Large assemblages of subaqueous speleothems, reported from some coastal caves of the island of Majorca (Spain), emphasize the processes involved in underwater carbonate deposition in the phreatic zone. Geochemical implications, yet unknown, are suggested as a result of this finding. It is thus appropriate to distinguish a specific subgroup of underwater speleothems, which we shall call phreatic speleothems; this term, in addition to indicating the inherent physical milieu of the mineral deposits, serves to establish their genetic factors in subterranean cavities. A few data concerning phreatic speleothems related to a marine base level are available in the literature. This second division is especially necessary due to the fact that phreatic carbonate deposits occurring in coastal caves (marine base level) are found to be more problematic in the case of phreatic speleothems, it is thus useful to distinguish between phreatic speleothems belonging to a continental base level and those produced in direct association with the marine base level (see Table I). Although some Pleistocene carbonate platforms of the Mediterranean sea have been recorded above the present-day pool level, these phreatic deposits are arranged radially around the tip of stalactites which penetrate the pool water surface or grow around any other suitable support. Both calcite and aragonite have been identified as their main constituent minerals. Optical microscopy, X-ray diffraction and scanning micrography of several samples collected in Cova de Sa Bassa Blanca seem to indicate that needle-like crystals of aragonite brook an smooth-surfaced subaqueous overgrowth. On the other hand, fibrous calcite and marls del intercal- cite crystals cause rougher and more wrinkled morphologies, very similar to some rimstone pool accretions. We presume that the petrological, geochemical and mineralogical differences existing in the deposits left by the different Pleistocene epochs, will allow us to determine the paleoclimatic conditions under which they were formed and also the evolution in time undergone by those.

Les nombreux exemples de spéleothèmes subaquatiques actuels et fossiles rencontrés dans quelques grottes côtières de l’île de Majorque (Espagne) mettent en évidence l’importance des processus de précipitation des carbonates au niveau de la zone phréatique karstique.

Ces cristaux aciculaires de aragonite donnent des concretions lisses en surface. En revanche, les cristaux aciculaires de calcite et les cristaux fibreux forment des concrétions rugueuses à aspérités, très semblables à celles trouvées dans les gours.

La sedimentation dans les sédiments phréatiques est déterminée par les niveaux de la mer, les processus actuels comme les différences géochimiques et géomorphologiques des dépôts laissés en place au cours des diverses périodes du Pléistocène nous permettront de déterminer les conditions paléoclimatiques auxquelles ils se sont formés.

Introduction

An understanding of the forms and genetic factors of mineral deposits occurring in subterranean cavities requires a classification which takes into account their order and relationships. Among the most notable attempts at systematizing these deposits are the studies by HILL (1976), WHITE (1976) and SWEETING (1973). These authors indicate the existence of a limited number of speleothem types that have developed in non-seri- al conditions: termed “subaqueous speleothems” by WHITE (1976) and “underwater speleothems” by SWEETING (1973). Their classifications, however, fail to con- sider the hydrogeological zoning in which the speleothems were produced. In this respect it will be useful to remember that the concept of phreatic speleothems does not necessarily imply their association with the phreatic zone, since subaqueous deposit environ- ments frequently occur within the vadose zone of any karstic massif; such, for example, is the case of the rimstone pools (gours).

It is thus appropriate to distinguish a specific subgroup of underwater speleothems, which we shall call phreatic speleothems; this term, in addition to indicating the inherent physical milieu of the mineral deposits, serves to establish their genetic factors in subterranean cavities.
The Morphogenetic Environment

Throughout the coastal karst of Majorca, the existence of caves is frequently occupied by saltwater lakes is widespread. These flood levels constitute the upper limit of a karstic aquifer found in hydrostatic equilibrium with the present sea level of the Mediterranean.

While these caverns may possibly be attributed to remote speleothems that took place under phreatic conditions, they have undergone a significant subsequent evolution in vadose milieu (breakdown, aerial stalagmitization) during periods of marine level descent according to the history of the glacial cycles. The caves were then partially inundated as a result of the relative rise in sea level connected with interglacial events. In this case it is no longer possible to find aerial stalagmitic concretions which are submerged in the subterranean lakes so characteristic of the coastal karst of eastern Majorca.

Phreatic Speleothems in Majorcan Caves

In order to describe with greater precision the morphology, texture and mineralogy of phreatic speleothems occurring in Majorca, we shall make a distinction between present-day forming speleomorphology, texture and mineralogy of phreatic speleothems and fossil speleothems belonging to paleolevels of the karstic ground water table. The chronological implications of this second group of phreatic deposits is the topic of another paper presented at this Congress (GINES et al., 1979); Sardina, Italy (FURREDDU and MAXIA, 1964); Curaçao, N.W.I. (GINES and GINES, 1973); and Bermuda (HARRISON, SCHWARTZ and FORD, 1978).

Phreatic crystallizations

Among the phreatic speleothems that are being formed at the present time in littoral subterranean lakes corresponding to the current plane of the Mediterranean, we shall mention the following:

a. Floating calcite. Formed by thin plates, white in color, suspended on the surface of the water by surface tensions. These plates are composed of rhombohedral calcite crystals; the rhombohedrons are usually arranged with the C-axis oriented in a radial direction around the crystallization nucleus. The aerial face of the plates is completely flat due to the fact that precipitation occurs below the air-water interface.

Nucleation of the floating calcite occurs in two forms. In the first form, numerous tiny crystals having edges 5 microns in length occur, growing in conjunction with the crystallization of calcite crystals varying between 10 and 20 microns. In the second form, one can observe abundant "rosettes" characterized by radial crystalline growth and joined to one another by the interpenetration of the crystals. These rosettes are notable for their considerably more rapid growth, surpassing the tiny initial crystallographic growths of 0.3 mm. These textural characteristics become gradually modified toward the middle zone of the speleothem, where one finds a greater perfection in terms of morphology and orientation of the crystals. The presence of unidentified organic filaments can be detected in all the crystallizations; these filaments are exceptional in profuse in the lower part of the concretion, paralleling the increase in the degree of degrading neomorphism that affects the crystals.

Epiaquatic crystallizations are found genetically linked to the water-air interface of some coastal cavern lakes. Their development and morphology are seen to be dependent upon the periodic fluctuations of phreatic waters, which change in turn determined by the periodic fluctuations of the sea level. These speleothems sometimes occur associated with floating calcite, consequently the epiaquatic crystallizations often include floating calcite flakes deposited on their upper zone.

Ancient crystallizations

The changes in sea level of the Mediterranean throughout the Pleistocene epoch implied a change in the water plane under which every enlargement of phreatic speleothems has been produced (Figure 1). Up to thirteen level lines have been detected in Sa Bassa Blanca Cave (Alcudia, Majorca); each speleothem-lining corresponds to the level reached by the Mediterranean during the last interglacial events (GINES and GINES, 1973). For study of phreatic speleothem samples from Sa Bassa Blanca Cave by means of optical microscopy, X-ray diffraction and scanning electron microscopy has permitted the identification of two distinct mineralogical groups, each with its own specific external morphology (GINES et al., 1976).

Needle-shaped aragonite crystals growing perpendicular to their supporting surfaces create thick subaqueous coverings with smooth surface morphology. On these coverings, which frequently occur associated with other speleothems that have developed in an aerial milieu, aragonite-calcite inversions are observable; these inversions could be responsible for the autoformentation of marls and the concretions. On the other hand, phreatic deposits consisting of fibrous calcite as well as rhombohedral calcite crystals create external rough surfaces, quite similar to the concretions that cover the interior of the rimstone pools.

Phreatic calcite coverings are frequently superimposed on previous aragonite coatings (Figure 4).
Coupled with this circumstance is the fact that the various mineralogies determined for the phreatic speleothems of Sa Bassa Blanca Cave correspond specifically to distinct Pleistocene marine paleolevels. A study of the differences in petrology, geochemistry and mineralogy existing in phreatic deposits left by the respective Pleistocene periods will likely permit the substantiation of considerable data regarding the paleoenvironmental evolution of the karstic aquifer throughout the last interglacial episodes.

In studying calcite rafts and epiaquatic speleothems, we encountered processes of phreatic carbonate deposition which were taking place in the water-air interface. In ancient phreatic deposits, the mechanisms of chemical precipitation were not, it would seem, limited to the zone affected by the daily fluctuations of the water plane; on the contrary, they extensively influenced the entire cavity portion that was below the water plane in each period. Even so, in the phreatic coatings of Sa Bassa Blanca Cave, maximum precipitation occurs in the water-air interface, causing the phreatic coatings to have a marked jutting overgrowth comparable to that of epiaquatic speleothems described above.

Conclusions

The study of extensive assemblages of phreatic speleothems in Majorcan coastal caves allows a broader idea of the morphology and texture of carbonate deposits originating in a subaquatic environment. At the same time it is perfectly clear that carbonate deposition in phreatic littoral conditions is a considerably important process, in terms of magnitude and geographical distribution.

The role of accumulation and cave filling played by phreatic speleothems contrasts with the primacy normally assigned to the processes of dissolution related to the chemical behavior of karstic phreatic waters. Geochemical implications, little recognized at present, are one of the most important conclusions to be drawn from these findings.

Important chronological data result from the altimetric correlation between ancient phreatic speleothems and the paleolevels of the sea occurring in the course of the last 300,000 years. By the same token, the mineralogical and textural differences among phreatic speleothems deposited throughout the Middle and Upper Pleistocene give rise to the expectation that important paleoclimatic and palaeoenvironmental data may be obtained.

The existence of phreatic speleothems which are developing at the present time will considerable facilitate an adequate morphogenetic interpretation of ancient phreatic deposits related to marine paleolevels of the Pleistocene.

Bibliography


Table 1

<table>
<thead>
<tr>
<th>SPELEOTHEMS</th>
<th>Dripping water speleothems</th>
<th>Flowing water speleothems</th>
<th>Seepage water speleothems</th>
<th>Vadose rimstone pool crystallizations</th>
<th>Continental base level</th>
<th>Present crystallizations</th>
<th>Marine base level</th>
<th>Ancient crystallizations (Pleistocene sea paleolevels)</th>
</tr>
</thead>
</table>

531
ANCIENT SEA LEVELS

First generation. Small-sized crystals

Calcite phreatic coating

Second generation. Large rhombohedrons

ANCIENT PHREATIC CRYSTALLIZATIONS
Cova de Sa Bassa Blanca

Figure 2 FLOATING CALCITE (Calcite Raft)
lateral view

EPIAQUATIC SPELEOTHEMS

PRESENT SEA LEVEL

Figure 1

EPIAQUATIC SPELEOTHEMS
Cova de Cala Varques

Figure 3

ANCIENT PHREATIC CRYSTALLIZATIONS
Cova de Sa Bassa Blanca

Figure 4
Phreatic Speleothems in Coastal Caves of Majorca (Spain) as Indicators of Mediterranean Pleistocene Paleolevels


Abstract

Oscillations in the level of the Mediterranean sea during the Pleistocene produced corresponding oscillations of the ground water table in the coastal areas. These levels reached in the Middle and Upper Pleistocene have been recorded in some caves in the Majorcan karst by means of the phreatic crystallizations left by each epoch.

Significant data can be easily obtained regarding speleomorphology and chronology of some coastal caves and their sediments, on the basis of the altimetric correlation between Pleistocene beach deposits and these phreatic speleothem-linings. Furthermore it is possible to survey with great accuracy the sequences of paleolevels and minor oscillations of the sea during the last interglacials.

Moreover, the Cova de Sa Bassa Blanca has shown formative thick carbonate coatings on the cave wall, which define thirteen speleothem paleolevels ranging from +35 to +1.2 meters above the present sea level pools. Hence it appears that several high levels of the water table have controlled the phreatic speleothem deposition during the interglacial events, leading to a sequence of extensive coatings and overgrowths of underwater speleothems on the cave walls. Good altimetric correlations with isotope - and faunally-dated beach deposits in the near coast of the cave suggest the presence in the Cova de Sa Bassa Blanca of several overgrowth levels pertaining to the Mindel - Riss interglacial.

Stratigraphic criteria can aid in the interpretation of the complex history of this unusual speleothem infilling, taking into account that the low sea levels corresponding to the glaciations have been recorded in the cave by aerial stalagmitic processes.

Résumé

Les variations de niveau de la mer Méditerranée au Pléistocène provoquent des oscillations du niveau piézométrique dans les systèmes karstiques littoraux. Les niveaux atteints au Pléistocène moyen et supérieur peuvent être reconnus dans plusieurs grottes côtières de Majorque grâce aux cristallisations phréatiques déposées lors de chaque événement.

Des données significatives, relatives à la spéléomorphologie et à la chronologie de certaines grottes côtières et de leurs sédiments, peuvent être facilement obtenues en analysant les couches successives des dépôts de plage, dans les grottes phréatiques phréatiques d’affinité, afin d’établir des corrélations entre elles. On peut ainsi déterminer avec une bonne précision les variations de niveaux de la mer survenues pendant les dernières interglaciaires, ainsi que d’autres variations de moindre amplitude.

Les recherches poursuivies dans la grotte de Sa Bassa Blanca ont permis de mettre en évidence des revêtements phréatiques successifs de carbonate calcique; ceux-ci traduisent l’existence de trois paléoniveaux s’étageant entre 1, 2 et 35 mètres au-dessus du niveau actuel de la mer. La bonne corrélation verticale observée avec les dépôts de plage aux environs immédiats de la grotte (dépôts datés par des méthodes isotopiques et faunistiques) nous a permis de constater la présence, dans la grotte de Sa Bassa Blanca, de plusieurs niveaux appartenant à l’interglaciaire Mindel-Riss.

En première approximation, on peut attribuer aux épisodes interglaciaires les périodes caractérisées par la formation de cristallisations subaquatiques, alors que les processus stalagmitiques au sens strict du terme se sont réalisés pendant l’abaissement du niveau de la mer pendant les glaciations.

Resumen

Las oscilaciones del nivel del Mar Mediterráneo durante el Pleistoceno implicaron la consiguiente oscilación del nivel piezométrico en los sistemas cársticos litorales. Los niveles alcanzados en el Pleistoceno Medio y Superior pueden ser obtenidos fácilmente en base a la correlación altimétrica existente entre estas alineaciones de espeleotemas freáticas y los depósitos marinos pleistocénicos. Además es posible deducir con gran precisión las secuencias de paleoniveles del mar, habidos durante los últimos interglaciares, así como otras oscilaciones menores.

Las investigaciones realizadas en la Cova de Sa Bassa Blanca han mostrado sucesivos revestimientos paritarios de carbonato calcáreo, los cuales definen hasta tres paleoniveles freáticos, abarcando desde 35 a 1,2 metros por encima del nivel marino actual. La buena correlación altimétrica observable con respecto a los depósitos de playa situados en las inmediaciones de la cueva, cuya edad ha sido establecida mediante estudios faunísticos e isotópicos, permite constatar la presencia de varios niveles de concreción freática pertenecientes al interglacial Mindel-Riss.

En una primera aproximación, se pueden atribuir a los episodios interglaciares las etapas de fosilización llevadas a cabo por cristalizaciones subacuáticas, mientras que los descensos del nivel del mar acuático durante las glaciations se caracterizarán por procesos de estalagmitización en sentido estricto.

Introduction

Since the end of the nineteenth century, when the speleological richness of the Manacor Marina (the south-eastern karstic region of Majorca, Spain) first became known, the subterranean lakes of this area have achieved considerable acclaim for their touristic interest. Almost all the caverns explored contain brackish lakes and their sediments, on the basis of the altimetric correlation between Pleistocene beach deposits and these phreatic speleothem-linings. Furthermore it is possible to survey with great accuracy the sequences of paleolevels and minor oscillations of the sea during the last interglacials.

Moreover, the Cova de Sa Bassa Blanca has shown formative thick carbonate coatings on the cave wall, which define thirteen speleothem paleolevels ranging from +35 to +1.2 meters above the present sea level pools. Hence it appears that several high levels of the water table have controlled the phreatic speleothem deposition during the interglacial events, leading to a sequence of extensive coatings and overgrowths of underwater speleothems on the cave walls. Good altimetric correlations with isotope - and faunally-dated beach deposits in the near coast of the cave suggest the presence in the Cova de Sa Bassa Blanca of several overgrowth levels pertaining to the Mindel - Riss interglacial.

Stratigraphic criteria can aid in the interpretation of the complex history of this unusual speleothem infilling, taking into account that the low sea levels corresponding to the glaciations have been recorded in the cave by aerial stalagmitic processes.

Criteria for Interpretation

Recent studies (GINÉS and GINES, 1974; POMAR et al., 1979) have made evident the wide range of processes, current as well as fossil, of carbonate precipitation in a phreatic environment; processes which have taken or are taking place within the framework of the subterranean lakes in the litoral karst of Majorca (GINÉS et al., m., also presented at this Congress). Some of the phreatic deposits belong to the group of calcite and/or aragonite subaquatic speleothems (POMAR et al., 1976) whereas others appear to be closely controlled by minor fluctuations in the water table, as is the case for floating calcite and epiaquatic speleothems (POMAR et al., 1975).

The most interesting aspect of phreatic speleothems found in the caves of the eastern karst of Majorca is probably that of the possibility of establishing altimetric correlations between the phreatic speleothem linings and fossil-beach levels belonging to interglacial stages of the Middle and Upper Pleistocene. In this respect, it becomes important to determine precisely the lines of carbonated enlargements, of phreatic origin, corresponding to the water table of each Pleistocene
flood level that was experienced synchronously by the cave and the coastline. There are fortunately a large number of studies on the geology and geomorphology of the many Pleistocene beaches of Majorca and Minorca (see BUTZER and CUERDA, 1962; BUTZER, 1975; CUERDA, 1975; and POMAR and CUERDA, 1980). It is thus available a wide range of data on sea level changes during many cycles of ice and sea level fluctuations that occurred during the interglacial intervals following the Mindel glaciation. This documentation has been corroborated and given greater chronological detail by means of the radiocarbon dating (see STEARNs and THURBER, 1967). Consequently, the flood levels recorded in many caves as a result of their alignment on the interglacial level of the Mediterranean Sea (Figure 1). The stratigraphic interpretation which we suggest is broadened by the differences in mineralogy and texture as observed among the various phreatic deposit layers. These differences definitely characterize the large accumulations of aragonite subaqueous crystallization deposits in beach deposits by groupings of Senegalese warm-water fauna, bear a direct relationship to the large accumulations of aragonite subaqueous crystallization deposits found in the cave. Another aspect to bear in mind for the interpretation of the stratigraphic sequence is that of the alternate layering of subaqueous and aerial speleothems of calcium carbonate: this alternation is caused by changes in the water table, which in turn is a result of major changes in climate and sea level during the Pleistocene. Thus the retreat of the high water levels during the glacial periods would have been accompanied by intensive development of aerial stalagmitic formations (dripstone and flowstone speleothems), whereas during periods of subaerial-concretion development in this type of subterranean lakes (Figure 2).

Phreatic Speleothems in Majorcan Caves

Just as the precipitation of floating calcite is a common occurrence at the present time in most of the lakes of Majorcan coastal caves, by the same token it is also possible to affirm that processes of phreatic crystallization are active in the present-day lakes of such caves as Cova de Cala Varques and Coves del Pirata, among others. The greatest interest from a speleochronological point of view, however, resides in the alignments of ancient phreatic crystallizations located at the same height above the current water table (approximately two meters) in another series of caves; Coves del Pirata, Cova des Font, Cova den Bassos, are among these. It is important to emphasize, at the same time, that the fact that these alignments of speleothems only constitute the upper limit (corresponding to a paleolevel of the water table) of much more extensive coatings that affect the cave walls located below the speleothem overgrowth level. The various Pleistocene interglacial events following the Mindel glaciation have caused the superimposition of phreatic crystallization layers, each of which was the result of a different period of aerial crystallization (dripstone and flowstone speleothems). It is also possible to affirm that processes of epiaerial crystallization (flowstone speleothems) have occurred during many cycles of sea level fluctuations that occurred throughout the interglacial intervals following the Mindel glaciation. The initial aim of the speleological literature on the Balearic Islands was that of correlating Tyrrhenian glacial events with karstic phenomena (cf. the study of the sequence of formations of Palma Blanca by BUTZER, 1965). The chronological study of phreatic speleothems in Majorca and their relationships to Pleistocene beach deposits was launched in 1972 with a paper presented at the Second Spanish Congress of Speleology (GINES and GINES, 1974). This paper described the unusual assemblage of phreatic speleothems found in Sa Bassa Blanca Cave, assigning to these groupings ages ranging from the Paleotyrrhenian (Mindel-Riss) interglacial up to the pre-Pleistocene (Pliocene). These speleothems are to be found in GINES et al. (1973) and GINES et al. (1975). It is reasonable to expect that the detailed study of subaqueous crystallization groupings in Majorcan coastal caves, which study we are carrying out during the present year (1981), will considerably enlarge our knowledge in this area within the near future.

Bibliography


---

Figure 1
A. Mediterranean relative sea levels as recorded in Majorca. Based on BUTZER 1975 and CUERDA 1975.
B. Paleolevels of the ground water table found in Cova de Sa Bassa Blanca. After GINES and GINES 1974.

---

535
Figure 2

Schematic cross-section of a passage in Cova de Sa Bassa Blanca. A chronological explanation is suggested.

1. Aerial stalagmitization and block breakdown
2. Subaqueous speleothems
3. Subaqueous coating
4. Subaqueous coating
5. Gravity-cone of eolian sand
6. Aerial stalagmitization
5.1. Speleothem lining
The Karsts of the Oriental Part of Cuba

Nacasio Viña
Sociedad Espedica Logica de Cuba

Abstract

The fundamental characteristic of the karsts of the five oriental provinces of Cuba, deeply studied to prepare the Karstological Map of Cuba, are presented.

The largest karstic units of this region are: the karstic Herradura of the Cauto, the Litoral karsts of the north, the karst of Gibara, the plane of the Nipe, the litoral barriers between Gibara and Moa, the karst of Segundo Frente, the karst of Manzanillo, the karst of Cabo Cruz, the Central Valley, the karstic stripe of Guantanamo (sierra of Maria del Pilar, sierra Canasta, the plateau of Guaso, the "cuesta" of Jucaral, the plateau of Caridad of los Indios, the plateau of Yateras, the sierra of Maquey, the litoral karst of the SE, the karsts of Maisi, the karst of Gran Tierra and the karstic in serpentinitic rocks.

Many little isolated karsts are briefly mentioned and grouped by their common characteristics. In the case of the largest unities are given data about the rocks, the morphology, the drainage, the evolution, the genesis, etc., of each one of these karsts.

Résumé

Les caractéristiques des karsts des cinq provinces orientales de Cuba, qui furent étudiées notamment pour la préparation de la Carte Karstological de Cuba, sont présentées.

Les plus grandes unités karstiques des provinces orientales sont: le Karstique Herradura du Cauto, les karsts littoraux du nord, le karst du Segundo Frente, le karst de Baire, le karst de Cabo Cruz, le Valldà Centrale, le frange karstique de Guantanamo (Sierra de Maria del Pilar, Sierra Canasta, plateau du Guaso, "cuesta" de Jucaral, plateau de Caridad de los Indios, plateaux de Yateras, Sierra de Maquey, Sierra de Caujaral), les karsts littoraux du SE, les karsts de Maisi, le karst de Gran Tierra et les karsts sur des roches vertes.

Beaucoup de karsts petits et isolés, qui sont agrupés pour leurs caractéristiques communes sont seulement mentionnées.

Dans le cas des unités plus grandes sont données les notes des roches, de la morphologie, du drainage, de l'évolution et de la gênésie de chacun d'elles.

The oriental part of Cuba formed by the provinces of Tunas, Granma, Santiago de Cuba and Guantanamo covers an area of about 800 km² where the karsts sometimes form large and continuous zones, but in other cases are little isolated areas.

In the Cauto area, where an extensive karst had not been mentioned in the literature until recently is the karstic "Herradura" of the Cauto, which surrounds the plane occupied by the river of the same name and which is essentially a karstic surface of tabular type, developed on a continuous crest, always limited by strong slopes directed to the interior. It must be noticed that the limits are discontinuous and of tectonic origin. The surface is cut by blind karstic valleys, seasonally active.

This karst sinks, under the fluvio-marine accumulations of the Cauto's plane, Cañada de la Herradura, in the central part of the "Herradura", where forms a large and continuous area of cryptokarst.

Some parts of the karstic "Herradura" of the Cauto had been destroyed by radial tectonic movements and had originated raised blocks that can be considered as "monadnocks" or remnants of the sunk tops.

Another karstic zone is related with the pleistocene limestones that form the litoral margin of the northwestern part of the investigated area. It is a zone of intense karst, well known, by its characteristics of karst of mixed marine-subaerial origin and it is a karstic surface recently developed by valleys fossilized by the karstification. In its northeastern part there have been formed several lobulate "balsa" bays, filling karstic depressions, of not too deep polje type, which are actually flooded by the sea.

The ways of drainage and invasion of the sea are now the narrow entrances of these bays, in the form of karstic canyons half sunk in the sea.

The karst of Gibara, represented by a block of limestones from the middle and upper Cretaceous, is one of the most developed in all the investigated area. It is an asimetric horst where the principal blocks sink gradually to the N and NE and actually form five principal crests. Between these crests there are, at several altitudes, large systems of lobulate complex polies of various types. In the bottom of these polies exist several "cuestas" remaining as relics. The biggest is the Yaguajay hill with 286 m. Independently of the cliffs hills considered as isolated karst, exist too calcareous hills and plateaus, deeply cutting in limestones from the same period, but isolated as isolated parts, strongly karstified, of the surrounding "cuestas" remaining as relics. The biggest is the Yaguajay hill with 286 m.

An area with independent characteristics is over the miocenic calcareous marls which form the ancient barriers between Gibara and Moa, which are arc shaped in its horizontal plane, reflecting the form of the zone with domes of the eastern end of the Gibara anticlinorium and the north part of the Nipe and Cristal domes. The barriers form massive crests with their fronts looking always inland, and their external slopes strongly karstified and divided in echelons by fossil marine cliffs.

One large area of karst is related to the limestones from the early and middle Miocene, forming the bottom of the Nipe plane, where there are not manifestations of positive forms of the karstic relief on the surface, but they are strongly karstified beneath the cover of deep soils.

A very interesting karstic area is related with the consolidated calcareous marls which surround the area of the Nipe and are known as the Nipe Karstic Ring. It is useful to point, in first place, that this ring is not completely closed and in second one, that in the SE of the Nipe dome-block it is continuous with the calcareous rocks which surrounded the SW of the Cristal dome-block, forming a triangular region between the dome-blocks and the relief of the Central Valley. Geologically this is a complex ring. In its NE part the most ancient stripes are not continuous and the eocenic limestones exist only, over gabbro, as isolated relics with well developed karst.

The western arc of the ring is formed by a wide and continuous stripe of eocenic limestones, cut by deep and narrow canyons, until active, and by several complex hanging and blind valleys, some of which end in very deep depressions. The surface between these fossilized valleys forms a typical karst of cupulas and irregular depressions, with numerous caves.

The south part of the ring is prolonged forming a large lobule that penetrates between the Nipe and Cristal domes, which is known as karst of Segundo Frente. It is, in general, a tabular karst of plateaux and "cuestas", interrupted by paricial domes constituted by serpentinitic rocks and of its cover of tertiary and quaternary serpicoletic rocks, or by their blocks raised along the faults and denudated by the erosion. The south limit of this karst is formed by a continuous stripe of limestones which sunk under a wide zone of marls of the same age.

The karst of Segundo Frente is developed in a deep sequence of limestones with different ages. Its most western part is characterized by the existence of relics that form isolated hills. From here to the east is developed the external karstic...
"cuesta" of this karst, where the limestones surround the south several partial domes constituted by insoluble rocks and are cut into deep canyons by the rivers that flow from the domes. The surface is divided by several semifossil valleys, and the interfluivial crests are transformed in mogotes and karstic cupolas, existing too many irregular depressions, ponors and vertical caves.

Another unity of the karst of Segundo Frente is formed by plateaus, some horizontal and others ascendant to the domes of Nipe and Cristal. They are separated by wide and deep canyons with vertical and eveloned slopes. The largest of these plateaus had developed, by fossilization of a net of consequent valleys, a system of polies with many ponors and descending caves, separated by karstic cupolas. Its highest part is transformed in an elongated group of asimetric mogotes and cupolas.

The karst of Baire, which forms part of the stripe of crests of the north side of the Sierra Maestra, can be considered between the most developed of Cuba. It is a combination of plateau type karst in the south part and "cuesta" type in the north part. From the geomorphological point of view, the relief has sings of "cuesta", with monoclinal crests cut by valleys and separated by longitudinal basins. In this karst, all the forms are of karstic or fluvio-karstic origin. The crests and the plateaus that remained between the basins and the valleys are transformed in a conidal karst, with chains of mogotes separated by "hoyos". The distribution of the positive and negative forms had been determined by the existence of two systems of perpendicular faults. From the paleogeographic point of view, it represents the most ancient surface of all the territory of the Sierra Maestra, with age from upper Miocene to Pliocene.

To the W of the karst of Baire, in the western margin of the Bayamo river, there is a little karst formed by a line of mogotes, separated by fragments of dead valleys, and resting as relics over the insoluble base.

Between the NW slope of the Sierra Maestra and the cost of the Guanayabay gulf was developed, on calcareous marls, the karst of Manzanillo which is similar by its morphology and hidrology to the Karstic Herradura of the Cauto. It has not surface karstic forms, but the subterranean forms of the karst are very developed beneath the pleistocenic fluvio-marine deposits of the plane, which constituted a SW elongation of the Cauto's plane.}

The karstic zone of the Cabo Cruz is a karstic plateau, cupula shaped, slightly inclined to the NW and the W and limited by vertical cliffs in the eastern and southern parts. The eastern margin is of denudative origin, but the southern is tectonic, and has been transformed by a long and intense marine erosion which formed the well known marine terraces of the zone and especially the famous terraces of Punta Escalereta, where it is possible to distinguish nine levels of emerged terraces. Under the surface the limestones are strongly karstified.

In the territory of the south of the Sierra Maestra there are, in many places, little isolated or separated karstic territories. They are develop in two types of forms. Some as relics of ancient covers and others as monadnocks of the calcareous bodies included in the volcanosedimentary series of rocks of the Sierra Maestra.

Two little isolated karst are in the northern slope of the Sierra Maestra, one near to Cruce de los Baños and the other in the area of Mongolosongo.

In the north part of the Santiago basin there are chains of hills with calcareous relics and in the south slope of Sierra de la Gran Piedra there are calcareous lens discovered by the erosion of the deep valleys.

A wide development of karst could be found in the Central Valley where all the bottom of this intramontain depression is formed by limestones strongly karstified that only crop out in its margins forming the "cuestas" of the Sierra de Puerto Boniato, where the biggest forms are eveloned canyons that divided it in several isolate bodies. They crop out too along the Jarahueca river near the town of Seboruco forming a well developed conical karst.

In the Central Valley there are several domified structures where the limestones are karstified exactly in the contact with its vulcano sedimentary or intrusive base.

In the northern margin of the mountain chain of Gran Piedra there is a narrow stripe of karst isolated by the erosion, which in its western part forms a very narrow hogback and to the east is cut transversally several times, forming a chain of low mogotes.

The karstic stripe of Guantanamo include the larger territories of elevated karst, of Cuba. Begins in SW with the high monoclinal "cuestas" of the Sierra de Maria del Pilar, with eveloned slope and flat surface with mogotes. In its base there are karstic resurgence.
Non-Relictual Terrestrial Troglobites in the Tropical Hawaiian Caves

Francis G. Howarth

B. F. Bishop Museum, P. O. Box 19000-A, Honolulu, HI, USA 96819

Abstract

The Hawaiian Archipelago is the most isolated group of high oceanic islands. The native fauna reflects this isolation. Consistently poorly represented are the aquatic, soil, and cave arthropods of the continents. Nevertheless, highly specialized, highly specialized troglobitic arthropods are relatively young lava tubes. Many caves species have preadapted close surface relatives still exist and are not relicts. They evolved from representatives of the speclating native fauna as a result of adaptive shifts such as other animals have adapted to different novel habitats. Their ancestors may have invaded lava tubes, or scavenge on dead rocky substrates, e.g. Caconomobius crickets. I hypothesize that where there are extensive systems of interconnected subterranean voids, such as one finds in basaltic or karst areas, caves for food energy is still being currently being captured by other animals, either because the resource is too diffuse to allow adequate harvestable energy to maintain their lifestyles, because of their inability to locate the scattered resources or reproduce in perpetual darkness, or because the resource is too ephemeral. Some terrestrial troglobites appear to have invaded caves only once on each island, although the cave moths, Schrankia spp. may be an excep-

Résumé

L'archipel hawaïen est le groupe le plus isolé des hautes îles océaniques. La faune indigène reflète cet isolement. Les groupes taxonomiques d'arthropodes aquatiques terrestres et cavernicoles continentaux s'y signalent par leur rareté. Des arthropodes troglobites qui sont remarquablement spécialisés habitent des tuyaux de lave assez récents à Hawaï. Beaucoup d'espèces cavernicoles ont des cousins proches parents érigés préadaptés que existent encore et qui ne sont pas rélictuels. Ils ont évolué d'espèces représentatives de la faune indigène par des procédés d'adaptation, tout comme d'autres animaux se sont adaptés pour coloniser de nouveaux habitats. Leurs ancêtres habitent en général soit les forêts humides, par exemple Oliarius (cylindres) et les forêts humides par exemple Oliarius (cylindres), ou sont relictuels, par exemple Caconomicus (sphères). J'admets comme hypothèse que là où il existe de vastes systèmes de réseaux souterrains, comme dans les régions karstiques ou basaltiques, l'énergie organique alimentaire se déplace continuellement, d'une part les animaux se dispersent dans les forêts humides et d'autre part, les animaux se dispersent dans les forêts humides. Les espaces vides du rocher. Mais c'est une fenêtre défectueuse, car elle est fragile et elle créé l'illusion d'un environnement qui offre peu d'alentours.

The Hawaiian Islands extend over 2400 km across the northern tropical Pacific. They are the tops of mammoth submarine volcanoes and are separated from each other by deep straits, 50 km or more wide. The islands become older as one moves to the northwest, with the main islands ranging from high sea age from ca. 6 million years for Kauai to less than 700,000 years for the youngest island, Hawaii (Dalrymple et al. 1973). Each island in turn was built by frequent flows of lava that covered 300 km of the Hawaiian Island is still active volcanically. The native terrestrial fauna is represented by those few groups that were able to disperse from the main islands. The Hawaiian Islands are well isolated. Some of those that won the dispersal sweepstakes adapted to new habitats and evolved into extensive systems of interconnected subterranean voids giving Hawaii a bizarre and unique fauna.

In 1971 a diverse assemblage of terrestrial troglobitics that were first discovered in lava tubes on Hawaii Island. This discovery was quite surprising given the relative youth of Hawaii Island and particularly the extreme youth of the lava tubes. Furthermore, according to the then accepted paradigm explaining their evolution and distribution, troglobitics were thought to be relics and to have evolved for eons of time. However, careful study of troglobitic species has revealed that some species have evolved to exploit the organic resources washing or falling into the deeper small voids in fractured cavernous rock. In the deeper zones of this system the environment is a rigorous one. One must live in perpetual darkness, with a relatively constant temperature, with a constantly saturated atmosphere that is above the limits of many terrestrial arthropods, and yet is encountered by cave-dwelling animals. This is a paradox. It is perpetually dark, with a relatively constant temperature, with a constantly saturated atmosphere that is above the limits of many terrestrial arthropods, and yet is encountered by cave-dwelling animals. This is a paradox.

Recently, (Howart, 1980) I proposed a bioclimatic model to explain the observed distribution of terrestrial troglobites. I believe that troglobites have evolved to exploit the organic resources washing or falling into the deeper small voids in fractured cavernous rock. In the deeper zones of this system the environment is a rigorous one. One must live in perpetual darkness, with a relatively constant temperature, with a constantly saturated atmosphere that is above the limits of many terrestrial arthropods, and yet is encountered by cave-dwelling animals. This is a paradox. It is perpetually dark, with a relatively constant temperature, with a constantly saturated atmosphere that is above the limits of many terrestrial arthropods, and yet is encountered by cave-dwelling animals. This is a paradox.

The Hawaiian Islands are the tops of mammoth submarine volcanoes and are separated from each other by deep straits, 50 km or more wide. The islands become older as one moves to the northwest, with the main islands ranging from high sea age from ca. 6 million years for Kauai to less than 700,000 years for the youngest island, Hawaii (Dalrymple et al. 1973). Each island in turn was built by frequent flows of lava that covered 300 km of the Hawaiian Island is still active volcanically. The native terrestrial fauna is represented by those few groups that were able to disperse from the main islands. The Hawaiian Islands are well isolated. Some of those that won the dispersal sweepstakes adapted to new habitats and evolved into extensive systems of interconnected subterranean voids giving Hawaii a bizarre and unique fauna.

In 1971 a diverse assemblage of terrestrial troglobitics that were first discovered in lava tubes on Hawaii Island. This discovery was quite surprising given the relative youth of Hawaii Island and particularly the extreme youth of the lava tubes. Furthermore, according to the then accepted paradigm explaining their evolution and distribution, troglobitics were thought to be relics and to have evolved for eons of time. However, careful study of troglobitic species has revealed that some species have evolved to exploit the organic resources washing or falling into the deeper small voids in fractured cavernous rock. In the deeper zones of this system the environment is a rigorous one. One must live in perpetual darkness, with a relatively constant temperature, with a constantly saturated atmosphere that is above the limits of many terrestrial arthropods, and yet is encountered by cave-dwelling animals. This is a paradox. It is perpetually dark, with a relatively constant temperature, with a constantly saturated atmosphere that is above the limits of many terrestrial arthropods, and yet is encountered by cave-dwelling animals. This is a paradox.

The Hawaiian Islands are the tops of mammoth submarine volcanoes and are separated from each other by deep straits, 50 km or more wide. The islands become older as one moves to the northwest, with the main islands ranging from high sea age from ca. 6 million years for Kauai to less than 700,000 years for the youngest island, Hawaii (Dalrymple et al. 1973). Each island in turn was built by frequent flows of lava that covered 300 km of the Hawaiian Island is still active volcanically. The native terrestrial fauna is represented by those few groups that were able to disperse from the main islands. The Hawaiian Islands are well isolated. Some of those that won the dispersal sweepstakes adapted to new habitats and evolved into extensive systems of interconnected subterranean voids giving Hawaii a bizarre and unique fauna.

In 1971 a diverse assemblage of terrestrial troglobitics that were first discovered in lava tubes on Hawaii Island. This discovery was quite surprising given the relative youth of Hawaii Island and particularly the extreme youth of the lava tubes. Furthermore, according to the then accepted paradigm explaining their evolution and distribution, troglobitics were thought to be relics and to have evolved for eons of time. However, careful study of troglobitic species has revealed that some species have evolved to exploit the organic resources washing or falling into the deeper small voids in fractured cavernous rock. In the deeper zones of this system the environment is a rigorous one. One must live in perpetual darkness, with a relatively constant temperature, with a constantly saturated atmosphere that is above the limits of many terrestrial arthropods, and yet is encountered by cave-dwelling animals. This is a paradox. It is perpetually dark, with a relatively constant temperature, with a constantly saturated atmosphere that is above the limits of many terrestrial arthropods, and yet is encountered by cave-dwelling animals. This is a paradox.

The Hawaiian Islands are the tops of mammoth submarine volcanoes and are separated from each other by deep straits, 50 km or more wide. The islands become older as one moves to the northwest, with the main islands ranging from high sea age from ca. 6 million years for Kauai to less than 700,000 years for the youngest island, Hawaii (Dalrymple et al. 1973). Each island in turn was built by frequent flows of lava that covered 300 km of the Hawaiian Island is still active volcanically. The native terrestrial fauna is represented by those few groups that were able to disperse from the main islands. The Hawaiian Islands are well isolated. Some of those that won the dispersal sweepstakes adapted to new habitats and evolved into extensive systems of interconnected subterranean voids giving Hawaii a bizarre and unique fauna.

In 1971 a diverse assemblage of terrestrial troglobitics that were first discovered in lava tubes on Hawaii Island. This discovery was quite surprising given the relative youth of Hawaii Island and particularly the extreme youth of the lava tubes. Furthermore, according to the then accepted paradigm explaining their evolution and distribution, troglobitics were thought to be relics and to have evolved for eons of time. However, careful study of troglobitic species has revealed that some species have evolved to exploit the organic resources washing or falling into the deeper small voids in fractured cavernous rock. In the deeper zones of this system the environment is a rigorous one. One must live in perpetual darkness, with a relatively constant temperature, with a constantly saturated atmosphere that is above the limits of many terrestrial arthropods, and yet is encountered by cave-dwelling animals. This is a paradox. It is perpetually dark, with a relatively constant temperature, with a constantly saturated atmosphere that is above the limits of many terrestrial arthropods, and yet is encountered by cave-dwelling animals. This is a paradox.

The Hawaiian Islands are the tops of mammoth submarine volcanoes and are separated from each other by deep straits, 50 km or more wide. The islands become older as one moves to the northwest, with the main islands ranging from high sea age from ca. 6 million years for Kauai to less than 700,000 years for the youngest island, Hawaii (Dalrymple et al. 1973). Each island in turn was built by frequent flows of lava that covered 300 km of the Hawaiian Island is still active volcanically. The native terrestrial fauna is represented by those few groups that were able to disperse from the main islands. The Hawaiian Islands are well isolated. Some of those that won the dispersal sweepstakes adapted to new habitats and evolved into extensive systems of interconnected subterranean voids giving Hawaii a bizarre and unique fauna.

In 1971 a diverse assemblage of terrestrial troglobitics that were first discovered in lava tubes on Hawaii Island. This discovery was quite surprising given the relative youth of Hawaii Island and particularly the extreme youth of the lava tubes. Furthermore, according to the then accepted paradigm explaining their evolution and distribution, troglobitics were thought to be relics and to have evolved for eons of time. However, careful study of troglobitic species has revealed that some species have evolved to exploit the organic resources washing or falling into the deeper small voids in fractured cavernous rock. In the deeper zones of this system the environment is a rigorous one. One must live in perpetual darkness, with a relatively constant temperature, with a constantly saturated atmosphere that is above the limits of many terrestrial arthropods, and yet is encountered by cave-dwelling animals. This is a paradox. It is perpetually dark, with a relatively constant temperature, with a constantly saturated atmosphere that is above the limits of many terrestrial arthropods, and yet is encountered by cave-dwelling animals. This is a paradox.
The presumed ancestral habitat of Caecemobius Gurney & Rentz; lives in lava tubes from near Kilauea Volcano (Howarth, 1979). This seacoast species was preadapted to colonize rocky sea cliffs and other rock habitats that meet the seacoast, such as sea caves and lava tubes. At some time, independently on Kauai, Maui, and Hawaii populations of seacoast crickets made the physiological transition from salt to fresh water habitats and moved inland from the sea. On Hawaii Island, one group was able to find the required moisture deep within cracks, lava tube entrances, and other voids in young unvegetated lava flows, and instead of feeding on wave-tossed debris, they fed on organic material carried out onto the young lava by wind. This adaptive shift opened up a new habitat with a rich resource much larger than any available on the mainland and thus the new population was able to expand and adapt rapidly to the new environment and evolved into C. fori. This cricket is so highly specialized that it lives only on unvegetated lava flows near Kilauea Volcano. It is strongly nocturnal and colonizes new flows within a month after an eruption, long before macroscopic plants appear. It disappears by the time the lava becomes vegetated (Howarth, 1979). The habitat is a rigorous one, but this is no hardship to the nearly continuously active Hawaiian volcanoes, since new flows cross older flows before the latter can become vegetated. Thus, the habitat that it had to adaptable was probably as long as the island of Hawaii has been subaerial, i.e. ca 400,000 years (Epp, Personal communication). Either the lava flow cricket itself or one of its congeners found another wet rock habitat within the voids and caves of young lava flows on Hawaii Island. Basaltic lava, particularly pahoehoe, is so porous that the species has evolved to exploit this subterranean resource on Hawaii Island. Compared to its surface relatives, C. varius has vestigial eyes, thinner, paler transverse cuticles, longer thinner appendages, particularly the hind legs, and a lower metabolism with no sign of gas vesicles. It is certainly not as well-adapted to an underground environment. The remarkable similarity of cave crickets were found allopatrically in neighboring karstic areas in temperate Europe, where they constitute a new genus with a prefix either "Speo-" or "Troglo-", and their relatives, also blind, would be sought in some boreal forest rather than among the big-eyed crickets among the neighboring wet rock habitats.

The evidence suggests that troglobites evolve from preadapted habitual visitors or accidentals in troglophiles. The former group requires an adaptive shift in order to fully exploit the cave resources. This adaptive shift may lead to the evolution of a troglobitic lifestyle. Well-adapted troglobites on the other hand tend to remain opportunistic exploiters of the cave environment. Some temperate troglobites may fit the scenario of isolation by changing climates (Barr, 1968). However, many species included those in the tropics probably do not fit this scenario. I postulate that the broad colonization of caves and evolution of troglobites, including most of those in temperate caves, but that the complex geological history of the continents including glaciations has obscured the early history and obfuscated the earlier distribution and the evolution of troglobites there.

Acknowledgements

I thank Ms. J. A. Short, Bishop Museum, for translating the abstract into French, Dr. J. R. Dalrymple, Bishop Museum, and Mr. C. A. Epp, University of Hawaii, for commenting on the manuscript, and Dr. David Epp, Hawaii Institute of Geophysics, for information on the ages of the Islands. To Mr. R. C. A. Rice and Dr. D. Otte, Philadelphia Academy of Science, should go the credit for the recent discovery of the seacoast species of Caecemobius from Maui Island, thus isolating the inland populations. Most of the research was supported by National Science Foundation Grants, numbers GB 23075, DEB 75-23106, and DEB 79-04760 to the author.

Literature Cited


During the days 10 and 11 of September 1979 the western part of Cuba suffered the effects of a Tropical Cyclone which according to the meteorological categories was only a depression. But this depression whose name was Frederic has not the strong winds that are necessary to be placed a hurricane but was followed by an enormous area of precipitations.

The amount of 500 mm of rain reached in the pluviometer of the international airport "José Martí" of Havana, constitute a new record in the cyclonological history of Cuba for a period of 24 hours. By this reason a great part of the mentioned airport and the surrounding part of the town, like others areas situated some kilometers to the west and to the south, were covered with several meters of water which could not drain by the surface because this mentioned flooded areas are situated in karstics depressions.

During the days 10 and 11 of September 1979 the western part of Cuba suffered the effects of a Tropical Cyclone which according to the meteorological categories was only a depression. This depression whose name was Frederic has not the strong winds that are necessary to be placed a hurricane but was followed by an enormous area of precipitations.

About the biggest amount of rain fall in Havana Province, which was very flat and mainly in the central and south part with a narrow chain of elevations in the northern part.

During an aerial exploration done after the tropical depression "Frederic" when it passed through the western part of Cuba on September 10 and 11, we shall present some of the karstic-geological elements which, jointly with the great rains, made possible the great flood we mention above.

Ariguanabo basin

The Ariguanabo basin has a total area of 185,6 km² and it is formed by the sub-basin of Gorea, 64,4 km², the sub-basin of the Ariguanabo lake, 108,5 km² and the sub-basin from San Antonio river, 12,3 km². This river, as we have already said, constitutes the superficial natural drain of the whole Ariguanabo basin.

The pluvial precipitation average is 1,600 mm, infiltration 0,30, which makes the average volume to be exploited almost 74,000 m³.

This basin is a complex one, for it does not have a geological nor structural uniformity, having also a great lithological variability. From a topographic point of view it is a well-defined basin.

The Ariguanabo lake is the largest of all its sub-basin, and its origins are due to the processes of denudation and flattening that have been shaping this area. All the superficial and subterranean flows converge in this area and at the same time carry putrid organic materials, as well as the products of erosion, lixiviation and decalcification, that have obstructed the subterranean conduits.

In the undersoil of the lake there is an abundance of limestone and marly limestone with some sandy layers of the Inferior Miocene to the Mid Miocene, with the presence of cavernous and typical limestone of the Güines Formation.

There are compact sediments of low porosity which act as retainers of water and belong to the Oligocene, as well as to the Superior Oligocene, mainly in its marly stages.

The presence of these low permeability rocks is what retains the water in the undersoil and does not let it go beyond it.

These geological elements favoured the storing of millions of cubic meters of water in the Ariguanabo lake in the days subsequent to the tropical depression.
Geological studies made in our country have demonstrated that there is no real and well-defined limit between Ariguanabo and Vento basins. In some plains such as the ones between the villages of Rincón and Murgas there is a contribution of the Ariguanabo basin to the Vento basin. This circulation has taken place when the groundwater level has reached 60 meters of altitude, which can be achieved after intense and continuous rains, when the undersoil has become saturated. This circulation takes place in the direction already mentioned, from Ariguanabo to Vento, through deep cracked rocks that are known to exist in the Northeast generally. This circulation between the basins of Ariguanabo and Vento when the groundwater level has reached 60 meters of altitude, is what contributed partly to the rapid flood of Boyeros area, which belongs to Vento basin, as all the springs of the zone became artesian and most of the ponores became springs, as it happened in Aguada del Cura. Talking with the neighbours of that area, they told us that the water had come from the Northwest just like the sea and in a few minutes all was flooded. We must point out that because the force of the flow opened the fossilized ponores, many of these areas were immediately drained, probably because they run into other basins, as Vento basin was completely saturated and its level was several meters above the surface of the land.

Geological studies made by the engineer Jesús F. de Albear show that the variations detected in the equipotential curve in water wells, during several years of observations, including those with great cones of influence such as the city aqueducts, have demonstrated that in natural, adequate and normal conditions, the subterranean waters should have overflowed from Ariguanabo lake to Vento basin. San Antonio de los Baños river This river feeds itself from the overflow of Ariguanabo lake from the south till it sinks its ponor and continues its course underground. In several occasions gauging has been done in two places on the San Antonio river, one of them at the outlet of Ariguanabo lake and the other one some 200 meters before its submergence within San Antonio village. After comparing both measurements it is obviously deduced that the river receives subterranean contributions that have a great influence on its flow. These contributions have been studied by the author. Many of them manifest themselves as potential springs in the bank of the river as well as in the form of minor subterranean currents that flow from small caves near the bank of the river.
Alpine Karst in the Sierra Nevada, California
Bruce W. Rogers

Abstract
Small areas of alpine karst have developed in the Sierra Nevada in calcitic to dolomitic marbles in roof pendant rocks from Ordovician to Triassic age as well as Recent travertine. The karst areas are located along the upper easterly portions of the Sierra Nevada from Yosemite National Park at an elevation of 2500 m southward past Mount Morrison to 3050 m, Kaiser Peak to 2700 m, Big Pine Creek to 3400 to 3600 m southwest of Mount Balding, to the west slope of the Mining District, located on the east slope of the Sierra about 30 km east of the Kaiser-Twin Lakes area. Many caves occur in the calcitic marble of upper (?) Paleozoic age. The marble portion of the pendant is about 5.6 km long, up to 500 m wide, and at least 2 km deep with a N. 20° W. strike and vertical dip (Bateman, 1956). Most of the marble is calcitic. Although the marble occurs at elevations of between 2875 and 3630 m, most of the solution cavities thus far encountered have been located between 2875 and 3335 m in the upper workings of the Pine Creek Mine. When the Zero Adit of the mine was driven, large amounts of water were drained from the caves at rates of up to 7600 liters per minute, and at pressures of up to 11.0 kg per cm. The caves were found adjacent to the cave mouths. The passages are up to 6 m in width and 60 m in length and parallel to the strike of the talus and marble. Many are loosely filled with gravel, sand, and cobbles of marble, granite, and talc. The bedding of the sands ranges from horizontal to nearly vertical with the latter being more common. Some of the sand fillings have undergone leaching as evidenced by saucer-like depressions 1 to 2 m in diameter. The marble is covered by a series of small karst springs that emerge from talus. About 75 m above the springs is a 2 m wide, partially blocked deep pit with a large inaccessible room at its bottom.

Introduction
Small areas of alpine karst occur along the crest of the Sierra Nevada in California. These areas are located in small lenses and pods of carbonate roof pendant rocks atop the western margin of the Batholith. The rocks include calcite to dolomitic marbles which are remnants of a former metamorphic terrain. The roof pendant rocks range in age from Pennsylvanian to Triassic with one small area of Holocene travertine. The marbles display a generally linear foliation striking about N.-E. parallel to the regional foliation.

Yosemite National Park
The northernmost known karst area occurs along the west slope of the Sierra Nevada in Yosemite National Park at an elevation of from 2300 to 3980 m. The roof pendant rocks here are composed of upper Paleozoic to Triassic age carbonate rocks. The white, coarse-grained marble is locally mantled with till (Wahrhaftig, 1955). The karst area includes a series of small karst springs that emerge from talus. About 75 m above the springs is a 2 m wide, partially blocked deep pit with a large inaccessible room at its bottom.

Pine Creek Area
Caves also occur in the Pine Creek Tungsten Mining District, located on the east slope of the Sierra about 30 km east of the Kaiser-Twin Lakes area. Many caves occur in the calcitic marble of upper (?) Paleozoic age. The marble portion of the pendant is about 5.6 km long, up to 500 m wide, and at least 2 km deep with a N. 20° W. strike and vertical dip (Bateman, 1956). Most of the marble is calcitic. Although the marble occurs at elevations of between 2875 and 3630 m, most of the solution cavities thus far encountered have been located between 2875 and 3335 m in the upper workings of the Pine Creek Mine. When the Zero Adit of the mine was driven, large amounts of water were drained from the caves at rates of up to 7600 liters per minute, and at pressures of up to 11.0 kg per cm. The caves were found adjacent to the talus and marble. Many are loosely filled with gravel, sand, and cobbles of marble, granite, and talc. The bedding of the sands ranges from horizontal to nearly vertical with the latter being more common. Some of the sand fillings have undergone leaching as evidenced by saucer-like depressions 1 to 2 m in diameter. The marble is covered by a series of small karst springs that emerge from talus. About 75 m above the springs is a 2 m wide, partially blocked deep pit with a large inaccessible room at its bottom.

Kaiser Peak-Twin Lakes Wilderness
The Kaiser Peak-Twin Lakes karst area lies about 40 km farther southwest of Mt. Morrison. The karst area occurs in upper Paleozoic or Triassic-age carbonate rocks. The caves are located in the calcitic marble portion of the roof pendant rocks. Karst features in the upper workings of the Kaiser Peak Mining District are filled with calcitic sediment. The caves have a nearly horizontal dip. The caves are located in the calcitic marble portion of the roof pendant rocks. Karst features in the upper workings of the Kaiser Peak Mining District are filled with calcitic sediment. The caves have a nearly horizontal dip. The caves are located in the calcitic marble portion of the roof pendant rocks. Karst features in the upper workings of the Kaiser Peak Mining District are filled with calcitic sediment. The caves have a nearly horizontal dip.
long roof pendant of Triassic-age metamorphic rocks (Christensen, 1963). Some karst is present in the Middle of Mineral King Valley in Holocene-aged travertine. At the northern end of the valley there is a 2 km long lens of marble containing an active sinkhole plain at an elevation of 2940 m. Large amounts of soil and vegetation are being washed into the 10 m deep sinkholes and cutters. A large spring 180 m below the sinkhole plain may be the resurgence of the karst water (Tinsley, and Fény, 1978). Jordan Cave, a 90 m long, 43 m deep decorated cave, and Glacier Flug Cave, a 6 m deep flirnplugged pit, are located in this area. Emu Mine Cave is located 1.5 km to the east of the sinkhole area, at an elevation of 3100 m. The cave was blasted open during mining operations in the late 1870's. Large amounts of water were moved by Tioga glaciation. With the waning of the ice floor covers the bottom of the main chamber due to the lack of warming water and entralled air normally brought in by the stream. Located high on the western wall of Mineral King Valley is a 1.5 km long lens of calcite marble. Water flowing from Eagle Lake descends to the marble and sinks in a series of swallets at an elevation of about 2740 m. Several breakdown-choked vertical solution tubes are found along the walls of the blind karst valley that bisects the marble. At the northern, lower end of the marble lens, a large, 70 m spring resurges at 2610 m. Water from the swallets moves down the lens through solution passages along the strike and emerges at this spring. The spring has a half discharge of 2.6 m³/sec, the spring is an 18 m high travertine mound with several very small caves. The stream is actively deepening calcite cones by flowing directly and slowly filling these caves. Another travertine mound is located 1.6 km down the Kaweah River from Spring Creek. Several small caves are located in it. The travertine was deposited from groundwater derived from the sinkhole plain and the marble lens draining Eagle Lake. Subsequent undercutting by the Kaweah River has drastically lowered the travertine and scattered the blocks along the river channel.

Age of the Karst

There is some evidence, especially in the Kaiser Peak-Twin Lakes, Pine Creek, and Mineral King areas that the initial solution of these caves was started in late Wisconsin time; perhaps during the allothermal period between the Tahoe (70,000 ybp) and Tioga (10,000 ybp) glaciations. Surface karst features, and to some extent the caves themselves, were removed by Tioga glaciation. With the waning of the glaciers, sediments were deposited in the caves in some cases filling them. Subsequently moderate amounts of these sediments have been removed from the caves and passages near base level enlarged by seasonal streams (Rogers, 1980).

Conclusions

The karst features of the Sierra Nevada are located in Paleozoic and Mesozoic deposits, they are strongly controlled by jointing and insoluble rocks in the marble. Most caves occur in calcite marble. Speleothems are scarce, but sediments are common, especially the coarser fractions. Many caves are portions of active hydrologic systems usually flowing in spring and draining in the fall. Portions of the caves may be pre-late Wisconsin glacial in age; other portions are undergoing active enlargement.

References Cited


Huber, N. K., 1981. Personal communication.


Rogers, B. W., 1980, Sequoia and Kings Canyon National Parks Karst Inventory: Unpub. manuscript, 328 p.

Soil Pipe Caves in the Death Valley Region, California

Bruce W. Rogers

Abstract

Under present climatic conditions, soil pipe caves are forming in the arid Death Valley Region of California. Two areas were studied: one in Pleistocene Lake sediments in the Lake Tecopa basin and one in Pliocene continental sediments in Cottonball Basin in Death Valley. In the Lake Tecopa locality, gradual upwale retreat of erosion surfaces first generate small vadose stream channels that generate small, 5 to 10 m long caves under a massive marl horizon after overlying alluvial fan deposits have been stripped. Breaching of the marl horizon and subsequent greater infiltration of thundershower waters has allowed larger caves to form in the underlying lake sediments. Caves up to 100 m long with roofs of 8 m diameter have been isolated. Thin marls and borate-cemented hardpan support the roofs of these caves. Secondary crusts of tincalconite on borax decorate the walls and ceilings as well as actively spalling blocks from the walls. Gypsum(s) and secondary stream sediments are also present. Breaching of the supporting hardpan allows roof collapse and subsequent transformation of these caves into gulies. At the Cottonball Basin the soils soil pipe away from the major desert pavements, approaching the density of tropical cockpit karst on a smaller scale. Secondary crusts of ulexite are seasonally common. Coalescing of aligned sinkholes gradually removes the roofs of these caves resulting in dendritic gulley complexes.

Introduction

Under present climatic conditions, suffosion caves are forming in the arid regions around Death Valley, California. These soil pipe caves occur in the finer-grained sediments present in the playa basins. Both lacustrine and continental sediments show piping features. Most of the cave enlargement takes place during the short, violent summer thunder showers characteristic of this region.

Tecopa Lake Basin

At the southeastern margin of Death Valley is a group of suffosion caves located in lacustrine sediments of the Lake Tecopa basin at an elevation of 425 m. Lake Tecopa was one of the many pluvial lakes existent during the Pleistocene. Deposits of this fine-grained sediment accumulated in the lake basin during most of this time (Noble, 1931). The sediments are buff to grayish tan siltstone with minor pale green bentonitic clay, white tuff, and tan to orange marl. Detailed sedimentological study of these beds has shown that they consist of mixed lacustrine and terrestrial sediments.

Cave development is initiated when the overlying sediments are stripped and the gravelly mudstone forms a desert pavement. Eventual breaching of the gravel layer initiates piping in lacustrine and continental fine-grained sediments. In addition, secondary deposition of salts assist in cave formation. Eventual solution of salts assist in cave formation. Eventual coalescing of sinkholes and bedrock rocks gradual removal of the roofs of these caves resulting in dendritic gulley complexes.

Cottonball Basin

Cottonball Basin is located 85 km to the northeast of Tecopa Lake in approximately the center of Death Valley. At this locality, Pleistocene and Holocene age sediments form a mixed lacustrine and continental fine-grained sediment. The sediments are assigned to the Lake Tecopa beds and are buff to grayish tan siltstone with minor pale green bentonitic clay, white tuff, and tan to orange marl. Detailed sedimentological study of these beds has shown that they consist of mixed lacustrine and terrestrial sediments.

Cave development is initiated when the overlying gravel is stripped from the Funeral Formation. Infiltration of torrential rainwater and subsequent piping remove the silt-sized fraction of the sediments. Capillary action deposits halite and ulexite at the surface of the cave floors causing ridge-like ground patterning. Subsequent rainfall is channeled into the cracks separating the polygons and localizes pitting and minor solution at the intersections of the cracks. The spacing of the sinkholes closely approximates that of the polygon intersections. The sinks enlarge at the expense of the polygons, sapping them until a surface very similar to tropical cockpit karst is formed. Small caves, less than 1 m in diameter and 20 m long, form under this surface (Hunt, 1974). Relief on the pan surface is limited to the local base level which is located about 7 m below the polygonal pan surface. The polygonal ground pattern is aided in spreading by the formation of low ramps along the gravel-siltstone contact. Sheetwash is ponded at this rampart and increased sapping of the gravel allows piping to develop in the newly-exposed siltstone. In the interior of the pseudokarst field, waters divide and form small waterfalls and cave roof collapse allow dendritic gulley complexes to form.

Conclusion

Suffosion caves are forming in the Death Valley region under present climatic conditions. Stripping of overlying desert pavements allows rainwater to initiate piping in lacustrine and continental fine-grained sediments. Eventual breaching of the marl horizon and subsequent greater infiltration of thundershower waters has allowed larger caves to form in the underlying lake sediments. Caves up to 100 m long with roofs of 8 m diameter have been isolated. Thin marls and borate-cemented hardpan support the roofs of these caves. Secondary crusts of tincalconite on borax decorate the walls and ceilings as well as actively spalling blocks from the walls. Gypsum(s) and secondary stream sediments are also present. Breaching of the supporting hardpan allows roof collapse and subsequent transformation of these caves into gulies.

References Cited

Karst Development in Siliceous Rocks, Venezuelan Guiana Shield

Franco Urbani
Department de Geología, Universidad Central, Apartado 47.028, Caracas 1041 A, Venezuela

Abstract

In the Precambrian shield area of southern Venezuela, there are extensive outcrops of non-calcareous quartz sandstones, siltstones, shales and conglomerates, all slightly metamorphosed and belonging to the Roraima Group. Those rocks are exposed as table mountains in which exceptionally large sinkholes (up to -314 m) and long caves (up to 1350 m) have been discovered. The area is covered by a thick jungle with rainfall of as much as 4 m per year.

Several hypotheses have been proposed to explain the development of the different cave types:

I) Hydrothermal alteration of the quartzite, softening the rock and loosening the quartz grains and subsequent enlargement of caves by piping. Examples: Simas mayor and Menor de Sarisarinama.

II) Chemical weathering of quartzite, especially along highly fractured zones near the edges of the scarps, and mechanical removal of the grains. Examples: Cuevas de Urutany.

III) Chemical weathering of originally softer rocks, as shales (mainly kaolinite), finely stratified siltstone and conglomerates. Examples: Cueva del Conglomerado and Cuevas de Guaiquinima.

IV) Open fractures near the edges of scarps, with possible enlargement by weathering and grain removal. Example: Cueva del Abismo.

Cave mineralogy shows very rare assemblages as opal, chalcedony, lithiophorite, iron and manganese and organic materials, pigotite, evansite and a new mineral: sveite.

All of the above mentioned phenomena are not rare but rather widespread and form one of the most unusual karst types of the world.

Resumen

En el escudo Precámbrico del sur de Venezuela, existen extensas zonas cubiertas de rocas no calcáreas, como areniscas cuarzoas, limolitas, lutitas y conglomerados, todas ligeramente metamorificadas y pertenecientes al Grupo Roraima. Estas rocas están expuestas formando extensas mesetas, en las cuales se han descubierto simas excepcionalmente profundas (hasta -314 m), así como largas cuevas (hasta 1350 m). El área en general, está cubierta por una espesa selva con alta precipitación de hasta 4 m al año con pH de 3,5 a 4,5.

Varios mecanismos se han propuesto para explicar el desarrollo de los diferentes tipos de cuevas, a saber:

I) Alteración hidrotermal de la cuarcita, ablandando la roca y soltando los granos de cuarzo, con posterior formación de cuevas por "piping". Ejemplos: Sima Mayor y Menor de Sarisariñama.

II) Meteorización química de la cuarcita, especialmente a lo largo de zonas muy fracturadas cerca de los bordes de los acantilados, posterior remoción mecánica de los granos. Ejemplo: Cuevas de Urutany.

III) Meteorización química de rocas originalmente blandas, como lutitas formadas esencialmente de kaolinita, limolitas finamente estratificadas y conglomerados. Ejemplos: Cueva del Conglomerado y cuevas de Guaiquinima.

IV) Fracturas abiertas cerca de los bordes de los acantilados, con ensanchamiento por meteorización y remoción de granos. Ejemplo: Cueva del Abismo.

La mineralogía de espeleotemas muestra asociaciones muy raras, como ópalo, calcedonia, litioforita, oxiróxidos de hierro y manganeso, materiales orgánicos, pigotita, evansite y un mineral nuevo: sveita.

Los fenómenos mencionados no son raros, sino mas bien extendidos y frecuentes en el área de Guayana, formando uno de los tipos de carso mas apartados de lo normal.
Vertebrate fossils in lava tubes in the Galápagos Islands

David W. Steadman
Department of Geosciences, University of Arizona, Tucson, Arizona 85721

Abstract

Collections of fossil vertebrates have been made recently in the Galápagos Islands. Lava tubes on the large islands of Santa Cruz, Floreana, and Isabela have yielded rich fossil deposits, while a reconnaissance of three of the smaller islands (Genovesa, Plaza, Santa Fé) has been unproductive. Fossils in lava tubes are deposited in tube roofs, through the feeding and excreta from rodent carnivals (Tyto alba punctatissima), and the capacity of the roof collapse to serve as a natural trap. Many of the fossils are mineralized, so definitive statements regarding certain aspects of the fossil fauna are not possible at present. Highlights of the fossils from Cueva de Kubler are the following:

1. Land and marine iguanas (Conolophus), are either absent or a found at higher elevations.
2. Large vertebrates, such as adults of tortoises (Gopherus), land iguanas and Megaoryzomys in sites on Isla Santa Cruz and Isabela that are not effective natural traps, and various birds in sites on Isla Floreana, are not possible at present. Highlights of the very rich deposit in Cueva de Kubler, Isla Santa Cruz, are ascertained by the fossilization of native versus introduced species. Deposits on Isla Isabela are significant mainly for documenting the former existence there of Nesoryzomys and Megaoryzomys. Fossil sites on Isla Floreana are dominated by remains of tortoise (Geochelone), mockingbirds (Mimus trifasciatus), and ground finches (Geospiza magnirostris), each of which is now presumed to be extinct on Floreana.

The terrestrial vertebrates of the Galápagos Islands have been very well documented, but there is a lack of evidence for these rodents in earlier stratigraphic units. During three trips to Galápagos (17-1 January 1978, 30 July - 8 August 1978, 1 October 1980 - 6 January 1981), I collected fossils of reptiles, birds, and mammals from lava tubes on Isla Santa Cruz (Indetigable), Floreana (Charles), and Isabela (Albatross), as well as other larger islands in the archipelago. Thorough searches of the smaller islands of Genovesa (Tower), Plaza, and Santa Fé (Barrington) produced nothing of paleontological interest. The collected fossils, most of which will be deposited in the United States National Museum of Natural History, Smithsonian Institution, represent the first serious paleontological attempt to document the evolution and past distribution of vertebrates in Galápagos.

The fossils gathered during the first two trips are largely derived from the terrestrial iguanids (Conolophus), and certain avian groups such as Darwin's finches, the identifications are still somewhat tentative. Fossils from the most recent trip are presently being cleaned and sorted. Thus this report is but a preliminary summary of my findings as of March 1981.

The Galápagos are characterized by a general lack of alluvial deposits, there being only one functional fresh water stream in the entire archipelago. Most of the fossil sites located thus far are in lava tubes with roof collapses, while one is in a large earthquake fissure. The fossils in each deposit are derived from one or both of two very different roosting habits of barn owls, or the action of natural traps. Ancient barn owl roosts are almost entirely responsible for two sites on Isla Santa Cruz (Cueva de Kubler and Cueva de Iguana), while natural trap sites include Andrés Cave on Santa Cruz and all of the localities on Isla Isabela.

That the barn owl, Tyto alba punctatissima, was responsible for the deposition of fossils in Cueva de Kubler and Iguana is ascertained by the following characters: 1. The sediments lack laminations or any sort of distinct stratigraphic units. This, in combination with the random orientation of the fossils themselves, argues against a fluvial or aeolian origin. 2. Large vertebrates, such as adults of tortoises (Geochelone) and land iguanas (Conolophus), are either absent or extremely rare. The fossil fauna almost entirely consists of specimens of a size well suited for prey items of Tyto. Especially noteworthy in this regard is the overwhelming dominance of the rodent Nesoryzomys indifessus, as Tyto today is known to be very abundant on Santa Cruz. Also important is the age distribution of the very large, extinct rodent Megaoryzomys curioi. Most fossils of M. curioi in Cueva de Kubler and Iguana are of all, immature individuals; the relative scarcity of fully grown adults suggests that such animals were too large to be taken as prey by Tyto. In contrast, Andrés Cave, a proposed natural trap site, has abundant remains of adults of M. curioi, while immature specimens are rare. Bony accumulations in natural traps tend to be concentrated near the entrance (roof collapse) of the lava tube in either situation, but in natural traps the fossils are randomly accumulated below the entrance, thinning as one goes farther from the entrance. In ancient barn owl roosts, the fossils are distinctively accumulated below wall ledges that served as the roost.

Certain fossils may represent animals that voluntarily entered the lava tube and died there. In many instances these fossils are difficult or impossible to distinguish from natural trap occurrences or isolated prey remains. However, adults of land iguanas and Megaoryzomys in sites on Isla Santa Cruz and Isabela that are not effective natural traps, and various birds in sites on Isla Floreana, are not possible at present. Fossil vertebrates in lava tubes.
from the overflow of the thick sediment accumulation above Exc. IIB. This accretion therefore occurred since the arrival of introduced rodents, probably no more than 60 years ago.

Unfortunately, Exc. IIB yielded nearly no plant material, but instead consists mainly of bones, land snails, and fine inorganic sediment, none of which is very well suited for radiocarbon dating. Two additional excise (IIC) were carried out in Cueva de Kubler in 1980, from which fossils are now being cleaned and sorted. Based on field identifications, Exc. IIC (4 m down) from IIB appears to be very similar to Exc. IIB in faunal and sedimentary features. Exc. IIA, however, contains carbonized plant fragments that are well suited for radiocarbon dating. In addition, Exc. IIA is located above Exc. IIB and IIC in a horizontal section of fine-grained but boulder-ridden sediment that is not living against the north wall of Cueva de Kubler and is separated laterally from the talus slope by a longitudinal series of boulders. The sedimentary features of Exc. IIB and IIC through simple gravitational slumping. Thus it appears that the fossils of Exc. IIA are in a re-deposition like those of Exc. IIB and IIC. Exc. IIA (1.0x3.0x0.8 m deep) was conducted in vertical increments of 0.2 m and horizontal increments of 0.5 m. Most units contain plant fragments associated with hundreds of land snails and hundreds to thousands of vertebrate fossils. A preliminary scan of the thousands of specimens of rodents reveals the presence of Rattus and Mus only in the surficial portion of Exc. IIA. As in Exc. IIB and IIC, these remains are fresh and unmineralized, unlike the dark, mineralized fossils of Nesoryzomys and Aegoporyzomys.

Two aspects of the fossil birds of Cueva de Kubler are particularly interesting. Firstly, no fossils of the mockingbird (Mimus polyglottos), yellow warbler (Dendroica petechia), or medium ground finch (Geospiza fortis) have been identified in Exc. IIB, nor have they been found in a brief perusal of Exc. IIA. Each of these birds is a conspicuous member of today's avifauna near Cueva de Kubler. As revealed by prey remains of prey remains of these species are preyed upon today by Tyto. Therefore, if C. melanopychus, D. petechia, and G. fortis also prove to be absent from the faunal assemblage of Exc. IIA (which contains several thousands of avian fossils), I believe that these three species did not occur on Isla Sante Cruz at the time of deposition of fossils in Cueva de Kubler. Through radiocarbon dating, it will be possible to state a maximum date for the colonizations by these species. No radiocarbon ages have yet been determined for Cueva de Kubler. Thus it appears that tortoises also occur in high numbers at these sites. Historical records show that tortoises have been extirpated from Floreana Island since the mid-1800s (Broom 1929). Three radiocarbon ages on surficial material from Cueva de Post Office (Inferior) have been determined at the University of Arizona. They are A-2088 (wood, Bursera graveolens) 990 ± 120 yrs. BP; A-2089 (wood, Prosopis subflava) 80 + 110 yrs. BP; and A-2090 (horny scute, not bone, of shell of tortoise (Geochelone) 310 ± 80 yrs. BP. All ages are corrected for 14C as reported. Thus it appears that organic material has been accumulating in this cave for at least 1000 years.

Acknowledgments

Field work was funded mainly by Fluid Research Grants from the Smithsonian Institution, through S. Dillon Ripley and Storrs L. Olson, with assistance from the Graduate Student Development Fund, University of Arizona. I thank the personnel of Charles Darwin Research Station and Parque Nacional Galápagos for permission and cooperation during field work. Martha José Campos, James R. Hill, III, Miguel Pono, and Edward N. Steadman amably assisted in the field. Work facilities and funds for museum research were provided by the United States National Museum of Natural History, Smithsonian Institution (Visiting Student Development Fellowship), and the Laboratory of Paleoenvironmental Studies, University of Arizona (NSF Grant DEB-7923840 to Paul S. Martin). Funds for additional museum research were provided by the National Geographic Society. This is contribution number 294 of the Charles Darwin Foundation for the Galápagos.

Literature Cited

Steadman, D. W. and C. E. Ray. ms to be submitted to Smithsonian Contributions in Paleobiology. The relationships of Nesoryzomys curiosus, an extinct cricetine rodent from the Galápagos Islands, Ecuador.
Isopods (Oniscoidea) from Caves in North America and Northern South America

George A. Schultz
15 Smith St., Hampton, N. J. 08827

Abstract

Probably all species of Oniscoidea except some from very dry regions can live in caves. Soil inhabiting species which normally live in dark, damp, highly organic places are able to get food in caves. They are usually lightly pigmented and have few or no ocelli when compared to their relatives from North America. Some examples from North America are in the genera Scleropactes and Tritchorhina. Some races, subspecies or even species have become locally adapted to life in caves and they have little or no body pigment and less developed or no eyes when compared to their soil dwelling relatives. They are in genera such as Ligidium and Miktoniscus, from the ground, and Cylindroniscus are truly adapted to cave life.

The species always are without body pigment or eyes and spend their whole life in caves. In the New World they are in the families Trichoniscidae and Philosciidae from about the ground. Most species in some genera (e.g., Brackenridgia and Cylindroniscus) are truly adapted to cave life.

Most subgroups of oniscoids are distributed worldwide which suggests that they evolved early, perhaps in the Paleozoic Era just before continental drift took place. There is good evidence that the closest relative of a trichoniscid from a cave in Spain is a trichoniscid from a cave in Mexico. The species always are without body pigment or eyes and spend their whole life in caves.

Some Genera from Caves in North America

Mexico, Cuba, Central America and northern South America. All species of Philosciidae from caves in the New World are from the tropics. The members of this family are the best represented among the isopods of caves in the tropics. All species of Philosciidae from caves in the New World are from the tropics. They are present in caves from California, New Mexico, Arizona, Texas, southern South America, South America and Colombia. The number of species of Philosciidae in each genus is in parentheses.

Colombophiloscia Vandel (1)

Halophiloscia Schultz (1)

Some species from Texas, New Mexico, Arizona, Texas, south through Mexico, even to caves near the border of Mexico and Peru.

Colombophiloscia--The genus is defined on a pigmentless blind species, R. aequatorialis, from Peru. Other species have been described from caves in northern, central and Yucatan, Mexico (Shultz, 1970a).

Mexiconiscus--The species of this genus are from caves in the tropics. The evolution of the two species (one in a different genus) can be shown to be related to the breaking apart of North America and Burasia by continental drift. Both species live in the water of cave pools (Vandel, 1965c).

Rothia riojensis--Only one species has been described. It is so far, the only one species has been described from caves. It is from Yucatan; the other from Cuba. The species appear to be well adapted to cave life. They also have more spindly appendages when compared to other members from non-cave locations (Brian, 1929; Schutz, 1977).

Colombophiloscia--Non member of the poorly defined genus have been recorded from Colombia, but one species is from Venezuela (Vandel, 1976).

Hawaiiscia and Halophiloscia--Each genus has only one species. They are pigmentless and without ocelli and live in lava tube caves in Hawaii (Schultz, 1973).

All genera in the family Trichoniscidae are located in temperate and tropical regions of North America from generally south of the continental glaciation line to southern Mexico. Genera in the family Philosciidae are located only in the tropics in Cuba, Guatemala and northern South America. The ranges of the genera of each family are primarily distinct, but the region of possible overlap, Yucatan, Guatemala and Cuba has not been thoroughly explored. According to Vandel (1965b:130) isopods are not commonly present in caves in the Old World tropics. However, species from caves in the Old World are common. Indeed, most of the species are from Mexico, Cuba, Central America and northern South America all of which are tropical. Those from the
The United States are from temperate regions and many are from caves in the dry southwestern part of the country.

**Discussion**

Vandell (1965b:128) stated, conservatively I think, that there are about 2000 species of oniscoids. Of the 2000 species, 70% are endemic to caves. He further stated that of the 230 cavernicolous species, 152 or about 70% were troglobions in the broad sense. The trogloniscids (family Trichoniscidae) are also the most common species in caves in North America. Vandell also stated that of the 230 species of cavernicolous oniscoids only 22 have been found in caves in the tropics which he considered to be truly troglobiontic. They were Troglophiloscia silvestrii (Cuba), Setaphora (Philosciidae) and Trogleubelum tenebrarum (Zaire). It appears that of the 2000 species, 230 are cavernicolous or live exclusively in caves. Vandell also stated that of the 230 species of troglobiontic oniscoids, only 22 have been found in caves in the tropics. The trichoniscids, which live in caves, the two species of Philosciidae are not known to me. However, species of oniscoids which I have recently described from caves in Sarawak, Borneo, which include species of Setaphora which are adapted to the caves and they were not different from specimens collected outside the caves. Species from caves in the tropics many times have been confused with species from the thick organic matter near the caves. From this dense organic matter habitat they easily can move into the caves.

In terms of the time of speciation of forms which live in caves, the two species of Philosciidae each in a separate genus from lava tube caves in Hawaii (not more than 6 million years old) might be cited (Schultz, 1973). The species apparently evolved from some species of the Latirolinae and have become pigmented and without ocelli all within the course of 6 million years. Whether pigment and eyes can be lost in this short time in other species of Philosciidae from caves in the tropics or anywhere must be subjected to further research.

**Evolution**

The oniscoids (suborder Oniscoidea) are first encountered in the fossil record in the Eocene part of the Paleogene Period about 50 million years ago. Since the earliest fossils are not much different from species living today, their evolution must go back many, many years. Vandell (1945) stated that by far most subgroups of oniscoids are worldwide in distribution their differentiation from the parent stock of lineages from the Mesozoic Era or more than 185 million years ago. This was before the beginning of continental drift so most subgroups got transported from the early continental supermasses into what is now North America and Eurasia. When the land mass split the members of the family were isolated early in their phylogenetic history and have evolved into two different groups of genera since the continents split.

The species of Philosciidae from caves apparently are more tropical and local in distribution and their higher category evolution, if it occurred, is not at all clear. Species from caves of the other families of oniscoids are even less known and their evolution, except for a few species, are not known.

**Literature Cited**


The study area includes about 300 km² in the Inner Bluegrass Karst Region of Central Kentucky, USA. It is underlain by nearly horizontal Middle Ordovician limestones with minor amounts of shale and other lithologies. The principal investigative tool has been water tracing using optical brightener and direct yellow dyes with cotton fabric detectors. The following methods are used for the absorption of these dyes and fluorescein dye crystals. Cotton fabric dyes are capable of absorption onto untreated cotton. In no case has a dye introduction appeared at more than one spring, although at high flows numerous overflow routes may appear near the spring.

Groundwater flow in this area is in at least 11 groundwater basins (Fig. 1). Three of these (Royal Spring, Russell Cave, and Slacks Spring) have areas in excess of 20 km², while 3 others (Lindsay Spring, Silver Springs, and Vaughns Spring) have areas between 10 km² and 20 km². The larger springs have base flows of about 50 l/s and peak flows in excess of 2000 l/s. The others have base flows of about 20 l/s, with peak flows in excess of 500 l/s.

Groundwater basins may or may not correlate with surface basins. Majors springs in basins such as Silver Springs (Spring Lake, Gents, and Gano) have drainages in other basins. Where surface streams exist, groundwater flow is often at an angle to surface flow direction. This is characteristic of the drainage systems in other basins. Where surface streams may exist, groundwater flow is often at an angle to surface flow direction. This is characteristic of the drainage systems of the area.

Solution development is concentrated in the central and downstream parts of groundwater basins, as indicated by dye traces; greater development of surface karst features, especially sinkholes; and greater conduit development, where accessible. Near groundwater springs, solution development is shallow or nonexistent and surface streams may exist. Depth of sinkholes (especially karst windows) and vertical relief along assumed flow paths indicates most solution development occurs within 25 m of the surface.

Both stratigraphy and structure exert variable influence on the movement of groundwater throughout the area. Spring Lake Spring appears to be the only major high level spring in the region. It is apparently perched on a less soluble unit (Cane Run Bed) and the stream issuing from the spring eventually sinks below the unit, and later resurges at Lindsay Spring (Fig. 1). All other springs are perched on a less soluble unit (Cane Run Bed).
is unusual in that its flow passes beneath a major surface stream. Initially, North Elkhorn Creek, South Elkhorn Creek and Town Branch, the major surface drainages of the area, were assumed to form the boundaries of groundwater basins. Although this is probably the case in most of the area, a trace from McGee Sink to Vaughns Spring crossed under North Elkhorn Creek (Fig. 3), which must, therefore, overlie the Vaughns Spring groundwater basin. The mechanism controlling the crossing is not known, but may be related to a local impermeable bed. It does not appear to be due to alluviation. Elsewhere, groundwater flow has been found to cross beneath smaller surface streams (Fig. 2). A fourth example of flow along a diaclase is the Slacks Spring basin to the west of the Royal Spring basin. Flow along such diaclases is in accordance with the suggestions of earlier workers (Hamilton, 1950; Mull, 1968; and Faust, 1977).

Elsewhere in the study area, however, the relationship of subsurface flow to diaclases, mapped faults, and linear sinkhole trends is not obvious, and in the Silver Springs basin, flow from a swallow on a fault flows away from the fault at nearly right angles (Fig. 2). Furthermore, a substantial segment of the Slacks Cave basin flow conduit can be examined in Slacks Cave, whose passage morphology shows little joint control.

The four diaclases discussed above are approximately parallel to regional dip, and the flow in these basins is approximately down the dip, but in both the Lindsay and Silver Springs basins, flow crosses anticlinal and synclinal axes at nearly right angles (Fig. 2). Although such mapped anticlines may not actually exist (W. C. MacQuown, pers. comm., 1980), the lack of correspondence between groundwater flow and mapped structures suggests the latter cannot be used to predict the former. Except for Spring Lake Spring (discussed earlier), all 11 of the springs discharging groundwater basins emerge from nearly the same stratigraphic interval in the Grier Limestone Member from 6 to 18 meters below its top, and it appears that this major conduit development in the area is in the upper Grier Limestone Member.

References
Figure 2. Cross-section from Blackburn Swallet to Silver Springs (see Fig. 1 for location). Geology from Miller (1967); stratigraphic units are members of Lexington Limestone: M, Millersburg; T, Tanglewood; and G, Grier. Anticlines and syncline indicated with appropriate symbols. Note 20:1 vertical exaggeration.

Figure 3. Map of lower part of Vaughns Spring groundwater basin (see Fig. 1 for location). Topographic contours in meters.

555
In the alpine limestone regions it is possible to recognize a great variety of karst landscapes and types of karstic forms. Their evolution was controlled by multiple factors: morphometrical, lithological, structural, geodynamical and morphodynamical.

Some areas of karst plateaus with dolinas, and of summits with glaciokarstic features are described here.

From a few morphological and paleopedological characters it can be inferred that the main karstic morphogenetical phases are rather old, likely of lower Pleistocene, or older. The successive evolution of karst shapes experienced both the neotectonical uplift, and the climatic changes of Pleistocene. During the rising the plateau were dismembered by faulting. Besides, in the course of the cold periods, the periglacial and glacial processes modified the karst relief, obliterating many of the karst dolinas. The resulting landscapes present polygenetical and complex aspects.

**Abstract**

In the calcareous areas of the Italian Alps there is a great variety of karstic landscapes and morphological types. The evolution was controlled by the following factors:

- morphometric features of the relief (slopes, height, etc.);
- local lithological and structural situations;
- neotectonic events;
- interference with other, non-karstic processes of fluvial, glacial and periglacial type, related to the alternation of various climatic phases during the Pleistocene.

For purposes of comparison, it seems useful here to summarize the morphological situations regarding some areas of the Italian Alps as they emerge from preliminary studies, together with more specific data and examples taken from areas with evolved karstic morphologies which, during uplift of the anticline, alternated deepenings and bending by the anticline. The state of alteration of the paleosols occurring on the terraces indicates respectively the Riss, Mindel, Günz and Middle/Upper Pleistocene (S. Venzo, 1977). During the cold periods of the Pleistocene the dolinas were partially filled by thick deposits of loess.

**Résumé**

Dans les régions karstiques alpines on peut reconnaître une grande variété de paysages karstiques et de formes de leurs reliefs. Leur évolution a été influencée par plusieurs facteurs: morphométriques, lithologiques-structurelles, géodynamiques et morphodynamiques.

L'on décrit brièvement quelques zones karstiques alpines ayant le caractère de plateaux avec dolinas et sommets avec érosions glaciaires karstiques. Les aspects morphologiques et paléopedologiques permettent de reconnaître que les principales phases morphogenétiques karstiques de ceux reliefs sont plutôt anéolliennes, pour la plupart du Pléistocène inférieur ou du Mésocène. L'évolution suivante du relief karstique est assurée soit des événements néotectoniques, soit des variations climatiques du Pléistocène. Pendant le soulevement les plateaux karstiques ont été démembrés par l'activation de failles. En outre pendant les périodes froides s'est vérifié un démembrement des formes karstiques par des processus périglaciaires et glaciaires. Les paysages qui en résultent sont de type complexe et polygénétique.

**In the Venetian plain the large flexure scarp passing northwards to a large syncline in which the polje lies, and which is due to a faulted anticline. The karstic relief with dolinas is mostly modelled in Cretaceous reef limestones.**

**d) Innumerable dolinas, including large types of irregular shape, funnel- and shaft-shaped types. Many karstic shafts also open on the surface.**

**e) Dome- and cone-shaped hillocks occur in certain areas of the plateau between the dolinas.**

**f) Fuchs has identified three main erosional flat surfaces, the highest of which was modelled after the Upper Miocene uplift. The largest dolinas are found on this surface.**
of the wide old valley bottoms. A neotectonic fault scarp defines the main karstic area to the south. Thick tectonized concretionary deposits corresponding to the fault plane are correlated to an important phase of karstic erosion.

4) a) Lessini Mountains (Venetian Prealps, Fogli 36-48) (A. Pasa, 1954; U. Sauro, 1973, 1974). See Figure 4. b) Plateaus with dolinas and landforms of periglacial and fluvo-karstic type, at heights between 600 and 1600 m. c) Plateau with faulted blocks inclined towards the west. Neotectonic scarps and fault bluffs. The karstic landscapes are modelled in Jurassic limestone. d) Many large depressions are cut through the thick periglacial deposits of loess and cryoclastic fragments. Many dolinas are filled to the rim. e) Some irregular cone-shaped hillocks are to be found among the dolinas.
f) Around the dolinas, both polygonal pattern and alignments along hydrographical furrows may be recognized. The intense weathering of the karstic relief by cryoclastic processes during cold phases of the Pleistocene and the fossilization of many of the depressions by the loess cover are evident. The deflation areas of the loess corresponded to the nearby large morainic and fluvo-glacial amphitheatres of the River Adige and Lake Garda.


b) Plateaus with dolinas and landforms of periglacial and fluvo-karstic type, at heights between 600 and 1000 m. The various cone-shaped hillocks are interpreted by Chardon as relics of an old relief of the "Regelkrast" type which evolved in subatlatic climatic conditions towards the end of the Tertiary. The "terra rossa" present in some of the karstic depressions is largely composed of kaolinite and illite, and may be correlated with these old morphogenetic phases.

6) Circo di Moncodeno - Grigna Group (Lombard Prealps, Foglio 32) (A. Bini, G. Cappa & A. Pellegrini, 1976 and relative bibliography on Figure 5).

b) The glacial crique of Moncodeno is deeply karstified, at heights between 1700 and 2400 m.

c) The cirque is arranged in a faulted syncline with sides accentuated by fault scarps and, on its bottom, a step-like arrangement formed of small fault bluffs.

d) In the area of the cirque bottom at heights of less than 1500 m large irregular dolinas prevail.

Instead, the higher zone is dominated by pit-dolinas, shafts and grikes. The density of the pit-dolinas and shafts is locally extremely high (up to dozens per hectare).

e) Some small dome-shaped hillocks rise between the largest dolinas.

f) A preliminary morphological analysis shows the intensity of the glacial erosion with the aim of a deeply karstified tectonic relief. Glacial modelling was also favoured by Pleistocene neotectonic evolution, which accentuated the irregularities.

8) a) Conca delle Carsene - Margareis (Ligurian Alps, Foglio 91) (G. Dematteis, 1963; M. Julian, J. Nicod & C. Orengo, 1972). b) Plateau in which a large glacial trough between 1800 and 2500 m is dissected. c) Faulted syncline with many evident scarps and fault bluffs, partly neotectonic. The limestones are of the Jurassic and Cretaceous.

d) Some large glacio-karstic depressions are to be found both along the Conca della Carsene, and near the edge of the large northern scarp. Dolina fields cover the flat northern ridge between 1900 and 2100 m. The bottoms of the glacio-karstic depressions are areas of very high density of shafts, although these are also found in other positions.

e) Some dome-shaped hillocks are located in the dolina areas.

f) This territory shows the pre-existence of a plateau of karstic erosion which cut off the main tectonic structures. Glacial erosion later operated efficiently in the fossil area. The fossil zone of the syncline which shows many glacio-karstic depressions corresponding to very numerous absolving cavities.

This short review produces elements indicating the evolution of some of the most characteristic karstic landscapes of the Italian Alps. In particular, we may deduce that many of the now-existing karstic or glacio-karstic landscapes are the result of a somewhat long and complex evolutionary history which began in the Neogene. The most efficient phases of karstic morphogenesis presumably correspond to relatively warm wet periods, both during the Upper Tertiary and Pleistocene, in which subtropical types of paleosol developed. During the Lower Pleistocene the areas in question must have been in the form of large plateaus by numerous large, deep dolinas, some with polygonal contours, with cone- or dome-shaped hillocks rising among them.

Today, in effect, in those areas where fluvial and glacial erosion and/or periglacial processes acted with less intensity, we can recognize the relics of this old karstic relief and filling deposits derived from old paleosoils in some cavities. However, most of the karstic depressions and karstic paleosoils were almost completely demolished by erosive processes or filled with loess deposits. Perimetal parts of many large dolinas, partially demolished, are easily recognizable on Monte Grappa and Monte Baldo.

In the high karstic areas, subjected more intensely to glacial erosion of entire karstic areas, some karstic relief is almost completely eroded. The very numerous shafts which open in these areas do not always show evident relationships with the current surface forms. Many of these are derived from the evolution - in subglacial and/or periglacial conditions - of absorbing conduits of old dolinas destroyed by erosion.

The role played by neotectonics, which contributed towards the accentuation of the reliefs and thereby favoured the erosional demolition of the karstic relief, is evident everywhere.


Deeper studies on these questions by research teams and specialists in karstic geomorphology, including paleontologists, pedologists and prehistorical archeologists, represents a stimulating field for investigations in the near future.

References


Boegan", v. 10, pp. 29-43.

References


Figure 2. Geomorphological sketch of the western area of the Colle del Montello. Legend:
1) contour lines, 2) Piave river bed, 3) old river beds of Piave, 4) main scarps, 5) heights of the main erosional terraces, 6) dolines, 7) anticline axis.
Figure 3. Geomorphological sketch of the southern area of the Monte Grappa plateau. Legend: 
1) contour lines, 2) main hydrographic net, 
3) fault line, 4) thick calcite concretions 
along a fault plane, 5) large tectonic scarp, 
6) neotectonic fault scarp, 7) old karstified 
deep valley bottom, 8) dolines, 9) wide 
karstic depressions, 10) karstic depressions 
demolished by fluvial and periglacial erosion, 
11) irregular cone- and pyramid-shaped 
hillocks.
Figure 4. Schematic profile of a doline in the Monti Lessini. Legend: C) limestone, B.V.) slope breccia, K.A.) Fundkarren, F) Fault and relative neotectonic scarp, O.G.) solution pipes, S.A.) agricultural soil, C.A.) anthropogenic colluvial silts, C.W.) wurmian colluvial silts (with loess structure), P.L.) upper paleosoil (Hapludalf), P.II.) lower paleosoil (Paleoudalf), 1) biface of lower Paleolithic, 2), 3) lens of colluvial flint fragments, 4) postwurmian soil with neolithic stone implements, 5) lens of colluvial flint fragments.
Figure 5. Geomorphological sketch of an area of Circo di Moncodeno - Grigna (Source: Carta morfologica del Bregai-Grigna Settentrionale, in A. Bini, G. Cappa & A. Pellegrini, 1976). Legend of some symbols only: 1) vertical shaft, 2) cave, 3) small cave, 4) natural bridge, 5) small doline, 6) wide and deep doline, 7) "open" doline, 8) complex doline, 9) cone- shaped hillock, 10) limestone pavements, 11) rock walls.

A brief review of a few of the most significant papers on karst geomorphology of Italy, issued in the last two decades, is presented here. Some reflections on the state of Italian karstological research are made.


The following short review deals only with some of the most significant research on karst morphology in Italy carried out in the last twenty years (including research undertaken by foreigners). This review supplies a schematic although representative picture of the state of karst research in Italy between 1960 and 1980.

Research on Chemico-physical Processes of Erosion and Deposition

An important international symposium on the chemico-physical processes occurring in speleogenesis and classification of subterranean forms was organized in 1972 by the Italian Society (various authors, A.A.V.V., 1975). On the basis of research carried out in the Grotte di Castellana, a graphic method for the solution was perfected (C.F. Nobile, 1975). The role played by carbon dioxide in solution processes of gypsum was shown (F. Forti & B. Sala, 1976; Dematteis, 1968; C. Federici, 1970; F. Cucchi, F. Forti & F. Ulcigrai, 1975). A study of the sediments of some caves, aimed primarily at research on prehistorical archeology, allowed palaeoecological reconstructions at various moments of the Italian Pleistocene (E. Borzatti von Löwenstein & D. Magaldi, 1969; F. Pedele, 1972; D. Magaldi & A. Ranpi, 1976; F. Martinelli Sala, G. Bartolomei, M. Tsonon & L. Cattani, 1974; G. Bartolomei & A. Broglio, 1975). Only a few caves have been equipped as experimental laboratories for biogenetic and speleological-physical research (S. Polli, 1969; T. Tommasini, 1978). As regards hydrogeological aspects, thanks to many experiments and studies, we have more data on the conditions of water circulation in karstic aquifers (A. Moretti, L. Pannuzzii, G. Stampononi & N. Zattini, 1965; A. Dal Pra & L. Stevan, 1969; D. Grassi, 1974).

Superficial Karst Forms


Cave Morphology

Thanks to intensified exploration, speleological documentation has grown greatly, and the terminology and methods of collecting data have been perfected (G. Cappa, 1974; A. Bini & G. Cappa, 1974; A.A. Cigna & C. Lewis Railton, 1978). Many studies devoted to caves are important for their scientific rigor and interdisciplinary widening of knowledge on various aspects of subterranean environments. Among the most important we note the studies on the Piagge Isabella system (Piedmont) and the Michele Cortani Cave (Emilia-Romagna) which are among the largest Italian cavities as regards respectively limestones and gypsum (G. Demattei, 1966; M. Bertolani & A. Rossi, 1972). Some research was particularly oriented towards the relations between subterranean karst morphology and chemico-physical and tectonic conditions (G. Cancian, 1976; F. Zezza, 1975; A. Casale & F. Vaia, 1972; F. Cucchi, F. Porti & A. Semararo, 1975). In the Abisso di Monte Cucco (Umbria) the relations between subterranean canalization and rock porosity were analysed (L. Paseri, 1972). In the Lessini Mountains (Veneto) a number of karstic cavities show very well-defined structural-morphological locations (U. Sauro, 1974) and occur tycically (G. Rossi & U. Sauro, 1977). The analysis of cavities in gypsum allowed the development of the concept of antigravity erosion (G. Pasini, in various authors, 1975). In the Lombard Prealps some karstic systems developed even before the Messinian event of "dissection" of the Mediterranean, bringing about the excavation of large valleys (A. Sini & G. Cappa, 1977). In the central-southern Appennines, a study of the subterranean karst systems, many of which are of the "crossing" type, showed several active events separated by filling episodes related to neotectonics, climatic oscillations, variations in sea level, and external mechanical erosion (H. Ghisalberti, 1965; U. Sauro, 1967; W.A. Bocchini Varani, 1971; C. Cattuto, 1976; A. Bocchini & M. Coltori, 1978; M. Bertucciolli, G. Reichenbach & F. Salvatori, 1978; F. Porti & D. Postpischl, 1979). A few studies on the present day karstic environments by means of the speleogenic method was produced (M. Coltorti, 1978; M. Bertuccioli, G. Reichenbach & P. Forti, 1979). Only a few caves have been equipped as experimental laboratories for biogeographical and speleological-physical research (S. Polli, 1969; T. Tommasini, 1978). As regards hydrogeological aspects, thanks to many experiments and studies, we have more data on the conditions of water circulation in karstic aquifers (A. Moretti, L. Pannuzzii, G. Stampononi & N. Zattini, 1965; A. Dal Pra & L. Stevan, 1969; D. Grassi, 1974).

Considerations

This brief review shows how geographic karstology has not everywhere always been able to keep up with progress made in this field in many other European countries, although it has been traditionally established over the last twenty years in Italy. In effect studies on regional morphology of karst areas are not numerous, even though they have been used to advantage with appropriate maps. The reasons for this are due to a crisis in Italian speleology and lack of research teams composed of both professionals and amateurs, but also in many amateurs.

Today, research on karst morphology seems to be influenced by various weaknesses and defects which may be summarized as follows:
- absence of research coordination, due primarily to the lack of interest on the part of official research organizations in Italy;
- scarcity of initiative of interdisciplinary research, aimed at complete knowledge on the various environmental aspects of the karst regions;
- poor connection of research with the problems of planning areas of the karstic districts;
- lack of use of data, to make available to the public knowledge of geomorphological aspects of the karst regions.

Considering the extent, variety and interest of the Italian karstic regions, they may be said to represent an ideal field for geographic-naturalistic investigation by research teams composed of both professionals and amateurs, for our better knowledge and utilization of this environmental heritage.

References


Bertolani, M. & Rossi, A. 1972. La Grotta Michele
Bertuccioli, M., Reichenbach, G.
Bini, A.
Belloni, S. & Orombelli, G. 1970. Osservazioni e
Casale, A. & Vaia, F. 1972. Relazioni fra schema
Cancian, G. 1976. II Carso Monfalconese: litostratigrafia, sedimentologia e geometria delle cavità naturali
Bartolomei, G.

1978.
Zezza, F. 1975. Le facies carbonatiche della Publia 
ed il fenomeno carsico ipogeo. Geol. Appl. e 
Idrogeol., Bari, v. 10/1, pp. 1-54.
Subterranean Phreatic Biocoenoses of North Western Iran

Giuseppe Lucio Pesce
Zoological Institute of the University of L’Aquila, Italy

Abstract

Results of the phreatobiological researches carried out in Iran by the Zoological Institute of the University of L’Aquila (Italy), during the years 1975-1979, are reported.

Introduction

According to some Authors, for what concerns the aquatic fauna, Iran may be divided in three different taunusional provinces, one going from the coasts of the Caspian Sea to the central high lands, the others respectively limited to the south-western and to the southeastern parts of the country. In the inner high lands there are mainly more ancient, palaeartic elements with different degree of specialization to the underground systems, which are generally limited to the coastal interstitial systems. In the southern provinces, at last, both western and palaeartic elements of different age can be found together.

Nevertheless, as far as we know, with the exception of the papers of Wolff (1959, 1960) and Lindberg (1941, 1942), in which a few, sporadic records of aquatic subterranean species are listed, until now practically nothing is known about the phreatic hypogean fauna of this country.

This fact prompted us to carry out, in summer 1977 and in a few months of 1978, a series of field investigations in the phreatic subterranean systems of the north-western part of Iran, viz. along the coasts of the Caspian sea (Kellar-Abad, Karabab, Nor ereshar, Chalus) and in the inner highlands around Isfahan (Shar-e-Kord, Farroch, Cialestore) and Teheran (Karas).

In the course of these researches, 41 collecting stations (man-made fresh and brackish-water wells and some cisterns) were sampled using the technique of Cvetkov (1968) modified by Danielopol and Dancu (in Bou, 1974). For each of them, the main geographical distribution. The species Asellus aquaticus (L) Racovitza which is well represented in our samples, both from the Caspian area and the inner highlands in a fresh-water well in the highland of Isfahan and which is at present to be considered endemic from Iran.

From a systematic point of view, the above species fits in the group of the fresh-water species of the genus Microcharon (after Pesce, in press), being close to the Cypridips, which are from central Asia and to the "phreatic" Coineau & Botosaneanu from Cuba.

As regard the genus Microcharon, it shows a wide, cosmopolitan, distribution (Europe, Asia, Africa, Wst Indies, New Caledonie, etc.); several species and subspecies are reported from islands and terrestrial freshwaters, other ones from interstitial marine habitat. According to some authors (Coineau, 1968; Pesce, 1977) the fresh-water species of Microcharon have a marine origin: they penetrated and got adapted to the inland freshwaters during the Miocene regressions of the "Caspian sea" in the same way of many other subterranean groups as cirolanids, stenasellids, thermosbenaceans, amphipods, inselliidae, naisidae and mysids. All of this was according to a model that Stock (1977) called "Regression Model".

The other isopods which were collected belong to the family Asellidae and to the widespread subgenus: Asellus s. str., Mesoasellus Birstein and Phreatoasellus Matsumoto.

At the present time, the genus Asellus Dudich is divided in three different phyletic lines which, according to some authors, represent three distinct subgenera: Asellus s. str., Mesoasellus Birstein and Phreatoasellus Matsumoto.

From a biogeographical point of view, it is to be considered an euasiotic group, with a wide geographical distribution. The species Asellus aquaticus recently penetrated deeply in western Europe, both in epigean and subterranean waters.

The material of Amphipods belongs to a new genus, Phreatoamphipoda Tattersall, from fresh-waters of the Anamane Islands and from Glava, Galapsillessi Barnard, from the Galapagos, as well as to the amphipods of the "Hadziid-group" sensu Stock (1977).

Besides its great systematic and biogeographical interest, the discovery of P. pacesae is remarkable, as far as we know, it represents the only and the first amphipod which is reported from the phreatic subterranean waters of this country.

As regards the oligochaetes, which are well represented in the groundwaters, are very abundant in our collections. Most of the species belong to the families Lumbriculidae, Naididae, Enchytraeidae and Tubificidae (mostly cocones), being generally distributed in the superficial layers of the sampled sediments. Some new species were identified: Peloscolex velutinus (Grube); Nais elegius Müller; Tubifex tubifex (Müller) Nais sp.; Peloscolex sp. and Lycodorus phareodriloides Malevich.

The majority of these show a wide geographical distribution and live in freshwaters and in subterranean waters, offering a little biogeographical

endemic for Iran, and by other stygophil or eustigophophil species as Attheyella crassa (Sars) and Canthocampus stathypinus (Jurine) which show a wide geographical distribution. Subterranean waters, other ones from interstitial marine habitat.

According to some authors (Coineau, 1968; Pesce, in press), the fresh-water species of Microcharon have a marine origin: they penetrated and got adapted to the inland freshwaters during the Miocene regressions of the "Caspian sea" in the same way of many other subterranean groups as cirolanids, stenasellids, thermosbenaceans, amphipods, inselliidae, naisidae and mysids. All of this was according to a model that Stock (1977) called "Regression Model".

The other isopods which were collected belong to the family Asellidae and to the widespread subgenus: Asellus s. str., Mesoasellus Birstein and Phreatoasellus Matsumoto.

At the present time, the genus Asellus Dudich is divided in three different phyletic lines which, according to some authors, represent three distinct subgenera: Asellus s. str., Mesoasellus Birstein and Phreatoasellus Matsumoto.

From a biogeographical point of view, it is to be considered an euasiotic group, with a wide geographical distribution. The species Asellus aquaticus recently penetrated deeply in western Europe, both in epigean and subterranean waters.

The material of Amphipods belongs to a new genus, Phreatoamphipoda Tattersall, from fresh-waters of the Anamane Islands and from Glava, Galapsillessi Barnard, from the Galapagos, as well as to the amphipods of the "Hadziid-group" sensu Stock (1977).

Besides its great systematic and biogeographical interest, the discovery of P. pacesae is remarkable, as far as we know, it represents the only and the first amphipod which is reported from the phreatic subterranean waters of this country.

As regards the oligochaetes, which are well represented in the groundwaters, are very abundant in our collections. Most of the species belong to the families Lumbriculidae, Naididae, Enchytraeidae and Tubificidae (mostly cocones), being generally distributed in the superficial layers of the sampled sediments. Some new species were identified: Peloscolex velutinus (Grube); Nais elegius Müller; Tubifex tubifex (Müller) Nais sp.; Peloscolex sp. and Lycodorus phareodriloides Malevich.

The majority of these show a wide geographical distribution and live in freshwaters and in subterranean waters, offering a little biogeographical
value. On the contrary, the species Lycodrilus phreodriloides is very interesting since, until now, it occurred only in the Lake Baikal. The other related species living together in the connected rivers Jenisej and Angara: L. phreodriloides lives on stony bottom or on sponges, the other species of the same genus prefer muddy or sandy sediments.

According to E. Dumnika, who kindly determined these materials, the specimens from Iran differ from the original description by some details, which could assure the identity of the Iranian populations of this species.

In association with the oligochaetes, insect larvae as Chironomids, Ephemerids, etc., occur abundantly in the same wells, being very numerous in the superficial layers of the groundwater.

All the other material which was collected are still in course of study by specialists who will publish their results as soon as possible.

At the end, this first, preliminary approach to the phreatic subterranean systems of Iran already revealed their remarkable interest from a biological point of view, as well as pointed out a rich and diversified fauna living in the underground waters of this country. However, still much has to be done in this field, since the species that we reported above most probably represent only a small portion of the subterranean aquatic fauna of Iran. Therefore, it is likely that the study of the remaining samples, as well as the continuation of the biological researches in the underground systems of Iran, will lead to additional discoveries and to a better knowledge of the Iranian fauna.

References


Pesce, G. L., in press. The first Microparasellidae from subterranean waters of Iran: Microcharon raffaellae n. sp. (Crustacea: Isopoda). Vie et Milieu, 28-29(2C0.


Running through the biospeleology history again, we realized that biological data concerning caves of the alpine southern region are available only in the second middle of the XIX century thanks to the work of geographers and geologists. Entomologists came much later on. A little or nothing is known about endogeneous fauna, which has been however, studied by famous entomologists such as Berbese, Silvestri, Agostino Dodero, or from time to time by Andrea Fiori.

The ecological classification of cave-dwellers is based on their morphology and it is a very old experience and acquired experience, even if it evolved and changed in the long run. The beginning of the XX century offers a great quantity of new research works, which reached their highest point in important monographies, particularly those on Coleopters as well as on Myriapods and Isopods.

Method of Work and Terminology:

In the wake of important works, as those on the Coleoptera written by Jeanne and G. Müller, the unsurpassed masters, a more specific type of research has developed—that in caves. There are a great number of naturalists who collect particularly in caves and send their material to important specialists who carefully describe it.

Along with these researches and systematics, an ecological classification of the organisms has been developed with the purpose of synthesizing their morphological characters and their adaptation capacity to life in caves.

Limits of Traditional Models:

Thanks to the setting-up of, on one side, laboratory researches (Mouilla, France) in the second middle of the XX century and, on the other, a more careful study of soils, the habitat of the so-called "troglobionts" seems to be in these later years much wider, not only in caves but also outside in the soil. However, soil researches are still at the beginning!

According to the most recent results, there are two categories of specialized hypogeous organisms:

1) The edaphophants, very little and flat, who colonize soil pores; 2) the troglobionts, with a greater size and extended legs, who colonize the micro-splits of the same soils and, from time to time, caves.

It is possible that, because of serious pedological instability due to climatic or human cause, troglobionts disappear from the superficial soil-stratum and are found only exclusively in caves. This fact is visible in a cline-environment such as the Prealps and the high plain in Northeast Italy.

The Present Situation of the Research and a Possible Approach for an Environmental Utilization

The more flexible understanding of soil populations offers greater possibilities for further studies and experimental researches. It is possible to forget as axiom, the model "cave-isle". New approaches on the soil are practicable, at least for the following three points:

1) The period, in which Invertebrates populations began to be endemic, must be considered shorter. There is evidence that it took place in post-glacial area.
2) The population dimension must be brought up-to-date, taking into account not only caves, but also endogeneous sides.
3) The above information seems to be very useful and convenient for environmental researches, as well as naturalistic interventions as for biogeography and genetics, as for agriculture and forestry use.

Soil Biology: Activity and Prospects of the Research Carried Out by the "Centro di Ecologia del Cansiglio", Venitian Prealps, Italy

Maruzio G. Paoletti
Centro di Ecologia del Cansiglio, Via Roma 39, 30020 Novento di Prove, Venezia, Italy

The "Centro di Ecologia del Cansiglio"

The "Centro di Ecologia del Cansiglio" is a public association among scholars, including University professors, with the purpose of increasing ecological information of one of the most interesting areas from the naturalistic point of view, and more respected in the Southern Italian Alps—the Cansiglio forest and its neighboring areas.

Cansiglio, set in the Northeast of Italy, is in particular a karstic plateau with the form of a wide "polje" at an average altitude of 1,000-1,200 m all surrounded by mountains. It is covered mainly by a beech (Fagus sylvatica) and tar-tree (Picea excelsa), white fir tree (Abies alba) forest. It is a vast and unique remnant of a much wider wood extension. Today it represents the greater wood of the Venitian Prealps as well as of the Italian Alps.

Activity:

The "Centro di Ecologia del Cansiglio" is carrying out many different projects on the following subjects: the study of local karsic phenomenon, speleology, glaciology and pedology, general soil biology and biospeleology, and many different aspects of ecology.

Soil Biology and Invertebrates Biospeleology:

These two items are of great interest, because they help to know better life strategy in a karstic soil (calcareaous Mesozoic) covered by a luxuriant and mixed forest.

A great deal of research work has been done both in deep caves (also 600 m deep) and on the superficial soil, and consequently a great deal of information is now available.
Carbonaceous Sediments in a Gypsum Karst (Hainholz/South Harz, Federal Republic of Germany)

Stephen Kempe and Kay Emeis
Geological and Paleontological Institute, University of Hamburg, Bundesstrasse 55, D-2000 Hamburg 13, Federal Republic of Germany

Abstract

Gypsum karst sediments from surface "Schlotten" and a solution cave (Jettenhöhle) were analysed for element (EDAX) and mineral composition (X-ray diffraction) and investigated by electron microscopy. Calcite content varies between layers, as observed in other gypsum karsts, reflecting different climatic conditions during the last ice age. Residual organic and inorganic authigenic forms of a calcite grains can be discerned and part of the cave sediment is formed by accumulating calcite floats.

Zusammenfassung


Introduction

Karstification processes in gypsum not only create caves by underground dissolution, but also sculpt the surface. Insolubles of gypsum rock or water- and windborne material will fill the solution cavities above and below ground. To assess the mineralogy and genesis of these sediments, the gypsum karst area "Hainholz" (Hauptanhydrite formation, Zechstein 3, Upper Permian) in the South Harz region of Germany was investigated. The former anhydrite is entirely gypsified and the original thickness of this formation of 35-60 m has been reduced to 10-40 m by karstification. The area, a nature preserve, is wooded and has an annual mean precipitation of 800 mm (Brandt et al., 1976).

Sampling and Methods

Typical karst surface features of the Hainholz are the so called "Schlotten", which are cylindrical pits up to 15 m deep and 1 m wide, forming at intersections of clefts by solution.

Underground 26 caves with together 1,4 km passages are known. The caves have developed in non-turbulent water bodies and are flooded by several meters of sediments. Thirty samples of various sediment types were taken from the floor and from wall pockets of one of these caves, the Jettenhole, being the longest and most advanced in development (Figure 1).

The mineralogy of selected samples was established by X-ray diffraction. Morphology of the grains was studied with electron microscopy and crushed samples were analyzed for their elemental composition by EDAX (=energy dispersive analysis of X-rays). EDAX was conducted at 20 kV, so that elements by assuming the presence of certain anions, however, are gypsum residuals as Mg-carbonates cannot be formed (Kosmann, 1969; Brandt et al., 1976). (Figure 2, layer 4).

The sediment composition varies considerably and miner-

Discussion of Results, Schlotten Sediments

The process of Schlotten formation is depicted in Figure 2, the x-axis representing time. Theoretically four sediment types of different origin may be trapped in these karstification processes. At the bottom, ongoing dissolution of gypsum leaves irregular, porous sediments, residualia, composed of calcite, dolomite, and calcite, which are accessories present in the Hauptanhydrite (Kosmann, 1969; Brandt et al., 1976) (Figure 2, layer 1). Top, from the former Hauptanhydrite caprock may accumulate (Figure 2, layer 2). In glacial times, loess could have entered the Schlotten (layer 3). Finally, residuals from surface dissolution may be washed into the deepening trap (layer 4). These sediments should be fine grained and more tightly packed than the leftovers in layer 1. Also, organic debris from the surface is to be expected.

The minerals found within the actual sediment are calcite, dolomite, magnesite, kaolinite, illite, and gypsum. Residual organic and inorganic authigenic forms of a calcite grains can be discerned and part of the cave sediment is formed by accumulating calcite floats.

Cave Sediments

Table 1 lists EDAX-composition of 30 samples recalculated for likely minerals of oxides and normalized to 100%.

The sediment composition varies considerably and minerals recognized by X-ray diffraction include calcite, dolomite, magnesite, quartz, kaolinite, illite, and gypsum. The high copper contents may be explained by the high copper content of Zechstein formation or by instrumental artefact. Gypsum is present mainly in samples near the entrance, where in winter cold and dry air is drawn into the cave and evaporation causes gypsum. In addition, calcite is precipitated when seepage drips to the floor. The calcite crystals thus formed are 10 my long steep rhombohedrons and are recognized throughout most of the samples.

Sample 25 is powdery gypsum, possibly formed by frost desintegration at a former entrance to the cave. Further inside the cave sediments have very high calcite contents, generally above 80%. Those samples with more than 10% MgCO3 (magnesite and/or dolomite) are gypsum residuals as Mg-carbonates cannot be formed under present hydrochemical conditions (FISCHBEK, 1974). Morphologically, these sediments show coated surfaces lacking idiomorphic shapes. Under the electron microscope, another group of carbonates is striking;
lancet like, with stepped surface, often bundled into radial groups (Plate 1.4). Single crystals are around between 50 and 300 my long and around 30 my wide. They are the residues of calcite floates (e.g. sample 29) precipitated at the surface of the cave pools. Already in 1930, Biese has described the origin, though the hydrochemical background was revealed only recently. The Jettenhohle is underlain by the karstified Stabfurt dolomite (Figure 4). Along clefts or small faults, the carbonate rich karst waters rise through the T3 clay into the lower part of the Hauptanhydrite (Y3), creating the solution caves there by dissolving additional CaSO4 and returning by gravitational convection into the lower aquifer. Hydrochemical monitoring of the cave pools in the Jettenhohle in 1975 has shown that all year round pressure in these water bodies is high in con- sideration to the water surface. One solid meter of these sediments could thus have formed within roughly 10,000 years, placing the cave sediments into Holocene times. Throughout the millenia, these calcite floates have accumulated to several meters of deposits in the cave.

Following the model calculations of Dreybrodt (1980) on the kinetics of calcite deposition from water films, a calcite float of the depth of 100 my and the area of 1 cm² would roughly need one to two years for its formation. The assumption in these estimations is that the water is exchanged after it had lost all calcite possible. The limiting rate in this deposition is the CO2 diffusion to the water surface. One solid meter of these sediments thus have formed within roughly 10,000 years, placing the cave sediments into Holocene times.

Table 1

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>MgCO₃</th>
<th>Al₂O₃</th>
<th>SiO₂</th>
<th>CaSO₄</th>
<th>K₂O</th>
<th>CaCO₃</th>
<th>Fe₂O₃</th>
<th>CuO</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.3</td>
<td>2.0</td>
<td>7.5</td>
<td>64.4</td>
<td>0.5</td>
<td>21.2</td>
<td>1.4</td>
<td>0.6</td>
</tr>
<tr>
<td>2</td>
<td>4.6</td>
<td>5.0</td>
<td>18.0</td>
<td>18.9</td>
<td>0.9</td>
<td>47.2</td>
<td>3.5</td>
<td>1.8</td>
</tr>
<tr>
<td>3</td>
<td>3.8</td>
<td>6.1</td>
<td>5.4</td>
<td>44.8</td>
<td>0.4</td>
<td>36.4</td>
<td>0.9</td>
<td>2.1</td>
</tr>
<tr>
<td>5</td>
<td>1.3</td>
<td>11.2</td>
<td>1.1</td>
<td>32.0</td>
<td>0.1</td>
<td>52.5</td>
<td>0.1</td>
<td>1.7</td>
</tr>
<tr>
<td>6</td>
<td>7.0</td>
<td>7.1</td>
<td>24.0</td>
<td>25.0</td>
<td>1.7</td>
<td>27.8</td>
<td>4.5</td>
<td>2.3</td>
</tr>
<tr>
<td>7</td>
<td>9.8</td>
<td>2.4</td>
<td>8.4</td>
<td>3.6</td>
<td>0.4</td>
<td>72.0</td>
<td>1.9</td>
<td>1.7</td>
</tr>
<tr>
<td>8</td>
<td>12.8</td>
<td>1.5</td>
<td>6.1</td>
<td>5.1</td>
<td>0.1</td>
<td>70.2</td>
<td>1.2</td>
<td>2.9</td>
</tr>
<tr>
<td>9</td>
<td>6.5</td>
<td>1.5</td>
<td>5.0</td>
<td>2.4</td>
<td>0.3</td>
<td>81.2</td>
<td>2.4</td>
<td>0.7</td>
</tr>
<tr>
<td>10</td>
<td>6.1</td>
<td>0.9</td>
<td>3.8</td>
<td>2.1</td>
<td>0.3</td>
<td>84.0</td>
<td>2.0</td>
<td>0.9</td>
</tr>
<tr>
<td>11</td>
<td>24.2</td>
<td>2.5</td>
<td>8.8</td>
<td>1.2</td>
<td>0.2</td>
<td>60.3</td>
<td>1.5</td>
<td>1.2</td>
</tr>
<tr>
<td>12</td>
<td>3.1</td>
<td>1.0</td>
<td>3.3</td>
<td>2.6</td>
<td>0.2</td>
<td>88.4</td>
<td>0.7</td>
<td>0.7</td>
</tr>
<tr>
<td>13</td>
<td>8.5</td>
<td>1.9</td>
<td>5.0</td>
<td>2.3</td>
<td>0.3</td>
<td>80.2</td>
<td>1.0</td>
<td>0.8</td>
</tr>
<tr>
<td>14</td>
<td>4.5</td>
<td>0.7</td>
<td>2.5</td>
<td>2.4</td>
<td>0.1</td>
<td>86.5</td>
<td>1.4</td>
<td>1.8</td>
</tr>
<tr>
<td>15</td>
<td>5.4</td>
<td>1.7</td>
<td>5.8</td>
<td>2.1</td>
<td>0.4</td>
<td>81.8</td>
<td>1.8</td>
<td>1.1</td>
</tr>
<tr>
<td>16</td>
<td>7.6</td>
<td>1.6</td>
<td>4.9</td>
<td>1.4</td>
<td>0.3</td>
<td>82.1</td>
<td>1.2</td>
<td>0.8</td>
</tr>
<tr>
<td>17</td>
<td>18.5</td>
<td>0.9</td>
<td>3.7</td>
<td>0.9</td>
<td>0.2</td>
<td>73.6</td>
<td>1.1</td>
<td>1.1</td>
</tr>
<tr>
<td>18</td>
<td>6.7</td>
<td>1.0</td>
<td>3.8</td>
<td>1.4</td>
<td>0.3</td>
<td>84.5</td>
<td>1.6</td>
<td>0.8</td>
</tr>
<tr>
<td>19</td>
<td>1.6</td>
<td>0.8</td>
<td>2.6</td>
<td>1.4</td>
<td>0.2</td>
<td>91.3</td>
<td>1.3</td>
<td>0.8</td>
</tr>
<tr>
<td>20</td>
<td>2.6</td>
<td>1.4</td>
<td>5.0</td>
<td>1.3</td>
<td>0.3</td>
<td>85.9</td>
<td>2.6</td>
<td>0.8</td>
</tr>
<tr>
<td>21</td>
<td>11.2</td>
<td>5.7</td>
<td>17.3</td>
<td>1.1</td>
<td>1.2</td>
<td>57.9</td>
<td>5.1</td>
<td>0.5</td>
</tr>
<tr>
<td>22</td>
<td>4.4</td>
<td>4.1</td>
<td>12.3</td>
<td>3.6</td>
<td>0.7</td>
<td>70.9</td>
<td>3.1</td>
<td>0.8</td>
</tr>
<tr>
<td>23</td>
<td>6.3</td>
<td>7.8</td>
<td>31.4</td>
<td>1.6</td>
<td>1.3</td>
<td>44.5</td>
<td>6.4</td>
<td>0.7</td>
</tr>
<tr>
<td>24</td>
<td>2.9</td>
<td>21.3</td>
<td>6.9</td>
<td>1.4</td>
<td>0.5</td>
<td>64.0</td>
<td>2.4</td>
<td>0.6</td>
</tr>
<tr>
<td>25</td>
<td>0.3</td>
<td>0.1</td>
<td>0.7</td>
<td>84.1</td>
<td>0.1</td>
<td>13.9</td>
<td>0.1</td>
<td>0.7</td>
</tr>
<tr>
<td>26</td>
<td>5.7</td>
<td>10.3</td>
<td>50.9</td>
<td>1.8</td>
<td>2.9</td>
<td>21.0</td>
<td>6.7</td>
<td>0.7</td>
</tr>
<tr>
<td>27</td>
<td>36.0</td>
<td>3.0</td>
<td>12.8</td>
<td>1.5</td>
<td>0.5</td>
<td>42.2</td>
<td>3.3</td>
<td>0.7</td>
</tr>
<tr>
<td>28</td>
<td>7.6</td>
<td>3.6</td>
<td>12.6</td>
<td>1.3</td>
<td>0.9</td>
<td>70.5</td>
<td>3.0</td>
<td>0.6</td>
</tr>
<tr>
<td>29</td>
<td>2.9</td>
<td>6.8</td>
<td>3.2</td>
<td>2.6</td>
<td>0.3</td>
<td>82.5</td>
<td>0.8</td>
<td>0.7</td>
</tr>
<tr>
<td>30</td>
<td>6.8</td>
<td>12.7</td>
<td>50.1</td>
<td>1.0</td>
<td>3.3</td>
<td>18.3</td>
<td>7.2</td>
<td>0.7</td>
</tr>
</tbody>
</table>

References

Figure 1: Map of Sediment Sample Points JETTENHOEHLE - South Harz

Figure 2: Model of Schlotten Development in South Harz Gypsum Karst

Figure 3: Mineral concentration in Schlotten

Figure 4: Sketch of geological profile through Hainholz
Techniques de Progression en Rivière Souterraine a Gros Débit

M. Jean François Pernette
33760 Escoube, France

Résumé

Avec la découverte récente de rivières souterraines aux débits exceptionnels (5 à 30 m³/s), notamment au Mexique et surtout en Papouasie Nouvelle-Guinee, de nouvelles techniques de progression ont dû être mises au point afin de vaincre les difficultés jamais rencontrées sous terre à ce jour. Les remarques qui suivent constituent la première approche de ces problèmes. Les techniques décrites ont été utilisées avec succès lors de l’expédition hebdomadaire de spéléologie en Nouvelle-Bretagne et notamment lors de l’exploration des rivières de KAVAKUNA/MATATAL et NARE.

Abstract

With the recent discovery of large river caves in Mexico and Papua-New Guinea (flow: 5 to 20 m³/s), new techniques had to be developed in order to compete with difficulties never encountered underground. This paper is a first approach to the problem. The techniques described have proven to be successful in the exploration of the KAVAKUNA/MATATAL system (flow: 15 m³/s; depth: 400 m; length: 3500 m) and the NARE river (flow: 15 m³/s; depth: 400 m; length: 4500 m). These explorations were made by the 1980 French national expedition to New Britain (PNG) led by the author.

Avec la découverte récente de rivières souterraines aux débits exceptionnels (5 à 30 m³/s), notamment au Mexique et surtout en Papouasie Nouvelle-Guinee, de nouvelles techniques de progression ont dû être mises au point afin de vaincre les difficultés jamais rencontrées sous terre à ce jour. Les remarques qui suivent constituent la première approche de ces problèmes. Les techniques décrites ont été utilisées avec succès lors de l’expédition hebdomadaire de spéléologie en Nouvelle-Bretagne et notamment lors de l’exploration des rivières de KAVAKUNA/MATATAL et NARE.

A. Matériel personnel:

- le port du gilet flotteur est obligatoire à tout moment; celui-ci devra être porté par dessus la combinaison, mais sous le baudrier (et les longes).
- l’assistance doit être bien serrée et escamotée.
- le casque doit être équipé d’un éclairage mixte (contre-courant, bac à traîne);
- l’usage d’un équipement de protection pour la vue est obligatoire.
- le port de la gaine de traction et d’assurage, le premier utilise les blocs qui émergent de la rivière, il faut laisser la corde en double (sans noue de l’autre berge) et l’amarrage de l’aval peut être réalisé par la méthode la plus sûre consiste à utiliser un bloc.
- l’utilisation d’une corde de traction peut être utilisée avec un objet lourd si le bloc n’est pas remontable, il faut laisser une cordelette de longueur suffisante pour pouvoir la récupérer en cas de coincement du grappin. L’expédition nationale de la Fédération Française de spéléologie en Nouvelle-Bretagne et notament lors de l’expédition de l’automne 1980 a. 

A. Dans la rivière:

- Dans la rivière: il est rarement possible de progresser directement dans les rivières à fort débit, mais part à partir de certains passages à fort débit, qui ne sont pas frappés de matières en sable, ou lors d’évasements en forme de lacs. Le premier sait de dériver au gré du courant, soit à la nage, soit en canot et installe un relais 30 à 40 m plus loin. De là, il assure la progression du second sur 40 m supplémentaires et ainsi de suite. Si le courant n’est pas remontable, il faut laisser une cordelette de longueur suffisante pour être utilisée avec un objet lourd si le bloc n’est pas remontable, il faut laisser une cordelette de longueur suffisante pour pouvoir la récupérer en cas de coincement du grappin. L’expédition nationale de la Fédération Française de spéléologie en Nouvelle-Bretagne et notament lors de l’expédition de l’automne 1980 a.
cas qui nous interresse, certaines precautions particu-
lières doivent être observées:
- ne jamais porter de sacs sur le dos ou être
relié à un sac
- ne jamais se mousquetonner sur une tyrolienne
ou pire, sur un bloqueur: il vaut mieux tomber à l'eau
et être récupéré par la corde d'assurage que de risquer
d'être bloqué sur la corde dans l'eau
- si un bloqueur doit être utilisé pour faciliter
la progression, il ne devra pas être relié à l'utili-
sateur (cf. accident équipe Suisse en Nouvelle-Guinée)
- en règle générale, il faut éviter des excès de
corde, de boucles et de sangles qui risquent de se
transformer en collet sous l'eau et essayer de pro-
gresser au maximum hors de l'eau.

Techniques D'Assurage
Ces techniques sont valables pour toute chute dans
une rivière à fort débit et doivent tendre à utiliser
la force de l'eau plutôt que de la combattre.
A. Par l'amont:
C'est la première idée qui vient à l'esprit
puisqu'elle tend à raccourcir au maximum la chute pos-
sible. En fait, elle est à proscrire totalement pour
plusieurs raisons:
- le nageur tracté par l'amont risque de plonger
sous l'eau par l'effet du courant
- la vague créée par le corps inerte recouvre la
tête
- la pression de l'eau sur la cage thoracique
plaque le baudrier et entraîne un risque d'étouffement
- il faut deployer une force considérable pour
lutter contre le courant
- une chute courte peut être plus dangereuse
(chocs, coincements).
B. Par l'aval:
C'est un assurage dynamique qui utilise le courant
sans le combattre. La chute est plus spectaculaire
mais plus sûre avec un minimum de sang froid. Il per-
met une grande mobilité, rapide de surcroît et un
amortissement non négligeable de la chute. Il convient
de choisir des emplacements propices pour un maximum
d'efficacité. Le point d'assurage doit se trouver
entre le point d'assurage et la zone de récupération ne
doit pas être inférieure à la largeur de la rivière.
En cas de chute, le nageur se laisse emporter par le
courant. Il doit, grâce au gilet, flotter même par gros
remous. Dès qu'il atteint la zone de récupération (par
exemple une zone de contre-courant ou plus calme), il
peut nager vers la berge. La personne qui l'assure doit
l'assister sans le tracter. Cette manœuvre ne nécessite
aucun effort particulier.
C. Cas particulier de l'assurage par le haut:
Lorsque la berge est très abrupte, voire verticale,
l'assurage devra se faire depuis le haut. Le principe
reste le même, mais l'assurage par l'aval n'est pas in-
dispensable puisque la traction sortira le nageur hors de
l'eau. La hauteur depuis le point d'assurage jusqu'au
niveau de la rivière devra cependant être supérieure à la
largeur de la rivière.

Conclusion
Ces techniques sont le premier résultat d'expéri-
ences face à des situations particulières. Elles
restent néanmoins très risquées et supposent une grande
habitude de l'eau vive et beaucoup de sang froid.
Ce type d'exploration constitue certainement un
premier pas vers une spéléologie différente de celle
pratiquée jusqu'alors. Outre les nouveaux problèmes
techniques qu'elle engendre, son approche suppose un
engagement certain. Mais en poussant à l'extrême, on
peut se demander si ce qu'il adviendrait du plaisir, de
l'intérêt et de la finalité d'une progression entière-
ment en artificielle au plafond d'une galerie pour les
deux simples raisons qu'il n'y a pas d'autre moyen connu
et que la cavére elle, continue...?
En ce cas, il est certain que nous sommes con-
frontés à des problèmes nouveau qui dépasse le cadre
de la spéléologie classique. Nul doute que dans un
futur que j'espère très proche, cet article fera
sourire...
Résumé
La découverte au cours de l'été 1980 d'un nouveau gouffre important sur le variant espagnol du massif de la Pierre St Martin a montré l'intérêt pour la recherche de la rivière Saint Georges. Cette exploration (non terminée) jusqu'à la cote - 1200 m constitue déjà la plus profonde jamais réalisée à partir d'une seule entrée. Elle relance également dans certains esprits l'idée de record du monde de profondeur.

Cet article fait le point sur l'état actuel des recherches de la rivière Saint Georges, et décrit ce nouveau gouffre qui devient (au 30 août 80) le 4ème plus profond du monde.

Abstract
During the summer of 1980, an entirely new system of caves was explored to the depth of -1200 m in the Spanish side of the Pierre Saint Martin karst. This exploration (uncompleted) is actually the deepest ever made starting from a single entrance. This new discovery gives the opportunity to talk again about the Saint Georges underground river as well as the possibility of a new world record.

This paper takes stock of the actual state of the St Georges searches and describes this new system that becomes (as of Aug 20th, 1980) the 4th Deepest in the world.

Introduction
Les nombreuses années passées à la recherche de la rivière Saint-Georges viennent de porter une grande longueur (7500 m) et jusqu'à la profondeur provisoire de 1192 m. Cette nouvelle cavité qui n'a pas encore reçu de nom démontre la profondeur de la plus grande cavité de la zone de Saint Martin. Elle constitue en outre pour les amateurs d'intégrales en tous genres l'expédition la plus profonde jamais réalisée. Ajoutons que la connaissance que nous avons actuellement de cette rivière ne permettent pas de trancher entre les diverses théories concernant le réseau Saint-Georges, dont ce collecteur est certainement tributaire.


C'est finalement la récompense d'une obstination, d'un travail de recherche et d'exploration que nous sommes en hommage à Félix Ruiz de Arcaute et Francis Zamora.

Contexte Géologique
Située à l'extrême sud du karst de la Pierre St Martin, dont elle fait partie intégrante, la zone de BUDOGUIA possède une géologie similaire à l'ensemble du massif de la Pierre St Martin. Le BU 56 a donc permis d'explorer une zone auparavant inexploitable. Cette nouvelle cavité qui n'a pas encore reçu de nom démontre la profondeur des plus grandes cavités de la zone de Saint Martin. Elle constitue en outre pour les amateurs d'intégrales en tous genres une nouvelle cavité la plus profonde jamais réalisée. Ajoutons que la connaissance que nous avons actuellement de cette rivière ne permettent pas de trancher entre les diverses théories concernant le réseau Saint-Georges, dont ce collecteur est certainement tributaire.


C'est enfin récompense d'une obstination, d'un travail de recherche et d'exploration que nous sommes heureux de pouvoir offrir aujourd'hui à Isaac Sanesteban, heureux de pouvoir offrir aujourd'hui à Isaac Sanesteban.

Historique
La découverte du BU 56 fin août 79 par Jean-François Perneettelie est arrivée au terme d'une prospection systématique d'en ouest de la Sierra de Budogulia. Une prospection exploration qui fut modérée par des blocs, absorbe le filet d'eau du névè. A la cote 92 après désobstruction du méandre "N". Un puissamment concis petit torrent a été ouvert. En juillet 1980, l'exploration est poursuivie par Jean-François Perneettelie, Richard MAIRE, Gérard BOUSQUET et Serge FULLARD. Bientôt rejoints par J.P. BLANCH, G. BOUEIEIL, D. MARTINEZ et Y. PASCAL qui regroupés sous le nom d'"AMALGAME 80", explorent et topographient avec l'INSTITUTION PRINCE DE VIANA le réseau sur 7500 mètres jusqu'à la cote -1192 m.
Après 300 mètres d'une progression très aisée, nous meandrons à faible pente. Le shiste y apparait de temps à autre. Prometteur s'échappe vers -460 dans des affluents. Un réseau court-circuitée, mais 150 mètres plus loin, nous arrivons dans un couloir. Nous resterons d'ailleurs bloqués 5 heures au pied du P 30, envahi par une cascade après l'orage du 14 août...

Une nouvelle étroiture agrandie nous permet heureusement de suivre le cours d'eau dans une galerie de taille moyenne, trés concretionnée. Le courant d'eau descendant nous donne l'espoir de déboucher incessamment dans l'immense galerie que l'on suppose à l'ouest d'Ukerdi et qui débouche dans un affluent. Après 300 mètres d'une progression très aisée, nous butons sur une voûte mouillante. Celle-ci est heureuse-ment court-circuitée, mais 150 mètres plus loin, nous arrivons à un siphon vertical de 475 m. Le courant d'eau prometteur s'échappe vers -460 dans des affluents. Tout espoir de trouver un couloir important grâce auquel nous pourrions passer à cette altitude, il reste toujours à voir par acquis de conscience le départ présumé du méandre de -387.

Quant au réseau amont proprement dit du "Rio de Budoguía", nous le remonterons à partir de -433 sur près de 900 m de développement. Après un parcours de 250 m, un fort grondement nous fait immédiatement penser à une diffluence. Esprit ou bien notre imagination ? Nous laisserons les blocs coinçès entre les parois encaissées du Canyon RONCAL.

Quant au reseau amont proprement dit du "Rio de Budoguía", nous le remonterons à partir de -433 sur près de 900 m de développement. Après un parcours de 250 m, un fort grondement nous fait immédiatement penser à une diffluence. Esprit ou bien notre imagination ? Nous laisserons les blocs coinçès entre les parois encaissées du Canyon RONCAL.

Après un dédale de couloirs et de blocs coinçès, une nouvelle etroiture agrandie nous permet de continuer le parcours. A -363, un puits de 65 m se dédouble en un ouvrage. Nous frisons alors les -900 m. Immédiatement, l'on arrive à un confluent. Dans une sorte de salle qui semble être un passage sous deux cours d'eau, nous franchissons le seuil. La grande galerie-salle précédente et escalader des couloirs de calcite impressionnants. L'autre équipe est parvenue à une impasse et nous la suivons, guidés par les rivières du massif: AN3, FR3, SC3, etc... Plusieurs cascades nécessitent des mains courantes mais heureusement de cout-circuiter la suite des puits plus étroits. Nous devalons à toute allure une nouvelle circulation d'eau cascade dans des petits siphons, mais à nouveau devrons tomber sur une nouvelle circulation d'eau. Nous devalons et nous rencontrons une nouvelle circulation d'eau dans une galerie qui s'amenuise en une première petite salle.

Une corde sera obligatoire pour descendre entre deux blocs violemment emplissus. Au-dessus, plus étroite mais très pentue. Il faut nous d'oublier dans une sorte de salle compliquée, une galerie arrive effectivement rive gauche, du sud. Serait-ce la rivière de l'A 60 ? L'actif en verticale de 600 m se dédouble à nouveau sous les blocs. Nous finissons enfin dans une coulée d'eau qui s'écoule à toute vitesse, un petit collecteur remonte à nouveau le flanc de la galerie. Le rio est donc trés encombré dans cette zone. Serait-ce la rivière de l'A 60 ? L'actif en verticale de 600 m se dédouble à nouveau sous les blocs. Nous finissons enfin dans une coulée d'eau qui s'écoule à toute vitesse, un petit collecteur remonte à nouveau le flanc de la galerie. Le rio est donc trés encombré dans cette zone.

C'est le début de la salle RONCAL, mais nous ne savons pas encore. Nous poursuivons dans une galerie de 80 mètres d'environnement. Nous descendons de plus en plus de blocs. De plus, nous nous retrouvons à nouveau dans une nouvelle circulation d'eau qui s'écoule à toute vitesse, un petit collecteur remonte à nouveau le flanc de la galerie. Le rio est donc trés encombré dans cette zone. Serait-ce la rivière de l'A 60 ? L'actif en verticale de 600 m se dédouble à nouveau sous les blocs. Nous finissons enfin dans une coulée d'eau qui s'écoule à toute vitesse, un petit collecteur remonte à nouveau le flanc de la galerie. Le rio est donc trés encombré dans cette zone. Serait-ce la rivière de l'A 60 ? L'actif en verticale de 600 m se dédouble à nouveau sous les blocs. Nous finissons enfin dans une coulée d'eau qui s'écoule à toute vitesse, un petit collecteur remonte à nouveau le flanc de la galerie. Le rio est donc trés encombré dans cette zone. Serait-ce la rivière de l'A 60 ? L'actif en verticale de 600 m se dédouble à nouveau sous les blocs. Nous finissons enfin dans une coulée d'eau qui s'écoule à toute vitesse, un petit collecteur remonte à nouveau le flanc de la galerie. Le rio est donc trés encombré dans cette zone. Serait-ce la rivière de l'A 60 ? L'actif en verticale de 600 m se dédouble à nouveau sous les blocs. Nous finissons enfin dans une coulée d'eau qui s'écoule à toute vitesse, un petit collecteur remonte à nouveau le flanc de la galerie. Le rio est donc trés encombré dans cette zone.
rive gauche, lequel finit par se rétrécir à 7-10 m vers -1100. Aux alentours de -1140, dans un autre "shunt" inactif, une petite escalade délicate (qui sera évitée au retour) est réussie juste à gauche d'un petit affluent. Puis nous poursuivons dans une superbe galerie de 20 m de large et à voûte arrondie : ici, la rivière s'écoule tranquillement sur toute la largeur dans un grand lit de galets pour se perdre finalement à travers les cailloutis au pied de la sala Linza que nous gravissions sur plusieurs dizaines de mètres. Par chance, la continuité est rapidement découverte sur le côté gauche où un passage bas de plafond conduit à une salle déclive en forme d'amande (120 m x 50 m). À l'extrémité aval de celle-ci, la rivière réapparaît (-1189) pour se jeter 15 m plus loin avec fracas dans le premier ressaut de 10 m d'un canyon sinistre à peine large de 2 m à sa base.

Le grondement assourdissant, l'eau écumante, le débit (1/2 m 3/s) les parois hautes et lisses constituent les éléments indissociables d'une ambiance que nous connaissions bien, nous qui revenons de Nouvelle Guinée. Mais cette fois, nous sommes à 1200 m de profondeur ! Un équipement en vire est installé grossièrement sur la gauche pour pousser une reconnaissance avec les quelques bouts de corde qui nous restent. Nous progressons avec précaution sur les flancs concrétionnés et déversants du canyon, pour descendre finalement à une verticale de 8 m entre la paroi et une coulée de calcite. Nous nous arrêtons là, à -1192, faute de matériel et de temps, au sommet d'une profonde fissure dans laquelle se déverse avec fureur le "Rio del Rincon de Belagua".

**Conclusion**

Si l'on tient compte des trois points fondamentaux suivants :

1. Coloration positive entre Belagua et l'émergence d'Illamina (Cf. I. Santesteban, 1980)
2. Module annuel d'Illamina = 5,64 m³/s (Cf. E.D.F.)
3. Superficie approximative de l'impruvium = 70 à 85 km² (Cf. précipitations et débit d'Illamina).

Il est possible d'affirmer aujourd'hui que le système du BU 56 constitue, la branche méridionale la plus importante du Saint Georges souterrain. Cette rivière du BU 56 (ou Rio del Rincon de Belagua) est formée par la confluence du Rio de Budoguia et du Rio de la Hoya vers -710. Ce Rio de la Hoya correspond très vraisemblablement au collecteur important découvert à -410 dans l'A 60. Le diagramme des directions de galeries du BU 56 (Cf. Fig.) illustre bien l'utilisation préférentielle de certaines fractures et met effectivement en évidence une direction générale E-O et une direction secondaire NE-SO. L'ensemble du réseau se développe ainsi à l'aplomb du vallon Sud d'Ukerdi et se dirige sous la vallée de Belagua selon un azimut de 263° par rapport au Nord géographique. Il semble donc de plus en plus évident que le puissant complexe souterrain du Saint Georges soit constitué par la réunion du BU 56, du système d'Ukerdi-Ania Larra, du dyke de Zampori et d'autres réseaux secondaires. En fin de compte, un ou plusieurs écoulements parallèles au BU 56 parallèlement à la direction générale E60 des fractures, soit dans le pendage axial des plis. De plus, une réorientation de ces écoulements vers l'avant en direction du NW doit intervenir à la faveur de failles perpendiculaires aux précédentes et en fonction du pendage des couches vers le Nord.

L'organisation du système du BU 56 met magnifiquement en lumière l'adaptation d'un grand réseau souterrain à la structure interne d'un massif calcaire. La zone de transfert verticaux s'effectue traditionnellement par une "cascade" de puits entrecoupés de méandres étroits jusqu'à -430 (calcaires des canyons), puis la rivière collectrice s'écoule sur le niveau imperméable des grès et shistes primaires en utilisant le grand système de fractures E60°. Le plafond très incliné de certaines galeries entre -300 (rio de budoguia amont) et -500 (à l'aval du Meandro Oprimido) correspond au pendage des couches vers le Nord.

Le grondement assourdissant, l'eau écumante, le débit (1/2 m 3/s) les parois hautes et lisses constituent les éléments indissociables d'une ambiance que nous connaissons bien, nous qui revenons de Nouvelle Guinée. Mais cette fois, nous sommes à 1200 m de profondeur ! Un équipement en vire est installé grossièrement sur la gauche pour pousser une reconnaissance avec les quelques bouts de corde qui nous restent. Nous progressons zlérement sur les flancs concrétionnés et déversants du canyon, pour descendre finalement une verticale de 8 m entre la paroi et une coulée de calcite. Nous nous arrêtons là, à -1192, faute de matériel et de temps, au sommet d'une profonde fissure dans laquelle se déverse avec fureur le "Rio del Rincon de Belagua".

**Schéma hydrogéologique du bassin-versant du Saint Georges souterrain** (légende : 1, limite approximative du bassin-versant. 2, principaux écoulements souterrains supposés. 3, principaux réseaux connus, 4, émergences.)

576
Enseignement de la Spéléologie au Québec

Daniel Caron
Société québécoise de spéléologie, C.P. 336, Station Delorimier, Montréal (Québec) Canada, H3C 3P8

Résumé

Fondée en 1971, l'Ecole québécoise de spéléologie, commission de l'enseignement de la Société québécoise de spéléologie, propose aux personnes intéressées à l'exploration souterraine, novices ou adeptes, un programme d'éducation en spéléologie. Ce programme vise la sensibilisation de la population à l'existence du phénomène cave, à la préservation de ces phénomènes ainsi qu'à la préservation des milieux naturels liés à ces phénomènes. Il est basé sur des projets éducatifs permettant d'accroître la qualité de la pratique spéléologique au Québec.

Cependant, ce qui distingue l'enseignement de la spéléologie québécoise c'est son intégration dans un concept de plein air global. Elle s'y définit comme un ensemble de moyens permettant de vivre temporairement dans le milieu naturel et débouchant sur une implication et une sensibilisation à l'environnement et caractérisée par une utilisation intelligente et respectueuse du milieu cavernicole afin de s'y recrérer, de la découverte et de se connaître.

Abstract

Founded in 1971, the Ecole québécoise de spéléologie is the education commission of the Société québécoise de spéléologie and, as a school, has elaborated on education programs in speleology for people interested in caving, ranging from beginners to experienced cavers. This program aims at introducing quebecers to caves, caving and related topics like cave preservation. It also permits the S.Q.S. to put forward education projects which have had an overall beneficial effect on the quality of caving activities and, hence on the effectiveness of our caving preservation program.

The uniqueness of this education program is most probably its close relationship with an integrated concept of outdoor activities. Hence, these activities are visualized as a set of means used for oneself to live in harmony with a natural environment and develop, as a consequence, a way of being and living closely related to the rules of this environment. This way of living is characterised by a comprehensive and respectful attitude towards its caving environment, and ultimately ends in a better knowledge of man and its intricate relations with its surroundings.

Introduction

L'année '81 constitué pour l'Ecole québécoise de spéléologie une dixième (10) année d'existence. Elle marqué le sommet d'une progression qualitative et quantitative des services visant à satisfaire les besoins d'un nombre croissant d'amateurs et d'intervenants en spéléologie. A ce jour, son intervention dans le développement de la spéléologie québécoise constitue un des facteurs dominants de la réussite de l'expansion de l'activité en accord avec la préservation du milieu.

Cheminement Pédagogique

Le cheminement pédagogique mis de l'avant par l'Ecole québécoise de spéléologie tente de répondre aux aspirations de deux catégories d'individus. (fig. 1) Il offre en première partie une formation individuelle commune. Les niveaux concernés sont identifiés en ordre chronologique par les noms suivants: information, découverte, sensibilisation et initiation.

A ce dernier niveau, l'individu se voit offrir la possibilité de poursuivre une progression axée sur sa formation personnelle ou celle de s'acheminer à travers les étapes de la formation de cadre. Les spéléologues optant pour l'enseignement ont accès à la totalité des niveaux de formation individuelle alors que l'inverse n'est pas possible. Au-delà du niveau initiation, le cheminement individuel comporte les niveaux du perfectionnement et de la spécialisation. Le niveau de cadre offre la succession des niveaux d'initiateur, de monitor et d'instructeur en spéléologie. Le niveau équiper est destiné à parfaire la formation de personnels répondant aux pré-requis du brevet d'initiateur.

Niveaux de Formation

Chacun des niveaux de formation est défini selon des objectifs spécifiques. Le détenteur d'un brevet cadre possède les connaissances et les compétences des stages des niveaux inférieurs selon la chronologie établie. C'est ainsi que l'instructeur pourra encadrer les stages à tous les niveaux, alors que l'initiateur ne pourra encadrer qu'à partir de celui de l'initiation. La définition de l'initiateur, du moniteur et de l'instructeur en spéléologie se situe comme suit:

L'initiateur est la personne reconnue comme possédant des connaissances la rendant apte à diriger un groupe, à la découverte, à la sensibilisation ou à l'initiation au milieu cavernicole.

Le moniteur est la personne reconnue comme possédant les connaissances techniques, scientifiques et pédagogiques nécessaires à l'enseignement et à l'animation d'activités spéléologiques.

L'instructeur est la personne reconnue comme possédant à fond les connaissances techniques, scientifiques et pédagogiques la rendant apte à l'enseignement et à l'animation d'activités spéléologiques.

Durée des Stages et Validité des Brevets

La durée spécifique de chaque stage est déterminée en fonction des objectifs de formation proposés. Les durées adoptées par l'E.Q.S. sont les suivantes:

- Découverte: 15 heures
- Sensibilisation: 15 heures
- Initiation: 45 heures
- Perfectionnement: 45 heures
- Spécialisation: 45 heures
- Moniteur: 270 heures
- Instructeur: 540 heures +

+ Inclus les heures d'implication obligatoires dans le milieu selon des modalités définies.

En ce qui concerne la validité des brevets de formation de cadre, ils sont valables pour une durée de 3 ans. Après cette période, déterminée à partir de la fin du stage, le cadre est tenu de participer à une session de reguaplification. Celle-ci lui permettra d'obtenir une nouvelle carte d'enseignant, indiquant la validité de son brevet pour 3 nouvelles années. A ce jour, les divers stages québécois de formation de cadre ont permis l'émission de 189 brevets.

Sujets de Formation

Les sujets de formation sont évidemment propres à chacun des niveaux. Pour l'étude des thèmes abordés, nous présentons ci-dessous la liste des sujets du niveau sensibilisation et celle du niveau initiateur:

- Sensibilisation (formation des amateurs) 15 heures
- Exploration souterraine
- Karst et cavernes
- Biospéléologie et microclimatologie
- Matériel et techniques d'exploration souterraine

577
Initiateur
(formations des cadres)
90 heures

Histoire et développement de la spéléologie
Spéléologie et plein air.

Karst et caverne
Microclimats des caverne
Vie en caverne
Caverne, habitat humain
Ethique du spéléologie
Adaptation psychologique et physiologique au milieu souterrain
Matériel d’exploration
Prospection: instruments et méthodes
Exploration du milieu souterrain
(techniques de progression)
Alimentation spéléologique
Topographie souterraine
Sécurité sous terre
Secourisme élémentaire
Sauvetage
Historique de la spéléologie
Organisation spéléologique québécoise
Sites cavernicoles québécois
Enseignement de la spéléologie

Contenu Pedagogique

Tous les niveaux de cheminement pédagogique possèdent non seulement une identification concrète des sujets de formation mais également un contenu pédagogique spécifique. C’est ainsi que chaque cadre peut lors de l’organisation d’un stage, utiliser un “guide pédagogique”. Ce document contient pour chacun des sujets de formation la description de divers éléments dont:

- l'objectif du cours
- le contenu, le champs d'action
- les actions à réaliser
- les moyens de réalisation
- les moyens d'évaluation
- une bibliographie ainsi que des données horaire (fig. 2)

Speleologie et Education au Milieu Naturel

La spéléologie au Québec fait partie de ce que l'on appelle le loisir de plein air et plus spécifiquement l'exploration du milieu naturel. Elle se définit, dans ce contexte, comme une activité constituée d'un ensemble de moyens qui choisit l'individu pour vivre temporairement dans le milieu naturel plus spécifiquement le milieu cavernicole. Ses principales composantes deviennent alors la connaissance et la compréhension du milieu cavernicole, la locomotion, l'habitation, l'alimentation et l'énergie. Ces composantes entraînent une manière d'être et d'agir conditionnée par l'environnement et caractérisée par une utilisation intelligente et respectueuse du milieu cavernicole afin de se récréer, de la découvrir et de se découvrir. C'est probablement cette façon de percevoir et de développer la spéléologie qui constitue l'apanage de l'exploration souterraine au Québec.

Conclusion

L'implantation d'une structure d'enseignement apparemment complexe mais très efficace a permis à la spéléologie de s'intégrer dans le développement du plein air au Québec. Elle conserve ainsi à la Société québécoise de spéléologie le privilège d'orienter les intervenants selon les intérêts des spéléologues et de la spéléologie en général. Elle permet, puisqu'en fonction depuis le début de l'exploration souterraine organisée au Québec, d'assurer un développement simultané et cohérent de l'activité et du potentiel cavernicole de notre pays, tout en s'intégrant dans une démarche conceptuelle d'éducation au milieu naturel.
Annexe 1: Cheminement pédagogique

EDUCATION EN SPELEOLOGIE:

FORMATION INDIVIDUELLE

FORMATION DE CADRE

SPECIALISATION

PRE-REQUIS

Pratique

PERFECTIONNEMENT

PRE-REQUIS

Pratique

INITIATION

PRE-REQUIS

Pratique

S sensibilisation

PRE-REQUIS

Découverte

PRATIQUE

PRE-REQUIS

Information

INFORMATION

PRE-REQUIS

Communication

INDIVIDUS

540 INSTRUCTEUR (2 ans)

270 MONITEUR (2 ans)

90 INITIATEUR (3 ans)

Enseignement 2 ans

Pratique enseignement 3 ans

Enseignement 3 ans

PRE-REQUIS (initié)

PRE-REQUIS (sensibilisé)

PRE-REQUIS (très intéressé)

PRE-REQUIS (informé)

INSTRUCTEUR

MONITEUR

INITIATEUR

5 DISCOVERTE

INFORMATION

LEGENDE

MONITEUR - Niveau de formation

PRE-REQUIS (intéressé)

2 ans - Années d'expérience requises depuis le niveau précédent

2 ans - Nombre d'heures d'activité de formation

(3 ans) - Période de validité du brevet sans renouvellement

SUJETS DE FORMATION

INTRODUCTION

(Disposition de l'information)

U.3.C.2.81

3.1 TITRE DU COURS

(Disposition de l'information)

Année de rédaction

Niveau

Cadre

Stages de formation

Sujet de classement: Éducation et formation

OBJECTIF:

But à atteindre.

CONTENU:

Description sommaire du contenu de cours.

CHAMPS D'ACTION:

Relations du contenu de cours avec les composantes fondamentales et les éléments généraux du concept plein air (voir 2.1).

SUJETS D'ENSEIGNEMENT:

Matières d'enseignement.

 ACTIONS A REALISER:

Les actions susceptibles d'être accomplies par le stagiaire afin de faciliter l'acquisition des connaissances.

MOYENS DE REALISATION:

Les méthodes et les moyens utilisables par l'enseignant pour faciliter l'acquisition des connaissances.

MOYENS D'EVALUATION:

L'objectif terminal, la maîtrise des connaissances théoriques et pratiques acquises. Evaluation généralement continue.

BIBLIOGRAPHIE:

Quelques ouvrages de référence.*

* Référence très importante (lecture)

Figure 2.
La Protection du Karst en France

Gérard Aime
Secrétaire Général, Fédération Française de Spéléologie (Société Spéléologique de France - Comité National de Spéléologie), 130, Rue Saint-Maur, Paris XIème, France

Résumé
Problème majeur aujourd'hui, la protection du karst revêt, en France, plusieurs aspects : la lutte contre les pollutions, qu'il s'agisse de la pollution des eaux résultant des rejets liquides dans le sous-sol calcaire (égoïts de villages, rejets résiduels de porcheries ou d'"usines à veaux", pollutions chimiques par des agrès, rejets des rejets solides (dolines et gougoufs, dépotoirs, transformés en charniers, en déchets publics ou clandestines) et la lutte contre les pillages des grottes, qu'il s'agisse de la destruction des cristallisations (qui se vendent très cher dans des "bourses" aux minéraux) des gisements archéologiques et paléontologiques.

Dans l'un et l'autre cas, les spéléologues sont des témoins privilégiés et attentifs de ce qui se fait. Ils ont un rôle multiple : ils doivent dénoncer avec vigueur toutes les atteintes au milieu souterrain dont ils sont les témoins et, pour cela, alérer les autorités, les administrations, le public. Ils doivent aussi essayer de protéger les grottes sans pour cela en réglementer et restreindre l'accès ce qui n'est pas facile. Ils essaient enfin de faire appliquer la législation fort complètement et fort complexe qui existe en ce domaine ou de la faire modifier quand elle est insuffisante.

Abstract
In France karst protection includes many aspects: the struggle against pollution, that is to say the subterranean water pollution from liquid injections into the calcareous underground (sewers from villages, waste from swine or real industrial breedings, chemical pollution by factories) as well as solid waste (many holes have been transformed in channel-houses or unofficial or clandestine rubbish-holes) and the fight against cave plundering, that is to say speleothems (which are sold at very expensive prices in the mineralogical fairs) and paléontological or archaeological cases of destruction.

In every case, speleologists are the first witnesses of this situation. Their list is multiple: it is incumbent upon them to educate against all the blows to the subterranean environment; therefore, they must alert the appropriate administration and make the regulations or limiting the access to them, which is not easy. As a last resort they try to make the legislation (very complete and complicated) to be enforced or to be modified when insufficient.

That is one of the urgent tasks of the French Federation of Speleology, because more and more land is being degraded.

La France comprend plusieurs régions karstiques plus ou moins vulnérables. À cet égard, il convient de distinguer la vulnérabilité d'un bassin ou massif karstique (problèmes de pollution) et la vulnérabilité d'une cavité par télèse (qui peut se rattacher au cas précédent ou présenter un aspect original et même spécifique). Cela nous conduit à examiner successivement deux domaines :

- la protection du karst proprement dit
- la protection de certaines cavités.

La Protection du Karst :
La notion du karst recouvre des réalités fort diverses. Si l'on admet qu'elle englobe tous les terrains calcaires ou assimilés susceptibles d'être transformés par l'eau, on constate, pour notre pays, qu'il existe une grande diversité de reliefs, de structures géologiques, de climats, qui ont déterminé des conditions humaines bien précisées. Par exemple, une structure tabulaire en marches d'escalier comme celle du Jura a formé un habitat relativement dense et groupé, propice à une pollution des eaux souterraines et des cavités, alors que les zones plissées et les karsts d'altitude sont des secteurs moins sensibles à cet égard, sauf en certains points où la construction massive d'installations d'accueil pour les sports d'hiver amène ou risque d'amener des effets comparables à ceux des "plateaux".

La lutte contre les pollutions est difficile, en effet, s'il est souvent aisé à un certain stade de reconnaître qu'une rivière souterraine ou une resur-gence est polluée, il l'est moins de définir la nature et l'origine de cette pollution. Pour cela, des prélèvements et analyses sont nécessaires, des colorations aussi pour prouver le bien-fondé d'une hypothèse quant aux causes.

En revanche, il est fréquent de constater que de nombreux gougoufs ou dolines-pertes, sont transformés en dépotoirs, en décharges clandestines, ce qui est, bien sûr, un facteur de pollution important. La loi française interdit tout rejet résiduel liquide ou solide dans le sous-sol, mais elle est bien mal appliquée. D'ailleurs les déprédations qui s'y persifrent, sont insuffisamment efficaces (par exemple, et c'est la règle générale, n'il n'existe pas en amont de ces concrétions, de goulfies, d'egouts : eaux pluviales - eaux usées, et si, en aval, il n'a pas été prévu de traitement technique, par exemple par lagunage ou épandage). Tout cela fait que nous connaissons des cas de pillages des grottes qui se rencontrent plus ou moins gravement polluées. Une vaste campagne d'information est actuellement en cours, concrétisée par des conférences - animations, doublées d'une exposition itinérante, de films et de diaporamas. En avril 1980, un colloque national sur la protection des eaux souterraines en pays calcaire a été organisé par la F.P.S. à Besançon.

A cette campagne d'information s'ajoute un travail de terrain qui consiste à recenser, sur place, les causes de pollution : égoïts et déchets qui rejet de rejets industriels, effluents de porcheries ou d'établissements industriels, rejets de fromageries etc... Une carte des pollutions est en cours de réalisations, et d'un cas grave est décél, un dossier est établi et remis aux administrations et à la presse. Responsables et opinion publique sont ainsi informés du danger. Le rôle des spéléologues s'arrête là mais c'est, on le voit, un rôle essentiel. Les exemples récents d'épidémies d'hépatite virale dues à la pollution des eaux de consommation montrent la réalité du mal et l'urgence d'une thérapeutique. Ils ne s'agit pas, en effet, de piller uniquement nos cavités, celles qui sont pénétrables mais l'ensemble du domaine karstique, d'est à dire du massif et des bassins naturels dont il se compose.

La Protection des Grottes :
Outre ces agressions de la vie moderne, le milieu souterrain est aussi victime, dans ses parties pénitrables par l'homme, d'autres déprédations qui exigent là aussi, des mesures de protection. On peut, à cet égard, distinguer deux catégories : la destruction des paysages ou des biotopes souterrains et le pillage des gisements archéologiques et paléontologiques.

La destruction des paysages ou biotopes souterrains est parfois plus ou moins involontaire ; elle est due, par exemple, à une trop grande fréquentation par les spéléologues chevronnés ou occasionnels. Il en résulte des altérations graves des gisements archéologiques ou paléontologiques.

Les spéléologues sont plus préoccupantes encore lorsqu'elles sont volontaires : il s'agit des briseurs de concrétions qui se constituent des collections privées ou qui en font le moins dans les basses aux cristaux et minéraux (la vente de concrétions de grottes n'est pas expressément interdite en France !). Ils rejoignent les pillages de gisements archéologiques et paléontologiques parmi lesquels on distingue également deux catégories : le pillage du charbon qui garnissent leurs vitrines privées et ceux qui commercialisent leur butin, même si la loi les condamne à mort.

Face à cette situation préoccupante, plusieurs solutions sont envisageables. L'une consisterait à réglementer sévèrement l'accès des cavités (sans quoi les entrées seraient fermées). Cette réglementation supposerait un contrôle strict des allées et venues des
visiteurs, l’octroi d’autorisations etc... et la limita-
tion du nombre de visiteurs.

La Fédération Française de Spéléologie est hostile à tout idée de réglementation, qui restreindrait la liberté de pratique de la spéléologie. Elle estime que ce genre de mesure doit demeurer tour à fait exceptionnel et que l’on ne doit y recourir que pour des cas eux aussi exceptionnels (par exemple, la Grotte de Las- ceaux).

Les spéléologues français ont délibérément opté pour une autre politique qui repose sur l’éducation des spéléologues habituels ou occasionnels afin que leur comportement sous terre respecte à la fois les impératifs de la sécurité et du respect de l’environnement.

À l’égard des pilleurs de concrétions, de sites archéologiques et paléontologiques, notre position est celle de la vigilance: surveillance rapprochée des cavités les plus menacées, poursuites judiciaires contre les contrevenants pris en flagrant délit, campagnes de presse. Enfin, la Fédération Française de Spéléologie est en pourparlers avec les responsables du Ministère de l’Environnement et du Cadre de Vie pour étudier des projets de loi et de décrets destinés à compléter ou amplifier la législation en vigueur (notamment en ce qui concerne le problème des bourses aux minéraux et cristaux et la vente des concrétions.)

C’est donc une série très complète et multiforme d’actions que la Fédération a entreprise. Il était grand temps car le mal progressait très rapidement. Il reste à espérer que ces initiatives ne demeureront pas sans effet.

The Foraging Behavior Of The Cave Cricket

Ellen Levy
Department of Zoology, Ohio State University,
1735 Neil Avenue, Columbus, Ohio, 43202

Abstract

Temperate zone caves have a limited amount of energy input especially the deep cave areas occupied by the cave cricket, Hadenoecus subterraneus. This cricket is an obligate troglobine as it must reproduce in the caves but must forage outside. Crop contents indicate that H. subterraneus is a scavenger, relying on rare and unpredictable food items such as carrion and fermenting fruits. It is hypothesized that a scavenger will forage more efficiently than a strict predator or herbivore which exploits a more common and predictable food source.

To test this hypothesis, baited and unbaited pitfall traps were set both inside and outside the cave to ascertain food preferences. H. subterraneus exhibited definite preferences among alternative bait types under a variety of experimental situations (natural and manipulative). These preferences were measured in terms of numbers of crickets attracted to each of seven baited traps and the control. The alternative food types were quantitatively ranked on the basis of several parameters: 1) nutritional value (calories per gram dry weight, calories per gram wet weight, % fat, % protein, % carbohydrate, % water) and 2) odor character (intensity, threshold, persistence). Preference was correlated most strongly with odor intensity and caloric content, especially the latter, for crickets of all sizes. Crickets selected baits high in available calories and therefore maximized energy gain per unit time. Ontogenetic differences in preferences were observed.

Zusammenfassung


Interpretation as a Primary Tool in Cave Conservation and Management

Edward E. Wood, Jr.
Chief, Interpretation and Resource Management, Lehman Caves National Monument, Baker, NV.

Abstract

Effective interpretation can be a valuable tool to aid speleologists in the presentation and perpetuation of cave resources. Since a majority of people are only occasional visitors to caves and they confine their visits to commercial or show caves, the burden of demonstrating the value of the underground environment falls upon the interpretive presentations available with the interpretive staff and the resources provided. Interpretive presentations must be maintained by the managers of show caves to demonstrate a high level of concern for conservation of their resource as well as in caves in general. From the instant a visitor arrives at a cave, he is influenced by every aspect of the operation -- the grounds, the facilities, the interpretive staff and the resource itself.

To be effective, interpretation must progress beyond the hypothesized speleogenesis of formations and into a much more meaningful resource than they do today. As people became dependent on surface forces makes their preservation paramount. A review of some techniques in use at show caves in the United States demonstrates that creativity does not have to be sacrificed in achieving the conservation theme.

Only by fostering a genuine appreciation throughout the general population, of the complexity of the forces affecting caves, can speleologists expect to be able to rally support for cave conservation. When caves become important resources to everyone, the job of conserving them will become easier.

Cave conservation is a concern of only a small segment of the world's population. In fact, a majority of people have never experienced "wild caves" -- these are left to the adventurers. How does one answer the common question: Why go caving? For a more inventive, they began to construct their own projects, developers, rock hounds and other groups who conditions not found elsewhere and for the recreationist, the cultivation of a conservation ethic comes paramount. A review of some techniques in use at show caves in the United States demonstrates that creativity does not have to be sacrificed in achieving the conservation theme.

Eigene eingrissweilige Darstellung über den Höhlenreichtum kann als wertvolles Werkzeug zur Präsentation der Höhlen angewandt werden. Da die Mehrheit der Bevölkerung nur gelegentlich Höhlen besucht, und diese Besuche sich meistens auf öffentliche Höhlen beziehen, liegt die Verantwortung der Interpretation. Daher ist es notwendig, ausführliche Details auf die Besuche in den Höhlen, besonders in der Öffentlichkeit, zu geben. Der Interpret, der Höhlen als natürliche Laboratorien behandelt, kann den Besuchern eine tiefergehende Verständigung vermitteln.


Zusammenfassung


I works of nature. These tours are more sensual experiences than others. All these techniques attempt to enter the person's profile, etc. Also in this category, I experiences -- the stillness, the dampness and the fragility of the whole group. The enthusiasm of a guide is not universal -- enthusiasm. Enthusiasm is infectious and an interpreter who can foster enthusiasm in everyone is rare. A cave must provide a strong emphasis on pleasing the "customer" if he wants to succeed. This is true whether there is a profit incentive or not. The technique of combining science with entertainment may be totally wrong at another. There are no numerical values assigned because the place where the tour begins. The guide can move the group along the grid only by overpowering the previous influences.

As far as conservation themes are concerned, the better tours are up and to the right (see Fig. 1). There are no numerical values assigned because the placement on the grid is subjective rather than objective. Each person who visits a cave may have a different value judgment that the commonplace does not permit the conservation theme as well as a unique experience. Conservation can be demonstrated in other ways. For example, the touching of cave formations discolors them and reduces their growth. At Lehman Caves, we employ a box of pieces of broken speleothems at the entrance and pass them among the members of the tour group with the understanding that they have been given the chance to feel "real" formations and they should not touch any in the cave. The practice seems to work quite well although there are still some individuals who find it necessary to touch a "wet one". Other caves have touch stones along the tour route and these are utilized in much the same manner.

Effective lighting is another way show caves can make their tours more enjoyable: the more indirect lighting used, the more intriguing the cave appears. Properly the visitor a map of the cave helps most people understand where they have been and the understanding that often the surface gives little sign of the cave resources below. Any technique that makes a visitor think, will aid the conservation cause. But the most important of all is the guide.

In summary, the most effective way to foster the conservation of cave resources is by presenting every cave visitor with an enjoyable and meaningful experience, thereby spreading the burden of the preservation ethic to everyone. Only by fostering a genuine appreciation throughout the general population, of the complexity and uniqueness of the forces effecting caves, can speleologists expect to be able to rally support for cave conservation. When caves become important resources to everyone, the job of conserving them will become easier.
Morphological And Behavioral Adaptations Of The Cave Cricket
For Exploitation Of Unpredictable Food Resources

Ellen Levy
Department of Zoology, Ohio State University,
1735 Neil Avenue, Columbus, Ohio 43202

Abstract

The cave cricket, Hadenoecus subterraneus, shows morphological and behavioral adaptations for reacting to and exploiting rare and unpredictable foods. Adult Hadenoecus have long slender legs which enable them to travel long distances quickly compared to younger instars which have shorter legs relative to their body size. Adults also possess extremely long antennae which get the sensory receptors further off the ground and into the air containing odors. Chemoreception is further enhanced by various waving patterns executed by the crickets as they triangulate in on odors which may be relatively far away. Behavioral observations and pitfall trap data show adult crickets are able to detect and get to food over greater distances than little crickets who are restricted to local food patches. Mean Free Path (an index of rectilinear motion) data add further support to these observations as adults travel rectilinearly (which is adaptive in getting them out of the cave to their natural food source) while juvenile instars show a high degree of turning which functions to keep them in the area in which they have been foraging successfully.

It is hypothesized that a scavenger like Hadenoecus should be a more efficient forager than an herbivore which exploits a more common and predictable food source. Ceuthophilus stygius, the camel cricket was studied for this purpose. Crop analyses indicate this species is more herbivorous in diet than Hadenoecus. The legs and antennae of Ceuthophilus are short and rather stout. The antennae are used as mechanoreceptors and observations indicate little or no chemoreceptive function. Ceuthophilus locates food by contact chemoreception using its maxillary and labial palps.

Zusammenfassung


Verhaltenbeobachtung und Fallendaten zeigen an das erwachsene Grille Nahrung über größere Entfernungen wahrnehmen und finden können als jungs, die auf lokale Nahrungsmöglichkeiten angewiesen sind. "Mean Free Path" Daten (i.e., ein Index geradliniger Bewegung) erhärten diese Beobachtungen, da Erwachsene sich geradlinig fortbewegen (was als Anpassung angesehen werden kann, weil sie dadurch aus der Höhle und zu ihren natürlichen Nahrungsquellen geführt werden) während jugendliche zwischen den Häutungsstadien (= instars) sich in Kreisen bewegen, was den Zweck hat, sie in dem Gebiet zu halten, wo sie mit Erfolg auf Nahrungssuche gehen können.

The Evolution of the Virginia Cave Commission

John M. Wilson, Robert W. Custard, Evelyn W. Bradshaw and Philip C. Lucas
P.O. Box 25594, Richmond, Virginia 23260

Abstract

The Virginia Commission on the Conservation and Use of Caves was established by the Virginia General Assembly in 1978. It published a report to the Governor and the General Assembly in less than six months, and with no direct appropriation and then ceased to exist.

This Study Commission recommended that a permanent Cave Commission be established and this came about in a two step process. After much negotiating with the leadership of the General Assembly, that body approved a one year Commission with $100,000 in funding. This budget was large enough to accomplish many things on a scale never before done in the Cave community.

One recommendation, The Cave Protection Act, contained several major improvements over the old law, including the ban of Speleothem sales and limitation of cave owner liability. Some of the recommendations of this Commission are described in this paper. The Cave Protection Act was approved overwhelmingly by the General Assembly in 1980 with little opposition, but several amendments, that protect the right of the cave owner to use his or her cave as he or she sees fit, were added.

In 1980 the Cave Commission was made a permanent State Agency as part of the Department of Conservation and Economic Development. However, no additional funding was provided. Since no operating funds are now available for the Commission, interested cavers formed the Virginia Cave Conservancy to provide a means of funding, not only the Commission but also for encouraging the ownership and management of caves. This Cave Conservancy will seek to raise funds from public solicitation and fund-raising projects such as bingo and dues. The funds will go to support cave acquisition and management as well as to assist organizations such as the Virginia Cave Commission.

Zusammenfassung


Dieser spezielle Ausschuss empfahl, dass ein ständiger Höhlenausschuss begründet werden sollte, was in einem zwetteiligen Vorgang zustandegekommen ist. Nach langen Verhandlungen mit der Führung, wurde ein einjähriger Ausschuss mit öffentlichen Geldern von $8000 gebilligt. Dieses Budget ermöglichte die Ausführung von vielen Sachen, die in solcher Weise nie vorher unter Höhlenforschern gemacht werden konnten.

Ein Vorschlag, das Cave Protection Act (Höhlenzugesetzes), enthielt einige grösse Verbesserungen des alten Gesetzes, u.a. die Verbannung des Verkaufs von Höhlenformungen (Speleothem) und die Begrenzung der Haftpflicht für Höhlenbesitzer. Einige dieser Empfehlungen des Ausschusses werden in diesem Vortrag beschrieben.

Das Höhlenzugesetzes wurde 1980 von dem Unterhaus überwältigend gebilligt, aber einige Zusatzartikel, die das Recht des Höhlenbesitzers bewahren, seine Höhle nach seiner Weise zu gebrauchen, wurden hinzugefügt.


Diese Höhlenbehörde wird versuchen, Gelder durch öffentliche Werbung und Fundierungsprojekte wie Bingo und Beiträge zu beschaffen. Die Gelder werden Höhlenenerwerbung und -verwaltung sowohl als Organisationen wie der Virginia Cave Commission unterstützen.

I first suggested the idea of a cave commission in 1970 to a caver in Richmond. He did not agree that getting the state involved with caves and caving would be a good idea. However, within several years, I did find a few cavers who agreed that a cave commission would be a desirable thing and by 1975 they had set the wheels in motion through Virginia State Delegate Bill Axelle. Together we set up a committee to study the problems of cave conservation and the role of the state in dealing with cave conservation.

The new committee was composed of cavers, a legislator, representatives of several appropriate state agencies and representatives of commercial caves in Virginia. After two meetings, it became apparent that the state agencies were not in favor of adding additional duties to their agencies. This, apparently because they felt that the General Assembly would not fund anything of this nature, and they did not wish to have any additional work without additional funding.

So, the cavers were told by the representative of the agency that before their agency could support any on-going state activity to protect caves, we would have to thoroughly document almost everything about caves in Virginia. This request was beyond our resources to accomplish in any reasonable length of time. It would require the help of many people to do that. The commercial cave representatives refused to help, in any way, opposed what the cavers were trying to do.

Since the current route appeared to be unproductive, I made the decision to go straight to the General Assembly with our ideas. I asked Delegate Axelle to draft a preliminary resolution. Joint House Resolution 10. I sent draft copy to everyone on this committee: commercial cave owners, agency heads, etc., plus all the NSCS chapters in Virginia, and asked for support and suggestions. No suggestions came in. As a result, Axelle set up a public meeting with the Rulse Committee prior to the session of the 1975 General Assembly in order to get any input from the Rulse committee and other interested people. Several changes were suggested at this meeting including the deletion of the word "overcommercialization" from the whereass. We agreed to that, and after that hearing, representative of commercial caves never again spoke publicly against any of our resolutions at any hearing over the next three years.

The one commercial cave representative who spoke against the resolution at that hearing in 1975 opposed the concept of commissions in general. He was opposed to any cave commission because he believed that it would lead to government regulation of commercial cave operations, even though this was prohibited by the resolution. This individual continued to oppose the commission to the end and tried unsuccessfully to get the Virginia Chamber of Commerce to oppose the resolution. I do not think that early opposition of the one commercial Cave representative had any eventual effect on how long it took to get the resolution passed.

In Virginia, many legislators believe that bad laws and bad resolutions are worse than no laws at all. So, when there is a new concept proposed, the General Assembly tends to take its time while considering all aspects of the proposed law. Three or four years is typical for bills and resolutions of this type to be published in Virginia. Up to that point, the commercial cave representatives had not, in any way, opposed what the cavers were trying to do.
The cave resolution was carried over in 1977 and then passed in 1978. The vote in the House was 76 to 7. It was amended by the Senate (funds deleted) and passed 40 to 0; the House then passed the Senate version. The resolution required the governor's signature so the committee was approved as of the final day of the General Assembly in March, 1978.

I found that many cavers did not understand the concept of commissions in general, even though the vast majority of laws in Virginia go the route of either Legislative Study Committee or Commissions. I had to convince cavers that ultimately the goal proposed was to be better served not solely by cave protection laws, but by ongoing structure, commission, agencies whose purpose is to protect caves, educate people, and even manage some caves. It is unlikely that punitive laws alone can adequately protect caves.

It is desirable to have people within state government who will come up with positive solutions to problems and be able to react quickly when threats to caves become apparent. This process of working for the support of cavers began to get results in late 1977, when numerous cavers began to contact their delegates. But, ultimately the commission was passed by Delegate Axselle was able to convince John Warren Cook, Speaker of the House and chairman of the Rules Committee to give the commission a try. It was the first year that the commission could have established under the circumstances.

Work and Recommendations of the Virginia Commission on the Use and Conservation of Caves

The Virginia Commission on the Conservation and Use of Caves was to make a report to the governor and the General Assembly; do this in less than a year with no direct appropriation and then cease to exist. That is what happened. Its 43 page report was published and went to the Governor and the General Assembly with three major recommendations and extensive background material.

The Cave Protection Act contained several major improvements over the old law, including the banning of speleothems or their export from Virginia's significant caves. The Commission recommended that cave owners be absolved from liability in the event of an accident in their cave. Persons entering a cave would then have to do so at their own risk except at commercial caves where an admission fee is paid. The provisions of the proposed Cave Protection Act (Appendix III) will permit the use of caves for recreational and scientific purposes without imposing unwarranted liabilities upon the cave owner.

Proposed Permanent Cave Commission

The Commission recommended establishing a permanent Virginia Cave Commission composed of eleven members, serving three-year staggered terms (See proposed legislation creating Commission). The members would be persons active and knowledgeable in the management, exploration, study and conservation of caves. Expertise in biology, geology, archeology, palentology, history, and recreation may be represented. Virginia's caves represent a unique, limited, and non-renewable natural resource of great scientific, historic, educational, economic and recreation al value. Virginia can not and should not be rapidly destroying this resource. In order to prevent Virginia's speleal wilderness from being destroyed within our lifetime, immediate steps need to be taken to protect Virginia's significant caves. The Commission recommends that a permanent Cave Commission be created to assist State agencies dealing with cave-related problems, that a new, more comprehensive Cave Protection Act be enacted, and that the Virginia Research Center for Archeology be granted a special grant by the 1980-82 biennium to conduct a two-year archeological survey of Virginia caves. Establishment of a Temporary Cave Commission and Passage of the Cave Protection Act

The Study Commission recommended that a permanent Cave Commission be established and that the Cave Protection Act be adopted utilizing a two-step process. After much negotiating with the leadership of the Virginia General Assembly, that body approved one year Commission with $8,000.00 in funds. The budget made it possible for accomplishing things on a scale never before done in the community. The Cave Protection Act was approved overwhelming by the General Assembly with cave file, but several amendments that protect the right of the cave owner to use his or her cave as he or she sees fit.

As public interest in outdoor recreation continues to grow and land development accelerates in the inter-montane valleys west of the Blue Ridge, increased pressure will be put on Virginia's limited and fragile cave resources. In order to preserve the unique educational, recreational, scientific, and economic values of Virginia's caves and karst areas, the Commonwealth needs to make a continuing commitment to safeguard this special wilderness. A permanent protecting caves permanent Cave Commission composed of concerned citizens, working in conjunction with other agencies of the Commonwealth, appears to be the most effective vehicle for focusing the attention of both government and the public on this goal.

It is anticipated that future efforts of the Cave Commission to conserve Virginia's caves will fall primarily into four broad areas - collecting and maintaining a complete data file on cave resources within the Commonwealth, providing information to the public about caves, their value and the laws protecting them, advising and assisting public agencies and private landowners making cave management and land use decisions, and studying those aspects of cave ownership and land use management that are directly affected by public policy.

The Commission has already made great progress in collecting and maintaining data files. In March, 1979, the establishment of the Virginia Significant Cave List and the inventory of publicly owned caves were great milestones in the assessment of Virginia's cave resources. The development of a computer database storage and retrieval system in cooperation with the Division of Mineral Resources has put a wealth of easily accessible cave data at the disposal of engineers and planners throughout the Commonwealth. A list of Virginia cave owners is currently being compiled and, when available, the Commission will add to and update these data files on a continuous basis.

In its ongoing role as a source of information about caves and their protection, the Commission has published several articles and brochures as noted above. In its coming year, the Commission plans to erect signs at significant caves stating the provisions of the Cave Protection Act and place displays at several of Virginia's commercial caverns. A continuing program of publishing articles and brochures on caves, their value and their protection is also envisioned. The Commission's speakers bureau on cave related subjects is expected to become a fully functioning entity. Co-operative efforts with other public agencies which provide information on caves to the public are anticipated as well.

The study functions of the Cave Commission will diminish significantly with the publication of this report. While some aspects of cave conservation and cave ownership law and the effectiveness and enforcement of the Cave Protection Act will require further study, the basic study establishing the value and extent of Virginia's cave resources and the threats to these resources have been completed. The principal focus of future annual commissions will be on the changes in the state of the Commonwealth's cave resources and on the Commission's ongoing efforts to conserve them.

In its advisory capacity, the Commission has been actively developing its ability to assist public agencies and private landowners in making cave management and land use decisions. For example, data on the location and significance of caves along the proposed route of US #58 in Lee County, in cooperation with the Department of Highways so that destruction of significant caves could be avoided. In another instance, the
Commission notified the Virginia Research Center for Archeology about an important find of Indian inscriptions in a Bath County cave and arranged permission for a James Madison University archeologist to visit the cave to evaluate the significance of the find. With the new computerized data base developed by the Commission and the unusual speleologic expertise of the Commission's members, an expanding role is foreseen for the Commission in the development of cave management plans, the protection of significant caves, and the study of land use in karst areas. It is hoped that the Commission can continue to provide the focus for cave conservation efforts in the Commonwealth and to serve as the source of authoritative information on all aspects of cave use from recreation to civil defense.

Establishment of the Permanent Cave Commission

In 1980 the Cave Commission was made a permanent State Agency as part of the Department of Conservation and Economic Development. However, no additional funding was provided. Since no operating funds are now available for the Commission, the interested cavers formed the Virginia Cave Conservancy to provide a means of funding not only the Commission but also for encouraging the ownership and management of caves. The purposes of a Conservancy are listed in the Appendix.

This Cave Conservancy would seek to raise funds from public solicitation, fund-raising projects such as bingo and dues, etc. The funds would go to support cave acquisition and management as well as to assist organizations such as the Virginia Cave Commission.

Quantitative Dye Tracing in an Alpine Karst Environment
C.C. Smart
Department of Geography, McMaster University, Hamilton, Ontario, Canada

Abstract
The karst of the Mount Castleguard area exhibits numerous (>100) springs, relatively few accessible sinks and high seasonal and diurnal variations in flow. In 1979 and 1980 a quantitative tracer program was undertaken, mostly using the fluorescent dye Rhodamine WT. Analysis was made with a Turner Designs Model 10 Series Fluorometer capable of continuous flow or discrete sample fluorometry. Twelve-volt snowmobile batteries provided power and resolution was better than one part per 10^11 Rhodamine. Grab sampling was by automatic water samplers at frequencies of one to six samples per hour.

Basic flow routes were first established. Then repeated tests from selected sinks under different flow conditions were made to test for the presence of underground drainage divides.

All tests were distributary to numerous springs and no true divides found. However, characteristic time-concentration curves allowed functional classes of springs to be identified. Varying multiple peaks in dye output under different flow conditions represent the changing importance of parallel conduits. Some pulses may represent the flushing by the diurnal flood of trapped dye. The tracing results plus a deep recession of the karst aquifer in summer 1980 allowed functional spring clusters to be identified. A simple model for the 4-dimensional network is envisaged.

Resume
La karst de la region du Mont Castleguard possede plusieurs (>100) sources karstiques, relativement peu de gouffres accessibles, et de fortes variations saisonnières et quotidiennes de débit. En 1979 et 1980, un projet de traçage quantitatif fut entrepris, utilisant principalement le colorant fluorescent Rhodamine WT. Les analyses furent menées à l'aide d'un fluoromètre Turner Designs Model 10 capable d'accompagner des échantillons individuels ou un flux continu. Des piles de motoneige (12 volts) constituaient la source d'énergie et la résolution dépassait une partie par 10^11 Rhodamine. L'échantillonnage fut mené automatiquement, à une fréquence de un à six échantillons par heure.

On a établi d'abord les trajectoires de flux. A partir de gouffres choisis, des tests furent répétés sous différentes conditions de flux, afin de vérifier la présence de lignes souterraines de partage des eaux.

Dans tous les cas, le traceur fut distribué à de nombreuses sources et aucune véritable ligne de partage des eaux ne fut identifiée. Cependant, des classes fonctionnelles de sources purent être distinguées à l'aide des courbes temps/concentration caractéristiques. Des crétes multiples variables dans le débit du colorant sous différentes conditions de flux reflètent l'importance changeante des conduits parallèles. Quelques pouls peuvent témoigner du rinçage par la crue quotidienne de colorant emprisonné. Les résultats des traçages et une récession profonde de l'aquifère karstique au cours de l'été 1980 ont permis l'identification de groupements fonctionnels de sources karstiques. Un modèle simple pour le réseau en quatre dimensions est envisagé.
Signaturen Für Höhlenpläne

Ralph Müller

Albert-Schweitzer-Str. 16, D 7311 Hochdorf (German Federal Republic)


Für die Tuschedarstellungen wurden Schablonen und Schreibgeräte entsprechend der ISONORM ISO 3098/1 verwendet. Drei wesentliche Merkmale zeichnen die Anwendung der ISONORM aus:

1. gute Lesbarkeit
2. internationale Vereinheitlichung
3. speziell zur Mikroverfilmung bestens geeignet.

Allen, die durch Diskussionen und anderweitige Mitarbeit zum Gelingen dieser Sammlung beigetragen haben, möchte ich meinen Dank aussprechen.

Die Übersetzung des Textes in die Kongreßsprachen erfolgte durch die Mitarbeit von Reno BERNASCONI, Michael FIELD, Jean Ch. GRUNENWALD, Irene SCHELLHAMMER, Roland WINKELHOFER.
<table>
<thead>
<tr>
<th>Nr.</th>
<th>Strichstärke im System</th>
<th>Signaturen</th>
<th>Beschreibungen, Bemerkungen</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0,7</td>
<td>▲ ▲</td>
<td>Vermessungspunkt erster Ordnung, markiert, z. B. Haken, Gewindebolzen, c. A.</td>
</tr>
<tr>
<td>2</td>
<td>0,7</td>
<td>● ●</td>
<td>Vermessungspunkt zweiter Ordnung, markiert, Befestigungspunkt natürlich oder künstlich</td>
</tr>
<tr>
<td>3</td>
<td>0,7</td>
<td>●</td>
<td>Visierlinien (von Messpunkt zu Messpunkt)</td>
</tr>
<tr>
<td>4</td>
<td>0,7</td>
<td>▲</td>
<td>Gang, Raumbegrenzung</td>
</tr>
<tr>
<td>5</td>
<td>0,7</td>
<td>●</td>
<td>Gang, unter anderem verlaufend (bei normaler Darstellung des Grundrisses gibt es nur diese Signatur)</td>
</tr>
<tr>
<td>6</td>
<td>0,7</td>
<td>▲</td>
<td>Gang, über anderem verlaufend (wird bei niveauabgebender Darstellung benötigt)</td>
</tr>
</tbody>
</table>

**engl. Cave Map Symbols**

No. 1: Survey point, marked, 1st grade (artificial i.e. piton or bolt etc.)

No. 2: Survey point, marked 2nd grade (artificial and natural relay points)

No. 3: Line of sight (from point to point)

No. 4: Passage limits

No. 5: Passage running under another

No. 6: Passage running over another

**ital. Segni per Cavità**

No. 1: Estacación topográfica principal, marcada, por ejemplo clavo, taco de expansión, etc.

No. 2: Repère ou marquage topographique principal (par exemple artificiel, piton, clou, spitz etc.)

No. 3: Ligne de visee (resultante de l'azimut et de l'angle de pente)

No. 4: Poligonale

No. 5: Galleria passante sotto un' altra galleria

No. 6: Galleria passante sopra un'altra galleria

**fr. Signes pour Plans des Cavités**

No. 1: Repère ou marquage topographique principal par exemple artificiel, piton, clou, spitz etc.

No. 2: Repère ou marquage topographique secondaire (par exemple artificiel: piton, clou, spitz etc. ou naturel: stalactite, grosses pierres ... ou tout autre repère remarquable)

No. 3: Ligne die visée (resultante de l'azimut et de l'angle de pente)

No. 4: Poligonale

No. 5: Galleria passante sotto un' altra galleria

No. 6: Galleria passante sopra un'altra galleria
<table>
<thead>
<tr>
<th>Nr.</th>
<th>Strichstärke im System</th>
<th>Signaturen</th>
<th>Beschreibungen, Bemerkungen</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>0.7</td>
<td>0.5</td>
<td>Gangfortsetzung, ohne Möglichkeit des Weiterkommens</td>
</tr>
<tr>
<td>8</td>
<td>0.5</td>
<td>0.35</td>
<td>Gangfortsetzung, mit Möglichkeit des Weiterkommens</td>
</tr>
<tr>
<td>9</td>
<td>0.35</td>
<td>0.25</td>
<td>angenommene, geschätzte Raumform</td>
</tr>
<tr>
<td>10</td>
<td>0.35</td>
<td>0.25</td>
<td>Deckenform</td>
</tr>
<tr>
<td>11</td>
<td>0.5</td>
<td>0.35</td>
<td>Trauflinie (hier beginnt die Höhle)</td>
</tr>
</tbody>
</table>

| No. 7 engl. Unpassable continuation of passage  
es. Continuación de galeria intransitable  
fr. Continuité de réseau non péntrable  
it. Prosecuzione inexplorata, intransitabile  
rus. Продолжение прохода без возможности дальнейшего прохождения |
| No. 8 engl. Possibility of continuation of passage  
es. Continuación de galeria transitable  
fr. Continuité de réseau éventuellement explorable  
it. Prosecuzione inexplorata, transitable  
rus. Продолжение прохода с возможностью дальнейшего прохождения |
| No. 9 engl. Estimated room shape  
es. Contorno supuesto o estimado  
fr. Contours et dimensions de cavité évalués  
it. Rilievo incerto o eseguito senza adeguati strumenti  
rus. Предполагаемая, оцениваемая форма пространства |
| No. 10 engl. Roof shape  
es. Forma de la bóveda  
fr. Contours des voutes ou plafond  
it. Rilievo della volta  
rus. Формы кровли |
| No. 11 engl. Drip line (the beginning of the cave)  
es. Línea marcando la entrada de la cavidad  
fr. Ligne marquant le seuil de la cavité (cette ligne est observable de façon naturelle au sol, par la trace des gouttes d’eau tombant du haut du porche)  
it. Linea marcante l’ingresso di cavità  
rus. Линия капилляра |
<table>
<thead>
<tr>
<th>No.</th>
<th>Strichstärke</th>
<th>Signaturen</th>
<th>Beschreibungen, Bemerkungen</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>0.5</td>
<td>0.35</td>
<td>Stufe (Steilabbruch, Wandstufe)</td>
</tr>
<tr>
<td>13</td>
<td>0.5</td>
<td>0.35</td>
<td>Abgrund in der Höhle (Innenschacht) Angabe der Tiefe in Meter</td>
</tr>
<tr>
<td>14</td>
<td>0.7</td>
<td>0.5</td>
<td>Schachteingang (Tageslicht) Angabe der Tiefe in Meter</td>
</tr>
<tr>
<td>15</td>
<td>0.35</td>
<td>0.25</td>
<td>Kamin und Schacht</td>
</tr>
<tr>
<td>16</td>
<td>0.35</td>
<td>0.25</td>
<td>Kamin (diese Darstellung ergibt sich aus der Signatur für Deckenformen)</td>
</tr>
<tr>
<td>17</td>
<td>0.35</td>
<td>0.25</td>
<td>Isobypsen (Höhenmeterangabe wie auf den int. Kartenwerken)</td>
</tr>
</tbody>
</table>

**Table: English Cave Map Symbols**

- **No. 12**: engl. Step or vertical drop (depth in metres)
  - es. Escalón, escarpa
  - fr. Décrochement apic ou ressaut vire corniche
  - ital. Salto
  - rus. Уступ /кругой обрыв, уступ в скальной стене/

- **No. 13**: engl. Interior shaft or pitch (depth, height in metres)
  - es. Pozo dentro de la cavedad (profundidad en metros)
  - fr. Puit en cavité
t  - ital. Pozzo
  - rus. Пропасть в пещере /внутренний шахта/

- **No. 14**: engl. Surface shaft or pitch (daylight, depth in metres)
  - es. Boca de una sima (al aire libre), profundidad en metros
  - fr. Gouffre
  - ital. Ingresso di cavità verticale
  - rus. Устье шахты на поверхности

- **No. 15**: engl. Chimney and shaft or aven
  - es. Chimenea y pozo
  - fr. Puit et cheminée
  - ital. Pozzo e camino
  - rus. Устья расщелины и шахта

- **No. 16**: engl. Chimney (see no. 10)
  - es. Chimenea (representación deducida de la representación de la bóveda, véase 10.)
  - fr. Cheminée (no. 10)
  - ital. Camino (no. 10)
  - rus. Устья расщелины

- **No. 17**: engl. Contour line, height in metres above sea level, written as on international maps
  - es. Curvas de nivel (isocuvas); indicación de los metros de altura como en los mapas topográficos
  - fr. Isobypse, altitude en metres
  - ital. Isoisse, altezza in metri
  - rus. Изогипсы /стрелка указывает на направление наклона/Данные м отнесены к нормальному уровню
<table>
<thead>
<tr>
<th>Nr.</th>
<th>Strichstärke im System</th>
<th>Signaturen</th>
<th>Beschreibungen, Bemerkungen</th>
</tr>
</thead>
<tbody>
<tr>
<td>18</td>
<td>0,35 0,25</td>
<td></td>
<td>Formenlinien, mit Gefällepfeil und Neigungsangabe</td>
</tr>
<tr>
<td>19</td>
<td>0,35 0,25</td>
<td></td>
<td>Gefällepfeil (in der Höhle)</td>
</tr>
<tr>
<td>20</td>
<td>0,35 0,25</td>
<td></td>
<td>Höhe über NN in Meter</td>
</tr>
<tr>
<td>21</td>
<td>0,35 0,25</td>
<td></td>
<td>Ganghöhe, Raumhöhe (Boden bis Decke) Angabe in Meter</td>
</tr>
<tr>
<td>22</td>
<td>0,35 0,25</td>
<td></td>
<td>Höhenendifferenz bezogen auf den Eingang, Angabe in Meter</td>
</tr>
<tr>
<td>23</td>
<td>0,35 0,35</td>
<td></td>
<td>Kluft, Spalte</td>
</tr>
<tr>
<td>24</td>
<td>0,35 0,35</td>
<td></td>
<td>Störung, Verwerfung</td>
</tr>
<tr>
<td>25</td>
<td>0,35 0,35</td>
<td></td>
<td>Schichtfuge</td>
</tr>
</tbody>
</table>

**Cave Map Symbols**

**Engl.** Cave Map Symbols

**Esp.** Signos de los Mapas Cavidados

**Ital.** Segni per Cavità

**Pers.** Сигнатуры для чертежи

**Engl.** Cave Map Symbols

**Esp.** Signos de los Mapas Cavidados

**Ital.** Segni per Cavità

**Pers.** Сигнатуры для чертежи

---

**No. 18**

Engl. Floor contour, arrow in direction of fall, with degree of slope

Esp. Forma del suelo, flecha indicando el sentido de la pendiente, inclinación en grados

Ital. Pendenza (la freccia indica il punto più basso)

Pers. Линии формы дна со стрелкой наклона и с указанием наклона

---

**No. 19**

Engl. Arrows in direction of slope (solid in cave, outlined outside cave)

Esp. Flecha de pendiente (dentro de la cavidad) flecha de pendiente (fuera de la cavidad)

Ital. Pendenza (la freccia indica il punto più basso)

Pers. Стрелка наклона /закрашена - в пещере, не закрашена - вне пещеры/

---

**No. 20**

Engl. Height above sea level in metres

Esp. Altura sobre nivel del mar (en metros)

Ital. Quota, sopra il livello del mare

Pers. Над-вым моря

---

**No. 21**

Engl. Passage or roomheight (distance floor to roof in metres)

Esp. Altura de la galeria (de suelo a bóveda) en metros

Ital. Altezza della volta (nel punto indicato)

Pers. Высота прохода, высота пространства /От дна до кровли/

---

**No. 22**

Engl. Height difference in relation to entrance (floor, in metres)

Esp. Desnivel con respecto a la entrada (en metros)

Ital. Dislivello rispetto all'ingresso principale

Pers. Разность ВСУТ ПО ОТНОШЕНИЮ К ВХОДУ

---

**No. 23**

Engl. Cleft, fissure

Esp. Díaclase, grieta

Ital. Diaclasi, fessura

Pers. Трешина

---

**No. 24**

Engl. Fault

Esp. Fallo, dislocación

Ital. Fascia di stratificazione

Pers. Нарушенние, Сброс

---

**No. 25**

Engl. Bedding plane

Esp. Plano de estratificación

Ital. Giunto di stratificazione

Pers. Плоскость наслепения
<table>
<thead>
<tr>
<th>Nr.</th>
<th>Strichstärke</th>
<th>Signaturen</th>
<th>Beschreibungen, Bemerkungen</th>
</tr>
</thead>
<tbody>
<tr>
<td>26</td>
<td>0,5 0,35</td>
<td></td>
<td>Schnitte (dünne Linie), schmaler Pfeil zeigt die Blickrichtung. Alle Schnittdarstellungen zur leichten Erkennung Schraffur unter 45° (ISO - Empfehlung). Benennung der Schnitte mit Buchstaben oder Zahlen.</td>
</tr>
<tr>
<td>27</td>
<td>0,7 0,5</td>
<td></td>
<td>Längsschnitt im Grundriss (dicke Strich-Punkt-Linie), breiter Pfeil zeigt die Blickrichtung. Wechselschraffur für umgelagerte Felsmasse (Tekttonik) z.B. Deckenbruch.</td>
</tr>
<tr>
<td>28</td>
<td>0,35 0,25</td>
<td></td>
<td>Tectonically formed cave or breakdown (hatching, direction varying).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>engl. Cave Map Symbols</th>
<th>ital. Segni per Cavita</th>
<th>fr. Signes pour Plans des Cavités</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.26</td>
<td>Cross section, arrows in direction of sight, small arrows, sections hatched at 45° as ISO, sections marked with letters or numbers</td>
<td></td>
</tr>
<tr>
<td>es.</td>
<td>Sección (líneas fina); la flecha fina indica la dirección de mira. Contornos de secciones rayados bajo 45° para obtener mayor claridad (recomendación de la ISO)</td>
<td></td>
</tr>
<tr>
<td>fr.</td>
<td>Repère et direction de vue en coupe transversale, petite flèche, hachures des coupes égale à 45° ISO</td>
<td></td>
</tr>
<tr>
<td>ital.</td>
<td>Sezione trasversale (freccia fine = direzione dello squadro)</td>
<td></td>
</tr>
<tr>
<td>rus.</td>
<td>Поперечные разрезы, профили, стрелка в направлении взора, маленькое изображение штриховки разрезов выполнить под углом 45°. Большая стрелка - профиль, поперечный разрез.</td>
<td></td>
</tr>
</tbody>
</table>

| No.27                  | Sectional elevations in groundplan, big arrows in direction of sight, with thick line-point-line |
| es.                     | Sección longitudinal en la planta indicada con línea fuerte de punto y raya; la flecha fuerte indica la dirección de mira |
| fr.                     | Repère et direction de vue en coupe longitudinale, grande flèche |
| ital.                   | Sezione longitudinale (freccia in neretto = direzione dello squadro) |
| rus.                    | Продольные разрезы, стрелка в направлении взора или вида, крупное изображение Большая стрелка - продольные разрезы, возможно вертикальная проекция |

<p>| No.28                  | Tectonically formed cave or breakdown (hatching, direction varying) |
| es.                     | Roca dislocada (por acción tectónica) indicada por medio de rayado alternado. Por ejemplo derrumbe (compréese 26) |
| fr.                     | Cavité tectonique par ex. par effondrement |
| ital.                   | Cavità tettonica, per es. per crollo |
| rus.                    | Передвинутые скальные горные породы, тектонически образованная часть пещеры |</p>
<table>
<thead>
<tr>
<th>Nr.</th>
<th>Strichstärke in System</th>
<th>Signaturen</th>
<th>Beschreibungen, Bemerkungen</th>
</tr>
</thead>
<tbody>
<tr>
<td>29</td>
<td>0,25</td>
<td>0,25</td>
<td>a) Höhlengewässer mit Fließrichtung (waagrechte Schraffur)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>0,25</td>
<td>0,25</td>
<td>a) Siphon (waagrechte und senkrechte Schraffur)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>b) Siphon, zeitweise</td>
</tr>
<tr>
<td>31</td>
<td>0,5</td>
<td>0,35</td>
<td>Wasserfall mit Angabe der Falltiefe in Meter</td>
</tr>
<tr>
<td>32</td>
<td>0,35</td>
<td>0,35</td>
<td>a) Fließrichtung</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>b) Fließrichtung, zeitweise</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>c) Fließrichtung, zeitweise Planaufnahme erfolgte am 12.4.67 bei trockenem Gerinne</td>
</tr>
</tbody>
</table>

**engl. Cave Map Symbols**

<table>
<thead>
<tr>
<th>Nr.</th>
<th>Beschreibung, Bemerkungen</th>
</tr>
</thead>
<tbody>
<tr>
<td>29</td>
<td>engl. Cave water, direction of flow, horizontal hatching (a) permanent cave water, (b) temporary cave water (33)</td>
</tr>
<tr>
<td>30</td>
<td>engl. Siphon, vertical and horizontal hatching (a) Siphon, temporary</td>
</tr>
<tr>
<td>31</td>
<td>engl. Waterfall with height (depth) in metres (34)</td>
</tr>
<tr>
<td>32</td>
<td>engl. Direction of flow, temporary direction of flow, (c) temporary direction of flow, mapping on 12.4.67, dry water course</td>
</tr>
</tbody>
</table>

**es. Signos de los Mapas Cavidados**

<table>
<thead>
<tr>
<th>Nr.</th>
<th>Beschreibung, Bemerkungen</th>
</tr>
</thead>
<tbody>
<tr>
<td>29</td>
<td>(a) Curso de agua (rayado horizontal) y sentido de la corriente (b) Curso de agua y sentido de la corriente temporal (véase también 33)</td>
</tr>
<tr>
<td>30</td>
<td>(a) Sifón (rayado horizontal y vertical) (b) sifón temporal</td>
</tr>
<tr>
<td>31</td>
<td>(a) Cascada con indicación de la altura de caída (en metros) (véase también 34)</td>
</tr>
<tr>
<td>32</td>
<td>(a) Sentido de la corriente (b) Sentido de la corriente temporal (c) Sentido de la corriente temporal: topografía efectuada el 12/4/67 con cauce seco</td>
</tr>
</tbody>
</table>

**fr. Signes pour Plans des Cavités**

<table>
<thead>
<tr>
<th>Nr.</th>
<th>Beschreibung, Bemerkungen</th>
</tr>
</thead>
<tbody>
<tr>
<td>29</td>
<td>Plan d'eau souterrain (a) permanent, (b) périodique (33)</td>
</tr>
<tr>
<td>30</td>
<td>Siphon, perenne (b) siphon, périodique</td>
</tr>
<tr>
<td>31</td>
<td>Cascade avec hauteur de chute en mètres (34)</td>
</tr>
<tr>
<td>32</td>
<td>Cours d'eau souterrain (a) perenne, (b) périodique, (c) avec date d'observation, cours d'eau aride</td>
</tr>
</tbody>
</table>

**ital. Segni per Cavità**

<table>
<thead>
<tr>
<th>Nr.</th>
<th>Beschreibung, Bemerkungen</th>
</tr>
</thead>
<tbody>
<tr>
<td>29</td>
<td>Corso d'acqua sotteraneo (a) permanente, (b) temporaneo</td>
</tr>
<tr>
<td>30</td>
<td>(a) Sifone (b) Sifone, temporaneo</td>
</tr>
<tr>
<td>31</td>
<td>Cascata (34)</td>
</tr>
<tr>
<td>32</td>
<td>Corso d'acqua (a) permanente, (b) temporaneo</td>
</tr>
</tbody>
</table>

**рус. Символы для чертежей**

<table>
<thead>
<tr>
<th>Nr.</th>
<th>Beschreibung, Bemerkungen</th>
</tr>
</thead>
<tbody>
<tr>
<td>29</td>
<td>Пещерные русла с направлением течения/горизонтальная штриховка/</td>
</tr>
<tr>
<td>30</td>
<td>Сифон (a) постоянный 6/ временный</td>
</tr>
<tr>
<td>31</td>
<td>Водопад с указанием высоты; 31,34 в зависимости от ширины потока и масштаба плана</td>
</tr>
<tr>
<td>32</td>
<td>Пееренные воды, направление течения a/ с датой наблюдения</td>
</tr>
<tr>
<td>Nr.</td>
<td>Strichstärke</td>
</tr>
<tr>
<td>-----</td>
<td>--------------</td>
</tr>
</tbody>
</table>
| 33  | 0,5          | 0,35       | a) Höhlengewässer mit Fließrichtung  
b) Höhlengewässer mit Fließrichtung zeitweise |
| 34  | 0,5          | 0,35       | Höhlengewässer mit Wasserfall  
Fallhöhenangabe in Meter |
| 35  | 0,5          | 0,35       | Höhlengewässer, Versickerung im Sediment an unbestimmbarer Stelle |
| 36  | 0,35         | 0,35       | a) Wasseraustritt, Quelle  
b) Wasseraustritt, zeitweise |
| 37  | 0,35         | 0,35       | a) Schluckstelle, Schwinde  
b) Schluckstelle, zeitweise |
| 38  | 0,35         | 0,25       | flächiger Wassereintritt  
a) Wassereintritt flächig aus der Wand  
b) Wassereintritt flächig aus der Decke (nur Schnittdarstellung) |

**engl. Cave Map Symbols**

**ital. Segni per Cavita**

**es. Signos de los Mapas Cavidados**

**rus. Сигнатуры для чертежи**

**fr. Signes pour Plans des Cavités**

**No. 33**

engl. Cave water course with direction of flow  
(a) permanent, (b) temporary  
es. (a) Curso de agua y sentido de la corriente  
(b) Curso de agua y sentido de la corriente temporal  
(véase también 29)  
fr. Ruissellement souterrain, direction d’écoulement  
(a) perenne, (b) périodique  
itl. Corso d’acqua (a) perenne, (b) temporaneo  

rus. Пещерные русла с направлением течения  
a/ постоянные  
b/ временные  
29,33 в зависимости от ширины потока и масштаба плана

**No. 34**

engl. Cave water course with waterfall and height (depth)  
in metres  
es. Curso de agua con cascada; altura de caída en metros  
(véase también 31)  
fr. Cascade avec hauteur de chute en mètres  
itl. Cascata  

rus. Водопад с указанием высоты; 31,34 в зависимости от ширины потока и масштаба плана

**No. 35**

engl. Cave water course, ooze (soak away) in the sediment  
in metres  
es. Curso de agua, pérdida en lugar indeterminable del sedimento  
fr. Perte dans les dépots sédimentaires  
itl. Perdita in sedimenti  

rus. Пещерные воды, просачивание в осадок

**No. 36**

engl. Spring, resurgence (a) permanent, (b) temporary  
es. Fuente (a) perenne, (b) temporal  
fr. Source ou résurgence dans la cavité (a) perenne, (b) périodique  
itl. Sorgente in una galleria (a) perenne, (b) temporanea  

rus. a/ Выходы воды постоянные, источник  
b/ Выходы воды временные

**No. 37**

engl. Sink, swallow (a) permanent, (b) temporary  
es. Pérda (a) perenne, (b) temporal  
fr. Perte dans la cavité (a) perenne, (b) périodique  
itl. Perdita in una galleria (a) perenne, (b) temporanea  

rus. Место поглощения в пещере  
a/ постоянные  
b/ временные

**No. 38**

engl. Water entry, seepage (a) wall, (b) roof  
es. Infiltración de agua (a) a lo largo de una pared  
(b) desde la bóveda (sólo se representa como sección)  
fr. Infiltration d’eau perenne (a) paroi, (b) plafond  
itl. Infiltrazione d’acqua (a) parete, (b) volta  

rus. Вход инфильтрационной воды  
a/ стена  
b/ кровля
<table>
<thead>
<tr>
<th>Nr.</th>
<th>Strichstärke in System</th>
<th>Signature</th>
<th>Beschreibungen, Bemerkungen</th>
</tr>
</thead>
<tbody>
<tr>
<td>39</td>
<td>0.25 0.25</td>
<td></td>
<td>a) Tropfwasserloch, aktiv</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>b) Tropfwasserloch, inaktiv</td>
</tr>
<tr>
<td>40</td>
<td>0.35 0.25</td>
<td></td>
<td>Wassertiefe, Angabe in Meter</td>
</tr>
<tr>
<td>41</td>
<td>0.35 0.25</td>
<td></td>
<td>Fliessfacetten</td>
</tr>
<tr>
<td>42</td>
<td>0.35 0.25</td>
<td></td>
<td>Wasserfläche mit schwimmenden Kalk-Häutchen</td>
</tr>
<tr>
<td>43</td>
<td>0.35 0.25</td>
<td></td>
<td>a) Kolk, Überflutet</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>b) Kolk (Boden)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>c) Kolk (Wand)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>d) Kolk (Decke)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>e) Kolk, versintert</td>
</tr>
</tbody>
</table>

**engl. Cave Map Symbols**  
es. Signos de los Mapas Cavidados  
fr. Signes pour Plans des Cavités  
ital. Segni per Cevita  
рус. Сигнатурь для чертежи

- **No.39**  
  - engl. Drip water hole (a) active, (b) inactive  
  - es. Origen de goteo (a) activo, (b) inactivo  
  - fr. Trou d'érosion duur aut dégouttement (a) actif, (b) inactif  
  - ital. Pozetto di stillicidio (a) attivo, (b) inattivo  
  - Рус. Отверстие капающей воды (a/активное b/неактивное)

- **No.40**  
  - engl. Water depth (in metres)  
  - es. Profundidad del agua en metros  
  - fr. Profondeur de l'eau (mètres)  
  - ital. Profondità dell' acqua  
  - Рус. Уровень воды

- **No.41**  
  - engl. Flow markings (scallop)  
  - es. Huellas de corriente  
  - fr. Facette d'érosion fluviale  
  - ital. Scultura alveolare  
  - Рус. Уроочная фасетка

- **No.42**  
  - engl. Water with floating calcite film  
  - es. Superficie de agua con membranas calcáreas flotantes  
  - fr. Plan d'eau recouvert d'une pellicule de calcite  
  - ital. Acqua con pellicola di calcite  
  - Рус. Водная поверхность с плавающим карбонатом

- **No.43**  
  - engl. (a) Pot, flooded (overflown), (b) pot, floor, (c) pot, wall (d) pot, roof (e) pot, with flowstone  
  - es. Marmita (a) inundada (b) en el suelo (c) en la pared (d) en la bóveda (e) concrecionada  
  - fr. (a) Marmite noyée, (b) marmite d'érosion (au sol) (c) niche d'érosion (dans la paroi) (d) dôme d'érosion (au plafond) (e) marmite concrétionnée  
  - ital. (a) Marmitta allagata, (b) marmitta al suolo, (c) marmitta alla parete, (d) marmitta inversa alla volta (e) marmitta concresciuta  
  - Рус. Промоина а/наводненная промоина б/дно в/стена г/крыша д/натечная промоина
<table>
<thead>
<tr>
<th>No.</th>
<th>Strichstärke im System</th>
<th>Signaturen</th>
<th>Beschreibungen, Bemerkungen</th>
</tr>
</thead>
<tbody>
<tr>
<td>44</td>
<td>0,35 0,25</td>
<td>Anastomosen</td>
<td>Wasserglau, gehört am 14.12.61</td>
</tr>
<tr>
<td>45</td>
<td>0,35 0,25</td>
<td>Luftzug, bemerkt am ...</td>
<td></td>
</tr>
<tr>
<td>46</td>
<td>0,35 0,25</td>
<td>flächen Vereisung</td>
<td></td>
</tr>
<tr>
<td>47</td>
<td>0,35 0,25</td>
<td>Schnee, Firn</td>
<td></td>
</tr>
</tbody>
</table>

**engl. Cave Map Symbols**

- No. 44 engl. Anastomoses
- No. 45 engl. Sound of running water (heard on ...)
- No. 46 engl. Draught, (observed on ...)

**ital. Segni per Cavita**

- No. 44 ital. Anastomosi
- No. 45 ital. Corrente di aria (sentita al ...)
- No. 46 ital. Corrente d'aria (con data)

**rus. Сигнатуры для чертежи**

- No. 44 рус. Анастомозы
- No. 45 рус. Шум воды, всегда слышно / при снегах с указанием даты /
- No. 46 рус. Свисток / наблюдался 15.12.67 г. в 17 часов /

**es. Signos de los Mapas Caviados**

- No. 44 es. Anastomosis
- No. 45 es. Sonido de agua, oído el 14/12/61
- No. 46 es. Corriente de aire, sentida el ...

**fr. Signes pour Plans des Cavités**

- No. 44 fr. Anastomoses
- No. 45 fr. Bruit de ruissellement, d'écoulement, chute d'eau (date...)
- No. 46 fr. Courant d'air (constaté le ...)

**рус. Сигнатуры для чертежи**

- No. 44 рус. Анастомозы
- No. 45 рус. Шум воды, всегда слышно / при снегах с указанием даты /
- No. 46 рус. Свисток / наблюдался 15.12.67 г. в 17 часов /

**итал. Segni per Cavita**

- No. 44 ital. Anastomosi
- No. 45 ital. Corrente di aria (con data)

**рус. Сигнатуры для чертежи**

- No. 44 рус. Анастомозы
- No. 45 рус. Шум воды, всегда слышно / при снегах с указанием даты /
<table>
<thead>
<tr>
<th>Nr.</th>
<th>Strichstärke</th>
<th>Signaturen</th>
<th>Beschreibungen, Bemerkungen</th>
</tr>
</thead>
<tbody>
<tr>
<td>49</td>
<td>0,35</td>
<td>a)</td>
<td>Stalagmit, a,b wahlweise</td>
</tr>
<tr>
<td></td>
<td>0,35</td>
<td>b)</td>
<td>Stalagmit, a,b wahlweise</td>
</tr>
<tr>
<td>50</td>
<td>0,35</td>
<td>a)</td>
<td>Stalaktit, a,b wahlweise</td>
</tr>
<tr>
<td></td>
<td>0,35</td>
<td>b)</td>
<td>Stalaktit, a,b wahlweise</td>
</tr>
<tr>
<td>51</td>
<td>0,35</td>
<td>a)</td>
<td>Tropfsteininsel, a,b wahlweise</td>
</tr>
<tr>
<td></td>
<td>0,35</td>
<td>b)</td>
<td>Tropfsteininsel, a,b wahlweise</td>
</tr>
<tr>
<td>52</td>
<td>0,35</td>
<td>a)</td>
<td>Sinterfahne</td>
</tr>
<tr>
<td></td>
<td>0,35</td>
<td>b)</td>
<td>Sinterfahne</td>
</tr>
<tr>
<td>53</td>
<td>0,35</td>
<td>a)</td>
<td>Heliktiten, Excentriques</td>
</tr>
<tr>
<td></td>
<td>0,35</td>
<td>b)</td>
<td>Heliktiten, Excentriques</td>
</tr>
<tr>
<td>54</td>
<td>0,35</td>
<td>a)</td>
<td>Sinteröhrchen, Macaroni</td>
</tr>
<tr>
<td></td>
<td>0,35</td>
<td>b)</td>
<td>Sinteröhrchen, Macaroni</td>
</tr>
<tr>
<td>55</td>
<td>0,35</td>
<td>a)</td>
<td>flächige Versinterung, a,b wahlweise</td>
</tr>
<tr>
<td></td>
<td>0,35</td>
<td>b)</td>
<td>flächige Versinterung, a,b wahlweise</td>
</tr>
<tr>
<td>Nr.</td>
<td>Strichstärke</td>
<td>Signaturen</td>
<td>Beschreibungen, Bemerkungen</td>
</tr>
<tr>
<td>-----</td>
<td>--------------</td>
<td>------------</td>
<td>----------------------------</td>
</tr>
<tr>
<td>56</td>
<td>0,35</td>
<td>a)</td>
<td>Sinterbecken (gross)</td>
</tr>
<tr>
<td></td>
<td>0,25</td>
<td>b)</td>
<td>Sinterbecken (klein, fläschig)</td>
</tr>
<tr>
<td>57</td>
<td>0,35</td>
<td>a) fläschige Sinterbildung</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0,35</td>
<td>b)</td>
<td>Montmilch</td>
</tr>
<tr>
<td>58</td>
<td>0,35</td>
<td></td>
<td>Kristalle</td>
</tr>
<tr>
<td></td>
<td>0,35</td>
<td></td>
<td>Sinterähnliche Formen z.B. Lehnmasten</td>
</tr>
<tr>
<td>59</td>
<td>0,35</td>
<td></td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>0,35</td>
<td></td>
<td>Sinter im Abbau (korrosiv)</td>
</tr>
</tbody>
</table>

**Engl. Cave Map Symbols**
- Gour pools, rimstone pools (a) large, (b) small
- Flowstone, walls and roof
- Crystal formation
- Corrosive destroyed flowstone formation

**Ital. Segni per Cavità**
- Concrezioni a vaschetta (gours) (a) grandi, (b) piccole
- Concrezioni, parietali, volta
- Concrezioni non calcitica (sabbiosa, argillosa, etc.)

**Esp. Signos de los Mapas Cavidados**
- Gours (a) grande, (b) pequeños, formando una superficie
- Colada (a) Leche de monte (Bergmilch), (b) Latte di luna
- Concrecciones de arcilla y/o limo

**Fr. Signes pour Plans des Cavités**
- Concretions non calcitique (siliceux, limoneux, etc.)
- Concretion destroyed anciennement en décalcification

**Rus. Сигнатуры для чертежей**
- Натечный бассейн а/большой б/ маленький
- Натек в кровле или натечные отложения на стене
- Горное молоко, кровля или стена

**Notes**
- Nr. 56: Gour pools, rimstone pools (a) large, (b) small.
- Nr. 57: Flowstone, walls and roof.
- Nr. 58: Crystal formation.
- Nr. 59: Corrosive destroyed flowstone formation.
- Nr. 60: Concretion destroyed anciennement en décalcification.

**Description**
- Sinterbecken (gross) and Sinterbecken (klein, fläschig).
- Kristalle (crystals).
- Sinterähnliche Formen z.B. Lehnmasten (similar Sinter forms e.g. clay stalactites).
- Sinter im Abbau (korrosiv) (Sinter in decomposition (corrosion)).
<table>
<thead>
<tr>
<th>No.</th>
<th>Strichstärke im System</th>
<th>Signaturen</th>
<th>Beschreibungen, Bemerkungen</th>
</tr>
</thead>
<tbody>
<tr>
<td>61</td>
<td>0.5 0.35</td>
<td>2.42 80</td>
<td>Gangerweiterung (mit Datum)</td>
</tr>
<tr>
<td>62</td>
<td>0.35 0.25</td>
<td></td>
<td>Blockwerk</td>
</tr>
<tr>
<td>63</td>
<td>0.35 0.25</td>
<td></td>
<td>Schutt, Erchmaterial (scharf)</td>
</tr>
<tr>
<td>64</td>
<td>0.35 0.25</td>
<td></td>
<td>Kies, Geröll, Geschiebe</td>
</tr>
<tr>
<td>65</td>
<td>0.35 0.25</td>
<td>H Rumus T Ton L Lehm S Sand</td>
<td>Ablagerungen, Sedimente</td>
</tr>
<tr>
<td>66</td>
<td>0.35 0.25 a)</td>
<td></td>
<td>Brekzie a)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b)</td>
<td>Knochenbrekzie</td>
</tr>
</tbody>
</table>

<p>| No.61 | engl. | Artifically enlarged passage (with date) | es. | Galeria ensanchada artificialmente (con fecha) |
|       | fr.   | Passage forcé (dynamitage, travaux de terrassement, date) | ital. | Passaggio forzato (con data) |
|       | rus.  | Искусственные прорывы или расширение проходов, с датой |
| No.62 | engl. | Boulder, large breakdown | es. | Bloques |
|       | fr.   | Grands blocs de pierre | ital. | Massi (grandi dimensioni) |
|       | rus.  | Система блоков |
| No.63 | engl. | Rubble (sharp cornered, small breakdown) | es. | Pedriscos, cascotes |
|       | fr.   | Remplissage, ébouli de pierres aux angles vifs | ital. | Massi (piccoli dimensioni) |
|       | rus.  | Обломки горных пород, обрушенные породы, не окатанные |
| No.64 | engl. | Gravel, pebbles (rounded stones) | es. | Cantos rodados, gravas |
|       | fr.   | Debris d'érosion fluviale, fluviu glacière (gravier) |
|       | ital. | Ghiaia |
|       | rus.  | Валуны /окатанные породы/ |
| No.65 | engl. | Sedimentation (Humus, Clay, Loam, Sand) | es. | Sedimentos (Humus, Arcilla, Fango, Arena) |
|       | fr.   | Sediment (Humus, Marme, Argile, Sable) | ital. | Sedimenti (Humus, Limo, Argilla, Sabbia) |
|       | rus.  | Отложения - Гумус, Тяна, Суглиниок, песок |
| No.66 | engl. | (a) Debris, (b) bone debris (remains) | es. | (a) brecha, (b) brecha ósea |
|       | fr.   | (a) Breccite, (b) breccite d'ossement |
|       | ital. | (a) breccia, (b) breccia ossifera |
|       | rus.  | a/ брекчия, б/ костоносная брекция |</p>
<table>
<thead>
<tr>
<th>Nr.</th>
<th>Strichstärke im System</th>
<th>Signaturen</th>
<th>Beschreibungen, Bemerkungen</th>
</tr>
</thead>
<tbody>
<tr>
<td>67</td>
<td>0,35 0,25</td>
<td>Konglomerat</td>
<td></td>
</tr>
<tr>
<td>68</td>
<td>0,35 0,35</td>
<td>zerstörte Sinterformen</td>
<td>Zerstörung</td>
</tr>
<tr>
<td>69</td>
<td>0,35 0,35</td>
<td>Abfälle, Müll</td>
<td></td>
</tr>
<tr>
<td>70</td>
<td>0,35 0,35</td>
<td>Kadaver</td>
<td></td>
</tr>
<tr>
<td>71</td>
<td>0,35 0,35</td>
<td>Fundstelle (geschichtliches Material)</td>
<td>Grab (menschlich)</td>
</tr>
<tr>
<td>72</td>
<td>0,35 0,35</td>
<td>Fundstelle menschlicher Knochen</td>
<td></td>
</tr>
<tr>
<td>73</td>
<td>0,35 0,35</td>
<td>Fundstelle tierischer Knochen</td>
<td></td>
</tr>
<tr>
<td>74</td>
<td>0,35 0,35</td>
<td>a) Fossilfundplatz (tierisch)</td>
<td>b) Fossilfundplatz (pflanzlich)</td>
</tr>
<tr>
<td></td>
<td>0,35 0,35</td>
<td>Grabungsstelle (keine Gangerweiterung)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nr.</th>
<th>Strichstärke im System</th>
<th>Signaturen</th>
<th>Beschreibungen, Bemerkungen</th>
</tr>
</thead>
<tbody>
<tr>
<td>75</td>
<td>0,35 0,35</td>
<td>Grabungsstelle (keine Gangerweiterung)</td>
<td></td>
</tr>
<tr>
<td>76</td>
<td>0,35 0,35</td>
<td>Grabungsstelle (keine Gangerweiterung)</td>
<td></td>
</tr>
<tr>
<td>77</td>
<td>0,35 0,35</td>
<td>Grabungsstelle (keine Gangerweiterung)</td>
<td></td>
</tr>
<tr>
<td>78</td>
<td>0,35 0,35</td>
<td>Grabungsstelle (keine Gangerweiterung)</td>
<td></td>
</tr>
<tr>
<td>79</td>
<td>0,35 0,35</td>
<td>Grabungsstelle (keine Gangerweiterung)</td>
<td></td>
</tr>
<tr>
<td>80</td>
<td>0,35 0,35</td>
<td>Grabungsstelle (keine Gangerweiterung)</td>
<td></td>
</tr>
<tr>
<td>81</td>
<td>0,35 0,35</td>
<td>Grabungsstelle (keine Gangerweiterung)</td>
<td></td>
</tr>
<tr>
<td>82</td>
<td>0,35 0,35</td>
<td>Grabungsstelle (keine Gangerweiterung)</td>
<td></td>
</tr>
</tbody>
</table>

**engl. Cave Map Symbols**
**ital. Segni per Cavità**
**es. Signos de los Mapas Cavidados**
**rus. Сигнатуры для чертежи**
**fr. Signes pour Plans des Cavités**
**пушеры**

**No.67**
- **engl.** Conglomerate
- **es.** Conglomerado
- **fr.** Conglomerat
- **ital.** Conglomerato
- **rus.** Koglomerenat

**No.68**
- **engl.** Damage, hammer with appropriate symbol
- **es.** Destrucción: martillo y signo del objeto destruido
- **fr.** Détérioration ou destruction
- **ital.** Concrezioni: distrutte
- **rus.** Повреждение образования: молоток относится к соответствующему символу/символу

**No.69**
- **engl.** Rubbish (date)
- **es.** Basura (con fecha)
- **fr.** Ordures abandonées (date)
- **ital.** Rifiuti abbandonati (con data)
- **rus.** ОТХОДЫ - МУСОР С ДАТОЙ

**No.70**
- **engl.** Cadaver (date)
- **es.** Cadaver (con fecha)
- **fr.** Charnier (date)
- **ital.** Cadaveri (con data)
- **rus.** ТРУНОС, С ДАТОЙ

**No.71**
- **engl.** Historic site
- **es.** Sitio arqueológico
- **fr.** Gisement archéologique
- **ital.** Sito archeologico
- **rus.** Доисторическое место находки

**No.72**
- **engl.** Grave or burial (human)
- **es.** Tumba (humana)
- **fr.** Tombe (protohistorique, préhistorique, historique, récente)
- **ital.** Tomba
- **rus.** ТУМБА

**No.73**
- **engl.** Bones (human)
- **es.** huesos humanos
- **fr.** ossements (humains)
- **ital.** Ossa (umanee)
- **rus.** КОСТИ ЧЕЛОВЕКА

**No.74**
- **engl.** Bones (animal)
- **es.** huesos animales
- **fr.** ossements (animaux)
- **ital.** Ossa (animali)
- **rus.** КОСТИ ЖИВОТНЫХ

**No.75**
- **engl.** Fossil site (a) animal, (b) vegetable
- **es.** Hallazgos fósiles (a) animales, (b) vegetales
- **fr.** Fossiles (a) animaux, (b) végétaux
- **ital.** Reperti fossili (a) animali, (b) vegetali
- **rus.** 4/ ИСКОПАЕМЫЕ ЖИВОТНЫЕ

**No.76**
- **engl.** Site of dig (no further passage widening)
- **es.** Excavación
- **fr.** Ouilles
- **ital.** Scarpa
- **rus.** МЕСТО РАСКОПОК

/нет расширения прохода для прохождения/
<table>
<thead>
<tr>
<th>Nr.</th>
<th>Strichstärke im System</th>
<th>Signaturen</th>
<th>Beschreibungen, Bemerkungen</th>
</tr>
</thead>
<tbody>
<tr>
<td>77</td>
<td>0.35 0.35</td>
<td>Guano</td>
<td>a) Rippen am Boden (kein Sinter)</td>
</tr>
<tr>
<td>78</td>
<td>0.35 0.35</td>
<td>Biwak</td>
<td>b) Rippen an den Wänden</td>
</tr>
<tr>
<td>79</td>
<td>0.35 0.35</td>
<td></td>
<td>c) Rippen an der Decke</td>
</tr>
<tr>
<td>80</td>
<td>0.35 0.35</td>
<td>Karren</td>
<td></td>
</tr>
<tr>
<td>81</td>
<td>0.25 0.25</td>
<td>Eiskristalle durch Kondensation</td>
<td></td>
</tr>
<tr>
<td>82</td>
<td>0.25 0.25</td>
<td>Blumenkohlsinter</td>
<td></td>
</tr>
<tr>
<td>83</td>
<td>0.35 0.35</td>
<td>Paletten, Diskus- oder Scheibensinter</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>79</td>
<td>engl. Ribs, (no stal); (a) floor, (b) wall, (c) roof</td>
<td>es. Aletas (a) en suelo (no concreciones)</td>
<td>(b) en las paredes</td>
<td>fr. Lames (a) au sol, (b) à la paroi, (c) au plafond</td>
<td>ital. Lame (a) sul pavimento, (b) paialetti, (c) sulla volta</td>
<td>pyc.</td>
<td>rus.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Literatur
Bini, Alfredo; Cappa, Giulio, Proposte die ammorder-namento della simbolologia per rilievi di cavità naturali scotterane, Bollettino dell' Associazione Italiana di Cartografia, Benevento, August, 1974.
Frank, Helmut. Signaturen für Höhlenpläne, Laichinger Höhlenfreund, Jg. 5, 1974, Nr. 1, Höhlenforschungsabteilung des HHVL.
Müller, Ralph. Definitionen und Signaturen zum Zeichnen von Höhlenplänen, Oberndorf/Neckar, Spéléo-Südwest 1976, Tagungsunterlagen.
Müller, Ralph. Signaturen zum Zeichnen von Höhlenplänen (Vorabdruck), Mählistetten, Spéléo-Südwest 1980, Tagungsunterlagen.
Preu, Dieter. Vorschlag zur Vereinheitlichung der Plandarstellung von Höhlen; Aus der Praxis, Mitteilungen, Jg. 9, 1963, Nr. 1, Verband der deutschen Höhlen- und Karstforscher e. V. München.
Standing Committee on Cave Map Symbols, NSS Section on Cave Geology and Geography Cave Map Symbols (NSS Standard Cave Map Symbols, 1976), The Bulletin, Quarterly Journal of the Nat. Spel. Soc., Jg. 41, 1979, Nr. 2, Huntsville, Alabama, USA.
The Rhagidiidae are introduced and the caverniculous species are discussed. Troglophilous and troglobitic species can be distinguished by their morphological adaptations, so-called troglomorphisms. All known cave cave rhagidiids of the U.S.A. and Mexico are being studied and new species with pertinent zoogeographic affinities to cool, moist and dark environments occur in caves in other biogeographical regions as well.

The most extensive and substantial works on the European cave material of this family were published by Willmann (1932, 1934, 1935, 1941, 1953, 1954). Later they were followed by others such as Lombardini (1951), Turk and Turk (1952), Cooreman (1959), Turk (1972), Baltac (1973, 1974, 1976), Rack (1974) and Zacharda (1978, 1980).

In North America cave rhagidiids were studied by Packard (1988), Banks (1897) and Banta (1907). Recently Holminger (1965), Elliott and Strandmann (1971) and Elliott (1976) published their contributions to the taxonomy and zoogeography of the Rhagidiidae in North American caves. At present, the cave rhagidiids of the U.S.A. and Mexico are being studied and new species with pertinent zoogeographic data will be described soon (Zacharda and Elliott, 1981, a; Zacharda and Welbourn, 1982).

Unfortunately data on the cave rhagidiids of other parts of the Holarctic region are quite limited. Morikawa (1963) described species from several limestone caves and R. japonica (= Poecilophysis pratenesis) from a mine and forest litter in Japan. Shibata (1971) described Rhagidia longisensilla (= Shibaiia coreasensis) from a limestone cave in South Korea and R. crenata (Shiba, 1949) from a lava cave in western Japan as well as from Japanese forests.

The taxonomic status of some of these species is uncertain and the types should be reviewed. Regardless of the taxonomic problem, it appears that R. uenoi may be troglobitic while other species are troglobiotic.

We must stress that although many scientific papers on rhagidiids have already been published, the correct identity of the species, especially in older papers and species lists, is often uncertain (e.g. 1934;: Thor and Willmann, 1941) or often has been obscure. At present a revision of the known world rhagidiid fauna (Zacharda, 1980) allows reliable identification of most species. Other cave species in need of taxonomic review are Rhagidia trisetata Elliott and Strandmann, 1971 (troglobiphile, Mexico, S.L.P.); Troglocheles concimoda (Lombardini, 1951) (troglobite, Italy); R. odontochela Turk, 1972 (troglobite, Great Britain); and R. vitzthumii Turk, 1972 (troglobite, Great Britain).

Troglobitic and Troglophilic Rhagidiidae

As shown in Table 1, thirty reliably distinguishable rhagidiid species have been found in caves (or mines) of the Holarctic region up to the present. Eighteen species are troglobiotic, and some of these are probably troglobites in statu nascendi* (see below). Twelve species are troglobitic.

Holminger (1965) and Elliott (1976) disclosed in cave rhagidiids evident morphological adaptations to life in caves, such as eyelessness, depigmentation of the integument, attenuation and elongation of the appendages and chaetotaxy, and a remarkable development of some special sensory organs. Recently, the morphological adaptations in the troglobotic Rhagidiidae were evaluated by Zacharda (1979 a, 1980) and named "troglomorphisms". In the Rhagidiidae they are the elongation and attenuation of the legs, pedipalps, chelicerae and chaetotaxy, the depigmentation of the very thin integument, and sometimes eyelessness (Fig. 1). Troglophilic cave rhagidiids are usually larger than the smaller hemiedaphic or euedaphic ones. Their special sensory organs, the so-called "rhagidial organs" located on tarsi I, II, and exceptionally III, are often strikingly developed. The rhagidial setae are enormously enlarged or increased in number, and the special sensory lancelocerciform setae on tibia II are hyperthrophied and protruding from its insertion point. The latter adaptation has evolved in parallel in several North American and European cave arachnids and has been described by Foss (1965) and Foll (1976) in Troglocheles strasserii (Willmann) they are unusually increased in number, or in Rhagidia varia (unpubl. species) they are enormously enlarged (Fig. 1).

In the troglobiotic rhagidiids we find only adaptations to life in caves and dark habitats, i.e. a fine depigmented integument and sometimes eyelessness, but the conspicuous troglomorphisms are always missing. In some, in Troglocheles strasserii s.l. (Zacharda, 1980: 646-658) inhabiting vast karst areas in West and Central Europe, or Traggaardia dalmatica (Willmann) from caves of the Balkan peninsula (Zacharda, 1980: 716-719), or Rhagidia varia from Virginia (Zacharda and Welbourn, 1982), the phenomenon of cave vicariation, supported by geographical and geomorphological isolation of the local cave population, should be taken in consideration. Unfortunately, the present shortage of material does not allow us to draw more detailed conclusions on cave vicariation in the Rhagidiidae.

Distribution

Genuine troglobitic rhagidiids are known to inhabit only caves, while the troglobilous species commonly occur also outside the caves. In some species, however, their position is not quite clear and the following example is given: Poecilophysis spelaea (Wankel) (= Rhagidia reussa Sig Thor) bears only indistinct troglomorphisms, but at present this species is known only from caves in Europe where it is often very abundant (Zacharda, 1978). No finds outside the caves have been reported up to the present.

* Holminger (1965) and Elliott (1976) discovered that some of the species are "in statu nascendi"* (see below).
Siberia. It is not out of the question that there may be a population of this species living outside the caves somewhere in the North Siberian tundra, while all the European populations occur only in caves as troglobites "in statu nascendi".

As an analogy, the North American rhagidid Robustocheles hilli (Strandmann) was originally described from lichens in Alaska, later found in the typepaper of the Canadian Arctic Archipelago (Zacharda, 1980), but in the U.S.A. it has been found only in caves (Elliott, 1976; Zacharda and Welbourn, 1962), where it is a very abundant and common rhagidid. This same probably applies to the North American rhagidid Povecheles tuktoyaktukensis Zacharda, discovered in Arctic Canada and in Greenbrier Caverns, West Virginia (unpubl.). Of course, both species bear no troglomorphisms and if they occur in the U.S.A. only in caves (not yet verified), they should be considered post-glacial relicts surviving in caves during post-Wisconsin time (Munroe, 1968; Matthews, 1979).

To summarize, we expect that evolutionarily older and conspiciously, morphologically specialized troglobites are distributed in relatively small areas, e.g. Elliotta howarthi (Elliott), Flabellorhagidia pecki Elliott, Troglocheles strasseri (Willmann), etc., while evolutionarily younger troglobites "in statu nascendi", or post-glacial troglobitic species, bearing only indistinct troglomorphisms, e.g. Poecilophysis spelaea (Wankel), occupy larger areas. Only troglobilic rhagidiids can facultatively occur in both the Holarctic and Nearctic regions, e.g. Poecilophysis weyerensis (Packard), P. pratensis (C. L. Koch), Rhagidia diversicolor (C. L. Koch). Many more species are expected.

Collection and Further Study

Further extensive collection of cave rhagidiids throughout the world is still highly desirable to expand our knowledge of their classification, bosomy, and evolutionary adaptations. We must stress, however, it is also important to collect these mites in the vicinity of caves to find which "troglobitic" species occur outside the caves and which do not.

Because season-dependent life cycles have been disclosed in some species (Zacharda, 1979 b, 1980), it is best to repeat collections several times a year. Then adults, which are indispensable for correct specific identification, are more likely to be collected.

The Rhagidiidae are usually observable as small, whitish, spider-like creatures running here and there on the substrate. We can collect them by using a fine, alcohol-soaked artist's brush or a small aspirator containing 80-96% ethyl alcohol. Especially in caves these mites can also be picked up from pool surfaces using small wire nets, or samples of cave substrate can be desiccated in a Berlese-Tullgren apparatus (Krantz, 1978). Moist to wet soil samples must be transported on wire nets bags in boxes with solid walls to protect them against pressure and sticking. However, this is not a very efficient method.

Pitfall traps, small jars about 8 cm in diameter, containing 3% formaldehyde solution and sunk to ground level, are a surprisingly successful method of collecting rapidly moving rhagidiids, especially when we use a bait, e.g. a sterile wafer, which should be placed on the substrate close to the pitfall trap. The bait attracts cave decomposers, mainly Collembola and, consequently, also their predators (Zacharda, 1978: 23.

Further study of the Rhagidiidae requires fresh preparations, specimens being preserved only in alcohol and not embedded permanently as is customary.

Table 1. A list of the cave Rhagidiidae of the Holarctic region.

Troglobitic species
* Rhagidia diversicolor (C. L. Koch, 1838). Czech. W. Ger.* U.S.A.*
* Poecilophysis faeroensis (Traugard, 1931). Faeroe Is., W. Ger.*, U.S.A.*

References


Figure 2. Cheliceral types in; non-trogloformic species: A - Rhagidia geilia; B - Poeciophysis macquariensis; and trogloformic species: C - Elliotta howarthi; D - Troglocheles strasseri s.l.
Horsethief Cave is located south of the Wyoming-Montana border at an elevation of 4685 feet (1429 meters) in a plateau (Little Mountain) formed from gently dipping Madison Limestone of Mississippian age. The plateau is formed across the crest of the asymmetrical Porcupine Creek anticline on the west flank of the Bighorn Mountains in the Middle Rocky Mountain Province (Frenneman, 1981). The cave lies in a partially dissected diplepe on which there are residual hills of the Pennsylvanian Amsden Formation (Figure 1). Such surface depressions, resulting from the dip of the Madison Limestone, exposing rocks as old as upper Devonian along 800 foot (244 meters) vertical walls. Approximately one mile (1.6 kilometers) west of Horsethief Cave, the Bighorn River flows northward in a meandering, 600 foot (183 meter) deep canyon superposed across the north end of the Bighorn Mountains.

Horsethief Cave with its adjacent and interconnected neighboring cave, Bighorn Caverns, forms a complex joint controlled maze system with an estimated 20 miles (32 kilometers) of passages (Figure 2). With only a few exceptions, passage forms where unaltered by breakdown are phreatic in nature. Most large passages have been altered by breakdown, and surface sediments have been washed into the cave in many locations. Additionally, dripstone features and crystal growths (primarily gypsum) are found throughout the cave. No surface expression of the cave system other than its entrances is currently observable. The eroding Amsden Formation has filled and obscured sinks and former collapse entrances.

Cave fill material is found in the upper part of the Madison Limestone in a unit consisting of 145 feet (44 meters) of tan, finely crystalline, and thinbedded siltstone with some breccia (Sutherland, 1955). The breccias contain limestone fragments in red siltstone or claystone matrix similar to the basal part of the overlying Amsden Formation. These zones of breccia are concentrated at the top and bottom of this upper unit of the Madison, and in part represent late Mississippian karst topography (Thom, 1937; Richards, 1955). Collapse structures are common in this unit, yielding a great variety of strikes and dips. The major part of the cave itself varies between 60 and 120 feet (18 to 37 meters) below the top of the Madison Limestone. Some narrow fissures, however, extend to the top of the Formation, being roofed with breccia and in some cases siltstone from the Amsden Formation. Narrow fissures can be seen in the ceilings of major passages, as well as at various angles to them. The variations in vertical positions of major passages are due primarily to varying amounts of passage collapse and infilling with breakdown.

The joint orientations which control passage development are related to Laramid and possibly also Mississippian age structures (Sutherland, 1976). These joints offer a great variety of directions for potential passage orientations. The dip of the Madison Formation is to the southwest near the cave system, and the Bighorn River lies directly west of the cave system (Figure 1). A rose diagram shows that passages such as Main Passages West (Figure 3) show that main passage orientations and their controlling joints are primarily east-west, with secondary trends shifting toward a southerly direction. This indicates that the steepest hydraulic gradient toward the Bighorn River exerted greater influence on which particular joints became main passages than did the southwesterly dip of the Madison Limestone.

The angular grid pattern of a network type maze which stands out in many parts of the cave system can be seen in the cave map (Figure 2). It attributes this type of pattern to uniform diffuse groundwater recharge from an overlying formation, or surface, which was uniformly enlarged from the top to the bottom of the Amsden Formation. The angular grid pattern pattern of diffusion extends to the top of the Madison Limestone as mentioned previously support this interpretation. The Amsden Formation was removed from Little Mountain while the Amsden Formation was the aquifer responsible for uniform diffuse recharge to the Madison Limestone. Terrestrial sediments on Little Mountain or traces thereof in cavern fills indicates that the Amsden Formation probably still covered the Madison Limestone during the Tertiary Period. This reinforces the contention that the Amsden Formation was the aquifer responsible for uniform diffuse recharge to the Madison Limestone during cavern development.

The development of large rooms and passages in Horsethief Cave appears to have begun as a modification of the lower portions of solutionally enlarged fissures. Such development apparently to have taken place in the vicinity of 90 feet (27 meters) or greater below the top of the Madison Limestone. Where large rooms have not formed below fissures, sponge work and makes occasionally are present. Since these modifications of fissures do not extend for any great vertical distance, less influence from the waters which enlarged the fissures is thought to have taken place at that level. Mixing corrosion as described by Bogli, 1964 (in Jennings, 1971) presents the most probable cause of such vertical restrictions on phreatic passage development. Secondary waters for mixing with water draining from the Amsden Formation could have easily been supplied from a bedding plane, or possibly even the paleokarst within the Madison.

The relative age of development of Horsethief Cave can be determined from a preceeding description of the cave and its surroundings, when compared with the erosional history of the Bighorn River (Mackin, 1937 and 1947; Merrill, 1947). The eastward gradient of the Bighorn River determined which joints in the limestone became main passages, the river must have been incised to a position lower than that of the cave system. Otherwise phreatic passage development would have been wither random in orientation, or the dip of the Madison Limestone would have influenced the orientation of main conduits.

The absence of passage modification by vadose waters in the cave system shows that the phreatic enlargement of the cave ended rather abruptly. One may conclude that the upper part of the cave was filled with breakdown. Such a change in hydrology in the cave system most likely occurred during a period of rapid Horsethief by the Bighorn River to the west, and by Porcupine Creek to the north. This situation is reinforced by the lack of evidence for any subsequent re flooding of the cave system at a later time. Once the cave drained, it remained drained.

The age limits on the development of Horsethief Cave are as follows: 1) it formed before the Amsden Formation was removed from Little Mountain while the Bighorn River was at an elevation somewhat lower than the elevation of the cave; 2) the Bighorn River was not
incised so deeply that a vadose cave system formed rather than a phreatic one; and 3) the end of phreatic cavern development occurred when the Bighorn River and Porcupine Creek rapidly downcut their channels, draining the cave quickly enough to preclude vadose modification of passages, and removing the large supply of water available for cave expansion.

The highest and oldest terrace in the northern part of the Bighorn Basin is the Tatman Mountain surface along the Greybull River, which flows into the Bighorn River 40 miles (72 kilometers) southwest of Horsethief Cave. Assuming past gradients of the Bighorn River to be similar to those at the present, the Bighorn River near Horsethief Cave was flowing at an elevation approximately 100 feet (30 meters) higher than the present cave entrance during the time of the cutting of the Tatman Mountain surface. Phreatic cavern development probably took place after the cutting of this surface.

The next lower terrace, the Yu Terrace, just northwest of Tatman Mountain and also of early Pleistocene age (Merrill, 1974), can be used to project a relative elevation of the Bighorn River west of Horsethief Cave approximately 700 feet (213 meters) below the present cave entrance. The present surface of Little Mountain near Horsethief Cave, which may in part represent an erosional terrace (Sutherland, 1976), slopes westward toward a river level about 500 feet (152 meters) below the cave entrance. The approximate slope of the passages in Horsethief Cave, which have not been altered by breakdown, points toward a Bighorn River elevation about 250 feet (76 meters) below the present cave entrance. Phreatic development in Horsethief Cave and draining of the cave system probably took place prior to the cutting of the Yu Terrace.

The geomorphic study of Horsethief Cave as related to its surroundings provides a means of determining the relative age of the cave system. The phreatic development of Horsethief Cave most likely occurred between the time of the cutting of the Tatman Mountain surface and the Yu Terrace. The relative age of the cave systems development is therefore early Pleistocene. This relative age determination can now be useful as a time frame for studies within Horsethief and other related caves on Little Mountain.

References
GENERALIZED GEOLOGY & STRUCTURE OF LITTLE MOUNTAIN

Figure 1

Figure 2
Ecosystem Of A Deep Confined Aquifer In Texas

Glenn Longley
Edwards Aquifer Research and Data Center
Box 47, Southwest Texas State University, San Marcos, Texas, 78666

Abstract

Studies of the Edwards Aquifer in Texas were initiated in 1973 and are continuing. More than 50 wells have been sampled. Most of the wells flow under artesian pressure from depths varying from 58 m to 610 m below the surface. Approximately 40 species (including 3 vertebrates) have been found in this unique system. Fossil energy is hypothesized as a major source of energy input into this ecosystem. This source of energy has not been previously considered important in subterranean aquatic ecosystems. These studies have provided good evidence for support of this hypothesis.

Zusammenfassung

The Toohey Ridge Cave System - A Geographical Overview

James D. Borden
9315 Friars Road, Bethesda, Maryland 20034, U.S.A.

M. E. Drake
Box 357, Franconia, New Hampshire 03580, U.S.A.

Abstract

The Toohey Ridge Cave System (Roppel Cave) is located in south-central Kentucky, one kilometer east of Mammoth Cave National Park. With presently over thirty-seven kilometers of surveyed passages, Toohey Ridge is the second longest cave region of the country.

The Toohey Ridge Cave System is developed in limestone of middle to upper Mississippian age and is underlain by a massive caprock consisting of upper Mississippian aged sandstones and shales, forming a roof to the underlining cave passages. Dip is gentle, and to the northwest. Being located in an area of intense groundwater basinial migration, the Toohey Ridge Cave System has developed into a canyonized array of tubes and canyons. This system of passageways exhibits a multitude of drainage 'trends', forming a paleo-hydrological puzzle that has yet to be solved.

Water in the cave system flows to at least two major active springs. Geographically, the cave system can be divided, quite definitively, into major sections -- the Old Cave, and the New Cave. The Old Cave, that which was found immediately after the cave's '76 discovery, is a complicated shaft drain system of limited extent; whereas the New Cave, that found one year after Labor Day, 1978, is more of the classic combination of sinkhole plain, valley, and shaft drain systems that make the caves of Central Kentucky so large. Potential in Toohey Ridge for finding cave is great, and should prove to be an invaluable piece to this immense subterranean puzzle that exists in the Central Kentucky Karst.

Zusammenfassung


For descriptive purposes, Roppel Cave can be broken into two separate entities, the Historic Section and the Main Section. The Historic Section is defined as the cave that was known prior to Labor Day, 1978, and its associated passages. The Main Section is the cave area found principally after Labor Day, 1978. This area can be exclusively defined as those passages beyond the S-64 Pit. This partition works out quite well since the Historic Section, with minor exceptions, bears little genetic relationship to the Main Section, enabling each to be easily described separately.

The Historic Section

The Historic Section is reached via the active drain to Coalition Chasm (Arrow Canyon), the entrance shaft complex. The Historic Section consists mainly of a intricate shaft-drain network that drains the flanks of the southwest corner of Eudora Ridge. Passages in this section tend to be small and difficult to traverse. Three major east-west drainage corridors can be observed in this section. These are: Grim Trail, Fossil Avenue, and Fishhook Canyon.

Grim Trail is the most northern, and perhaps the oldest of the three corridors. Now abandoned, Grim Trail once drained waters westward from the two primary sources in opposing extremes of the Historic Section. From the south, waters originating from shafts near Fishhook Canyon flowed through a one-half meter high, five meter wide phreatic tube, 500 meters long, known as C Crawl. Geologically, Grim Trail is anastomosed to the Eudora Ridge, whose ultimate destination is not yet known. It is likely that Grim Trail will be found to lead to a drainage net beyond the Eudora Ridge. From the north, Arrow Canyon was a later tributary to the Grim Trail corridor, completing an excellent example of a dendritic drainage system. With a close look at Grim Trail, one can see a clear path of the abandonment of C Crawl and the formation of the southernmost east-west drainage corridors. Fishhook Canyon now flows down rapidly, with a few systems to a yet to be determined point. Exploration of Fishhook Canyon has barely yet begun.

With the abandonment of C Crawl, the only recharge...
for Grim Trail remaining was Arrow Canyon, which with subsequent downcutting, broke through a lower chert-zone forming Bicentennial Shaft and the resultant drain. This chain is one kilometer long and is a tributary to the Crayfish River Passage, a low-level drainage conduit underlying Dry Valley. The Bicentennial Shaft drain apparently formed under mixed phreatic and vadose conditions resulting in a highly irregular canyon passage with several instances of positive gradient. At present, this drain has been abandoned for a lower, unexplored bedding-plane conduit.

Fossil Avenue, an abandoned high level conduit, lies between the Fishhook Canyon and Grim Trail corridor. The source of Fossil Avenue is not known, but is speculated to be shafts and associated valleys at the eastern flanks of Eudora Ridge. Vivian Way is a connected eastern extension of Fossil Avenue about two hundred meters long and three meters high and wide. Fossil Avenue has been modified heavily by shaft development, however its true dimensions appear to be about two meters high and five meters wide. Fossil Avenue terminates in breakdown beneath Dry Valley, but its continuation has been found in the Main Section.

The Main Section

The Main Section is reached via an abandoned drain to Coalition Chasm. This drain, the S Survey, intersects an old shaft drain system that eventually provides access to a trunk network beneath the northeast lobe of Toohey Ridge.

The Main Section is notable because of a network of trunk passages about seven kilometers long. At first appearance, it seems that many drainages converged here. However, this trunk network is actually a complex of distributaries, piracies, and cutoffs having perhaps just one source that is only now becoming understood. Passages in this trunk network range from two to six meters high and five to ten meters wide and exist on two principal levels. This trunk network provides access to at least two groundwater basin drainage--Turnhole, to the south, and Pike, to the north.

Arlie Way is the lowest of the Main Section trunk passages. Drainage in Arlie Way is still puzzling. To the south, Arlie Way intersects the main component of Turnhole Spring Drainage, Logsdon's River. Logsdon's River can be followed two kilometers downstream before dumping and flowing into Proctor Cave of the Mammoth Cave System. A physical connection here is not likely. Logsdon's River flows through a tubular conduit two meters high and five meters wide. In the upstream direction, Logsdon's River has only been followed a short distance, but it is likely that this conduit is traversable for several kilometers.

The Black River Complex is a major shaft drain system reachable via Arlie Way and drains northward to join a major valley drain, Elysian Way. The active stream, Black River, drains shafts on the periphery of a large sinkhole. This area is quite confusing with its multi-tiered canyons and tubes. This is due to the fact that Black River Complex has been the victim of a zone of wandering basin boundaries of two major springs. This has resulted in innumerable flow reversals that provide a fascinating potential for further discoveries.

As stated earlier, Elysian Way is a major drain to Dry Valley. Its source has not yet been explored but Elysian Way has been followed far to the north, yielding a continuously traversable passage five kilometers in length. Dimensions vary from two meters high and six meters wide in the upstream segment to 20 meters high and six meters wide in the downstream direction. Farther downstream, the passage exhibits an intricately braided pattern in three levels. Exploration has stopped in the downstream section at base-level passage. Elysian Way appears to ultimately be a tributary to Salts Cave of the Mammoth Cave System.

At a point 1.8 kilometers from the end of Elysian Way a major tributary is encountered. Each trip made into the system reveals scores of leads of high complexity. Exploration is geared to extending the limits of the system into areas of large ridge in both Toohey and Eudora Ridge. It is entirely probable that the length of the Toohey Ridge Cave System will exceed 100 kilometers. Eventually a connection to Mammoth Cave may also be found, but this remains to be seen.
Figure 1.

ROPPEL CAVE
TOOHEY RIDGE CAVE SYSTEM,
KENTUCKY

38.4 KILOMETERS, JANUARY, 1981

Survey by
CENTRAL KENTUCKY KARST COALITION

Cartography
J.C.Currens