístico

Para serem desenvolvidas atividades ecoturísticas no PETeR, é condição *sine qua non* que seja na modalidade de passeio guiado, considerando os riscos inerentes a expedições espeleológicas e a necessidade de equipamentos adequados (Figura 1).

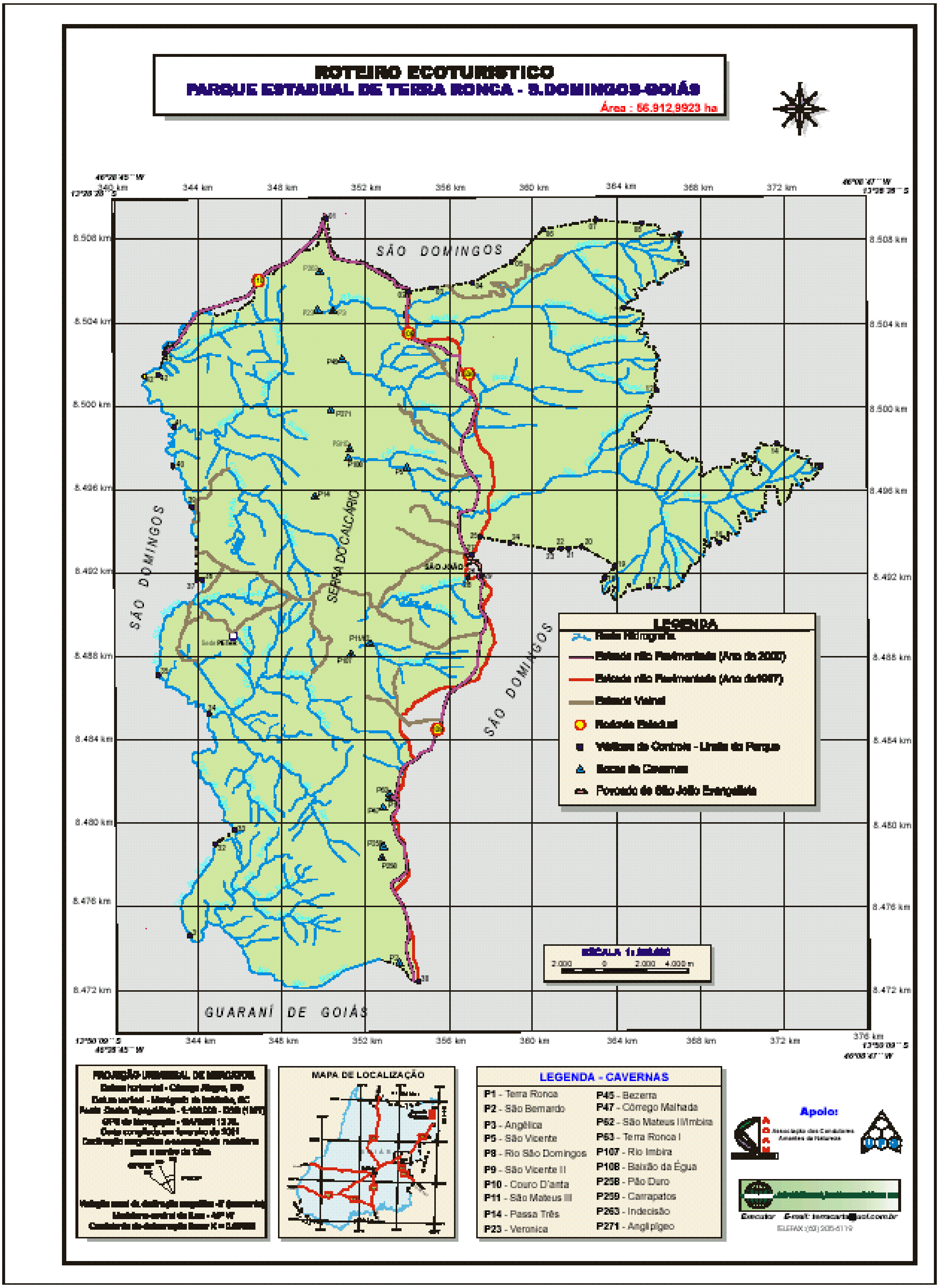

Figura 1 – Roteiro ecoturístico, localizando as principais cavernas do PETeR.

7.1 O Acesso ao parque

O acesso ao parque deverá ser feito pela estrada estadual GO-108, uma via sem pavimentação que interliga as cidades de São Domingos e Guarani de Goiás. Na rodovia não existe sinalização indicativa de distância ou de acesso as cavernas do parque. Em determinados trechos algumas placas informam que a área pertence ao parque mas sem outros dados.

7.2 O Acesso as cavernas

Para o acesso as cavernas que compõe o parque é necessário orientação de quem conheça bem a região e a localização das mesmas, pois apesar de estarem situadas próximas a rodovia GO- 108, a exceção de Terra Ronca e Angélica, para as demais se faz necessário utilizar trilhas com trechos de difícil acesso.

O início do passeio poderá obedecer a dois sentidos. Uma primeira sugestão seria partindo de São Domingos para Guarani de Goiás e a segunda no sentido inverso, independentemente de distância a ser percorrida, isso porque a Lapa da Terra Ronca está localizada na região central do parque a aproximadamente 50 km da cidade de São Domingos, e a Lapa da Angélica no extremo norte do parque a 22 km da sede do município.

Se o acesso for via cidade de São Domingos, para a primeira hipótese, o circuito teria inicio pelo complexo Angélica, em seguida se deslocaria até o povoado de São João Evangelista ou proximidades da caverna Terra Ronca, para no dia seguinte prosseguir a expedição pelas cavernas Terra Ronca I e II. Em caso de um passeio mais prolongado, o próximo destino seria uma visita a caverna São Bernardo.

Para a segunda hipótese, o passeio teria inicio pelo complexo cavernas Terra Ronca I e II. Havendo tempo e interesse a expedição permaneceria por mais um dia nas proximidades da Lapa de Terra Ronca ou no povoado para num segundo dia de visitas conhecer a caverna São Bernardo e no terceiro se deslocar a Lapa da Angélica.

No caso de apenas dois dias de excursão no dia seguinte a visita a Terra Ronca iria em direção ao complexo Angélica passando pelo povoado de São João Evangelista.

As demais cavernas do complexo são mais apropriadas para visitação por parte de estudiosos ou espeleologistas experientes.

8. Agradecimentos

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Estratégias para Conservação das Cavernas Brasileiras

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Abstract

The Brazilian caves are more and more in the menace of destruction, because the degradation caused by disordered urban expansion, lack of consistent conservation plans and guidelines related to the preservation of speleological patrimony. Trying to revert this view, it is suggested new strategies that identify priority areas, besides governmental politics guidelines that allow the creation of new conservation units, effectively guaranteeing the protection of the brazilian speleological patrimony. Besides it, one process of consciousness must be made trying to obtain more compromise of the society concerning this patrimony.

Resumo

As cavernas brasileiras encontram-se cada vez mais ameaçadas. Isto se deve ao alto grau de degradação verificado no país, principalmente devido à ocupação desordenada, à falta de planejamento e à desarticulação por parte dos diversos segmentos da sociedade. Para fazer frente a esse processo, sugere-se a adoção de novas estratégias, que contemplem a identificação de áreas prioritárias, bem como a definição de políticas públicas que visem a criação de novas unidades de conservação, buscando garantir a efetiva proteção do patrimônio espeleológico nacional. Paralelamente, todo um processo de conscientização deve ser iniciado buscando um maior comprometimento da sociedade como um todo para com este patrimônio.

Introdução

A maioria das nações do mundo, preocupadas com a conservação e manejo dos seus ecossistemas nativos e das espécies que neles habitam, vêm há muito estabelecendo medidas legais para proteger ou regular o uso da terra em seus territórios. Dentre os principais instrumentos regulatórios encontram-se as unidades de conservação ou áreas protegidas. Apesar de se tratar de um instrumento bastante antigo no trato dessas questões, a expansão do número de áreas protegidas no mundo foi considerado como uma estratégia particularmente vital para a conservação dos recursos naturais do planeta a partir do III Congresso Mundial de Parques, realizado em Bali em 1982. A Declaração de Bali enfatiza a importância das áreas protegidas como elementos indispensáveis para a conservação da biodiversidade, já que asseguram a manutenção de amostras representativas de ambientes naturais, da diversidade de espécies e de suas variações genéticas, além de promover oportunidades para a pesquisa científica, educação ambiental e turismo (FONSECA, 1997).

Deve-se considerar ainda a Convenção Sobre Diversidade Biológica, um dos documentos mais importantes que trata da conservação *in situ*, que estabelece como estratégias:

> a) estabelecer um sistema de área protegida ou áreas onde medidas especiais precisem ser tomadas para conservar a diversidade biológica;
>
> b) desenvolver, se necessário, diretrizes para a seleção, estabelecimento e administração de áreas protegidas ou áreas onde medidas especiais precisem ser tomadas para conservar a diversidade biológica.

Desta forma é unânime a posição de que a única forma de se garantir a perpetuação de algumas amostras dos diferentes ambientes é através da adoção de medidas que instituam áreas naturais protegidas. Em relação ao patrimônio espeleológico deve-se destacar, ainda, o escasso conhecimento sobre o assunto, e a carência de estudos principalmente relacionados à fauna cavernícola e suas inter-relações. Salienta-se que muitas espécies encontradas nas cavernas tem características específicas, sendo diversas potencialmente endêmicas e novas para a ciência. Também as informações disponíveis sobre áreas cársticas e suas diferentes interfaces são insuficientes.

Instrumentos Jurídicos

Apesar da atuação da comunidade espeleológica brasileira há muitos anos, a proteção das cavernas em termos jurídicos, surgiu muito posteriormente. Até o ano de 1987 não existiam instrumentos legais específicos de proteção, com isso apenas uma parcela das cavidades eram protegidas através do uso e interpretação indireta de leis que disciplinavam outros temas correlacionados (SESSEGOLO e THEULEN, 1990).

Após esse período, diferentes instrumentos jurídicos estão à disposição para proteção a das cavernas, destacando-se resumidamente (SESSEGOLO e THEULEN, 1990):

Ω Resolução n° 05 de 06/08/1987, do Conselho Nacional do Meio Ambiente - CONAMA, que instituiu o Programa Nacional de Proteção ao Patrimônio Espeleológico, tratando de assuntos relacionados à preservação do patrimônio espeleológico brasileiro;

Ω Constituição Federal de 1988, que considerou as cavidades naturais subterrâneas como bens da união;

Ω Portaria Normativa n° 887, de 15/06/1990, do IBAMA, que constituiu o Sistema Nacional de Informações Espeleológicas e limitou o uso das cavidades naturais subterrâneas apenas nos casos de estudos técnicos científicos e atividades de cunho espeleológico, étnico-cultural, turístico, recreativo e educacional;

Ω Decreto n° 99.556, de 01/10/90, dispõem sobre a proteção das cavidades naturais subterrâneas existentes no território nacional, entre outras providências; e

Ω Portaria n° 057, de 05/06/97, do IBAMA, que criou o Centro Nacional de Estudo, Proteção e Manejo de Cavernas – CECAV.

Estratégias para Conservação

Embora diferentes instrumentos jurídicos estejam à disposição, as cavernas efetivamente continuam desprotegidas. A única maneira eficiente para a conservação do patrimônio espeleológico brasileiro é através da criação e implantação de unidades de conservação de uso indireto, especialmente as de domínio público. Ressalta-se que as áreas protegidas particulares podem e devem ser incentivadas, embora não substituam as do poder público que exercem um papel fundamental na conservação, principalmente quando trata-se de áreas cársticas maiores.

Tem-se lutado para o estabelecimento de unidades de conservação a nível municipal, estadual e federal, ou mesmo particular, porém estas ações são esparsas e possuem pouca expressividade. Há que se reconhecer a importância da recente criação de unidades de conservação federais que abrigam cavernas, tais como Serra da Bodoquena – MS, Vale do Peruaçu – MG e Serra das Confusões – PI, porém muitas das áreas cársticas importantes ainda não foram contempladas.

Muitos autores tem destacado que o Brasil está no último momento de conseguir estabelecer unidades de conservação visando resguardar a elevada riqueza do país. Não obstante, a situação das cavernas brasileiras não é diferente, estas encontram-se no último limiar possível para se definir uma forma mais eficiente de conservação.

Neste caso, a melhor forma de se planejar áreas protegidas com cavernas é através do entendimento das áreas cársticas, não há como se estabelecer estratégias de conservação sem considerar este item como fundamental. Se não se idealizar áreas com este cuidado perder-se-á para sempre a chance de se resguardar áreas relevantes sob o enfoque conservacionista.

Outro ponto a se destacar é que, quando não se puder trabalhar com os sistemas cársticos como um todo, devido às grandes extensões, deve-se minimamente contemplar as bacias hidrográficas onde o patrimônio esteja inserido.

Para o caso de cavernas que possuam grande atrativo cênico e que possuam condições para uso público, este fator deve ser considerado relevante devendo sempre conciliar o uso à conservação do ambiente. Aqui vale destacar que para as cavidades que já possuem uma visitação instituída, mesmo que de forma deficiente, devem ser priorizados estudos que definam o melhor manejo a ser implantado. Não há como proibir ou impedir a visitação, inclusive esta deve ser entendida como uma estratégia de conservação bastante utilizada e reconhecida, como lembra TAKAHASHI (1998): “a crescente demanda por atividades recreativas em unidades de conservação, torna de fundamental importância o planejamento do uso público destas áreas. Para tanto, estas atividades devem estar baseadas em instrumentos de gestão cujos principais objetivos de manejo das unidades são: manter a integridade dos ecossistemas, e dos valores culturais destas áreas, além de promover a conscientização do público e melhorar a qualidade de vida da população".

Salientando que muitas cavernas talvez sejam alguns dos poucos lugares no mundo que ainda não tenham tido nenhuma forma de interferência humana, ou em baixíssima escala, devem ser identificadas ainda aquelas a serem mantidas sem uso público.

Sistema Nacional de Unidades de Conservação

Considera-se Sistema Nacional de Unidades de Conservação o conjunto de unidades, que, devidamente selecionadas, planejadas e manejadas como um todo é capaz de viabilizar em objetivos nacionais de conservação. O sistema refere-se, portanto, a um conjunto de unidades articuladas tanto geograficamente como por categorias de manejo (MILANO, 1990)

Ao se analisar a implantação do sistema brasileiro de unidades de conservação, nota-se que a época de criação e a sua distribuição geográfica estão intimamente ligadas à diferentes etapas do processo de desenvolvimento do país. Em geral, a criação de parques nacionais ou outras áreas protegidas, precede ou coincide o avanço de frentes pioneiras sobre regiões virgens. Desta forma, o desenvolvimento estaria impulsionado a criação de áreas naturais protegidas. Contraditoriamente, este mesmo desenvolvimento ameaça a existência das áreas protegidas já estabelecidas (BERNANDES, 1983).

Após tramitar quase 10 anos foi aprovada em agosto de 2000 a Lei 9.985 que institui o Sistema Nacional de Unidades de Conservação. Analisando-se a lei, em termos de proteção total de cavernas, as categorias mais indicadas para a criação de unidades de conservação são Parque e Monumento Natural. Vale destacar que atualmente a lei deixa o precedente do poder público criar monumento natural em áreas públicas ou privadas, embora nestas últimas deve-se ter um cuidado especial, haja vista que muitas das áreas tem um valor único e expressam uma importância que extrapola a propriedade particular.

A categoria Reserva Particular do Patrimônio Natural, devido a um equívoco da legislação, acabou sendo enquadrada em uso sustentável, destacando que o que a definia como tal foi vetado na leitura final da lei, que acabou por propiciar uma interpretação confusa. Resumidamente, deve-se lembrar que embora tenha sido enquadrada como uso sustentável, continua tendo sua base como de proteção total, podendo ser utilizada como uma das alternativas para a proteção de cavidades naturais subterrâneas em áreas privadas.

Discussões Finais

Todas as áreas protegidas contribuem para a conservação da biodiversidade, mas a modificação de critérios de seleção e de sua administração irá aumentar a sua contribuição. Precisam ser estabelecidos objetivos explícitos para a conservação da biodiversidade em cada área protegida e, na maioria dos casos, estas precisam ser melhor integradas ao bem-estar social, ambiental e econômico (WRI, 1992).

Considerando a riqueza do patrimônio espeleológico brasileiro, é fundamental que se estabeleçam medidas e estratégias políticas que garantam a conservação das cavernas através da criação e implantação de novas unidades de conservação, sempre considerando sua especificidade correlacionada às diferentes categorias de manejo.

As estratégias de guardar e proteger amostras significativas dos mais diversos ecossistemas contra a ocupação irracional têm, assim, contemplado as finalidades ambientais, científicas, culturais, recreativas e mesmo econômicas intrínsecas às áreas destinadas a esse fim, que devem ter seu uso e administração planejados de maneira que sua perpétua conservação seja garantida. Para isso, conceitos e técnicas mundialmente testadas e discutidas devem ser empregadas (MILANO, 2000).

Ressalta-se que além dessas iniciativas devem ser estabelecidos, paralelamente, programas de educação ambiental e de difusão de informações que propiciem o conhecimento da sociedade em geral sobre a importância das cavernas e de sua conservação.

O patrimônio espeleológico brasileiro somente será efetivamente conservado, se políticas públicas forem concebidas contemplando ações que garantam eficientemente a conservação e a proteção das cavidades naturais do país.

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Manejo do Parque Municipal da Gruta do Bacaetava, Colombo – PR/Brasil

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Abstract

The Gruta do Bacaetava (PR-0003) is one of the most known and visited cave, in the state of Paraná, because its nearness of the urban area of Curitiba and easy access. Specifics researches, involving different areas of study, were made aiming to provide information for an adequate management of the Gruta do Bacaetava. The results of this research helps the creation of the Parque Municipal do Bacaetava, consciousness the municipality about its role in the preservation of this speleological patrimony.

Resumo

A Gruta do Bacaetava (PR–0003) é uma das cavidades mais conhecidas e visitadas do Estado do Paraná, devido à sua proximidade de Curitiba e o fácil acesso. Com o objetivo de ordenar o uso desta gruta, realizaram-se levantamentos interdisciplinares que embasaram a definição do manejo adequado. O resultado desse planejamento, entre outros aspectos, conduziu à criação do Parque Municipal da Gruta do Bacaetava, como reconhecimento da municipalidade em relação à conservação desse sítio espeleológico.

Localização

O município de Colombo localiza-se na porção leste do estado do Paraná, no Primeiro Planalto Paranaense, inserido na Região Metropolitana de Curitiba. A Gruta do Bacaetava, encontra-se na porção norte do município, na divisa com o município de Rio Branco do Sul, com sua ressurgência localizada nas coordenadas 25º13´54"S e 49º12´26"W.

Materiais E Métodos

Estudos específicos foram realizados na Gruta do Bacaetava, visando fundamentar a proposição de manejo, tais como o levantamento histórico e uma caracterização ambiental, englobando aspectos físicos (destacando-se o mapeamento geoespeleológico e topográfico) e biológicos. Também avaliou-se a situação ambiental da cavidade e de seu entorno, incluindo a bacia à montante.

Com base nos resultados obtidos, apontou-se estratégias e ações visando a conservação da Gruta do Bacaetava e seu manejo adequado.

Em relação ao zoneamento, foram utilizadas as mesmas zonas propostas para parques nacionais (Decreto 84.017, de 21/09/79).

Resultados

Condicionantes do Meio Físico

Os estudos efetuados por GENTHNER e RABELO *in* ECOSSISTEMA CONSULTORIA AMBIENTAL/GEEP-Açungui (1999), concluíram que a caverna apresenta-se intensamente condicionada aos planos de acamamento e planos de fraturas da rocha carbonatada. Identificou-se como maior risco geológico da caverna, áreas onde o metadolomito maciço possui um sistema de fraturas muito intenso. É o caso do teto próximo ao sumidouro, onde já pode ser observada uma grande concentração de blocos que se desprenderam do teto, caracterizando este setor como área de risco para o visitante.

Estes autores também identificaram mudanças ambientais causadas pela mineração de calcário existente à montante da bacia do rio Bacaetava e de seus afluentes, as quais afetam diretamente a gruta do

Bacaetava. Destaca-se, entre as alterações, o assoreamento e a turbidez do rio Bacaetava. A existência de lavras de calcário em atividade nas proximidades, provoca a instabilidade física do maciço rochoso no qual a gruta se insere. Verificou-se no sumidouro da Gruta do Bacaetava a existência de sistemas de fraturas suscetíveis a abalos provocados por detonações. Desta forma, indicou-se para se evitar o fluxo de visitantes nas proximidades do sumidouro, devido ao risco de desabamento.

Condicionantes do Meio Biótico

Nos estudos efetuados por PINTO-DA-ROCHA (*in* ECOSSISTEMA CONSULTORIA AMBIENTAL/GEEP-Açungui, 1999), foram registradas 39 espécies, representando a diversidade que normalmente se observa nas cavernas paranaenses (vide PINTO-DA-ROCHA, 1996). Nenhum animal especializado para a vida subterrânea (troglóbio) foi registrado. Não foram constatados exemplares vivos de morcegos hematófagos, apenas guano seco, indicando que há pelo menos alguns meses não existia uma colônia dessa espécie na gruta. Destacou-se a presença de lontra na Gruta do Bacaetava por tratar-se de uma espécie ameaçada de extinção. Com base nestes estudos, formulou-se as seguintes recomendações para o manejo com relação à fauna cavernícola:

definir um caminhamento para visitação;

promover periodicamente a retirada de produtos estranhos ao ambiente cavernícola;

promover a manutenção e o adensamento da vegetação do entorno da caverna;

estabelecer um horário de visitação que não perturbe os hábitos alimentares dos morcegos;

evitar a matança de morcegos hematófagos.

Situação Ambiental da Gruta do Bacaetava

A Gruta do Bacaetava vem sofrendo com a visitação sem controle há várias décadas, encontrando-se muito lixo em seu interior. Também, como consequência, verifica-se muitas pichações, principalmente nas zonas de entrada.

Rejeitos, de diversas granulometrias, resultantes das atividades de mineração existentes à montante da gruta, são carreados pelo rio e por drenagens temporárias formadas por enxurradas. Este tipo de material compõe grandes bancos de sedimentos no interior da caverna, que já chegaram a provocar inclusive o represamento do rio.

Manejo e Desenvolvimento

Fatores Condicionantes e Suposições

Através da análise dos recursos naturais e de outras características, a área em questão foi enquadrada na categoria de manejo Monumento Natural dada a singular importância da caverna como principal elemento. Devido ao fato dessa categoria não ser reconhecida no Brasil na época da realização do estudo, sugeriu-se a adoção da categoria parque, a nível municipal.

A criação de um Parque Municipal da Gruta do Bacaetava é de grande importância considerando-se a relevância da conservação dessa caverna em relação ao município de Colombo e à Região Metropolitana de Curitiba.

A Gruta do Bacaetava possui grande importância histórica, tendo sido citada por diversos autores, desde o século passado e possuindo um vínculo muito forte com a comunidade da região. Suas dimensões, sua facilidade de acesso e proximidade com a sede do município e com a cidade de Curitiba, possibilitam a realização de atividades de recreação e educação ambiental a um amplo público. Acaba, dessa forma, por representar a cavidade natural subterrânea mais acessível e mais próxima à população dessa região.

Apesar de se encontrar relativamente alterada devido à ação antrópica pelo fato de inexistir orientação ou fiscalização na área, resguarda ainda considerável beleza cênica e espeleotemas de grande porte, representando um local potencial para uso público e fundamental para a conscientização da importância da conservação desses bens da União.

Determinou-se como fatores condicionantes para o Parque Municipal da Gruta do Bacaetava:

a área do entorno direto do Parque é utilizada predominantemente para a exploração de calcário; considerando-se a proximidade desta atividade em relação ao parque, poderá ocorrer sua interferência nos processos naturais ali ocorrentes;

a bacia do rio Bacaetava à montante da caverna encontra-se bastante alterada, principalmente devido ao significativo uso de áreas em suas margens para extração de calcário, além do uso agropecuário; e

considerando-se os processos dinâmicos, o manejo ora proposto bem como o zoneamento estão sujeitos à alterações.

Ainda consideraram-se as seguintes suposições:

com a crescente ocupação do município de Colombo, a exploração de calcário inadequada, o desmatamento, bem como outras formas de degradação ambiental correm o risco de serem ampliadas nas áreas circunvizinhas ao Parque, comprometendo ainda mais a qualidade da bacia;

as nascentes do rio Bacaetava localizam-se fora da área do Parque, estando essas vulneráveis à ação de poluentes, bem como do assoreamento proveniente do manejo inadequado do solo; e

com a oficialização da criação do Parque e a implantação de novas infra-estruturas, poderá ocorrer um aumento no número de visitantes, o que poderá comprometer a conservação dos recursos naturais.

Recomendou-se ainda, que seja considerada uma Zona de Transição, que englobe a bacia do rio Bacaetava e seus afluentes à montante da caverna e a área de influência da Gruta do Bacaetava.

Objetivos de Manejo

Foram definidos como objetivos de manejo do Parque Municipal da Gruta do Bacaetava:

conservar em estado natural uma amostra do Patrimônio Espeleológico da região; recuperar e conservar a cobertura vegetal nativa, especialmente a existente sobre a Gruta do Bacaetava; fomentar atividades de pesquisa científica e monitoramento ambiental; e possibilitar atividades de recreação, educação e conscientização ambiental.

Zoneamento

Para a definição do zoneamento do Parque Municipal da Gruta do Bacaetava foram considerados os levantamentos prévios de caracterização da área, bem como as recomendações e considerações da equipe interdisciplinar.

Sendo assim, o parque resultou ordenado em quatro zonas distintas: Zona de Uso Extensivo, Zona de Uso lntensivo, Zona de Uso Especial, Zona de Recuperação, conforme pode ser visualizado nas Fig. 1 e 2.

Zona de Uso Extensivo

Possui como objetivo geral manter o ambiente natural ou pouco alterado, propiciando facilidades de acesso ao público com fins educativos e recreativos em escala extensiva. Possui como objetivos específicos: conduzir e orientar os visitantes possibilitando o desenvolvimento da atividades de recreação controladas; possibilitar ao visitante o conhecimento e entendimento dos contrastes da natureza através da interpretação da mesma em áreas distintas; e conservar amostras significativas dos ambientes existentes.

Zona de Uso Intensivo

Possui como objetivo geral promover uma maior integração entre o homem e a natureza, e propiciar lazer intensivo, com o mínimo de impacto negativo ao ambiente. Especificamente, objetiva: centralizar e organizar as atividades de uso público da área a partir do centro de visitantes; proporcionar oportunidades de educação e interpretação ambiental, destacando a valorização dos recursos anturais e dos processos ecológicos que os mantém; proporcionar informações sobre a finalidade e manutenção do parque e proporcionar temas de recreação em contato com os recursos naturais.

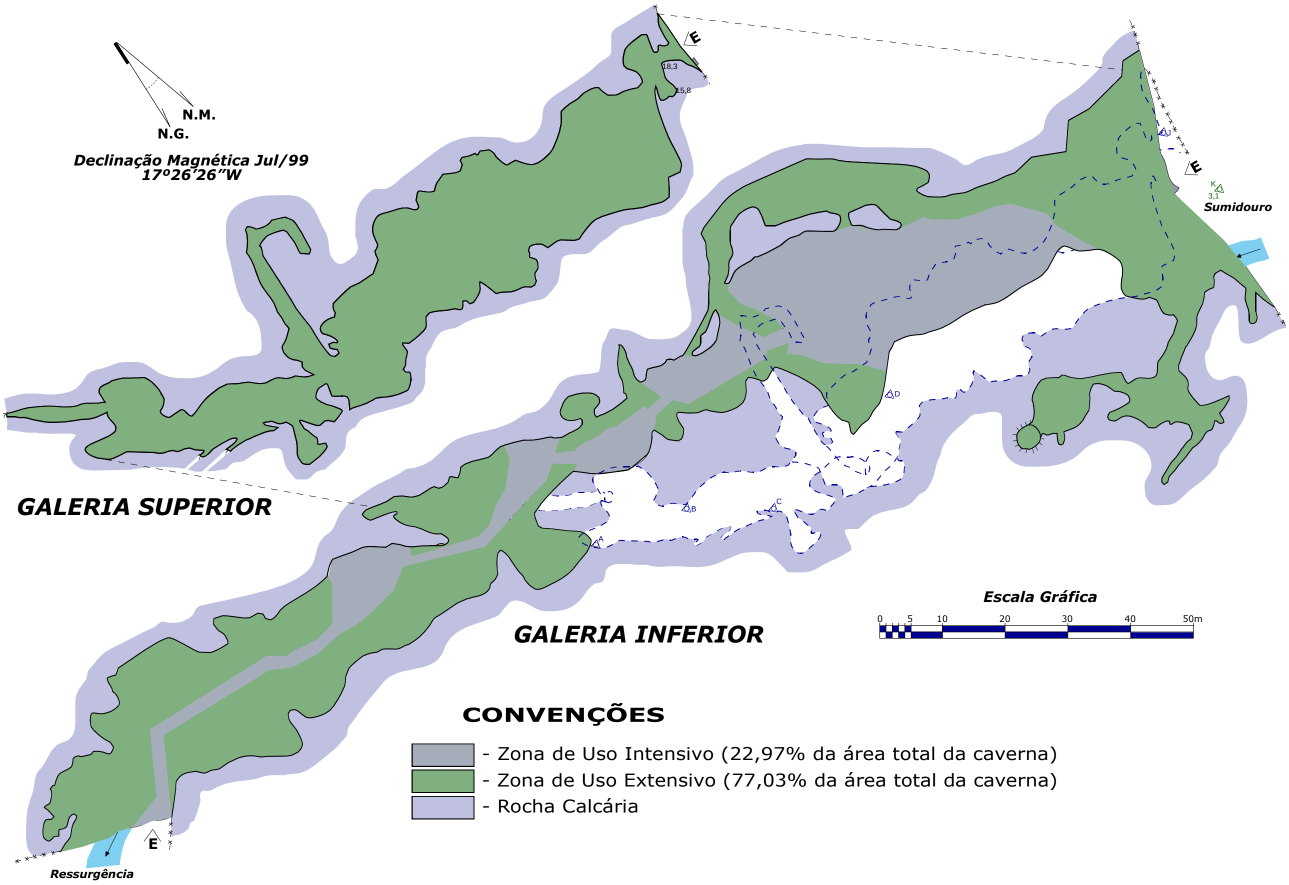

Figura.1:- Zoneamento interno da Gruta do Bacaetava

Zona de Recuperação

Objetiva deter a degradação dos recursos naturais do parque e promover a restauração dos ambientes locais. Especificamente objetiva propiciar a recuperação de diferentes núcleos degradados, promover o plantio de espécies arbóreas nativas e conter os processos erosivos.

Zona de Uso Especial

Esta zona objetiva minimizar o impacto causado pelas estruturas necessárias ao desenvolvimento do manejo do parque, prevendo centralizar as atividades de administração e serviços e concentrar em local isolado do público as instalações da área.

Determinação da Capacidade de Suporte

Considerando-se as características locais, o nível das ações antrópicas, o número de visitantes verificado atualmente, as condições de visitação da gruta, a fauna cavernícola associada, aliados a outros fatores, pretendeu-se direcionar o fluxo de visitantes, tomando-se por base uma estimativa do número de pessoas passível de visitar a cavidade ao longo de um determinado período.

As condições topográficas e de infra-estrutura da Gruta do Bacaetava permitem a entrada de um grupo de visitantes com no máximo 20 pessoas. Considerando que o percurso da Trilha Interpretativa Gruta do Bacaetava tem duração de 45 minutos, definiu-se como períodos de visitação, segundo a época do ano:

Ω verão: entrada dos grupos entre 8:00 e 17:00 h, a cada 45 minutos, definindo um limite de 13 grupos por dia, com um número máximo de 260 pessoas/dia;

Ω inverno: entrada dos grupos na gruta entre 8:00 e 16:15 h, de modo a que o último grupo esteja saindo da gruta às 17:00 h, reduzindo a capacidade para 240 pessoas/dia.

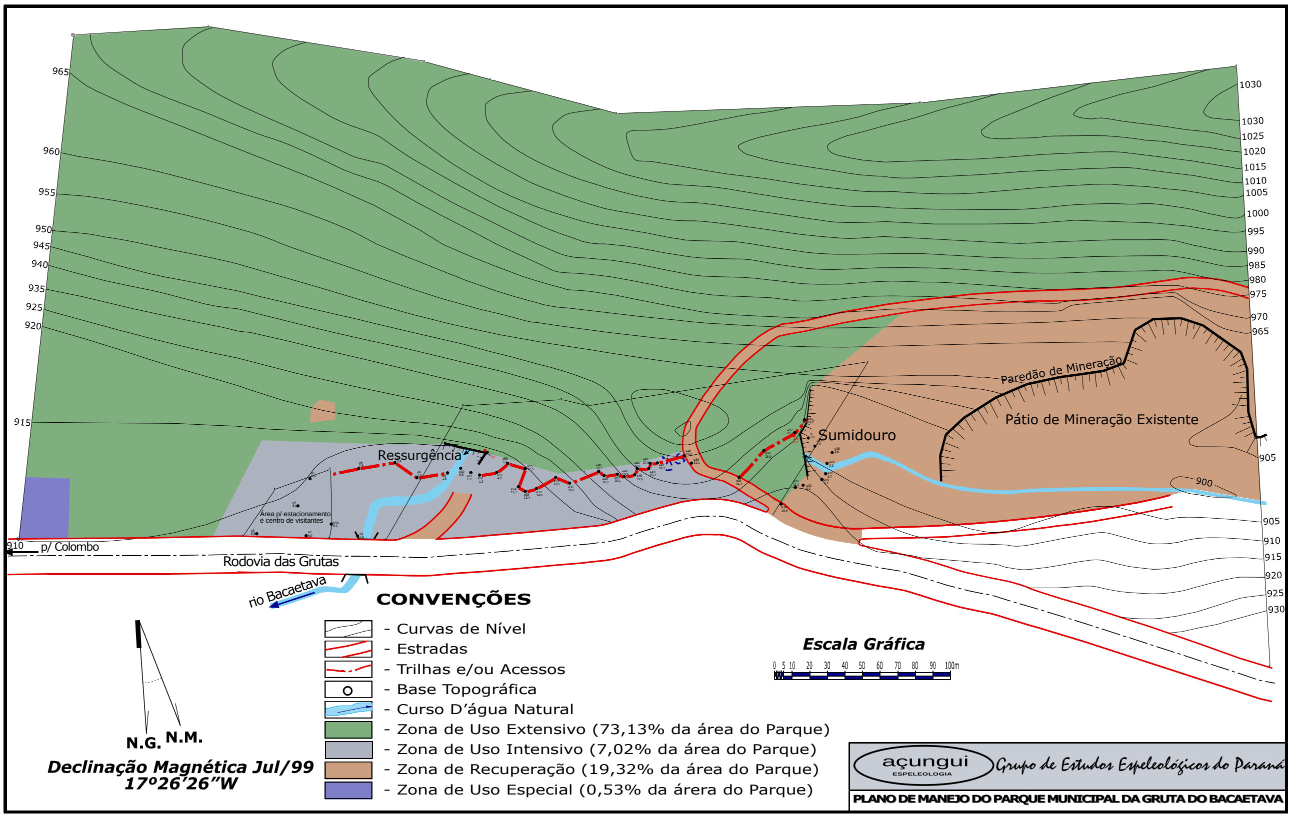

Figura 2:- Zoneamento do Parque Municipal da Gruta do Bacaetava

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Propostas para a Conservação do Patrimônio Espeleológico do Município de Dr. Ulysses-Pr/Brasil[15]

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Abstract

Using the data obtained in the research of the caves located in the Doutor Ulysses county, this work recommends basic guidelines to protection of then. This county, located in the North of the Metropolitan Region of Curitiba - PR, was choose because its great speleological potencial related to the presence of Proterozoic limestones (Acungui Group) and to the evidence of important karst features. Considering that one cave can only be protected after its official register, the GEEP-Açungui propose this research to provide further information for mineral and environment licensing , reducing conflicting uses in this region. Aiming to define methods for preserve this speleological patrimony, Protected Areas were proposed in this couty, besides explanations to the land owners, of the areas with speleological interest, to provide more information and guide them related to the environmental issues.

Resumo

Utilizando-se dos resultados obtidos pelo levantamento das cavernas do município de Dr. Ulysses (GEEP-Açungui, 1999), este trabalho propõe embasar ações de proteção destas. O município, situa-se ao norte da Região Metropolitana de Curitiba e foi escolhido por apresentar características geomorfológicas que lhe conferem um grande potencial para a ocorrência de cavernas. Considerando-se que uma cavidade somente pode ser conservada após seu cadastramento e documentação, o GEEP-Acungui propôs a execução deste estudo, de modo a fornecer subsídios aos processos de licenciamento ambiental e mineral, possibilitando a redução dos conflitos de usos nessa região. Com o objetivo de garantir a conservação desse patrimônio espeleológico, elaboraram-se propostas para a criação de unidades de conservação, bem como para o desenvolvimento de trabalhos junto aos proprietários das áreas de interesse, visando informá-los e orientá-los quanto às questões ambientais.

Introdução

O presente estudo resulta de projeto realizado com apoio do FNMA - Fundo Nacional do Meio Ambiente (Convênio 055/97), visando realizar o levantamento das cavernas do município de Dr. Ulysses, de forma a embasar ações de proteção e manejo. Este município, situado ao norte da Região Metropolitana de Curitiba, foi escolhido por apresentar características geomorfológicas que lhe conferem um grande potencial para a ocorrência de cavernas. Além disto, as cavidades já identificadas e cadastradas encontram-se em significativo estado de conservação.

Considerando-se que uma cavidade somente pode ser conservada após seu cadastramento e documentação, o GEEP-Acungui propôs a execução deste estudo, de modo a fornecer subsídios aos processos de licenciamento ambiental e mineral, possibilitando a redução dos conflitos de uso nessa região.

Como resultados do projeto, identificou-se 5 sistemas cársticos em 9 regiões estudadas dentro do município, além de outras tantas cavernas isoladas Na sua totalidade foram mapeadas 26 cavidades e 9 feições espeleológicas, perfazendo um total de cerca de 10.000 m de topografia interna e 6.000 m de topografia externa (GEEP-Açungui, 1999). Verificou-se ainda no município, além da descoberta de mais 17

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[15] Componente do Projeto “Levantamento, conservação e manejo do patrimônio espeleológico do município de Dr. Ulysses, PR”. Convênio Ministério do Meio Ambiente / Fundo Nacional do Meio Ambiente 055/97.

cavidades não cadastradas anteriormente, a presença da maior caverna do estado (Gruta Dá a Volta, GENTHNER, *et alli*, 2001).

Apesar de verificar-se que a cobertura vegetal é predominantemente secundária, além dos diversos povoamentos de pinus existentes, a maioria das cavidades encontra-se bem conservada, a despeito da inexistência das áreas de preservação permanente dos corpos d'água, como previsto por lei.

Convém ressaltar que, na época do projeto, a maior parte do sub-solo com rochas calcárias, existente no entorno de Curitiba, já se encontrava requerido para mineração, havendo o interesse em se obter requerimentos no município de Dr. Ulysses. Em vista disso e com o objetivo de garantir a conservação desse patrimônio espeleológico, elaborou-se propostas para a criação de unidades de conservação no município, bem como para o desenvolvimento de trabalhos, junto aos proprietários das áreas de interesse, visando informá-los e orientá-los quanto às questões ambientais.

Localização

A região de estudo (Figura 01) engloba o município de Dr. Ulysses, Região Metropolitana de Curitiba, ao norte do estado do Paraná, fazendo divisa ao sul com Cerro Azul, a leste o estado de São Paulo, e a noroeste com Sengés, Jaguariaíva e Castro.

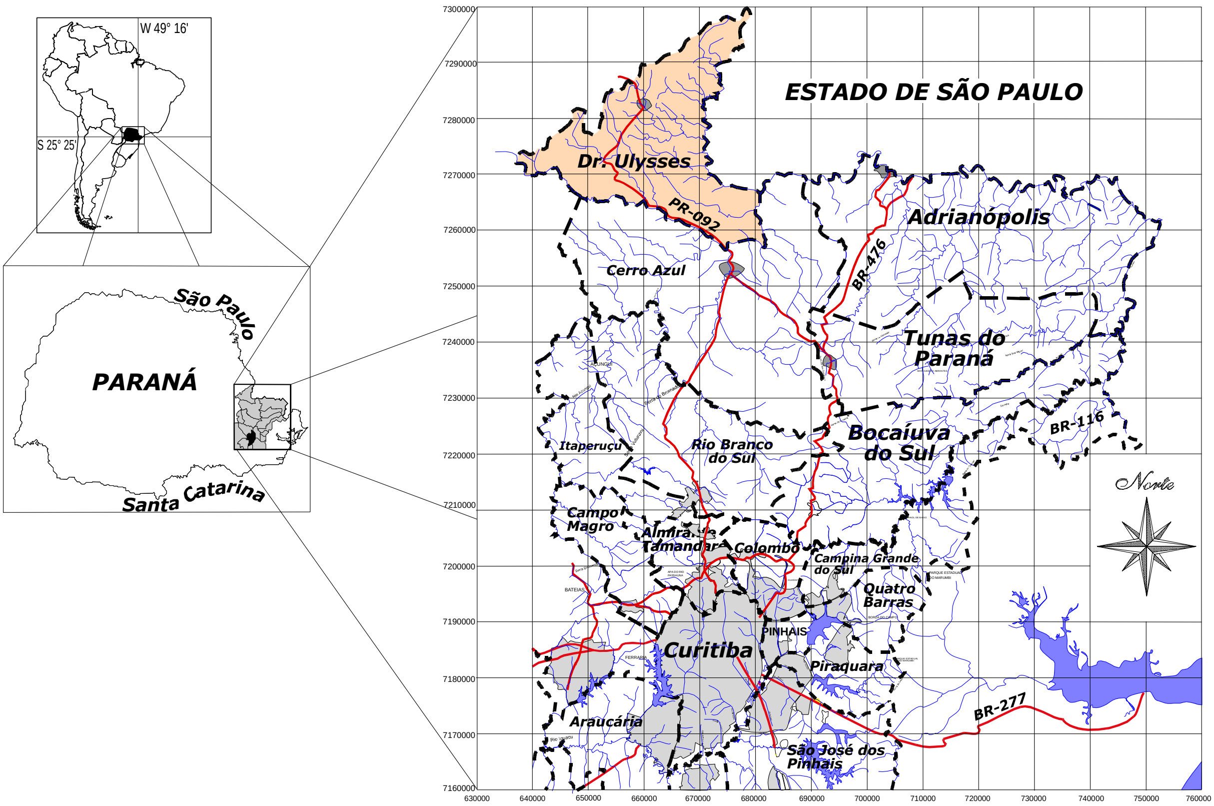

Figura 01: Localização do município de Dr. Ulysses

Materiais e Métodos

Para a elaboração das propostas de conservação do patrimônio espeleológico do município, considerou-se os dados levantados nas fases de campo, em relação às cavidades descobertas, as cavernas já mapeadas e cadastradas, bem como a análise do seu estado de conservação e de seu entorno. Além disto, foram levados em consideração as relações históricas, o interesse turístico, a beleza cênica e a importância das cavernas em termos de biodiversidade.

Como material de apoio para definição das áreas a serem conservadas, foram utilizados fotos aéreas (ITC, 1980), cartas topográficas (IBGE, 1975), bem como os mapas topográficos das cavidades e os mapas das bacias hidrográficas dos sistemas espeleológicos produzidos pelo projeto (GEEP-Açungui, 1999).

Resultados E Discussão

Com base nas análises realizadas, foram propostas as seguintes alternativas, visando a proteção do patrimônio espeleológico da região:

Criação de Unidade de Conservação de Proteção Integral – Sistemas Varzeão, Canavial, Lagoa de Dentro, Malfazido e Água Sumida

Considerando-se a proximidade e o estado de conservação dos Sistemas Varzeão, Água Sumida, Canavial, Malfazido e Lagoa de Dentro, sugere-se a implantação de uma unidade de conservação que os englobe (Figura 02).

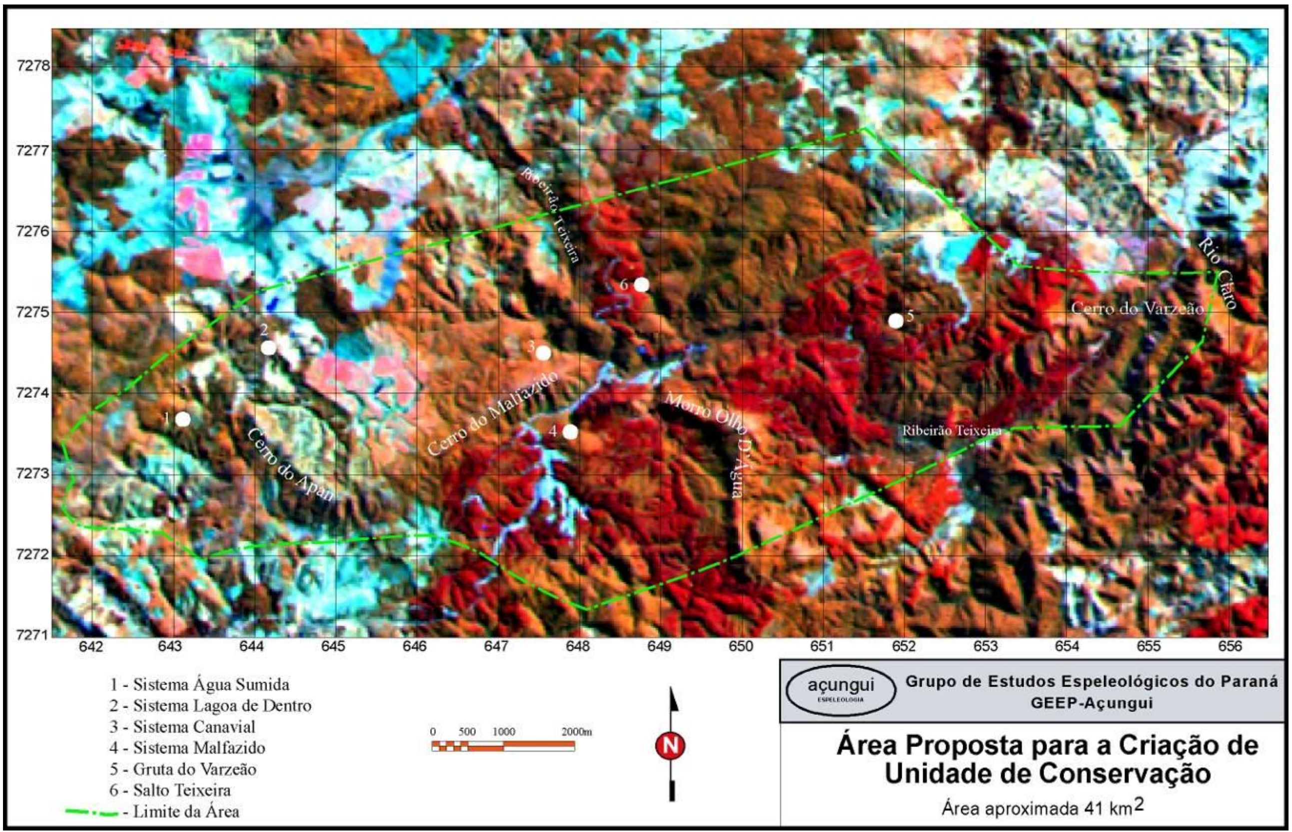

Figura 02: Área 1, proposta para Unidade de Conservação no município de Dr. Ulysses.

Propõe-se a criação de um parque estadual, uma vez que as características físicas, biológicas e histórico-culturais da região, bem como o tamanho da área (41 km^2, ou seja, 4.100 ha), condizem com os objetivos primários e secundários desta categoria de manejo (BRASIL, 2000).

O limite proposto contempla também a cachoeira do Teixeira, possuidora de grande beleza; os cerros Apan, Malfazido e Varzeão, constituintes da Serra de Paranapiacaba, e um grupo de Araucárias (*Araucaria angustifolia*) isoladas, de grande porte (altura acima de 40 m), testemunho da exuberante floresta que existia na região. A maior parte da área encontra-se recoberta por vegetação natural (destacando-se porções de floresta no estágio avançado), incluindo resquícios de campos naturais do planalto de Faxinal que, embora descaracterizados, apresentam valor cênico e científico. Desta forma, serão contemplados dentro de uma mesma unidade de conservação, distintos ambientes e, principalmente, serão protegidas as nascentes dos ribeirões que cruzam as cavidades e grande parte das suas bacias de drenagem.

Quando comparada à região de entorno, esta área mostra-se relativamente bem conservada podendo, assim, compor uma unidade de conservação onde poderão ser desenvolvidos programas de recuperação de áreas degradadas, educação ambiental e ordenamento de ecoturismo.

Quanto à questão fundiária, dentro dos limites da área proposta para a criação da unidade, a maior parte das terras pertencem a grandes proprietários (Fazenda Serena, Fazenda Lagoa de Dentro, e empresas Calpar, Floema e Kurashiki), existindo ainda alguns moradores, ocupando pequenas propriedades.

Criação de Unidade de Conservação para a Gruta do Varzeão.

Caso não seja viável a implantação de uma unidade de conservação de proteção integral, conforme o acima proposto, sugere-se prioritariamente a criação de um Monumento Natural ou Parque Natural Municipal para a Gruta do Varzeão, abrangendo parte da bacia hidrográfica do rio Teixeira, situada à montante da caverna (com cerca de 4 km^2, Figura 03). Esta cavidade representa o principal sítio espeleológico a ser conservado no município, considerando-se sua extensão, seus atributos cênicos e espeleológicos, a diversidade e raridade de alguns espeleotemas, seu potencial biológico e científico. Também possui grande importância devido a seu potencial turístico e educativo, apesar de sua distância dos grandes centros urbanos.

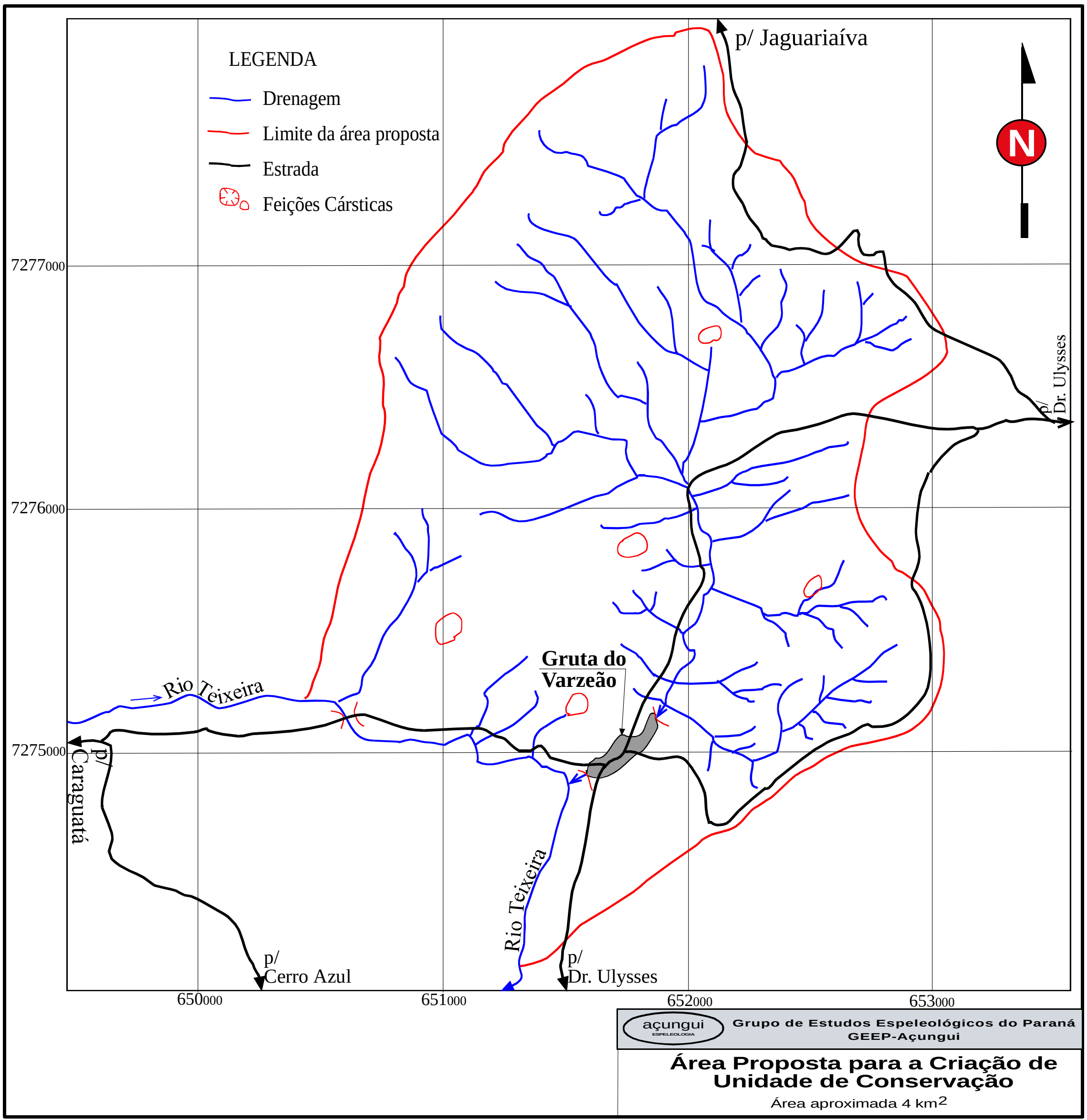

Figura 03: Área02, proposta para Unidade de Conservação no município de Dr. Ulysses.

Para os demais sistemas espeleológicos (Malfazido, Água Sumida, Canavial e Lagoa de Dentro) sugere-se a realização de um trabalho de informação junto aos proprietários, a respeito da importância de preservar as cavernas existentes. Também deve-se orientá-los para a recuperação dos ecossistemas da área de influência direta das cavidades e das áreas de preservação permanente. Além disto, durante este processo pode-se identificar áreas com potencial para implantação de RPPN's (Reserva Particular do Patrimônio Natural) e estimular os respectivos proprietários para tal.

Criação de Unidade de Conservação de Proteção Integral – Sistema Casa de Pedra

Visando proteger este sistema de grande interesse científico, propõe-se a criação de um Monumento Natural, possibilitando, desta forma, a conservação de inúmeras cavidades em pequena área territorial (cerca de 14 km^2, Figura 04).

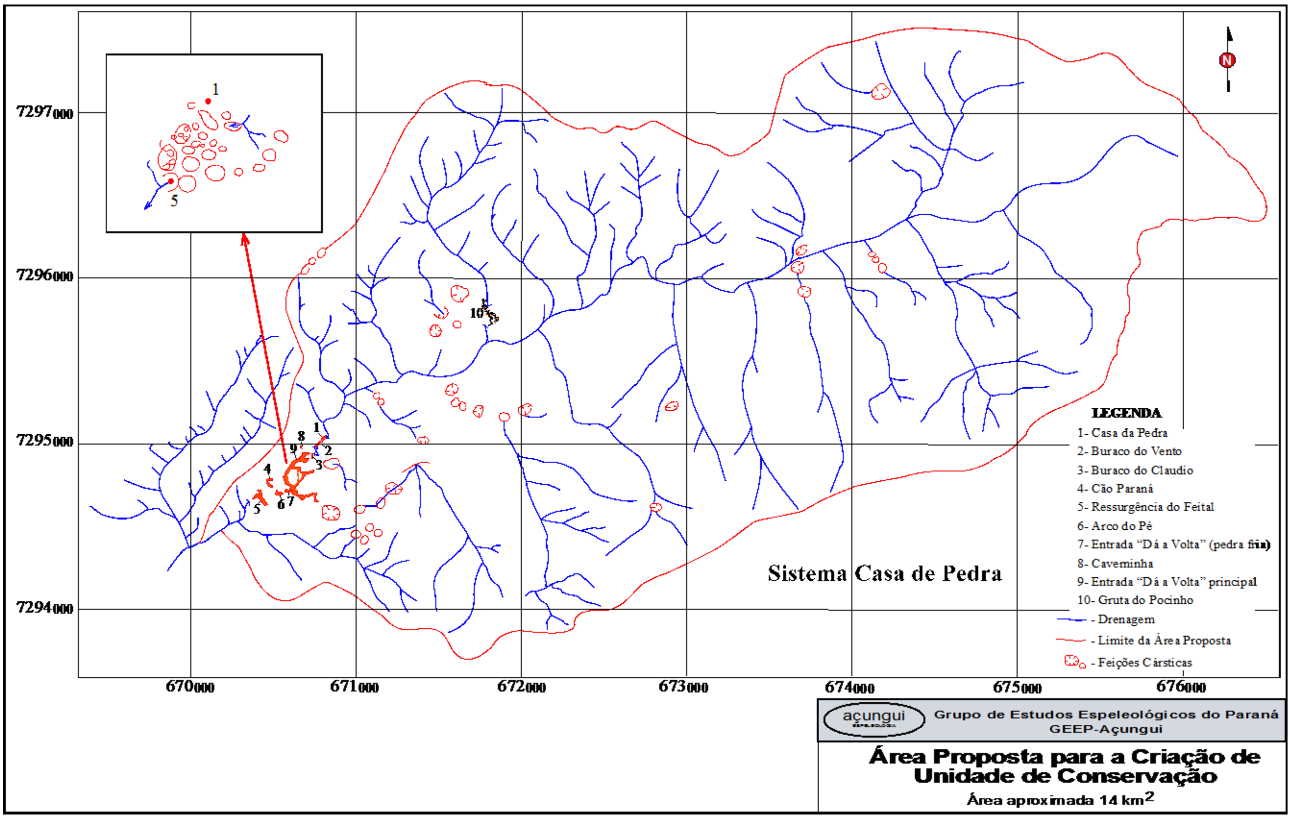

Figura 04: Área03, proposta para Unidade de Conservação no município de Dr. Ulysses.

Optou-se, neste caso, por esta categoria de manejo, pois é a que melhor se enquadra, levando-se em contas seus objetivos primários e secundários. Além disto, esta categoria pode ser criada em propriedade particular, desde que o uso desta última não entre em conflito com os objetivos da unidade de conservação (BRASIL, 2000).

Na região do Sistema Casa de Pedra verifica-se a presença de vegetação natural, nos estágios sucessionais inicial e médio, bem como áreas com monocultura de pinus, além de agricultura de subsistência.

A comunidade local é composta por pequenos proprietários rurais, cujo uso predominante do solo é um sistema rotativo de agricultura e pastagem, que utiliza-se de queimadas.

Informação e orientação dos proprietários da região.

É fundamental, em termos de conservação do patrimônio espeleológico e natural da região, a realização de atividades educativas juntos aos proprietários e comunidades locais.

Propõe-se que estas atividades priorizem os propriedades das áreas onde localizam-se as cavidades assim como suas bacias hidrográficas associadas.

No caso dos pequenos produtores rurais, em função das características culturais e sócio-econômicas destes, sugere-se uma orientação e apoio técnico para a recuperação das áreas de preservação permanente e reserva legal de suas propriedades. Além disto, podem ser propostas alternativas de produção, com o objetivo de, paulatinamente, inserir a agricultura orgânica, buscando-se, assim, minimizar os impactos negativos nos rios e nos solos da região.

Com relação aos grandes proprietários de terras, além do exposto acima, deve-se incentivar, apoiar e orientá-los para a criação de RPPN's. Neste caso, seriam realizados estudos, com o objetivo de determinar quais as áreas mais adequadas para a implantação destas, buscando-se criar corredores com vegetação nativa entre as diferentes propriedades.

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Impactos Ambientais do Turismo na Região do PETAR – Parque Estadual Turístico do Alto Ribeira – São Paulo – Brasil

[Tourism Environmental impacts on PETAR area – Alto do Ribeira State Tourist Park – São Paulo – Brazil]

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Abstract

The Alto do Ribeira State Tourist Park (PETAR) in the Ribeira River Valley in São Paulo is an important receptive center of ecological tourism once it possesses one of Brazil´s major speologic patrimonies. Among its four nuclei Santana nucleus stands out as the most visited. The Santana nucleus and Ouro Grosso nucleus are located close to the Serra District along Betari River, an affluent to Ribeira River.

An expressive number of tourists visit the area especially on weekends and long weekends making use of lodgings and restaurants in the Serra District that provides access to several natural attractions within and outside the Park's nuclei.

The growing influx of tourists in the area and the precarious sanitation of Serra District result in possible negative impacts on the natural patrimony and human environment thus posing risks to Public Health especially the local population.

The present study aims at assessing the relation between the intense population fluctuation originated by the visitation of caves and the risk to Public Health along with the negative impacts on natural water bodies like Betari river by domestic waste pollution. Such information will be useful for the fostering of the sustainable planning and development of the area.

Resumo

O Parque Estadual Turístico do Alto Ribeira (PETAR), no Vale do Ribeira em São Paulo, é um importante centro receptivo de turismo ecológico, devido ao fato de possuir um dos maiores patrimônios espeleológicos do Brasil.

Dentre seus quatro núcleos, destaca-se o Núcleo Santana como de maior visitação, que juntamente com o Núcleo Ouro Grosso, situa-se nas proximidades do Bairro da Serra em Iporanga, margeando o Rio Betari, afluente do Rio Ribeira de Iguape.

Grande número de turistas desloca-se para a região, sobretudo em finais de semana e feriados prolongados, utilizando serviços como hospedagem e restaurante do Bairro da Serra, localidade que propicia acesso a diversos atrativos naturais dentro e fora dos núcleos do Parque.

O crescente fluxo de visitação turística na região e a precariedade do saneamento básico no Bairro da Serra acarretam possibilidades de impactos negativos ao patrimônio natural e ao meio ambiente humano, constituindo riscos à saúde pública, essencialmente à população local.

O presente estudo visa avaliar a relação entre a intensa flutuação populacional advinda da visitação às cavernas com os riscos à saúde pública, e com os impactos ambientais negativos aos corpos d´água naturais, como a poluição do Rio Betari por esgotos domésticos. Tais informações deverão ser úteis para fomentar o processo de planejamento e desenvolvimento sustentável da região.

Introdução

A Mata Atlântica, que originalmente ocupava a costa brasileira do Rio Grande do Norte ao Rio Grande do Sul adentrando para o interior, é considerada como uma das principais florestas tropicais em razão da biodiversidade e do risco de extinção, sendo, desde 1991, reconhecida como uma ampla Reserva da Biosfera pela UNESCO por solicitação do governo brasileiro (COSTA, 1997).

Tal bioma atualmente conta com apenas 6,34% de sua cobertura original, entretanto, é no Estado de São Paulo que são encontrados alguns dos principais remanescentes, com destaque para o Vale do Ribeira, onde diversas unidades de conservação integram um conjunto ao qual pertence o PETAR – Parque Estadual do Alto Ribeira (SÃO PAULO, 1999).

O PETAR localiza-se nos municípios de Apiaí e Iporanga, no Vale do Ribeira, Estado de São Paulo, Brasil, situando-se entre as latitudes de 24º16´S e 24º 38´S e longitudes 48º29´O e 48º44´O (MENEZES & GONÇALVES, 2001).

Em seus limites apresenta cobertura vegetal característica de Floresta Ombrófila Densa e Floresta Ombrófila Mista (SÃO PAULO, 1999).

O Turismo na Região

Os diversos atrativos naturais da região conferem grandes possibilidades de desenvolver práticas de turismo e lazer associadas ao contato com a natureza. O PETAR, com mais de 200 cavernas cadastradas, é possuidor de um dos maiores patrimônios espeleológicos do Brasil (BURGI & MARINHO, 1997 *apud* MENEZES & GONÇALVES, 2001), que constituí o principal atrativo para os visitantes do parque.

Além das cavernas, existem outros elementos que compõem o patrimônio natural e histórico-cultural do Parque, tais como rios dotados de corredeiras em superfície e dentro das cavernas, cachoeiras, piscinas naturais, sítios paleontológicos e arqueológicos (SÃO PAULO, 1991).

Tal unidade de conservação teve a estrutura de implantação definida a partir de núcleos, uma vez que possuindo grande extensão e forma alongada tornava difícil o acesso às localidades. A sede administrativa encontra-se no município de Apiaí, em área urbana (ALLEGRINI, 1999). Existem quatro núcleos de apoio dentro dos limites do Parque, são eles: Santana, Caboclos, Ouro Grosso e Casa de Pedra (MENEZES e GONÇALVES, 2001).

O Núcleo Santana é responsável por 80% da visitação neste Parque (ALLEGRINI, 1999). Tal núcleo, além de receber visitantes diaristas, conta com infra-estrutura para camping, além de diversos atrativos naturais.

O Núcleo Santana encontra-se nas proximidades no Bairro da Serra, povoado que pertence a Iporanga, distante 13 Km da sede muncipal. Também nas proximidades do Bairro da Serra fica o Núcleo Ouro Grosso.

O Bairro da Serra e os núcleos Santana e Ouro Grosso margeiam o Rio Betari, com cabeceiras no município de Apiaí, fora dos domínios do PETAR, esse rio percorre 25 Km até chegar a sua foz no Rio Ribeira de Iguape (GERHARD, 1999).

Grande parcela dos turistas que freqüenta a região utiliza recursos de hospedagem, alimentação e serviços de bar do Bairro da Serra. No entanto, é necessário salientar que dentre àqueles que se alojam no Bairro da Serra, muitos destinam-se a outros atrativos fora dos núcleos do Parque, como cachoeiras, as corredeiras do Rio Betarí e especialmente cavernas.

Para ilustrar o papel do Bairro da Serra na recepção dos visitantes da região, verifica-se, em termos de hospedagem, que a maioria dos turistas têm preferência pelas pousadas, ranchos e campings do Bairro da Serra (ROSSI, 1996). Segundo MENEZES e GONÇALVES (2001), dos 1100 leitos disponíveis em hotéis e pousadas no município de Iporanga, 678 estão no Bairro da Serra.

GOGONI e FLAMÍNIO (1999) afirmam que o Bairro da Serra, em Iporanga, surgiu muito antes da criação do PETAR, em razão do extrativismo do palmito (*Euterpe edulis*), madeiras e mineração. Posteriormente, com a criação do Parque, essas atividades passaram a ser coibidas, gerando desaprovação da comunidade local. Entretanto, nos dias de hoje, graças ao crescimento do turismo, diversos moradores largaram seu trabalho extrativista para se dedicar a esta nova atividade.

Classificado como a principal atividade econômica do mundo na atualidade, o turismo vem despertando o interesse de muitas regiões por suas possibilidades de geração de renda (SILVEIRA, 2000). Ressalta-se que, na “indústria” turística, as maiores taxas de crescimento relacionam-se com o segmento do ecoturismo

(SERRANO, 1997), que constitui alternativa de trabalho e geração de renda para moradores do Bairro da Serra.

Todavia, a extrema valorização dos aspectos econômicos do turismo negligencia o planejamento de longo prazo, propiciando situações de turismo de massa – deslocamento de grande número de pessoas para os mesmos lugares – que podem acarretar efeitos negativos ao meio ambiente natural, à cultura e aos aspectos psicosociais das comunidades receptoras (RUSCHMANN, 1997).

Segundo SWARBROOKE (2000) o ecoturismo parece ser o segmento mais próximo do conceito de sustentável, no entanto, devido às tendências de crescimento, pode se tornar modalidade de massa em determinadas localidades, acarretando problemática contraditória à sustentabilidade.

Verifica-se que o fluxo de visitação no PETAR apresentou um aumento considerável, principalmente a partir de 1990, sendo que o turismo é bastante intenso durante os feriados e finais de semana (ALLEGRINI, 1999). De acordo com MENEZES e GONÇALVES (2001) o número de visitantes ao parque que em 1988 foi inferior a 10.000, em 1993 se aproximou de 30.000 e em 2000 houve quase 40.000 visitantes.

No sentido de demonstrar a intensidade da visitação aos finais de semana e feriados, através de consulta ao Livro de Movimento de Caixa da Portaria do Núcleo Santana, constatou-se que no último carnaval houve no sábado (24/02/2001) um total de 497 ingressantes e no domingo (25/02/2201) um total de 888 ingressantes no parque (entende-se por ingressante todo aquele que passa pela portaria e paga ingresso), números muito superiores as médias de visitação nos três finais de semana anteriores, que aos sábados foi de 112 e aos domingos foi de 59 ingressantes.

A Problemática Ambiental e a Questão de Saúde Pública

SCALEANTE (1999) afirma que o Bairro da Serra apresentou crescimento populacional de 44% desde 1995, em razão da centralização da educação na escola local e do crescimento da oferta de trabalho associado ao ecoturismo. Ressalta ainda que aos finais de semana a população dobra em razão das flutuações associadas ao turismo.

Frente ao crescimento populacional bem como de suas flutuações nas adjacências do PETAR, pressupõe-se a intensificação das ameaças ao meio ambiente natural por intermédio de impactos negativos e ameaças ao rico patrimônio natural da região decorrentes do aumento do fluxo de visitação. Por outro lado, também são relevantes os impactos influenciando negativamente o próprio ser humano, pois a população local sofre com os reflexos da passagem dos turistas, problemática que pode ser evidenciada principalmente nas condições de saneamento básico.

A partir de visita à campo e à regional da SABESP em Registro/SP (março de 2001), unidade responsável técnico-admnistrativa pelo Vale do Ribeira, foi possível obter informações que apontaram a precariedade do saneamento básico no Bairro da Serra, localidade que conta com abastecimento de água proveniente de uma Estação de Tratamento de Água, além de poços e nascentes nas adjacências. No entanto, não há rede coletora de esgotos, tão pouco existe destinação adequada para esses dejetos domiciliares.

A contaminação do solo e dos cursos d´água por disposição inadequada de esgotos domésticos acarreta riscos à saúde pública, sobretudo na propagação de doenças de veiculação hídrica (ROUQUAYROL, 1988). Um estudo realizado por GIOIA (1995) na Fazenda Intervales, unidade de conservação limítrofe ao PETAR e com problemas de saneamento similares, demonstrou, através de exames de fezes em 393 moradores locais, elevados índices (72,5%) de indivíduos portadores de parasitas e comensais intestinais.

No tocante à contaminação de cursos d´água, segundo GERHARD (1999), as principais influências humanas diretas sobre o Rio Betari são os esgotos domésticos, deposição de lixo, e áreas de agricultura e pastoreio no Bairro da Serra, além da passagem de estrada que liga Apiaí a Iporanga.

Devido a poluição por esgotos domésticos, o corpo d´água pode sofrer mudanças indesejáveis em suas propriedades físicas, químicas e biológicas, que propiciam comprometimento sanitário e danos a biota aquática, sobretudo à fauna ictica (BRANCO, 1986). Esse fato torna-se mais grave, quando se verifica elevada riqueza de espécies existente nesse rio (GERHARD, 1999).

Tal comprometimento sanitário no Rio Betari pode por em risco, ou mesmo inviabilizar, a prática de recreação de contato primário, que ocorre na natação e na prática do "bóia cross", atividades freqüentes entre os turistas e moradores da região, especialmente as crianças locais.

Verifica-se que a necessidade de proteção da água evitando contaminações constitui o principal aspecto de controle da veiculação de doenças em águas recreacionais em locais turísticos. Em localidades sujeitas às grandes flutuações de contingentes humanos, devem haver facilidades, equipamentos e estrutura de saneamento, projetadas de maneira a compatibilizar o atendimento durante os picos de visitação (SALVATO JR., 1976).

Em campo, foi possível visitar o Posto de Saúde do Bairro da Serra, que atende os moradores das localidades, com a colaboração da agente de saúde local pôde-se verificar os prontuários das famílias atendidas, dentre estes, alguns possuíam registros de exames parasitológicos que indicaram prevalências de protozoários, como *Giárdia lamblia*, *Entamoeba coli*, *Endolinax nana* e *Iodamoeba butschlii*, e também nematodos como: *Ascaris lumbricoides*, *T. trichiura* e *Ancylostomideos*. No entanto, haviam poucos registros de exames parasitológicos, fato justificado pelas dificuldades de locomoção dos moradores, que necessitam visitar o Centro de Saúde de Iporanga para levar material e posteriormente para pegar o resultado, verifica-se ainda que os exames são executados pelo Instituto Adolfo Lutz, no município de Registro.

O médico pediatra Walter Maisano, que atende a população local semanalmente, afirma que devido às dificuldades de realizar exames parasitológicos freqüentes na população admnistra doses de medicamento contra parasitas duas vezes ao ano para cada morador. Segundo ele são muito elevadas as prevelências de helmintos entre estas pessoas, sobretudo de *Ascaris lumbricoides*.

Considerações Finais

Considerando o crescimento da visitação turística na região torna-se necessário planejamento com relação a infraestrutura adequada para receber e minimizar os impactos das populações flutuantes que buscam os atrativos naturais da região.

Especificamente no Bairro da Serra é fundamental a adequação do saneamento básico em estrutura capaz de atender as necessidades da população fixa residente bem como absorver as grandes variações nos picos de visitação turística.

Verifica-se que a problemática ambiental local acarreta riscos diretos à saúde das populações, sobretudo aos moradores locais que ficam constantemente expostos.

A questão do saneamento básico é elemento intrinsecamente ligado ao desenvolvimento de uma determinada região, destaca-se que como conseqüência de precariedades em saneamento temos a proliferação de inúmeras doenças que afetam o ser humano e ainda, como no caso deste estudo, as altas prevalências de doenças parasitárias na população debilitam os indivíduos e constituem fator de subdesenvolvimento.

Finalmente, cabe alertar que devido ao constante fluxo de visitantes provenientes de localidades diversas e frente às fragilidades locais ocorre a ameaça de incidência de doenças que até então não são endêmicas na região.

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Riscos Ambientais em Apiaí – SP

[Environmental Risk Assessment in Apiaí – Southern São Paulo]

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Abstract

The present paper consists of a series of maps of the region of the city of Apiaí, in the Valley of the Ribeira River in the south of the state of São Paulo. The superposition of these maps provides information about the geology and physiography of the area, as well as information about human occupation of the land. The study was designed to furnish a risk assessment of this karst landscape, including the possibility of collapse, as well as to identify those regions where the present use has a negative impact on the environment. The methodology used to determine the physiography of the land and its use included the division of the area using geotechnical maps, interpretation of aerial photographs, application of questionnaires to local community representatives, and field studies, in addition to numerous photographs of critical situations in the area.

Resumo

Este trabalho se desenvolveu no município de Apiaí, Vale do Ribeira, sul do estado de São Paulo, e consta de uma série cartográfica de dados geológicos, fisiográficos e de uso da terra visando a superposições diversas com o objetivo de identificar as áreas mais favoráveis à ocupação humana e aquelas sujeitas a riscos ambientais ou inadequadas para determinados fins. Dentre as situações de risco ambiental investigado inclui-se o colapso em áreas cársticas. Os principais procedimentos metodológicos para se chegar a uma configuração fisiográfica dos terrenos e seu uso foram: compartimentação da área através de cartas geotécnicas, interpretação de fotos aéreas, aplicação de questionários a representantes da comunidade local, atividade desenvolvida junto à rede de ensino e trabalhos de campo, além de farto material fotográfico relativo a situações críticas do uso e ocupação. Como resultado prático da pesquisa apresenta-se uma Carta-síntese de uso do solo para fins de planejamento e um conjunto de sugestões para melhor aproveitamento do solo urbano, incluindo opções de exploração turística da área.

I. Introdução

O objetivo geral deste trabalho é a identificação das fragilidades e potencialidades do ambiente natural ou alterado pela ação antrópica, através de um mapeamento de riscos ou suscetibilidades diante de determinadas formas de ocupação do espaço. Partindo da prática corrente de urbanização sem planejamento, visa-se a um melhor uso do solo, de modo a evitar situações de ameaças às pessoas e ao ambiente, que signifiquem obstáculos para a melhoria de qualidade de vida e desenvolvimento do município de Apiaí. Dentre os objetivos específicos, citam-se os seguintes: a) caracterização física da área de estudo com a elaboração de um banco de dados e, em decorrência, prover o município de material cartográfico compilado e elaborado durante a pesquisa; b) transmitir a metodologia de mapeamento de riscos ambientais elaborado em conjunto com pessoas da própria cidade, de maneira que essas pessoas se tornem multiplicadoras do processo, que é passível de aplicação didática, podendo ser utilizado pela comunidade no campo da educação formal e não-formal; c) oferecer ao habitante de Apiaí um produto de apoio ao entendimento da região em que vive; d) aumentar a conscientização das pessoas sobre proteção ambiental e preservação dos recursos disponíveis como melhor modo de garantir o exercício da cidadania e elevar o nível de vida da comunidade; e) oferecer um produto que seja utilizado como um ponto de partida para a busca de soluções aos problemas existentes; f) demonstrar a importância de se planejar o uso da terra, incentivando também o planejamento do turismo no município.

A escolha do município se deve a trabalhos já desenvolvidos na área voltados à temática ambiental e ao turismo, reforçada pela ocorrência de um problema geotécnico de colapso em terrenos cársticos na zona urbana, peculiaridade que desperta interesse nas pessoas que estudam cavernas.

II. Metodologia

Em razão do trabalho se destinar a uma aplicação prática pela comunidade, a série cartográfica foi elaborada artesanalmente, com participação da comunidade local na elaboração do mapa de riscos, sendo informatizada apenas em sua fase final. Esta pesquisa foi desenvolvida em duas vertentes: uma, individual e a outra, em conjunto com pessoas que moram na cidade de Apiaí.

A visão adotada na presente pesquisa, de se aproximar das pessoas, a quem se destinam as informações e quem as fornece também, teve como fonte de inspiração os trabalhos de mapeamento de riscos ambientais desenvolvidos pelo Professor Dr. Arsênio Oswaldo Sevá Fº em vários lugares do Brasil. Um aspecto relevante dos trabalhos é a idéia de "alfabetização cartográfica" para formação de outras lideranças dentro da comunidade. Trabalhou-se com pequenos grupos em duas atividades: na elaboração do mapa de riscos, onde os grupos foram pequenos, e no diagnóstico por percepção, com um grupo maior. O que se espera é que as pessoas envolvidas venham a ser multiplicadoras do processo.

Outro aspecto a se mencionar é de um estudo horizontalizado, o que Milton Santos define como resultado da vizinhança, da cohabitação, da coexistência do diverso. Significa uma valorização do local inserido no global. Santos afirma ainda que "o lugar dá conta do mundo" e que "é no lugar que tudo acontece". É o território então que "mostra todos os movimentos da sociedade, onde se realiza a vida coletiva, onde estão presentes os que mandam e os que não mandam, os ricos e os pobres, os poderosos e os não-poderosos" (SANTOS, 2000). Em uma escala mais ampla, e objetivando a conservação, o uso racional e o desenvolvimento do espaço geográfico em benefício de toda biosfera, especialmente a sociedade humana, trabalha-se aqui com o conceito de geossistema (TROPPMAIR, 2000). Relacionando geossistema com paisagem, esta se traduz na fisionomia ou na feição que cada geossistema apresenta. A paisagem reflete o caráter integrado e único do espaço (GESAMTCHARAKTER EINER GEGEND, apud TROPPMAIR, 2000), permitindo ao geógrafo referir-se à geodiversidade, assim como o biólogo se refere à biodiversidade.

O meio ambiente a que esta pesquisa se refere compõe-se da paisagem assim definida como o "conjunto de todos os elementos urbanos e rurais, em cujo contexto os habitantes vivem, se movimentam e se relacionam, entre si e com ela" (BACELLI, 1986). Os riscos ambientais são aqueles inerentes à sociedade moderna, que é uma "sociedade de risco", onde o fenomenal desenvolvimento da ciência e da tecnologia produziu uma situação de incertezas e descontrole nunca antes sentida pela humanidade. Apesar de sempre se ter convivido com riscos, os atuais são muito específicos e diferentes quanto às suas fontes e abrangência. "Os riscos aparecem com um caráter irredutível, sem garantias, sem certezas, com efeitos globais, invisíveis e, às vezes, irreversíveis" (GIDDENS, 1991 apud HERCULANO et alii, 2000). O crescimento das cidades, via de regra, é desordenado. A explotação sem controle das fontes de bens naturais constitui ameaça à economia e à qualidade de vida (CARDOSO, 2000). Segundo MENDONÇA (1994), as proporções da degradação ambiental se tornaram insuportáveis, com tecnologias cada vez mais sofisticadas e de fortes impactos sobre o ambiente. Diante da situação catastrófica, optou-se por um novo estilo de desenvolvimento, o desenvolvimento sustentável, que prevê a manutenção da qualidade ambiental para garantir aproveitamento máximo e duradouro dos recursos naturais, com o mínimo de impactos negativos. Tal desenvolvimento sustentável consiste no desafio de administrar os conflitos gerados pela apropriação dos bens, levando em conta as restrições impostas pela natureza diversificada e complexa (CARDOSO, 2000).

O diagnóstico sócio-ambiental de Apiaí foi feito com base nos dados compilados na pesquisa ou elaborados a partir deles, além de questionários e entrevistas junto à comunidade local.

Desta forma, para sua execução concorreram os resultados da pesquisa ambiental desenvolvida pela CETESB e coordenada por BACELLI (1986), bem como a utilização da metodologia desta mesma pesquisa para se iniciar a elaboração de um diagnóstico ambiental através da percepção. À semelhança dos trabalhos realizados por SEVÁ (1997), o objetivo desta metodologia foi obter um diagnóstico dos problemas ambientais a partir da própria comunidade, do senso comum ou dos fatos de domínio público, "pois sabe-se que, em geral, a percepção das pessoas é subestimada em relação ao conhecimento chamado técnico ou científico" (SEVÁ, 1997).

Houve intenção de aproximar as pessoas das causas ambientais, de modo que todos tenham condições de participar do planejamento de sua cidade, neste caso relacionado com a implantação do turismo ecológico. O envolvimento dos moradores, segundo BACELLI (1986), é de grande importância para que qualquer trabalho desenvolvido na cidade seja aceito ou recebido com satisfação pelos seus habitantes.

III. Localização da Área de Estudo no Município de Apiaí, Vale do Ribeira – SP / Acessos

A área objeto desta pesquisa, com quase 18 km^2, tem seu foco na zona urbana de Apiaí, embora a extrapole. O marco central de Apiaí está à latitude de 24º30'35,19"S e longitude de 48º50'33,48"W, altitude de 926 metros nesse ponto. Apiaí dista 324 km. da cidade de São Paulo-SP, 220 km. de Sorocaba e 165 km. de Curitiba-PR. Um dos acessos é através da rodovia Raposo Tavares (SP-270), percurso asfaltado de 164 km. até Itapetininga; SP-127 até Capão Bonito, 65 km., finalmente SP-250, 95 km até Apiaí. Outro caminho possível é a rodovia Régis Bittencourt, BR-116, que liga São Paulo a Curitiba, perfazendo 217 km. até Jacupiranga, prosseguindo-se por via asfaltada até Iporanga, em um percurso de 105 km. A partir daí, percorre-se 40 km. por estrada não pavimentada até Apiaí (total de 362 km).

IV. Caracterização do Meio Físico

Foram produzidos os seguintes mapas (base e temáticos) em escala 1:10.000, tendo suas informações cruzadas através de sobreposição em mesa de luz, de modo a proporcionar análises e gerar interpretações: a) Mapa-base, onde se delimitou a área de estudo, que abrange toda a zona urbana de Apiaí, com aproximadamente 8 km^2, além de área contígua, perfazendo um total aproximado de 18 km^2. A delimitação considerou principalmente as sub-bacias hidrográficas existentes na área, tendo em vista o risco de poluição das águas pelas atividades urbanas. Desta forma, o limite foi traçado segundo o critério de topos, fundos de vale e, na impossibilidade do uso desses dois parâmetros, um pequeno trecho a sudeste se baseou no limite da própria carta; b) Mapa Geológico; c) Mapa Geomorfológico de 1962 e de 1997, através da fotointerpretação de fotografias aéreas; d) Mapa Hidrológico, onde foram delimitadas as três sub-bacias de interesse para o estudo; e) Carta Clinográfica; f) Mapa de Solos; g) Mapas de Uso da Terra relativos às datas de 1962 e 1997, também elaborados através de fotointerpretação; h) Mapa Topomorfológico; i) Mapa de Riscos Ambientais: foram montados grupos de três a quatro pessoas com cinco saídas a campo, não apenas para trabalhar com o mapa, mas para fotografar eventos significantes. A confecção deste mapa foi de suma importância para a pesquisa, tendo em vista que sempre envolveu a comunidade. Essas pessoas foram escolhidas principalmente por suas condições de futuras multiplicadoras da metodologia adotada. Plotou-se no mapa as ocorrências que impactam de modo negativo o ambiente e de algum modo ameaçam, exigem providências, demandam melhor planejamento ou sugerem uma nova abordagem, um olhar diferente, bem como fenômenos naturais que se configuram como fatores limitantes para o uso do solo: esgoto a céu aberto ou lançado em corpos d'água, lixão, postos de gasolina, oficinas mecânicas, garagens de ônibus, hospital, cemitério, lavadoras de veículos, ferro-velho, serrarias, indústria, "bota-fora", colapso, subsidência, sumidouros, dolinas, cavernas, captação de água, rios canalizados, solo descoberto, afloramentos de rocha, áreas sujeitas a erosão, erosão em taludes, áreas sujeitas a deslizamentos, áreas sujeitas a enchentes e áreas de ocupação inadequada.

Patrimônio ambiental regional: matas tropicais (Mata Atlântica), rios e cachoeiras, cavernas. A primeira reserva ambiental criada no Vale do Ribeira foi o PETAR, Parque Estadual Turístico do Alto Ribeira, instituído em 1958, com 35.102,83 hectares, estando 24% dessa área dentro do município de Apiaí e os restantes, 76%, em Iporanga (BURG, 1998). Depois do PETAR foram criadas mais dez unidades de conservação na porção paulista do Vale do Ribeira. Como conseqüência da criação dessas unidades de conservação, 48% do total da área do estado de São Paulo sob proteção ambiental integral estão na região. E, em mais da metade do Vale do Ribeira, as atividades econômicas são proibidas ou exigem regulamentação.

É importante destacar que, embora seja inegável que as restrições impostas pela legislação ambiental têm implicações sobre o uso dos recursos naturais, as unidades de conservação não podem ser responsabilizadas pelo atraso econômico da região. Na realidade, ocorreu o contrário. A falta de desenvolvimento provocada por inúmeros fatores sociais, políticos, econômicos e ambientais permitiu que o Vale chegasse ao final deste século em um estado de conservação ambiental único nas regiões Nordeste, Sudeste e Sul do país, levando o poder público, pressionado pela sociedade, a criar essas áreas protegidas. Embora possua boa parte de seu território sob proteção, o Vale do Ribeira apresenta índices de desmatamento elevados. Esse problema, agravado pela falta de programas de governo dirigidos a desenvolver o enorme potencial econômico da região, representado pelo turismo e pela exploração sustentável do patrimônio natural, incluindo-se aí a riquíssima biodiversidade, tem agravado as condições sociais do Vale.

As conclusões dos trabalhos de uma comissão especial do Conselho Estadual do Meio Ambiente, que analisou detalhadamente os planos dos diversos órgãos de governo e iniciativa privada para a região, mostra a gravidade da situação. Evidencia-se a inexistência de um plano integrado de desenvolvimento para o Vale do Ribeira. Esta falta de visão sistêmica na formulação de políticas públicas setoriais gera um evidente conflito de diretrizes e sobreposição de atribuições e de atividades das instituições atuantes na região. Esta situação, agravada pela morosidade das ações de regularização fundiária, tem como decorrência direta a dispersão e perda dos parcos recursos financeiros, humanos e materiais disponíveis para essa região historicamente alijada do processo de desenvolvimento do estado, com o comprometimento de seu valioso patrimônio natural e cultura. Agravando tal quadro constata-se ser extremamente incipiente a participação da sociedade regional na definição das políticas setoriais, programas e projetos.

Nesse quadro de omissões e negligência do Estado em todas as áreas, especialmente nas da saúde e educação, quem planeja o desenvolvimento do Vale do Ribeira são os grupos econômicos que, via de regra, manipulam a opinião pública com promessas de empregos e desenvolvimento para obterem apoio a seus projetos. Um dos exemplos mais impressionantes desse processo de manipulação foi a discussão sobre a aprovação da hidrelétrica de Tijuco Alto, proposta pela Companhia Brasileira de Alumínio, empresa do Grupo Votorantim, para ser construída no rio Ribeira de Iguape. Esse exemplo, entre outros, mostra a necessidade de que sejam definidos, com urgência, programas de desenvolvimento adequados às peculiaridades sociais e ambientais do Vale do Ribeira, sob pena de, permanecendo o atual processo, perder-se o patrimônio existente na região, sem que sejam gerados reais benefícios a seus habitantes.

Situação ambiental de Apiaí através da percepção de educadores e alunos

Tendo em vista as condições excepcionais de conservação da natureza no Vale do Ribeira, além de sua riqueza histórico-cultural ser reconhecida como patrimônio da humanidade, o governo do estado criou em 1995 a “Agenda de Ecoturismo para o Vale do Ribeira”, mantendo até hoje políticas públicas de investimento efetivo no turismo da região. Em outubro de 2000 concretizou-se um documento denominado “Programa de Turismo Sustentável para o Vale do Ribeira”, elaborado através de uma parceria entre diversas instituições (Conselho Nacional da Reserva da Biosfera da Mata Atlântica, dentre outras).Engajado nesse projeto, o município de Apiaí investiu no turismo como possível alternativa de desenvolvimento durante a gestão do prefeito Donizete Borges Barbosa, de 1997 a 2000. Vários foram os produtos resultantes do interesse por esta fonte de renda, em cuja elaboração a autora participou**:** volume impresso intitulado “Banco de imagens da oferta turística e da capacidade instalada do município de Apiaí” (SCALEANTE, 1998); cursos (guia de turismo e espeleologia), palestras, trabalhos diversos com a população local, além do Projeto de Implantação/Acompanhamento do Turismo no Município. Uma das etapas deste projeto foi chamada de “Conscientização para o Turismo”, constando de uma fase inicial baseada na caracterização ambiental por meio de percepção (BACELLI, 1986). Foi feito um levantamento junto aos alunos sobre sua percepção das situações ambientais mais críticas da cidade, aquelas que envolvem ameaça ao bem-estar das pessoas. Os resultados foram agregados à pesquisa realizada pela CETESB em 1986, denominada Caracterização Ambiental do Estado de São Paulo por Percepção, sob a coordenação geral de Ronei Bacelli, em que o município de Apiaí obteve as seguintes posições dentro do Quadro-síntese de problemas ambientais:

QUADRO 1: Quadro-síntese de problemas ambientais em Apiaí (BACELLI, 1986)

AR	Percebido
ÁGUA	Percebido
SOLO	Não percebido
LIXO	Não percebido
AGROTÓXICO	Percebido
AGROPECUÁRIOS	Percebido
MINERAÇÃO	Não percebido
INDÚSTRIA	Percebido
FLORESTA	Intensamente percebido
FAUNA	Não percebido

V. Riscos Ambientais - Descrição do mapa de riscos

Lembrando que riscos são ameaças ao bem-estar das pessoas que vivem, trabalham ou passam por determinados lugares, como estradas; também produtos agroquímicos que são utilizados na lavoura provocando agressões ao meio ambiente, dentre outros, diversos riscos foram detectados no município de Apiaí, constando do mapa denominado “Riscos Ambientais”.

Os resíduos que significam ameaça direta às águas superficiais são provenientes de:

- 5 garagens de ônibus, incluindo a da Prefeitura, que se localiza ao lado de um dos principais rios do município, o Tijuco;
- 9 postos de gasolina com área de lavagem e troca de óleo, sendo que seus efluentes, sem qualquer tratamento, se destinam a fossas não impermeabilizadas;
- 27 oficinas mecânicas e 13 funilarias/pintura, muitas com lavadoras de peças próximas a cursos d'água e as demais com seu esgoto correndo a céu aberto;
- 4 lavadoras de carros e/ou caminhões na área da sub-bacia 2 Tijuco;
- 1 ferro-velho nessa mesma região;
- 1 depósito de carvão coque a céu aberto no interior da empresa Camargo Corrêa, já saturado e com um escorrimento constante de líquido escuro, também a céu aberto, extrapolando os limites da fábrica em direção à rodovia Apiaí/Ribeira, desembocando em um dos tributários do rio Tijuco;
- 1 bota-fora da Camargo Corrêa em áreas de nascentes da sub-bacia 3 Cárstica;
- no mínimo umas dez áreas de ocupação inadequada (margens de rios e encostas);
- vasta área sujeita a enchente a norte da zona urbana;
- 2 áreas sujeitas a deslizamentos: uma próxima ao hospital e outra em frente à Prefeitura;
- 1 hospital com esgoto sem tratamento despejado no curso d'água afluente do ribeirão Palmital;
- 1 lixão a céu aberto, que não é bem operado tecnicamente, com presença constante de urubus e cujo chorume percola para a sub-bacia 2 Tijuco, provocando sérios problemas para as comunidades a jusante, conforme documentado no jornal "APIAÍ DIZ". De acordo com a reportagem, não apenas o chorume, mas também grande quantidade de lixo sólido desce do lixão de Apiaí, além de óleo proveniente de postos de gasolina e oficinas mecânicas.

No centro da cidade há dois trechos de cursos d'água canalizados, que recebem esgoto: o córrego do Ouro até o cruzamento com a rua da Biquinha (sub-bacia 1 Palmital) e o córrego do Fundão (sub-bacia 2 Tijuco), cujas nascentes já foram canalizadas, também recebendo esgoto doméstico.

O cemitério da cidade, segundo informação do responsável técnico, Marcos, faz 95% dos seus sepultamentos por inumação (caixão colocado em cova rasa) e o restante por entumulamento

(túmulo de concreto). Cemitérios significam riscos ao meio ambiente e à saúde quando seus dejetos e microorganismos provenientes dos cadáveres contaminam as águas subterrâneas, conforme pesquisas realizadas pelo CEPAS, Centro de Pesquisas de Águas Subterrâneas, do Instituto de Geociências da USP, São Paulo. O Código Sanitário Estadual, de 1978, contém a principal legislação sobre a implantação de necrópoles, visando à proteção ambiental e à saúde pública .

Há pelo menos 3 pontos críticos de erosão: um no bairro Pinheiros, o segundo na pista de *motocross* e o terceiro na estrada Apiaí/Iporanga.

Os riscos registrados em mapa estão relacionados com aspectos do meio natural, como: Erosão/assoreamento; Enchentes; Áreas sujeitas a deslizamentos; Áreas de ocupação inadequada; Afundamentos de terreno por processos cársticos.

Recomendações

MINERAÇÃO: A atividade mineradora em regiões cársticas devem ser precedidas de estudos complexos sobre a área, pois podem causar danos ao escoamento sub-superficial da rede de drenagem, obstruindo o fluxo normal da água. Tal fato pode ocasionar o desaparecimento de cavernas e a deformação do relevo característico do carste.

LIXÃO: O lixão da Prefeitura de Apiaí, situado a sudoeste do município, encontra-se em local indevido, pois a área possui uma grande quantidade de nichos de nascentes que correm o risco de se contaminar com a deposição de rejeitos de origens diversas. Em termos de litologia também há que se rever a situação do lixão, pois ele se encontra sobre granitos, onde os solos são do tipo CX29 Cambissolos Háplicos, impróprios para aterros sanitários.

BOTA-FORA DA CAMARGO CORRÊA: Também se encontra em local inadequado, sobre calcário, um tipo de rocha que favorece contaminação do lençol freático, sendo equiparável à contaminação superficial das águas.

DEPÓSITO DE CARVÃO DA CAMARGO CORRÊA: Providências imediatas deveriam ser tomadas, pois além de ser esteticamente inadequado, os resíduos estão sendo carreados para o rio Tijuco, colaborando para aumentar sua carga poluidora.

CEMITÉRIO: Cemitérios são considerados “vilões ambientais” nas grandes cidades. Assim sendo, qualquer município deve analisar se está operando tecnicamente bem o seu cemitério e, especificamente no caso de Apiaí, pode-se repensar a maneira de se fazer os sepultamentos, abolindo aqueles por inumação (caixão diretamente na terra, em covas rasas). O cemitério de Apiaí encontra-se sobre rochas graníticas, assim como o lixão, e os cuidados devem ser redobrados.

EROSÃO EM TALUDES: Os cortes de barrancos apontados no mapa de riscos indicam que não está havendo orientação técnica nesse sentido, o que exige uma postura mais atuante da Prefeitura.

ÁREA SUJEITA A DESLIZAMENTOS: Providências urgentes da Prefeitura, principalmente em época de chuvas mais intensas, no sentido de proteger a população de riscos de vida.

RIO DA CACHOEIRA DO CALABOUÇO: O esgoto da cidade é lançado sem qualquer tratamento em cursos d’água. Um deles forma a cachoeira do Calabouço, de valor histórico/cultural, e importante área próxima da cidade para ser explorada turisticamente. É de fundamental importância que suas águas sejam límpidas, de modo que possa se tornar um atrativo turístico da cidade.

RIOS CANALIZADOS: Canalizar não resolve os problemas, apenas piora a situação da dinâmica natural. Seria conveniente mudar a maneira de se olhar um rio, que não deve ser um canal de esgoto a céu aberto, mas estar cheio de vida em benefício da própria população. Em lugar de cobrir o rio, o ideal é revitalizá-lo, fazer jardins ao longo de seu curso, plantar mata ciliar.

RIOS POLUÍDOS: Providências no sentido de eliminar as causas da poluição, que geralmente se originam na falta de tratamento do esgoto doméstico.

COLAPSOS E SUBSIDÊNCIAS: Seguir orientações do IPT. Os afundamentos ocorridos em Apiaí são de dois tipos, tanto os rápidos (caso da área próxima à Rodoviária), como os lentos (residência com um muro que afunda).

OCUPAÇÃO INADEQUADA: Evitar a instalação nessas áreas por acarretarem riscos às pessoas que aí moram, aos recursos naturais impactados e ao aspecto da beleza cênica, tão valiosa para o turismo.

ÁREAS SUJEITAS A ENCHENTES: Providenciar local seguro onde essas pessoas possam morar e evitar que outras acabem ocupando as mesmas áreas.

DESMATAMENTO: O relevo acidentado de Apiaí necessita de cobertura vegetal para evitar erosão. As margens dos rios também não devem ficar desprotegidas da mata ciliar.

GARAGENS, OFICINAS, POSTOS DE GASOLINA, FERRO-VELHO: Medidas devem ser tomadas para que a população a jusante não sofra as conseqüências desses efluentes, como mencionado na reportagem do jornal APIAÍ DIZ, de 30 de janeiro a 15 de fevereiro de 2002.

AGROTÓXICOS: Incentivo às iniciativas de agricultura orgânica.

CAPTAÇÃO DE ÁGUA: 500 metros depois do local de captação, as águas do córrego Água Limpa se acham poluídas em razão de ocupação inadequada de suas margens.

EDUCAÇÃO AMBIENTAL: A atividade realizada com os alunos do nível fundamental em Apiaí revelou um grupo de pessoas muito participativas e ávidas por conhecimentos relacionados a meio ambiente, portanto, é aconselhável que se promova eventos nessa área.

COOPERATIVA/ESTUFAS: Incentivar iniciativas do gênero.

ATIVIDADES TURÍSTICAS: Devem ser estimulados porque a paisagem de Apiaí é belíssima, seu clima é muito agradável e seu povo é amigo.

Conclusão

A pesquisa feita em Apiaí foi muito proveitosa, principalmente devido à inexistência de estudos já realizados na área, o que levou a um dispêndio de tempo muito grande. Elaborou-se um material que pode ter muita utilidade para a comunidade, que antes não possuía um acervo de mapas temáticos para compreensão do seu meio físico, de modo a apropriar-se dele da melhor forma. Trabalhou-se com um grupo de habitantes locais que poderão auxiliar na divulgação do trabalho, atuando como multiplicadores. O município de Apiaí apresenta riscos ambientais, tanto naturais como tecnológicos, que podem ser minimizados e/ou eliminados se forem respeitados os limites impostos pelo meio físico. As áreas sujeitas a enchentes, por exemplo, não são apropriadas para edificação de moradias, assim como terrenos cársticos também exigem uso restrito. Com base no cruzamento dos dados de mapas temáticos elaborados e no uso já estabelecido, além do trabalho da comunidade no mapeamento dos riscos decorrentes da urbanização, foi elaborada uma Carta-síntese de uso do solo, que não pretende esgotar o assunto, mas ser um exemplo de sobreposição dessas informações para se conseguir um desenvolvimento sustentável, aqui definido como: "... tal desenvolvimento sustentável consiste no desafio de administrar os conflitos gerados pela apropriação dos bens, levando em conta as restrições impostas pela natureza diversificada e complexa" (CARDOSO, 2000).

Factor Analytic Study of Adolescent Attitudes towards Caves

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Abstract

The protection of caves depends principally on the collaboration of the general public. One way to stimulate this collaboration is through the involvement of children and adolescents to caves while they are young so they will become interested in them. The present study presents a factor-analytic study identifying five factors underlying adolescent attitudes towards caves which can be explored.

“As cavernas não estão ali para serem dominadas, mas interpretadas e admiradas!” Lourdes Rezende de Souza.

The speleological patrimony of Brazil does not yet have a set of laws to protect it as such, although various decrees, resolutions and other measures provide some guidelines. For many years, caves were protected by their location, far from urban nuclei (FURQUIM, 1997), but in recent decades they have been at the mercy of the activities of man, from predatory tourism and mining to the construction of roads (PEREZ et al, 1986).

Na analysis of the limestone regions of the country, called Speleological Provinces (KARMANN, SÁNCHEZ, 1979), as can be seen in Figure 1, shows that they are no longer so far from urban nuclei. In fact, many are located in highly urbanized areas and have suffered the consequences of this. This, for example, is the case of Cajamar, in the the area of Greater São Paulo, where karst sink has occurred as a consequence of the use of water extracted from underground to supply the general public (OLIVEIRA et al, 1998; PRANDINI et al, 1995).

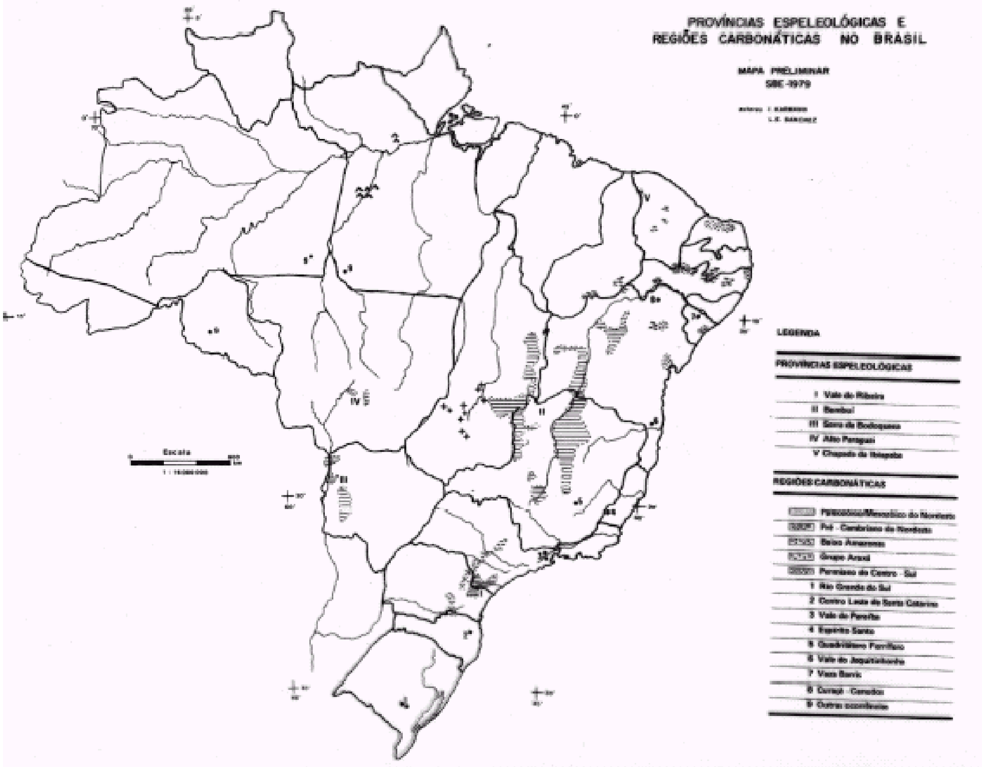

Figure 1

Nowadays, many people live in karst areas, or close to them, and this presents a tremendous demand for karst water, as well as the mining of minerals, agricultural activity, the construction of dams to supply electric energy and meet the demands of tourism and recreation (PILÓ, 1999).

This proximity of human communities leads to the need for educational awareness programs, since preservation requires a social commitment (PAULA et al, 1997). Before people are concerned with preservation, they must value what is to be preserved.

LABEGALINI (1995) has suggested the installation of a Program of Environmental Education in tourist areas to help overcome the impact of this activity on the environment. Such a task should be accompanied by various phases, from the development of projects to the execution of thd necessary work and the implantation of a plan of management, which should remain in effect as long the area has touristic potential. This author also recommends that this program should be directed to the following groups:

a) the population working in construction

b) tourist guides

c) the local population

d) the visitors

The environmental education of the local population requires the implantation of programs in the schools, both elementary and secondary, as well as technical schools and the educational system in general in order to reach the local population. Some possibilities include projects in public parks, educative posters, lectures, etc.

In order to develop an effective program, however, it is necessary to understand how to reach the individuals involved. Without careful investigation this is not possible. The present investigation is a first step In an attempt to provide a basis for such studies.

The methodology involved a study of the imaginary of adolescents of some 219 individuals, mostly from 13-16 years of age, although a few scattered individuals were as old as 20. All were studying in the schools in Campinas, and most had never visited a cave before.

A questionnaire was developed to test their feelings about caves. The spontaneously elicited comments about caves of the subjects in the study of FIGUEIREDO (1999) was used as a basis for the development of this questionnaire. This author identified the terms used to refer to caves in his population, which included individuals living in urban areas and karst areas, and those terms which were repeated by more than two or three indivuals were included in our questionnaire. These terms were presented in a Likert-type format, using a seven-point scale for evaluation of importance. The subjects of the present study were then asked to evaluate each of these terms on this scale of 1 to 7 in relation to its importance in their feelings about caves.

A factor analysis of the results showed that five underlying factors can explain approximately 50% of the variation observed. These are shown below in Table 1, with their respective weightings (weightings above .4 are included, although given the limited size of the sample these results must be considered as only suggestive. The five most highly weighted factors have been identified as 1) Adventure, 2) Danger, 3) Scientific nature, 4) Factual description, and 5) Peace and security.

Table 1. Factors revealed and relative weightings

Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
.76 challenge	.68 silence	.72 minerals	.76 immense	.76 snug
.74 adventure	.62 bats	.65 speleothems	.67 large	.62 peace
.64 emotion	.58 loneliness	.55 stones/rocks	.49 deep	.61 balance
.58 mysterious	.53 dangerous	.55 exploitation*	.42 interesting	.54 living place
	.49 fear			

The term used in Portuguese (explorar) has two independent meanings, one in relation to exploring the unknown, and the other of exploitation and the taking advantage of something. Given the other items in this factor, it was assumed that the interpretation had bee the latter.

Almost no differences were identified in relation to age or sex, nor did having visited a cave seem to influence the factors revealed. These factors suggest the mixed nature of feelings about caves. On the one hand, they excite the emotions with ideas of challenge and adventure, while they also solicit feelings of danger and fear. What was surprising was the importance of the fifth factor in the group as a whole, apparently involving feelings of peace and security. Various subjects feel the attraction of caves as a site of peace and comfort (or reject this idea), whereas others are much more interested in the ideas of challenge and adventure (or, again, reject caves for this reason).

The results of this study can be seen to suggest that any program of environmental education should take varied factors into consideration. Not only is it necessary to approach the subject of caves in a factual way, including information about their importance, but more emotional aspects should also be included.

These results suggest that the aspects which are considered do not change after contact with caves. Since it is impossible to anticipate individual reactions from only vicarious experience, more direct contact caves is necessary.. Future studies are planned to study the effect of actual contact with caves on the profile of individuals in relation to these factors.

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"Have Cave, WIll Travel" - A Portable Cave Exhibit for Environmental Education

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Abstract

A traveling cave exhibit can be used very effectively to help get across the messages of cave resource conservation and ethics. The Bureau of Land Management designed and constructed such a cave for use as an environmental education exhibit. It was constructed of 1" pvc pipe, covered with chicken wire, burlap, and sprayed with industrial grade polyurethane foam. The exhibit has been used several times across the United States and has held up quite well. It contains bilingual interactive interpretive signs, running stream and plunge pool, bat roosts, interpretive video, an interactive cave restoration station, and is wired for sound, lights, and climate control.

The Challenge: As part of the 1997 Boy Scouts of America (BSA) National Jamboree the Bureau of Land Management requested a cave as one of their exhibits on the "BSA Adventure Trail". The Carlsbad Field Office was contacted to design and produce the exhibit. The objective was to produce an exhibit that would convey the sights, sounds, and feel of being in a real cave and combine that with the elements of cave resource education, conservation, and safety.

The Design: The most efficient design was an S shaped structure with two common interior walls (see Figure 1). The entrance is at one end of the S and the exit at the other. This design creates three parallel passages, each with a different theme. Both ends have crawl way and wheelchair-accessible entry and exit. The wheelchair access is through a light-tight removable door. The entrance passage contains a running stream and plunge pool and the interpretive signs tell about cave and karst geology. The middle passage has speleothems and a bat roost. The interpretive signs discuss bat myths and bat truths. The exit passage has a restoration section and interpretive signs that convey messages on cave conservation and safety.

The Construction: After several unsuccessful initial construction concepts it was decided to construct it out of one inch PVC pipe as a frame, covered with one inch chicken wire, then covered with burlap. The entire structure was then sprayed with structural polyurethane foam. The speleothems were constructed in the same manner. First the outline of the exhibit was drawn out on the floor of the BLM warehouse. It measured 20X28 feet and averaged a six and one half foot ceiling height. The PVC pipe was laid out, fitted together with couplers, and glued. Where the pipe was arched to make the roof, a hot air gun was used to relieve the stress on the PVC.

The structure was wired to incorporate electrical outlets for lighting sconces, sound, and video capability. The wiring was installed in electrical pvc conduit with all outlets a minimum of eighteen inches above ground height and ground fault boxes to meet electrical codes. The lighting is indirect and uses 4 watt night lights.

Once the frame and wiring were complete, 1x12 pine boards were mounted in the areas where the interpretive signs were to be installed. This gives the signs something to be screwed into and hold them securely. The frame was then covered with one-inch chicken wire, and burlap was applied to the chicken wire using hog rings. The next operation was to contract the spraying of the polyurethane foam. Two *55* gallon drums of urethane and catalyst were used to cover the structure. The foam was sprayed on hot, using a direct displacement pump. The inside was sprayed first. By the time the outside was ready to be sprayed the structure was sturdy enough lo walk on. After the outside was sprayed the structure was coated with a heavy weather resistant latex paint. The inside was painted with a light grey base coat then highlighted with spray paint in just the right cave colors.

The structure was then cut into eight pieces so it could be loaded into a truck and transported. Removable polyurethane speleothems were then added.

Bells & Whistles: To add realism to the exhibit, enhance its interpretive value, and increase its fun-factor several special effects were added.

Interpretive Signs: Twelve interactive interpretive signs are used in the exhibit. All the signs are in English and Spanish. One part of the message is on the front of the sign; then the sign can be opened up for the rest of the message inside. Interpretive signs cover cave geology, karst hydrology, cave biology, cave climatology, bat myths and truths, cave conservation and safety.

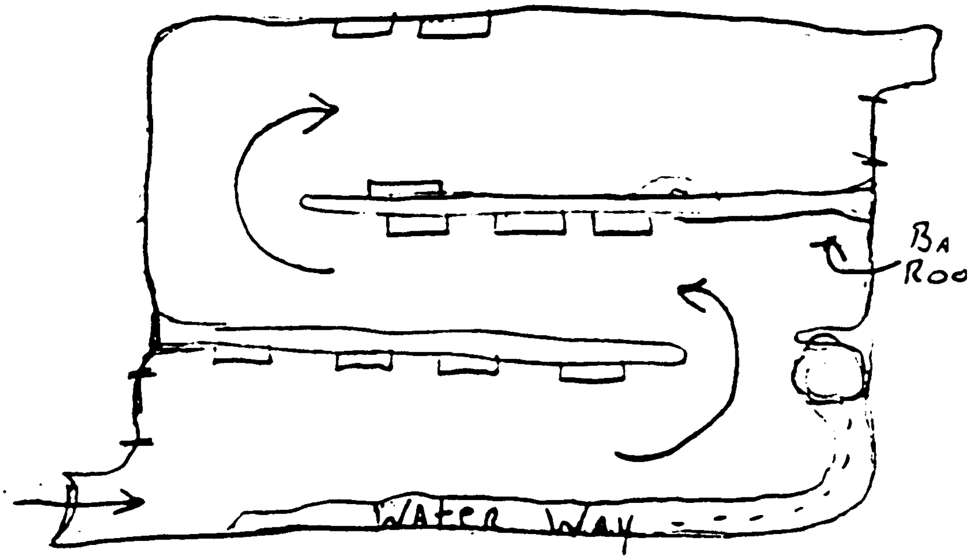

Figure 1

Stream and Plunge Pool: The right side of the entrance passage has a live stream which comes out of the wall and flows down a trough to the end of the passage, turns the corner and disappears into a plunge pool. The plunge pool is about 18 inches deep with a submersible water pump in the bottom. A hidden 3/8-inch tube returns the water to the spring source.

Bat Roost: Around the corner you enter the bat roost area. The bats are made of cast resin and are actual size and anatomically correct. There are clusters of Mexican freetails, and individual Big Brown Bats and Myotis Velifer. Under the bats are guano piles. Bat squeak and flutter sounds are heard from a specially produced compact disc. The CD player is hidden under a rock ledge that is accessible from the outside. The bat sounds play on a repeating track. A 13 inch TV-VCR plays a three minute continual loop video about bats and bat conservation. Four interpretive signs cover bat myths and truths.

Speleothems: The middle passage also contains a number of speleothems which can be removed when the exhibit is transported. Stalactites, stalagmites, sodastraws, and columns grace the hall way. They are affixed using velcro and made fast with spray polyurethane foam.

Climate Control: the cave is given a further touch of realism by the addition of refrigerated air. An air-conditioner is placed outside the exhibit and refrigerated air is fed into the cave through an air duct. This reduces the noise level of the air-conditioner and fans. The refrigerated air gives the entire cave cool realism and also adds positive air pressure inside the cave which creates a cool breeze blowing out the entrance and exit crawl ways.

Restoration Station: Around the next corner you face a wall of graffiti. On the floor is a limestone block which also has spray paint on it and several nylon bristle scrub -brushes. This is the visitors´ opportunity to get first hand experience on how difficult it is to remove spray paint from cave walls. The interpretive signs give a “Leave No Trace” message and points on cave conservation and safety.

The exit passage is filled with the echoing sounds of dripping water. The specially produced sound track comes in from a CD player hidden behind a false rock.

Transportation and Assembly: The pieces of the structure can be craftily loaded into a 24-foot moving truck, with only one piece left over. the last piece can be transported on a 16 fool flat bed trailer. Once on location the pieces can be placed together and drawn tight using binding cinches. The joints are then filled with spray foam and allowed to dry over night. The foam can then be spray painted to match the interior of the cave; the speleothems are then added. When the cinch straps are removed the structure is sturdy enough to walk on. There are electrical outlets on the outside of the exhibit that can be plugged in and provide current to the entire display. It is easiest to assemble the exhibit with five or six people but it has been done with two. Complete assembly takes from six to eight hours. Disassembly is best done with a keyhole saw to cut the foam joints apart. A reciprocal saw may also be used but there is a greater possibility of cutting into the structure of the exhibit.

Availability: The exhibit has been on display at Fort AP Hill, Virginia for the two week BSA National Jamboree. Nearly forty-thousand scouts visited the exhibit during that time. It has also been on display in Phoenix; AZ; Bishop, CA; and Tucson, AZ; Santa Fe, NM; Roswell, NM, and Carlsbad, NM. For further information contact Jim Goodbar at the BLM Carlsbad Field Office, 620 E. Greene SI. Carlsbad, New Mexico 88220. (505) 234-5929, james_goodbar@blm.gov.