Cave diving has made some impressive advances in the past few years. I dived in caves on more than thirty occasions in England between 1954 and 1959, and in America four or five times after that. The purpose of this article is to discuss some of the problems as they existed in cave diving in England at that time - NOT for the purpose of putting the clock back - but hopefully so as to encourage present-day cave divers to examine and then to re-examine their underwater techniques and training procedures so as to improve both the effectiveness and the safety aspects of their sport. (These problems have also been discussed by Boon, 1977 and by Farr, 1980.)

Visibility Underwater

Lack of visibility can create serious problems for the cave diver. There are four stages involved: First, under exceptionally good conditions it may be possible to see for tens or even hundreds of feet, and you may find yourself being lured on and on and ON. First, you must always assume that you will not be able to see anything at all on your way out. Second, when the visibility comes down to five feet or less, you will only be able to see small parts of the walls and floor as they drift in and out of view. Third, when the visibility comes down to zero or less, you will only be able to see small parts of the walls and floor as they drift in and out of view. Fourth, when the visibility is zero or less, you will only be able to see small parts of the walls and floor as they drift in and out of view.

Walking and Swimming Divers

A swimming and a walking diver are shown in Figure 1. It shows a mud floor sloping down to an opening at the lowest point, and on many occasions you may have to go to the deepest point to find the way out. The water flow in times of flood can determine the shape of the (sandy) passage floor in a horizontal submerged passage also. This can be helpful when exploring under conditions of limited visibility. For example, while walking along a horizontal underwater passage on an upstream dive in Threapland Cave in Yorkshire on 23 June, 1956 with John Burton, I emerged into an underwater chamber having a height of 4 or 5 feet, and extending sideways beyond the limit of visibility. Such chambers often contain slow whirlpools, and this was no exception, with the mud cloud slowly sweeping across in front of me from the right. What to do? The first priority is to accept the guide wire of the diver who goes straight out into such a place, and cause difficulties on the way out. I had done this. The next priority is to keep ahead of the mud cloud. By advancing at right angles to the ripple marks in the sand on the floor I was able to find the way upstream. I then came to a definite funnel in the sandy floor going downwards at a slight angle under a low archway in the wall. This was the way on. If I emerged this through a low squeeze, and explored a gently rising passageway in total darkness by the sense of touch for about five or ten feet; at which point it was clearly time to return. Before returning, however, I sat there for a minute or two without being able to see a think, when I had the good fortune to notice that the top of my mask was in air. Dry land was only a few yards away. Later, we made the return trip without being able to see anything. This dive would have failed if I had not studied the floor. (J.S.B. dived in caves for several years before I did and, together with J.A. Thompson and F.G. Balcombe, initiated me into cave diving.)

Floor or Roof?

Figure 1 has been drawn to emphasise the difference between the roof and the floor. Very often, the roof contains bell chambers and similar solutionally determined forms. The floor will very often consist of small stones, sand and mud that are rearranged by the water flow in times of flood. Indeed, it would sometimes even appear that passages underwater will all be tilted up eventually unless they are periodically scavenged out in times of flood. From the practical point of view this often means that you can learn more about the water flow by examining the floor than you can by examining the roof.

Abstract

The author was active in cave diving in England between 1954 and 1959. Both the techniques and the equipment have improved considerably since then. This paper describes the methods used in the 1950's for the purpose of comparison with those of today.

Résumé

Les techniques et l'équipement de la plongée spéléologique s'ont beaucoup améliorées depuis l'époque où l'auteur la pratiquait en Angleterre de 1954 à 1959. Nous décrivons ces méthodes anciennes à fin de comparaison.
In the late 1940s, D.A. Coase and R.E. Davies carried out an extended series of swimming cave dives at Wookey Hole and elsewhere using what were essentially World War II "frogman" techniques. Balcombe (1981) offers the following tribute to Coase: "Coase was a first-class diver and a great companion always, and a steadfast support when I was stressed." Davies (1981) wrote: "Don Coase was a major force in the post-World War II diving explorations associated with the Cave Diving Group in England. He was bold, reliable and always ready to push ahead. His early death during surgery was a great loss."

Swimming is faster than walking. Thus, Davies and Coase covered 360 feet in less than seven minutes of exertion must be kept low (which is another reason for swimming rather than swimming when using this type of equipment). Here, we cannot do better than to quote from Empleton et al. (1962; p. 105): "Only a very few semiclosed-circuit scuba units are in use by sport divers. Most of these are used by former commercial or military divers who have had several years of training and experience in the use of the equipment. The safe use of such equipment requires knowledge, training, and experience under the supervision of a competent instructor. . . . The many disadvantages and limiting factors encountered in the safe use of closed- and semiclosed-circuit equipment were not caught on as rapidly as it should have done. I could have saved him a lot of embarrassment on that occasion if I had had the intelligence to hold onto his elbow - he covered in front of me while trying to untie the knot of the rope from his reel - but I digress."

Communication Underwater

A major problem is how to communicate between two divers (especially in muddy water). According to the simplest scheme, if two divers are available, then they should go in together laying a guide line from a reel. The problem is, that as soon as any difficulty arises, then it becomes more or less essential to return to dry land in order to discuss whatever has arisen. (This problem is considerably diminished if you are using a "controller" on dry land. How should the exploring diver indicate his wishes to the controller? Giving sharp pulls on the rope according to an agreed code has definite limitations.)

In 1958 I constructed an underwater signalling device in an effort to solve some of these problems. It contained a transisterized amplifier with a small microphone and a pair of headphones that could be heard for several yards. Although the signal had to be sent to the controller, it was possible for the diver to send dot and dash signals along the guide wire to a telephone receiver at base. This gave a "bleep" which could be repeated for several yards and was used for normal operation, the codes were as follows: three beeps for "more line," two beeps for "less line," and one bleep for "out." Under all other circumstances, the line could be paid out or pulled in as required. However, if a walking diver should have the misfortune of walking over the edge of an abyss, then a
tighter control would be required. There was a system of signals (which in fact were never needed) to allow for this. This device worked well during the successful passage of Sumps 4 and 5 in Swildons Hole on 13/14 Sept. and 8/9 Nov. 1958, when we used the sound-powered phone from the far side of each of these sumps.

(A telemetry system so that the controller in Fig. 3 could be continuously informed of the diver's depth would be a useful feature if it could be devised.)

Training and Background

Expertise in underwater work is not sufficient for cave diving. Phillip Davies, who was an active cave diver in the 1950's, wrote in response to the first draft of this paper: "It might be useful to add that people involved should be cavers first, using breathing apparatus as a tool to tackle a particular problem, just as they might use explosives under different circumstances. It is wrong to encourage divers to tackle caving problems."

I have saved until last my comments on the subject of commitment. As a one-time cave diver, I am sensitive on the subject of safety. In my active cave diving days I had convinced myself that, if you are willing to take the proper precautions, then cave diving can be a sensible thing to do. So what do we mean by "proper precautions"? The main requirement is to spend enough time underwater every month so as to maintain an adequate level of proficiency. In many types of activity for which a high degree of skill is required (such as flying a private aeroplane, for example) it is necessary to spend at least ten hours a month, every month, to stay competent. (This is in addition to the initial training, of course.) A similar commitment in underwater time is required for yourself and for your friends to maintain proficiency for cave diving. Think about this, please.

Acknowledgments

This article is based on numerous discussions and explorations with many different people at many different times. Certainly, I am grateful to F.G. Balcombe, J.A. Thompson, R.E. Davies and J.S. Buxton for introducing me to cave diving; and to F.G.B., Thomas Cook, R.E.D., Phillip Davios, Derek C. Ford, Warren Hall, Christopher Hawkes and Oliver C. Lloyd for commenting on the first draft of this article - but really, the main acknowledgment must go to the numerous non-diving companions D. Hasell, J. Swinhill, O.C. Lloyd and many others who located sumps, identified problems, obtained local permissions, discussed points involving safety with the divers; acted as controllers, and generally made the whole thing possible. (Dan Hasell was the controller for cave dives at Wookey Hole for many years. Jim Swinhill located the sump in Threapland Cave, acted as controller, provided dinner at his home for eleven extra people after the dive described above, and so on. Oliver Lloyd took up cave diving in the 1960's and has greatly influenced the sport.) Why is it that such people are sometimes never mentioned in cave diving accounts?

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Note Added in Proof

The walking diver in all three diagrams is tied onto a safety line which is held by a supporter on dry land. For longer dives it was common practice to lay lines from a reel. The device being carried by the exploring diver in Fig. 3 is the APLD (Apparatus For Laying Out lines and navigation). The line reel is visible in Fig. 3 on this device.

Figure 3. The basic question with a preliminary dive is whether the supporting diver should enter the sump with the exploring diver or whether, as shown here, he should remain on dry land and wait for a signal to go in.
An Analysis on the Palaeogeographic Elements of Karst Development in the Wumin Basin, Guangxi, Southern China

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Abstract

By analysing the distribution of caves and terraces, the lithology of sediments, the ancient vertebrate fossils and sporo-pollens in the Wumin Basin, the conclusions may be drawn as follows:

1. During the Tertiary, the Wumin Basin was under erosion-denudation condition. The present peak-top plantion surface of 230-300 m above the sea level represents an old peneplain. In the Quaternary, the basin with its current karst features was gradually developed.

2. In the Quaternary, the paleoclimate experienced several great fluctuations with humid-hot conditions alternating with dry-cool climates. For instance, the accumulation of Gigantopithecus fauna fossils in the Ganxu Cave in the early Middle Pleistocene as well as Elephas maximus fossils and Liquidambar-Polypondaeae-Pteris-Cyatheaeae monsoon forest sporo-pollens complex in the late period of Late Pleistocene, all reflect a moist-hot environment.

3. The rhythmic variations of the paleoclimate eventually lead to an unbalance of corrosion intensity. In addition, the base-level fluctuations which were resulted from the neotectonic movements and the global paleoclimatic variations resulted in an obvious differentiation of karst development intensity both temporal and spatial. The stratified caves at different level bear evidence to such a process (see figure).

4. As the latitude in the Wumin Basin begin rather low, the duration of humid-hot periods has been longer and, when entering into the dry-cool periods, the amplitude of temperature lowering has been less conspicuous. These are very favorable for corrosion action. For example, the corrosion-denudation intensity in the Elephas-peat accumulated period (about 30000-40000 B.P. as dated by C14 and corresponding to a sub-interglacial stage of Wurm glaciation), was more than double that of present day.

Consequently, the "peak-forests" (Fenglin) landscape in the Wumin Basin is a typical tropical karst topography, which has undergone repeated humid-hot environments since the Quaternary. To a certain extent, it represents the case nearby the Tropic of Cancer in south China.

From this it may be seen that the palaeogeographic conditions are a basic evidence to study the development of the karst geomorphology and exogenic process, as well as to divide the basic karst geomorphologic types.

![Figure 1](image.png)

The distribution curves of caves:

\[ \text{number} \]

\[ \text{length} \]

\[ \text{volume} \]

\[ \text{relative value} \]

Figure 1. Correlation between the trend curve of temperature variation in Quaternary and the distribution curve of caves along different elevation in the Ganxu-Changan area of Wumin, Guangxi. Distribution curve of caves (modified after Liu Jinrong, 1973).
Sur Le Contour Des Poljes Karstiques

J. Nicod

RÉSUMÉ

Les levés géomorphologiques montrent bien que les poljes présentent des contours variés, généralement composés, d'où des problèmes de figuration. Ces contours peuvent être:

- rectilignes, traduisant un accident tectonique majeur: faille ou chevauchement; exemples du polje de Minde (Portugal), de Duvno (Yougoslavie), ou dans les Pélouses françaises du S, celui de Caille.
- à vallées affluente avec souvent un côte de déjection actuel ou hérité à leur débouché dans le polje (en Provence, partie N du polje de Cuges), et même des cônes rocheux.

Seul, ce dernier type de contour est caractéristique de la prépondérance des processus karstiques, dans des zones de fractionnement intense:

- dissolution au contact et sous les alluvions de fond de polje;
- érosion régressive à partir des porons;
- tassements dans le polje, soutirages (dolines),
- effondrements sur la bordure et à proximité (cf. dolines géantes sur le pourtour du polje d'Imotski (Yougoslavie).

Cette prépondérance des processus karstiques se traduit par un contact brutal entre la plaine et le versant, un Knick net. Ce knick a un caractère ubiquiste: on le trouve aussi bien dans les poljes tropicaux que méditerranéens (cf. les embayeements de la basse-plaine de la Neretva) et même tempérés: partie NW du polje de Sault. Dans ce dernier cas, des versants nus et corrodiés dominent les embayeements qui s'opposent aux versants couverts ou de dépôts de pente (grès périglaciaires) présents dans d'autres secteurs. Un knick net traduit bien les parties actives d'un polje.

Le levé des cartes géomorphologiques à grande échelle (1/20 000, 1/25 000, etc) montre bien le caractère varié et composite des contours des poljes, ce qui pose des problèmes de figuré. Tantôt, ce contour rectiligne ou sinueux s'exprime clairement dans la morphologie, tantôt on en est réduit à fixer arbitrairement la limite du polje à la plus haute courbe isohypse fermée, indiquée sur la carte topographique, ou à d'autres critères (rupture de pente), laissés à l'appréciation du cartographe.

Types De Contours De Poljes Mediterraneens

En simplifiant, et en fonction de notre connaissance personnelle de nombreux poljes, 3 types essentiels peuvent être retenus:

1 - Des contours rectilignes traduisent un accident tectonique majeur: faille, ou chevauchement (à forte inclinaison). Ils s'expriment par des escarpements, qui peuvent être perpendiculaires entre eux (SE du polje de Cuges). Un seul escarpement (Minde, Portugal) correspond à une fracture majeure souvent génératrice de barrage karstique; deux escarpements en vis à vis délimitent un polje-graben (ex: p. de Cugnies, Kastav, 1965); un système d'écaillés peut donner aussi un escarpement rectiligne (S du polje de Zafarrayas, Andalousie).

L'escarpement rectiligne peut directement être hérité du mouvement tectonique (graben du Val di Diano, Campanie) ou être lié à l'exploitation d'une zone broyée provenant d'un coulisement actif (El Yamouné, Liban). Mais, le plus souvent, c'est le contact structural qui est exploité, et l'escarpement de "ligne de faille" est en partie dans des roches imperméables (Minde), ou semi-perméables (dolomies à Rogues, fig. 1a), qui déterminent le barrage karstique. Dans de nombreux poljes méditerranéens, irréguliers, (irregular polje de la Neretva, de Cugnies) 3 processus sont présents dans de nombreux poljes. Très souvent, ces cônes de déjection, actuels ou hérités, se trouvent à leur débouché et rendent très apparent la fractionnement du contour réel du polje (Cuges, partie N, Fig. 1b).

Sous eux aussi, il s'agit de cônes rocheux (rock-fans) hérités, qui se raccordent à une banquette ou au niveau de corrosion du fond du polje (N du polje de Zafarrayas, au débouché des vallons de la Sierra Gorda).

2 - Les contours sinueux, à embayeements et hums, sont très caractéristiques des bordures des véritables poljes, au voisins des porons et des "estavelles" (inversacs). Le fond plat du polje dessine une multitude de goulées au pied des versants corrodiés, et il est parsemé de hums et de chicos, comme au S du polje de Cugnies (cf. carte au 1/50 000 de GOSPODARIC'HABIC' 1978), sur la majeure partie de celui de Nikšíć, (fig. 1c). Au voisins, les plateaux sont affectés d'une multitude de dolines d'effondrement, traduisant des phénomènes karstiques majeurs. Ce type de contour est vraiment caractéristique de l'activité karstique.

Processus En Action Sur Les Contours Sinueux, À Embayeements Et Hums Karstiquement Actifs

D'une façon générale, ces portions de poljes, marquées par les phénomènes hydrogéologiques majeurs (porons et inversacs) correspondent à des zones à haute densité de fractures, comme l'ont bien montré les recherches géotechniques (bordure W du BuMoiko Blato, RODLIC' 1972). L'inalité de la fracturation explique d'ailleurs les hums résiduels.

Cette condition étant remplies, 4 processus sont à l'œuvre:

1 - Les actions hydro-mécaniques au voisins des porons, sont en relation avec les variations brutes de charge des circulations karstiques, bien démontrées sur la bordure N et E du polje d'Imotski par les dolines-lacs jouant le rôle de cheminé d'équilibre. Ces actions peuvent se traduire par des effondrements de bordure, de la formation de vallées aveugles, l'apparition, dans le fond du polje, de dolines d'effondrement sous-avéoliaves (signalée à Cuges au XIXe siècle), et, surtout au-delà du polje, à la détermination de l'extension du polje, suivant le modèle offert par le petit polje de Njeguš (Crna Gora).

2 - La dissolution de bordure, en surface, est à mettre en rapport avec la nappe d'inondation, ou les marciages semi-permèables qui occupent très généralement ces portions de poljes. Ils sont dépendants des conditions hydrologiques: incapacité des porons à absorber toutes les eaux (Cuges), multiplicité des sources.
(N Mošćarško Blato), mise en charge des inversac et envahissement du fond du poljé par les eaux karstiques ainsi que dans certaines zones du bassin marin (exemple classique des semi-poljés de la basse-vallée de la Neretva).

Dans les poljés montagnards (Pays de Sault, Kuprës), l’existence de toundrâs, aux eaux très acides, augmente les possibilités de dissolution des bordures. 3 - La corrosion des bordures, est assurée, en profondeur, sous le niveau du poljé, par les eaux infilttrées dans les alluvions de fond de poljé, et y constituant des aiguifères en relation avec les circulations karstiques. Ce type d’aiguifère a été bien mis en évidence par les sondages dans le poljé de Zafarraya (HERAK, 1978; PEZZI, 1976), et dans ceux de Kestel (GÜLDALI, 1970).

On rappellera aussi l’importance du processus de crypto-corrosion (NICOD, 1975) au contact des argiles fersiéllitiques, dans les petits poljés et ouavlas.

4 - L’érosion régressive, à partir des ponors de bordure, joue un rôle antagoniste du processus précédent. En incisant le fond du poljé, le cours d’eau fait apparaltre, en les dègageant des alluvions, les surformations locales, mettant en évidence le rôle des divers processus et les incidences morphoclimatiques, a donc un double but: - scientifique, en nous éclairant sur la genèse des dépressions majeures du karst; - géotechnique, en attirant l’attention sur l’incidence de ces processus sur les activités humaines (êtanèchité des réservoirs, stabilité des constructions, etc…).

Les Contours De Poljé Et L’Evolution Morphoclimatique

Les contours sinuex, à embayments et hums, offrent une délimitation aisée, suivant un Knick, entre le fond du poljé et ses bordures. Toutefois, plusieurs types existent en fonction de l’évolution morphoclimatique.

1 - L’encoche basale de dissolution (Loeung-unter schneidung) caractéristique des poljés tropicaux humides, dans un contexte généré de Kegel ou de Turm-karst, est en relation avec les eaux acides des marécages (Fig. 2a), et se traduit par la multiplicité des demi-grottes, la base des moyotes (Fussühälte). Trois remarques limitent l’intérêt de cette forme spécifique:

- les demi-grottes sont liées à des sources karstiques à la base des tourelles (à Belliz, d’après MACDONALD, 1976), alors que dans les poljés méditerranéens, les formes de corrosion sont principalement au voisinage des ponors;
- l’encoche basale de dissolution n’existe par partout dans le karst tropicaux: dans le Kellelfy, à Madagascar, elle est absente, aussi bien sur le versant calcaire du poljé de bordure d’Ambodimanga, que des ouavlas ambôfibads.

- elle n’existe qu’exceptionnellement dans les poljés méditerranéens (cas du Lac des Rives, sur le Cauze de Lzarac).

2 - Dans les poljés méditerranéens, le Knick se trouve au contact d’une surface d’accumulation, celle du fond du poljé, et d’un versant. Il n’est donc que partiellement karstique. Ce remblaiement suivant l’altitude et les conditions locales peut être indifféremment fluvio-glaciaire (hauts poljés du Montenegro ou de l’Appennin), péri-glaciaire (Duvno, Cuges), fluвиatile (Popovo), fluviomarin (Basse-Neretva).

Deux cas sont à considérer:

a) le versant est parfaitement régé ("de Richter"), et à peu près nu, comme ceux du Popovo (Fig. 2b), ou du rebord SW du poljé de Duvno. Les matériaux cryoclastiques, corrélés de cette morphogenèse, sont piégés dans le fond du poljé, ou ont été partiellement éliminés par la corrosion de bordure. Cela est particulièrement évident dans le cas du poljé de Sault, dans l’Arlège, où les versants sont nus dans le secteur des toundrâs, et en partie masqués par des grèzes würmliennes dans une voûte de voile près de Belcaire. Dans le cas du Popovo, le problème est plus délicat, car le remblaiement a un caractère alluvial, mais les déformations provoquées par lui à la base, sont nécessairement plus anciens.

b) les versants sont irréguliers et corrodés avec des poches nombreuses de tourra-rossa, comme c’est le cas en bordure du poljé d’Otočak (Fig. 2d), remblayé d’un matériel lité, où les actions niveales sont plus nettes que l’effet de la cryoclase. Dans ce cas, le Knick est entièrement karstique, et le fond de poljé, vraisemblablement commandé par le niveau de l’aquifère, s’est établi au sein de la masse calcaire corrodée, et dont les formations résiduelles sont soutirées par le jeu des circulations karstiques au voisinage des ponors. Un tel dispositif témoigne de la continuité des actions karstiques:

- soit en raison de la nature dolomitique des roches formant les versants et reliefs résiduels (les dolomies étant les sélives);
- soit du fait que la région a connu, au cours des dernières phases froides, une prédominance des périodes nivales sur celles de froid sec.


La cartographie détaillée des bordures de poljé, en mettant en évidence le rôle des divers processus et les incidences morphoclimatiques, a donc un double but:

- scientifique, en nous éclairant sur la genèse des dépressions majeures du karst;
- géotechnique, en attirant l’attention sur l’incidence de ces processus sur les activités humaines (êtanèchité des réservoirs, stabilité des constructions, etc…).

Orientation Bibliographique

(ouvrages généraux et monographies récentes)


Figure 1. Contour de 3 poljé karstiques - Borders of 3 karstic poljes:
   a) Rogues (Causse de Blandas), b) Cuges (Basse-Provence), c) Niksic (Montenegro) (d'après HEDAK et RADOJICIC')

1 - Contour de corrosion-corrosion borders;
2 - escarpenment tectoniques-tectonic scarp;
3 - terra-rossa; 4 - cryo-clasts; 5 - cône rocheux-rock-fan; 6 - source k.-karst spring;
7 - ponor; 8 - estavelle (inversac).
Figure 2. Contact brutal entre la plaine et le versant - Sharp contact between the plain and the slope.

a) grottes basale foot-caves - dans le poljé d'Amboadoaka, Narinda, Madagascar
n: niveau de la nappe en saison sèche - groundwater in dry season;
v: vertisol

b) knick entre le versant régulé et la plaine alluviale - knick point between regular slope and alluvial plain - Popovo Poljé, Herzégovine.

c) Idem, à l'Ouest - in W border of - du Poljé de Sault (Pyrénées)
t: tourbières, peat-bogs

d) Knick entre un versant corrodé, à poches de terra rossa et la plaine alluviale - Knick point between corroded slope, with terra-rossa pockets and alluvial plain - E du poljé d'Otocak, Croatie.

e) coupe correspondante, fp - fluviatile à éléments périgl. fins
Hydrogeology of the Corchia Marbles (Apuane Alps-Italy): New Data From Water Tracing Experiments

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Abstract

The discovery of a new important cave near the top of the Corchia mountain obliged the authors to make water tracing experiments to discover if it was a part of the Antro del Corchia cave or not.

In the present paper the experimental results and the possible hydrogeological structure for the studied area are reported.

Discussion

The water tracing experiments showed that the Fighiera pothole and the Antro del Corchia cave are in direct hydrological connection, being a part of the same karstic system with NW-SE flow direction and without any retarding basin.

Moreover owing to the fact that all the positive risings are at an altitude less or equal to 450 m a.s.l., this has to be regarded as the base level for the Corchia karstic system; but, due to the fact that this level it's the same of the Antro del Corchia bottom, it's impossible in this cave to find new galleries deeper than the present ones.

The presence of the base level of the hydrological system at the Antro del Corchia bottom can be explained in two different ways:

1) This altitude still is the actual base level inside the marble formation, and its higher level with respect to the surface one can be justified by the recent rejuvenation of the Apuane valleys.
2) This altitude represents the lowest limit of marble formation, and here the phyllite begins, whose permeability is only due to fractures.

The second hypothesis seems to be more probable: in fact if this altitude would correspond to a karstic base level inside the marble formation, it would be an active or, at least, fossil karstic rising in the zone.

Moreover at the bottom of the Corchia cave the phyllite formation can be seen and this obviously makes stronger the presence of a marble phyllite boundary at this level, where, owing to their plasticity at the metamorphic temperature, the "grezzoni" formation has been bended by tectonic processes.

So that the hydrological situation of the Corchia M. can be reconstructed as in Fig. 2.

The Corchia karstic basin is formed by a large syncline with marble at its nucleus.

The two caves (Antro del Corchia and Fighiera) are in hydrological continuity and are parts of a single large karstic system, in which the water flows in NW-SE direction, even if with local deviations.

At the bottom of the Corchia cave there is the water inlet into the fillite and from this point the water circulation becomes phreatic along the tectonic fractures. At the end there are the risings in the Stazzema valley, all below the phreatic level defined by the Corchia cave bottom.

Conclusion

The water tracing experiments carried out in the two largest caves of the Corchia mountain led not only to the definition of the hydrological continuity and risings of the two karstic systems, but also to new informations about the hydrogeological structure of the Corchia marbles.

In fact due to the tracing experiments and the direct speleological observations, the general knowledges on the hydrology and the tectonic structures of...
all the zone have been largely increased.

Now to reach a complete definition of the hydrological basin it's necessary to control its NE boundaries and this will be possible in the next future, making the same tracing experiments starting from the river inside the "Uomo Selvatico" cave (see fig. 2) which has to be very close to the NE limit of the structure.

Acknowledgment
The authors thank the G. S. Piemontese, G. S. Bolognese, U. S. Bolognese, G. S. Faentino, and all the Speleological Groups of the Speleological Federation of Toscana for the help given during the water tracing experiments.

Bibliography

Table 1. The Corchia M. formations with their lithologic, hydrologic and karstic features

<table>
<thead>
<tr>
<th>Formation</th>
<th>Period</th>
<th>Lithologic type</th>
<th>Karstificability</th>
<th>Water circulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marbles</td>
<td>Jurassic</td>
<td>Marbles, saccharoidal and nodular limestones</td>
<td>high (large and complex caves)</td>
<td>well developed subterranean karstic rivers</td>
</tr>
<tr>
<td>&quot;Grezzoni&quot;</td>
<td>Triassic</td>
<td>weakly recrystallized dolomite</td>
<td>small (few important caves along tectonic structures</td>
<td>small phreatic tubes or large joints partially widened by corrosion</td>
</tr>
<tr>
<td>Phyllites</td>
<td>Paleozoic</td>
<td>Phyllites, porphyritic schist</td>
<td>none</td>
<td>small fractures</td>
</tr>
</tbody>
</table>
Fig. 1. The Corchia marbles area: 1) Fighiera pothole; 2) Antro del Corchia cave; 3) Uomo Selvatico cave. The risings are indicated by the numbers inside the small squares; the arrows show the dye underground way to the springs. In the Cardoso area only the 7 spring was not reached by the dye due to its altitude higher than 450 m a.s.l. A-B and A-C are the directions of the section of fig. 2.
Fig. 2. The hydrologic reconstruction of the Corchia M. A-B and A-C are the same direction that in fig. 1. 1) dye inletting place; 2) dye dispersion after the sump at the bottom of the Antro del Corchia cave; 3) dye underground way 4) Boundary of the Metamorphis autochton unit; 5) sections of cave galleries which cross the A-B and A-C sections; 6) Marbles; 7) "Grezzoni"; 8) Phyllities; 9) Fighiera pothole; 10) Antro del Corchia cave.
Genetical Observations on some Macrocrystal Cave Pearls Found in Two Caves of Lombardia (Northern Italy)

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Abstract

Some small macrocrystal cave pearls were observed in two caves of Lombardia. The laboratory analyses showed that the smallest ones were perfect calcite monocrystals.

In the present paper the authors define the genetic physico-chemical conditions which caused the growth of such unusual cave formations.

Introduction

During a systematic morphological study carried out in the greatest karst cavities of Lombardia (Northern Italy), inside the Forgnone cave (1010 Lo/Bg) several undestroyed ooliths (0.1-4.0 mm in diameter) (see fig. 2, A) were observed.

Some of these cave pearls were carried out and analyzed to define their genesis.

In the present paper these analyses are described and the conclusion from the experimental discussed.

Experimental part

The entrance of the Forgnone cave is in the Imagna valley at 750 m a.s.l.

The rocks in which the cave is carved belong to the limestone of Reticul and are pure limestone, marly limestone and marl, all well stratified from 10 to 18 cm thick.

Owing to the different karstification of these rocks, the cave passages present several horizontal blades in the walls.

The cave (see fig. 1) is practically a single gallery with an active water flow inside.

There are also some side passages, the most important of which is the "Possale-230 branch" (A and B in fig. 1); this is an ox-bow in the first part, while in the second there is water circulation, which sometimes partially fill this part as testified by the large mud traces present on the wall.

Just at the end of the 230 branch at 3 m from the floor and 2 m from the ceiling of the gallery there is a small wall pocket (see fig. 1, C) 12 cm deep and inside this cut there was a small amount of sand and mud, both white in colour.

The optical microscope analysis showed that the larger fraction of the sand (0.1-4.0 mm) consists of a spherical macrocrystal oolith not smoothed or rounded at all (see fig. 2, A).

Their surface is characterized by the juts of the tops of several not eroded calcite crystals (external acicular structure: Ullastre and Masriera, 1973).

Some of these cave pearls (about 50) were sectioned to expose their nuclei, and the thin sections showed that the ooliths are of two different kinds.

The first one (see fig. 2, B) is the normal one, and has a fibrousradial (spherulitic) structure with calcite crystals elongated along the Z axis and starting from a nucleus built up by a superficial oolith grown on a non calcareous grain.

The second kind of ooliths consist of calcite microcrystals while the external part (spherulitic) of large calcite crystals.

The second kind of pearls are quite equal to the first one but has no nucleus (see fig. 2, C); all its structure consists of calcite macrocrystals, often with concentric impurity layers, which don't interrupt the radial deposition of the crystals (Ullastre and Masriera, 1973).

Some ooliths of the second kind showed an interruption in the crystal growth due to an aphanitic layer of calcite crystals of the surface of a smaller oolith all over the layer and the radial structure of calcite macrocrystals is repeated.

The smaller fraction of the sand (0.1-0.2 mm) has been analysed by a scanning electron microscope and consists of rhombohedral calcite monocrystals: traces of cleavage are evident and in the center of the faces of the principal rhombohedron there are one or more tops of inverse rhombohedrons with different orientations.

Discussion

The position in which the ooliths have been found is too high to be reached by the river water even when the level changes in the 230 branch.

Moreover they can't be reached by dripping water owing to the fact that the cup, in which the pearls are, is protected by a limestone blade.

For these reasons the only water which can reach the cup is the thin condensation layer ever present on the walls and always in movement more or less on a downward level.

Nevertheless water supply has to be sufficient to avoid the ooliths linkage to the cup floor, but at the same time it has to be not too strong, otherwise the tops of the crystals on the pearls surface nave to be smoothed.

So that the growing conditions are those of quiet environment interested by continuous supply of water saturated with respect to CaCO₃.

The water condensation certainly undergoes periodsical (seasonal) and aperiodical variations due to the hydrological conditions of the gallery.

Sometimes there are favorable conditions for water evaporation with consequent supersaturation and then CaCO₃ precipitation.

Insulated monocrystal can grow due to the quiet condition existing in the wall pocket; with the crystallization process in the centre of the faces of the original crystal the inverse rhombohedrons appear and due to the growing process they come in contact to each and form the ooliths without nucleus, if we don't count the rhombohedron which has firstly crystallized as a nucleus.

So that the structure of these ooliths has to be considered primary and not diagenetic.

The aphanitic layers of calcite microcrystals are to be ascribed either to periods in which noncrystallization takes place (Gnaccolini, 1978), or more probably to periods in which the water supply was larger than the normal one, and consequently due to the water stirring inside the cup, microcrystals and not macrocrystals were deposited.

The ooliths with nucleus have the normal origin as described in several other cases; but it's interesting to notice that the length of the crystals grown on the superficial oolith is of the same dimension of those grown on the aphanitic layer in the pearls without nucleus.

This fact seems to test the hypothesis of an higher water circulation for the growth of microcrystals and also demonstrates the occurrence of periods of exceptional water supply which caused the paphanitic layer of the pearls and nuclei, while at the same time, bringing non calcareous nuclei into the cup, give to the "normal" ones the possibility to develop.

Conclusion

The analysis of this particular kind of cave pearls allows us not only to prove the existence of anomalous ooliths in which the nucleus is completely absent, but also demonstrate that the cave undergoes periods of high and low water supply: the first of which is responsible of the growth of the radial macrocrystals and of the "normal" ools, while the second of the discontinuities in the crystal growth and of the supply of non calcareous grains, which are utilized as nuclei for the "normal" ooliths.

A short time after the finding of the Forgnone pearls, other similar have been observed in the same zone, inside the Buco del Castello cave (1309 Lo/Bg).

This fact clearly indicates that the genetical mechanism as described has to be considered not exceptional and perhaps is quite common but not observed till
now owing to the small scale at which it can be noticed.

Bibliography


Fig. 1 The Forgone cave: A-B is the "Fossil-230 Branch"; the star indicates the place in which the ooliths have been found.

C: the section of the gallery wall, with the cup
Fig. 2. Cave pearls from Forgnone Cave - The scale is always in mm except that in D case in which it is in 0.1 mm

A) general view of the ooliths

B) Thin section of a "normal" oolith with non calcareous nucleus, superficial oolith and external spherulitic structure

C) thin section of an oolith without nucleus: it's evident the aphanitic layer that covers a smaller oolith

D) S.E.M. photo of a calcite monocrystal which represents the smallest fraction of the wall pocket sand: it's evident an inverse rombohedron in the centre of a face of the crystal.
In the 1950's, the "karstic reactivation" theory developed by N. Llopis Lladó was used by this and other investigators in order to reject the arguments on the stratigraphic position of the Asturian, a local Epipalaeolithic culture, established by Vega del Sella in the early twenties. These suppositions of "karstic reactivation" with the deposition-erosion sequence in late and Post-Palaeolithic sites is analyzed in this paper. The conclusion points towards the validity of Vega del Sella's depositional scheme supported by stratigraphic sequences and radiocarbon dating, and the lack of evidence in favor of Llopis' interpretation.

### Resumen

En los años cincuenta la teoría de la "reactivación karstica" desarrollada por N. Llopis Lladó fue utilizada por éste y otros investigadores para rechazar los argumentos sobre la posición estratigráfica del Asturiano, una cultura Epipaleolítica local, tal como habían sido establecidos por Vega del Sella a comienzos de los años veinte. En esta comunicación analiza la supuesta implicación de la "reactivación karstica" con la secuencia de depósito y de erosión de los yacimientos del Paleolítico Final y Postpaleolítico. La conclusión apunta hacia la validez del esquema de depósito propuesto por Vega del Sella, apoyado por secuencias estratigráficas y dataciones de radiocarbono, y a la falta de evidencia en favor de la interpretación de Llopis.

### Historical Background

In 1914 the Count of Vega del Sella dug a test pit in the cave of Fonfría, close to the small village of Neuva (Asturias, Spain), finding a prehistoric industry, unknown in the current archaeological record. The lack of a clear context led him to assign these materials to the Lower-Middle Palaeolithic transition, only on typological grounds (Vega del Sella, 1914).

The systematic research conducted by this archaeologist during the following years in several sites of Eastern Asturias offered him a considerable amount of information about this particular culture, called Asturian, a denomination created by H. Obermaier (Obermaier, 1916, 1924). The most important features of the Asturian were a lithic industry dominated by choppers and, specially, very typical picks made from quartzite cobbles: the "Asturian picks"; and also the association of this industry to shell-midden sites, preferably located on the coastal areas of Eastern Asturias and Santander, in the North of Spain (Figure 1).

These shell-middens, the "concheros", commonly appear in caves and rock shelters in protected zones, with important concentrations close to the estuaries. The character of this culture has been analysed in detail in some studies (Vega del Sella, 1923; Clark, 1976; Gonzáles Morales, 1981).

The Nature of Asturian Deposits

We have said that most of the Asturian sites were shell-middens. Strictly speaking, they are usually the remains of shell-middens. After the accumulation of Asturian deposits at the entrance of caves and rock-shelters there was an erosive phase that affected them, with very few exceptions, destroying the main part of the middens. The evidence we commonly find today is limited to fragments of the original deposits cemented against the walls and/or ceiling of caves and shelters.

As these cemented deposits appeared always over Upper Palaeolithic strata in caves, or Asturian tools were found on the surface of some sites, Vega del Sella assigned them to a post-palaeolithic date, and proposed the following depositional scheme (Figure 2):

- Deposit of Upper Palaeolithic layers
- Deposit of Asturian conchero
- Period of partial concretion of the shell-midden
- Destruction of the conchero by the action of water, leaving fragments cemented against the walls and/or ceiling (Vega del Sella, 1923).

This sequence of facts was supported by some other arguments: at least in one site (the cave of La Riera), the conchero remained intact, because it was covered by a thick stalagmite crust and, on the other hand, the cave itself did not seem to have any water circulation (at least of the necessary volume) after the deposition of the shell-midden; the crust sealed a very complete sequence of Upper Palaeolithic levels. At La Riera the stratigraphic position of the Asturian was, therefore, quite clear; in other sites, like the cave of Fonfría (Fonfría close to La Riera), the facts were similar (Vega del Sella, 1930).

Vega del Sella's scheme was considered valid until the development of Llopis' theory and its application to this matter.

### Llopis' Point of View

In 1953, N. Llopis Lladó and other investigators explored some caves in the lower Río de Las Cabras (Asturias), where La Riera and other caves are located (Llopis, 1953a, 1953b). As a result of these explorations, Llopis suggested the idea that Asturian middens were allochthonous deposits and that there had been an erosive phase before the deposits of Late Palaeolithic levels. In a further development of this theory, Llopis seemed to say that the concheros were redeposited at the entrance of the caves, transported from their original location by the action of the waters (Jordá, 1954:178-179).

In 1957 the problem goes one step beyond; Llopis and other authors formulated the following arguments: the great antiquity of Asturian industries and sites, the former opinion justified by their crude aspect, the later one by the arguments cited above, reinforced by the "demonstration" obtained in the caves of La Cámara and, specially, La Lloseta (Hernández-Pacheco et al., 1957: 21-24).

Llopis applied his ideas about speleogenesis and cycles in the evolution of caves to the problems of the Asturian sites as follows: since the shell-middens have been heavily cemented after their deposition, in the case of cyclical reactivation of Karstic circulation, the waters would destroy the less consolidated Upper Palaeolithic levels, and not the shell-midden.

In the cave of La Cámara, near Meré (Llanes, Asturias), Llopis and his collaborators find what they suspected was a validation for that hypothesis: two fossil resurgence mouths, located at different levels over-looking the Río de Las Cabras (+5 m. and +8 m.) in the upper one there is an Asturian conchero with typical picks; in the lower one scanty remains of archaeological layers are to be seen cemented against the ceiling. These facts were interpreted by Llopis as evidence of the several stages of occupation: first, the upper cave was inhabited, while the lower one was still active as a resurgence; after the disappearance of the water circulation through this last cave, it was occupied, "maybe in Magdalenian times". On the basis of such evidence a pre-magdalenian date was proposed for the Asturian conchero.

In this interpretation there are several major debatable points. First of all, there is no evidence, as far as we can see, of the necessity of the palaeo-archaeological strata in the lower cave precisely to the Magdalenian. The only thing we can see now at the cave are some cemented patches that include flint and quartzite flakes.
and fragmented bones which in any case could be considered roughly of Upper Palaeolithic age, without a higher degree of precision. Second, in this cave the erosive destruction of Upper Palaeolithic levels is plainly evident, and the Asturian shell-midden, located at a slightly higher level, was preserved. Third, the Palaeolithic deposits at the lower cave filled it completely, as attested by the remains cemented against the roof; so, any later occupation would necessarily take place in the upper entrance.

The conclusion is that the data available from La Cámara cannot support Llopis' interpretation, the alternative hypothesis (Asturian occupation later than the Upper Palaeolithic one) seeming more probable. In fact, the sequence: "prior Upper Palaeolithic occupation in the lower cave/deposit of Asturian midden in the upper mouth later" is non-contradictory and easier to accept.

Approximately at the same time, F. Jordá developed some consequences of Lloips' theory, applying them again to the problem of the chronology of Asturian deposits. Jordá paid special attention to the consolidation or "petrification" of shell-middens, emphasizing the fact that "petrified" brecias were more resistant to the erosive action of the waters than the "loose" Upper Palaeolithic levels. In his study of the cave of La Lloseta (= de la Morla o del Rió), near Ribadesella (Asturias), this investigator developed such argumentation in detail, as a definitive basis for his own hypothesis about the very old chronology for the Asturian industries. About this cave, Llopis even explained that the cemented remains of Asturian conchero were covered by Magdalenic deposits, again a supposedly definitive proof of their point of view (Llopis, 1970: 177-178).

But there were a couple of aspects which seemed to be forgotten. First of all, the idea of the original concheros as petrified masses of shell cannot be supported by an evidence; of course, the shell-middens seemed to have great dimensions in some caves, reaching the roof and walls of cave mouths. But the only cemented parts of these middens were just the ones located in contact with roof and/or walls where a necessary amount of precipitation was present; because of that we very often find fragments of conchero hanging from stalactites or dripstones. The midden itself was loose, even when covered by great travertine formations, like at La Riera, and this mass of shells is very easily eroded by water action.

Second, and more important, at La Lloseta there is in fact a cemented shell-midden deposit on the walls, covered by Magdalenic levels. But it is not an Asturian shell-midden, but a Magdalenic one. In this cave there is evidence of two clearly separated levels of conchero remains on the walls: the lower one corresponds as faunal remains and C14 shows - to the Lower-Middle Magdalenic, and the upper one - not covered, of course, by Magdalenic levels - has been radiocarbon-dated as Late Asturian. In this case it seems evident that the mechanical identification "shell-midden" = "Asturian" led Llopis into a very serious mistake.

Third, at La Lloseta the action of the waters as an erosive agent is very doubtful: in a recent study M. Hoyos concluded that the deposits in the cave collapsed, maybe because of technical or gravitational adjustments of blocks in the cave system where La Lloseta is located; so, the actual position of shell-midden remains cemented against the walls is due to such fall, and not the result of hydric erosion (Mallo et al., 1980).

And a final comment on the idea proposed by Llopis of Asturian shell-middens as allochthonous deposits having been transported to cave mouths by the water: recent sedimentological studies of Asturian conchero samples reveal their character of cultural deposits, and there is no evidence of secondary deposition (Butzer and Bowman, 1976).

Conclusions

Briefly, the main conclusion we can retain is the lack of evidence supporting Llopis' points of view about the erosive actions on Asturian concheros supposedly related to ancient cycles or karstic reactivation. As far as we know from recent studies and, specially, radiocarbon dates, the erosion of Asturian shell-middens took place in a quite recent date, maybe during the Subboreal or Subatlantic phases.

The sequence proposed by Vega del Sella in the second decade of this century seems to be the correct one, a more simple and logical interpretation of the facts, and now reinforced by new studies and analyses. The radiocarbon information places the Asturian concheros between 9,000 and 5,000 years B.P., this culture being a long-term coastal adaptation as many others in Mesolithic Europe.

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An Evaluation of the Polaroid Ultrasonic Ranging System as a Tool for Cave Surveying

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Abstract

The ultrasonic ranging system consists of an ultrasonic transmitter/receiver, a pulse detection circuit, a visual display. This device was evaluated in both the laboratory and caves for its usefulness, reliability, accuracy and ease of operation. Its limitations as a cave surveying tool are defined and enhancements are recommended. A new surveying methodology which uses the device's attributes is presented. A cave map produced with the help of this device is shown.

The Hardware

The Polaroid Ultrasonic Ranging System is a range measuring device manufactured by the Polaroid Corporation of Cambridge, Massachusetts, U.S.A. The system consists of three basic subsystems: the transducer, the electronics and a mounting system.

The transducer is cylindrical in shape, about 38 mm in diameter and 8 mm thick. It has a foil stretched over a grooved plate. When the range system is activated, the transducer emits a pulse of sound, then waits to receive the echo returning from whatever object the sound pulse has struck. The emitted pulse is a high-frequency, inaudible pulse lasting for 1 millisecond, and consisting of 56 pulses of 4 ultrasonic frequencies: 60kHz, 57kHz, 53kHz and 50kHz. Using 4 frequencies enhances the possibility of a single frequency being cancelled by a target of a particular shape in which case there would be no echo from the target.

The electronics consists of two circuit boards, one to control the transmitting/receiving function and the other to generate a digital display. A digital readout displays measured distance to a tenth of a foot five times each second. The electronic display is a Polaroid evidently does not manufacture a display circuit for distances in meters.

The mounting system is comprised of a collapsible camera tripod, a protractor and the packaging of the transducer and the electronics. The ultrasonic transducer was mounted in a small metal box which in turn was fastened to the tripod. The box was free to rotate about the protractor indexed to measure the relative change in angle. All the circuits and the batteries were placed in another metal box. The power switch and digital display were positioned on one face of this box. Figure 2 shows how the equipment was arranged.

Cave Mapping with the Range Finder

The range finder's main attribute as a tool for cave surveying technique, measuring distance is usually much easier than determining azimuth and inclination. Thus for the instrument to be useful it would have to work much faster, easier and more accurately than the conventional method of stretching a survey tape. The polar coordinates of each set of 36 measurements were converted to a 3-dimensional Cartesian coordinate system. The calculations were done on a Hewlett-Packard 9830 desktop computer. Since the H-P 9830 did not have enough memory to handle a hidden line algorithm, the entire figures were drawn out for each plane on the H-P plotter. The final pictures (Figure 4) were obtained by selecting the lines so the mutually perpendicular planes would be shown. Each orientation of the planes was given a different type of shading lines. In addition, 3 sides of a 5x5-foot box were drawn as if viewed from the same viewpoint point used to view the cave. Figure 4 gives 2 views of the same data from opposite viewpoints. Both are taken as if viewed 25 degrees above the horizontal plane.

The laboratory evaluation consisted of ascertaining the accuracy and effectiveness of the basic principles which we planned to use in the cave. The range resolution of 0.1 foot (0.03 meter) was deemed accurate enough and there was no significant degradation of performance noted using the packaging system we had implemented. The instrument often gave erroneous readings if the transducer was aimed either towards a corner, or so it had a low grazing angle with a flat surface. In these cases the readings fluctuated even though the transducer was stationary. Caves are usually irregular in shape and the boulder cave we mapped was exceedingly so. As with all line-of-sight measuring devices, some forethought
and planning should be exercised to preclude erroneous sampling attributable to overhangs and other obstacles.

In the cave environment the range finder provided to be versatile and easy to use. The speed of operation has already been mentioned. One of us would operate the transducer and call out the readings while the other would record the data. Much more detail can be included in the survey with a significant savings in time.

The range limit of 35 feet (10.7 meters) proved to be no obstacle in Greenhorn Cave. It could, however, be a significant factor if an area had a radius larger than the maximum range of the system.

This system promotes safety since it is no longer necessary to ascend or traverse hazardous areas in order to obtain survey data. Just aim the transducer over the hazardous area, take a reading and record the range.

Any person considering purchasing the Polaroid ultrasonic ranging system should understand that it is necessary to ruggedize and encapsulate the transducer and circuit boards before taking the system into a cave. Even then it must be treated as a delicate instrument.

The booklet provided by Polaroid with the ranging system gives several suggestions on how to adapt the performance of the unit to specific needs, such as how to increase the sampling rate of the transducer but rather of the decoding circuit. A redesigned circuit could greatly enhance the range.

In conclusion, the merits of the system are: 1) ease of operation, 2) rapid sampling rate, 3) operable by one person, 4) compactness, 5) lightweight, 6) accuracy, and 7) safety. We believe safety (hazardous areas can be avoided) and the speed of taking measurements are the two most important factors in favor of using this system.

Reference
Polaroid's booklet on the Ultrasonic Ranging System. S. Kempe and P. Schneider critiqued the German translation.
Figure 2: Arrangement of Equipment

Figure 3: Measurements taken at station 4
Figure 4: Two views of the same section of Greenhorn Cave
The Shape of "Gypsum Bubbles"

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Abstract

A "gypsum bubble" (Quellungshöhle in German) is a phenomenon of gypsum karst caused by the hydration of anhydrite (CaSO₄) to form gypsum (CaSO₄·2H₂O). The expansion of rock during the hydration process forces the superstrata into a hollow, bubble-shaped dome. A mathematical model for the shape of "gypsum bubbles" is obtained by solving three differential equations of (1) the compressive stress resulting from localized hydration, (2) the effect of gravity, and (3) shear stress. The model predicts that the shape can be expressed as a function of one parameter. Results comparing field measurements with the theoretical model are given.

Zusammenfassung

Eine Quellungshöhle ist ein Phänomen des Gipskarst, das durch die Hydratation des Anhydrits (CaSO₄) in Gips (CaSO₄·2H₂O) verursacht wird. Die Ausdehnung des Gesteins während des Hydratation-Prozesses zwängt die obere Schicht zur Bildung eines hohlen, blasenförmigen Dom. Ein mathematisches Modell für die Gestalt der Quellungshöhlen kann durch Lösen von drei Differentialgleichungen für (1) die Druckkompression auf Grund der lokalen Hydratation, (2) die Wirkung der Gewichtskraft und (3) Scherbelastung aufgestellt werden. Das Modell zeigt, dass die Domgestalt als Funktion nur eines Parameters ausgedrückt werden kann. Resultate, welche Messungen im Feld mit dem theoretischen Modell zeigen, dass die Domgestalt als Funktion nur eines Parameters ausgedrückt werden kann. Resultate, welche Messungen im Feld mit dem theoretischen Modell verglichen werden, aufgeführt.

Introduction

When water contacts anhydrite (CaSO₄), the anhydrite is hydrated to form gypsum (CaSO₄·2H₂O). The gypsum takes up a much larger volume than the original anhydrite. Estimates of the increase range up to 250%. Anhydrite sometimes occurs at or near the surface of gypsum karst. Surface water causes the expansion of the rock. The newly-formed gypsum is pushed up from the horizontally-bedded anhydrite into hollow domes which we call "gypsum bubbles". These tend to be round or elliptical when viewed from above.

The earliest description of a gypsum bubble is probably by Stolberg (1923). He described the Weischmeide in the Harz region of Germany. This "Quellungshöhle" was 8 by 7.5 meters across, 2.5 meters high and 0.5 meters thick. Reinboth (1967) has reported its collapse.

In the USA, Myers (1960, 1969) briefly described a gypsum bubble in Oklahoma. All the gypsum bubbles measured for this paper were found in the Permian-age gypsum of Eddy County, New Mexico. The biggest gypsum bubbles found in New Mexico were about 2 meters in diameter, stood 0.3 meters high and were 0.1 meters thick. Many had holes or were partially collapsed but this probably happened after they were formed. Figure 1 shows a contour map of two gypsum bubbles. The contour interval was 5 cm. Measurements of its height were made every 20 cm. in a grid pattern shown by +'s in the figure.

Mechanics

In this section we develop a mathematical theory which predicts the shape of the gypsum bubble. We chose a Cartesian coordinate system with the +y plane horizontal and at the mid-thickness level of the neighboring gypsum plane. The +x-axis points downward through the center of the bypass bubble. We assume that Hooke's Law describes the strain produced by stresses in the gypsum layer. If we consider a thin slice through the bubble is the +x-z plane, the problem of predicting the shape of the gypsum bubble reduces to that of computing the deflection of a prismatical beam (that beam being the cross sectional slice of the bubble). Forces in the +y-direction must be in balance or else the bubble would be in motion, hence these forces can be ignored.

Timoshenko and MacCullough (194) give the curvature of the deflection curve of a prismatical beam in bending as

\[ \frac{1}{p(x)} = \frac{M(x)}{EI} \]  

(1)

where: p(x) = radius of curvature at distance x from the origin (cm),
M(x) = bending moment at distance x from the origin (dyne cm),
E = Young's modulus for the material of the beam (dyne cm⁻²), and
I = area moment of inertia of the cross section of the beam with respect to the neutral axis (cm⁴).

Note that the value of E may depend on the direction chosen for the +x-axis. i.e., E may be a vector. This may be responsible, at least in part, for the noncircular bubbles.

With the assumption that the deflection is small, or more precisely that \( \frac{dz}{dx} \) is << 1, equation (1) may be rewritten

\[ E I \frac{d^2z}{dx^2} = M(x) \]  

(2)

There are at least three sources of bending moment which must be considered. The principal cause of the deflection is thought to be a compressive stress resulting from the localized hydration of the gypsum layer. This deflection is modified by gravitational stress on the bubble. A small additional modification is produced by the shear stress. The principle of superposition allows equation (2) to be written

\[ E I \frac{d^2z}{dx^2} = M(x) + \rho w t (e: - z(x)) \]  

(4)

where: z₁(x) = deflection of the beam due to hydration (cm),
ρ = compressive pressure produced by the hydration (dyne cm⁻²),
w = width of the beam (cm),
t = Thickness of the beam (gypsum layer) (cm),
e = eccentricity of the load (cm).

The solution is:

\[ z(x) = \frac{1}{k} \left( \frac{M(x)}{E I} \right) e: - x + \frac{1}{E I} \int \left( \frac{M(x)}{E I} e: - x \right) dx \]  

(5)

with boundary condition: z₁(x) = 0 at x = ± r, and
z₁(x) = -b₁ and dz₁(x)/dx = 0 at x = 0.

The solution is:

\[ \frac{1}{\mu} = \cos kr - \cos kx \]  

(6)
where: 
\[ r = \text{radius of the bubble in the x direction (cm)} \],
\[ h_1 = \text{height of the gypsum bubble if compression alone were acting on the gypsum layer (cm)} \].

Since we have assumed that the square of the derivative of the deflection curve is small compared with unity, we must have
\[ z_1(x) + z_2(x) + z_3(x) = h_1 \left( \frac{\pi}{2} \right)^2 - 1 \] (9)

Once the compressive stress lifts the beam from its supporting sub-layer the beam is subjected to deformation by gravity. The differential equation of the deflection curve is
\[ z_1(x) = h_1 \left( \frac{\pi}{2} \right)^2 - 1 \] (9)

Gravity

In addition to the above deflections, the shearing force produces an additional deflection in the form of a mutual sliding of adjacent cross sections of the beam along each other (Timoshenko and MacCullough, 1949). The differential equation of the deflection curve is
\[ \frac{d^2 z_3(x)}{dx^2} = - \frac{3}{2} \frac{g \cdot g}{G} \] (12)

with boundary conditions: \( z_3(x) = 0 \) at \( x = 0 \), and \( \frac{dz_3(x)}{dx} = 0 \) at \( x = \pm r \), where: \( z_3(x) = \text{deflection of the beam due to gravity (cm)} \),

\( g = \text{density of the gypsum bubble (gm cm}^{-2} \) and

\( g = \text{acceleration due to gravity (cm sec}^{-2} \). Since for a beam of rectangular cross section, \( r = w \sqrt{3}/12 \), the solution of equation (10) is
\[ z_2(x) = \frac{g \cdot g}{2} \left( \frac{\pi}{2} \right)^2 - 6 \left( \frac{\pi}{2} \right)^2 + 5 \] (11)

Shear

In addition to the above deflections, the shearing force produces an additional deflection in the form of a mutual sliding of adjacent cross sections of the beam along each other (Timoshenko and MacCullough, 1949). The differential equation of the deflection curve is
\[ \frac{d^2 z_3(x)}{dx^2} = - \frac{3}{2} \frac{g \cdot g}{G} \] (12)

with boundary conditions: \( z_3(x) = 0 \) at \( x = \pm r \), and \( \frac{dz_3(x)}{dx} = 0 \) at \( x = \pm r \), where: \( z_3(x) = \text{deflection of the beam due to shear (cm)} \), and

\( G = \text{modulus of elasticity in shear (dyne cm}^{-2} \). The solution is
\[ z_3(x) = \frac{3}{4} \frac{g \cdot g}{G} \left( \frac{\pi}{2} \right)^2 - 1 \] (13)

Combined Deflection

The combined deflection of the beam, hence of the gypsum bubble cross section, as given in equation (3) and a little algebra is
\[ z(x) = K \left( \frac{\pi}{2} \right)^4 + (1 - K) \left( \frac{\pi}{2} \right)^2 - 1 \] (14)

where:
\[ K = \frac{g \cdot g \cdot r^2}{2E \cdot t^2 \cdot h} \]
\[ h = \text{height of the gypsum bubble (cm)} \]
\[ E = \text{modulus of elasticity (dyne cm}^{-2} \)

The dimensionless shape of the gypsum bubble cross section is thus seen to depend solely on the dimensionless shape parameter \( K \), in which we have concealed our ignorance of the physical properties of gypsum. This can be demonstrated by writing out the height of the gypsum bubble in terms of fundamental physical parameters, viz.,
\[ h = \frac{E \cdot t^2}{6 \cdot p \cdot r^2} - 1 \]

Incorporated into the above mathematical development is the assumption that the beam (the gypsum bubble cross sectional slice) is freely supported at \( x = \pm r \). This means that the cross sections of the beam at the two ends are free to rotate. This, in turn, means that the gypsum bubble should have a well defined edge where the surface of the neighboring gypsum plane meets the surface of the bubble, a feature in agreement with the observations.

We note that it is possible that the shape parameter \( K \) is so small that it is quite negligible compared with unity. This would be the case were the bubbles formed in another type of rock, such as limestone. We have here retained all the terms in equation (14) because we do not know the values of Young's modulus or the shear modulus for gypsum. Neither do we know the pressure or the eccentricity of the compressive load.

Field Data

The shapes of actual gypsum bubbles were determined by measuring down from a horizontal beam resting on top of each gypsum bubble. Six gypsum bubbles in New Mexico were measured in this manner. Three typical shapes are shown in Figure 3. Our model predicts that these shapes should be given by equation (14), a fourth degree polynomial with one unknown \( I \). In order to estimate \( I \), the least squares fit equation was derived for data of the form given by our model. The estimates for \( K \) derived by this method were not consistent. Indeed some estimates of \( K \) were negative, a physical impossibility since each of the factors making up \( K \) is a positive number. \( K \) is probably close to 0. Figure 3 shows the modelled shapes of gypsum bubbles of these dimensions if \( K \) were 0 or 1. Several of the gypsum bubbles were unsymmetric. This could have been due to many causes including variations in the thickness of the typsum, Young's modulus not being isotropic, unequal weathering, and damage to the gypsum bubbles during or after their formation. Many of the gypsum bubbles had holes, usually near the edge where stresses caused by the bending are the greatest.

In summary, the fundamental assumption of our model that the strains produced by stresses in the typsum layer are described by Hookes Lae, leads to a relatively simple mathematical solution, producing a result (equation(14) easy to compare with the observations. This simple model leads us to believe that gravity and compressive and shear stresses are the dominant forces in determining the shapes of gypsum bubbles. More complicated models involving elastic-plastic theory are probably not warranted in the absence of more detailed information on the time development of the structures.

Acknowledgements


References

Figure 1: Contour maps of Gypsum Bubbles

Figure 2: The geometry of a beam under compression. The geometric variables are defined in the text.

Figure 3: Typical Gypsum Bubbles
- $x$ = data points on real gypsum bubbles
- = shape of real gypsum bubbles
- $-$ = shape of modelled gypsum bubble if $K = 1$
- $-$ = shape of modelled gypsum bubble if $K = 0$
A cupstone petroglyph of possible astronomical significance from an Early Woodland Site in the Karst Region Jackson County Kentucky

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Abstract

A cupstone petroglyph, found in a karst region of south central Kentucky, may represent a portion of a prehistoric astrolabe. This petroglyph may have been used to observe the position of celestial bodies during significant astronomical events. An accurate perception of the seasons would have been important to an early agricultural group. This type of activity, by Late Archaic/Early Woodland cultures, may represent another example of mesoamerican influence. Gypsum speleothems, intensively mined by Woodland cultures, might have been a valuable natural resource utilized in mesoamerica.

Tassammenfassung


A cupstone petroglyph of possible astronomical significance was recovered from a rockshelter site containing a Late Archaic/Early Woodland component. The coordinates of the Cliff Palace Cave site (see figure 1) are 37°31'30" North latitude and 83°55'10" West longitude, in a karst region of north eastern Jackson County Kentucky. Charcoal recovered from a fire pit feature yielded a radiocarbon date of 1050 B.C. (Ua-3300). This plateau has an elevation of 1,400 feet and is the highest point on the Leighton Quadrangle (USGS, 7.5 minute). This plateau has an elevation of 1,400 feet and is the highest point on the Leighton Quadrangle (USGS, 7.5 minute).

The cupstone is composed of a very finely grained sandstone with indistinct bedding. The lithic material is from the upper member of the Coso Sandstone Member of the Lee Formation. Haney and Rice (1978) have found that the unit is exposed in the immediate vicinity of the site. Each flat surface of the artifact is covered with six conical perforations (60°). This plateau affords a 360° view of the horizon, an important feature for accurate astronomical viewing. For the cupstone date (ca. 1050 B.C.), the obliquity ecliptic would be around 23°48' (Joseph P. Foster: personal communication). This data can be used with the latitude to calculate the rising azimuth of the sun during significant solar events.

\[ \alpha = \text{Angle between the earth's equatorial plane and the plane of the ecliptic (1050 B.C. = 23°48')} \]

\[ \lambda = \text{Latitude (37°31')} \]

\[ h_s = \text{Usual elevation (12°)} \]

\[ \theta = \text{Azimuth (east of north)} \]

Refraction correction = -24°44'

\[ \sin 23.80 + h_s \sin 37.52 = 60°18' \]

\[ \cos 37.52 \cos 2 37.52 - \sin 23.80 = 121°20' \]

\[ \cos 37.52 \cos 2 77.52 - \sin 2 23.80 = 90° \]

The cupstone perfections can result from a drilling process, brushfire manufacture, and can be used to hold nuts for cracking. Nuts, of course, have been used by many cultures for subsistence.

The cupstone from the Cliff Palace Cave site has, in addition to twelve conical perforations, a circular depression (G) pecked onto the stone's surface (see figure 2). This depression on the stone's edge would not facilitate the holding of nuts, but is a deliberate addition to the geometry of the petroglyph. A groove, formed by percussion flakes, on the side of the cupstone has an angular relationship of 37° with the stone's surface. This is also the angle of latitude for the site area, a fact which of course may be coincidental. However, this angle could have been determined in prehistoric times by sighting the area of the celestial north pole. Recurrent angular prehistoric petroglyphs (60° and 90°) appear on the cupstone's surface. If we suppose that these angular relationships may have been of some astronomical significance, re-examination of certain site data may provide a clue to their interpretation. At the northernmost portion of the Cliff Palace Cave site an ascending ledge rises over 33 m, allowing easy access to the plateau above (Indian Staircase, see figure 1). This plateau has an elevation of 1,400 feet and is the highest point on the Leighton Quadrangle (USGS, 7.5 minute).

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conical perforations on the cupstone. Plummets are problematical artifacts, described by Converse (1978) as similar in appearance to a surveyor's plumb bob, with a tiny groove or hole near the top. Most are composed of a high grade hematite (a very dense ore of iron). Webb (1968) found that plummets occurred in abundance at the Poverty Point site. Webb and Funkhouser (1928) noted that in Kentucky plummets usually occurred in caches, or in graves, indicating a ceremonial association.

Plummets suspended from a stick would allow astronomical alignment between the plummet strings, or along the stick's surface. The great density of a hematite plummet would pull the crudest primitive string taut and vertical. Plummets used in this manner could be suspended over the conical perforations of a cupstone as shown in figure 2. A ceramic, stone, or vegetal tube could be added to the stick to increase accuracy. Young (1910) indicates that grooved hour glass shaped tubes composed of steatite and indurated clay up to twelve inches long have been found in Kentucky and might have been used for astronomical purposes.

Plummets were made in abundance by the Poverty Point culture in Louisiana. Webb (1968) has the Poverty Point culture antecedent to Hopewell and Adena cultures and established on the coast and in major valleys between 1500 B.C. and 1000 B.C. Ford has established a sunrise equinox alignment with the ramp and village of the Poverty Point site, and uses this as a Mesoamerican increment.

Cupstones were made in the arid southwest and the first regions of Kentucky ca. 1050 B.C. Gypsum (CaSO4·2H2O) was a common natural resource. Gypsum occurred in the warm post glacial climate of the southwest as evaporite deposits from Pleistocene playas lakes and in the Karst areas of Kentucky as abundant cave deposits (speleothems).

In prehistoric times the caves of Kentucky were intensively mined for gypsum during the woodland period. Watson (1974), working in Mammoth Cave National Park, has found woodland gypsum mining in Salts Cave, Mammoth Cave, Lee Cave, and Bluff Cave. Chert was also found mined from Mammoth Cave in prehistoric times. Watson has concluded that because of the large quantities of gypsum removed, some or all of these substances not only were used locally, but also were traded outside the cave regions.

Approximately 1.6 km south of the Cliff Palace Cave site lie Wind and Big Rat Caves. As in Mammoth Cave, the caves are developed in the Newman Limestone Formation, which includes the chert bearing St. Genevieve and St. Louis Members. Both caves show evidence of prehistoric gypsum and chert mining. Redeposited oleanugious plastic clay also occurs in the caves and would have been a valuable resource in ceramic production.

Conclusion

Mesoamerican cultures used gypsum for frescos and pigment. According to Roglic (1972) the karst areas of the Yucatan and Mexico are characterized by isolated steep hills and vertical development. This would have limited their accessibility to prehistoric mesoamerican cultures. Gypsum prehistorically mined in the karst areas of Kentucky would have provided a valuable trade item. By 3000 B.C. mesoamerica had nine major cultigens and cultivars including maize, beans, squash, and gourds. These would have been important trade items to the less developed cultures of North America. Determination of important solar alignments would have been important to an early agricultural group.

In addition to agriculture, the Mesoamericans had an accurate perception of the seasons based on astronomical events. Ethnography has shown that ideas and concepts, as well as materials can and have been traded. Given our present technology, we should be able to determine at least the regional source area for the calcium sulfate based products of prehistoric mesoamerica.

References


Figure 1: The Cliff Palace Cave site, brunton and tape survey (1978).

Figure 2: The cupstone petroglyph from the Cliff Palace Cave site, showing the recurrent angular relationships of the conical perforations and their theoretical relationship with plummets.
Sinkhole flooding is a serious problem for urban areas located upon sinkhole plains. In Bowling Green, Kentucky, where homes, streets, apartment complexes, and businesses are affected, the problem has been exacerbated by insufficient design of drainage systems. Ten drainage wells have caused subsidence and sinkhole collapse. As the city expands toward the southeast into the sinkhole plains, where the bed-rock is greater, the danger of sinkhole collapse is increased. Cities attempting to prevent future flooding problems by restricting development in sinkholes which flood by holding back subsurface stream flow and preventing sinkhole flooding. Retention basins are also effective in reducing urban stormwater pollution of karst aquifers.

Sinkhole Zoning Restrictions

Sinkhole flooding is a serious problem for urban areas located upon sinkhole plains. In Bowling Green, Kentucky, where homes, streets, apartment complexes, and businesses are affected, the problem has been exacerbated by insufficient design of drainage systems. Ten drainage wells have caused subsidence and sinkhole collapse. As the city expands toward the southeast into the sinkhole plains, where the bed-rock is greater, the danger of sinkhole collapse is increased. Cities attempting to prevent future flooding problems by restricting development in sinkholes which flood by holding back subsurface stream flow and preventing sinkhole flooding. Retention basins are also effective in reducing urban stormwater pollution of karst aquifers.

Stormwater Drainage Wells

Over 300 stormwater drainage wells have been drilled in the Bowling Green area. There is direct evidence that several drainage wells have caused subsidence and sinkhole collapse. As the city expands toward the southeast into the sinkhole plains, the bed-rock is greater, the danger of sinkhole collapse is increased. Cities attempting to prevent future flooding problems by restricting development in sinkholes which flood by holding back subsurface stream flow and preventing sinkhole flooding. Retention basins are also effective in reducing urban stormwater pollution of karst aquifers.

Urban stormwater runoff carries pollutants into the caves under Bowling Green. Although oil and grease and some heavy metals are problem locally, the major concern is with sediment and debris. These contribute to flooding problems by clogging swallets, drainage wells, and cave passages. How can this be prevented, and how can the original capacity of a subsurface stream after it has been reduced by siltation?

Pollution of Karst Aquifers by Urban Stormwater Runoff

Urban stormwater runoff carries pollutants into the caves under Bowling Green. Although oil and grease and some heavy metals are problem locally, the major concern is with sediment and debris. These contribute to flooding problems by clogging swallets, drainage wells, and cave passages. How can this be prevented, and how can the original capacity of a subsurface stream after it has been reduced by siltation?

Stormwater Management Recommendations

In order to facilitate stormwater management decision-making in karst regions, an investigation of the complex groundwater system in the Bowling Green area was initiated. Possible correlations between precipitation input, subsurface stream flow, and sinkhole flooding were identified. Unfortunately, poorly designed trash guards often contribute to the flooding problem by becoming clogged with debris at the onset of stormwater runoff. (G.R.W. Engineers, Inc. and Daugherty and Trautwein, Inc., 1980.)

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Introduction

One of the most serious karst-related problems for urban areas located upon sinkhole plains is periodic flooding of karst depressions. The most severe problems occur in Bowling Green, Kentucky, where homes, streets, apartment complexes, and businesses are affected. The problem has been exacerbated by insufficient design of drainage systems. Ten drainage wells have caused subsidence and sinkhole collapse. As the city expands toward the southeast into the sinkhole plains, the bed-rock is greater, the danger of sinkhole collapse is increased. Cities attempting to prevent future flooding problems by restricting development in sinkholes which flood by holding back subsurface stream flow and preventing sinkhole flooding. Retention basins are also effective in reducing urban stormwater pollution of karst aquifers.

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will increase the flood crest of the Lost River as more stormwater runoff is directed underground southeast, upstream in terms of the subsurface. An intensive investigation is needed of the effects not flooded in the past may flood in the future. Flood retention reservoirs to retain water into a nearby stream. Drainage wells attempt the surface while the Lost River is still at low discharge. A solution to localized stormwater flooding problems in non-karstic areas is to excavate a ditch in order to facilitate the flow of water to underground streams in karst areas and are therefore somewhat analogous to vertical ditches. However, it appears that very few drainage wells actually intersect caves. Most drain through very tight bedding planes. Consequently most wells are not very efficient in delivering large quantities of water quickly to the larger subsurface streams. If the Lost River and its large tributaries could be isolated by exploration, geophysical techniques and exploratory drilling, perhaps large diameter drainage wells or vertical shafts could be used to direct stormwater into the subsurface streams.

References


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Figure 1. (Source: Booker, R.W., and Associates, Inc., 1978).

Figure 2. Sinkhole Flooding: Elimination of Constriction in Sinkhole No. 1 Results in Increased Flooding in Sinkholes Nos. 2 and 3.
Pseudo Karst Caves of Arkansas
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Abstract
Caves are common in the sandstones of northern Arkansas. The caves are characteristically a single large room (up to 1000 ft), are developed on a single plane with no side passages, and have large breakdown blocks covering a sandy floor. Speleothems may be present if carbonate rocks are near the roof of the cave. The Ordovician St. Peter and Everton sandstones are the most important of the cavernous units. These sandstones are clean, friable and poorly cemented.

The sandstone caves can be divided into three categories based on their mode of origin: 1) collapse, 2) piping, and 3) gravity sliding. The first two processes are often difficult to separate and commonly occur simultaneously. The St. Peter and Everton sandstones crop out in north-central Arkansas. Leakage from these aquifers to underlying carbonate members within the Everton may initiate solution widening of joints that allows the piping of sands and/or the collapse of sandstone blocks into the caves. Otvos, Jr. (1979) or collapse of the thick Newton or Calico Rock sandstone members into other Everton carbonate members is subsequently followed by upward stoping in the sandstones and downward piping of insolubles.

The least common type of sandstone cave in the Ozarks is that formed by gravity sliding, slumping, and/or joint infilling. The basal sand of the Pennsylvanian Atoka Formation is a massive unit that caps mountains. Wide-spaced joints allow large blocks to break off and slide downward on underlying shales. Breaks between the blocks are subsequently partially filled with colluvium forming caves known to be up to 1200 ft long.

Introduction
Caves are abundant in Arkansas. Over a thousand caves are believed to exist, but an accurate count has not been made. This is due primarily to the few number of cave explorers, their lack of organization, and the ruggedness of the terrain. An initial survey of the period "Silurian interior," situated at St. Peter and Everton are the most important features in the formation of these caves. These are the currently used by geomorphologists to refer to a diversity of landforms that have evolved in a variety of rock and sediment types, both soluble and insoluble. Pseudo Karst has been applied by geomorphologists to a diversity of landforms that have evolved in a variety of rock and sediment types, both soluble and insoluble.

Application of the Pseudokarst Definition
The origin and occurrence of pseudokarst has not received wide attention in the literature, being discussed primarily as a curiosity. The term "pseudo-karst" has been applied by geomorphologists to a diversity of landforms that have evolved in a variety of rock and sediment types, both soluble and insoluble. The term "pseudo-karst" has been applied to depressions and caves in glacial, volcanic, and eolian terranes and to features in sandstone, conglomerate, tuff, basalt, unconsolidated sediments, and calcite-rich igneous and metamorphic rocks.

Processes that have formed pseudokarst include solution, piping, collapse, subsidence, differential compaction, and thawing of permafrost. Gravity sliding as a pseudokarst process has almost been ignored in the literature. In Arkansas some sizeable caves and natural bridges have formed exclusively by this process. Werner and Medville (1980) suggest gravity sliding as one of processes involved in the development of caves in the quadrates of southeast New York. Sandstone caves similar to those of Arkansas have been described by Halliday (1960), Rastning (1979), Huse and Strong (1979), and Kress and Alexander, Jr. (1980). A geologic roadlog to some pseudokarst areas of north-central Arkansas has been made by Ogden (1980). Sandstone caves in sandstone have been described and mapped by Warshaver (1978), Ogden (1979), and members of the Cave Research Foundation (Bloore, personal communication). Since Arkansas' pseudokarst occurs only in sandstone, a review of all the different types of pseudokarst is beyond the scope of this paper. For such a review, the reader is referred to Otvos, Jr. (1976) and the abstracts to the Pseudokarst Symposium held at the 1979 National Speleological Society Convention (Kastning, 1979).

Location and Geology
Pseudokarst is located in two distinct areas of Arkansas with the location dependent on which of the following two processes is dominant: 1) piping or 2) gravity sliding. Caves and dolines formed primarily by piping are located where the Ordovician aged St. Peter and Everton formations crop out on upland surfaces (Figure 2). Where deep dissection has exposed only thin outcrops of St. Peter and/or the narrow gorge along the Salem Plateau erosional surface. The Salem Plateau is the lowest of the Boston Mountain erosional surfaces (Quinn, 1958). The rocks dip gently to the south-southwest off of the Ozark Dome which is capped by Pleistocene till and Missourian Missouri. The stratigraphic dip of this asymmetric dome seldom exceeds two degrees in Arkansas. Greater dip
angles occur in the proximity of the south-southeast dipping (common near vertical) normal faults.

The St. Peter and Everton formations are absent or thin in northwest Arkansas, but thickened to the east. The St. Peter sandstone consists of fine to coarse-grained, well rounded, well sorted friable quartz arenite beds. A maximum outcrop thickness of 21 feet has been reported, but occurrences of thickness of 50 feet or more are more common in Stone and Izard counties where most St. Peter caves are found. The St. Peter sandstone may overlie either a carbonate or a sandstone member of the Everton formation. Sandstone caves have been found only where the St. Peter overlies a carbonate unit. In the first portion of the cave being in carbonate rock. This may be masked by the sandstone breakdown. Generally, the collapse can be identified by the lower massiveness of the overlying carbonate unit, wideness of the area, and solely surrounded by carbonate rock walls, the area marked as "A" on Figure 3 represents how most Arkansas sandstone caves form by gravity sliding commonly involving rotational movement (slumping) of sandstone blocks.

Operating Processes
The caves in Arkansas can be classified based on the major formational processes. These five primary processes are: 1) solution collapse, 2) piping and collapse, 4) gravity sliding, and 5) slumping. These can be envisioned as end members of a pyramid (Figure 3). There are sandstone caves that form solely by each of the non-solution processes, but most sandstone caves form by piping and collapse aided by solution. Solution is considered here to operate in three manners: 1) cause of a sandstone collapse, 2) removal of carbonate cement between sand grains, and 3) enlargement of joints to aid in the piping process. Therefore, by disregarding those caves formed entirely by solution and solely surrounded by carbonate rock walls, the area marked as "A" on Figure 3 represents how most Arkansas sandstone caves form.

Piping and Collapse
The development of pseudokarst in Arkansas is therefore generally not a function of a single process or rock type, but of a combination of either friable, poorly cemented sandstones overlying carbonates, or of massive sandstones overlying shale beds. In the first situation, piping is the primary process that forms the caves and causes collapse (Figure 4). This is obviously aided by solution of the carbonate cement between the grains and the enlargement of the joints in the underlying carbonate rock. In some instances, there may be direct collapse of the sandstone into a void that formed by solution of the underlying limestone. Even in this case, piping of sand grains is an important cause of enlargement after the collapse (Figure 5). Generally, the collapse can be identified by the larger portion of the cave being in carbonate rock. This may be masked by the sandstone breakdown.

Speleothems are usually absent of sparse in sandstone caves. In some instances, seemingly anomalous, well decorated, sandstone caves have been found. Close inspection has shown that the speleothems occur only where a carbonate unit overlies the sandstone forming the cave. Other factors controlling speleothem development are soil thickness, solubility and thickness of the overlying carbonate unit, width of joints, and the surface relief (controlling infiltration vs runoff).

Gravity Sliding and Slumping
Some Arkansas sandstone caves occur even in the absence of any soluble rock. Figure 6 helps to demonstrate how the gravity sliding process forms caves in the Atoka Formation. Deep dissection and differential erosion has left the Atoka sandstones capping ridges in high relief areas. Farther erosion of the shales, expansion of joints due to loading, and gravity, work together causing massive sandstone blocks to slowly creep down the hillside. Slumping causes the joint face to open at the base of the sandstone block and close off at the surface, thus forming the cave (Figure 6). In rarer cases, caves form where the face joint opens more at the top and is later filled with talus (Figure 6). At Devils Den State Park in Washington County, sandstone caves hundreds of feet long have formed in such a manner. These caves are generally narrow, but passageways may be 15 feet high; nearly the thickness of the sandstone blocks.

Summary
Abundant and sizeable sandstone caves occur in northern Arkansas. Two broad classes exist based on the operating processes and the dominant process. Most of the sandstone caves form by piping, aided by collapse and solution. This occurs when there is a carbonate unit under the sandstone. In high relief areas, piping is an important process. The growth of joints to aid in the piping process. Therefore, by disregarding those caves formed entirely by solution and solely surrounded by carbonate rock walls, the area marked as "A" on Figure 3 represents how most Arkansas sandstone caves form.

References
Figure 1. Ozark plateaus, escarpments, and generalized underlying stratigraphy. The St. Peters occurs above the Everton only in north-central Arkansas.

Figure 2. Location of areas in the Atoka and (St. Peter)-Everton formations containing sandstone caves.

Figure 3. Major processes operating to form pseudokarst in sandstones of Arkansas.

Figure 4. Diagrammatic representation of a sandstone cave formed by piping of sand through solution-enlarged fractures.

Figure 5. Diagrammatic representation of a sandstone cave formed by collapse into a solution cavity and piping of sand through solution-enlarged fractures.

Figure 6. Diagrammatic representation of the development of sandstone caves by gravity sliding and slumping.
Speleogenesis of Arkansas Ozark Caves
Albert E. Ogden, Wyndal M. Goodman, and Samuel R. Rothermel
Department of Geology, University of Arkansas, Fayetteville, Arkansas 72701

Abstract
Extensive caves are found developed within the Springfield and Salem plateaus of the Arkansas Ozarks. The origin of the caves can be divided into four classes: 1) Pocket caves, 2) Perched water-table caves, 3) Confined aquifer or sandwiched caves, and 4) Vadose caves. A pocket cave is generally a single room that forms in cherty carbonate formation in which chert and limestone beds are not laterally continuous. These caves form at random depths below the water table and exhibit little or no structural or level control.

Perched water-table caves formed directly above a perching unit and above present base level. If the perching unit is thick and impermeable, the cave will have a phreatic ceiling phase. As base level cut below the perching unit, vadose downcutting caused stream entrenchment into the perching formation. Where the perching unit is very thin or semi-permeable (aquitard), leakage caused caves to form above and below the aquitard and generally along a structural weakness. Later breakdown of the aquitard causes integration of the two caves.

Maze caves are found in thinner limestone aquifers that are sandwiched between aquicludes. The confined water exerts a pressure head evenly distributed throughout the joints thereby causing a maze pattern.

Vadose caves are common on the sides of steep hills where high gradient surface streams have been pirated to the subsurface through fractures. Fracture enlargement and downcutting give these caves a canyon-passage cross-section and a meandering plan view.

Introduction and Purpose
No accurate survey of caves exists in Arkansas, but members of the former Arkansas Speleological Survey and the present Association for Arkansas Cave Studies (Dave Taylor, personal communication) have estimated that there are over 1000 caves more than a hundred feet in length. Approximately 500 limestone caves have been filed, but few have been mapped due to the low number of organized cave explorers. Detailed geologic investigations of Arkansas caves are nonexistent, although Missouri speleologist such as Bretz (1956), Beams and Feder (1974) have expounded at length on the karst of Arkansas neighbor.

The purpose of this paper is to discuss in a broad manner, the occurrence and origin of limestone caves in Arkansas. It is not the purpose of this paper to reiterate details of the classical theories of such researchers as Davis (1930), Bretz (1942), Davies (1969), White (1960), and Ford (1965). Most speleologists realize that for every theory of cave origin, there is another. Beaucoup de grottes ont été découvertes dans les aquifères calcaires Moins épais, qui sont coincés entre des “apuicludes” – L’eau captive exerce une pression également distribuée à travers les fissures, causant ainsi l’établissement d’un labyrinthe semblable à un tableau.

The limestone caves of Arkansas are located within rocks cropping out on the Boston Mountain Escarpment and the Springfield and Salem erosional plateau surfaces (Fig. 1). The rocks generally have a southeast dip of less than a degree off the asymmetrical Ozark Dome. The stratigraphic dip is occasionally greater in the proximity of nearly vertical, south-southeast dipping normal faults. The general number of caves are found within the cherty Mississippian Boone Limestone and chert-free St. Joe Limestone which together average 450 ft thick (Fig. 1). The limestone crop out on the sides of the Boston Mountain Escarpment and are limited in aerial extent.

Location and Geology
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Therefore, this "lithologic base level" can be either above or below the elevation of the White and Illinois by controlling the depth of circulating ground waters. Chattanooga Shale. The Chattanooga acts as base level before the dissection of the Boston Mountain Plateau, Bretz, J.H., 1942, Vadose and phreatic features of sequent erosion of the Springfield Plateau (Fig. 2). Joe limestone aquifer. Relatively young caves have in the St. Joe Limestone from water perched on the Vineyard, J.D., and G.L. Feder, 1974, Springs of with several entrances. Under certain idealized geo-

...limestone caversn: J. Geol., 50:675-811.

...aquifers: Ground water, v. 7, pp. 15-21.

Figure 2. Generalized stratigraphy of the Ozark Plateau Province in Arkansas.

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Figure 1. Ozark plateaus, escarpments, and generalized underlying stratigraphy. The St. Peter occurs above the Everton only in north-central Arkansas.

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Figure 3. Controls on the development of solution conduits with emphasis on the effect of perching layers.

Figure 4. Diagrammatic representation of the "water table" in limestone as explained by adjacent aquifer and aquitard blocks caused by fracture density changes.

Figure 5a. Top of the zone of saturation corresponding to surface streams in a carbonate containing no perching unit.

5b. Discontinuous perching layers allowing caves to form above the zone of saturation.

5c. Integrated caves forming above a continuous impermeable layer causing the zone of saturation to be above local base level.

5d. Integrated caves forming above a continuous impermeable layer but below local base level; Integrated maze caves are formed sandwiched between impermeable layers.

Figure 6. Frequency plot of the tops of caves intersected during drilling in Searcy County, Arkansas.

Figure 7. Frequency plot of cave entrance elevations in Northwest Arkansas.


James A. Pisarowicz and R. Mark Maslyn

Abstract

Using scallop data collected from Spring Cave, Colorado, Curl's flow velocity equations were used to calculate fluid flow velocities during periods of flooding. These values were compared to actual fluid volumes measured from Spring Cave's resurgences during the 1978 snow melt. The calculated and measured volumes agreed to within 8.3%, well within Curl's 15% theoretical margin of error.

"Zusammenfassung"

Bei der Anwendung von den aus Spring Cave, Colorado gesammelten Ausbuchtungsangaben, wurden Curl's Gleichungen zur Flussgeschwindigkeit gebraucht, um den Wasserandrang bei Flut zu Kalkulieren. Die berechneten Werte entsprechen den tatsächlichen Flutvolumina innerhalb von Curl's theoretischem Irrtumsfaktor von 15%.

In dynamic cave systems, one of the most important observations concerns the volume and velocity of water which flows into, through, and out of the cave. These measures become even more interesting during periods of flooding since the magnitude and velocities of flow are at their maximum during these periods of time.

Flow velocities and volumes may be measured by directly observing the stream itself and the cave's resurgences or by measuring the scalloping found in the passages of the cave. This latter technique tends to only reflect the past history of higher velocity flows through a given cave conduit since scallop patterns develop most rapidly at higher velocities of flow (Curl, 1974). Logically, flow velocities are highest at the cave's resurgences or by measuring the scallopping found in the passages of the cave. This latter technique tends to only reflect the past history of higher velocity flows through a given cave conduit since scallop patterns develop most rapidly at higher velocities of flow (Curl, 1974). Logically, flow velocities are highest at

The above developments, through intriguing, are supported solely on theoretical arguments set forth by Curl (1974) who also noted a theoretical margin of error of 15% because of assumptions made in deriving these formulas. The purpose of this investigation was to collect scallop measurements, use these to calculate flow velocities following Curl's equations, and then compare these values to actual stream flow. In this regard, data from Spring Cave, Colorado was useful in attempting to empirically confirm Curl's (1974) flow velocity calculations.

Spring Cave is a river system located on the White River Plateau in north-western Colorado. The cave is wholly developed within the Mississippian Leadville Limestone and contains over 3000 meters of surveyed passage (Pace, 1977, 1979; Pisarowicz, 1979). The cave entrance (elevation, 2280 m) is located at the head of a small tributary of the South Fork of the White River. This stream carries water only during times of very high water when the entrance passage acts as an overflow route for water backed up from the Thunder Road Sump. Nineteen meters twenty-eight was the first year in at least the last twenty that the entrance passage carried water (Davis, 1979).

Initial passage development in Spring Cave correlates with a terrace along the White River 110 meters above modern stream level. The cave shows both phreatic and younger vadose passages developed at this level. Phreatically developed passages exist as upper level segments of the cave, beginning with the section from the double entrance to Thunder Road, a vadose passage carrying the modern cave stream. Thunder Road is one of a network of highly joint-controlled fissure passages with up to 15 meters of relief. Much of this area developed as a result of solution during the backflooding that resulted from pooling at the Thunder Road sump at times of high flow.

Continuing from Thunder Road involves traversing the Buttercush and Bridge Room passages, both segments of the older phreatic system. This section is followed by 1500 meters of enlarged canyon passage which carries the main cave stream, interrupted midway by Sump One. Several meters overhead this vadose passage is seen to intersect the rounded phreatic tube passage. Throughout the entire section of the cave proceeding Sump One, the main passage development alternates between various joints, but maintains orientation very close to the strike of the Leadville Limestone.

Spring Cave's stream flow, both within the cave and at its resurgences were observed at various times during May and June 1978 (Pisarowicz, 1979) and during the low water ebb in December of that same year (Dowds, 1979). Measurements of the scalloping in various sections of the cave were collected during the December visit. Flow volumes were calculated from the scallop data and compared with the stream flow data.

| Table 1: Volume of water flowing from Spring Cave's resurgences. |
|-----------------|----------------|----------------|
| **Resurgence**  | **Flow Volume** | **Resurgence** |
| Overflow        | 0.57 m³/sec    | Lower Level    |
| Group           | 5.66 m³/sec    | Resurgence     |
| Total           | 31.72 m³/sec   |

On the surface, water from Spring Cave was noted to resurge in three distinct areas—the entrance, an overflow resurgence group (Williams and Pisarowicz, 1979), and the lower level resurgence group (Hassemer, 1976). The flow from each of these resurgences was estimated and totaled in Table 1. The volume of this water was approximately 31.72 m³/sec.

Flow volumes for the cave passages were calculated using scallop measurements. From Figure 2, the ratio of conduit diameter or width (D) to mean scallop size (L) was used to determine a Reynolds number (Re). Using the predicted Reynolds numbers derived from Figure 2 in Curl's equation, mean flow velocities for various sections of Spring Cave were calculated (see Table 2).

**Flow volumes are not given for Cobble Road and the Bridge Room since both these sections of Spring Cave are overflow routes.**

| Table 2: Calculated flow velocities and volumes in Spring Cave. |
|-----------------|----------------|----------------|
| **Sump One**    | 1.10 m/s   | 32.71 m³/sec   |
| Flume           | 1.04 m/s   | 36.72 m³/sec   |
| T Junction      | 1.82 m/s   | 34.31 m³/sec   |
| Cobble Room     | 2.10 m/s   | **           |
| Bridge Room     | 2.05 m/s   | **           |
| Thunder Road    | 1.98 m/s   | **           |

Mean = 34.58 m³/sec

Concerning these measures, note that the highest velocities occurred in Cobble Road and the Bridge Room. These areas of the cave are certainly high level over-
flow routes and thus are currently being scalloped only during periods of flood. The Bridge Room may also be showing evidence of older flow patterns as well, before the cave changed from phreatic to vadose.

In Table 2 also note that apparently all the water that flows from the Sump One area is accounted for. The calculations at Sump One, the Flume, and the T Junction all agree within an order of magnitude. The mean flow from these areas is 34.58 m³/sec.

The calculated volume of water flowing through Spring Cave agrees quite well with the volume flowing from the resurgences. The difference is only 8.26% of the calculated volume. It appears that Curl’s theoretic flow velocity calculations from scalloping correctly describe actual cave stream flow.

References

Pace, N. "Spring Cave, Colorado." Alpine Karst, summer 1977.
Pace, N. "Into Sump 4." NSS News 37 (6), 1979.
Pisarowicz, J. "Spring Cave—Sump Two and Beyond." Alpine Karst, summer 1978.
Williams, A. and Pisarowicz, J. High Level Resurgence Group of Spring Cave, survey and map, 1979.

Figure 1: Map of Spring Cave, Colorado
Figure 2: Predicted relation between the ratio of conduit diameter or width (D) to mean scallop size ($L_{32}$) and Reynolds Number ($R_{fl}$). All calculations based upon Parallel-Wall Conduits. It should be pointed out that the Cobble Road passages could be described as a circular conduit instead of a parallel wall conduit. Figure after Curl (1974).
Classification des Concrétions Calcaires Stratifiées en Fonction des Conditions de Milieu

Jacques Choppy
68. Boulevard Pasteur, 75015 Paris, France

Résumé
On peut classer toutes les formes de concretions, en particulier les concretions calcaires stratifiées, selon trois critères minéralogiques, morphologiques ou de conditions de milieu.

La classification proposée porte d'une part sur le milieu précis au contact duquel croissent ces concretions (film d'eau, eau profonde stagnante ou courante, séduits sableux ou argileux, etc.), d'autre part sur les facteurs qui influent sur ce milieu, en particulier climatiques.

Le choix de ces conditions de milieu est pragmatique, puisque fondé sur l'observation des circonstances dans lesquelles se rencontre tel ou tel aspect morphologique des concretions considérées; il s'agit donc d’une classification dans laquelle le critère morphologique est en quelque sorte sous-jacent; ce qui semble la condition nécessaire pour que les problèmes de génese puissent être abordés.

Abstract
We can classify all kinds of speleothems, particularly the stratified calcareous deposits, according to three criteria:

- mineralogical, morphological or environmental.

On the one hand this classification depends upon the nearest environment in which these formations grow (film of water, deep standing or running water, sandy or clayey sediments,...) on the other hand it depends upon the agents which have an influence on this environment, particularly the climatic ones.

The choice of these environmental conditions is pragmatic, because it lies on the observation of the circumstances in which occur such and such morphological appearance of the involved speleothems. Thus it is a classification in which the morphological criterion is more or less underlying it seems the necessary condition to handle the problems of genesis.

1. Trois Modes de Classification des Concrétions

La classification des concretions peut se faire selon divers critères:

- L'un des plus fréquemment adoptés est la nature minéralogique ou, ce qui n'est pas très différent, le processus physico-chimique de dépôt; et on distingue alors les concretions carbonatées, des sédiments siliceux, les dépôts d'oxydes métalliques, etc.

- On peut aussi tenir compte de la morphologie des concretions: aux cristaux définies dans des publications précédentes comme représentant une structure cristalline, il convient d'opposer les concretions stratifiées dont la structure est commandée par un dépôt en couches superposées. À ces deux grandes catégories, on ajoutera les concretions amorphe, beaucoup plus rares; et l'on précise que le mono-mich a une structure le croaco-chant, tandis que son mode de dépôt s'apparente souvent à celui des concretions stratifiées.

- La classification par les conditions de milieu serait la plus satisfaisante dans la mesure où elle livrerait la clé de chaque dépôt, permettant de définir le processus physico-chimique de dépôt; et l'on distingue alors les concretions carbonatées, des sédiments siliceux, les dépôts d'oxydes métalliques, etc.

Mais il est exceptionnel, dans la littérature spéléologique, de voir un dépôt de concretions cristallin et la friabilité rappellent les caractéristiques de la craie; elles se rayent à l'angle; beaucoup sont blanches; elles ne ressemblent pas à de telles concretions stratifiées.

Les concretions molles ont une consistance variable, mais elles encroûtent généralement sous la pression du doigt, et certaines sont constituées de montmorillonite; une croûte induite recouvre parfois ce type de concretions molles; la classification peut rendre molles des concretions initialement dures.

3. Les Conditions de Croissance

Les concretions calcaires stratifiées se déposent toujours dans l'eau:

- pour la plupart il s'agit d'un film ou d'une goutte d'eau stalactites et draperies, stalagmites, planchers stalagmitiques, bords de gours, etc.

- d'autres se déposent dans des eaux plus profondes, animées d'un mouvement plus ou moins rapide; dans ce dernier cas, les formes sont liées au sens du courant (formes "en lamiers", "en écaillles").

Dans des rivières souterraines mais aussi sub-aériennes, on trouve des dépôts stratifiés érodés par endroits. Certaines de ces concretions noyées sont molles, qu'elles prennent la forme d'une bande de niveau ou de sortes de choux-fleurs d'un monochromieux.

Les concretions stratifiées peuvent présenter trois types de concretions, avec certaines couronnes de concretions: le film de montmorillonite massif ont toujours une structure cristalline massif.

Les concretions stratifiées peuvent présenter trois types de concretions: sans que la forme en soit profondément affectée en général:

- les concretions dures sont les plus connues; en l'absence de précision supplémentaire c'est d'elles que je parlerai;
- les concretions molles, dont l'aspect micro-
croissance de stalactites jointives, surtout quand l'épaisseur du plafond au dessus de la cavité est faible; inversement, des calcéars marneux sont peu favorables au dépôt de concrétion.

Par ailleurs, sous un karst nu, la teneur en CO₂ de l'eau est, quelques fois, assez élevée à cause des concrétions n'y soit pas inconnu, les concrétions des manteau", stalactites en mammelle. Les zones A climat plus vite en direction de la lumière. Bien que l'eau n'est pas soumise à l'écoulement (comme sous un karst couvert), lorsque l'eau peut s'enrichir en CO₂ durant le traversée du sol végétal, que le concrétionnement peut être abondant.

L. Montoriol Paste observe par ailleurs que, dans le cas d'égouts de galeries superposées, il y a alternance entre les étages concrétionnés et ceux qui ne le sont pas; pour une part, cette observation peut s'expliquer par le phénomène de décanter du gaz carbonique.

5. Influence du Climat Régional

Comme il est logique, l'influence de ce climat se fait sentir surtout à proximité des entrées.

- Dans les régions où le gel est fréquent, les zones des cavités proches des entrées sont généralement dépouvrues de concrétions, car les parois sont délitées par le gel. Par ailleurs, dans les régions froides, les concrétions sont d'autant plus abondantes que l'on approche des concrétions en mond-milch et plus généralement des calcéarines, présentes sous forme érodée, des stalactites et des stalagmites sont en zone profonde; et l'on connait deux grottes françaises dont les alcoves, notamment A section triangulaire, mais il existe de même des stalactites massives et des draperies monocrystallines; ces dernières, précédemment supposées par P. Cabrol, ont été découvertes par moi dans la grotte de Sant'Ana, Sao Paulo, Brésil.

Certains auteurs (W.M. Davis, F. Trombe, etc.) ont cru que l'atmosphère des zones karstiques les plus profondes étant saturée de vapeur d'eau, que son taux de CO₂ étant en équilibre avec la teneur de l'eau qui parvient de la surface, le dépôt de concrétion y était impossible. En fait, la décanter (ou sédimentation) du CO₂ se traduit en permanence par un déséquilibre dans le taux de ce gaz dans l'air, rendant parfaitement possible le dépôt de calcite; il est du reste facile de constater que le dépôt de concrétions stratifiées d'aspect parfaitement classique est souvent très actif même dans des zones bien isolées des influences extérieures.

7. Cas de Confinement

Avant de décrire les formes liées au confinement, il faut observer que l'écoulement est toujours s'étendant un peu plus profondément sous terre que ce climat est peu variable; en climat tropical humide, les formes caractéristiques se rencontrent dans des conditions de confinement beaucoup moins sévères que dans un karst européen.

Le confinement est nécessaire à l'élaboration des cristallisations et de ces formes intermédiaires. D'autres concrétions déformées par un courant d'air - Les Aphanolithes

Parmi les concrétions déformées par un courant d'air, les plus connues sont sans doute les stalagmites etles stalactites. Certaines concrétions sont allongées selon la direction de l'écoulement du CO₂; à celle du courant d'air d'hiver (dans les tubes à vent) (fig. 5).

D'autres concrétions, conservant leur morphologie habituelle, se contentent de s'étendre latéralement en direction du courant d'air; stalactites et stalagmites d'«épaisseur d'orchidée» ou de stalagmites en "borne kilométrique".

D'autres concrétions déformées par un courant d'air sont encombrées d'objets de type Jura (fig. 6); ces formations spectaculaires ne semblent pas, quoique on en ait dit, liées à un climat particulier à l'origine, mais elles se trouvent toujours à un niveau intermédiaire entre deux dénivellations notables, les formes les plus élaborées se rencontrent lorsque le dénivellation supérieure débouche en surface (fig. 7); ces observations conduisent à penser que des courants de convection sont responsables de ces formes.
W. Prinz - 1908, Les cristallisations des grottes de Belgique, Mém. Soc. Belge Géologie
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Figure 1. (d'après Prinz): coupe d'une stalagmite ayant englobé des éléments de sol

Figure 2. (d'après Aucant et Petrequin - dessin G. Piquard): groupement de cierges de la salle des Mille Colonnes du gouffre de Granges Mathieu (France)

Figure 3. irrégularités cycliques de surface des concrétions stratifiées; a) étages à mini-dais, b) renflements horizontaux jointifs, c) mini-gradins, d) micro-gours

Figure 4. (d'après Eraso): forme de concrétions stratifiées en fonction de pH (= log pCO2 en atmosphères) et pC (= log débit en litres/sec.)

Figure 5. (d'après Bakalowicz): stalactite anémolithe de la grotte de Pinargözü (Turquie); la flèche indique le sens du courant d'air d'été

Figure 6. stalagmite en tronc de palmier de l'aven Armand (France)
Gypsum-Anhydrite Karst on the Territory of the USSR
K.A. Gorbunova
Perm University, USSR

Résumé
L'environnement géologique, hydrogéologique, physiogéographique du développement du karst gypsum-anhydrite sur le territoire de l'URSS sont caractérisés. On note aussi les particularités de morphologie du type lithologique donné du karst.

GyPSUM-ANHYDRITOVYI KARPST NA TERRITORII CCCP
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В докладе охарактеризованы геологические, гидрогеологические, физико-географические обстановки развития гипсо-ангиридитового карста на территории СССР. Осматриваются также особенности морфологии данного литологического типа карста.

Gypsum and anhydrite are included into hologen formations widely distributed on the territory of the USSR. They occupy the largest area on the platforms and in the foredeeps. The total area of sulphate-bearing hologen formations of stages makes up approximately 10 million sq.km. The formations fall into three regions: the East-European, mainly Permian, the East-Siberian, chiefly of Cambrian age, and the Middle-Asian with the prevalence of Jurassic-Cretaceous and Paleogene-Neogene.

The paleokarst and recent karst areas can be singled out of these regions. Recent karst is manifested in the zones of active waterexchangeable arctian basins or hydrogeological massifs.

Depending on the rock composition karst proceeds into gypsum-anhydrite, dolomite-gypsum-anhydrite, limestone-gypsum-anhydrite, gypsum in the terrigene rock mass and saline-gypsum types.

Physical-geographical situations of sulphate karst manifestations are various: arctic (Novaya Zemlya), silvan (the greatest part of the Volga-Kama, Northern Dvina, Pribaltic areas), silvan-steppe (southern part of the Volga-Kama, Pridnestr areas), steppe (the Donets area), semidesert and desert (Prikaspiian area). Karst of the East-Siberian region develops in the permafrost zone, and in the Middle-Asian region it is formed under desert and highland conditions.

Active gypsum karst is observed at insignificant erosive ruggedness of relief in the lowlands (Pricaspian area), on the plains (the Privolga area), on the plateau (the Kulyosko, Ufimsko), on the slopes of mountain structures (the North Caucasian, Pamirs-Alai).

Usually gypsum-anhydrite massifs due to quick attenuations of jointing with depth differ in less thickness of vertical descending circulation karst water zone and in less depth of karstification comparatively with carbonate ones. The zones adjacent to deep paleovalleys, zones of tectonic joints, contacts of sulphate and carbonate rock masses, where karst is developed at the depth of more than 100 m, represent the exception. Karst waters of high mineralization have sulphate-calcic composition.

Surface karst forms are represented by karren at the sites of exposed and sodded karst, by ponors, karst wells, dolines, the density of which is 500-1000 forms per sq.km, by karst basins, trenches, depressions (of several kilometres across), by karst and karst-erosion ravines, cirques and remnants. Karst ponds, springs and shallow rivers with water mineralization 2-3 gr/l are characteristic of sulphate karst.

Subsurface forms: cavities, channels, corridors or lattice type caves pass along the system of tectonic distribution. The length of separate longest caves in Podoliya achieves 136 km (Optimistitcheskaya Cave).

The regions of active sulphate karst are unfavourable for engineering geology as well as for search for fresh underground waters. But they are perspective for exploration of mineralized waters, hydrosulphuric in particular.
Genetical Observations on Some Natural Cavities of the Masua Mines (SW Sardinia)

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Abstract
The study of the calcite crystals found on the walls of two karstic cavities inside Masua Mine (Inglesias-SW Sardinia) allowed the definition of seven different periods in the cave speleogenesis. In the present paper the authors discuss the conclusions achieved for the chronology of the observed phenomena.

Summary
Nella miniera di Masua sono state incontrate alcune cavità carsiche senza diretta comunicazione con l'esterno.
Le pareti di queste grotte sono completamente coperte da grandi cristalli di calcite, corrosi e quindi rigenerati.
Lo studio di questi cristalli ha permesso di definire 7 differenti periodi speleogenetici per le cavità studiate.

Introduction
Mining activities inside the Masua mine (Inglesias-SW Sardinia) came across some karstic cavities without direct communication with the surface.
The walls of these caves were completely covered with large calcite crystals, which were corroded and in a second time partially regenerated.
The study of these crystals allowed the definition of seven different periods in the cave speleogenesis.
In the present paper, the experimental observations and the laboratory analyses are firstly reported, then the authors discuss the conclusions achieved for the chronology of the observed phenomena.

Experimental
In the cambric carbonate formations of the Masua mine the mining activities came across some karstic cavities without direct communication with the surface.
The lowest caves, called Phaff 1 and 2, are at 42 m b.s.l., much lower than the preexistent water level, which was at 176 m a.s.l., as testified in the "Capstan room cave" (see fig. 1) by a large reempoa well which are vadose concretions, while below there are phreatic formations.
The Phaff 1 cave (see fig. 2) is a large bell shaped room (30X40X40 m) with a dome shaped top of about 60 m; the Phaff 2 cave is quite equal to Phaff 1 but smaller.
The two cavities contain no concretions at all, but their walls are completely covered by large pale yellow calcite disphenoid, which have inside avident layers of more intense colour.
The crystals are quite completely detached from the limestone substratum, being connected only in few places by small rock bridges.
The floor is covered by large boulder choke, and each boulder has only one side, but not necessary the upper one, covered by calcite crystals.
All the crystals are very corroded and then covered by small white transparent or lactescent calcite tabular crystals.
The upper faces of the crystals whether on the walls or on the collapsed boulders are covered by reddish-black clots, which are in turn under layered clay silt: there is a thickness of 2-3 cm over the crystals, while on the floor the thickness is ten times greater.

Discussion
The cavities shape in relation to the cambric rocks bedding and steering clearly indicates that the first speleogenetic stage (corresponding to the vacuum formation) began after the sudetic tectonic phase (middle carboniferous-permian).
Moreover the total absence of calcite sinter is due to the fact that the caves were carved in phreatic conditions by highly aggressive waters.
The cause of the corrosion was the \( \text{H}_2\text{SO}_4 \) in-gression due to the oxidation of the Pb and Zn sulphides in the top of the ores, which probably is related to a period of a hot climate (upper Pleistocene).
The corrosion due to \( \text{H}_2\text{SO}_4 \) rich waters caused also the detachment of the calcite crystals crusts, which are now linked to the walls only by few calcareous bridges. In fact it's more difficult to solubilize the large crystals than the micritic structure of the dolomite substratum, which is more rapidly corroded.

The second speleogenetic stage is coincident with the collapse of the ores, which probably is related to the formation of the cave system.

As in similar cases the oxide coagulation (i.e. the sixth speleogenetic stage) is probably related to the corrosive solutions with low mineral content, normal in metheoric waters.
This stage led to the deposition of the black-reddish clots over the second type of calcite crystals; but the Fe, Mn oxides are quite absent under the collapsed boulders and this fact confirms that this period has to be following the previous one.

As in similar cases the oxide coagulation (i.e. the seventh speleogenetic stage) is probably related to strong pedologic variations, which can be ascribed to the glaciations.

The outlined genetic schema is also confirmed by isotopic analyses.

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Moreover the starting of the forth speleogenetic stage (the collapsing one) is probably to be ascribed to the \( \text{H}_2\text{SO}_4 \) rich waters.
This period is also characterized by phreatic conditions, as it's testified by the cutting edges of the large collapsed blocks and by the fallen crusts of crystals, which normally have not been broken when they fell.

When the \( \text{H}_2\text{SO}_4 \) in-gression ended, a new but weaker crystalization phase began, which led to the deposition of small calcite crystals, different in habit and colour from the previous ones, which covered the large and eroded crystals as a thin layer.

This fifth speleogenetic stage is characterized by waters with low mineral content, normal in metheoric waters.
This variation in water mineral content is confirmed by the chemical analyses of samples of the crystals, which are normal in case the Pb and Zn oxides, which in turn are in contact with the crystal.

The water evolution went on with a progressive lowering of the acidity, when the mineral oxides (mostly goethite, but also pyrolusite) coagulation was allowed.

This stage led to the deposition of the black-reddish clots over the second type of calcite crystals; but the Fe, Mn oxides are quite absent under the collapsed boulders and this fact confirms that this period has to be following the previous one.

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The outlined genetic schema is also confirmed by isotopic analyses.

The isotope composition shows an increasing in the \( \text{O}^{18}/\text{O}^{16} \) ratio and at the same time the lowering in the \( \text{C}^{13}/\text{C}^{12} \) ratio from the center to the surface of a single calcite crystal.
The oxygen observed trend indicates a progressive temperature lowering of the concreting waters with time and, perhaps, also a variation in water isotopical composition towards \( \text{O}^{18} \) negative values (which are to be expected for metheoric waters).
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variation of the water from those of seawater (connate water?) to those of meteoric ones and this coincides with the difference found in chemical composition of the pale yellow and in the transparent calcite crystals.

Conclusions

The study of the crystals in the karstic cavities of the lowest level of the Masua mine allowed not only the reconstruction of the 7 different speleogenetic stages the studied caves have undergone, but also the definition of the chemical evolution of the circulating waters. All the first 6 speleogenetic stages have been developed in phreatic conditions, while the chemical composition of water is gradually changed from connate to meteoric type. Moreover the sulphide oxidation in the top of the ores represents a well defined moment in the geological history of the country.

In the future the karstic studies will be directed to the punctual correlation of the speleogenetic phases with the geological evolution and this will probably be achieved analysing several other caves present in the Monteponi and in the St. Giovanni mines (few km from Masua mine in S direction).

The importance of such studies is to be found essentially in the definition of the general chemical evolution of the groundwaters in the SW Sardinia, where the most important Pb and Zn ores are located.

Acknowledgments

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Bibliography

Figure 2. Horizontal projection and vertical sections of Phaff 1 cave
La Nouvelle Bretagne a fait l'objet de deux expéditions spéléologiques de la F.P.S (1978,80). Celles-ci ont permis la découverte de vastes et difficiles systèmes hydrogéologiques dans les karst des Mts NakanaI (500-1500 m d'alt.). Compte tenu d'une tectonique Plio-Quaternaire très active et d'un climat hyperhumide (~5-10 m/an), le karst évolue à une vitesse accélérée (dissolution spécifique X = 250-400 mm/1000 ans). Les rivières souterraines à violent débit (15 m³/s à l'étage) circulent dans de larges galeries de 40 m x 40 m. On y trouve d'immenses puits de 200 à 400 m de profondeur (~150-500 m). Ces puits hors du commun remontent sans doute au Quaternaire ancien ou moyen. Incontestablement, la démesure des phénomènes karstiques traduit magnifiquement l'hyperactivité de la karstification, certainement une des plus actives du globe.

Abstract

The French Federation of Speleology has organized two expeditions in New Britain (1978,80) which have permitted the discovery and the exploration of huge and difficult underground rivers in the doline karst of NakanaI Mountains. With an active Plio-Quaternary tectonic (large anticlinal), Miocene limestones very thick (1300-1500 m), an excessive wet climate (5-10 m/year), the karstic evolution is inevitably very quick (specific dissolution X=250-400 mm/1000 yrs). Subterranean rivers (discharge = 15 m³/s in low water) run inside big galleries (40 m x 40 m). Caves can reach these systems by giant pitches (collapse dolines) 200-400 m deep and 150-500 m wide. Such shafts are more or less old (middle and old Quaternary). Certainly, the uncommon dimension of karst phenomena is the result of the hyperactivity of karst processes in one of the limestone regions the most active in the world.

I. Les Conditions de la Karstification:

I-1. Géologie: Le karst des Mts. NakanaI s'identifie à un plateau calcaire de 1000 à 1200 m d'altitude reposant directement sur les roches volcaniques du Pélagoné. Cette formation carbonatée du Miocène moyen est épaisse de 1300-1500 m et présente des variations verticales de faciès (calcaires crayeux, calcaires en petits bancs, argilites...). Dans l'ensemble, ces calcaires sont assez poreux et très tendres. Au point de vue tectonique, on constate qu'il s'agit d'un géotectonique d'axe NSW-ENE formé à partir du Pliocène. Le soulèvement actuel est encore très sensible comme en atteste l'importante activité sismique de cette côte méridionale située à proximité de la fosse sous-marine de la Mer de Salomon (~7880 m). La plateforme corallienne Quaternaire de cette même bande côtière a été portée localement jusqu'à 300 m d'altitude.

I-2. Climatologie: Cette région connaît un climat de mousson typique. À la station côtière de Pomio, les précipitations annuelles sont de 6541 mm, mais il peut tomber jusqu'à 11000 mm certaines années. 

Pomio 235 151 226 262 449 846 1261 1395 777
Pomio 235 151 226 262 449 846 1261 1395 777
O N D J J A S A N D J J A S
Année - 6541 mm

Dans la montagne, la pluviosité est encore plus forte et il faut s'attendre à une moyenne annuelle supérieure à 8 ou 10 m. Au niveau de la mer, la température moyenne annuelle est de 24 °C. L'activité évapotranspiration (1500 mm/an) - la forêt créant ses propres nuages - le volume d'eau disponible pour la karstification demeure colossal, soit 5 m sur la côte.

I-3. Végétation et sols: L'intérieur de l'île est occupé par ce fameux "enfer vert" constitué par la forêt pluvieuse de basse et moyenne montagne. Cette couverture dense et continue détermine avec les pluies surabondantes l'hyperactivité de la karstification. Les précipitations, en traversant les sols en décomposition, se chargent en abondance d'acide carbonique. En surface, dans les mares, les eaux croupies ont des pH acides (6-6.8). Dans les sols, l'acidité est encore plus forte (pH = 5,4 - 5,7) en effet, plusieurs mesures de la pCO2 dans les sols ont donné des valeurs 20 fois supérieures à 40 cm de profondeur (pCO2 = 0,45%) qu'en surface. En surface, les dolines-avens et dans les grands conduits souterrains, la pCO2 demeure assez forte (0,15%), soit 6 à 7 fois plus que dans la forêt.

II. Les Systèmes Souterrains Géants:

Les Mts. NakanaI présentent un exemple remarquable de karst polygénique à deux domaines. D'une part un karst à dolines jointives ("cockpit karst"), d'autre part un fluviokarst à petits bassins hydrographiques fermés. Ces phénomènes géomorphologiques, dans lesquels il est possible de localiser des dolines-avens géantes transperçant comme à l'emporte pièce la surface ondulée des plateaux. Sept de ces cavités phénoménales ont pu être descendues et explorées: elles mesurent 100 à 700 m de diamètre et 150 à 400 m de profondeur, pour des volumes compris entre 10 et 60 millions de m3. Le cas le plus spectaculaire est celui de l'ensemble "Bikbik Vuvu" profond de 160-200 m. Exploré en saison relativement sèche, nous avons pu poursuivre l'exploration dans un véritable canyon souterrain faisant suite au canyon aérien. Là, nous avons rencontré des marmites de géants d'une taille encore jamais constatée sous terre. Certaines sont des marmites-puits de 10-25 m de diamètre et de 10-20 m de profondeur, et que l'on ne peut franchir parfois qu'en escalade artificielle. D'autres, plus évasées, peuvent former des bassins de plus de 30 m de large. Une telle morphologie ne peut s'expliquer que par un torrent débitant 50 à 100 m³/s en haute saison, possédant des crues spectaculaires capables de transporter les plus gros crones d'arbres jusqu'au siphon terminal situé à plus de 2 km de l'entrée et à 414 m de profondeur. Du point de vue hydrologique, on constate que les grands réseaux souterrains (système de la Matali: ~459; système de Naré: ~400; système de Minyé ~366; système d'Ora: ~260) correspondent à une mosaïque de bassins-versants de taille moyenne mesurant chacun 100 à 200 km². Les débits spécifiques sont très élevés: 150-230 m³/km². L'émergence de la Matali, d'un débit d'étage de 20-25 m³/s, a connu au niveau de son embouchure avec la mer une crue estimée à 1000 m³/s (en 1977, pont détruit).

III. Formation des Dolines-Avens Géantes:

Les puits géants des Mts. NakanaI sont des dolines d'effondrement de très grandes dimensions. Comme le montre la planche 6, on remarque que l'âge et la nature de la relation entre le plafond d'une grande salle souterraine et le fond d'une grande doline. L'exemple d'évolution le plus simple est fourni par Naré ou Minyé puisque l'on obtient d'immenses puits réguliers, très verticaux, à profil en cloche ou en tube. Dans le cas de Kavakuna, la dissymétrie de la cavité est due au décalage entre la salle et la doline. Pour Ora, on a affaire à une évolution plus complexe donnant lieu à une doline-aven double. Ce sont en fait de grands puits-avens rapides qui se réunissent en un ouvala puis qu'il ne reste qu'un pont rocheux relativement peu important. Enfin, dans le cas de l'enceinte "cratère" de Luré, il semble qu'on soit en présence d'un ouvala effondré montrant un stade
d'évolution plus avancé que celui d'Ora.

Dans quatre exemples sur cinq, on note qu'il existe une relation directe avec une circulation souterraine importante. L'existence de très grandes salles est un fait certain. En effet, plusieurs vides considérables ont été découverts dans les réseaux de Minyé et de la Matali (KaII). Ainsi, la salle d'Olain dans le KaII mesure près de 200 m de haut et présente un superbe profil en cloche (volume 2 millions de m3). Compte tenu de la vitesse d'évolution de ce karst en général et des dolines, de tels effondrements sont tout à fait logiques. Quant à la datation des phénomènes, on peut avancer quelques hypothèses. Par exemple, l'ouverture de Minyé doit remonter au Quaternaire moyen. En effet, l'éboulis de base, malgré ses 80 m de haut, est bien petit comparé au volume total de la cavité, une grande partie des blocs éboulés ayant été digérés par l'intense dissolution (affaissement progressif in situ et lessivage des carbonates vers la rivière). En estimant le volume de l'éboulis disparu, on peut situer l'effondrement majeur à - 200,000 - 300,000 ans BP environ.

L'importance des dépôts argileux en plusieurs points du système de Naré ou de Minyé tendrait à prouver que des mises en charge considérables se sont produites. Il est sans doute probable que l'éboulement massif du plancher suspendu d'une doline ait provoqué simultanément le barrage de la rivière et la remontée consécutive des eaux à l'intérieur de la cavité. Ce phénomène a d'ailleurs déjà été signalé à Cuba (cf. Corbel-Muxart, 1970). La genèse des grands collecteurs est étroitement liée à l'important soulèvement Quaternaire de l'île à cause que ces "fleuves" souterrains ne circulent pas sur un niveau imperméable mais tout simplement dans la masse même de la série carbonatée Oligocène épaissie de plus de 1300 m. Le perchement des émergences au flancs des parois de canyons (ex: Ora, Naré) prouve que le creusement de ces canyons s'effectue plus rapidement, les systèmes hypogènes étant loin de leur profil d'équilibre.

IV. Hydrochimie et Dissolution Spécifique:

Les eaux souterraines et d'émergences ont une température moyenne de 20 - 21 °C et un pH compris entre 7,2 et 7,8. Leur dureté totale voisine dans une fourchette de 14 à 20°F. Ainsi, compte tenu d'un TH moyen des eaux d'émergences et de rivières de 17 - 18 °F et d'un volume d'eau disponible de 3,5 à 7,5 m³/an (lame d'eau écoulée), les taux de dissolution spécifique sont de l'ordre de 230 à 430 mm/mille ans. Il n'y donc pas de doute, la karstification superficielle et souterraine est ici exceptionnellement rapide en raison de l'extrême pluviosité.

Conclusion

A l'inverse de certains karsts tropicaux à longue évolution principalement antéquaternaire comme dans les calcaires primaires de la Chine du SW (Kwangai) et où la morphologie est celle d'un karst à inselbergs, donc à reliefs résiduels, les Mts. Nakanaï de Nouvelle Bretagne constituent un exemple saisissant de karstogenèse Plio-quaternaire particulièrement accélérée. L'intense dissolution souterraine exercée sur des calccaires tendres explique la formation de vastes salles dont l'éboulement du plafond est à l'origine des grands puits. Ainsi, on observe bien une pêjoration de tous les phénomènes naturels: nébulosité, précipitations, couverture forestière, dissolution, volume des cavités, débits des rivières... Sans doute avons-nous là les conditions optimales de la karstification en climat tropical humide.

Bibliographie


Figure 1: Distribution des karsts en Nouvelle Bretagne
(1, Zones karstiques sur calcaire Miocène. 2, volcans actifs et récents).

Figure 2-3: Contexte géologique et coupe géologique des Mts. Nakanaï (Fig. 2: 1, alluvions Quaternaires. 2, calcaires coralliens Quaternaires. 3, conglomérats fluvialaires. 4, volcanisme récent. 5, calcaires de Yalam du Miocène moyen. 6, volcanosédimentaire de l'Oligocène supérieur. 7, volcanisme sous-marin de l'Olig. Sup. 8, laves basiques de l'Eocène sup. 9, volcans actifs. 10, volcans éteints. 11, caldéra. 12, failles. Fig. 3: A, volcanisme récent. B, calcaires de Yalam. C, volcanosédimentaire. D, volcanisme sous-marin (Olig. sup.). E, Laves basiques (Eocène sup.).
Figure 4: Les trois grands bassins-versants de Minye, Naré et Ora (Mts. Naknai) (1, émergences; 2, dolines-avens géantes et réseaux connus. 3, trajet supposé. 4, limites approximatives des bassins-versants. 5, dolines et grandes dépressions. 6, canyons. 7, escarpements.)
Figure 5: Plan et coupe du réseau de Naré (-400).
Figure 6: Formation probable des grandes dolines-avens des Mts. Nakanaif.
Résumé

Les montagnes calcaires du pourtour méditerranéen renferment un large éventail de karsts d'altitude. En se fondant sur le double critère "précipitations et taux de dissolution spécifique", on peut classifier ces régions en quatre types morphoclimatiques: les hauts karsts méditerranéens sub-arides (Espagne du Sud, Atlas marocain, Zagros iranien), les hauts karsts méditerranéens humides (Grèce occidentale) et les hauts karsts méditerranéens hyperhumides (Appennin central, Alpes Julienes, Durmitor).

Abstract

The limestone mountains of the mediterranean periphery contain numerous high altitude karsts. According to the rainfalls and the rates of specific dissolution, it is possible to classify these karst regions into four types: high karsts (Betic regional in the Mediterranean and semi-arid karsts (Basque mountains), the Mediterranean and semi-humid high karsts (Dinaric Jura, South Alps, Taurus), the Mediterranean and humid high karsts (Western Greece) and the Mediterranean and hyper-humid high karsts (Gra Sasso, Julian Alps, Durmitor).

Introduction

Le pourtour de la Méditerranée est caractérisé par la présence de chaînes de montagnes importantes appartenant toutes au système calcaire. Si les chaînes de montagnes importantes appartenant basses et moyennes altitudes sont nombreux, les hauts karsts de la zone supraforestière sont également très bien représentés. En effet, lorsqu'on se fonde sur deux critères essentiels: les précipitations et la vitesse de corrosion (solution spécifique), selon certaines cartes (cf. tableau hors texte), on remarque que les taux de dissolution spécifique évoluent dans une fourchette de 25 à 108 mm/1000 ans (certains valeurs sont provisoires). Pour précipitations reste impressionnante. On distingue ainsi la courbe d'augmentation de la dissolution en fonction des deux critères essentiels: les précipitations et la vitesse de corrosion. Malgré certains éléments pouvant contrarier localement cette règle (structure, lithologie, altitude, température), la courbe d'augmentation de la dissolution spécifiques reste impressionnante. On distingue ainsi sans mal quatre types de zones morphoclimatiques:

I. Les Hauts Karsts Méditerranéens Sub-arides (P < 1000 mm/an et X = 20-40 mm/1000 ans).
II. Les Hauts Karsts Méditerranéens Semi-humides (P = 1000-1500 mm/an et X = 60-90 mm/1000 ans).
III. Les Hauts Karsts Méditerranéens Humides (P > 2000 mm/an et X > 90 mm/1000 ans).

IV. Les Hauts Karsts Méditerranéens Hyperhumides: (Espagne du Sud), du Haut Atlas central calcaire (Maroc). Les taux de dissolution spécifiques les plus bas semblent être de 25 mm/1000 ans environ dans le Haut Atlas. Ces hauts karsts sub-arides renferment une morphologie nivale et glacio-karstique dans un contexte de calcaires marins kastiques. Dans le Moyen Atlas, les précipitations sont un peu plus fortes et peuvent atteindre 1000 mm (X = 31 mm/1000 ans). En effet, les précipitations annuelles sont pratiquement toujours supérieures à 500 mm, mais la sècheresse estivale est longue et intense. La distribution de ces karsts sub-arides est pratiquement coincisée dans les deux aires géographiquement opposées: Espagne-Maroc et Liban-Irak-Iran.

I. Les Hauts Karsts Méditerranéens Sub-arides: le qualificatif de sub-aride ne doit pas prêter à confusion. En effet, les précipitations annuelles sont pratiquement toujours supérieures à 500 mm, mais la sècheresse estivale est longue et intense. La distribution de ces karsts sub-arides est pratiquement coincisée dans les deux aires géographiquement opposées: Espagne-Maroc et Liban-Irak-Iran.

Les Hauts Karsts Periméditerranéens
Richard Maire

E.R.A. no. 282 du CNRS, Aix-en-Provence/Nice, France

Les cartes de dissolution spécifiques dans une fourchette de 25 à 108 mm/1000 ans (certains valeurs sont provisoires). Pour précipitations reste impressionnante. On distingue ainsi sans mal quatre types de zones morphoclimatiques:

I. Les Hauts Karsts Méditerranéens Sub-arides (P < 1000 mm/an et X = 20-40 mm/1000 ans).
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Richard Maire

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précipitations comprises généralement entre 2000 et 3000 mm/an et de l'absence d'aridité estivale notamment dans les Alpes Juliennes, ces exemples sont de type haut-alpin. En effet, la dissolution spécifique est voûte ou supérieure à 100 mm/100 ans et s'inscrit bien dans le cadre des hauts karsts tempérés très humides du domaine haut-alpin traditionnel (X = 90 mm/1000 ans dans les Hautes Alpes calcaires franco-suisses). Dans le massif côtier de l'Orjen (1895 m) situé à proximité de Kotor en Yougoslavie, les hauteurs de précipitations enregistrées sont extraordinaires (P = 5317 mm/an. J. Nicod: com. personnelle) de sorte que le taux de dissolution dépasse 200 mm/1000 ans.

Conclusion
Cette classification des hauts karsts du pourtour méditerranéen permet de mettre en évidence de grandes zones morphoclimatiques comme les domaines sub-arides du Haut Atlas et du Zagros et les domaines semi-humides et humides du Taurus et de Grèce. C'est évidemment au niveau des seuils que l'on rencontre des difficultés de classement d'autant plus que de nombreux taux de dissolution spécifique ont encore seulement une valeur indicative par suite de contradictions entre certains auteurs et aussi de carences en renseignements (chiffres de précipitations imprecis, analyses hydrochimiques peu nombreuses ou absentes, rôle méconnu de la sublimation...). Il est donc nécessaire d'évoluer dans des fourchettes de valeurs en faisant intervenir des taux planchers.

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Maire (R) - 1978 - "Les karsts d'altitude du Moyen-Orient", Actes 6e Congrès suisse de Spéléo... (Porrentruy), Stalactite, suppl. no 10, p. 123-130.
Pulina (M) - 1974 - "Denudacja Chemiczna na obszarach krasu weglanowego (Chemical denudation on the carbonate karst area)", Thèse, Wroclaw.
### Tableau 1. Précipitations et dissolution spécifique dans les hauts karsts de la Méditerranée occidentale.

<table>
<thead>
<tr>
<th>Massifs</th>
<th>Altitude (en m)</th>
<th>Précipitations (en mm/an)</th>
<th>Dissolution spécifique (X en mm/1000 ans et pour une tranche d'alt.)</th>
<th>X (valeur moyenne)</th>
<th>Auteurs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Djurdjura (Algérie)</td>
<td>2308</td>
<td>1500-1800</td>
<td>56-63 (1700-2300 m)</td>
<td>59</td>
<td>Quinif, 76, Estimation Maire</td>
</tr>
<tr>
<td>2. Haut Atlas (Maroc)</td>
<td>4068</td>
<td>700-900</td>
<td>22-31 (2500-3500 m)</td>
<td>26</td>
<td>Couvreur, 78, Estimation Maire</td>
</tr>
<tr>
<td>4. Sierra Magina (C. bétique, Esp.)</td>
<td>2167</td>
<td>800-1000</td>
<td>36-39 (1700-2100 m)</td>
<td>37</td>
<td>Pezzi, 75, Estimation Maire</td>
</tr>
<tr>
<td>5. Sierra Arana (C. bétique, Esp.)</td>
<td>2029</td>
<td>800-900</td>
<td>36-38 (1700-2000 m)</td>
<td>37</td>
<td>Estimation Maire</td>
</tr>
<tr>
<td>6. Sierra del Port del Comte (Pyr. catalanes, Esp.)</td>
<td>2332</td>
<td>1000-1400</td>
<td>36-44 (1800-2200 m)</td>
<td>40</td>
<td>Chevrier Magne 74, Estimation Maire</td>
</tr>
<tr>
<td>10. Grande Sélane (Alpes du Sud, France)</td>
<td>2909</td>
<td>1500</td>
<td>48-60 (2500-2800 m)</td>
<td>54</td>
<td>Estimation Maire</td>
</tr>
<tr>
<td>12. Mt. Canin (Alpes Juliennes, It.)</td>
<td>3000</td>
<td></td>
<td>94-103</td>
<td>98</td>
<td>Kunaver, 76, Corbel, 57</td>
</tr>
<tr>
<td>13. Triglav (Alpes Juliennes, Yougoslavie)</td>
<td>2864</td>
<td>2000-3000</td>
<td>63-128</td>
<td>95</td>
<td>Pulina, 74, Corbel, 65</td>
</tr>
</tbody>
</table>

### Tableau 2. Précipitations et dissolution spécifique dans les hauts karsts de la Méditerranée orientale.

<table>
<thead>
<tr>
<th>Massifs</th>
<th>Altitude (en m)</th>
<th>Précipitations (en mm/an)</th>
<th>Dissolution spécifique (X en mm/1000 ans et pour une tranche d'alt.)</th>
<th>X (valeur moyenne)</th>
<th>Auteurs</th>
</tr>
</thead>
<tbody>
<tr>
<td>15. Aroania (Péloponnèse, Grèce)</td>
<td>2341</td>
<td>1800-2000</td>
<td>83-78 (1800-2200)</td>
<td>80</td>
<td>Maire</td>
</tr>
<tr>
<td>17. Kandyla (Péloponnèse, Grèce)</td>
<td>1935</td>
<td>1500-1700</td>
<td>67-83 (1500-1800)</td>
<td>75</td>
<td>Maire</td>
</tr>
<tr>
<td>18. Taygète (Péloponnèse, Grèce)</td>
<td>2407</td>
<td>1800-2200</td>
<td>83-88 (1600-2200)</td>
<td>86</td>
<td>Maire</td>
</tr>
<tr>
<td>19. Mt. Ida (Crête)</td>
<td>2456</td>
<td>1400-1800</td>
<td>51-67 (1600-2200)</td>
<td>59</td>
<td>Bonnefont, 71, Maire, 80</td>
</tr>
<tr>
<td>20. Levka Ori (Crête)</td>
<td>2453</td>
<td>1800-2200</td>
<td>84-88</td>
<td>86</td>
<td>Estimation Maire</td>
</tr>
<tr>
<td>21. Pirin (Rhodope, Bulgarie)</td>
<td>2914</td>
<td>900-1100</td>
<td>47-52</td>
<td>50</td>
<td>Pulina, 74</td>
</tr>
<tr>
<td>22. Dedegol Dag (Taurus occid., Turq.)</td>
<td>3000</td>
<td>1400-1600</td>
<td>57-52 (2000-2900 m)</td>
<td>55</td>
<td>Maire</td>
</tr>
<tr>
<td>23. Anamos Dag (Taurus occid., Turq.)</td>
<td>2200</td>
<td>1000-1400</td>
<td>41-60 (1800-2200 m)</td>
<td>50</td>
<td>Maire</td>
</tr>
<tr>
<td>24. Bolkar Dag (Taurus centr. Turq.)</td>
<td>3585</td>
<td>1000-1200</td>
<td>29-33 (2500-3400 m)</td>
<td>31</td>
<td>Maire, 78</td>
</tr>
<tr>
<td>25. Ala Dag (Taurus central, Turquie)</td>
<td>3734</td>
<td>1200-1400</td>
<td>33-40 (2500-3500 m)</td>
<td>37</td>
<td>Maire, 78</td>
</tr>
<tr>
<td>26. Nemrut Dag (Taurus orien., Turq.)</td>
<td>2100</td>
<td>1000-1200</td>
<td>46-57 (1800-2100 m)</td>
<td>51</td>
<td>Maire, 80</td>
</tr>
<tr>
<td>27. Muntzur Dag (Taurus orien., Turq.)</td>
<td>3449</td>
<td>900-1100</td>
<td>43-48 (2000-3000 m)</td>
<td>46</td>
<td>Maire, 80</td>
</tr>
<tr>
<td>29. Ravansar (Zagros, Iran)</td>
<td>2900</td>
<td>600-900</td>
<td>21-28 (2000-2800 m)</td>
<td>25</td>
<td>Maire, 78</td>
</tr>
<tr>
<td>30. Parau (Zagros, Kermanshah, Iran)</td>
<td>3300</td>
<td>600-1000</td>
<td>26-36 (2500-3300 m)</td>
<td>31</td>
<td>Maire, 78</td>
</tr>
</tbody>
</table>
31. Zardeh Kuh (Zagros central, Iran)  
32. Mt. Liban (Liban)  
33. Mt. Hermon (Liban)  
34. Antiliban (Liban)

<table>
<thead>
<tr>
<th>Location</th>
<th>Elev (m)</th>
<th>Base Altitude (m)</th>
<th>Max Altitude (m)</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zardeh Kuh</td>
<td>4548</td>
<td>500-1000</td>
<td>22-28 (3000-4200 m)</td>
<td>25</td>
</tr>
<tr>
<td>Mt. Liban</td>
<td>3083</td>
<td>1500-1700</td>
<td>50-66 (2000-2900 m)</td>
<td>58</td>
</tr>
<tr>
<td>Mt. Hermon</td>
<td>2814</td>
<td>1000-1200</td>
<td>28-37 (2200-2800 m)</td>
<td>33</td>
</tr>
<tr>
<td>Antiliban</td>
<td>2659</td>
<td>900-1000</td>
<td>21-30 (2000-2600 m)</td>
<td>26</td>
</tr>
</tbody>
</table>

Figure 1: Distribution géographique des hauts karsts méditerranéens (1, Djurdjura. 2, Haut Atlas central calcaire. 3, Moyen Atlas. 4, Sierra Magina. 5, Sierra Arana. 6, Sierra del Port del Comte. 7, Marquaires. 8, Oserot. 9, Mt. Mounier. 10, Grande Sélolane. 11, Gran Basso. 12, Mt. Canin. 13, Triglav. 14, Durmitor. 15, Aroania. 16, Erymanthe. 17, Kandyla. 18, Taygète. 19, Mt. Ida. 20, Levka Ori. 21, Pirin. 22, Dedegöl Dag. 23, Anamos Dag. 24, Bozkur Dag. 25, Ala Dag. 26, Nemrut Dag. 27, Munzur Dag. 28, Hasobesir. 29, Ravansar. 30, Paraú. 31, Zardeh Kuh. 32, Mt. Liban. 33, Mt. Hermon. 34, Antiliban.)

Figure 2: Distribution géographique des quatre grands types morphoclimatiques de hauts karsts méditerranéens (1, type sub-aride. 2, type semi-humide. 3, type humide. 4, type hyperhumide).
On the Hyporheic Hydracarians of Cuba
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Institute of Speleology, Str. Mihail Moxa 9, 78109 Bucharest 12, Romania

The biospeleological expeditions organized by both the Academy of Sciences of Cuba and the Academy of the Socialist Republic of Romania in 1969, 1970 and 1973 succeeded in making evident the exceptional scientific interest of the Cuban subterranean fauna, from both a quantitative and a qualitative point of view.

About 300 new taxa have been described up to now and there is still plenty of material rich in organisms whose study has not yet come to an end.

As concerns the study of the hyporheic hydracarians - living in the alluvial interstices under the water of the rivers - the province of Oriente has been in the center of our attention for it was there that we found out several dozens of new species 25 of which have already been described. They belong to 7 new genera some of which we had to introduce into new sub-families.

The first striking characteristic of this fauna is its endemic character, and this is also true for a great part of the underground fauna discovered in Cuba.

Another remarkable feature of the hydracarians is given by peculiar morphological dispositions in the case of several species belonging to the genera of several families, or by completely unknown dispositions, such as:

a) enormous legs in the case of several species of the Kongutherfordia and Axonopsis genera.
b) the first coxa having the form of a hook, has a gland, too (f) in the case of the 2 species of the new Crocokongutherfordia sub-genus.
c) aberrant - completely different - structure of the first leg tarsus in the case of the 2 representative of the Stygonomoninae, and
d) the morphological peculiarities of the Cladomomonia and the genitals structure in the case of Sibonyacarus sordidus.

All these characteristics have been so far unknown with Hydracarians.

In our work we try to explain these morphological peculiarities starting from the ascertained fact that the island is an isolated center of evolution with many specializations creating new species and even new types within the same group.

In the end the other zoological groups are considered, trying to find certain ways of paleogeographical interpretations (insatisfactory so far) for realistically explaining the island's populating process.

Figure 3: Variations de la vitesse de dissolution (dissolution spécifique) en fonction des précipitations.
Comparaison du Métabolisme Respiratoire de Niphargus Rhenorhodanensis (Crustace Amphipode Hypoge) Provenant de Deux Systemes Karstiques Différents

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Résumé
La métabolisme respiratoire de Niphargus rhenorhodanensis provenant de deux cavités différentes est étudié. Il n’apparaît aucune différence entre les valeurs moyennes de la consommation d’oxygène (720 et 664 µl/gs/h) et des paramètres caractérisant les droites de régression consommation/masse. Ces résultats, comparés à d’autres acquis précédemment pour des Niphargus rhenorhodanensis d’origine phréatique, montrent donc une homogénéité de la consommation d’oxygène de ces animaux souterrains testés à une même température.

Abstract
The respiratory metabolism of Niphargus rhenorhodanensis from two different caves is studied. There is no difference between oxygen consumption means (720 and 664 µl/dw/h) and between the parameters of the consumption/weight regression. Compared to others previously found, these results point out an uniformity of oxygen consumption in these subterranean animals at one and the same temperature.

Zusammenfassung


Malheureusement, la disparition de la population karstique précitée m’a obligé à trouver une autre cavité hébergeant la même espèce de Niphargus et possédant des caractéristiques écologiques relativement semblables, afin de pouvoir terminer ces comparaisons.

L’expérience concernant l’action de la température et possédant des caractéristiques écologiques relativement semblables, afin de pouvoir terminer ces comparaisons.

C’est le complexe hydrogéologique de Dorvan (Jura méridional) (grotte du Cormoran et résurgence du Flassoir) qui m’a permis de récolter des animaux en quantité suffisante pour mener à bien la série d’expériences concernant l’action de la température sur le métabolisme respiratoire, avec des témoins possédant les mêmes caractéristiques que ceux de la cavité précédente.

Dans un premier temps, afin de ne pas perdre les données acquises de la population de Niphargus du Vercors, il était essentiel de comparer la consommation d’oxygène de témoins obtenue avec l’une et l’autre des deux populations karstiques. Ce sont les résultats de ce test comparatif qui constituent l’essentiel de la présente publication.

Materiel et Methodes
Les individus testés appartiennent à l’espèce Niphargus rhenorhodanensis (Schell, 1937); ils ont été récoltés:
1 - dans le ruisseau temporaire de la grotte du Pont des Aniers près de Villars de Lans dans le massif du Vercors (Isère, France) (Ginet et Mathieu, 1968);
2 - soit dans le ruisseau souterrain de la grotte du Cormoran, soit à la résurgence de la grotte du Flassoir, ces deux stations étant dans le massif karstique du Jura méridional situé près de Torcieu (Ain, France) (Gibert et Coll., 1978).

Cette similitude m’a amené à faire figurer ces derniers dans l’exposé sous la même dénomination: “grotte du Cormoran”.

Dans les deux cas, un certain nombre de facteurs du milieu ont été mesurés; il a été possible de remarquer principalement que la température de l’eau varie peu; la moyenne de ces données à 18° à 19°5 au Pont des Aniers et à 10° pour la grotte du Cormoran (Gibert, communication personnelle).

Les animaux capturés sont transportés au laboratoire et mis en élevage dans des pièces obscurcies climatisées à 11°C.

L’expérimentation a porté que sur des individus mâles au stade d’intermue C.

La technique de mesure individuelle de la consommation d’oxygène a été décrite précédemment (Mathieu, 1973, 1975). Elle est basée à 11°C. L’intervalle de temps entre deux mesures consécutives a été de 1/4, 1/2 et une heure pour les individus de la grotte du Pont des Aniers, une heure pour ceux de la grotte du Cormoran. Chaque individus est testé pendant deux heures.

Résultats
Les résultats obtenus sont consignés dans le tableau I, ou représentés sur la figure 1.

Dans un premier temps, afin de ne pas perdre les données acquises de la population de Niphargus du Vercors, il était essentiel de comparer la consommation d’oxygène de témoins obtenue avec l’une et l’autre des deux populations karstiques. Ce sont ce résultat, et un soucis d’économie en individus, qui m’ont amené, pour la population de la grotte du Cormoran, à effectuer seulement des expériences dont l’intervalle de temps entre deux mesures est de une heure.

<table>
<thead>
<tr>
<th>Pont des Aniers</th>
<th>Cormoran</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/4</td>
<td>1/2</td>
</tr>
<tr>
<td>µl/h</td>
<td></td>
</tr>
<tr>
<td>5 731</td>
<td>5 090</td>
</tr>
<tr>
<td>+0 758</td>
<td>+1 284</td>
</tr>
<tr>
<td>µl/gs/h</td>
<td></td>
</tr>
<tr>
<td>1368</td>
<td>1272</td>
</tr>
<tr>
<td>+ 319</td>
<td>+ 345</td>
</tr>
<tr>
<td>N</td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>17</td>
</tr>
<tr>
<td>Φ (mg)</td>
<td></td>
</tr>
<tr>
<td>5 1</td>
<td>3 8</td>
</tr>
</tbody>
</table>
Dans les conditions expérimentales précisées: tests à 11°C avec un intervalle de une heure entre deux mesures, les valeurs témoins de la consommation, ramenées à l'unité de masse, ne sont donc pas différentes entre les deux populations (720 et 664 μl/gs/h : t = 1,93 pour 50 ddl).

Une preuve supplémentaire de cette identité entre les deux populations est fournie par la relation entre la consommation horaire par unité de masse, et la masse des animaux (figure 1). Les pentes des droites et les ordonnées à l'origine ne sont pas statistiquement différentes. On obtient un résultat identique si l'on exprime la consommation horaire en fonction de la masse (figure 1). Ceci apparaît en accord avec le fait que la consommation horaire est effectivement différente entre les deux populations (2,736 et 3,875 μl/h : t = 7,36 pour 50 ddl) : la masse moyenne des individus de la grotte du Cormoran est plus importante que celle des autres (6,2 contre 4 mg).

**Discussion**

Ces résultats rendent à prouver la similitude de la consommation d'oxygène de *Niphargus rhenorhodanensis* provenant de grottes différentes, mais à caractéristiques écologiques semblables. Les valeurs citées dans ce travail ne sont pas statistiquement différentes. Elles ne diffèrent pas non plus de celles obtenues par Wautier et Trolani (1960) (environ 720 μl/gs/h) avec des exemplaires de la même espèce provenant d'une troisième cavité.

Les valeurs obtenues avec les témoins d’origine phrétatique (732 et 684 μl/gs/h : Mathieu, 1982) dans les mêmes conditions expérimentales ne sont, elles non plus, pas différentes de celles exprimées dans ce travail. De plus, les pentes des droites de régression consommation/masse ne sont pas différentes (-0,338 et -0,484 pour les Niphargus phrétatiques, -0,382 et -0,437 pour les karstiques).

Les valeurs élevées citées dans Mathieu (1972) correspondent à un intervalle de temps de 1/4 d'heure entre deux mesures. En fait, avec cette condition expérimentale particulière, 1306 μl/gs/h obtenus en 1973 et 1368 μl/gs/h trouvés ici ne sont pas différents. Les résultats trouvés sur la population phrétatique (Mathieu, 1982) et ceux énoncés ci-dessus, confirment que c'est bien la fréquence de l'agitation de l'eau liée à la technique de la mesure, qui provoque des différences de valeurs de la consommation d'oxygène des individus pris comme témoins.

Ainsi, avec les conditions expérimentales amenant à caractériser la consommation d'oxygène de *Niphargus* témoins provenant du domaine karstique, les paramètres semblent constants: les valeurs globales sont sensiblement les mêmes, ainsi que la relation qui lie cette respiration à la masse. Les comparaisons entre populations provenant de deux systèmes aussi différents que celui des eaux karstiques et celui des eaux phrétatiques pourront donc se poursuivre normalement en utilisant désormais les animaux originaires de la grotte du Cormoran.

**Bibliographie**


Figure 1. Valeurs individuelles de la consommation d'oxygène en fonction de la masse sèche (en mg) pour les populations de la grotte du Cormoran (+) et de la grotte du Pont des Aniers (●). Coordonnées logarithmiques.
The swimming activity in bredings of an Astyanax Mexicanus river population (Rio Teapao, Mexico) and cave population (Cueva de El Pachao) was studied in artificial light-dark-cycles (LD), in constant darkness (DD), and after light pulses. The activity was registered in two forms: surface (OA) and bottom activity (BA).

Teapao: OA and BA can be entrained by any kind of Zeitgeberprogramm. Both phases differ by a shift of 180°. The maximum values of OA correspond to the dark-phases, those of BA to the light-phases of the LD. Ciradian rhythms are synchronized in LD with period lengths (T) differing from 24 hours. In DD the entrained rhythms damp out within one or a few periods. The above mentioned phase-shift between OA and BA is no longer detectable. Freerunning circadian rhythms are obvious.

Pachon: OA and BA were generally entrainable by any LD in the same way as in Teapao by increasing length of the LD. In particular cases, however, there are difficulties in entrainment, if T of LD differs from 24 hours. In general the activity rhythms are not as strong as in Teapao. Ciradian rhythms are rarely superposed. In DD the entrained rhythms disappear at once. An overt freerunning circadian rhythm appears in DD after LD 12:12 h and less strong in DD after LD 8:8 h. In all other cases no significant rhythms can be detected.

Light pulses of 6 and 12 hours length shift the phase of a freerunning oscillation. Moreover, the 6 h-puls produces damped oscillations of 12 hours length. In LD with a periodenlänge (T) ≠ 24 Std. is the Zeitgeberrhythmik a circadian Schwingung überlagert. In DD geht die Zeitgeberrhythmik nicht sofort verloren. Sie dämpft vielmehr innerhalb von einer bis mehrerer Perioden aus (Nachschwingen). OA und BA verlaufen nicht mehr inverse. Freilaufende circadian Rhythmen sind nachweisbar.

Lightpulse von 6 und 12 Std. Länge wird eine ausgedämpfe Rhythmik wieder angestoßen, eine freilaufende in ihrer Phase abrupt verschoben. Der 6-stündige Puls erzeugt außerdem ein 12-stündiges Nachschwingen.


Light pulses of 6 and 12 hours length switch on a damped circadian oscillation and shift the phase of a freerunning oscillation. Moreover, the 6 h-puls produces damped oscillations of 12 hours length. In LD with a periodenlänge (T) ≠ 24 Std. is the Zeitgeberrhythmik a circadian Schwingung überlagert. In DD the entrained rhythms damp out within one or a few periods. The above mentioned phase-shift between OA and BA is no longer detectable. Freerunning circadian rhythms are obvious.

Die Schwimmaktivität von Nachzuchten aus einer Flußpopulation (Rio Teapao, Mexico) und einer Höhlenpopulation (Cueva de El Pachao, Mexico) des Astyanax Mexicanus ist in künstlichen Licht-Dunkel-Wechseln (LD) und in Dunkelheit (DD) sowie nach Lichtpulsen aufgesucht worden. Die Aktivität wird eingeteilt in: Oberflächenaktivität (OA) und Bodenaktivität (BA).


Light pulses of 6 and 12 hours length shift the phase of a freerunning oscillation. Moreover, the 6 h-puls produces damped oscillations of 12 hours length. In LD with a periodenlänge (T) ≠ 24 Std. is the Zeitgeberrhythmik a circadian Schwingung überlagert. In DD the entrained rhythms damp out within one or a few periods. The above mentioned phase-shift between OA and BA is no longer detectable. Freerunning circadian rhythms are obvious.

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with a period length about 12 hours). The free-running circadian rhythm proves the existence of a second activity controlling system. The properties are: nonlinear, self-sustained and circadian.

Results of PACHON

The activity of the cave fish is generally entrainable in the same way as in TEAPOAO, though the fish itself is less sensitive for light signals. To stabilise the forced oscillation the amplitude of the forcing signal has to increase. Nevertheless the forced oscillation remains less strong than in TEAPOAO and the forced system reacts less uniform and quick. Effects of light pulses are weak. After transition from LD to DD the forced oscillation disappears at once. That means: the passive system of the river fish has developed to an extremely passive one, unable to oscillate, and thus has been simplified. It has remained linear because output signal and input signal ever show the same frequency.

In any LD with a period length differing from 24 hours and its harmonies a circadian rhythm is detectable (LD with a period length corresponding to harmonies of 24 h were not applied). In DD after LD 12:12 hours and less strong in DD after LD 8:8 hours a circadian rhythm is overt. In all other cases the activity is arrhythmic. These results lead to the conclusion that the cave fish has kept a nonlinear, self-sustained, circadian oscillator but its ability of self-sustenance is restricted.

It is notable that the time-measuring systems of the cave fish have degenerated not as quick as several morphological and ethological structures! At this moment only speculations about the reasons are possible because the applied methods of this work don't allow to prove any hypothesis. Perhaps the bats inhabiting the Pachon cave set at least as weak zeitgebers. Perhaps the possession of a clock is still an advantage in internal regulation, yet unknown.

Dinaric Karst Poljes and Neotectonics

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Abstract

The detailed investigations in the NW dinaric karst regions proved the importance of the geologic setting and neotectonics on the karst poljes morphogenesis, beside erosional, corrosional and collapse influence. In the Postojna and Cerknica regions the neotectonic block movements along the NW-SE directed regional faults, for example Idrija wrench-fault zone, were stated. They reflect in the geologic setting, in faulted quaternary sediments, in the karst relief and in the morphology and genesis of karst caves, specially in water channels between the karst poljes. The typical examples of neotectonic movements and their influence on the polje morphology will be illustrated in the paper.

Résumé

Les recherches du karst détaillées autour Postojna et Cerknica dans la partie NW du karst dinarique ont montré que à part de l'influence d'érosion, de corrosion et d'effondrement pour la morphogenèse des poljés karstiques sont importantes surtout la structure géologique et la néotectonique. Le long de failles orientées dans la direction dinarique ayant le caractère régionale, comme par exemple la zone de faille d'Idrija il y sont constatés les mouvements quaternaires et même récents de blocs de différente taille dans la région de Cerknica et Planina poljés. Ces mouvements reflètent dans la structure géologique, dans la fracturation de roche entre les sédiments quaternaires, dans le relief karstique le long de poljés et sur eux mêmes et aussi dans la distribution et développement de cavernes souterraines, surtout de grottes actives dans le karst de soutirage entre les poljés karstiques.

Dans la communication les examples caractéristiques de mouvements tectoniques récents et leur influence sur la formation de poljés seront présentés.
Sensation Seeking and Locus of Control in Spelunkers: Further validation of these personality constructs

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Abstract

The personality of spelunkers was investigated by means of a mail-survey to a random sample of National Speleological Society members. Demographic variables, amount and intensity of caving activity, sensation-seeking and internal-external locus of control scores were obtained for each subject. Results showed spelunkers to be a heterogeneous group with sensation-seeking and locus of control scores not significantly different from the general population. Amount and intensity of caving activity, however, did correlate significantly with sensation-seeking, with the most active cavers being high sensation-seekers. Locus of control scores only showed significant correlations with certain types of spelunking. Males and females showed no significant difference in caving activity.

Résumé

Une enquête sur la personnalité de spéléologues était faite au moyen d’un sondage par poste d’un échantillon au hasard des membres de la Société Nationale de Spéléologie. Les variables démographiques, la quantité et l’intensité de l’activité spéléologique et les scores du sensation-seeking (recherches-sensation) et du locus de control interne-extérieur ont été obtenus pour chaque sujet. Les résultats ont indiqué que les spéléologues sont un groupe homogène dont les comptes du locus de control et du sensation-seeking ne différaient pas d’une manière trop significative de la population générale. La quantité et l’intensité de l’activité spéléologique, cependant, se trouvent en corrélation avec sensation-seeking. Les spéléologues les plus actifs sont supérieurs vis-à-vis l’aspect sensation-seeking. Les comptes du locus de control ne reflètent pas de différences significatives d’activité spéléologique.

Why do some people like to crawl, walk or climb in cold, dark holes in the earth? What type of person chooses to be a spelunker? This study was designed to investigate the relationship of certain personality dimensions to amount and nature of caving activity. The conceptual focus of this study was on sensation-seeking and internal versus external control of reinforcement.

Sensation-seeking was conceptualized as curiosity, exploratory drive or a need for stimulation. The total concept of sensation seeking comprises four distinct subscales: thrill and adventure seeking, boredom susceptibility, disinhibition, and experience seeking. Experience seeking is the need to try new, varied, and exciting experiences, whereas thrill and adventure seeking is the desire to attempt activities which most would consider exciting or dangerous. Boredom susceptibility and disinhibition are self-explanatory. Research has shown wide-spread individual differences in this trait which may be biologically based. (See Zuckerman, 1978 a & b for a more detailed discussion of this construct and a review of the research literature.)

The concept of internal vs. external control of reinforcement was developed by Rotter (1966 & 1971) from social learning theory to describe the degree to which individuals perceive reinforcements contingent upon their own behavior. Internal control refers to individuals who regard the locus of control to be internal (self-generated) while external control refers to individuals who believe reinforcements are not under their personal control but are under the control of external forces or fate, other persons, or other circumstances. Both sensation seeking and belief in internal or external control are measured by a forced choice test where the subject selects which of 2 choices best describes him or her.

Since sensation-seeking has been shown to be higher in those involved in physical risk taking, such as skydiving, race car driving, snowmobiling and underwater diving (Zuckerman, 1978 a, p. 519), it was hypothesized that spelunkers also would show high sensation-seeking scores. Previous research (Joe, 1971, p. 632) also suggests a relationship between internal-external control and risk-taking behavior respectively. Internals are described as cautious and conservative than externals in risks-taking situations in an attempt to control events. Zuckerman (1978 p. 508) also reports a correlation between a belief in external control and various aspects of sensation-seeking. Thus, it was hypothesized that cavers would be high both in sensation-seeking and belief in external control. A random sample (n = 200) of members from the National Speleological Society (NSS) was selected from the NSS 1978-1979 membership listings. These members were sent a survey covering explaining the research project; (2) A Background Data Sheet, to ascertain demographic variables and the amount and intensity of caving activity; (3) a modified version of Rotter’s Internal-External (I-E) Locus of Control scale (Rotter, 1966); and (4) Form V of the Sensation-Seeking scale (Zuckerman, 1971). Subjects were asked to complete the questionnaires, and return the answer sheet, anonymously if they preferred, to the researchers.

Seventy-nine questionnaires were returned, yielding a 40% response rate. Sensation-seeking scales (SSS) were scored for Thrill and Adventure Seeking (TAS), Experience Seeking (ES), Disinhibition (Ds) and Boredom Susceptibility (Bs), as well as a total score (TSS). The scale was scored for the amount of belief in external control, with high scores indicating high external orientation, low scores indicating high internal orientation.

The frequency and intensity of caving activity was scored by tabulating responses to various items on the Background data sheet. Three subscores were derived in the following manner: (1) "Group" caving indicated the amount of participation in group meetings, cave projects, society newsletters, group caving, and cave conservation projects; (2) "Sport" caving indicated the extent of involvement in actual spelunking, vertical caving, and caving and carousing activities; (3) "Recreational" indicated the extent of involvement in partying at NSS conventions, extra and premarital sexual activities, and consumption of marijuana and alcohol.

Histograms were constructed to observe the patterns of scores, and Pearson product-moment correlations computed to explore the relationships between background variables, caving activity and the scores on the personality measures.

Statistical analyses showed that spelunkers as a whole are a heterogeneous group. Their mean scores on the Sensation-Seeking scales did not differ significantly from those found in the standardization sample (see Zuckerman, 1971), although the scores on the sensation seeking scales did not differ significantly (p < .05) with Total Sensation-Seeking scores and with subscale scores. For example, scorers who are high in Sport caving, Group caving, and carousing are also high in Sport and Group caving all correlated significantly (p < .05) with the Sensation-Seeking subscales of Experience Seeking and Disinhibition, only those high in Sport caving tended to have high scores on the subscale for Thrill and Adventure Seeking.

Locus of Control scores only correlated significantly with caving, with high external Locus of Control being significantly correlated (p < .05) with amount of caving.

As an interesting adjunct, all variables were compared for males vs. females. None of the caving related variables showed any significant differences. In fact, only two of all the variables were significantly different: gross income and Thrill and Adventure Seeking subscores. Zuckerman (1978) has already reported the latter in several studies. An unpublished survey by Carol Vesely and Dave Bunnell, conducted at the 1979 NSS conventions, did find a significant difference in thrill of caving activity between males and females. It is hypothesized that this discrepancy is the result of sampling technique.

In summary, spelunkers, as reflected by the NSS sample, seem to be a heterogeneous group in personality, 798
with scores on Sensation-Seeking and I-E Locus of Control scales varying as in the general population. High Sensation-Seeking, however, does seem to differentiate between very active and less active cavers. In addition, the Sensation-Seeking subscales differentiate among different types of cavers, with all active groups showing high scores in Experience Seeking and Disinhibition, but only active Sport cavers showing high scores on Thrill and Adventure Seeking.

Locus of Control does not seem to differentiate the active versus less active cavers, except in the area of carousing, where belief in external control was correlated with carousing activity. Thus, those cavers who are more likely to drink, take drugs, be sexually promiscuous and party frequently are more likely to believe in external locus of control.

Such data adds further construct validity to the concepts of Sensation-Seeking and Locus of Control, in that these personality dimensions seem to have some expected behavioral correlates. Although the original prediction that spelunkers as a total group would be generally higher in Sensation Seeking was not supported, it can be seen that the amount and intensity of caving activity definitely correlates with Sensation Seeking. Although caving activity, in general, did not correlate with external locus of control, intensity of carousing activity did. Thus, while spelunkers do not seem to be a homogeneous group, clearly distinguishable from the general population, the amount and type of caving activity, however, does seem to have various personality correlates.

Acknowledgements
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References
Recent years have seen significant progress in cave surveying and mapping techniques. Along with the increased reliance on computer techniques for cave mapping and the analysis of survey data, the subject of cumulative errors is now increasingly apparent.

This analysis uses probability equations to show that the zone of uncertainty generated by the statistical errors in a survey shot is in the shape of an ellipsoid. The process for the statistical addition of these ellipsoids for a series of survey shots is discussed.

In modernen Jahren haben Höhlenforscher in Bezug auf Höhlenvermessungstechnik und Höhlenkartographie bedeutsame Fortschritte gemacht. Weil das Vertrauen auf Computers für Höhlenkartographie und Analysis der Höhlenmessunen immer mehr steigt, kommt die Frage der kumulativen Fehler immer mehr ins Gewicht.

Diese Analyse nutzt Wahrscheinlichkeitsgleichungen um zu zeigen, dass der Unsicherheitsbereich durch statistischen Messungsfehler erzeugt die Gestalt eines Ellipsoids hat. Die statistische Addition von diesen Ellipsoiden wird für eine Reihe von

Diese Analyse kann man für die Abschätzung von Versuchsfehler nutzen. Sie gibt auch relative Bedeutungen zu den Berechnungen die man für die Anpassung eines Vermessungsverschlusses durch die Methode der Mindestquadrate nutzen kann.

Important aspects of cave surveys and maps are the determination of the interrelationships of cave and the relationships of cave passages to topographic and geologic surface features. The determination of these distance relationships involves both the calculated survey distance between the two points in question and the value for the potential amount of error based on the level of accuracy of the measurements.

Survey error analysis is also useful in cave survey computer programs. These programs are used to close all the tapes loops in every survey so that there will not be any discrepancies between the first and last stations in each loop. Mathematically, the most sophisticated type of closure program is a simultaneous closure program which uses the method of least squares and weighting based on error propagation calculations. Application of the simultaneous equations results in the least amount of distortion during the closure adjustment process.

The accuracy of a cave map depends on the accuracy and precision of surveying instrument use. There are several error causing problems involved in the process of surveying which cause inaccurate cave maps and cave sections. These problems can be classified into three kinds: statistical error, systematic error, and blunders. Statistical errors include small measurement errors resulting from the intrinsic lack of precision in the typical cave surveying instruments; measurement errors caused by the fact that humans are using the instruments; and the error in positioning the instruments at the survey stations. Statistical errors are characterized by: the occurrence of error in some random amount in every measurement; lack of cancellation of error as well as the addition of error because of the opposite error directions that are possible; and the inability of mathematical error analysis to simulate the cumulative error. Systematic errors include: inaccurate compass readings caused by a compass magnetically or mechanically out of alignment; reading of clinometer readings caused by a stretched tape; et cetera. Systematic errors are characterized by: the occurrence of the error in a defined amount in the same direction in every measurement; lack of cancellation by errors in opposite directions; and a regular propagation of error that is faster than the propagation of statistical error. Blunders include: reading the compass backwards within a 10-degree interval, i.e., 117° instead of 123°; a spurious reading of the wrong scale on the clinometer; incorrect transcription of data such as 110 feet versus 11.0 feet; et cetera. Although blunders occur randomly and can occur and cancel each other, they do not occur in a random amount in every measurement and they do not follow a regular propagation pattern.

The intrinsic amount of precision in the cave survey instruments, and the precision inherent in the use of the instruments by cave surveyors define the amount of statistical error that propagates along a surveyed passage, and is less the number of errors in the sample of the survey. Conversely, blunders and systematic errors result from mistakes and poor instrument use, and the detection of these kinds of error provides for an opportunity to correct poor survey closures.

Because blunders disturb the normal propagation of statistical error, and systematic errors propagate at a much faster rate, the presence of these kinds of errors can be detected by comparing a calculated expected amount of statistical error with the observed survey error.

The statistical error of cave surveys is based on the standard deviations of error in the surveying instruments, which are the compass, tape, and clinometer. These three sources of error cause three mutually perpendicular linear special errors, generating a three-dimensional error space or zone of uncertainty. These three generating axes are: A, the axis perpendicular to the survey shot in the 'horizontal plane' generated by compass errors of too far or too near; and B, the axis perpendicular to the A and B axes, generated by clinometer errors of too much above or below the true position of the sighted station.

The standard deviations of the error on the axes A, B, and C of a survey shot can be calculated using Gauss' law of propagation of error. If F is a function of several random variables, F = f(A, B, C, D,...), and the standard deviations of the variables (e.g., 0A, 0B, 0C, etc.) are known, the square of the standard deviation of F is:

\[ \sigma_F^2 = \sigma_A^2 + \sigma_B^2 + \sigma_C^2 + \sigma_D^2 + \ldots \]

with the partial derivatives evaluated at their average values. For the application of Gauss' law and further analysis, each survey shot will have its own three-dimensional coordinate system in which the survey shot will be defined as being on the y axis with zero inclination of the y axis. The average value of Lx is, of course, zero. However, the application of Gauss' equation gives the variance of the error in the x axis as 0Lx = 0F (Cos 0 Cos C). Similarly, the length of a survey shot in the horizontal perpendicular direction, allowing for errors in D, 0, and C, is Lx = D Sin 0 Cos C. The average value of Lx is, of course, zero. However, the application of Gauss' equation gives the variance of the error in the x axis as 0Lx = 0F (Cos 0 Cos C) 2, which, when evaluated at average values of D, 0, and C, gives 0Lx = D 2 0F. The variance of error in the vertical distance, Lz = D Sin C, is 0Lz = D 2 0F Cos 0 D 2 0F. Therefore, the standard deviation of the variable Lz (is the variance of the x axis). In the case of three dimensional survey error, we have a trivariate distribution: f(x, y, z) = [f(x)]f(y)[f(z)] = \[ \frac{1}{\sqrt{2\pi} \sigma_x} e^{-\frac{(x-x_0)^2}{2\sigma_x^2}} \cdot \frac{1}{\sqrt{2\pi} \sigma_y} e^{-\frac{(y-y_0)^2}{2\sigma_y^2}} \cdot \frac{1}{\sqrt{2\pi} \sigma_z} e^{-\frac{(z-z_0)^2}{2\sigma_z^2}} \]

The graph of this function can be visualized as an ellipsoid in three-dimensional space. The shape and orientation of this ellipsoid reflect the relative standard deviations of the variables (a2 is the variance of the x axis).
the p.d.f. of the trivariate distribution is a four-dimensional copula with each of the errors \( x_1, x_2, y_1, y_2, \) and \( z_1, z_2, z_1' \) being associated with a certain probability \( P \).

An important statistic is chi-square, defined as:

\[
\chi^2 = \sum \frac{(x_i - \mu_i)^2}{\sigma_i^2}
\]

The chi square appears in the convolution of the p.d.f.s of the summed statistical errors.

According to the reproductive property of a chi-square distribution, if \( x \) is a chi-square variable, each with \( n \) degrees of freedom, are added statistically, the resulting quantity (the convolution) is also a chi-square distributed variable which has \( n = \sum n_i \) degrees of freedom. In the trivariate case, all the \( n = 3 \), so the chi-square variable for a string of \( S \) shots has 3 degrees of freedom, where \( S \) is the number of shots in the string. The chi-square variable for a survey string of \( S \) shots is:

\[
\chi^2 = \sum \frac{(x_i - \mu_i)^2}{\sigma_i^2} + \sum \frac{(y_i - \mu_i)^2}{\sigma_i^2} + \sum \frac{(z_i - \mu_i)^2}{\sigma_i^2}
\]

This equation is in as many \( x, y, \) and \( z \) variables as are present, since each survey shot is in its own coordinate system.

The sum of squares for a survey string in terms of variable bearing and inclination is:

\[
\chi^2 = \sum \frac{(x_i - \mu_i)^2}{\sigma_i^2} + \sum \frac{(y_i - \mu_i)^2}{\sigma_i^2} + \sum \frac{(z_i - \mu_i)^2}{\sigma_i^2}
\]

This equation results in an ellipsoid in only three spatial variables. The number of degrees of freedom is now reduced to 3 by the coagulation transformation equations:

\[
x_1 = x + x_1' + x_2', \quad y_2 = y_1 + y_2' + y_3', \quad z_3 = z_1 + z_2' + z_3'
\]

This substitution of the transforming equations into the complementary ellipsoid equation produces the general rotation and summation form:

\[
\left( \frac{x_1}{a_1^2} \right)^2 + \left( \frac{y_2}{b_2^2} \right)^2 + \left( \frac{z_3}{c_3^2} \right)^2 = 1
\]

where \( a_1^2 \), \( b_2^2 \), and \( c_3^2 \) are the standard deviations: \( a_1 = \sigma_{x_1}, b_2 = \sigma_{y_2}, \) and \( c_3 = \sigma_{z_3} \), with the ellipsoids of single survey shots.

We now have the size of the error ellipsoid of a string of survey shots in terms of its semi-axes, and we have the orientation of the ellipsoid in three-dimensional space in terms of \( \theta \) and \( \phi \). For most applications, the desired result is a radial equation. An equation will give the magnitude of error at any given bearing and inclination (\( \theta, \phi \)) in the prime coordinate system. The substitution of cartesian to spherical coordinate system transformations into

\[
x_3 = x_1 + x_2 + x_3 = x_1 + x_2 + x_3 + x_1' + x_2' + x_3'
\]

explained earlier, the averages of error variables which can be in opposite directions are zero. The values of \( x_1, x_2, x_3, \) etc., are therefore all zero. The chi-square part of the trivariate distribution p.d.f. can now be written as:

\[
\chi^2 = \left( \frac{(x_1 - \mu_1)^2}{\sigma_1^2} \right) + \left( \frac{(y_2 - \mu_2)^2}{\sigma_2^2} \right) + \left( \frac{(z_3 - \mu_3)^2}{\sigma_3^2} \right)
\]

The calculation of \( \chi^2 \) for the three-dimensional error of a survey string requires that all the individual survey shot coordinate systems be related to the same coordinate system. Therefore, we need to develop transformation equations to transform an ellipsoid equation to another coordinate system. We can define a prime coordinate system where the \( y' \) axis is at 0° North, the \( x' \) axis is at 90° East, and the \( z' \) axis is at 90° up. Each survey shot coordinate system is defined so that the bearing (direction) of that shot is on the y axis in that shot's coordinate system and the inclination is 0° in that system. The actual instrumentally measured azimuth and clinometer readings for each survey shot are then \( \theta_i \) and \( \phi_i \) respectively, the transforming angles between the coordinate system of the shot and the prime coordinate system.

The transformation equations are:

\[
\begin{align*}
x_1 &= x' \cos \theta_1 - y' \sin \theta_1, \\
y_2 &= y' \cos \theta_1 + x' \sin \theta_1, \\
z_3 &= z' \cos \phi_1 + x' \sin \phi_1, \\
\end{align*}
\]

The substitution of these transforming equations into the trivariate chi-square equation results in an ellipsoid in only three spatial variables (\( x', y', \) and \( z' \)), rather than 38 spatial variables. The number of degrees of freedom is now reduced to 3 by the coagulation transformation equations:

\[
\begin{align*}
x_1 &= x + x_1' + x_2', \\
y_2 &= y_1 + y_2' + y_3', \\
z_3 &= z_1 + z_2' + z_3',
\end{align*}
\]

The statistical addition of ellipsoids in the same coordinate system on congruent axes is in the form:

\[
x^2 + y^2 + z^2 = x'^2 + y'^2 + z'^2 = 3
\]

In order that ellipsoids

\[
E_1^2 + E_2^2 + E_3^2 = 1
\]

from various other coordinate systems be added, we use the coordinate system transformation equations. It is necessary, however, that to avoid a summation equation which causes ellipsoids to become smaller instead of larger, we prove the following complementarity form:

\[
a_1^2 x^2 + b_1^2 y^2 + c_1^2 z^2 = 1
\]

before substituting the transforming equations.

References

5. Ibid. p. 288.
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7. Ibid. p. 299.
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Motiv Höhle und Motivation zur Höhlenforschung

Thomas Kesselring

Zusammenfassung

WELCHE SIND DIE SPEZIFISCHEN MOTIVE ZUR HÖHLENFORSCHUNG? - Diese Frage wird zwar da und dort ansatzweise diskutiert. Im vorliegenden Referat soll sie in einem größeren Rahmen aufgeworfen werden.1

Insbesondere sind spekulativ Motive, die für die Höhlenforschung im Unterschied zu anderen Berufen und Hobbys spezifisch sind. In diesem Beitrag soll dieser Frage in lockerer, auch philosophischer und wissenschaftlicher Hinsicht, was die Höhlenforschung im Unterschied zu anderen Berufen und Hobbys spezifisch sind. In diesem Beitrag soll dieser Frage in lockerer, auch philosophischer und wissenschaftlicher Hinsicht, was die Höhlenforschung im Unterschied zu anderen Berufen und Hobbys spezifisch sind.

Es ist der Grundmotiv des Höhlenforschens, die Höhlenforschung als ein Selbstzweck ist. - Was sind diese Motive?

In diesem Beitrag soll dieser Frage in lockerer, auch philosophischer und wissenschaftlicher Hinsicht, was die Höhlenforschung im Unterschied zu anderen Berufen und Hobbys spezifisch sind. In diesem Beitrag soll dieser Frage in lockerer, auch philosophischer und wissenschaftlicher Hinsicht, was die Höhlenforschung im Unterschied zu anderen Berufen und Hobbys spezifisch sind.

Das Motiv der Höhlenforschung wird, und ihre Verbreitung hydrologischen Zusammenhanges in einer Karstgegend und Sport sicherlich beides. Nun spricht aber auch vieles mit anderen Tatigkeiten teilt. So ist beispielsweise Motive im Spiel sein, Motive, durch deren Betrachtung doch wohl Überdimensioniert. Als motivationaler

Denn gemessen an diesen Zielen sind der Aufwand, der dafür, daß sich die Motivation zur Speleologie nicht auf die Erkenntnis der geologischen Verhältnisse und die Kamteradschaft, obwohl sie bei Höhlenbefahrungen

1) Der Referent ist Höhlenforscher im Hobby und Philosophie-Assistent im Beruf; er vertritt die Ansicht, daß er in beiden Fällen dasselbe tut - nur auf unterschiedliche Weise.

Abstract

WHAT ARE SPECIFIC REASONS FOR EXPLORING IN THE FIELD OF SPELEOLOGY? As this subject has been sometimes arisen among several groups of cavers, it is this paper's intention to discuss its main points.1 What is not focused are general (sporting and scientific) ambitions, focused are exclusively speleologic motivations.

Especially ten motivations should be mentioned: 1. CURIOSITY: darkness, mystery, first exploration, discovery of new passages. pioneer spirit. 2. PENETRATION: Walking on the surface forbids itself as speleologists indulge in the earth. Analogy: Indulging in philosophic ways of thinking, which should lead to cores of problems. 3. HYPOTHERM CONNECTIONS: Discovering not certain caves belong together may give new hints concerning orientation about the respective region. Analogy: Proving connections among scientific systems creates new theories. 4. ESTHETIC RECOGNITION: Galleries, halls, pits are hollow bodies. Hollow sculpture, lively play of light and shadow, comparable with modern art (as well as music). 5. EXPERIENCE OF CONTRASTS: Descending and ascending. Homeliness and danger. 6. TIME EXPERIENCE: Time seems to be shorter (e.g. 36 hours as 24-30), meanwhile space seems to be larger (overestimating of distances in caves). 7. CAVE AS VAGINA AND UTERUS: Associations towards psychology. 8. FLEEING FROM CIVILIZATION: Masculine: as last residences of nature. 9. TURNING TOWARDS THE PAST: Caves as prehistoric and archeological places. Petrifications represent former earth ages. 10. REBIRTH: Change of life and darkness (climate hostile to life). Comparison of returning to earth's surface with awakening to new life. Analyzing these motivations is done with regard to myths, fairy-tales, symbols and dreams. It is not supposed that the above mentioned motivations are to be conscious to speleologists. They should merely be brought into discussion.

1) Writer of this, a speleologist by hobby and assistant-professor of philosophy by profession, supposes that in both cases he is doing one and the same thing, but in different manners.
Man kann nur den Eingang lokalisieren, kennt aber nicht selbst den Weg, den er im Unbekannten entdeckt. Lücken und Locher behält, was wir AHNUNGEN nennen, den Weg, der von da aus weiterführt. Im Bereich solcher Tiefe Höhlen bieten den besonderen Reiz, daß auch für diejenigen, die das Geheimnis gelüftet haben, noch ein Teil des Geheimnisses in der Tiefe bleibt. Kurze und ganz erforschte Höhlen sind für manchen weniger faszinierend als lange und teilweise noch unerforschte.

Dieser Motivkomplex legt einen Vergleich mit der GEWINNUNG VON NEUEN ERSCHONNENTNISSEN und mit ENTDECKUNGEN in der WISSENSCHAFT nahe: Höhlen wirken in der Landschaft ähnlich wie Lücken oder Löcher in unserem Wissen. Man kann nur den Eingang lokalisieren, kennt aber nicht den Weg, den der von da weiterführt. Im Bereich solcher Lücken und Löcher behält, was wir ANTWORTEN nennen, den Weg, der von da aus weiterführt.

Der Höhlenforscher bleibt bekanntlich nicht an der Oberfläche. Er dringt in die Dunkelheit ein, er schießt gleichmäßig in die Materie vor und entschließt neue Systeme.


Verborgene Zusammenhänge


Verborgene Zusammenhänge sind für spekulativen Künstler von besonderer Bedeutung. So hat man bei gleichem Aufwand an physischer und psychischer Energie kürzere Strecken zurück zu erreichen. Tatsächlich verändert sich der Weg, der im Labyrinth nicht wieder zurückzufinden ist. Es handelt sich um eine Art von Körpers, durch die Höhlen und Formen zu tun mit Höhlen und Formen. Art im Vergleich zu den Höhlen und Formen, die auf weißer Welt zu finden sind.

Die Erfahrung von Raum und Zeit in Höhlen weicht von der Erfahrung in der Außenvelt ab. Höhlen bilden eine neue Dimension, die man bisher noch nicht so genau kennt. Höhlen sind ein Beweis für die Vielfalt der menschlichen Erfahrungen und Denkweisen. Höhlen bilden eine neue Dimension der Wahrnehmung, die man bisher noch nicht so genau kennt. Höhlen sind ein Beweis für die Vielfalt der menschlichen Erfahrungen und Denkweisen.

Höhle als Vagina, Uterus und Muttersymbol

Flucht Vor der Zivilisation

Abstieg in die Vergangenheit
Daß in Höhlen die Zeit stillsteht (vgl. 6.), erweckt die Assoziation an Urzeitliches, die ja bekanntlich viele Menschen mit der Höhle verbinden. Höhlen sind tatsächlich Stätten archäologischer und paläontologischer Funde. In die Kalkschichten, durch die sich Höhlen ziehen, sind Versteinerungen eingelagert, die frühere Erdezeitalter repräsentieren. Der Vergleich von Erde und Mutter (7.) legt den Vergleich des Abstiegs durch die Schichten mit dem Bild des Abstiegs zu früheren Generationen (zum Reich der Mütter nach Goethes Faust II) nahe. Mit dem Schritt ins Anorganische wird gleichsam ein Rückblick in die tiefste erdgeschichtliche Vergangenheit vollzogen (vgl. 6.).

Wiedergeburt

Mit der Aufreibung von diesen zehn Motiven wird weder ein Anspruch auf Vollständigkeit erhoben noch unterstellt, daß jeder Höhlenforscher in all diesen Punkten sich selbst wiedererkennen müsse. In bezug auf jedes einzelne Motiv müßte durch Umfrage mit statistischer Auswertung ermittelt werden, ob und wieweit es einen signifikanten Aspekt in der Motivation zu Höhlenbegehungen darstellt (mit einer solchen Umfrage könnten allerdings nur die bewussten Motive festgestellt werden). Die hier angestellten Überlegungen haben in der vorliegenden Form einzig und allein die Funktion einer Anregung zu eigenen Gedanken und zur Diskussion. - Der Verf. will zum Schluß bekennen, daß er Höhlenforscher im Hobby und Philosophie-Assistent im Beruf ist und daß er die Ansicht vertritt, in Beruf und Hobby ein und dasselbe zu betreiben - allerdings auf verschiedene Weise.
Karo and Caves in the Turks and Caicos Islands, B.W.I.

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Abstract

Karat and caves in the Turks and Caicos Islands, B.W.I., are formed in ailly calcarenite, the episodic deposition of which is interpreted to have developed as a result of Pleistocene eustasy. The Conch Bar Caves in the Middle Caicos represent the largest, and de facto the only known cave system in the islands. The caves, developed in at least three horizons, have been developed at least in three horizons, the lowest cave level has evidently connected with fluctuation of sea level and variable intensity of precipitation in the Pleistocene. Two main phases of extensive breakdown occurred in the caves; the earliest one during groundwater activity in the middle of the last glacial period and a latest phase that opened cave domes and connected low-level karst depressions. Speleothems of the Conch Bar Caves belong to several generations. Bulky stalagmites and stalagnates, later corroded and weathered, probably form the oldest generation. The youngest generation is represented by white, recently active stalactites. An archaeological survey (Kotas 1980) resulted in the discovery of discontinuous Arawak settlement in the caves.

Geologic and Geomorphic Setting

The basic geologic and geomorphic features of the Turks and Caicos Islands are presented elsewhere (Gregor 1980) as generally similar to them of Bahama Islands and, in some aspects, to them of Bermuda (Forney 1976). Relatively extensive areas of flat land, generally a few meters in elevation, are the dominant geographic features of the major islands, especially of the Caicos group. To the south of the group, the low-lying carbonates give way to vast areas of dry and wet tidal flats up to 13 km off the north, north east and east coast of the islands. The hills are formed of eolian calcarenite, they extend for a few kilometers with the lower level, always partially flooded with seawater, the rock bottom of which is situated up to 2 m above present sea level; (c) the lowest level, now permanently below sea level.

The main level (A) is known in discontinuous fragments; they are relics of cave passages, the course of which was discontinued by the development of cave domes. In comparison with the main level, cross profiles of the upper level show substantially smaller dimensions.

Cave Passages and Levels

The length of the Conch Bar Caves exceeds 2.5 km, but only a few tens of meters have been mapped (Fig. 1). The passages are based on the blocks. There are numerous rock pillars in the domes, some separated from the ceiling and floor. The pillars are characterized by a large sinkholes above the domes and subsequent perforations.

Cave Domes

The passage system of the Conch Bar Caves is articulated by more or less spacious cave domes. They originated by solution and collapse. The bottom of the domes (corresponding with the main level) is covered by bulky calcarenite blocks in some places. The blocks are interpreted as karstified; they were covered by calcarenite. The break down occurred during ground- }

tion of the rock partition by vertical chimneys) and collapse (the younger phase of breakdown).

**Speleothem Deposits**

Six basic morphogenetic type of speleothems, mostly secondary calcite formations, were found in the Conch Bar Caves: stalagmite, stalactites, stalagnates, flowstones and mineral coatings, helicitites, and plastic sinter (soft sinter, Mondmilch). Bulky stalagmites and stalagnates (up to 4 m high and 1.5 m in diameter) are the most conspicuous speleothems of the caves. They are often irregularly formed, sometimes doubled, corroded and weathered. These speleothems represent the oldest generation (with up to 35 cm thick bottom sinter); they were formed under intensively sintering water trickles of the zone of vertical circulation whereas the present trickles (as far as they exist) seem only to be drooling the toes of the stalagmites.

Quite different conditions were found in the East Seawater Chambers. Conic and spherical stalactites, straw stalactites, stouted straw stalactites with eccentric outgrowths, plural stalactites, small curtains and draperies are characteristic of the local dripstone decoration. They are milk-white, drenched by vertical trickles. Local stalagmite formations are represented by thick sinter crusts with sinter basins, low and flat sinter heaps, and high and slim stick stalagmites. A trickle dripping from a stalactite and forming a white heap within the tidal zone is a vivid example of recent sinter formation. We often can find broken speleothems cemented to the bottom sinter.

Three types of stalagmite sites are present in the caves: sites permanently above sea level, sites periodically flooded by seawater, and sites permanently below sea level. At all these types of sites we may find marine incrustations of aragonite and Mg-calcite on top of speleothems as a result of temporary flooding of the caves with seawater. Such occurrences are common in presently submerged and periodically flooded parts of the caves, and in the parts free of seawater within a few meters of present sea level.

**Cave Development**

This is the first working hypothesis on relative chronology of main development phases of the Conch Bar Caves:

1. Genesis of the upper level (A) at a 10-12 m elevation of sea level.
2. Genesis of the main level (B) at a 0-2 m elevation of sea level.
3. Extensive breakdown of the cave ceiling during the development of the main level; beginning of the development of cave domes.
4. Genesis of the lower level (C) at a -2 to -4 m elevation of sea level.
5. Genesis of the lowest level (?).
6. Formation of the oldest speleothem generation.
7. Late phases of sea level fluctuation, temporary flooding of the caves with seawater, sinter corrosion and formation of younger speleothem generations in air filled part of the caves.
8. Stabilization of sea level approximately at present level, collapse of the rock partition between cave domes and surface sinkholes, origin of large circular cave entrances, continuing formation of speleothems in caves free of seawater, sinter corrosion.
10. Recent karst processes; formation of the youngest speleothem generation, recent breakdown, etc.

The caves were probably formed during the Middle Pleistocene (in sense of Woldstedt 1954). At least, a distinct regression (depression of sea level) occurred between the genesis of the upper and main cave level. Considering the course of Pleistocene climate, the Yarmouthian (Mindel-Riss) may have been favourable of the genesis of the upper level, and the Illinoian (Riss) of the genesis of the main and lower cave level. However, this schedule is only hypothetical. According to Woldstedt's (1958) classification of the Pleistocene, the genesis of the upper level occurred at the end of the Middle Pleistocene, and the genesis of the other cave levels at the beginning of the Late Pleistocene. The calcarenite deposition and primary phase of the karst and cave development can be ascribed to earlier phases of the Pleistocene.

**References**


Explanation to Figure 1

B - the main cave level (B)
C - the lower cave level (C)
a - rock pillars
b - coarse blocks - the 1st phase of breakdown
c - blocks and minute scree of the 2nd phase of breakdown
d - cave parts always flooded with seawater
e - cave parts periodically flooded with seawater
Two different interpretations of hte number and geological age of the cave levels in the Moravian Karst have been used over the last decades. Geological studies (Panos, 1963; Stelcl 1963) developed a hypothesis indicating three levels (though Panos, 1963, admitted a higher number of introduction of the term of "posthumous levels"), geologists (Burkhardt 1949, Pelisek 1950) found out to fifteen cave storeys. The principal definition of the term "cave level" was published by Stelcl (1963) and completed by Gregor (1977). Our (Gregor et al., 1969-1977) investigation of the northern part of the Moravian Karst revealed in succession of 9-11 cave levels (in sense of Stelcl-Gregor's definition) differing in age, the origin of which is related to changes of the local erosion level, and can be correlated with the development of the valley network. According to Panos (1963) and Stelcl (1963) the valley and cave network of the Moravian Karst was established in the Lower Miocene. In the Lower Miocene, the valley network was deepened and the origin of two or more distinct cave levels occurred. The development of the valley and cave network was discontinued by Lower Tortonian transgression. Later, after regression of the Lower Tortonian, the surface (valley) drainage was restored and impervious Lower Tortonian marls were removed. The origin of several (?) posthumous levels between the Paleogene one and the Lower Miocene levels was related to this process. The intensity of e.xhumation of the valley network reached the maximum in the Upper Pliocene. A wave of retrogressive erosion employed the low-lying Lower Miocene levels, swiftly slipped from the karst points of issue to the ponors and evoked deep articulation of the karst pediment in the marginal areas. In the author's opinion, the valley and cave network of the Moravian Karst (except the Lazanky Valley - Kettner 1970) was established in the Pliocene and developed during the Pleistocene. Three main karst erosion sybcycles can be distinguished in the cave development. The first subcycle was commenced in the Pliocene and brought to an end by an expressive sedimentation phase (Pribyl 1973), probably before the Riss (in the Mindel or R/R). The second subcycle was commenced after this sedimentation phase, and brought to an end in the Interglacial R/R or, more probably, in W 1. The third and last karst-erosion subcycle proceeded in the Uppermost Pleistocene and Holocene; it is still lasting.

Zusammenfassung


* * *

Two different thems have been used to describe horizontally (subhorizontally) set caves and cave passages in the Moravian Karst: "cave storey" and "cave level". Absolon (1905-1911 introduced an idea based on the existence of three cave storeys, and Panos (1963) developed a hypothesis indicating three levels (though Panos, 1963, admitted a higher number of introduction of the term of "posthumous"), geologists (Burkhardt 1949, Pelisek 1950) found out to fifteen cave storeys. The principal definition of the terms "cave storey" and "cave level" was published by Stelcl (1963) and completed by Gregor (1977). According to this definition, caves storeys are essentially connected with the erosion base, of Oligocene age, and not dependent upon the erosion base; the main role is played by local structural and tectonic conditions. They are connected with valley terraces, and individual phases of the cutting down of karst streams.

Cave levels are formed by continuous systems of horizontal (subhorizontal) caves and cave passages whose origin is connected with the level of erosion base, i.e. depends upon the level of underground karst streams. Cave levels may be followed along long distances. They can be compared with terraces and individual phases of the cutting down of karst streams. Vertically, they take up a differently wide belt formed by 2nd and 3rd Čivjíc's hydrographical zone.

In Stelcl's (1963) opinion, the surface stream of the Moravian Karst cut down in three successive phases divided by orogenic movements. The movements took place towards the end of the Oligocene, and between the Holocene and Lower Tortonian. The youngest erosion phase was influenced by climatic changes in Early Holocene. Stelcl and Panos (1963) developed a thesis indicating three cave levels in the Moravian Karst: (A) the highest one, genetically connected with the 1st phase of the valley cut down, of Oligocene age, (B) the lowest one, genetically connected with the 3rd phase of the valley cut down, of Lower Pliocene, of Oligocene age, and (C) a higher cave level situated above the lowest one, genetically connected with the surface of Pleistocene valley sediments, of Holocene age. The presented number is at variance with Panos' (1963a) opinion on the origin of two Loer Miocene (Burdigal and Upper Helvetian) cave levels and several "posthumous" cave levels in the northern part of the Moravian Karst.

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In 1969-1977, the author performed geologic and geomorphological research in the northern part of the Moravian Karst, especially in the Sloup and Macocha region (the Sloupne udoli Valley, the Sloup-Macocha jeskyne Caves, the Pusty zleb Valley, the Macocha Abyss, the Punkevní jeskyne Caves, etc.). At least, nine cave levels were found in the Sloup-Macocha region, at different heights related to the level of the Punkva River in the Velky vytok (karst outlet). These are problematic cave levels in the region, situated cca 10 m, 0 m, and -22 m. However, there are two more with changes of level of the local erosion base. It resulted from erosional and solutional water activity of underground streams of the Sloupsky potok Brook and the Punkva River, and are genetically connected with changes of level of the local erosion base. It is possible to correlate them with terraces and valley forms. Their origin was conditioned by Pleistocene climatic changes and by the role of Quaternary tectonics (neotectonics - Gregor 1978).

According to the study of cave sediments (Pribyl 1973), and cave and valley geomorphology, the cave levels of the northern part of the Moravian Karst were formed during three main karst-erosion subcycles, which periods of cave senility, reactivation and rejuvenation occurred. It is very difficult to parallel these phases with the course of Pleistocene climate. According to Geze (1965), karst erosion took place after culmination of cold periods, according to Kettner (1970) during warm periods. Pelisek (1950) ascribed intensive speleogenesis to warm periods, and very slow speleogenesis to cold periods. In the course of Quaternary climate not only cold and warm periods but also dry and humid periods occur. Though various combinations may be found, the principle of connection of humid with warm, and dry with cold periods is generally accepted. However, the climatic changes form a continuous succession which is divided into many single phases and secondary minute oscillations.

Neogene sediments in situ (?) were found only in a few caves situated high up above the Pleistocene valley network (the 110 m cave level). Test wells drilled in valleys of the Moravian Karst found only Quaternary sediments except the Lazanecky zleb Valley. The low part of the Punkva Valley (up to 120 m thick Lower Badenian sediments in the Lazanecky zleb Valley) but this part of the valley network occupies a quite different position in the geomorphological development and paleohydrography of the Moravian Karst (Kettner 1970, Gregor 1977).

References
Chez l’Opilion troglobile Sabacon paradoxum les auteurs décrivent l’ultrastructure des poils tumeur glandulaires et sensibles des pedipalpes. Chaque unite adéno-sensoirielle est composée de 5 à 6 neurones dont les plus profonds sont les neurones basaux de l’organe. La partie basale de l’appendice est entourée de nombreux doigts de tégument qui caractérisent ce type de sensoirielle. Les neurones sont enveloppés par une première, puis une seconde cellule enveloppe laquelle est entourée de 3 cellules glandulaires aplanithes, dont la sécrétion emplit la lumière du poil.

La partie distale du sensoirielle est faite de 2 parties: une basale, lisse et une distale présentant de nombreux pores par lesquels la sécrétion est émise et de nombreux spinules entre lesquels elle s’accumule.

**Abstrat**

In the troglobitic Harvestmen Sabacon paradoxum the authors describe the ultrastructure of the “villous hairs” of the pedipalps. Each adeno-sensory unit consists of 5 or 6 bipolar neurons, the dendrites of which are ensheathed by a cuticular sheath; beyond the centriole the axonema is made of 9 doublets with one centriole, then a second cell is enveloped by which is endowed with 3 flat cells, glandular in nature, the secretion in which fills the lumen of the hair.

**Materiel et Methodes**

Les animaux étudiés sont des adultes des 2 sexes récoltés dans la grotte de la Baccoulette (Hérault). Les pedipalpes et les thorax ont été fixés selon les méthodes déjà décrites (Juberthie et coll. 1980).

1. Morphologie externe (fig. 1 et 2).

Chaque pedipalpe mesure 160 µm de long; relié au tégument par un bourrelet circulaire, il se compose d’une partie proximale lisse et d’une partie distale qui porte des spinules. Chez l’Opilion troglobile, il est long, élargi à son extrémité, renferme un centrode non racine ciliare, portant 9 expansions lamellaires. Chez Sabacon paradoxum il est relié par du tégument dense au niveau de la paroi interne contenant une différenciation chitinise originale, agencée comme un long rossent à boudin, localement attaché à la paroi. Les spires, de section circulaire, ont un diamètre d’enroulement égal aux 2/3 de celui du poil. Il pourrait donner une certaine élasticité à la partie distale. La cavité interne contient une substance émousse à l’extérieur, entre les spinules, par des pores en forme de boutonnières effilées, alignées longitudinalement de façon régulière (Rimbaud 1979); la cavité interne contient une substance émousse à l’extrémité une certaine quantité de sécrétion visqueuse à laquelle on a attribué un rôle dans la capture des proies.

1 - 2. Partie distale spinulée. La face antérieure porte de spinules raides et plissés. La cavité interne contient une substance émousse à l’extérieur, entre les spinules, par des pores en forme de boutonnières effilées, alignées longitudinalement de façon régulière (Rimbaud 1979). Le bourrelet semble donner au poil une certaine souplesse à la partie distale. Sur L’Equipement Adeno-Sensoriel du Pedipalpe de L’Opilion Troglophile Sabacon Paradoxum Simon (Palpatores, Sabaconidae)
2 - 4. Cellule enveloppe n° 2. Allongée, elle s'étend le long des segments proximaux, du côté opposé à la précédente, à mi-hauteur; elle se referme sur elle-même par un mésé, entoure la lèvre cellule et la base de la gaine cuticulaire; elle se prolonge le long de la gaine presque jusqu'à l'extrémité du poil par une langue cytoplasmique émettant localement des digitations. Du côté externe, elle présente à son extrémité un bouquet de microvillusités et participe à la formation de la cavité lymphatique externe.

1 - 3. Cellules glandulaires (Adénocytes).
Constituants les plus volumineux, elles sont au nombre de trois, une centrale, et deux périphériques. Elles entourent les axones du nerf pédipalpal, les neurones, les cellules enveloppe 1 et 2 et se présentent donc comme des cellules enveloppe de troisième ordre. Chaque adénocyte est aplati en lame trapézoïdale flexueuse, plus ou moins perpendiculaire à la surface de l'article et s'incurvant dans le sens transversal en segment de cylindre ou en dièdre. De ce fait, les adénocytes d'une même unité s'imbriquent les uns dans les autres en adoptant une disposition plus ou moins concentrique. Leur extrémité inférieure émet des prolongements pédiculés délimitant un espace de filtration labyrinthique au-dessus de la membrane basale. L'extrémité supérieure de l'adénocyte périphérique s'applique sur l'extérieur de la base du poil, entre une cellule hypodermitique étirée en languette tandis que celle de l'adénocyte central s'applique contre la cellule enveloppe.

Les adénocytes paraissent être assurée qu'au niveau des bords et de la base par des desmosomes et des jonctions septées. Les faces libres mènent entre elles de longues cryptes flexueuses en rapport avec la cavité lymphatique externe du poil; ces faces sont extrêmement hérissées de microvillusités. Dans chaque adénocyte, l'élément essentiel est constitué par des grains de sécrétion arrondis et de faible densité; ils peuvent occuper sans ordre apparent toute la hauteur de la cellule ou s'aligner à la base des microvillusités soit sur une rangée, soit en double file alternante. Cette sécrétion emplit les cryptes intercellulaires et la cavité lymphatique externe du poil.

Discussion et Conclusion

La structure des poils tomenteux des pédipalpes permet de leur assigner une double fonction sensorielle et glandulaire. La nature de leur fonction sensorielle n'est pas clairement établie; la présence d'une gaine cuticulaire enfermant plusieurs dendrites sans corps tubulaire plairait pour une fonction gustative mais l'existence d'un pore terminal n'est pas prouvée; l'existence d'une structure en forme de ressort hélicoidal est l'indice d'une déformation de la partie distale du poil et de la gaine; cette formation, de même que la structure particulière de la partie basale de l'axonème carcinée par un doublet plein plairait pour un mécanorécepteur d'un type tout à fait particulier. Ces poils ont aussi une fonction glandulaire, probablement liée à la capture des proies, et sont ainsi similaires aux soies des Nemastomatidae (Wachman, 1970); leur sécrétion est retenue par une palette spinulée et non par une collerette comme chez ces dernières.

Bibliographie

Figure 1. Base d'un poil tomenteux du pédipalpe.

Figure 2. Portion de la partie distale spinulée du même poil; b. bourrelet d'insertion; c. a. canal intrapariétal; C12, cellule enveloppe n° 2; ci, cil; d. digitations; g. gouttière; g. c. gaine cuticulaire m. d., matériel dense; P., pore; r, différenciation chitineuse en forme de ressort; s, sécrétion; sp, spinules; t, tégument.
Figure 3. Schéma d'unité oléno-sensorielle d'un poil tomenteux de la papille. Mêmes abréviations que fig. 1 et, ac, couronne claire; ad, couronne sombre; C1,2,3 cellules enveloppes 1, 2, 3; C ep, cellule épidermique; cg, cellule gilale; cie, cavité lymphatique externe; ci, cavité lymphatique interne; d, desmosome et desmosome septé; ee, épicuticule externe; ei, épicuticule interne; en, endocuticule; ex, exocuticule g s, grain de sécrétion; mb, membrane basale; n, axones; ns, neurone sensoriel.
Karst Valley Development and the Headward Advance of the Sequatchie Valley of Tennessee Along the Sequatchie Anticline

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Abstract

Caprock streams flowing down dip off the Sequatchie Anticline of Tennessee often breach the silicious caprock and invade the underlying carbonates. A conduit cave is formed by the aggressive waters of an invading stream as it flows from its swallet to a rising at the head of the Sequatchie Valley. Slope retreat by sapping proceeds in all directions away from the site of the initial invasion, resulting in large karst valleys completely surrounded by caprock. The anticlinal mountain is first reduced to karst valleys which are then assimilated into the Sequatchie Valley as it advances headward up the Sequatchie Anticline. Thus subterranean stream invasion, conduit cavern development, and the growth of karst valleys play a crucial role in forming anticlinal valleys.

An investigation of the processes associated with karst development along the Sequatchie Anticline involved dye tracing, geologic mapping, cave surveys, and a quantitative investigation of subsurface erosional processes. Two conduit cave systems were monitored for fifteen months by continuous recording instrumentation and frequent water sampling and analysis. They were treated as open systems, with input occurring at swallets and from diffuse sources, the output occurring at risings.

Introduction

The Sequatchie Valley of Tennessee is a deep incision into the relatively flat sandstone-capped Cumberland Plateau. It is six to eight kilometers wide with a floor 400 to 500 meters below the plateau. The spectacular cliffs of the canyon extend in virtually straight, parallel lines, cutting into the plateau from the south for over 90 kilometers. Figure 1 is a classic example of an anticlinal valley, having formed along the thrust-faulted Sequatchie Anticline.

The geomorphic history of the Sequatchie Valley has been a story of an anticlinal mountain being changed into an anticlinal valley. The anticlinal mountain, still existing along the northerly portion of the Sequatchie Anticline, north of Crab Orchard Cove. Between the anticlinal mountain and the head of the Sequatchie Valley is an anticlinal axis 60 kilometers long which is transitional between mountain and valley. This is a region of karst valleys, locally referred to as coves. Within this area are six major examples of karst valley development (Figure 1). Grassy Cove, the largest karst valley, or anticlinal polje, is the hollowed-out center of the Sequatchie Anticline. The anticline remains as mountains surrounding the cove, protruding 300 meters above the Cumberland Plateau, and in places well over 400 meters above the flat floor of the cove. This cove resembles a volcanic caldera, a great mountain with a large depression in the center. Grassy Cove is drained by the Cove Creek which flows into Mill Cave and then under Brady Mountain to a large spring at the head of the Sequatchie Valley, eleven kilometers to the south. The spring, appropriately called Head of Sequatchie, is the headwaters of the Sequatchie River.

Hypothesis

This study of karst valley development along the Sequatchie Anticline is part of a much larger investigation of the relationship between subterranean stream invasion, subsurface hydrology, conduit cavern development, and stratigraphy along the Cumberland Plateau Escarpment of Tennessee (Crawford, 1979 and 1988). A surface subsurface erosion model was hypothesized stating that conduit caves form by subterranean invasion by surface streams along retreat caprock karst. The model includes the following:

1) Invasion occurs near the contact between the impermeable, clastic caprock and the underlying carbonates as caprock streams, highly aggressive to calcium carbonate, dissolve the most efficient flow routes through the carbonates to resurgences near the escarpment base.
2) Suspected and bed loads contribute to the enlargement of the conduits by abrasion.
3) Most conduit caves are enlarged almost exclusively by the corrosion and corrosion of subterranean streams, particularly during floods.
4) Other conduit caves result from vertical shaft input which is also aggressive to calcium carbonate since its source is the pennkite caprock aquifer.
5) Percolation input becomes supersaturated on losing carbon dioxide upon entering the cave atmosphere and consequently is not important in cavern development.
6) Subterranean streams take a "stair step" route down the escarpment due to intermittent impermeable strata.
7) A sinkhole plain resulting from weathering of carbonates containing less soluble material follows the retreating escarpment.
8) A structural high may result in a stream cutting through the caprock and invading underlying carbonates behind the escarpment. Slope retreat by sapping proceeds away from the initial invasion forming a karst valley.

Testing of Hypothesized Model

Field testing the hypothesized model involved dye tracing subsurface stream systems, geologic mapping, mapping cave systems, and a quantitative investigation of subsurface erosional processes. Conduit cave systems at the head of the Sequatchie Valley were monitored for fifteen months by continuous recording instrumentation and frequent water sampling. They were treated as open systems, with input occurring at swallets and from diffuse sources, the output occurring at risings.

Recording stream gauges were installed at the swallet and at the rising for two cave systems. About three hundred water samples were taken during the fifteen months at the swallets and at the risings in order to investigate changes which occurred as water travelled through the systems. Percolation input was monitored by taking drip samples from within the caves. Some of the less stable water variables were analyzed in the field at the time of sample collection, others within twenty-four hours, in a mobile laboratory. The more stable variables were analyzed at a later date in the geochemistry laboratory at Vanderbilt University. Data collection and analysis dealt with the solutional and suspended loads of the subsurface erosion system.

Research Findings

Dye tracing and cave investigations revealed that in the area of karst valley development along the Sequatchie Anticline, invading subsurface streams flow down dip influenced by jointing, and that they are perched upon impermeable strata. As they approach the anticline they turn to flow along joints which parallel the anticlinal axis. The joints near the base of the anticline appear to have been produced by increased bending, indicated by a steeper dip, and they appear to extend through some of the more resistant and impermeable strata such as the Hartselle Formation (Figures 2 and 3).

The quantitative input-output analysis provided considerable evidence in support of the hypothesized model. During the research period:

1) Caprock streams were always aggressive to calcium carbonate.
2) Water resurfacing at risings was virtually always aggressive swallet input. Mixing corrosion was also partly responsible for the aggressivity at the rising. (This is indicated in the 37.10% difference between measured and calculated output at Bristow Spring, Table 1).
3) Percolation input was always supersaturated with calcium carbonate on joining the cave system.
4) An inverse correlation existed between total hardness and discharge for the swallet input and rising output, indicative of the importance of floods in conduit cavern development (Figures 4 and 5).
5) Percolation total hardness and aggressivity was not correlated with drip water but instead with drip water temperature, which reflects soil temperature and biogenic CO2 content of the soil atmosphere (Figures 6 and 7).
6) All suspended sediment samples were negative for calcite and dolomite, but due to impoundment problems associated with the study, the negative abrasion results are considered inconclusive.

Conclusions

Caprock streams flowing down dip off the Sequatchie Anticline...
Anticline, on breaching the sandstone caprock, are diverted underground into the underlying carbonates. The aggressive water of invading caprock streams forms conduit caves as it flows from swallets to risings at the head of the Sequatchie Valley. Slope retreat by sapping proceeds in all directions away from the site of the initial invasion. Large karst valleys result from this subterranean invasion, and it appears that karst valley development plays a major role in changing anticlinal mountain into anticlinal valley, thereby greatly affecting the headward advance of the Sequatchie Valley along the Sequatchie Anticline.

By assimilation of karst valleys the Sequatchie Valley has advanced headward up the Sequatchie Anticline from the southwest toward the northeast. The anticlinal mountain is first reduced to karst valleys as surface-flowing streams are diverted underground, and finally the karst valleys are assimilated into the Sequatchie Valley itself as it advances headward. A very important factor which has contributed to the formation of karst valleys in a sequential fashion from southwest to northeast in advance of the Sequatchie Valley, has been the increased thickness of the Pennsylvanian caprock from southwest to northeast. It has progressively required more time for streams flowing down the dip of the anticline to cut through the Pennsylvanian caprock in a southwest to northeast direction. Karst valley development therefore appears to have marched right up the anticline from the southwest being followed by the headward advance of the Sequatchie Valley (Figure 8).

References
Crawford, N.C., 1979, The karst hydrogeology of the Cumberland Plateau Escarpment of Tennessee, Part II: Karst valley development and the headward advance of the Sequatchie Valley in the Grassy Cove area, Cumberland County, Tennessee; Cave and Karst Studies Series No. 2, Center for Cave and Karst Studies, Department of Geography and Geology, Western Kentucky University, 50 p.
Crawford, N.C., 1980, The karst hydrogeology of the Cumberland Plateau Escarpment of Tennessee, Part IV: Erosional processes associated with subterranean stream invasion, conduit cavern development and slope retreat; Cave and Karst Studies Series No. 4, Center for Cave and Karst Studies, Department of Geography and Geology, Western Kentucky University, 152 p.
FIGURE 2.

GEOLOGIC MAP OF LITTLE COVE

FIGURE 3.

STRATIGRAPHIC SECTION ACROSS LITTLE COVE
REVEALING THE SUBTERRANEAN STREAM INVASION OF UPPER HARRIS BRANCH

SCALE

Vertical Exaggeration 8x

FIGURE 3.
LITTLE COVE SWALLET

BRISTOW SPRING

AGGRESSIVITY TO CALCIUM CARBONATE IN PPM

FIGURE 4.

FIGURE 5.
CAVE DRIPS FROM BRISTOW AND MILL CAVES

50 25°

Warm Months (Nov.-April)

Cold Months (May-Oct.)

May-Oct.

Bristow Cave

Mill Cave

Number of Month when sample was collected indicated by each dot

CAVE DRIPS FROM BRISTOW AND MILL CAVES

-80 -70 -60 -50 -40 -30 -20 -10 0 +10

AGGRESSIVITY TO CALCIUM CARBONATE IN PPM

FIGURE 6.

-80 -70 -60 -50 -40 -30 -20 -10 0 +10

Drip Water Temperature in Degrees Centigrade

FIGURE 7.
MEAN INPUT - OUTPUT MEASUREMENTS FOR THE LITTLE COVE - BRISTOW SPRING SYSTEM FOR THOSE OCCASIONS WHEN SWALLET INPUT, DIFFUSE INPUT, AND RISING OUTPUT WERE EACH SAMPLED ON THE SAME DAY

<table>
<thead>
<tr>
<th></th>
<th>MEAN SWALLET INPUT</th>
<th>MEAN DIFFUSE INPUT</th>
<th>MEAN RISING OUTPUT</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>MEAN INPUT</td>
<td>MEAN INPUT</td>
<td>MEAN MEASURED</td>
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<tr>
<td></td>
<td>OF OUTPUT</td>
<td>OF OUTPUT</td>
<td>OUTPUT</td>
</tr>
<tr>
<td></td>
<td>(%)</td>
<td>(%)</td>
<td>(%)</td>
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<td>DISCHARGE</td>
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<td>0.07257 QMS</td>
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<td>11.83 ppm</td>
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<tr>
<td>HARDNESS</td>
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<td>0.04 ppm</td>
<td>0.08 ppm</td>
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<tr>
<td>AGGREGIVITY</td>
<td>-1.66 ppm</td>
<td>+1.66 ppm</td>
<td>+2.26 ppm</td>
</tr>
</tbody>
</table>

TABLE 1.
Ground Water Geothermal Energy from Subsurface Streams in Karst Regions
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Abstract

The objective of this research is to ascertain if ground water heat pumps utilizing cave streams or large springs are an economically feasible and environmentally sound alternative to conventional heating/cooling systems in karst areas. Instrumentation for continuously monitoring water temperature, stream discharge and water quality has been installed at two locations along the Lost River as it flows under the city of Bowling Green, Kentucky. A ground water heat pump system is being built in order to investigate potential heat pump problems and the environmental effects of possibly altering the water temperature of subsurface streams.

Preliminary findings indicate that there are economic advantages in using subsurface streams, such as, not needing a discharge well. Large units for commercial buildings or "community systems", with one well serving several residences, appear to be economically feasible alternatives to conventional heating/cooling systems. Only natural gas heat/electric air conditioning is competitive, but this is expected to change rapidly with government decontrol of natural gas prices.

Potential findings also indicate that thermal alteration, even by large scale use of cave streams may not be a serious problem. This is due to the ability of the karst aquifer to act as a natural heat exchanger, thus rapidly restoring heat pump discharge (which is only changed by 2.8°C (5°F) in passing through the water-to-refrigerant heat exchanger of most heat pumps) to its original temperature.

If ground water heat pump technology applied to subsurface streams is found to be economically attractive and environmentally sound, cities such as Bowling Green, Kentucky, located over large subsurface streams, may benefit greatly through the utilization of a less expensive, environmentally clean, locally abundant and renewable energy resource for space conditioning of residences and commercial buildings.