International Congress of Speleology
Congrès International de Spéléologie
Internationaler Kongress für Speläologie
Congreso Internacional de Espeleologia
Congresso Internationale di Speleologia
Международный Срелеологический Конгресс

10.

PROCEEDINGS – COMMUNICATIONS – ABHANDLUNGEN – COMUNICACIONES – COMUNICAZIONI –

СБОРНИК ДОКЛАДОВ

I.

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13-20. August 1989.

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PREFACE

The deadline for the submission of the Congress papers was the 15th of February, 1989. The papers started to turn up by the end of February. The Editor had a quantity of papers worth to start editing with almost a month after the deadline. In the middle of April papers still kept arriving. The final deadline of the printer being the 15th of May, 1989, the Editor and his staff were able during those two months of voluntary work to prepare to volumes You hold in your hands as they are.

We are delighted with the appearance of many papers and tried to rescue the substandard ones. Many authors seemingly had not comprehend that the papers were to be published without any alteration except for formal page setting. None of the papers were turned down for any reason other than illegibility. Some papers may be subtandard in more than their looks but the short period of time available did not permit us to read them with any proper criticism. Since the average of the papers was somewhat under the permitted extension the Editor did not abridge any of those that were too lengthy. We regret if some of the authors were not completely satisfied with the final appearance of their works. Like those who will not find their photographs printed. Photos were mostly weeded out because the applied printing method did not permit to publish them - sending them at all was against the set rules.

In spite of our best intentions there may be errors in the editing. Before blaming the editors please consider that they are also entitled to the basic human right to make mistakes.

The papers were edited continuously as they arrived so please do not look for a system in the sequence, there is no any except that we tried to keep the papers of the same author(s) and those written in Cyrillic characters grouped.

As a consequence of the continuous editing and the different printer's deadlines for the two volumes the Contents of the Proceedings was set at the end of the second volume. It is easier than usual to locate information in the two volumes as we supply separate alphabetical lists of authors, papers (listed by sections) and countries.

AVANT-PROPOS

Le délai de présentation des textes des rapports de congrès a été prévu le 15 février 1989. Les premiers textes sont observés vers la fin du mois de février. Presque un mois après ce délai, les rédacteurs ont déja disposé un volume suffisant des rapports de congres pour entamer les travaux de rédaction. Cependant vers le mi-avril, les rédacteurs recevaient les envois de texte. Le délai définitif pour l'imprimerie était fixé le 15 mai 1989. Aprés deux mois de travail volontaire du rédacteur et de son équipe ont pu produire une récolte que vous avez dans vos mains.

Une partie des rapports a été mise en forme d'une façon excellente qui nous a fait un grand plaisir, mais en fait, l'autre partie exigait des traitements pour la sauver. Plusieurs auteurs visiblement n'ont pas compris les préavis de rédaction selon lesquels les textes seront imprimés sans changement, sauf le mise en page. L'équipe de rédaction n'a pas refusé aucun rapport, sauf la variante illisible. Il est possible qu'il y a quelques textes qui sont au dessous du niveau souhaité, mais le temps disponible à la rédaction était trop court pour les évaluer et lire a esprit critique.

Nous regrettons, si éventuellement quelques auteurs ne seront pas contents complétement de la présentation finale de leur travail. Les auteurs par exemple, qui ne retrouvent pas les photographies sous forme imprimée, c'est parce que la méthode d'imprimerie n'a pas rendu possible leur édition, ainsi ces images ont été mis à coté conformément aux principes de rédaction établis et publiés préalablement. Étant donné que la longueur moyenne des textes des conférences reste inférieure à celle admissible, le rédacteur n'a pas raccourci les textes trop longues.

Malgré notre bonne volonté, il est possible que la rédaction n'est pas sans faute. Avant l'accusation des rédacteurs, nous vous prions de bien vouloir tenir en compte que les rédacteurs même ont le droit humaine à commetre les erreurs.

Les textes de conférences ont été rédigé en fonction de la chronologie de récéption, ainsi nous vous prions de ne pas rechercher un systéme dans l'arrangement des rapports, en outre que nous avons essayé à regrouper les travaux d'un même auteur, et les textes en lettres cyrilliques.

La table des matiéres a été mis à la fin du deuxieme volume à cause des différents délais de rédaction et d'imprimerie des deux volumes. L'usage des volumes est facilité par les indices par auteurs, par sections et par géographie (pays) classés dans l'ordre alphabétique.

VORWORT

Der Einsendetermin für die Texte der Kongreßbeiträge war der 15. 2. 1989. Ende Februar begannen sich die Texte langsam zu sammeln. Fast einen Monat nach dem Termin standen dem Redakteur so viel Vorträge zur Verfügung, daß es sich schon mit der Arbeit zu beginnen lohnte. Mitte April kamen immer noch neue Texte hinzu. Da der Schlußtermin der Druckerei der 15. 5. 1989 war, konnten der Redakteur und seine Mitarbeiter in 2 Monaten Arbeit das produzieren, was Sie in der Hand halten.

Die äußere Form vieler Vorträge hat uns Freude bereitet, und viele die unter dem Niveau waren, versuchten wir zu retten. Viele Autoren haben es offensichtlich nicht verstanden, daß die Texte ohne Veränderung erscheinen werden, äußer des Umbruches. Wir haben keinen Text zurückgewiesen, sofern er nicht unlesbar war. Es ist möglich, daß manche Beiträge auch inhaltlich unter dem Niveau liegen, aber in der uns zur Verfügung stehenden kurzen Zeit konnten sie nicht mit präzisen, kritischen Augen durchgelesen werden.

Es tut uns leid, wenn machen Verfasser mit dem äußersten Erscheinen ihrer Arbeit nicht ganz zufrieden sein sollten, diejenigen z.B., die ihre Photos nicht in der Ausgabe finden. Die angewandte Drucktechnik gestattete uns die Reproduktion eines Großteiles von ihnen nicht, so haben wir diese nicht weitergereicht - die Zusendung dieser widersprach schon den Vorschriften. Da der Umfang der Beiträge durchschnittlich unter der vorgeschriebenen Länge ist, hat der Redakteur diejenigen, die zu lang sind, nicht gekürzt.

Trotz unseres besten Willens sind der Redaktion sicher Fehler unterlaufen. Bevor Sie jedoch die Redakteure beschuldigen sollten, berücksichtigen Sie bitte, daß auch ihnen die grundlegenden Menschenrechte betreffen der Begehung von Fehlern zustehen.

Die Beiträge haben wir fortlaufend, in der Folge des Eintreffens redigiert. Wir bitten Sie deshalb, in der Reihenfolge kein System zu suchen, das es nicht gibt, äußer, daß wir uns bemühten die Beiträge von demselben Autor (von denselben Autoren) sowie die zyrillischen Texte zusammen zu lassen.

Wegen der fortlaufenden Redaktion und der verschiedenen Druckereitermine der beiden Bände finden Sie das Inhaltverzeichnis am Ende des zweiten Bandes. Den Gebrauch der Bände erleichtert das alphabetische Verzeichnis der Autoren, das Verzeichnis nach den Sektionen und das geographische Verzeichnis.

PREFACIO

El plazo de entrega de los discursos del Congreso fué el 15 de febrero de 1989. Los textos empezaron a llegar a fines de febrero. El redactor tuvo a su disposición la cantidad de material requerida para empezar el trabajo con un mes de atraso. Aún llegaban textos a mediados de abril. Puesto que el plazo último de la imprenta era el 15 de mayo de 1989., después de 2 meses de trabajo voluntario el redactor y su equipo lograron lo que Usted tiene en sus manos.

La presentación de muchos discursos nos ha causado gran encanto y hemos tratado de salvar varios de bajo nivel. Muchos autores notablemente no han comprendido, que los textos serán impresos sin ninguna alteración excepto la compaginación. No hemos rechazado ningún texto, solamente los que eran ilegibles. Es posible que algunos discursos no alcanzaron el nivel requerido en cuanto al contenido pero debido al corto tiempo a nuestra disposición no hemos podido leerlos con un espíritu crítico.

Sentimos, si algunos autores no estarian satisfechos con la presentación final de sus trabajos. Los que por ejemplo ne encuentren sus fotografias impresos. El método de imprenta utilizado no permitió 'a publicación de la mayoria de estas, asi que han sido seleccionadas - ya que su envio era contrario a las prescripciones.

Puesto que la duración de los discursos está por debajo de lo permitido, el redactor no ha cortado demasiado los textos. A pesar de nuestra mejor voluntad es posible que hayan errores en la redacción. Antes de que acusen a los redactores pedimos considerar que ellos también tengan en cuenta el factor humano de cometer errores.

Los discursos han sido redactados continuamente según el orden de llegada, por ello pedimos nu buscar cualquier sistema en el orden de apariencia, ya que no lo tiene, excepto que hemos tratado de mantener junto los trabajos de un autor(es), y los textos en letras cirilicas.

Por la redacción continua y por los diferentes términos de impresión de los dos tomos el contenido lo hemos colocado el final del segundo tomo. El indice alfabético, de los autores, de las secciones y geográfico facilita el uso de los tomos.

PREFAZIONE

Il termine della consegna dei testi del Congresso era il 15 febbraio 1989. I testi cominciavano ad arrivare verso la fine di febbraio. Il redattore aveva a sua disposizione soltanto quasi un mese dopo il suo termine un numero sufficiente di relazioni con le quali già valeva la pena di mettersi a lavorare. Verso la metá di aprile i testi ancora continuavano a giungere. Siccome il termine finale della tipografia era il 15 maggio 1989, dopo un lavoro volontario di due mesi il redattore e il suo stato maggiore non potevano produrre piu di quanto Lei tiene nelle mani.

La forma esteriore di molte relazioni ci rallegrava, ma anche dovevamo tentare di salvarna parecchie dia basso livello. Molti autori ovviamente non hanno capito che i testi saranno pubblicati senz'alcuna modificazione tranne l'impaginazione. Non abbiamo rifiutato nessun testo tranne quelli illegibili. Può darsi che ci sono ancora alcune relazioni sotto il livello richiesto dal punto di vista del contenuto, ma durante il tempo breve che abbiamo avuto a nostra dispozione non ci era possibile di leggerle tutte con il necessario spirito di critica.

Ci dispiacerebbe se ci fossero degli autori non del tutto contenti dell'apparenza finale dei loro lavori. Quelli per esempio, che non trovano le loro fotografie nella versione stampata. In molti casi era il metodo di stampa impiegato a non rendere possibile la pubblicazione delle foto, cioe siamo stati costretti a cancellarle tanto più che gia la loro annessione era contro le regole prefissate. Siccome la lunghezza media delle relazioni non supera quella permessa, nemmeno le relazioni che la eccedono furono accorciate.

È certo che malgrado la nostra premura ci sono rimasti errori anche nella versione finale. Prima di incolparne i redattori cortesemente si prega di tener conto che anche a loro spetta il fondamentale diritto umano di sbagliare.

Le relazioni sono state redatte continuamente, secondo l'ordine di arrivo. Perciò si prega di non buscare nessun sistema nell'ordine di successione che non ci può essere tranne che si trattava di tenere raggruppati assieme i lavori degli stessi autori e quelli in caratteri cirillici.

Dovuto alla redazione forzatamente continua e ai diversi termini di stampa dei volumi, l'indice si trova alla fine del secondo volume. L'uso dei volumi è facilitato dagli indici alfabetico secondo autori, secondo temi (sezioni) e secondo luoghi geografici (paesi).

ПРЕДИСЛОВИЕ

Срок представления текстов докладов конгресса был 15 февраля 1989 г. Тексты эти начали поступать в конце февраля. Почти на месяц позже предусмотрено срока в распоряжении редактора собралось столько докладов, когда уже стоило начать работу. В середине апреля материалы все еще поступали. Поскольку окончательным сроком для типографии было 15 мая 1989 г., после двух месяцев добровольной работы редактор и его штаб могли подготовить материал, который вы держите в руках.

Внешний вид многих докладов доставил нам удовольствие, наряду с этим мы постарались сохранить многое из того, что было ниже соответствующего уровня. Многие авторы не поняли того, что тексты будут изданы без каких-либо изменений, за исключением верстки по страницам. Мы не отклонили ни одного текста, только если его невозможно было прочитать. Возможно, что некоторые доклады по своему содержанию не достигают соответствующего уровня, но в течение имеющегося в распоряжении короткого времени невозможно было их прочесть с точным критическим подходом.

Мы очень сожалеем, если некоторые авторы останутся недовольны окончательным оформлением их работы. Например те, кто не найдет в изданном материале свои фотографии. Примененный типографский метод не пригоден для печатания большинства из них, таким образом такие фотографии мы изъяли - уже сам факт их присылки противоречит установленным правилам.

Поскольку средняя длина докладов меньше допустимой, редактор не урезал слишком длинные. Не смотря на наши самые наилучшие стремления, по всей вероятности, в готовом материале встречаются ошибки. Перед тем, как обвинить в этом редакторов, просим принять во внимание тот факт, что и они имеют элементарное человеческое право ошибаться.

Доклады обрабатывали последовательно в порядке их прибытия, поэтому просим вас, не ищите какую-либо систему в их очередности, ведь таковой нет, кроме этого труды тех же авторов и тексты с кирилловскими буквами постарались сгруппировать вместе.

Из-за последовательного редактирования и различного типографского срока двух томов "Содержание" поместили в конце второво тома.

Пользование томами облегчает алфавитный указатель по авторам, по секциям и по географическому положению /по странам/.

ELŐSZÓ

A kongresszusi előadások szövegeinek beadási határideje 1989. február 15-e volt. A szövegek csak február vége felé kezdtek jövögetni. A szerkesztőnek csaknem egy hónappal a határidő után állt a rendelkezésére annyi előadás, amennyivel már érdemes volt a munkát megkezdeni. Április közepén még mindig érkeztek szövegek. Minthogy a nyomda végleges határideje 1989. május 15-e volt, két hónap önkéntes munkája után a szerkesztő és stábja azt tudta produkálni, amit Ön a kezében tart.

Sok előadás külalakja okozott örömet és sok színvonal alattit próbáltunk megmenteni. Sok szerző láthatóan nem értette meg, hogy a szövegek bármi változtatás nélkül fognak megjelenni, kivéve az oldalba tördelést. Egyetlen szöveget sem utasítottunk vissza, hacsak az olvashatatlan nem volt. Lehet, hogy néhány előadás tartalmilag sem üti meg a színvonalat, de a rendelkezésre álló rövid idő alatt pontos kritikai szemmel nem lehetett őket átolvasni.

Sajnáljuk, ha néhány szerző nem lenne teljesen elégedett munkája végső megjelenésével. Azok például, akik nem lelik fényképeiket a nyomtatásban. Az alkalmazott nyomtatási módszer nem engedte meg legtöbbjük megjelentetését, így ezeket kigyomláltuk - már elküldésük is ellenére volt a felállított szabályoknak. Miután az előadások átlagos hossza alatta van a megengedettnek, a szerkesztő nem vágta meg a túl hosszúakat.

Legjobb akaratunk ellenére is bizonyára kerültek hibák a szerkesztésbe. Mielőtt vádolnák a szerkesztőket, kérjük vegyék figyelembe, hogy őket is megilleti a hibák elkövetésének alapvető emberi joga.

Az előadásokat beérkezésük sorrendjében folyamatosan szerkesztettük, kérjük ezért, ne keressenek bármely rendszert a sorrendiségben, ugyanis nincs benne, azon kívül, hogy azonos szerző(k) munkáit és a cirillbetűs szövegeket igyekeztünk együtt tartani.

A folyamatos szerkesztés és a két kötet különböző nyomdai határideje miatt a Tartalomjegyzéket a második kötet végére helyeztük. A kötetek használatát megkönnyíti az alfabetikus szerző szerinti, a szekció szerinti és a földrajzi (országonkénti) mutató.

RECENT AND PALEOKARST SYSTEMS AND THEIR RELATIONS TO ORE MINERALIZATION IN THE IBERG-REEF-COMPLEX, HARZ MOUNTAINS

REINER, Andreas - KEMPE, Stephan

The Iberg-Winterberg reef complex, a massive Devonian limestone formation, is exposed in a small outcrop (2.5km²) in the south-western Harz Mountains, FRG. It is surrounded by Carboniferous greywackes and by strike-slip branch faults of the WNW-ESE trending Upper Harz mineralized vein system.
Geological investigations were carried out in a 5 km long cave and mine complex (Eisensteinstollen) situated in the SE corner of the Iberg. Faulting and fracturing in this zone was followed by deposition of iron-manganese ores and baryte. Large parts of the limestone are replaced metasomatically by dolomite, ankerite and siderite. Lenses of well bedded, yellow sediments, formerly described as "dolomite", were recognized as altered quartz and clay mineral deposits in paleokarst cavities of possible Permian or younger age. In Late Tertiary or Early Quaternary times the system of isolated caves existing today developed under phreatic conditions without any indication for turbulent flow. These rooms follow the steeply dipping, NW-SE striking ore veins or limestone-dolomite contacts and a gently (30°) SE-dipping fault zone. In situ generation of CO2 from slowly oxidizing siderite may have fueled the cave genesis in this unique system.

1. INTRODUCTION

In the SW Harz Mountains (F.R.G.) the dome-shaped Devonian Iberg-Winterberg reef limestone emerges from the surrounding Carboniferous graywackes. The small limestone outcrop (2.5 km²) consists of two atoll-like structures, the Iberg in the SE and the Winterberg in the NW. The original reef shape is suppressed by boundary faults, separating the limestone from the clastic rocks. Its total extension may have amounted to 12.5 km², with a thickness of 600 m (FRANKE, 1973). More than 80 cavities are known within the complex, descending a few to 50 meters below the surface. Most of them are closely associated with iron-manganese ore bodies, which gave rise to intensive mining activity during the last centuries. The natural caves served as shafts for both descending into the mines and hauling the iron ores in the earlier periods of mining. In the middle of the 19th century a gallery (Eisensteinstollen) was driven into the Iberg, but already in 1887 the last mine was abandoned. In 1986 the gallery and the system of natural caves and mines was made accessible again exceeding a total length of 5 km (Figs. 1, 2).

2. GEOLOGY OF THE IBERG AREA

During the Middle to Upper Devonian the Iberg-Winterberg reef grew up on a local rise within a shaly basin facies. In the Lower Carboniferous the limestone complex was overwhelmed with flysch-type graywackes and afterwards included in the Variscan orogeny. Whereas the clastic sediments were intensively folded the massive limestone was only deformed to a dome-like structure.

The Variscan consolidation of the Harz Mountains was accomplished by intrusions of gabbroic and granitic magmas during the Upper Carboniferous. In the Early Permian some rhyolitic vulcanism occurred and a fault system developed, transsecting and displacing the folded Paleozoic rocks. It is characterized by zones of predominantly WNW-ESE striking diagonal slip faults or strike-slip faults containing important base metal ore deposits, generally galena, sphalerite and some chalcopyrite. Main gangue minerals in the ore veins are quartz, calcite, siderite, barite and fluorite.

The sources of the ore forming fluids as well as the time of the mineralization are still uncertain. As it is widely accepted that the hydrothermal mineralizations are not differentiates of the granitic intrusions two models are favoured. From REE (rare earth elements) -distribution in gangue minerals MÖLLER et al. (1984) and LÜDERS (1988) conclude that highly saline solutions from great depths, mobilized in the basement by the Permian heatflow event, are responsible for the base metal deposition. The fluorite mineralization is presumed to be related to the Permian rhyolitic vulcanism and therefore to have a different origin. In contrast, fluid inclusion measurements support the origin of ore fluids from sedimentary basin brines (BEHR & GERLER, 1987). Highly saline, Na-Ca-Cl-type waters may have developed within Upper Permian and Triassic mollasse troughs rich in clastic and evaporitic series. The fossil formation water then migrated into marginal basement areas along the fault system established during Permian uplift and Mesozoic wrench tectonics. STOPPEL et al. (1983) suppose a still younger age for the deposition of barite in relation to the Cretaceous uplift of the Harz Mountains and reactivated tectonic movements on the Hercynian fault system.

One of the vein fault zones, the Rosenhof Lode, represents the southern boundary fault system of the Iberg (SPERLING & STOPPEL, 1979). A strongly mineralized zone branches off the ore lode into the SE-flank of the Iberg limestone, where the Eisensteinstollen cave system and most of the smaller cavities are situated (Fig. 1).

3. EXTENSION OF THE CAVE SYSTEM

The area which the Eisensteinstollen system occupies is small, just 40,000 m². The natural rooms are connected by two principal mining galleries, the deeper of which is flooded today. The total accessible length is more then 5 km. The vertical extension from the highest point at +435 m a.s.l. to the mean water table at +355 m a.s.l. amounts to 90 m, but the deepest point has been reached by diving about 50 m below the water level. Mining documents also report of several caves discovered at greater depths.

The cavities are remarkably different in shape. They are either elongated in a WNW-ESE direction, narrow and 5-15 m high, or have flat forms, 3-20 m wide, 1-10 m high and mainly dipping to the SE. Combinations of these types occur as well as cupolas. One of them exceeds a high of 15 m. The system as a whole continuously descends to the SE under the overlying graywackes and predominantly stays 30-50 m below the limestone surface (Fig. 2, FRICKE et al., 1988).

4. TECTONICS AND MINERALIZATION IN THE CAVE SYSTEM

Corresponding to the trend of most cave rooms two essential tectonic features appear. The first is a system of steeply dipping, WNW-ESE to NW-SE striking vein faults and fractures, that can be compared to the nearby boundary faults. The second tectonic element is uncommon in the Upper Harz region. This SE-dipping (30°-45°) thrust fault zone may have developed from synsedimentary boundary layers during the Variscan folding act.

The amount and direction of displacement along the faults is hard to determine. Within the massive limestone no marker horizons exist and primary structures have been obliterated by dolomitization and iron ore deposition. The vertical offset along the steep faults and fractures commonly seems to be small but in some cases may amount up to 30 m. Moreover, strike-slip movements are indicated post-dating the dolomitization but preceding the deposition of iron hydroxides.

The mineralization sequence starts with the partial replacement of the limestone by dolomite followed by ankerite and manganese-rich siderite. Dolomite/limestone contacts are either very sharp (within a few cm) or characterized by slightly increasing quantities of scattered dolomitic rhombohedrons finally grading into dense, xenotopic mosaics (over a distance of some meters).

Siderite, accompanied by euhedral zoned dolomite and ankerite crystals, occurs in form of irregular bodies in compact dolomitic rocks. The accurate shape of most siderite deposits is impossible to define because metasomatic contacts with the dolomitic wall rock are diffuse and widely obliterated by black manganoferous coatings. The sideritic ores predominantly (but not exclusively) occur in deeper parts of the cave system. Where the SE-dipping thrust zone is exposed the deposits as well as dolomite and lenticular to vein-like limonitic ore bodies are intercalated between thick layers of yellowish gouge clays.

Iron-manganese hydroxides are the common ores to be found at the Iberg. They occur in veins, sills, lenticular bodies or irregular bunches which are clearly distributed along the main tectonic directions described above. Dominant iron-bearing phases are goethite and lepidocrocite, having an iron/manganese ratio comparable to the sideritic ores. Black fibrous varieties of the goethitic ores may have been mistaken for diverse manganese minerals which have formerly been reported. In contrast, only todorocite and possible rancieite could be detected by XRD.

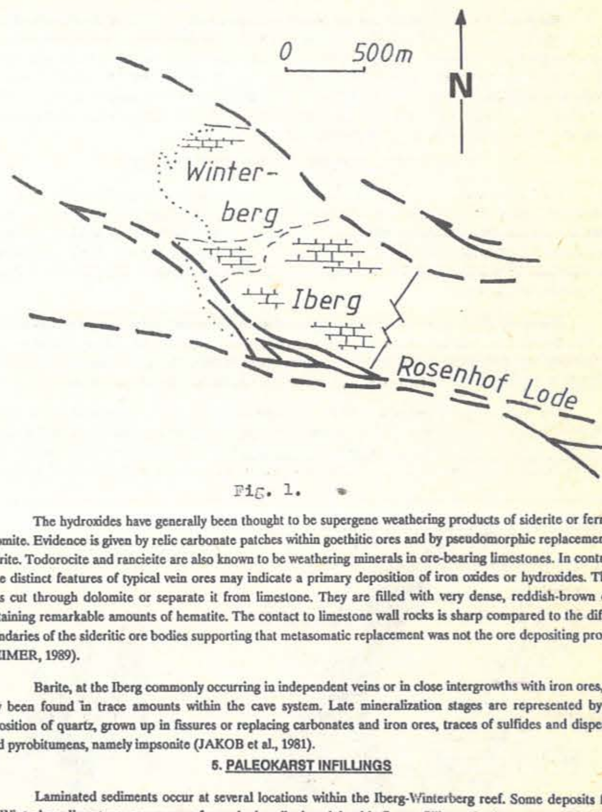


Fig. 1.

The hydroxides have generally been thought to be supergene weathering products of siderite or ferroan dolomite. Evidence is given by relic carbonate patches within goethitic ores and by pseudomorphic replacement of siderite. Todorocite and rancieite are also known to be weathering minerals in ore-bearing limestones. In contrary, some distinct features of typical vein ores may indicate a primary deposition of iron oxides or hydroxides. These veins cut through dolomite or separate it from limestone. They are filled with very dense, reddish-brown ores containing remarkable amounts of hematite. The contact to limestone wall rocks is sharp compared to the diffuse boundaries of the sideritic ore bodies supporting that metasomatic replacement was not the ore depositing process (REIMER, 1989).

Barite, at the Iberg commonly occurring in independent veins or in close intergrowths with iron ores, has only been found in trace amounts within the cave system. Late mineralization stages are represented by the deposition of quartz, grown up in fissures or replacing carbonates and iron ores, traces of sulfides and dispersed solid pyrobitumens, namely impsonite (JAKOB et al., 1981).

5. PALEOKARST INFILLINGS

Laminated sediments occur at several locations within the Iberg-Winterberg reef. Some deposits from the Winterberg limestone quarry were formerly described as dolomitic fissure fillings of unknown age (FRANKE, 1973). Similar sediments are exposed within the Eisensteinstollen cave system and sometimes at the limestone surface. They are composed of claystone and siltstone layers exceeding sometimes a thickness of a few meters. The finer layers mainly consist of illite, the silty ones of quartz, illite and minor quantities of chlorite. In coarser grained layers lithic fragments of metamorphic and magmatic origin are dominant. Feldspar has never been found. Intraformational breccias containing rounded red clay pebbles may occur as well as slump structures and convolute lamination. The sediments are normally less consolidated but often cemented by silicification and dolomitic replacement near ore bodies. White to yellow, greenish-grey or reddish-brown colors are present.

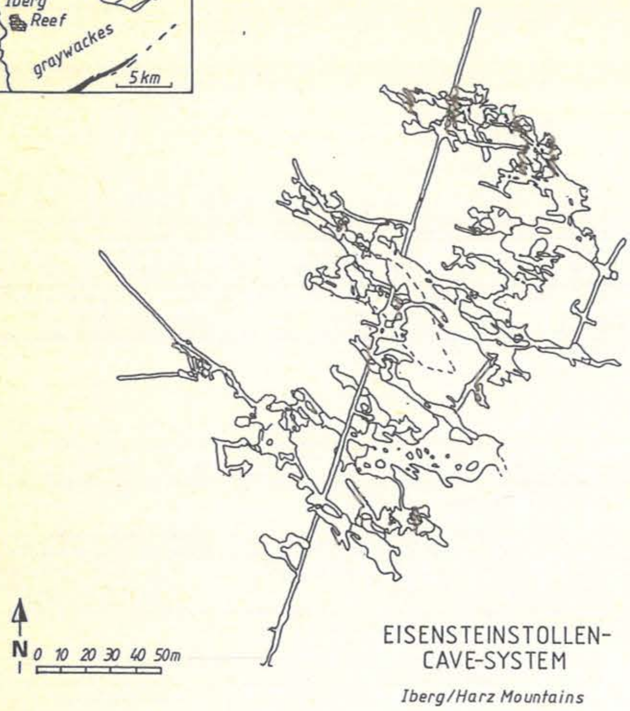


Fig. 2.

The sedimentological features and the general occurrence near the edges of the limestone complex support a (fluvial) deposition in an ancient cave system. Within the mineralized zone of the SE-Iberg the original shape of the sedimentary deposits has completely been destroyed but the former assumption is proved by outcrops in the Winterberg quarry where some tubular cavities are exposed, totally filled with laminated sediments. Development and filling of cavities precedes ore deposition but must post-date long erosional phases that followed the Variscan orogeny. Therefore the cave system should be of Early Permian age but can be much younger if a Cretaceous mineralization age is assumed (REIMER, 1989).

6. DEVELOPMENT OF THE EISENSTEINSTOLLEN CAVES

Field studies and the reports on the mined ore quantities suggest that roughly half of the room volume present may originate from enlargement by dissolutional processes and half from mining. Artificial holes occur mostly near the cave floor whereas the ceiling and upper parts of the walls display natural forms. Typical features are dissolution pockets, facets and flat or concave ceilings (Fig. 3a) supporting that the caves developed under phreatic conditions with slow convective flow (KEMPE et al., 1975). No canyons or other indications of vadose entrenchment have been found.

The rooms obviously follow the main tectonic and mineralogical boundaries. Along the contact of steep ore veins and dolomitic wall rocks passages have the form of widened voids (Fig. 3b) whereas parallel to the SE-dipping fault zone they show rounded or flattened, tapered cross sections. Passages often connect large halls or terminate in cupolas (Fig. 4). Isolated cavities are also common, made accessible only by mine passages.

The Eisensteinstollen system is a maze cave. Occurrence of maze caves is favoured in hydrodynamic environments characterized by trapping effects (represented by the aquitard boundary faults surrounding the Iberg limestone) or in areas where CO_2-enriched waters are supplied by hydrothermal activity (FORD, 1987). In case of the Iberg no indication is given for the ascent of hydrothermal waters. Instead, the slowly release of CO_2 by in-situ

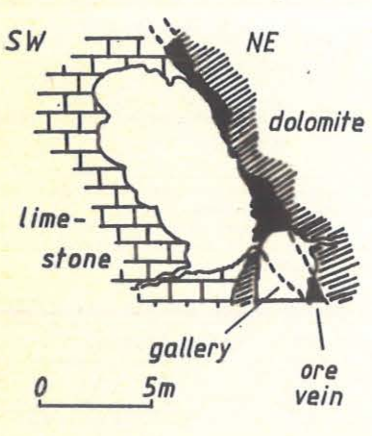
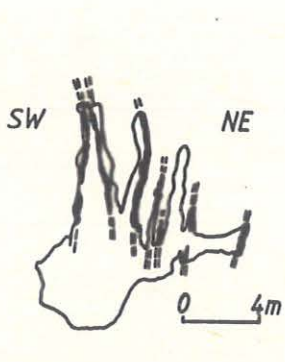


Fig. 3 a



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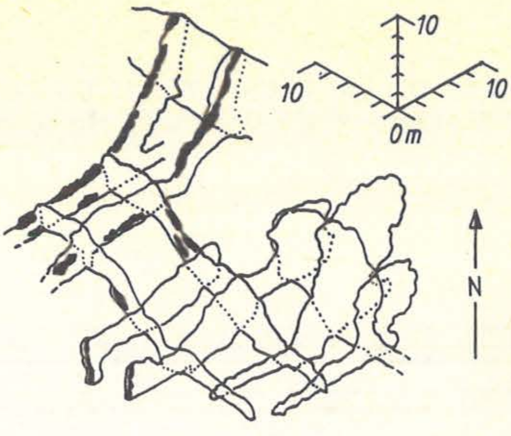

Fig. 4.

oxidation of siderite is assumed to have been the driving mechanism for cave development, in order to explain the morphological features and the extreme density of cavities (KEMPE, 1975; SVENSSON, 1988; SVENSSON & KEMPE, this volume).

7. ACKNOWLEDGEMENTS

The authors gratefully acknowledge the enthusiastic help during the field work provided by the ArGe Stellwerk, Clausthal/Zellerfeld (F.R.G.), and especially by UWE FRICKE who spearheaded the mapping of the Eisensteinstollen.

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HYDROCHEMISTRY OF KARST WATERS IN THE IBERG-REEF-COMPLEX, HARZ MOUNTAINS

SVENSSON, Uwe - KEMPE, Stephan

The chemistry of cave and surface waters from the Devonian Iberg reef limestone in the southwestern Harz Mountains (F.R.G.) was monitored during 6 months. Cave pools and drip waters from the 5km long cave system "Eisensteinstollen" and from surface springs were analyzed and evaluated for their PCO_2 and saturation with regard to calcite and dolomite. Water types were discriminated statistically.

Most of the cave waters have high magnesium concentrations. This is in accordance with the fact that large parts of the reef have metasomatically been altered to dolomite. Pool and drip waters differ significantly suggesting ongoing dissolution of limestone/dolomite in the cave pools. One of the pools is stratified and has a pH of 6.6, a PCO_2 of 100,000 ppmv, increased Ca, Mg and HCO_3 concentrations and decreased oxygen concentrations at the bottom. This is indicative of ongoing siderite oxidation causing the liberation of additional CO_2.

1. INTRODUCTION

The morphologically prominent Iberg/Winterberg (560 m a.s.l., SW-Harz Mountains, F.R.G.) is formed by a Middle to Upper Devonian massive and erosion resistant limestone. It represents a former atoll reef (FRANKE, 1973). The reef is surrounded by Lower Carboniferous graywackes which were intensively folded during the Variscan orogeny. The limestone has only a very small area of outcrop, i.e. 2.5 km², but it is intensively karstified. The SE part of the Iberg has the largest concentrations of caves. Here the reef limestone has been altered metasomatically to dolomite and siderite (REIMER, 1989). Within an area of 250x150 m a cave system, the "Eisensteinstollen" has developed, totaling 5 km in length and 135 m in vertical extension (Fig. 1, FRICKE et al., 1988). It was made accessible by miners, which, until the last century, recovered goethite and siderite from the system, thereby opening up some mine passage to connect the natural caves. Nevertheless the system is the deepest natural system in Germany north of the Alps and one of the longest in the country. The hydrochemistry of this system, including surface, seepage and pool waters, was studied to gain an understanding of processes which determine the composition of the karst water and which are responsible for the genesis of the cave system (SVENSSON, 1988). Today, the lower part of the system serves as a reservoir for drinking water of the town Bad Grund collecting the seepage from the caves and the border faults of the Iberg.

2. METHODS

During several field campaigns a total of 75 pool waters, 43 seepage waters and 25 surface waters (creek and spring waters) were sampled within a period of five months (Aug.-Dec. 1986). Temperature, pH, conductivity and alkalinity were determined in the field. Major ions and other aqueous species were analyzed by standard methods at Hamburg. In addition, the vertical variation in hydrochemistry was studied in detail in one of the cave pools. Partial pressure of CO_2 (PCO_2), and saturation indices ($SI = \log_{10}(IAP/K_{Mineral})$) with respect to calcite and dolomite were calculated applying a computerized electrolyte model (KEMPE, 1975a; 1982). Multivariate statistics, i.e. discrimination, cluster and factor analysis, were applied to all data in order to group samples and to extract common factors governing the hydrochemistry (SVENSSON, 1988).

3. RESULTS

3.1 General Description of Karst Water Hydrochemistry

The multi-component scatter plot of relative concentrations of major ions (Fig. 2) illustrates that Ca^{2+}, Mg^{2+} and HCO_3^- dominate the chemical character, while Na^+, K^+, Cl^- and SO_4^{2-} seem to be less important. According to the ground water classification scheme of FURTAK & LANGGUTH (1967), all samples fall into the category of "normal alkaline earth waters" (< 20 meq % $Na^+ + K^+$ and > 80 meq % $Ca^{2+} + Mg^{2+}$). They belong either to the sub-categories "mainly bicarbonatic" (> 60 meq % HCO_3^-) or "bicarbonatic-sulfatic" (40-60 meq % HCO_3^- and 60-40 meq % $SO_4^{2-} + Cl^-$). Only a few surface samples group with the "mainly sulfatic" sub-type (> 60 meq % $SO_4^{2-} + Cl^-$). In Figure 2 the sample points are grouped according to their origin: Type 1 = cave pools; Type 2 = seepage waters and Type 3 = surface waters. Table 1 shows ranges and averages for pertinent chemical parameters in these three types of water.

Table 1

Ranges and averages of some chemical parameters for the karst waters of this study.

Parameter	Range	Average
1.) Cave pool waters		
µS (specific conductance)	241-804	367.
Ca^{2+}/Mg^{2+} (molar)	0.6-4.6	1.8
pH	7.2-8.2	7.9
PCO_2 (atm)	$10^{-1.71}$-$10^{-3.17}$	$10^{-2.72}$
$SI_{calcite}$	-0.34 to +0.62	+0.08
$SI_{dolomite}$	-0.62 to +0.59	-0.03
2.) Seepage waters		
µS (specific conductance)	200-650	331
Ca^{2+}/Mg^{2+} (molar)	1.2-7.6	2.6
pH	7.7-8.2	8.0
PCO_2 (atm)	$10^{-2.62}$-$10^{-3.35}$	$10^{-2.99}$
$SI_{calcite}$	-0.43 to +0.43	+0.09
$SI_{dolomite}$	-0.51 to +0.32	-0.11
3.) Surface waters		
µS (specific conductance)	95-630	319
Ca^{2+}/Mg^{2+} (molar)	0.8-6.1	2.7
pH	7.0-8.1	7.5
PCO_2 (atm)	$10^{-1.10}$-$10^{-3.28}$	$10^{-2.60}$
$SI_{calcite}$	-1.74 to +0.57	-0.64
$SI_{dolomite}$	-1.84 to +0.27	-0.83

Type 1: **Cave pools** belong exclusively to the sub-category "mainly bicarbonatic", they contain up to 65 meq % Mg^{2+} (dolomitic waters). Concentrations of Na^+ and K^+ do not exceed 5 meq % and Cl^- and SO_4^{2-} concentrations are < 10 and < 20 meq %, respectively.

Type 2: **Seepage waters** can be characterized as bicarbonate to sulfate waters containing up to 40 meq % chloride additionally. They have generally lower absolute concentrations of Ca^{2+} and Mg^{2+} than cave pool waters. Particularly, Mg^{2+} does not exceed the 40 meq % level, while Ca^{2+} can vary by as much as 30 meq % and can reach as much as 80 meq %. Alkaline earths, mainly Na^+, can contribute up to 20 meq %. The decrease in the relative contribution of bicarbonate is associated with a simultaneous increase in Cl^- and SO_4^{2-}, which can contribute up to 30 and 40 meq %, respectively (Fig. 2, lower right triangle).

Type 3: **Surface waters** occupy the largest area in the multi-component diagrams, i.e. they represent the most diverse type of water. Especially in creeks relative $Na^+ + K^+$ and $Cl^- + SO_4^{2-}$ contents are larger than in Type 1 and 2 waters. These creeks probably originate from the mixture of meteoric runoff and soil waters. Spring waters, however, are more similar to seepage waters if they derive from either limestone or dolomite source rocks. Surface waters are generally lower in specific conductivity, pH, $SI_{calcite}$ and $SI_{dolomite}$ than both pool and seepage water (Table 1).

Differences among the three water types are, however, slight and discrimination among the types remains rather subjective because of considerable overlapping in the relative concentrations of major ions. Because of this lack in confidence in such descriptive grouping, discrimination analysis was applied (e.g. DAVIS, 1973). Two analyses were performed successfully and yielded statistically significant information. The first analysis suggests (with a reliability of 75 %) that Na^+, K^+ and HCO_3^- are the normative variables for discriminating surface versus cave waters. The second analysis indicates that Ca^{2+}, Mg^{2+} and HCO_3^- are responsible (with a reliability of 85 %) for discriminating seepage versus cave pool waters. These findings confirm the results obtained by the purely descriptive grouping methods.

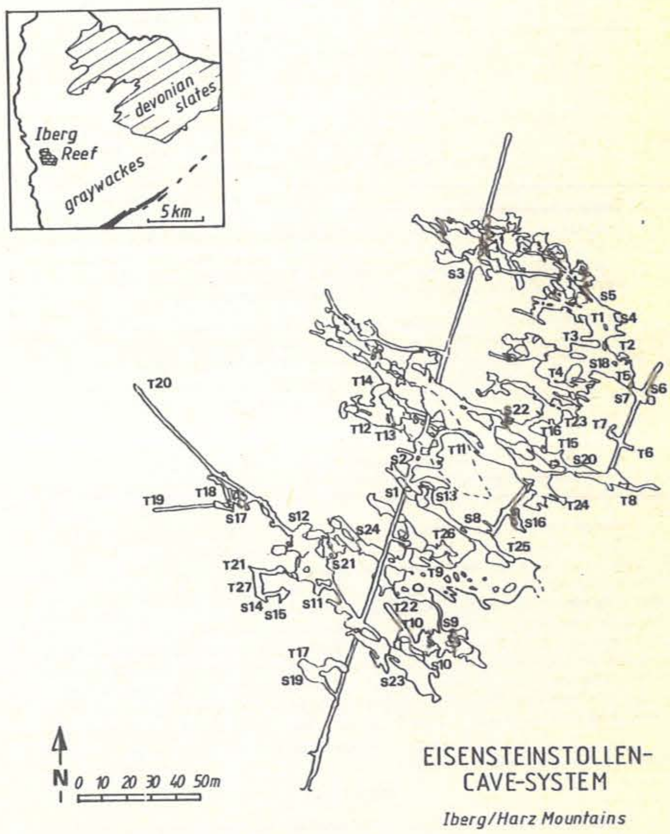

Fig. 1.

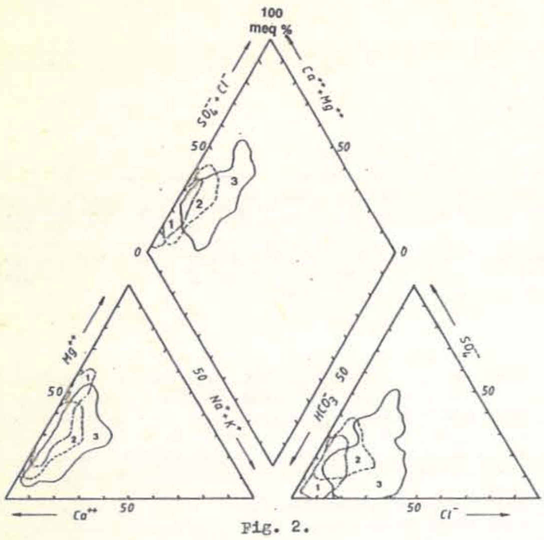

Fig. 2.

3.2 Statistical Evaluation of Cave Water Hydrochemistry

Cave pools and seepage waters (Table 1) are, on average, slightly supersaturated with respect to calcite ($SI_{calcite}$ positive). Both are undersaturated with respect to dolomite ($SI_{dolomite}$ negative), but pools seem to be more closer to saturation than seepage. In pool waters higher PCO_2 (lower negative exponent) and lower molar Ca^{2+}/Mg^{2+} ratios are observed in comparison with the seepage waters. In order to elucidate the specific chemical patterns effective in cave pool and seepage waters, cluster analyses were performed to uncover normative entities of the different cave water types.

Results of the R-mode cluster analysis for the cave pool waters are plotted in form of a dendrogram in Figure 3A. Correlation of 23 parameters yields three different clusters, in which the normative chemical parameters are linked on various levels of their similarity. Highest similarities to each other are shown by total hardness (GH), total dissolved ions (TDI) and conductivity. Together with Mg^{2+}, HCO_3^- (Alk.), $SI_{calcite}$ and $SI_{dolomite}$ they form Cluster 1. On a lower similarity level, pH and $pPCO_2$ ($-\log PCO_2$) are combined to form Cluster 2. Na^+ and Cl^- are linked together in Cluster 3 on an even lower level of similarity.

The three clusters may be interpreted as representative of the three most important hydrochemical factors shaping the hydrochemistry of pool waters: Dissolution of dolomite (Cluster 1), PCO_2 (Cluster 2) and salt (Cluster 3). All other parameters do not show statistically significant similarities with each other.

Results of the R-mode cluster analysis for the seepage waters are plotted in the dendrogram Figure 3b. In this case we obtain five clusters which are very different from the clusters in Figure 3A. Strongest similarities to each other are shown by conductivity and total dissolved ions together with Na^+, K^+ and Cl^- (Cluster 1). Saturation indices for calcite and dolomite are linked with total hardness and Ca^{2+} in Cluster 2. On a lower similarity level pH and $pPCO_2$ are combined in Cluster 3 and dissolved iron and manganese are linked in Cluster 4 while temperature of air (Tl) and water (TW) group in Cluster 5.

Again, these clusters represent certain processes and factors determining the observed variability in concentrations: Cluster 1 represents the influence of "salt" on the amount of total dissolved ions. This is in contrast to the pool waters where Mg^{2+} and HCO_3^- are linked to the TDI/conductivity pair. Cluster 2 represents the dissolution of calcite. Cluster 3 is the PCO_2 cluster, Cluster 4 represents dissolution of ore metals and Cluster 5 is representative of temperature (temperature of dripping waters is in accordance with air temperature).

3.3 Investigation of Pools

The difference in the two cluster analyses suggests that the chemical evolution of pool waters is distinctly different from the evolution of the seepage water. Pool waters are not merely puddles of seepage water, rather something must happen in the pools to alter the chemistry fundamentally.

These pools are small parcels of water, up to a meter deep, standing in pockets produced by the mining for siderite/goethite in the metasomatically formed dolomite. Figure 4 shows the vertical structure of one of these pools (65 cm deep) in detail. The water is stratified and conductivity and concentrations of major ions increase considerably downward. pH decreases tremendously downward which is caused by an increase in the PCO_2 (decrease in the numeric value of the $pPCO_2$). Also the saturation indices of calcite and dolomite change from supersaturation at the surface to undersaturation at a depth of 10 cm. Furthermore, a strong decrease in the oxygen concentration and a significant drop in the redox potential from plus 500 to below 200 mV is noticed in the upper 20 cm of the pool. This causes a tenfold increase in the concentration of dissolved manganese towards the bottom and the precipitation of black manganese oxides at the upper perimeter of the pool. On the other hand the concentration of dissolved iron decreases by a factor of three downward, causing precipitation of vivid red iron hydroxides at the lower part of the pool giving it a peculiar banded coloring. Chloride concentrations remain stable, however, suggesting that no salt is added to the water in the pools and that the salt present there was carried into the pool by the seepage water feeding it.

4. DISCUSSION

Two largely unexpected results emerge from the statistical analysis and from the pool investigation: 1) Na^+ and K^+ chlorides govern, instead of Ca^{2+}, Mg^{2+} and HCO_3^-, the variation of the TDI budget of seepage waters, and 2) additional dolomite is dissolving in the pools.

The fact that ions derived from rock salt play such an important role for the TDI budget is indicative of pollution. The southern part of the cave system is crossed by a federal highway where salt is applied for deicing in winter. Spray and wind transport of dust probably disperses the salt even uphill and "contaminates" seepage water throughout much of the system. If the observed high relative sulfate content in surface waters is due to acid aerosol deposition, or if it derives from local weathering of sulfide ores remains to be shown.

The ongoing dolomite dissolution in pools is not only revealed by increasing concentrations of HCO_3^- downwards, but also by the specific Ca/Mg molar ratio, which, at depth, is slightly above 1, typical for the incongruent dissolution of dolomite (LANGMUIR, 1971; WIGLEY, 1973). At the surface of the pool the Ca/Mg ratio falls below 1 indicative of precipitation of calcite from the system, as in fact observed at the rims of the pool. These "active" pools are a rather curious finding because the seepage water found in the cave has essentially been saturated with calcite and -almost- with dolomite at the PCO_2 of the cave air (measured to range from 350 ppmv to 600 ppmv) before the water can reach the pool. Thus CO_2 must be generated within the pool. This is confirmed by the enormous increase in PCO_2 in the pool with depth. At the bottom the PCO_2 amounts to 130,000 ppmv, i.e. roughly 300 times the PCO_2 of the air in the cave system. The increase in CO_2 seems to be linked to a consumption of oxygen. Since no organic matter is available in the pool to fuel a respiration reaction, the most plausible alternative to explain the observations is by assuming ongoing oxidation of siderite:

$$4FeCO_{3,siderite} + O_2 + 6H_2O = 4Fe(OH)_{3,goethite} + 4CO_2$$

Even though most of the siderite seemingly was oxidized to goethite in the ore body, REIMER (1989; see also REIMER & KEMPE, this volume) has found unaltered siderite in macroscopic quantities and by X-ray diffractometry in the cave system. Both goethite and siderite have been mined from the cave system until 100 years ago. Discovery of ongoing dissolution of dolomite and ongoing generation of CO_2 plus the presence of siderite confirms the siderite weathering hypothesis suggested by KEMPE (1975b) in order to explain the extreme cave density in this area and the peculiar morphology of the cave rooms. Caves appear to have been rather isolated voids, not systematically interconnected. The ceilings are dome-shaped as typical for dissolution in slowly convecting water bodies. No canyons have been found in this part of the Iberg, indicating that the caves formed phreatically around isolated sources of CO_2. This isolated source was the in-situ weathering of siderite fueled by the slow infiltration of oxygen from the surface. Later the caves drained, the goethite was largely mined and the isolated voids were connected by mine passages. Today the processes which formed this vast system can be studied only in few isolated pools.

5. ACKNOWLEDGEMENTS

The authors thank UWE FRICKE and his colleagues for providing the survey of the Eisensteinstollen without which this study would not have been possible. Furthermore we are indebted to the members of the ArGe Stellwerk, Clausthal/Zellerfeld (F.R.G.), for their enthusiastic support given during our field studies.

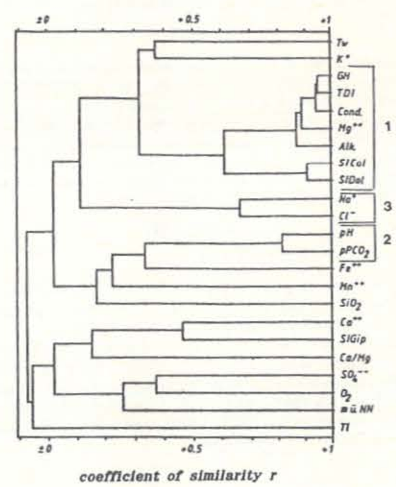

Fig. 3 a

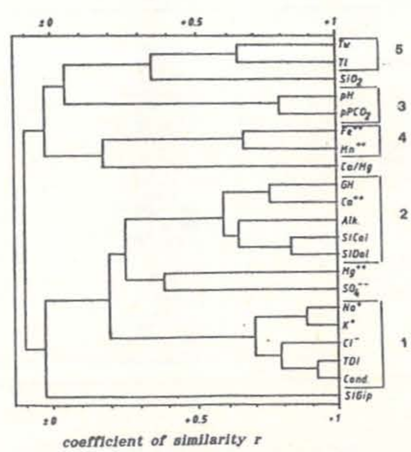

Fig. 3 b

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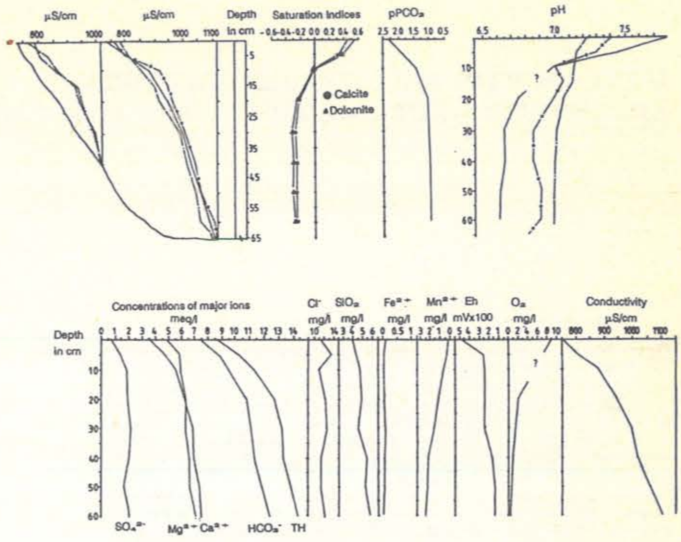

Fig. 4.

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HÖHLENGRABUNGEN IN DER STEIERMARK
ERGEBNISSE NEUER FORSCHUNGEN UND PROBLEME

FUCHS, Gerald

Zusammenfassung:

Für das Höhlenschutzprogrammes der Steiermärkischen Landesregierung werden seit 1986 auch Sondierungsgrabungen durchgeführt, mit dem Ziel die Schutzwürdigkeit ausgewählter Objekte hinsichtlich ihres wissenschaftlichen Potentials genauer zu bewerten und geeignete Schutzmaßnahmen vorzuschlagen. Die Grabungen in der Tropfsteinhöhle (2784/3) und in der Tunnelhöhle (2784/2) sind als interdisziplinäre Untersuchungen realisiert worden. Zahlreiche Spezialisten widmeten sich der Bearbeitung des Fundmaterials und naturwissenschaftlichen Analysen; daran waren beteiligt: S. Ehrenreich, F. Fladerer, G. Glöckner, E. Hudeczek, I. Kainz, W. Kainz, H. Kusch, B. Moser, G. Pachler, G. Rabeder, M.Schneider, J. Steinbach und R. Wedenig. Diese Arbeiten werden hier mit berücksichtigt und sind für das Gesamtergebnis von größter Bedeutung. Wesentliche neue Ergebnisse konnten zur Stratigraphie, der Datierung der Ablagerungen, den Faunengesellschaften pleistozäner Schichten und der Interpetation archäologischer Befunde gewonnen werden.

Abstract:

Excavations in Styrian caves: Results of recent research and problems.

A program for the conservation of caves, conducted by the responsible Styrian authorities, started in 1986. It includes trial excavations to evaluate the scientific significance of sediments in selected caves. The results of excavations in the Tropfsteinhöhle (2784/3) are presented here; our work was supported by many specialists - see their names in the german abstract above - who were engaged in processing the material and in scientific analyses. New results especially concern the stratigraphic sequence, the date of cave sediments, the pleistocene faunal assemblage and the interpretation of archaeological evidence.

Allgemeines

Die Bedeutung der Höhlensedimente für viele Sparten der wissenschaftlichen Forschung, insbesondere aber für die Paläontologie und Archäologie ist seit langem bekannt. Im regionalen Maßstab besitzt der Raum Peggau - Deutschfeistritz eine Schlüsselposition, die für die Steiermark - und darüber hinaus - einzigartig ist.

Die geographische Lage (Abb. 1) nahe dem Südostrand der Alpen und zugleich an einem wichtigen natürlichen Verkehrsweg, aber auch lokale Faktoren haben dazu wesentlich beigetragen. Die Talweitung ist seit Jahrtausenden besiedelt und daher als eine typische Siedlungskammer anzusprechen. Die Fundplatzdichte liegt vier- bis fünfmal über dem Durchschnitt weiter südlich gelegener siedlungsgünstiger Gebiete (Fuchs & Kainz 1988: 21). In diesem Gebiet sind sieben altsteinzeitliche Fundplätze bekanntgeworden, zwei davon haben eine internationale Bedeutung - es handelt sich um die Repolusthöhle (2837/1) und die Große Badlhöhle (2836/17).

Die Kenntnis der Situation im Umland ist für die Beurteilung eines einzelnen Fundplatzes von grundlegender Bedeutung. Der Forschungsstand im Raum Peggau - Deutschfeistritz ist relativ gut, doch ergeben sich Schwierigkeiten bei der Interpretation älterer Forschungsergebnisse, da sie die heutigen Anforderungen - v.a. hinsichtlich der Grabungstechnik und Dokumentation - nicht annähernd erfüllen. Wir können in diesem Gebiet auf eine immerhin 150-jährige Forschungsgeschichte zurückblicken (Unger 1838; Wurmbrand 1871; Mottl 1951 a, 1953 a), doch mangelte es stets an einer kontinuierlichen Weiterführung der Forschungen.

Dagegen sind die Höhlen seit langem und in zunehmendem Maße von Raubgräbern heimgesucht worden - schon H. Bock (1913: 24) weist auf dieses Problem hin -, mit dem Ergebnis, daß wir heute einige Objekte im Raum Peggau - Deutschfeistritz für die wissenschaftliche Forschung 'abschreiben' müssen, in anderen sind die obersten Schichten schwer beeinträchtigt worden.

Im Vergleich zu anderen europäischen Ländern sind wirksame Schutzmaßnahmen sehr spät eingeleitet worden; von besonderer Bedeutung sind die Unterschutzstellungen im Bereich Peggau (Tanneben, Peggauer Wand, Repolusthöhle) durch das Bundesdenkmalamt in den frühen 70-er Jahren (Trimmel 1972 a); im Zuge dieser Aktivitäten ist auch die Repolusthöhle abgesperrt worden [2].

Nach der Änderung der Kompetenzen ist seit 1975 die Steiermärkische Landesregierung für Höhlenangelegenheiten zuständig; 1985 konnte mit der Umsetzung eines von der 'Arbeitsgemeinschaft Naturhöhlen' ausgearbeiteten *Höhlenschutzprogrammes* begonnen werden. Ein darin enthaltener Schwerpunkt sind Sicherungsgrabungen mit dem Ziel einer fachlich fundierten Beurteilung der Schutzwürdigkeit ausgewählter Höhlen.

Die erste derartige Grabung ist 1986 und 1987 in der Tropfsteinhöhle (2784/3) realisiert worden (Abb. 2). Die Erkenntnisse verdanken wir vor allem der Anwendung einer verfeinerten Grabungstechnik.

Trotz recht umfangreicher Forschungen in sieben der 24 Höhlen am Kugelstein in den Jahren 1946 bis 1963 (Mottl 1953 a; 1964) sind die Kenntnisse selbst grundlegender Fakten, wie die Stratigraphie und die zeitliche Einordnung der Schichten, äußerst bescheiden geblieben; das gilt auch für die Tropfsteinhöhle (2784/3).

Ergebnisse, Interpretationen und Probleme

Die Schichtenfolge, welche im oberen Bereich ergraben und dokumentiert werden konnte, ist Teil einer mehr als 4,3 m mächtigen Ausfüllung. Es wurden 25 stratigraphische Einheiten mit rund 75 untergeordneten Komponenten unterschieden, die zu folgenden Gruppen zusammengefaßt werden können (Abb. 3, 4):

- Rezente Planierschichten und verfüllte Altgrabungen: stratigraphische Einheiten 1 bis 3.
- Archäologische Fundschichten, Grubenfüllungen, Grabenfüllung, Pfostenlöcher: stratigraphische Einheiten 4 bis 15.
- Unverfestigte pleistozäne Sandschichten: stratigraphische Einheiten 16 bis 19.
- Verfestigte pleistozäne Sandschichten mit Bruchschutt: stratigraphische Einheiten 20 bis 25.

[2] Die Maßnahmen erfolgten in Zusammenarbeit mit dem Landesverein für Höhlenkunde in der Steiermark, Graz

Die Höhlen am Kugelstein gehören einem Horizont an, der im Altpleistozän entstanden ist [3]. Das Vorkommen mächtiger pleistozäner Sandschichten in Höhlen am Kugelstein, aber auch z.B. in der Repolusthöhle (2837/1) und in der Großen Badlhöhle (2836/17) steht in einem bisher nicht näher untersuchten Kontext zu den mächtigen Ablagerungen lößartiger Sande in der näheren und weiteren Umgebung.

Diese sind auf den Verebnungsflächen und Hängen im Norden am Kugelstein (Mottl 1946), am Hiening (Höller & Kolmer 1965; Kolmer 1968), aber auch im Raum südlich von Graz und an den Höhenzügen parallel zu den Rändern des Leibnitzer Feldes beobachtet worden; z.T. handelt es sich um Lößlehme. Sie sind in Höhenlagen von 10 bis 200 m über der Würm-Terrasse anzutreffen und werden von Kolmer (1968: 11) als würmzeitliche äolische Bildungen angesprochen, die aus dem Schotterfeld des Flusses ausgeblasen worden sind. Ohne einer Beurteilung durch Fachleute vorgreifen zu wollen, wird auf einen möglichen Widerspruch zwischen dieser Aussage und unserer Datierung der verfestigten Sandschichten (Schichten 20 bis 25) in der Tropfsteinhöhle, nämlich in das Prä-Würm, hingewiesen.

Aus dem Westprofil von Schnitt 1 in der Tropfsteinhöhle sind Sedimentproben für Analysezwecke entnommen worden [4], deren Bearbeitung im Rahmen einer Diplomarbeit begonnen worden ist [5]. Ergebnisse können erst nach ihrem Abschluß vorgelegt werden; gegenwärtig ist die Genese dieser nach ihrem Mineralbestand sehr einheitlichen Schichten [6] noch weitgehend unklar. Zu dieser Frage können aber Sedimentanalysen wesentliche Beiträge leisten (vgl. Laville et al. 1980: 46 - 102).

Die Schichten 20 bis 25, die zum Komplex der 'verfestigten pleistozänen Sandschichten (mit Bruchschutt)' zu zählen sind, gehören - soweit die Schichtenfolge ergraben werden konnte - zu den ältesten Schichten im Schnitt 1. Für ihre Datierung gibt es mehrere Anhaltspunkte. Von besonderer Bedeutung sind:

- Das paläontologische Material mit dem Nachweis von *Hystrix* sp. und *Microtus malei*, woraus auf ein Prä-Würm-Alter geschlossen werden kann (Bearbeitung durch F. Fladerer).
- Die Ergebnisse der Holzkohlenuntersuchungen (M. Schneider) mit dem Nachweis von *Quercus* sp. aus Schicht 20 c bzw. *Quercus* sp. und *Carpinus* sp. aus Schicht 22 d.
- Beide Arten deuten auf ein trockenes und warmes Klima in einer Prä-Würm-Phase hin. Das Fehlen von *Fagus* ist möglicherweise ein Hinweis auf das wärmere Klima im Riß-Würm-Interglazial.

Die älteren Schichten 20 bis 25 sind in Resten nahe den Höhlenwänden erhalten - Schicht 24 ist eine paläolithische Fundschicht; in einer trogartigen Mulde liegen jüngere unverfestigte Sandschichten (Schichten 16 bis 19), daraus müssen wir a) auf eine Phase schließen, in der ein Teil der älteren Schichten ausgeräumt worden ist und b) die nachfolgende Ausfüllung der entstandenen Hohlform durch die Ablagerung von Sanden. Das heißt, es gibt Perioden, die nicht durch Höhlensedimente belegt werden ('discontinuous record' nach Gamble 1987: 74). Die Dauer dieser Zäsuren ist, wenn sie überhaupt erkannt werden, meist nur annähernd zu bestimmen.

Weitere vergleichbare Ausräumungsphasen können aufgrund der diskordanten Lagerung der Schichten 18 über 19 a - und noch deutlicher 17 über 18 und 19 - angenommen werden. Die Darstellung des komplizierten stratigraphischen Aufbaus wurde mittels dreidimensionaler Computer-Graphiken (I. Kainz & W. Kainz) realisiert, wodurch der Aufbau noch wesentlich anschaulicher präsentiert werden kann, als mit herkömmlichen Plana und Profilen.

Die spärliche Fauna aus den unverfestigten Sandschichten weist eher auf eine klimatisch kältere Phase - die Holzkohleproben belegen neben *Carpinus betulus*, *Fagus sylvatica* aber auch *Quercus* sp. Im Fundmaterial aus den lockeren Sandschichten (v.a. Schicht 16) sind aufgrund der Konsistenz gewisse Anteile jüngeren Materials nicht auszuschließen, die durch Störungen (Wurzeln, Wühltiere, Tropflöcher und nicht erkennbare Störungen in den obersten Lagen der Schicht 16) hineingelangen können. Bei der Interpretation ist daher eine gewisse Vorsicht angebracht: es spricht jedoch nichts gegen eine Stellung der unverfestigten Sandschichten in das Würm. Eine genauere Einordnung ist gegenwärtig nicht durchzuführen.

[3] Mit der geomorphologischen Entwicklung des Murdurchbruchs im Raum Peggau und den Zusammenhängen, die sich daraus für die Entstehung und Veränderung der Höhlen und ihrer Sedimente ergeben, befaßt sich derzeit Univ.Prof. Dr. V. Maurin, Graz

[4] Probenentnahme 1987 durch Univ.Prof. Dr. A. Fenninger und Univ.Ass. Dr. K. Stattegger, Institut für Geologie und Paläontologie der Universität Graz, aus den Schichten 16 a, 16 b, 16 c, 17, 18 d, 19 b, 22 d und 23.

[5] Bearbeitung durch R. Otto am Institut für Geologie und Paläontologie der Universität Graz

[6] R. Otto: Tabelle Sedimentpetrologie - Tropfsteinhöhle (2784/3), Schnitt 1, Westprofil (unpubliziert)

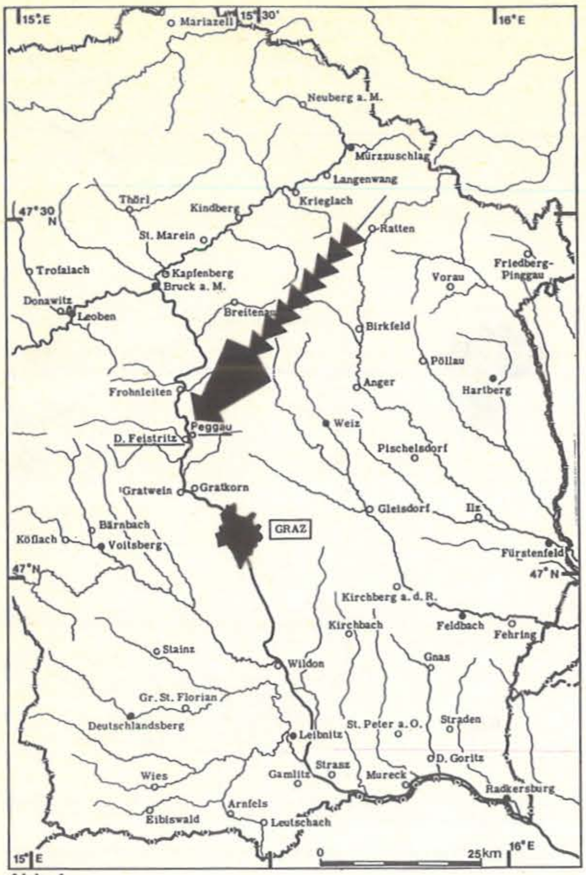
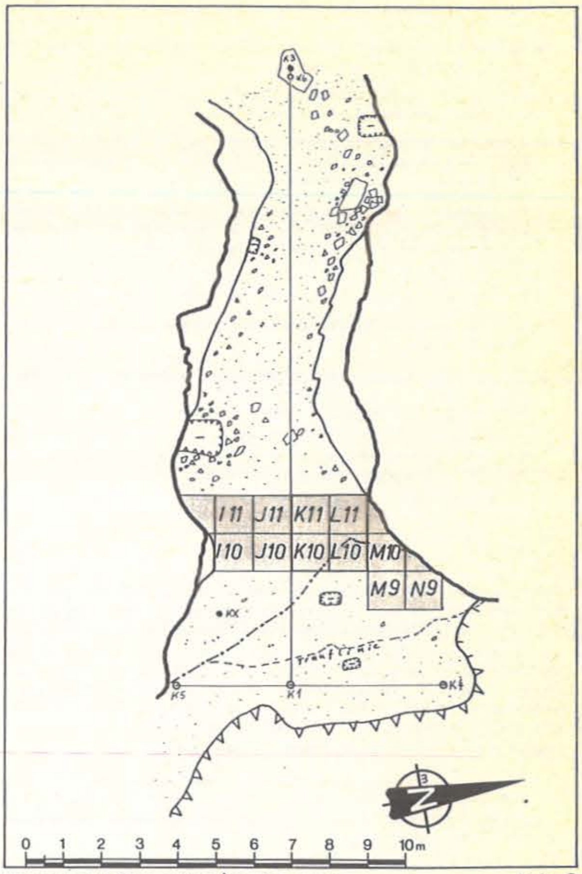


Abb. 1



Tropfsteinhöhle 2784/3: Schnitt 1
Lage und Quadrantenübersicht

Abb. 2

Wie die Befunde der Altgrabungen mit der pleistozänen Schichtenfolge im Eingangsbereich zu korrelieren sind, muß offen bleiben, da der stratigraphische Zusammenhang nicht bekannt ist und die Dokumentation der früheren Untersuchungen zu einer sicheren Beurteilung nicht ausreicht. Die morphologische Analyse der Höhlenbärenzähne durch G. Rabeder legt eine Datierung dieser Schichten in das Spät-Würm, in die Zeit des Höhepunktes der Würmvereisung, nahe.

Zwischen dem Ende des Pleistozäns und der Römerzeit gibt es im stratigraphischen Befund eine Lücke, die durch die Abräumung älterer Schichten zur Römerzeit im Zuge der Umgestaltung des Eingangsbereiches erklärt wird. Die Funktion der artifiziell hergestellten Gruben kann durch das Fundmaterial in den Hohlformen (Gruben, Gräbchen) nicht erklärt werden.

Die Position des Grabens (stratigraphische Einheit 8) mit dem Bruchsteinmäuerchen (8 c) und den Pfostenlöchern (13) an der engsten Stelle des Höhleneinganges weist dagegen auf eine römerzeitliche Höhlenabsperrung, die gut zu der vermuteten Funktion der Höhle als Kultstätte in der Römerzeit paßt. Die Interpretation wird durch den Fund eines Schlangengefäßfragmentes (Abb. 5) gestützt, woraus – mit Vorbehalt – eine Verwendung der Höhle als Mithraeum abgeleitet werden könnte (R. Wedenig).

Das archäologische Fundmaterial (Bearbeitung durch S. Ehrenreich und G. Glöckner) belegt folgende Perioden:

Paläolithikum: ein Quarzit-Artefakt aus Schicht 24.

Mesolithikum: einige Mikrolithen aus Hornstein in sekundärer Fundlage in jüngeren Schichten. Das Rohmaterial dürfte aus größerer Entfernung stammen, da in der Nähe keine Hornsteinvorkommen bekannt sind, die dem Material der Mikrolithen entsprechen (mineralogische Untersuchungen durch B. Moser).

Prähistorie allgemein: einige nicht genauer datierbare Keramikfragmente.

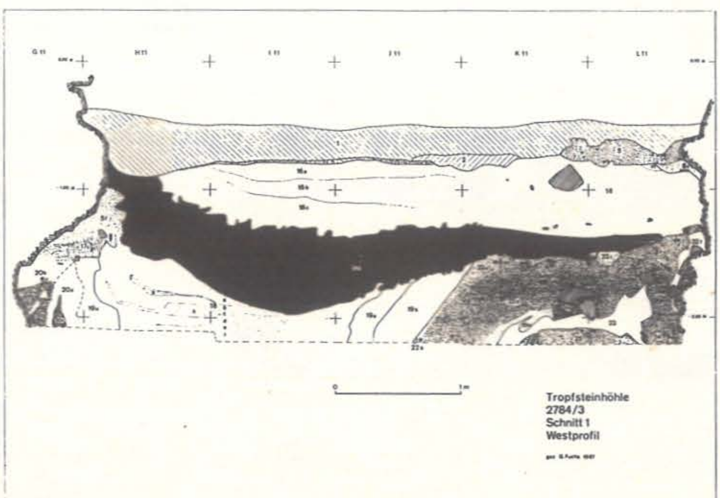
Römerzeit: Der Großteil des Fundmaterials und die meisten artifiziellen Veränderungen gehören dieser Periode an.

Frühmittelalter: ein Streufund (Keramik).

Hochmittelalter und Neuzeit: Streufunde in größerer Zahl.

Die intensive römerzeitliche Nutzung der Tropfsteinhöhle steht in einem topographischen Zusammenhang mit der Höhensiedlung am Kugelstein, während die vergleichsweise geringe Zahl von Funden aus nachrömischer Zeit die Verlagerung des Siedlungsschwerpunktes vom Kugelstein in die etwa zwei Kilometer weiter südlich gelegene Talweitung von Peggau – Deutschfeistritz wiederspiegelt.

Abb. 3



Die wesentlichsten Ergebnisse sollen kurz zusammengefaßt werden:

- Nachweis einer massiven, kompliziert aufgebauten Schichtenfolge, die nur in den obersten Bereichen rezent gestört ist.
- Nachweis mehrerer archäologischer Fund- und Kulturschichten, sowie umfangreicher artifizieller Veränderungen aus verschiedenen Perioden.
- Die ältesten ergrabenen Schichten können aufgrund der pleistozänen Fauna und der Ergebnisse der Holzkohleuntersuchungen in das Prä-Würm, wahrscheinlich in das Riß-Würm-Interglazial datiert werden.
- Der Nachweis einer pleistozänen Hundsaffenart, *Macaca sp.*, - der Fund des Zahnes stammt aus einer rezent verfüllten Altgrabung - ist im Ostalpenraum bisher einzigartig, wenn man von dem wesentlich älteren Material aus Deutsch-Altenburg absieht (Fladerer 1987).
- Die Faunenliste konnte wesentlich erweitert werden (F. Fladerer).
- In der Römerzeit ist die Tropfsteinhöhle wahrscheinlich als Kultstätte (Mithraeum ?) verwendet worden.
- Die artifiziellen römerzeitlichen Veränderungen im Eingangsbereich (Gruben, Gräbchen, Plattform, Pfostenlöcher etc.) konnten in Österreich erstmals in dieser Form in einer Höhle dokumentiert werden.
- Alle diese Ergebnisse zeigen, daß die Tropfsteinhöhle in wissenschaftlicher und kultureller Hinsicht von größter Bedeutung ist. Für zukünftige Forschungen besitzt sie ein außerordentlich großes Potential als *Archiv der Vorzeit*.
- Die Höhle ist daher in besonderem Maße schutzwürdig.

Ausblick

Es hat sich gezeigt, daß durch Anwendung verfeinerter Grabungsmethoden, einer adäquaten Dokumentation und einer Auswertung mit interdisziplinärer Ausrichtung eine ganze Reihe wertvoller Ergebnisse erzielt werden können.

Auf der Grundlage einer kleinflächigen - prinzipiell nicht problemorientierten Grabung sind keineswegs alle auftauchenden Probleme zu lösen; daher bedarf es einer weiteren Untersuchung spezieller Fragen, die über die Zielsetzungen der Arbeiten für das Höhlenschutzprogramm hinausgehen und somit auch in einem anderen Rahmen in Angriff zu nehmen sind - zu Kooperationen aller Art sind wir bereit.

Folgende Probleme drängen sich für weitere Untersuchungen auf:

- Die Datierung der pleistozänen Schichten mit naturwissenschaftlichen Methoden (z.B. Uran/Thorium-Datierung) wäre erforderlich, um die bisherigen Ergebnisse mit anderen Mitteln zu überprüfen; unmittelbare Auswirkungen ergeben sich für alle weiteren Fragestellungen.
- Untersuchungen der Höhlensedimente, besonders hinsichtlich ihrer Herkunft und Genese, unter Berücksichtigung der klimatischen Bedingungen und der Faktoren, die an der Entstehung und Veränderung der Ablagerungen beteiligt waren.
- Erweiterung, Absicherung und Ausbau der wissenschaftlichen Grundlagen durch Grabungen in anderen Höhlen und ergänzende Untersuchungen im Gelände.
- Eine systematische Revision der Ergebnisse von Altgrabungen erscheint notwendig.

Langfristig sollten die Untersuchungen zu einer genaueren Kenntnis der geomorphologischen und klimatischen Entwicklungen am Südostrand der Alpen beitragen und die Einarbeitung neuer Ergebnisse in die - inzwischen überholte traditionelle - Chronologie des Eiszeitalters im alpinen Raum ermöglichen.

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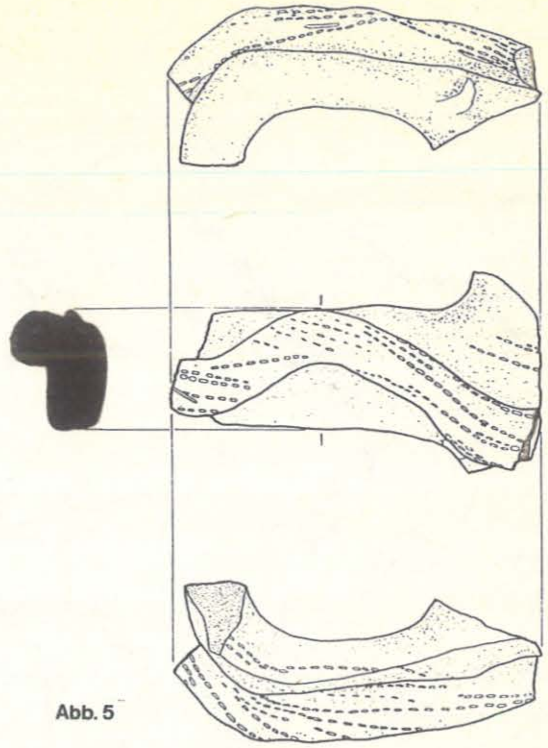

Abb. 5

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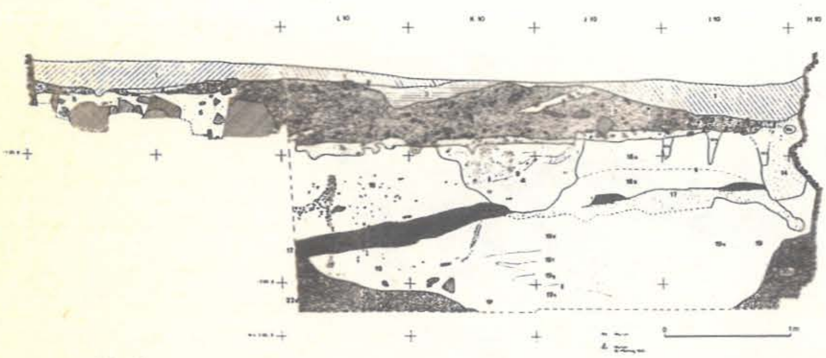

Abb. 4

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THE ENDOGENETIC DRAINAGE AT THE KARST AREA OF GLOMDALEN, MELFJORD-UTBYGGINGEN, THE PREDICTION METHOD AND ITS RESULTS

LUND, Cecile - ERASO, Adolfo

Abstract:

The investigation on the endogenic drainage of Glomdalen karst area, a part of the Melfjord project, was carried out in 1987. Being a selected area for a hydropower project, the underground drainage, the karst, the corrosion and the denudation were focused, expected to give construction problems to the engineering work.

A highly karstified marble band of 7 km from Glomdalen through Vesterdalen was investigated. Mapped caves were examined and proved the hypothesis of the appearance of only shallow karst. Most caves showed a maximum depth of 50 mts. Surely no vertical cave will interfer with the trasée of the planned water tunnel.

The drainage direction given by the the Prediction Method show two main directions. 1. N 30° - N 45°. 2. N 0° - N 15°. Leakage into or from the projected water tunnel, or other problems due to karstic underground drainage is considered.

The karst water is still very aggressive at the end of the cave systems in Glomdalen, due to a steep topographic gradient and thus, high water velocity and short time for chemical reactions. Water samples show a mean content of about 40 ppm $CaCO_3$.

The denudation is estimated to 27 mm/1000 year.

INTRODUCTION:

Glomdalen is located south of the "Svartisen" glacier in North Norway, right where the polar circle is crossing the maps. The mountainous area was formed during the Caledonean orogeny. Shale and limestone were metamorphosed into micaschist and marble alternating in wavy bands, forming the geological "Meløy group". The last glacial period ended about 7000 years ago. During the retreat of the glacier, subglacial water took part in the corrosion process of the limestone bands and large cave systems were formed. Glaciers still exist, covering about 369 km2 in the Saltfjellet - Svartisen area. The retreat of the glaciers today produces huge amounts of melting water, a very important factor of the active karstification process.

Glomdalen karst area imposes engineer geological problems to the Melfjord Project. The Melfjord Project uses the glacial water and the heavy annual precipitation in a hydro power project of 486 GWh. A tunnel is planned to cross Glomdalen cave area from east to west, more or less perpendicular to the marble bands. Also other constructions planned have turned out problematic to realize due to the appearance of karst. The first regulation in this area, however, was carried out in 1957. It affected only the hydrological conditions as no construction was made here.

2. METHODOLOGY

The field work and the research are developed in three directions:

1st.: Exploring caves and endogenic flows that exist in the area.

2nd.: Applying the Prediction Method of the principal drainage directions in karst.

3rd.: Sampling water in ponors and springs.

2.1 Explorations are made by several trips, visiting the main mapped caves, Storbekken grotten, Fosshullet and Pikhauggrottene (HJORTHEN, G. 1968) (LUND, C. 1986)

2.2 Prediction of subterrainean karstic drainage is made using the Prediction Method (ERASO, A. 1987).

This Method is based on two hypothesis: one qualitative, the other quantitative.

1. "The three-dimensional net of drainage in karst regions is predetermined, preprinted or imposed by tectonic conditions suffered by the rock massif. It determines the underground drainage net, according to its geological history".

2. "The most probable drainage directions are organized inside plans which have the main stress, $\sigma 1$, and the intermediate stress $\sigma 2$. Each one of the principal stresses of the ellipsoid is given by every tectonical phase. Consequencely, $\sigma 2$ are perpendicular to the minor stress $\sigma 3$, of each respective ellipsoid".

The field work investigations were in fact limited to the application of structural geological techniques, searching for tectoglyphs in the field and reading its parameters at each station found.

Tectoglyphs are: Stylolite plans, plans of mineral veins and fault plans. Parameters of lecture are principally: Strike, dip and sense of dip. By applying the stereographic projection, the ellipsoids of the principal stresses in WULFF's or SCHMIDT's net are resolved for each case.

The method is available with three computer programs: GEORED, GEODRE and GEOPOL.

The Prediction method gives the quantitative estimation of the directional aspect of anisotrophy in rock massives, and consequencely, its underground drainage in karst regions.

2.3 Hydrochemical works:

Hydrochemical investigation has been carried out in Glomdalen for three years, 1983-86, by analysing the pH, the alkalinity, the conductivity, the temperature conditions, the ions of Calcium, Magnesium, Sodium, Potassium, Clorid, Sulphate and the hysteresis effect.

The aim of the hydrochemical work has been to estimate the denudation rate and the rate of corrosion in the "natural" condition of today and thus state the situation before this new regulation. Such work might be of importance to the hydropower project, although more indirectly than the other parts of the project work. Though, from hydrochemical results conclusions concerning subterrainian waterways can be drawn.

The denudation rate is estimated from the formula:

$$K = \frac{K_G}{pA \cdot 10^6} \qquad \text{(Bögli 1980)}$$

K = denudation rate, mm/1000 years
K_G = the waterflow . $CaCo_3$ concentration/year
P = the density of limestone
A = field acreage

The temperature of the local waters is a very important denudation or corrosion factor because of its relation to the water's potential of CO_2, and thus to the corrosion of limestone.

3. RESULTS

The results are given by the field work between Bjørnefossvatnet and Glomdalvatnet in a marble band of 7 Km, in which karstification takes place.

3.1 Caves and karstic drainage

1929 mts of galleries are measured:

PIKHAUGGROTTENE	907 mts
FOSSHULLET	586 mts
STORBEKKENGROTTEN	436 mts

In the region 14 stations of tectoglyphs (th.i. mineral veins), are found with the follow relation:

NO.	STRIKE	DIP	SENSE	MINERAL
1	316	80	45	Calcite
2	225	80	85	"
3	228	85	135	"
4	115	53	20	"
5	40	80	120	"
6	42	81	120	"
7	25	60	35	"
8	26	58	35	"
9	2	59	270	"
10	358	59	271	"
11	220	52	135	"
12	222	50	135	"
13	5	62	270	"
14	1	60	270	"

All results are compiled in TABLE 1. The interval Ø of direction or strike, contents each one a lot of galleries (in meters) and a number of stations of tectoglyphs, respectively.

The intervals are defined every 15g (12° in 180°). The orientation is always referring to the magnetic north.

From the values of TABLE 1, the polimodals are constructed. These are visualized in:

- FIGURE 1, The results of exploration, and
- FIGURE 2, The prediction given by the Prediction Method

FIGURE 1 shows the existence of two directions of underground flows in the area of Glomdalen - Vesterdalen:

- The main direction: N 30° to N 45° with 49% probability
- The associate direction: N 0° til N 15° with 17% probability

FIGURE 2 show a similar position and amount of the both modes of subterrainean flow:

- The main direction: N 30° to N 45° with 43% probability.
- The associate direction: N 0° to N 15° with 21% probability.

Both polimodals show high similarity, as in the FIGURES.
To estimate the degree of accuracy between them, it is necessary to apply the KOLMOGOROV'S test. The results are given in the FIGURE 3 which shows the degree of accuracy:

DEGREE OF ACCURACY = 97,44%

"COMPARISON BETWEEN BOTH DIRECTIONAL PROBABILITY POLIMODAL"

Explorations versus prediction:

Predictions given by the method is shown by graph no. 1, the results of the explorations is shown by graph no. 2 of the figure 3.

3.2 Hydrochemical Analyses

As most CO_2 is dissolved at about 4 °C, the icecold glacial water of Glomdalen and other places of the Melfjord project reaches always a CO_2 content close to maximum. Surface water in the Melfjord project is highly aggressive or corrosive through the whole year. The karst water measured has never reached more than 8 °C.

Plotting the measured pH-values against the total hardness in a Trombe Plot give undersaturation of all water samples except for two. Fig. 4 shows the results of saturation in some of the samples from the season of 1984.

pH-values range between 7,0 - 8,5 with some extremes, 5,05 and 9,03, and the measured interval of $CaCO_3$ is about 35-45 ppm with extreme values at 80 ppm. The results of the conductivity measurements are 65,0 - 95,0 $\mu S/cm^2$ with extremes 38,3 and 133 $\mu S/cm^2$.

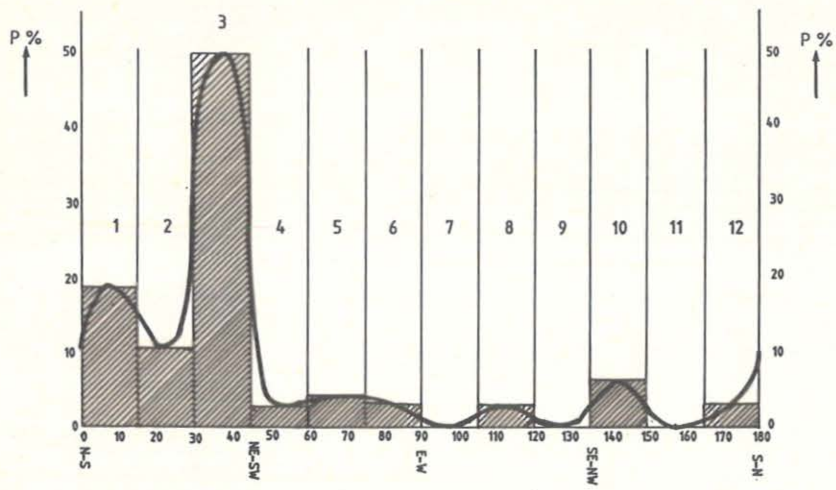
The content of dissolved $CaCO_3$ decreases with an increasing waterflow. In fig. 5 the total hardness is plotted against the waterflow. The shown decrease is a result of several factors whereas the dilution and short residue time is of most importance. Short residue time diminish the chemical reaction rate with undersaturation as result.

The marble bands consist of calcite and dolomite with small amounts of muscovite among other types of rocks squeezed into the bands during the metamorphosis. The content of analysed ions from watersampling can be read from TABLE 2.

MELFJORD - UTBYGGINGEN KARST AREA

" POLIMODAL OF RESULTS IN KARSTIC FIELD EXPLORATIONS "
(TOTAL LENGT OF THE CAVES = 1929 mts.)

FIGURE 1



MELFJORD - UTBYGGINGEN KARST AREA

" POLIMODAL OF KARSTIC FLOW DIRECTIONS GIVEN BY THE PREDICTION METHODE"
(NUMBER OF STATIONS = IN A BAND OF 7 km)

FIGURE 2

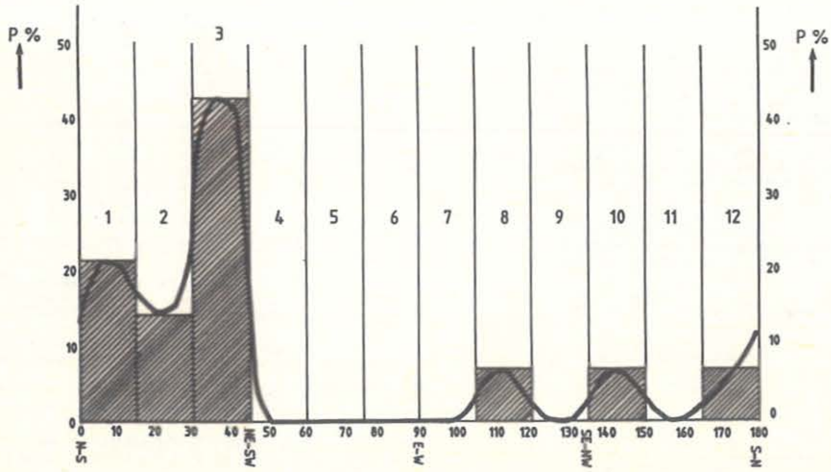


TABLE - 1

MELFJORD - UTBYGGINGEN AREA: KARST FIELD WORKS

Ø	INTERVAL	EXPLORATIONS: CAVES MAPPED IN THE AREA					PREDICTIONS: STATIONS OF TECTOGLYPHS	
		PIKHAUG--GROTTENE	FOSSHULLET	STORBEKKEN--GROTTEN	Σ mts	%	Nr.	%
1	N0̊ - N 15̊	139	90	99	328	17,00	3	21,43
2	N 15° - N 30°	50	12	148	210	10,89	2	14,29
3	N 30° - N 45°	568	380	-	948	49,14	6	42,86
4	N 45° - N 60°	55	-	-	55	2,85	-	-
5	N 60° - N 75°	16	62	7	85	4,41	-	-
6	N 75° - N 90°	19	42	-	61	3,16	-	-
7	N 90° - N105°	-	-	-	-	-	-	-
8	N 105° -N 120°	-	-	59	59	3,06	1	7,14
9	N120° - N 135°	-	-	-	-	-	-	-
10	N 135° - N 150°	38	-	85	123	6,38	1	7,14
11	N 150° - N 165°	-	-	-	-	-	-	-
12	N 165° - N180°	22	-	38	60	3,11	1	7,14
	Σ	907	586	436	1929		14	
	%	47,02	30,38	22,60		100		100

MELFJORD - UTBYGGINGEN KARST AREA

KOLMOGOROV'S TEST BETWEEN BOTH KARTIC POLIMODALS:

1.- PREDICTION GIVEN BY ERASO'S METHODE
2.- RESULTS OF THE FIELD EXPLORATIONS (CAVES AND ENDOGENIC FLOWS)

	INTERVALS Ø	1	2	3	4	5	6	7	8	9	10	11	12
1	PREDICTED VALUES %	21,43	14,29	42,86	-	-	-	-	7,14	-	7,14	-	7,14
	CUMMUL. VALUES Σ_1	21,43	35,72	78,58	78,58	78,58	78,58	78,58	85,72	85,72	92,86	92,86	100
2	EXPLORED VALUES %	17,00	10,89	49,14	2,85	4,41	3,16	-	3,06	-	6,38	-	3,11
	CUMMUL.VALUES Σ_2	17,00	27,89	77,03	79,88	84,9	87,45	87,45	90,51	90,51	96,89	96,89	100
	$\lvert\Sigma_1-\Sigma_2\rvert$	4,43	7,83	1,55	1,30	5,71	8,87	8,87	4,79	4,79	4,03	4,03	0
	MAX. ERROR Σ %	1,28	2,26	0,45	0,38	1,65	2,56	2,56	1,38	1,38	1,16	1,16	-

DEGREE OF ACCURACY $\geq 100 - \Sigma\,\%$; $Ø = 12$; $\Sigma\,\% \geq \dfrac{\lvert \Sigma_1 - \Sigma_2 \rvert}{\sqrt{Ø}}$.

100 - 2'56 = 97'44

DEGREE OF ACURACY ≥ 97'44 %

"CUMMULATIVE VALUES OF BOTH POLIMODALS TO ESTIMATE THE ACCURACY BY KOLMOGOROV'S TEST"

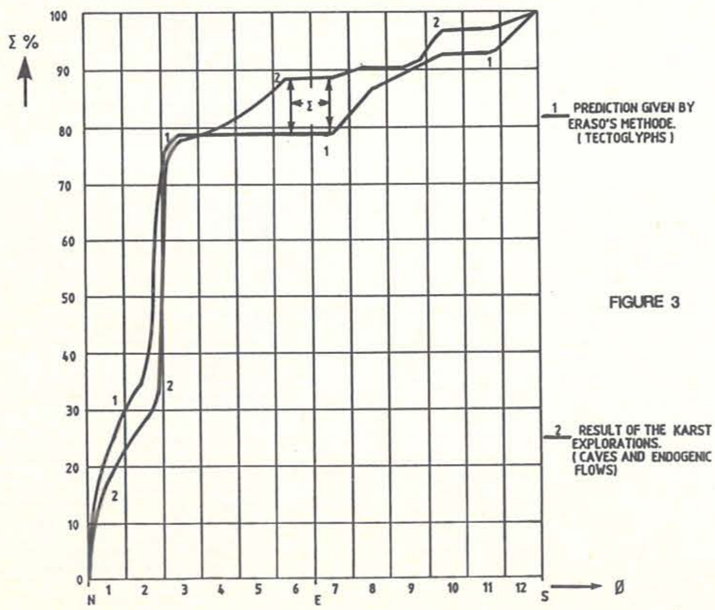
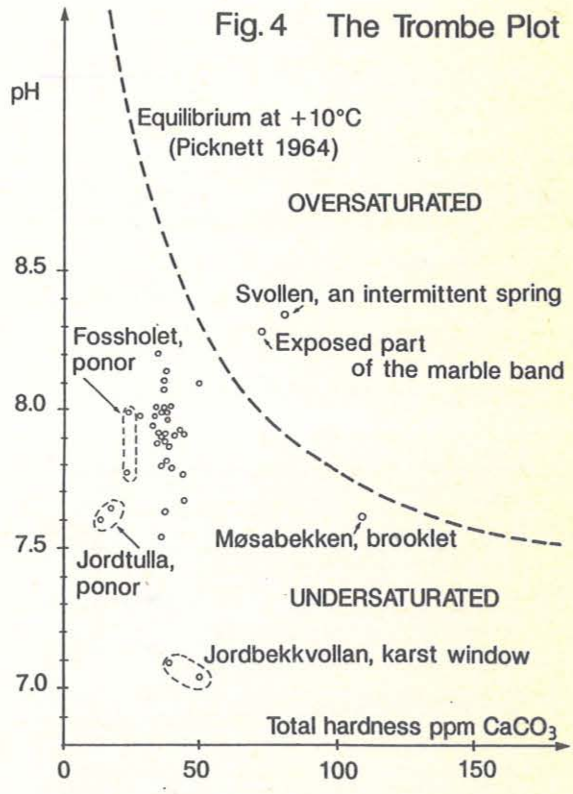


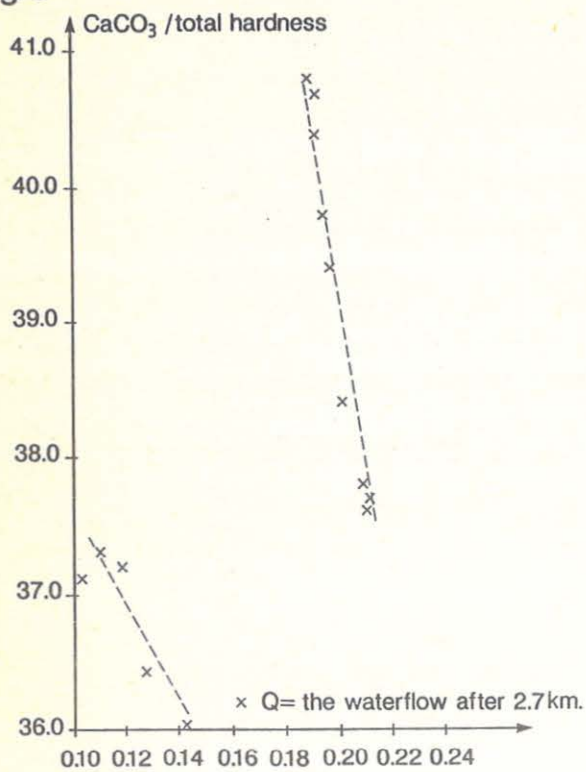
FIGURE 3

Fig. 4 The Trombe Plot



TOTAL HARDNESS PLOTTED AGAINST THE WATERFLOW OF THE INVESTIGATED KARSTIFIED MARBLE BAND. WHEN THE WATERFLOW INCREASES, THE CONTENT OF $CaCO_3$ DECREASES.

Fig. 5



The phenomenon of hysteresis occurs in all the chemical investigations carried out. Variable waterpulses, cave morphology and the variable subcutanus conditions are factors responsible for the residue time.

The hysteresis effect is thus a result of variability in residue time and rate of chemical reaction and give a good indication of the hydrological groundwater conditions. In the Melfjord project the hydrochemical results have helped us state the fact that we are only dealing with shallow karst in the Glomdalen - Vesterdalen area.

4. CONCLUSIONS

1st. Karstic drainage in the area of Melfjord is developed in two directions.

- The main is N 30° to N 45° with 50% probability.
- The associate is N 0° - N 15° with 20% probability.

2nd. The karst in Glomdalen is shallow. The depths are mostly 40 - 50 mts, and most probably developed after the last retreat of the glaciers, 7000-8000 years ago.

3rd. The degree of accuracy of the Prediction Method tested in the Glomdalen area is very high, more than 97%. Thus, the Method can also be used on limestone karst in arctic/subarctic regions.

4th. The glacial water holds such temperatures that dissolved CO_2 is always at its maximum. Thus, there is always the best CO_2 conditions for maximum corrosion.

5th. Acid precipitation, which activate the corrosion process, is neutralized by dissolved calcite. Thus, surface water in the limestone area holds a pH slighly alkaline with values of 7,0 - 8,5. This indicates a high corrosion rate due to the acidity of precipitation.

6th. Due to short residue time, the karst water is always undersaturated. All over the field area, water samples taken and analysed are found still very aggressive, th.i. the waters hold a high potentional rate of corrosion.

7th. The high potential of aggressive water can affect the engineering works of the area where concrete constructions are to be made.

8th. The denudation rate is estimated to 27 mm/1000 years as a mean value under the "natural" conditions of today. The denudation value stated is of high scientific interest.

TABLE 2 HYDROCHEMICAL RESULTS OF THE MELFJORD PROJECT 1983

Date	Time	Water level cm	T°C	K_{18} μScm^{-1}	pH	Toth ppm	Ca^{2+} ppm	Mg^{2+} ppm	Alk mekvl $^{-1}$	Mg/Ca
21/8	12.30	42.5	-	63.9	7.94	32.4	31.7	0.7	0.66	0.022
23/8	21.30	46.0	-	68.7	7.91	44.0	-	-	0.72	-
24/8	14.30	43.0	-	65.9	7.88	35.0	32.6	2.4	0.70	0.073
31/8	19.00	48.5	5.5	63.5	8.02	34.1	34.5	0.3	0.65	-
1/9	12.00	44.3	5.0	65.9	8.01	33.8	34.5	0.6	0.69	-
"	20.00	43.0	5.2	66.8	7.99	35.2	36.3	1.1	0.70	-
2/9	10.00	32.0	5.8	68.8	7.90	36.0	31.3	4.7	0.71	0.15
"	22.15	30.8	5.5	71.2	7.92	42.2	-	-	0.76	-
3/9	15.15	27.2	6.1	69.6	8.01	38.5	36.3	2.2	0.68	0.062
"	20.40	26.9	6.0	81.9	8.14	37.6	37.2	0.4	0.70	0.011
4/9	10.00	27.5	6.6	71.5	7.91	37.4	34.5	2.9	0.62	0.086
"	22.00	27.3	6.5	70.9	8.00	36.7	-	-	0.62	-
5/9	18.00	27.0	6.9	72.8	7.91	35.3	-	-	0.62	-
6/9	12.00	29.5	6.8	68.1	7.54	35.3	34.5	0.84	0.59	0.024
7/9	08.00	27.1	6.9	75.6	8.20	34.6	-	-	0.61	-
"	21.00	29.4	7.0	69.1	7.98	33.9	-	-	0.59	-
8/9	15.00	28.5	7.0	69.0	8.10	36.2	-	-	0.55	-
"	18.30	28.0	6.7	70.0	8.08	36.6	-	-	0.59	-
9/9	09.00	26.3	7.0	69.0	7.80	36.0	30.8	4.8	0.68	0.16
10/9	11.00	24.2	6.8	67.7	7.89	36.4	35.4	1.0	0.69	0.030
11/9	14.30	22.1	6.4	69.5	7.87	37.2	36.3	0.9	0.70	0.020
"	21.30	22.0	6.1	69.7	7.97	37.1	34.5	2.7	0.73	0.077
12/9	10.15	21.2	6.3	73.5	7.99	37.3	31.7	5.6	0.74	0.17
"	20.15	20.5	6.2	69.2	7.81	37.1	31.5	5.6	0.74	0.18
14/9	09.00	19.0	6.2	71.5	7.63	37.1	38.0	0.9	0.77	-
12/11	16.00	24.5	1.0	85.2	7.67	43.8	44.6	0.8	0.68	-
13/11	12.00	-	1.8	85.2	7.77	43.3	44.6	1.3	0.68	-

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RELATION BETWEEN NATURAL CONVECTION AND CAVE FORMATION IN HYDROTHERMAL KARST

RUDNICKI, Jan

Typical hydrothermal cave differ in shape from cold water cave systems. They constitute of separate chambers or groups of chambers, sometimes without any visible entrance. Such caves are usually situated near the surface, and can be entered mainly as a result of roof-collapsing or by another casual outcrops. Large chambers of such caverns are irregularly shaped, often resembling the shape of a pear, and are vertically elongated. Smaller chambers usually have quite regular spherical shape. Walls and roofs of such chambers are sculptured by corrosional hemispherical niches and spherical copulas often overlapping each other and differing in size.

Several explanation were proposed, but formation of hydrothermal caves is still disputable.

It is presented opinion that chambers in hydrothermal karst are formed due to circular movement of water caused by natural convection. Such convection in phreatic hydrothermal karst system may be caused by the difference of temperatures between hot water and cool rock. Thermal conditions in which convection forms are created are discussed.

ОБРАЗОВАНИЕ ПЕЩЕР В РЕЗУЛЬТАТЕ ЕСТЕСТВЕННОЙ КОНВЕКЦИИ ГИДРОТЕРМАЛЬНЫХ ВОД.

Типичные гидротермальные пещеры заметно отличаются по своей форме от систем пещер,образованных холодными карстовыми водами.

Гидротермальные пещеры обычно состоят из отдельных полостей или группы полостей,часто без заметного входа. Они располагаются нередко вблизи поверхности земли и их открывают случайно в каменоломах и других искусственных обнажениях. Большие полости имеют неправильную,грушеподобную форму,удлинённую по вертикали. Малые полости обычно являются правильно сферическими, а в их стенах и сводах находятся многочисленные полукруглые коррозийные ниши и небольшие сферические купола.

Был выдвинул целый ряд теорий, объясняющих образование этих форм,однако генеза их является по-прежнему спорной.

Представлено мнение, что гидротермальные пещеры возникают в результате обводного течения вод, вызванного естественной конвекцией. Конвекция в гидротермальной карстовой системе может быть вызвана различием температур между горячей водой и окружающей породой. Проанализированы термические условия в пещерах, в которых образовываются карстовые конвекционные формы.

1. INTRODUCTION

The term "hydrothermal karst" is used here for the system of caverns produced by hot waters of any origin with their temperature higher than that of ground waters in the near-surface zone.

Many observations made in hydrothermal caves lead to the conclusion that some solution forms are typical of this kind of caves and seldom, if ever, occur in cold water cave systems. This is especially true for spherical forms which are common and sometimes dominant in hydrothermal karst systems.

Papers on the origin of spherical forms are scarce. These peculiar forms in hydrothermal caves were described by Hungarian scientists long time ago, but their origin was explained in terms of non-karstic processes. F. Pávai Vajna (1931) thought that the spherical chambers were formed by desintegration of limestones due to the action of hot water steam. According to L. Jakucs (1948) limestones were altered by hot waters, and then mechanically washed out by waters impact.

Recently, the karst origin of such forms has been generally accepted (Jakucs 1977, Müller, Sarvary 1977), but the mechanism of their formation is still disputable. P. Müller (1974) is of the opinion that spherical forms in thermal caves originate above water level, due to convecion in the air containing water vapour. Thus, the spherical forms situated at different levels correspond to successive stages of lowering of hot water table. This hypothesis was also discussed and some theoretical models were presented by S. Szunyogh (1984). According to J. Rudnicki (1978) the spherical forms are created in phreatic hydrothermal caves by natural convection in water.

2. GENERAL DESCRIPTION OF HYDROTHERMAL CAVES

According to hitherto collected data, hydrothermal caves belong to two different categories (fig.1 A, B).

1/ vertical caves - made up of spherical chambers, of diameter from one to several meters, connected by narrow tube-like conduits. The cave system is arranged vertically, but individual branches may develop in various directions. Growth of spherical chambers can often lead to the conjunction of two or several neighbour forms. This way larger chambers or vertical chimneys are formed. The whole cave resembles somewhat vertically arranged bunch of grapes (cf. Jakucs 1948 p.55). According to Hungarian authors this, very special, category of caves were formed by ascending thermal waters.

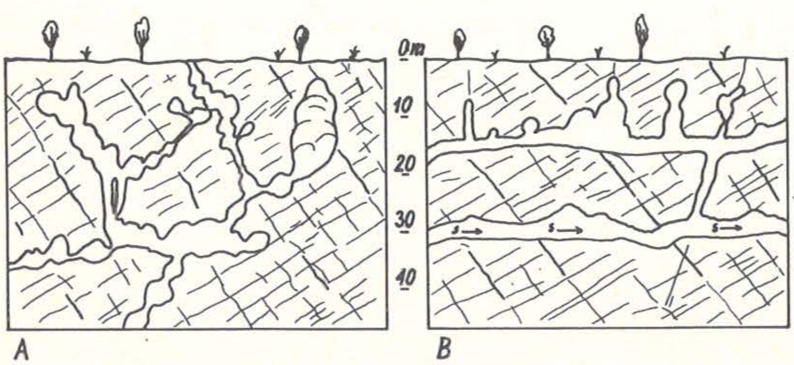

Fig.1. - scheme of two categories of hydrothermal caves
A - vertical cave, B horizontal cave, s - scallops

2/ horizontal caves - represent typical shallow-phreatic systems with the horizontal network of joint-controlled conduits. Scallops sometimes occur indicating the role of currents in the cave development. Walls are often covered with aragonit and other minerals precipitated from hot solutions. Numerous hemispherical or nearly spherical cupolas which developed above the conduits, are confined only to the uppermost, near-surface levels of the caves.

On the grounds of above description two different kinds of spherical forms (fig.2 A, B) are distinguished:

1/ spherical chambers typical of vertical caves, which represent enlarged part of conduits and form integral part of drainage system.

2/ hemispherical, or nearly spherical cupolas, situated above hot water conduits in horizontal caves.

It is assumed that these two kinds of convective spherical forms develop by different mechanisms of heat transfer through the rock.

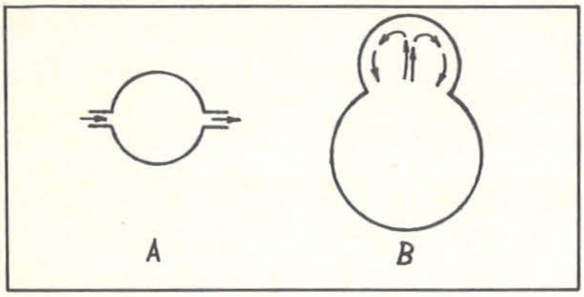

Fig. 2 - scheme of two kinds of spherical forms,
A - spherical chamber from vertical cave,
B - spherical cupola from horizontal cave.

3. BASIC PRINCIPLES OF HEAT TRANSFER IN ROCKS AND CONVECTION MOVEMENT

The process of heat transfer from hydrothermal conduit to rock surface is characterized by constant heat flow through rock perpendiculary to the surface of heat exchange. Temperature gradient, established inside the rock body, depends mainly on: diameter of conduit, thickness of overlaying rocks, thermal conductivity of rock and difference in temperature between water in conduit and rock surface. Temperature gradient is always the highest near a hot conduit and diminishes asymptotically towards the surface (fig.3 A).

Natural convection results from the action of gravitational field on fluid in which the density is not constant, as is the case when fluid is subjected to temperature gradient.

Intensity of convective heat transfer is characterized by non-dimensional Grashof number (Gr).

$$Gr = \frac{\beta \Delta t g d^3}{\nu^2}$$

where:
g - acceleration of gravity
d - sphere diameter
ν - kinematic viscosity
β - coefficient of cubic expansion
Δt - difference in temperature of boundary layer

In the established convection system, for any given temperature gradient, convective heat transfer has to be exactly balanced by conductive heat loss through the rock.

Velocity of convection current (w) may be caculated from the equation:

$$w = \sqrt{2gd\beta\Delta t}$$

Tentative calculations indicate, that within the hydrothermal karst the velocity of convection currents seldom exceeds ten centimeters per second (high d and Δt), generally remaining much lower.

4. EVOLUTION OF SPHERICAL FORMS

As usual several problems arise when simplified theoretical cases are applied. However, one can assume that presented conclusions describe the analysed process qualitatively.

To outline the evolution of spherical forms it is necessary to evaluate the intensity of convection and the magnitude of heat transfer in each of the two categories of caves*.

4.1. Evolution of spherical chambers in vertical caves

Evolution of spherical chambers was described by J. Rudnicki in 1979 and is breefly repeated here. As such form develops by enlargement of the very conduit, the convection current should be established within the flowing water. This means that the velocity of convection current must be higher than flow velocity in conduit. The best conditions for this kind of convection, exist already at the initial stage of karst system development, when laminar flow dominates. At water temperature of 60°C and the diameter of anastomosic conduit of 30 cm the biggest value of laminar flow velocity is 0.3 cm/sec. Under such conditions convection current with the velocity of about 2 cm/sec. may be established when the Δt is only 0.1°C. In the example described above the water discharge is merely 0.25 l/sec. Such amount of water assures its permanent exchange and maintenance of constant temperature only for forms of small diameter. With the growth of a form, the heat input does not compensate the loss of heat, then Δt decreases causing decrease in the convection and corrosion intensity.

4.2. Evolution of spherical cupolas above the conduit in horizontal caves

Contrary to the above, the development of spherical cupolas is independent of flow velocity in conduit. In any vertical fissure situated above and connected with the main conduit, water is cooled in response to a temperature gradient in adjacent rock which causes flow in fissure. Intensity of cooling is proportional to the temperature gradient and to the length of fissure.

Above the large conduit with voluminous flow of hot water a strong temperature gradient may be maintained which promotes continuous convection in the fissure. In such circumstances low Gr number in incipient fissure, increases gradually as the form is enlarged. This reciprocally increases the velocity of convection current and more rapid development of the whole form.

Whether or not these forms could develop, depends on the balance between convective and conductive heat transfer. Total conductive heat transfer rate (Q') increases asymptotically when thickness of overlaing rocks diminishes (fig.3 B), while total convective heat transfer rate (Q) depends on the supply of hot water to the developing form. When the hot water supply is secured the best conditions for the development of spherical cupolas exist near the limestone surface, where conductive heat transfer rate is the highest.

* The problem of how the hydrothermal solutions dissolve and how they maintain aggressivenes with respect to carbonate rock is beyond the scope of this paper.

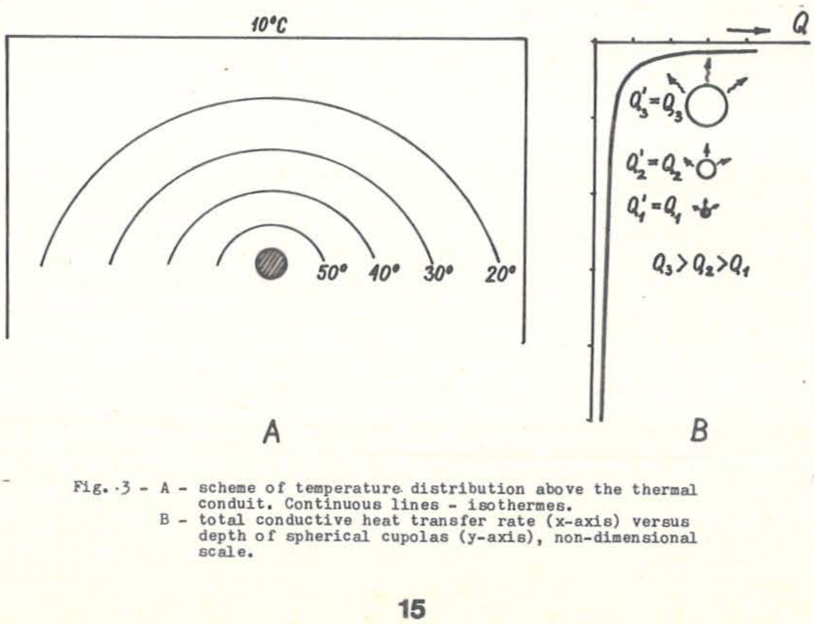

Fig. 3 - A - scheme of temperature distribution above the thermal conduit. Continuous lines - isothermes.
B - total conductive heat transfer rate (x-axis) versus depth of spherical cupolas (y-axis), non-dimensional scale.

5. CONCLUSIONS

These considerations enable to conclude, that spherical forms probably were formed in two different hydrodynamic and thermal systems.

Development of spherical chambers in vertical caves is connected with the ascending, disperse and very slow movement of hot waters.

On the other hand, the most favorables conditions for development of spherical cupolas exist in shallow-phreatic, near-surface flow. Voluminous flow of hot water with moderate velocity assures strong temperature gradient necessary to excite and maintain the convection movement.

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THE PROBLEM OF CACO3 DEPOSITION IN WATERS SATURATED WITH CARBONATES IN THE LIGHT OF FIELD EXPERIMENTS

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The hydrochemical studies of the rivers and springs yielding up to 300 $dm^3.s^{-1}$ were carried out on the Lublin Upland and Roztocze areas. These water are of the calcium-bicarbonate type /HCO_3^- up to 6,5 $meq.dm^{-3}$/. As a result of many years of investigations it was stated that waters draining cretaceous and neogene aquifers are saturated with calcium carbonates almost during the whole year. The state of saturation was ascertained with: a/ the pH measurements, b/ the pH equilibrium statements /Hem,1965/, c/ change of the thermodynamics potential ΔG, and with d/ calcite saturation index SI_c /Langmuir,1971/. The values of SI_c are ranging from +0,032 to +0,115. No traces of depositions of the $CaCO_3$ were found in over 100 of springs.

In rivers fed by these springs the measured values of pH /7,9-8,1/ are higher by 0,7-0,9 of the unit in relation to pH of the equilibrium. The values of ΔG are also positive. These waters are clearly oversaturated with calcium bicarbonates, but no precipitation was observed. Such precipitations were created in laboratory by means of mixing waters with common ion /Ca^{2+}-CO_3^{2-}, $2Na^+$-CO_3^{2-}/.

The frequent appearance in nature of waters over saturated with carbonates indicates the necessity of verifications of the $CaCO_3$ deposition classical model when changes the system: H_2O-CO_2-$CaCO_3$. The investigations proved that $CaCO_3$ depositions can easily happen with mixing waters containing common ion CO_3^{2-}.

ПРОБЛЕМА ОПРЕДЕЛЕНИЯ $CaCO_3$ В ВОДАХ НАСЫЩЕННЫХ КАРБОНАТАМИ В УСЛОВИЯХ ПОЛЕВОГО ЭКСПЕРИМЕНТА

ЯНЕЦ, Бронислав

(Польша)

В пределах Люблинской возвышенности и Розточа (ю-в Польша) проведено гидрохимическое обследование рек и источников с дебитом до 300 $дм^3.с^{-1}$. Воды гидрокарбонатно-кальциевые (HCO_3 до 6,5 $мэк.дм^{-3}$). В результате многолетних полевых исследований, установлено, что воды источников, дренирующих меловые и неогеновые карбонатные отложения, большую часть года насыщены карбонатами кальция. Это подтверждают данные определения: а) pH по замерам, б) pH равновесия (Hem , 1965), в) смены термодинамического потенциала ΔG , а также г) показателя насыщения вод кальцием SI_c (Langmuir, 1971). SI_c составляет +0,032 - +0,115. В местах выхода более чем 100 источников карбонатные осадки не обнаружены.

В реках для периода преимущественного подземного питания pH (7,9-8,1) выше на 0,7-0,9 по сравнению с pH равновесия. SI_c составляет +0,80 ÷ +,90, аналогично изменяется ΔG. Эти показатели указывают на пересыщение воды карбонатом кальция, однако его осаждения не наблюдается. Отложение карбоната отмечено при смешении исследованных вод $CaCO_3$ и Na_2CO_3 состава в лабораторных условиях.

Проведенные исследования показывают, что осаждение карбоната кальция может происходить активно при смешении вод, содержащих совместный ион CO_3^{2-}. Важной является проблема определения модели нахождения $CaCO_3$ в системе $CaCO_3$-H_2O-CO_2 в связи с частым нахождением в природе вод, пересыщенных карбонатом кальция.

1. INTRODUCTION

In the literature concerning carbonates more complicated conditions of $CaCO_3$ dissociation and deposition in the natural environment are often hypothesized from the results of laboratory experiments, which refer to pure calcite /ideal system: H_2O-CO_2-$CaCO_3$/.

In this paper attention has been drawn to the state of dynamic equilibrium in spring waters by characterizing the concentration of the main ions, their activity coefficients,the ion strength of solutions, specyfic conductance, measured reaction /pH/ and pH equilibrium, as well as calcite saturation index and thermodynamic potential.

The parameters mentioned above were also studied in rivers supplied by the spring waters in periods of underground supply. The stability and variability of the parameters of waters changing their condition of the system: from closed to open were examined.

Despite a considerable oversaturation of river waters with carbonates, neither changes in their ion composition nor traces of $CaCO_3$ deposition were observed.

Studies were carried out by titrimetric analysis, potentiometrically and conductometrically.

2. CHARACTERISTICS OF THE REGION

The area of studies was the Western Roztocze of about 500 km^2, situated in SE Poland /Fig.1/. About 100 springs occur in this region, which drain the cretaceous and Tertiary-Miocene water-bearing stage. Geologically it is a fragment of the Danish-Lublin basin. In the alpine orogenesis /laramian and later phases/, the SW extention of this basin underwent an antielinal flexion, elevation and dislocation. These disturbances, denudation processes and the contemporary elevating movements resulted in the formation of the Roztocze ridge and the dislocated bench of Miocene deposits adhering from the south. Neogene deposits form here a structural-geological edge which is water-bearing over length /Janiec,1984/. The Miocene springs draining the water-bearing stage are not discussed in this paper because of a lower mineralization level of their waters in relation to the cretaceous horizon.

Among several dozen of springs draining carbonaceous "opokas" and cretaceous marls, 21 were selected for stationary studies. Their distribution is illustrated in Fig.1. The springs are situated in the bottoms of deeply cut in valleys, or at the foot of slopes. In the former case they are ascending springs /Nos 2, 16, 17/, whereas in the latter - descending ones. The height difference between narrow bottoms of river valleys and interfluve areas reach 100m. The underground water level has little in common with the formation of the topographic surface. Asa result the average depth of the water level in the catchment areas is or exceeds 35m, and the maximal - 60m.

The Western Roztocze is one of the richest in water Poland's regions. The output of some of the springs exceeds 100, 200 or even 300 $dm^3.s^{-1}$ /spring No 16/. These are springs of the vanclu-se type.

The aeration zone of the catchment areas studied is characterized by lithological dichotomy. The lower part of the profile largely consists of carbonaceous "opokas" and marls of the Campanian and Maestrichian, whereas its roof is formed by Pleistocene rocks - often loesses and loess-like deposits. The problem of carbonate deposition in water being in contact with these deposits in the period of infiltration was discussed on the basis of laboratory studies and field experiments /Janiec, 1983, 1984, 1987/.

The Western Roztocze is an area which is relatively intensively denudated chemically /45-50 $tons.km^{-2}.year^{-1}$/. However, typical forms of underground and surface karst are almost absent. This results from the structure and chemical composition of the rocks which form the region studied /silica skeletons in carbonaceous "opokas"/.

The effect of regional impurities on changes of the chemical composition of the Western Roztocze waters is small /agriculture, precipitations/.

According to the Polish and european standards the quality of the waters of these springs is of first-class purity. With respect to the chemical composition they are simple waters - bicarbonate--calcareous. The basic physico-chemical parameters of the waters of 8 selected springs /of 21/ are presented in Table I. The results of studies of the waters of two rivers in this region are also given in this table. In the period of underground runoff, the rivers of the Western Roztocze are supplied only by the springs. Therefore it is possible to observe the changes of the physico-chemical properties of the spring waters which take part in the surface runoff, i.e. in rivers. Mean values of several dozen of the examination series are summarized in this Table. In addition to these data it should be noted that both the spring and river waters are characterized by a small temporal variability of the main qualitative features in the periods of underground supply. A good index of this state are standard deviations. In the case of HCO_3^- ion they range from 0,035 - 0,193. The standard deviation of Ca^{2+} cation is 0,066 to 0,175, and the specyfic conductance /10°C/ ranges from 2,65 - 6,15.

3. RESULTS OF FIELD EXPERIMENTS

The waters flowing out of the springs in Western Roztocze are saturated with carbonates in conditions of the predominating closed system /Deines et al.,1974/. The differentiation of the level of total mineralization, largely of $Ca-HCO_3$ ion pair, is conditioned by spatial differentiation of the solubility of cretaceous rocks and the extension of the cover of carbonate loesses /Janiec, 1983, 1984, 1987/.

3.1. Water Reaction /pH/ - Measurement Results of Springs

The reaction of the waters was measured with an electric pH-meter OP-205/1 /Radelkis-Hungary/, giving a guarantee of the required accuracy of readings. From the results summarized in Table I it may be concluded that there is a relationship between the concentration of calcium and bicarbonates and pH. Higher values of the pro-

3.2. pH equilibria - Calculation Results

The pH values computed /Table I/ for the waters of the particular springs were determined by Hem's formula /1961/, using empirically obtained Ca and HCO_3 values:

$$pH\ /calculated/ = -\log \frac{[Ca^{2+}][HCO_3^-]}{K_{eq}} \qquad [1].$$

For natural temperature of the waters /10°C/ the value of K_{eq} = $= 1,22 \times 10^2$ was assumed.

According to Hem /1961/ the calculated pH should be verified /in plus/ by the value ΔpH resulting from the coefficients of Ca^{2+} and HCO_3^- activity /γ/. The activity coefficient γ increases the computed pH by the amount:

$$\Delta pH = -\log \gamma_{Ca^{2+}} \cdot \gamma_{HCO_3^-} \qquad [2].$$

From Table I it appears that in all springs studied the pH values obtained from measurements and calculations are identical, or very similar. The differences are bidirectional and amount only from -0,07 to +0,02 pH unit. The compatibility of the results is for us a convincing evidence that spring waters are saturated with calcite.

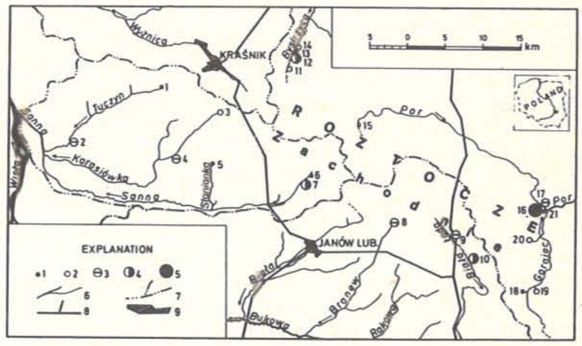

Fig. 1. Cretaceous springs and the river net in the Western Roztocze: 1 - 5 - location of cretaceous springs and their output in the period of studies; 1 - below 10 $dm^3.s^{-1}$, 2 - 10-50 $dm^3.s^{-1}$, 3 - 50-100 $dm^3.s^{-1}$, 4 - 100-200 $dm^3.s^{-1}$, 5 - over 200 $dm^3.s^{-1}$, 6 - river net, 7 - more important watersheds, 8 - main roads, 9 - towns.

The more important physical and chemical features of the waters of the selected springs and rivers in the Western Roztocze

Table I

Object	Concentracion $meq.dm^{-3}$ HCO_3^-	Ca^{2+}	Hardness Noncarb	Activity Coefficient γ HCO_3^-	Ca^{2+}	Ionic Strength μ $mol.dm^{-3}$	Specyfic Conductance /10°C/ μS.cm	pH Measured	pH Computed	Saturation Index Calcite SI_c	Thermodynamic Potential ΔG $kcal.mol^{-1}$
Spring-No											
1	5,15	4,36	0,11	0,913	0,705	$8,103 \times 10^{-3}$	347	7,20	7,22	+0,086	-0,107
5	4,72	4,36	0,19	0,915	0,712	$7,596 \times 10^{-3}$	329	7,24	7,17	+0,090	-0,104
6	5,39	4,50	0,07	0,912	0,700	$8,450 \times 10^{-3}$	372	7,19	7,19	+0,109	-0,076
7	5,48	4,72	0,10	0,911	0,698	$8,650 \times 10^{-3}$	380	7,14	7,16	+0,106	-0,105
8	5,35	4,55	0,05	0,911	0,700	$8,492 \times 10^{-3}$	363	7,17	7,19	+0,089	-0,100
9	5,80	4,97	0,08	0,909	0,693	$9,087 \times 10^{-3}$	396	7,12	7,13	+0,121	-0,070
12	4,90	4,35	0,10	0,914	0,707	$7,965 \times 10^{-3}$	363	7,25	7,25	+0,115	-0,070
16	6,49	5,42	0,01	0,905	0,681	$1,015 \times 10^{-2}$	449	7,03	7,05	+0,103	-0,070
River											
Sanna	5,08	4,44	0,12	0,913	0,703	$8,210 \times 10^{-3}$	351	7,97	7,22	+0,859	+0,893
Por	6,00	5,34	0,28	0,904	0,680	$1,010 \times 10^{-2}$	444	8,04	7,30	+1,072	+1,181

ducts of $CaCO_3$ dissociation correspond to lower pH values. From the curves of calcite solubility of Roques and Muxart /Muxart, Birot, 1977/, on which the data were plotted, it appears that the pH values indicate the state of dynamic carbonate equilibrium in the closed system. At the same time pH is here an index of relative H_2CO_3, HCO_3^- and CO_3^{2-} proportions in the waters studied /Muxart, Birot,1977, Deines et al.,1974, Hem,1985/. From the studies it also appears that in stable pressure /including pCO_2/ and temperature conditions the carbonate systems studied are characterized by a considerable stability. In the annual cycle and in a period of many years the recorded pH oscillations were from 0,04 to about 0,40 pH units in the particular springs, but in late summer and autumn this index often signalizes a little higher saturation with carbonates.

3.3. Index of Water Saturation with Calcite

To determine the index of water saturation with calcite - SI_c, Langmuir /1971/ proposed the formula:

$$SI_c = \log \frac{[Ca^{2+}][CO_3^{2-}]}{K_s} \qquad [3],$$

in which the adoption of the constant value K_s of calcite solubility ratio as the mean of the results of Roques, Picknett /fide: Muxart and Birot, 1977/ and Jacobson-Langmuir /1974/ seems to be reasonable. For 10°C temperature $K_s = 3,9355 \times 10^{-9}$ /mol.dm^{-3}/.

The proposition of taking into consideration such a determination of the index of water saturation with calcite results from the need to admit the activity of those ions which determine this saturation. According to Langmuir /1971/ natural waters, SI_c indices of which range from 0,0÷±0,1 are apparently saturated with calcite.

SI_c indices of the waters of all springs studied are in the interval from +0,032 to +0,115, and even +0,121 in one case.

3.4. Thermodynamic Potential

In the process of $CaCO_3$ dissociation the aspiration of the system to pass from the initial to final state is determined by the difference of the thermodynamic potential ΔG. A spontaneous course of the chemical reaction is only possible when ΔG is negative, i.e., when the thermodynamic potential decreases during the reaction. A positive ΔG value indicates a reverse course of the reaction, whereas in equilibrium $\Delta G = 0,0$.

In the cases studied the values of the thermodynamic potential refer to unitary concentration /mol.dm$^{-3}_{H_2O}$/.

The data presented in the table have negative signs in regard to springs, but ΔG values are small.They are from -0,07 to -0,107 kcal.mol^{-1}.dm^{-3}/Table I/.

3.5. River Waters

The results of studies of the ion composition of waters in the rivers draining the Western Roztocze allow us to find that the content of the chief ions in flowing waters is the weighted mean of Ca^{2+} and HCO_3^- concentration in the springs supplying rivers. This concerns the rivers presented in the table, as well as other streams of this region. The calculated pH values corresponding to the Sanna and Por rivers are 7,22 and 7,30, respectively. However, the mean values recorded by the pH-meter are 7,97 and 8,04. With respect to the annual course it should be stressed that a slight decrease of pH values is observed in river waters in the winter half-year.

Changes of pH are a natural consequence of changed partial pressure of pCO_2 in underground spring waters on the way of their gravitation flow in the river beds. However, a considerable inertia of the carbonate system was observed here, the consequence of which is the absence of $CaCO_3$ deposition.

An equally instructive example are the results of studies carried out in the region neighbouring with the Roztocze area from N and NW. Waters of Wieprz, the largest river in the Lublin Upland, flow over 160 km in this region /the Łęczna break/, which is also built of carbonate rocks. This river also drains a considerable part of the Western Roztocze. Over the whole year the waters of the river Wieprz contain in underground flow about 5 meq of Ca^{2+}.dm^{-3} and over 5 meq of HCO_3^-.dm^{-3} at the average value of pH ≈ 8,0. This indicates over-saturation of water with carbonates, however, $CaCO_3$ deposition is not observed.

Another evidence of disturbed carbonate equilibrium in the river waters of the Western Roztocze are the values of the calcite saturation index. In the two rivers presented in Table I the SI_c values are +0,859 and +1,072. Other rivers of the region studied as well as the river Wieprz have similar indices.

The values of the thermodynamic potential increase over tenfold in river waters in relation to ΔG in springs. This increase to distinctly positive values /Table I/ is still another argument accounting for oversaturation of waters with carbonates.

4. DISCUSSION

Among over 100 springs draining the Roztocze water-bearing horizon, $CaCO_3$ depositions are visible only in two spring niches.

In spring No 13 /Fig.1/ situated in the Bystrzyca river valley, distinct precipitations of amorphous form of calcium carbonate up to 20mm in thickness was observed. The waters of this spring are characterized by a low level of calcium /3,95 meq Ca^{2+}.dm^{-3}/ and bicarbonates /4,14 HCO_3^-.dm^{-3}/, and their pH is 7,28. The index SI_c = 0,032 is the lowest in all waters studied. The depositions in such waters must evoke controversies about the rational causes of these precipitations. The causes are undoubtedly complex, and the presented problem itself is of great theoretical and practical importance.

Depositions of another type were observed in the roof of the spring niche No 6 situated in the Sanna river valley. They are calcite sinters of stalactites, stalagmites and stalagnates of several centimetres in length. In the light of the hydrochemical studies carried out in loesses /Janiec, 1987/ it should be assumed that these depositions have nothing in common with spring waters. They come from waters infiltrating through the cover of carbonate loesses which underwent then exudation in relatively considerable quantities.

In the author's opinion some amounts of calcium carbonate may be precipitated in conditions of natural water circulation, among other things, as a result of the occurrance of electrolytes with a common ion in water solutions. In a laboratory experiment the contact of waters of the type Ca^{2+}- CO_3^{2-} and Na^+- CO_3^{2-} was simulated. One of many possible causes of the occurrence of such a case in nature is sodium silicate,which, in the presence of CO_2 turns into sodium carbonate. A relative easiness of Na_2CO_3 to enter the hydrosphere implies the presence in water of dissociation products of this substrate even in considerable amounts. At higher pH values, however, small amounts /additional/ of CO_3^{2-} are sufficient to exceed the ratio of calcite solubility and to start the process of deposition.

In the experiments carried out, in some natural waters /e.g. of carbonate hardness 2,95 meq.dm^{-3}/ calcium carbonate precipitations could be observed macroscopically in the presence of dissociation products of 0,0005 mole of Na_2CO_3.

5. CONCLUSIONS

The possibility of the existance of waters saturated with carbonates /Alekin, 1970/ and the frequent occurrence of such waters in nature creates the need for verification of a classical model of $CaCO_3$ deposition with changed conditions of the system: H_2O-CO_2-$CaCO_3$. Such a model is often the basis of interpretation of various phenomena observed in areas of carbonate karst. It is advisable to approach the interpretation of karst phenomena indyvidually, because it often happens that the same effect, e.g. deposition, can have different causes which are also conditioned by geochemistry of the environment.

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10.000 : 160 = 62 m²/dolina
400
Átlagos dolina $\phi \approx 20$ m

SURFACE FEATURES AND THEIR RELATIONS TO THE CAVES IN THE AKIYOSHI PLATEAU IN JAPAN

MIURA, Hajime

In Japan, the Akiyoshi plateau is known as the widest limestone terrain extended over 130km² including more than 200 caves. This limestone plateau is subdivided into three erosion surfaces with low reliefs. The number of dolines on each ersion surface is the greatest on the middle surface occupying about 68% of the total area. As for the doline density, it is the highest on the high surface.

Vertical distribution of caves in this plateau are respectively concentrated at three levels. Akiyoshido, the largest cave, is one of low level caves and Takaga-ana, the second largest cave, is one of middle level caves.

Takaga-ana cave has a vertical shaft like a collapse doline on the middle erosion surface. It is recognized that three cave levels at 180m, 160m and 140m above sea level exist in this cave and these levels are closely related with depositional surfaces in Yowara Uvala. An analysis of orientation of karren on the ground surface reveals high frequencies in N50-70°E, N25-40°E, N35-55°W and E-W. And this tendency nearly corresponds to fequencies in direction of cracks in this cave and the logitudinal cave form.

Die Beziehung der Oberflächengestalt und der Höhle des Akiyoshiplateaus in Japan.

In Japan ist das Akiyoshiplateau mit seinen 13o km² und über 2oo Höhlen der bekannteste Karst.
Das Kalksteinplateau besteht aus 3 Abtragungsoberflächen mit niedrigem Relief.
Die Zahl der Dolinen ist am größten auf der mittleren Abtragungsoberfläche, die 68% der gesamten Karstfläche einnimmt.
Die Dolinendichte ist die höchste auf der höchsten Abtragungsoberfläche. Vertikal sind die Höhlen auf alle drei Stufen verteilt: Akiyoshido ist die größte Höhle auf der unteren Stufe und die Takaga-ana Höhle die größte auf der mittleren Stufe. Die Takaga-ana Höhle hat einen vertikalen Schacht auf die mittlere Abtragungsoberfläche hin. Man hat 3 Höhlen-Höhenunterschiede gemessen. Eine auf 18om, eine auf 16o m, eine auf 14o m über Null. Diese drei Höhlen entsprechen der Aufschüttungsfläche in Yowara Uvala.
Die Analyse der Orientierung des Karren auf der Oberfläche zeigen große Häufigkeit in den Richtungen N 5o-7o° O, N 25-4o° O, N 35-55° W und O-W. Diese Richtungshäufigkeit korrespondiert mit der Richtung der Spalten in der Höhle und der Richtung der Höhle selbst.

1. INTRODUCTION

In Japan, the Akiyoshi plateau is known as the widest limestone terrain extending over 130km² for its abundant karst features including dolines, karrenfeld, polje, karst-springs, caves. This limestone terrain is about 100m to 400m in height above sea-level with gently undurated surface and mostly serrounded steep marginal slope.

About 2,200 dolines are located and mean doline density for total area is about 20/km² on the plateau. But the highest density display 140-160/km² in the central part of the east Akiyoshi plateau.

Over the Akiyoshi limestone terrain, it is possible to divided into three levels of erosion surfaces with low reliefs. The writer threw light on the geomorphological feature and the dating of this three erosion surfaces. On the other hand, this plateau is the most cave-crowded terrain including about 300 caves and the spatial distribution at altitude of each caves is becoming to reveal by devoted cavers. Accordingly, the writer is going to make clear the relationship of surface features and caves in this limestone plateau.

2. GEOMORPHOLOGICAL FEATURES OF EROSION SURFACES IN THE AKIYOSHI PLATEAU

2.1. Identification Method of Erosion Surfaces

The writer made a slope classification map of the Akiyoshi limestone terrain using the topographical maps of 1:25,000. A distribution map that was drawn out only areas with gentle siope less than 15 degrees in gradient and coordinated to three levels of erosion surfaces, sudivided into six levels, in the same altitude zone is Fig.2. It is recognized to be well preserved in a state of the initial surface with low reliefs.

Moreover, it is Fig.3 that is generalized on the three surfaces, subdivided into six levels, on the basis of the distribution map by the above-mentioned method over the Akiyoshi limestone terrain.

2.2. Geomorphological Features and Dating of Erosion surfaces

The high levels are Jigokudai surface of 410-370m at elevation and Managadake surface of 350-320m. The middle levels are Chōjaga-mori surface of 310-280m, Wakatakebara surface of 260-240m and Kinokubo surface of 220-180m. The low level is Ōbanyama surface of 160-130m.

The writer made a distribution map of dolines over the Akiyoshi plateau on the basis of interpretation of stereoscopy on aerial photograghs of 1:10,000. It is Tab.1 that draw out a tabular form calculating the number of dolines on each erosion surfaces. The results reveal distinctly their difference of each surfaces, to say more precisely the number of dolines is the greatest on the middle surfaces and extremly few on the newer low surface. As for the doline density, it is the highest on the old high surfaces.

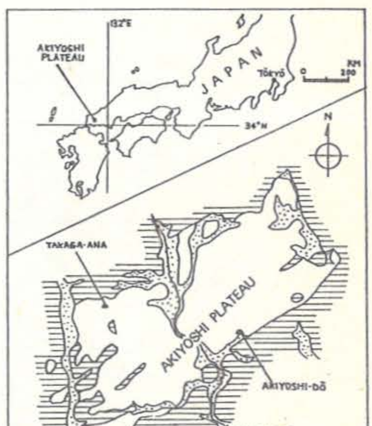

Fig.1. Location of the Akiyoshi Plateau.

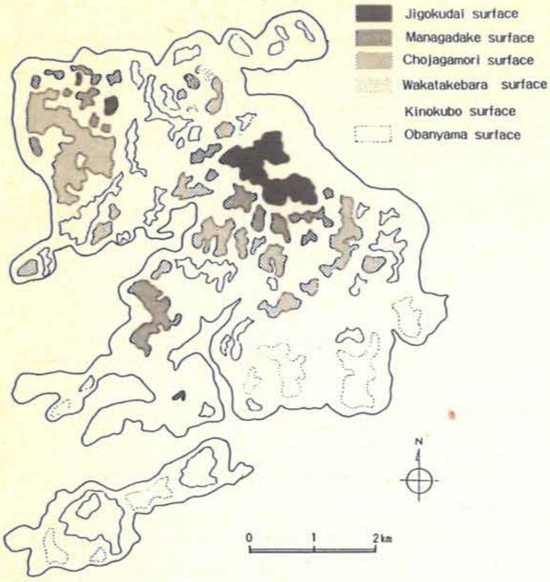

Fig.2. Erosion surfaces in the West Akiyoshi Plateau.

The high surfaces, Jigokudai and Managadake, stand like monadnock with flat summit above the surround middle surfaces. Considering to identify Jigokudai surface with the Kibikōgen erosion surface in the Chūgoku region, its formation stage may be during the late Pleiocene. Among the middle surfaces occuping 43% of the total area, Chōjagamori surface is presumed to had been formed at the time of the early Pleistcene with reference to age of Kitayamakitano-yokoana cave gravel(after Dr.Kawano) and Wakatakebara, Kinokubo surfaces formed during the middle Pleistcene on the basis of age of Fusenana cave gravel.

3. SURFACE FEATURE AND THEIR RELATIONS TO TAKAGA-ANA CAVE IN THE WEST AKIYOSHI PLATEAU

3.1. A General Feature of Distribution at Altitude of Caves in the Akiyoshi Plateau

In recent years, it has been becoming to clear up about 300 caves and their length,size,altitude on this plateau as the result of investigation by devoted cavers.

After Dr.Kawano(1983) and other, caves in the Akiyoshi plateau are possible to be divided into three groupes; the high altitude caves at 300-250m in height, the middle caves at 200-160m and the low caves at 130-80m near by allvial plain.

The high altitude caves are mostly located on Chōjagamori surface. The middle altitude caves are crowded at level of 180-160m and their entrances exsist mostly on Wakatakebara surface. Most of the low altitude caves are lateral caves that their entrances are situated at the foot of this limestone plateau.

Akiyoshidō, the largest cave in the Akiyoshi plateau, is one of the low altitude caves and Takaga-ana, the second largest cave, is one of the middle altitude caves.

Then it would be discussed fully the surface features and their relationship to cave as example of Takaga-ana cave.

3.2. Morphological Features on Plane and Section of Takaga-ana Cave

Takaga-ana cave is located on the northern part of the west Akiyoshi plateau and its entrance is situated at 240m in height. This cave is a large complex cave with vertical entrance of 41m in depth like a collapse doline and lateral caves connected with several passages. It extends more than 1,500m along main cave route and its total length along measuring lines of the cave system including more than 40 branch caves attain about 4,500m.

This cave plane is as following Fig.4. Outline of cave system is seemed to be composed of the network of halls and passages developed along many fissures of NE-SW, NW-SE, N-S and E-W for direction. Actually, the fissures,joints and faults of these direction are found in this cave.

The longitudinal section along main cave route is shown on Fig.5. It is recognized that the levels of cave floor and flat ceiling exist at 200-180m, 170-160m and 140-130m in height. Among these levels, the dominant level of cave passages is about 170-160m.

3.3. Direction of Lapies on the Ground Surface and their Relations to the Cave

It is commonly known that caves are formed along lines of weakness in the pervious rock such as fissures, joints, bedding planes and faults. As previously stated, it is presumed that outline of Takaga-ana cave system may be defined along about four lines of weakness in limestone mass.

On the other hand, the writer investigated thoroughly the direction of lapies in the vicinity of Takaga-ana cave. It is rarely the case that find an outcrop of limestone on the ground surface because this plateau is deep-soiled with about 5m in the mean depth. But the direction of lapies were surveyed in 117 points of the scattered outcrops in the field. Its result is shown on Fig.6 as the distribution map, on Fig.7 as the frequency diagram.

An analysis of the direction of lapies reveals high frequencies in NE-SW (N25-40°E, N50-70°E), NW-SE (35-55°W, N65-75°W) and E-W. And this tendency nearly corresponds to frequencies in the direction of cracks or fissures in Takaga-ana cave. Comparing with two results of survey in the cave and investigation on the ground surface, it is suggested that a network of directions of lapies, expressly the set of NW-SE and NE-SW, represents the conjugate system of joints in limestone mass.

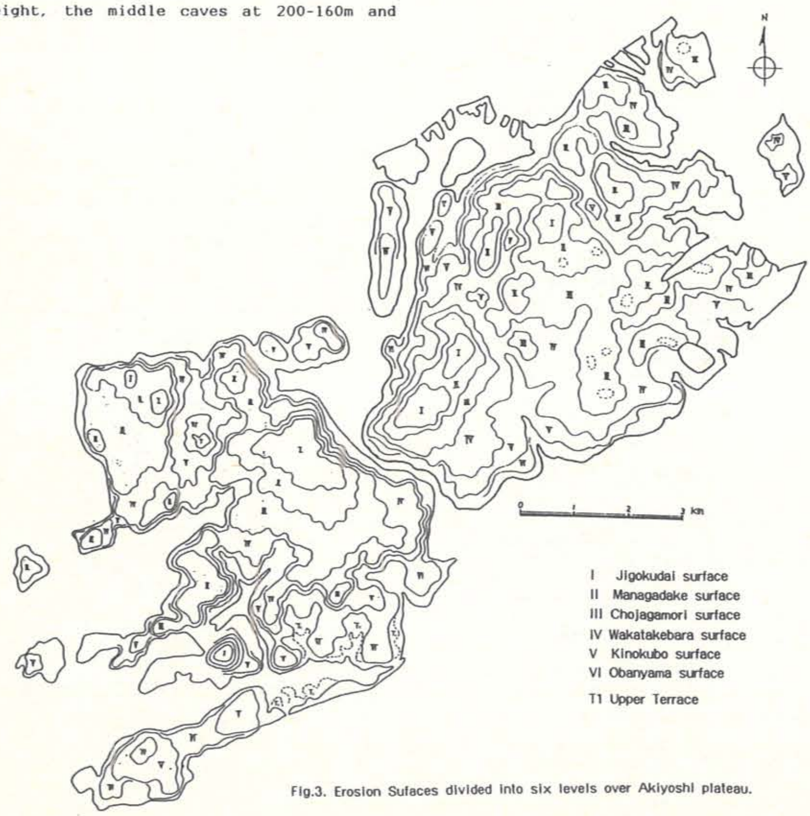

Fig.3. Erosion Sufaces divided into six levels over Akiyoshi plateau.

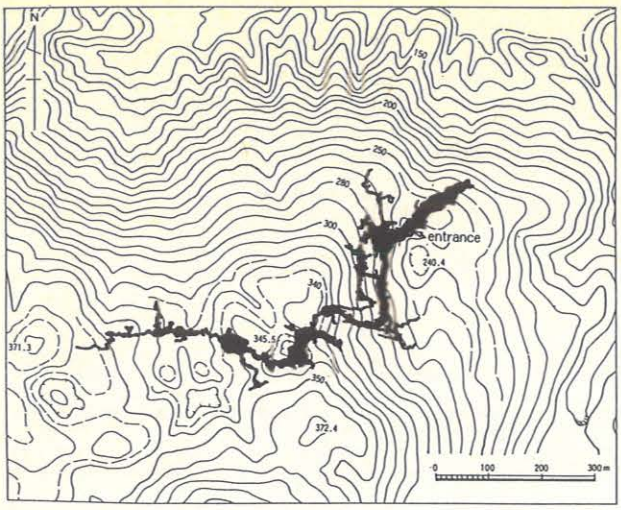

Fig.4. Plane of Takaga-ana Cave and topography of the ground surface.

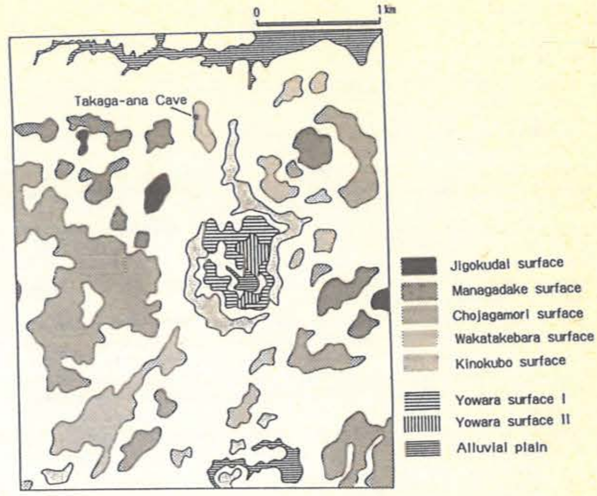

Fig.8. Geomorphic surfaces in the vicinity of Yowara Uvale.

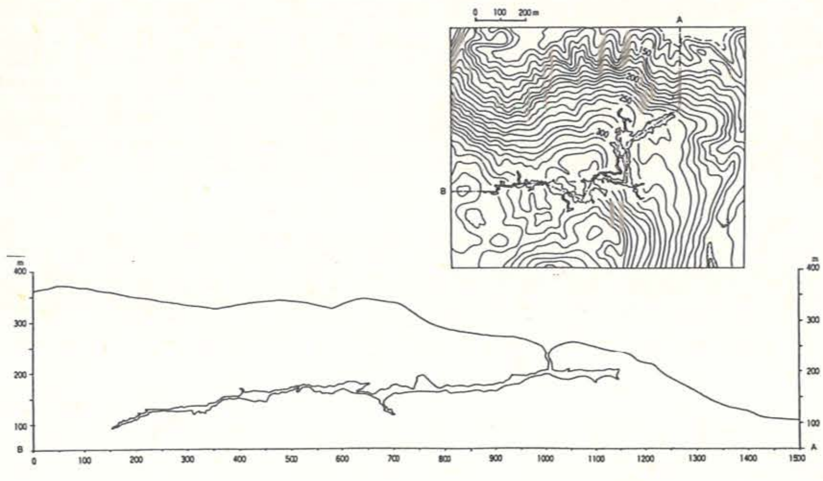

Fig.5. Longitudinal section of the Takaga-ana Cave.

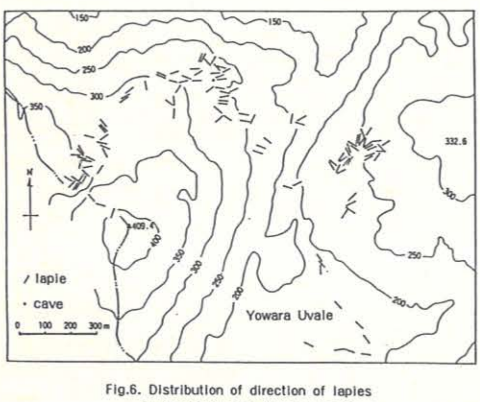

Fig.6. Distribution of direction of lapies in the vicinity of Takaga-ana Cave.

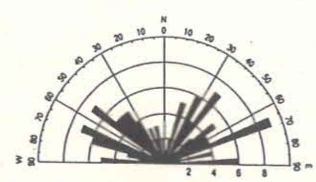

Fig.7. frequency diagram of direction of lapies in the vicinity of Takaga-ana Cave.

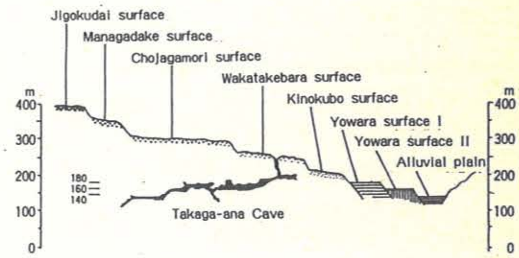

Fig.9. Relations between the Takaga-ana Cave and geomorphic surfaces.

Tab.1. Number of Dolines and Doline Density on Each Geomorphic Surfaces in the Akiyoshi Plateau.

Geomorphic Surfaces		Area ha	Number of Dolines	Doline Density	Mean Doline Density
High Surface	Jigokudai S.	255.5	143	0.56	0.57
	Managadake S.	636.3	364	0.57	
Middle Surface	Chōjagamori s.	1222.3	763	0.62	0.51
	Wakatakebara S.	1177.9	681	0.58	
	Kinokubo S.	755.7	174	0.23	
Low Surface	Ōbanyama S.	302.4	28	0.09	0.09
Total		4350.1	2153		0.49

However, the fissures of N-S direction influenced in formation of parts of main cave route is scarcely found in the surface feature of joint system. On the basis of carful survey in the cave, it came out that were a newer large fault breaked the west Akiyoshi limestone mass.

3.4. Geomorphic Surfaces and their Relations to the Development of the Cave

Geomorphic surfaces in the vicinity of Takaga-ana cave are developed into the erosion surfaces of six levels and the depositional surfaces of three levels. A distribution of geomorphic surfaces is shown on Fig.8. The depositional surfaces are two levels of diluvial terraces and alluvial plain in the Yowara Uvale. The high terrace is called Yowara surface I of 180-170m in height and the low terrace is called Yowara surface II of 160m. Alluvial plain of the lowest surface in Yowara Uvale is 140m in height. The geomorphic surfaces and their relation in height of Takaga-ana cave is shown on Fig.9.

Initial formation of Takaga-ana cave had been originated as an underground conduit in the phreatic zone at stage of Wakatake-bara erosion surface. That is provably gussed at the early age of middle Pleistocene. Successively , it had been extended as lateral passage of 180m level at stable age of the ground water table during the formation of Kinokubo erosion surface. Its level corresponds to Yowara surface I. This stage is provably during the middle Pleistocene. The stream in cave of 180m level had been flowed toward the west, some time later were captured toward the east by the Kotō River.

As seen on Fig.9, the major part of this lateral cave had been enlarged as passages of the under ground river type at about 170-160m in height. Its cave level corresponds to Yowara surface II of 160m.That stage may be the late age of middle Pleistocene.

The westernpart in Takaga ana cave is the lateral passage with flat ceiling at 140-135m level, developed as the ground water table type cave during the late Pleistocene. There are the two kinds of volcanic ash origied from Aso volcano and Aira volcano, redeposited in this passage. Its cave level corresponds to the lowest surface covered with gravelly allvium of 140m in altitude in Yowara Uvale. This geomorphic surface in Uvale is higher about 40m than the surrounded karst marginal plain along the Koto river.

Consequently the main part of the middle altitude cave, for example of Takaga-ana, had been developed during the formation of large Uvale in the Akiyoshi limestone terrain.

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PRELIMINARY ZOOGEOGRAPHIC ANALYSIS OF FIVE GROUPS OF CRUSTACEAS FROM ANCHIALINE CAVES IN THE WEST INDIAN REGION

HOLSINGER, John R.

ABSTRACT

The near congruent ranges of five recently discovered genera of crustaceans from anchialine caves (i.e., caves with bodies of water that have subterranean connections to the sea) in the West Indian region form a generalized distribution track that extends west-southwest from the Bahamian island chain, across Cuba, to the Yucatan Peninsula of Mexico. These crustacean genera, which consist of Speleonectes (Remipedia), Bahadzia (Amphipoda), Bahalana (Isopoda), Tulumella (Thermosbaenacea), and Agostocaris (Decapoda), are represented by 19 stygobiont species, 17 of which occur in two disjunct areas of endemism: (a) the Bahamian archipelago (Bahamas and Turks and Caicos Islands) and (b) the northeastern coastal region of the Yucatan Peninsula and the nearby island of Cozumel.

On the assumption that this generalized track is an estimation of the distribution of the ancestors of the present stygobiont species, it is hypothesized that the latter evolved from a putative marine ancestral fauna previously ranging from the Bahamian archipelago to the Yucatan Peninsula. It is also hypothesized that caves in both areas of endemism were colonized by preadapted marine ancestors in response to changes of sea level during the Quaternary, and perhaps even earlier for some caves. It is likely that additional species in some or all of these crustacean genera will eventually be found in suitable subterranean habitats on Cuba.

RÉSUMÉ

Les répartitions congruente de cinq genre des grottes anchialines (c'est à dire les grottes ayant des liasons souterraines à la mer) dans la region des Indes occidentales, forment une trace de distribution général qui etend des Iles Bahama, au travers de Cuba, jusqu' à la Péninsule de Yucatan de Mexique. Ces genre crustacéens, qui consistent de Speleonectes (Remipedia), Bahadzia (Amphipoda), Bahalana (Isopoda), Tulumella (Thermosbaenacea), and Agostocaris (Decapoda), sont representées par dix-neuf espèces stygobiontes. Dix-sept de ces espèces sont endémiques à deux régions distincte: (a) l'Archipel Bahama (les iles Bahama et Turks et les iles Caicos) et (b) la région cotière au nord-ouest de la Péninsule Yucatan et l'ile de Cozumel.

Si on assume que cette trace est une estimation de la distribution des ancêtres des espèces stygobionte présente, on emets la hypothèse que les dernieres ont fait evoluer d'une faune marine ancestrale qui s'est trouvée de l'Archipel Bahama jusqu' à la Péninsule Yucatan. On suppose aussi que les grottes dans chaque région sont été colonisées par des ancetrès marines qui sont étés préadaptes à cause des changes de niveau de la mer pendant la Quatenaire et peut-etre auparavant dans le case de certaines grottes. C'est possible qu'on trouveront eventuellement des espèces additionelle de ces genre crustacéens dans les habitats souterraines appropriés à Cuba.

1. INTRODUCTION

Recent biological exploration of anchialine caves (i.e., caves with bodies of water that have subterranean connections to the sea) in the West Indian region have revealed a surprisingly rich diversity of stygobiont crustacean taxa. These newly discovered taxa are providing valuable data for biogeographic analyses and further insight into the evolutionary history of West Indian cave faunas. In the present study, which is still very preliminary, the remarkably similar geographic distributions of five exclusively stygobiont crustacean genera are analyzed.

2. OBSERVATIONS

During an ongoing investigation of the systematics and biogeography of subterranean amphipods from the West Indian region, it was observed that the genus Bahadzia (Hadziidae) (Holsinger & Yager, 1985; Stock, 1985, 1986a; Holsinger, in preparation) shared similar patterns of geographic distribution with four other genera of subterranean crustaceans. These genera include the remipede Speleonectes (Speleonectidae) (Yager, 1987a), the thermosbaenacean Tulumella (Halosbaenidae) (Yager, 1987b; Bowman & Iliffe, 1988), the isopod Bahalana (Cirolanidae) (Bowman, 1987), and the decapod shrimp Agostocaris (Agostocarididae) (Kensley, 1988). As presently known, all of these crustacean genera, including Bahadzia, are monophyletic and contain only a small number of stygobiont species. With the exception of a single species of Speleonectes from the Canary Islands, their ranges are nearly congruent and collectively form a generalized distribution track that extends west-southwest from the Bahamian island chain, across Cuba, to the Yucatan Peninsula of southern Mexico (Figs. 1-6). These genera occur almost exclusively in anchialine caves, where they are often found beneath a halocline in water with very low oxygen content. All of them have been discovered in recent years.

To date, 17 of the 19 species recorded in these genera occur in two widely separated areas of endemism in the West Indian region: (a) the Bahamian archipelago, including the Bahamas and Turks and Caicos Islands (11 species) and (b) the northeastern coastal region of the Yucatan Peninsula amd nearby Isla de Cozumel (6 species). These areas, situated 800 to 1000 km apart, are physically separated by Cuba and open marine waters of the Caribbean Sea in several places. In addition, Bahadzia is represented by one species, which is recorded from shallow groundwaters in southeastern Haiti (Stock 1985) on the island of Hispaniola (see fig. 3). Interestingly, this species inhabits shallow wells with predominantly freshwater, rather than anchialine caves with brackish/marine water like all other species observed in this study.

3. DISCUSSION

The generalized distribution track formed from the broadly overlapping ranges (see Fig. 6) of the five crustacean groups considered in this study suggests that they have shared a similar distributional history, and that this pattern is best explained by a vicariance model. This model holds that the present distributions of these crustaceans resulted from fragmentation of earlier, continuous ranges of putative ancestors, and that their common areas of endemism were affected by the same isolating events.

An alternative hypothesis to the vicariance explanation is a dispersal model, e.g., migration from a "center of origin," such as the Bahamas, to the Yucatan area. This argument is statistically weak, however, because it is improbable that members of five different groups of crustaceans would have dispersed to the same area(s) and have nearly identical patterns of distribution. Moreover, with the possible exception of the shrimp Agostocaris, none of these taxa has a dispersing larval stage, and adults of all of them are apparently restricted to caves or related subterranean habitats. Finally, even though these species are generally marine, there is no evidence to suggest that any of them, or their putative ancestors for that matter, were or are good dispersers; and considering their apparent restriction to subterranean waters, it is unlikely they would move into epigean ocean water outside caves except by accident.

The complex geological history of the Gulf of Mexico-Caribbean region for the last approximately 50 million years, although still far from being completely resolved, tends to support the vicariance model described above. For example, recent syntheses of the geological history and biogeography of this region by Rosen (1975, 1985) suggest contact, or near contact, between parts of Cuba, Hispaniola and Jamaica, between western Cuba and southern Mexico (Yucatan), and between eastern Cuba, parts of Hispaniola and the Bahama Bank at various times in the Tertiary between 48 and 7 million years ago. Minimal contact in the past between islands that occur in the intervening area between the Bahamas and the Yucatan Peninsula could have provided putative shallow water, ancestral faunas with the means for continuous distributions across the entire span of the generalized track. Continuous ranges would have been fragmented and ancestral faunas isolated as islands drifted farther apart and became separated by deep marine waters. An important prediction of this model is that additional species in these taxonomic groups will be found in anchialine caves on Cuba, Hispaniola, and possibly Jamaica. If this prediction is correct, careful investigation of anchialine caves on these islands by biologically trained cave divers, similar to the work already done in the Bahamas and coastal karst of the Yucatan Peninsula, should result in significant discoveries of new species.

The question as to when putative stygobiont ancestors invaded and colonized subterranean habitats -- i.e., before, or after fragmentation -- cannot be resolved by the present data. It is, however, entirely possible that the present generation of anchialine caves was colonized in reponse to changes in sea level during the Quaternary. It is also possible that the present inhabitants of these caves, or their predecessors, were already stygobionts before the hypothesized Quaternary colonizations. There is some indication from other studies that many stygobiont taxa living in anchialine caves might have inhabited crevicular and interstitial habitats (or even older generations of anchialine caves) for millions of years before the Quaternary (see Holsinger et al. 1986; Stock, 1986b; Holsinger, 1988). Elevations of sea level during glacial minima in the Pleistocene would have provided access to newly developing anchialine cave habitats, especially in karst areas at lower elevations, for preadapted ancestors or pre-existent troglobites living in nearby subterranean habitats.

Providing that enough new data become available, future studies on the distributional history of these taxa should employ one or more of the newer, comprehensive methods of vicariance biogeography, such as reduced area cladograms, component analysis or parsimony analysis (see Wiley, 1988 for a review). I used track analysis (see Humphries & Parenti 1986) in the present study, primarily because of the limited data set, which involved only a few species, little phylogenetic information except for Bahadzia (Holsinger, in preparation), and no more than two principal areas of endemism. A more comprehensive analysis will require additional species, detailed phylogenies (cladograms) for each genus, and recognition of three or more areas of endemism.

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Figure 1.--Distribution track of the remipede genus *Speleonectes*. Single locality records denoted by closed circles and species by numbers as follows: 1, *S. lucayensis*; 2, *S. benjamini*; 3, *S. tulumensis*; 4, *S. ondinae* (Lanzarote, Canary Islands -- not shown on above map).

Figure 2.--Distribution track of the thermosbaenacean genus *Tulmuella*. Single locality records denoted by closed circles and species by numbers as follows: 1, *T. grandis*; 2, *T. bahamensis*; 3, *T. unidens*.

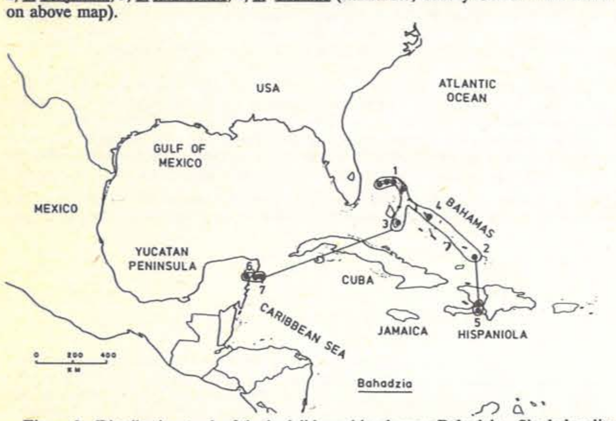

Figure 3.--Distribution track of the hadziid amphipod genus *Bahadzia*. Single locality records denoted by closed circles and species by numbers as follows: 1, *B. williamsi*; 2, *B. stocki*; 3, *B. setimana*; 4, *B. obliqua*; 5, *B. latipalpus*; 6, *B.* n. sp. A; 7, *B.* n. sp. B.

Figure 4.--Distribution track of the cirolanid isopod genus *Bahalana*. Single locality records denoted by closed circles and species by numbers as follows: 1, *B. geracei*; 2, *B. cardiopus*; 3, *B. mayana*.

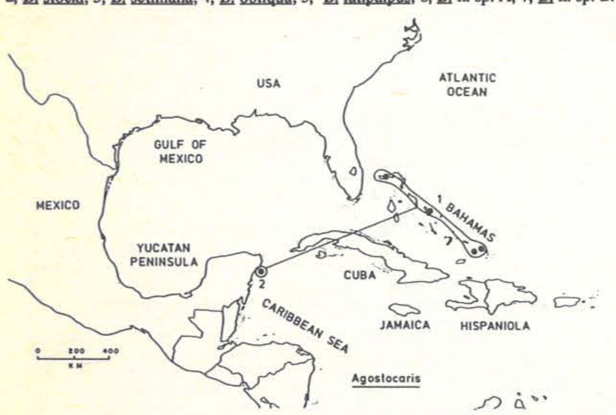

Figure 5.--Distribution track of the decapod shrimp genus *Agostocaris*. Single locality records denoted by closed circles and species by numbers as follows: 1, *A. williamsi*; 2, *A. bozanici*.

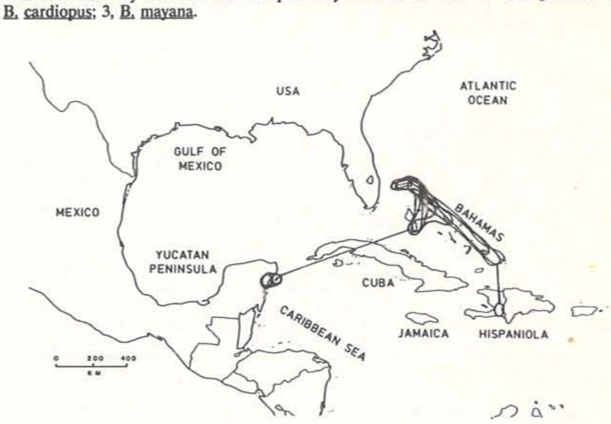

Figure 6.--Generalized track and summary of the distributions of five genera of subterranean crustaceans discussed in this paper.

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BIOLOGY AND WATER QUALITY OF CAVES RECEIVING URBAN RUNOFF IN COOKVILLE, TENNESSEE, USA

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ABSTRACT

Hydrologic physiochemical data were collected and benthic macroinvertebrate communities were sampled from three caves in Cookeville, Tennessee, USA. Capshaw and Ament caves are hydrologically connected and exhibited the greatest physiochemical variability. City Spring Cave was less contaminated and had the highest Shannon diversity index (0.49) for benthic macroinvertebrates followed by Capshaw Cave (0.32) and Ament Cave (0.25). A difference ($p<0.05$) among all three communities was found to exist. A relationship between declining water quality and reduced biotic diversity is suggested. Conduit systems receiving urban runoff and sewage have a lower diversity than cave waters recharged diffusely in agricultural settings.

RESUMEN

Data fisicoquimica hidrológica fue acumulado y comunidades de macroinvertebrados bénticos fueron muestreados en tres cuevas en Cookeville, TN EE.UU. Las cuevas Capshaw y Ament son hidrólogicamente conectados y sin embargo demostraron la variación fisicoquimica más grande. La cueva City Spring estaba menos contaminado y tenía el más elevado (0.49) índice de diversidad Shannon de macroinvertebrados bénticos. Los índices de Capshaw y Ament son 0.32 y 0.25 respectivamente. Se distinquió una diferencia ($p<0.05$) entre las tres comunidades. Se sugiere que existe una relación entre la declinante calidad de aqua y la reducción en diversidad biótica. Sistemas de cavernas que reciben desaqüe urbano y aquas negras tienen una diversidad menor que aguas de cuevas recargadas en forma difusa en areas agrícolas.

INTRODUCTION

During recent years there has been increasing concern for protecting the quality of karst ground water systems. Attitudes concerning disposal of solid and liquid wastes in karst environments have changed with the realization of the dynamic relationship between surface water and subsurface cave and spring systems. In the southeastern United States, major karst regions are associated with Mississippian limestones of the Interior Low Plateaus and faulted and folded limestones in the Appalachian Valley and Ridge Province. As municipalities located in these regions grow, new and innovative actions will be necessary to avoid contamination of ground water systems.

Many areas have already experienced the results of inadequate disposal facilities, especially with sewage. In Cookeville, Tennessee, much of the surface water runoff enters sinkholes and flows through a series of fractures and cave passages before emerging as springs. Physiochemical degradation of this subterranean system by improperly treated municipal waste and urban development was previously documented by Smithson (1975), Faulkerson et al. (1981), and Wilson (1985). Prior to this study, no quantitative assesment of the cave fauna in Cookeville had been performed. As Cookeville continues to grow with both urban and industrial development, the quality of water entering these caves will continue to have a profound impact on their biological community structure and associated spring water quality.

The specific objectives of this study were to:

1. Determine the effects of urban water runoff in Cookeville on cave and spring water quality.
2. Conduct a benthic macroinvertebrate survey of selected caves in and around Cookeville.
3. Determine the relationship between water chemistry and cave stream benthic community structure.

LOCATION AND GEOLOGY

Cookeville, Tennessee, USA, is located on the eastern Highland Rim of the Cumberland Plateau (Figure 1). Streams originating on the plateau to the east of town flow over shales and sandstones until underlying Mississippian-aged limestone beds are intersected. Some streams sink when they reach the Bangor Limestone while others sink into the lower Monteagle, St. Louis, or Warsaw limestones. Subterranean water moves through caves, pits, and solution enlarged fractures until emerging as spring flow. Deep, pit-type vertical caves form in the Bangor and Monteagle limestones, whereas long, horizontal caves usually occur in the St. Louis and Warsaw limestones. The underlying Fort Payne Formation, a dense silica-rich limestone, acts as an aquaclude and is not conducive to cave development. Stream sinkpoints are either open cave entrances which can be explored or sediment-filled sinkholes and fractures along stream bottoms. Descriptions of the caves were made by Barr (1961), Matthews (1971), Faulkerson et al. (1981), and the Tennessee Cave Survey. To date, approximately 11 kilometers of cave passage have been surveyed within the city limits of Cookeville. Most of these caves occur in the Warsaw Limestone and all are hydrologically active.

Benthic macroinvertebrate samples were collected from City Spring, Capshaw, and Ament caves and water samples were collected from their respective resurgences. City Spring Cave is located approximately 300 meters north of the former Cookeville filtration plant on City Lake. The associated spring was used as a water supply for the City of Cookeville during the 1920's. Surveyed length of the cave is 629 meters, the first half consisting of stoop-size passage. The remaining passage is walking size and terminates in a large breakdown fill. A small stream flows the entire length of the cave.

Capshaw Cave was described by Faulkerson et al. (1981). The cave is over 6 kilometers long, much of which is walking size passage. The cave is hydrologically related to several sinking sreams and sinkholes on the surface.

As shown in Figure 2, the water from Capshaw Cave resurfaces at the Canal, a karst window, flows approximately 300 meters, and sinks into Ament Cave at a sump. The cave is developed into two sections; a large, lower stream passage, and a dry, upper level maze. The surveyed length of the stream passage is 792 meters from the upstream sump to the resurgence at the head of Pigeon Roost Creek. This passage averages 8 meters wide and contains long pools separated by riffles. Flotation devices or swimming are necessary to explore this section of the cave. The upper level is easily traversable and heavily visited.

In July 1980, Katman and Brinkhurst (1984) gathered qualitative collections of benthic invertebrates from Ament Cave and seven other southeastern U.S. caves.

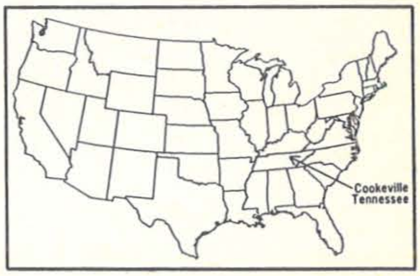

Figure 1. Geographic location of Cookeville, Tennessee, USA

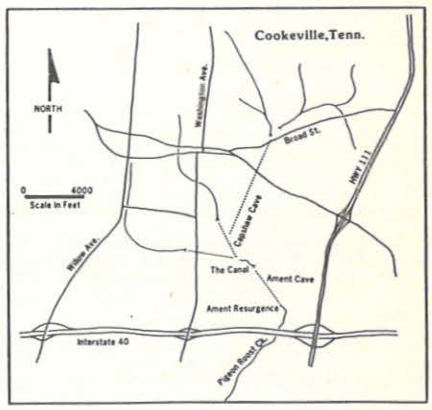

Figure 2. Locations and hydrologic relationship of the Capshaw and Ament Cave systems, in Cookeville, Tennessee, USA. Dotted lines indicate straight-line subterranean flow paths.

In Ament Cave they reported finding one species of oligochaete (Limnodrilus hoffmeisteri), one species of chironomid (Cricotopus bicinctus), and one genus of amphipod (Stygobromus sp.)

Ament Cave is a summer roosting site for a bachelor colony of gray bats (Myotis grisescens), both a state and federally listed endangered species. Harvey and Pride (1986) reported an estimated 4700 bats in the cave in August 1986. The bats were not counted during the study period to avoid disturbing them. Recognition as an endangered species specifically prohibits the disturbance of the bats in this cave during the summer roosting season (1 April through 1 October).

METHODS AND MATERIALS

Water samples were collected from the Canal, Ament Resurgence, and City Spring. Most sites were sampled every two weeks from May 1987 through April 1988, although measurement of some parameters did not begin until June 1987. A more comprehensive characterization of Cookeville's sinking streams and spring water quality is given by Pride et al. (1988).

Table 1

Means and Ranges of Selected Physiochemical Data from the Canal, the Ament Resurgence, and City Spring, Putnam County, Tennessee March 1987 - May 1988

Parameter	Units	$\bar{X}$	Min - Max	Median
		Canal		
Temperature	C°	14.0	9.4 - 19.4	12.9
Dissolved Oxygen	mg/l	7.9	5.2 - 10.6	7.6
Conductivity	umhos/cm	324	211 - 416	317
Turbidity	N.T.U.	13.2	1.9 - 54.0	6.0
Nitrate	mg/l	0.7	0.05 - 1.3	0.8
Chloride	mg/l	10.4	4.9 - 18.6	9.0
Sulphate	mg/l	16.3	9.5 - 23.9	15.9
O-Phosphate	ug/l	39.4	20.3 - 67.7	37.4
Alkalinity	mg/l	129	98 - 167	121
Hardness	mg/l	130	59 - 170	133
Total Organic Carbon	mg/l	5.7	0.5 - 10.0	5.0
Fecal Coliform	#colonies/100ml	2579	88 - 10000	490
Fecal Streptococcus	#colonies/100ml	930	30 - 2500	485
		Ament Resurgence		
Temperature	C°	14.7	9.7 - 20.8	13.6
Dissolved Oxygen	mg/l	7.5	4.0 - 10.0	7.4
Conductivity	umhos/cm	343	232 - 404	351
Turbidity	N.T.U.	14.8	3.3 - 67.0	7.2
Nitrate	mg/l	0.8	0.05 - 1.4	0.8
Chloride	mg/l	12.3	6.1 - 18.6	12.1
Sulphate	mg/l	13.9	9.4 - 19.1	13.3
O-Phosphate	ug/l	55.5	24.9 - 107.1	35.6
Alkalinity	mg/l	137	92 - 172	144
Hardness	mg/l	150	101 - 193	152
Total Organic Carbon	mg/l	4.9	2.1 - 9.1	5.1
Fecal Coliform	#colonies/100ml	2135	10 - 10000	440
Fecal Streptococcus	#colonies/100ml	1518	10 - 14000	770
		City Spring		
Temperature	C°	14.2	13.0 - 15.0	14.3
Dissolved Oxygen	mg/l	8.9	7.7 - 11.0	9.0
Conductivity	umhos/cm	364	274 - 435	374
Turbidity	N.T.U.	2.2	0.5 - 10.4	1.4
Nitrate	mg/l	3.1	0.18 - 4.1	3.5
Chloride	mg/l	11.7	8.4 - 16.7	11.6
Sulphate	mg/l	9.1	5.2 - 32.4	6.6
O-Phosphate	ug/l	56.6	30.7 - 98.2	53.5
Alkalinity	mg/l	155	107 - 191	162
Hardness	mg/l	167	90 - 202	173
Total Organic Carbon	mg/l	3.0	0.3 - 10.0	1.8
Fecal Coliform	# colonies/100ml	222	0 - 1000	130
Fecal Streptococcus	#colonies/100ml	626	0 - 4000	235

Riffle areas in all three caves were randomly sampled from October 1987 to March 1988. Samples were collected with a modified version of a Surber sampler (0.09 m^2) and transported to the laboratory for processing. All organisms were preserved in a 70% EtOH solution, enumerated, and identified to the lowest taxonomic level possible.

RESULTS

In order to compare water quality data an analysis of variance and the Tukey test were performed with parameter means from City Spring, Ament Resurgence, and the Canal (Tables 1 and 2). Means of dissolved oxygen, turbidity, sulphate, total organic carbon, fecal coliform, and fecal streptococcus at City Spring were slightly better, qualitativelty speaking, than means at the Canal and Ament Resurgence. However, dissolved oxygen, sulphate, and fecal coliform were significantly better at City Spring when compared to the Canal. When comparing City Spring and Ament Resurgence, dissolved oxygen and nitrates were the only parameters with a significant difference; both were higher at City Spring. Although water quality appeared to decline based on some parameters (dissolved oxygen, turbidity, chloride, sulphate, ortho-phosphate, and fecal streptococcus) between the Canal and Ament Resurgence, no significant differences were seen.

Both Capshaw and Ament Caves have historically received large amounts of pollution, mostly in the form of raw or improperly treated sewage from an antiquated watewater treatment plant and receiving lines (Dailey, 1975; Faulkerson et al., 1981). In January of 1985, a new treatment plant located downstream of all the study sites began receiving Cookeville's wastewater. The Capshaw/Ament system has since recovered somewhat although occasional discharges of raw sewage in the system resulted in Ament Resurgence having the lowest dissolved oxygen readings compared to all other sites.

Table 3 lists the benthic macroinvertebrates found in City Spring, Capshaw, and Ament caves from October 1987 to March 1988. A surprisingly large number of epigean forms were found in all three caves. The only troglobitic organisms found were <u>Asellus</u> sp. (Isopoda) and crayfishes (<u>Orconectes</u> sp.) from City Spring and Capshaw caves. It is possible the single <u>Gammarus</u> sp. (Amphipoda) taken from City Spring Cave is a troglobite, however, damage to the organism's head made further identification impossible. Non-pigmented crayfish were observed in Ament Cave but no individuals were taken with the Surber.

Besides the benthos, organisms observed in City Spring Cave included cave salamanders (<u>Eurycea lucifuga</u>), southern cavefish (<u>Typhlichthys subterraneus</u>), cave crickets (<u>Ceuthophilus gracilipes</u> and <u>Hadenoecus subterraneus</u>), and an unidentified species of beetle. Unidentified millipedes, spiders, and beetles were observed in both Capshaw and Ament caves. In Capshaw Cave, stonerollers (<u>Campostoma anomalum</u>) were often seen in the murky water and an unidentified species of catfish was seen on one occaision.

Pooled Shannon diversity indices were computed for each cave for the entire sampling period and are shown in Table 4 along with the percentage of occurence of each taxon. Many organisms could not be identified to species level; therefore, to remain consistent, order was used as the lowest level of taxa in all computations. Capshaw and Ament caves were dominated by oligochaetes and dipterans; the remaining organisms made up less than 6.0% of the individuals in Capshaw Cave and less than 1.5% of the individuals in Ament Cave. It is interesting to note that none of the oligochaetes or chironomids found during this study were the same as Katman and Brinkhurst (1984) found in 1980. City Spring Cave contained the largest number of taxa of the three caves with isopods making up the largest percentage (67.9) of organisms.

Capshaw and Ament caves had diversity indices of approximately 0.32 and 0.25, respectively. City Spring Cave was somewhat higher at 0.49. Using Hagg's (1987) method for multiple comparisons of diversity indices, a difference ($p < 0.05$) among all three communities was found to exist.

CONCLUSIONS

Although a statistical difference existed between diversities of Capshaw and Ament caves, percentage of occurence of the dominant groups (oligochaetes and dipterans) were very similar. High abundance of Oligochaeta and dipteran larvae are commonly used as an indicator of organic pollution in surface streams.

Table 2

Results of Pair-wise Comparisons (ANOVA) of Physiochemical Data from City Spring, the Ament Resurgence, and the Canal at Alpha = 0.10 and Alpha = 0.05

Parameter	City Spring and Canal	City Spring and Ament Res.	Canal and Ament Res.
Temperature	*	*	*
Dissolved Oxygen	0.10	0.05	*
Conductivity	*	*	*
Turbidity	*	*	*
Nitrate	0.05	0.05	*
Chloride	*	*	*
Sulphate	0.05	*	*
O-Phosphate	*	*	*
Alkalinity	0.10	*	*
Hardness	0.05	*	*
Total Organic Carbon	*	*	*
Fecal Coliform	0.10	*	*
F. Streptococcus	*	*	*

* = no difference at Alpha - 0.10

When viewed with the existing water quality data,this relationship is highly suggested for Capshaw and Ament caves. City Spring Cave had both better water quality for some parameters and the highest diversity of benthos. In addition, common indicator organisms for high levels of organic pollution were present only in low numbers. It would therefore appear that water quality had a positive influence on biological diversity in City Spring Cave.

Although City Spring Cave had better water quality, evidence suggests it is receiving low levels of human and/or animal wastes. Relatively high nitrate, chloride, and ortho-phosphate values could be associated with overlying septic fields and pasture land. Holsinger (1966) found an increase in relative abundance of troglobitic isopods in an Appalachian cave stream when exposed to low levels of human wastes from septic tanks. The abundance of isopods in City Spring Cave may, therefore, be explained by low levels of organic pollution.

Another hypothesis lends support to the one presented above. As in most karst areas, Cookeville is located in a region geomorphologically characterized by sinkholes, caves, and springs. Most of these subterranean systems appear to be open having a direct hydrologic connection to the surface via sinking streams. Other systems may be diffuse where the recharge component filters through the soil and minute cracks in the overlying bedrock. In reality, most systems are a combination of both, the terms open or diffuse being applied according to which ever contributes the most recharge to the system.

Table 3

Checklist of Benthic Macroinvertebrate Organisms Found in City Spring, Capshaw Cave, and Ament Cave, Putnam County, Tennessee October 1987 - March 1988

Organisms	City Spring	Caves: Capshaw	Caves: Ament
Amphipoda			
Gammaridae			
Gammarus sp.	X		
Coleoptera			
Elmidae			
Optioservus sp.		X	
Oulimnius latiusculus	X		
Stenelmis cf. humerosa		X	
Copepoda			
Attheyella cf. illinoisensis		X	
Macrocyclops albidus			X
Decapoda			
Astacidae			
Orconectes sp. (immature)	X	X	
Diptera			
Chironomidae (unknown pupae)		X	
Conchapelopia sp.			X
Cricotopus tremulus sp. gp.	X	X	X
Glyptotendipes sp.			X
Parametriocnemus cf. *lunbecki*	X	X	X
Polypedilum sp. (pupae)		X	X
Polypedilum fallax		X	X
Polypedilum cf. halterale			X
Polypedilum illinoense		X	
Rheocricotopus robacki		X	
Tanytarsus sp.		X	
Tuetenia bavaris sp. gp.		X	
Simuliidae (pupae)		X	
Hydracarina			
Hydrachna sp.			X
Isopoda			
Asellidae			
Asellus sp.	X		
Oligochaeta			
Tubificidae			
Spirosperma nikolsky		X	X
Lumbriculidae		X	X
Lumbriculus sp.	X	X	
Odonata			
Coenagrioniidae			X
Plecoptera			
Leuctra sp.	X		
Trichoptera			
Hydropsychidae			
Diplectrona modesta	X		

With these definitions, Capshaw and Ament caves may be classified as open systems. Physiochemical data collected during this study suggests that City Spring Cave has a significant diffuse recharge component. Diffuse systems are able to filter out some contaminants from the water but is highly dependent on a wide range of geologic, hydrologic, and contaminant factors. Open systems, in contrast, may have very little buffering or filtering capacity. Degraded water entering Capshaw and Ament caves had little chance of recovery until emerging at Pigeon Roost Creek. Relatively high organic loading observed in stream samples consumed oxygen faster than it could be replaced by contact with cave air or generated in riffles. An open system, therefore, may contribute to water quality degradation. Of course, dilution with a less polluted stream may lessen the effects of degradation.

Classical diversity hypotheses often point to the temperate-tropical diversity increase (for terrestrial ecosystems) as evidence that more stable ecosystems support higher diversities. If this is true, it would not be unreasonable to expect cave systems with significant diffuse recharge to have greater diversities than open systems due to greater stability of water quality parameters. A study encompassing many more caves would be necessary to lend conclusive support to this idea.

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Table 4.

Frequency of Occurrence, Percentage of Organisms, and Shannon Diversity Indices of Benthic Cave Communities in Capshaw, Ament, and City Spring Caves, Putnam County, Tennessee October 1987 - March 1988

Capshaw Cave

Taxon	f_i	P_i
Oligochaeta	104	76.5
Diptera	24	17.6
Copepoda	5	3.7
Coleoptera	2	1.5
Decapoda	1	0.7

n = 136
H' = 0.3174

Ament Cave

Taxom	f_i	P_i
Oligochaeta	342	78.8
Diptera	87	20.0
Copepoda	2	0.5
Hydracarina	2	0.5
Odonata	1	0.2

n = 434
H' = 0.2491

City Spring Cave

Taxon	f_i	P_i
Isopoda	89	67.9
Oligochaeta	15	11.5
Trichoptera	12	9.2
Diptera	7	5.3
Coleoptera	4	3.1
Decapoda	2	1.5
Amphipoda	1	0.8
Plecoptera	1	0.8

n = 131
H' = 0.4912

f_i = frequency of occurrence

P_i = percentage of total organisms found

H' = Shannon diversity index

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L'OCCUPATION PALEOLITHIQUE DU KARST DE CHARENTE (FRANCE)

DEBENATH, André

Les phénomènes karstiques sont particulièrement bien développés en Charente dans la région de La Rochefoucauld où ils affectent les terrains du Jurassique supérieur. Le karst de La Rochefoucauld a joué un grand rôle dans la mise en place des dépôts quaternaires de la vallée de la Tardoire et du Bandiat ; les nombreux abris et les grottes qui lui sont liés ont constitué des lieux d'habitat privilégiés pour les hommes du Paléolithique. Les phénomènes karstiques de la région Montbron-Marthon-La Rochefoucauld sont déterminés par la tectonique complexe qui a affecté la bordure ouest du Limousin. Ils influencent fortement l'hydrographie de cette région : les pertes des rivières sont nombreuses et se font par des entonnoirs qui atteignent 10 mètres de diamètres et 3 ou 4 de profondeur. Il existe de multiples réseaux fossiles très développés, peu praticables. Une partie des eaux ainsi perdues est récupérée par la Touvre dont les résurgences sont les plus importantes en France après la Fontaine de Vaucluse.

Dans les environs de Cognac et de Saintes, les terrains du Crétacé supérieur sont moins atteints par la karstification, les réseaux sont peu développés, peu profonds, tantôt semi-actifs, tantôt fossiles.

C'est dans ce cadre qu'ont vécu les hommes du Paléolithique. La région de la Rochefoucauld présente de nombreuses grottes souvent profondes : La Chaise, Montgaudier, Fontéchevade, dans lesquelles les hommes se sont succédés depuis la glaciation rissienne jusqu'à la fin du Würm. D'autres n'ont connu d' occupation que pendant le Würm : Würm ancien uniquement à Marillac et à La Cave, Wüm ancien et récent au Placard et dans les grottes et abris du Bois-du-Roc. L'une des cavités qui atteint le plus grand développement la grotte de Rancogne n'a été habitée que pendant le Post-glaciaire.

Le karst crétacé présente des abris largement ouverts mais peu profonds dans lesquels ne se rencontrent pas de traces de présence humaine antérieure au Würm ancien : grottes de la vallée du Bruant (La Vauzelle, La Rochecourbon, La Fléterie), grottes de la vallée de l'Antenne près de Cognac, dont la plus importante sur le plan de la Préhistoire, la grotte Marcel Clouet est l'une des rares dans cette région à avoir livré du Moustérien de tradition acheuléenne.

Plusieurs abris des environs d'Angoulême ont livré soit des vestiges moustériens (vallée des Eaux-Claires), soit magdaléniens (abri de la Chaire-à-Calvin dans la vallée de la Boëme).

HUMAN PALEOLITHIC OCCUPATION OF THE KARST OF CHARENTE (FRANCE)

Karstic phenomena are important in the area of La Rochefoucauld (Basin of the Charente River) and affect the Upper Jurassic limestones. The karst of La Rochefoucauld has taken a prominent part in the deposition of the quaternary sediments of the valley of Tardoire and Bandiat rivers. The numerous caves and rock shelters which are opened in the karst have been inhabited by the paleolithic peoples. These karstic phenomena of the area Montbron-Marthon-La Rochefoucauld are for a part the result of the complex tectonic of the Ouest part of the Limousin. They have an influence on the hydrography. The rivers disapear in large and deep holes. We can see many fossil network, difficult to enter.

The karstification is less important in the Upper Cretaceous close by Cognac and Saintes and the caves are smaller, not so deep.

In this surrounding lived paleolithic men. The area of La Rochefoucauld shows many deep caves : La Chaise, Montgaudier and Fontéchevade have been inhabited since the rissian glaciation to the end of the glacial epoch. Some others were used only during the wurmien glaciation : Old Würm at Marillac and La Cave, Old and Early Würm at the Placard Cave and the shelters of the Bois-du-Roc.

One of the largest caves : The Cave of Rancogne has been occupied only during the Post glacial epoch.

The shelters which are opened in the cretaceous karst are large but not deep and human impressions are not older than the Old Würm : caves of the valley of the Bruant (La Vauzelle, La Fléterie, La Roche-Courbon) and of the Antenne. Among them, the Clouet Cave is one the few which has given Acheulian type Mousterian.

Several caves and shelters close to Angoulême contain either mousterian remains (valley of the Eaux-Claires) or magdalenian remains (Chaire -à-Cavin shelter in the Boëme valley).

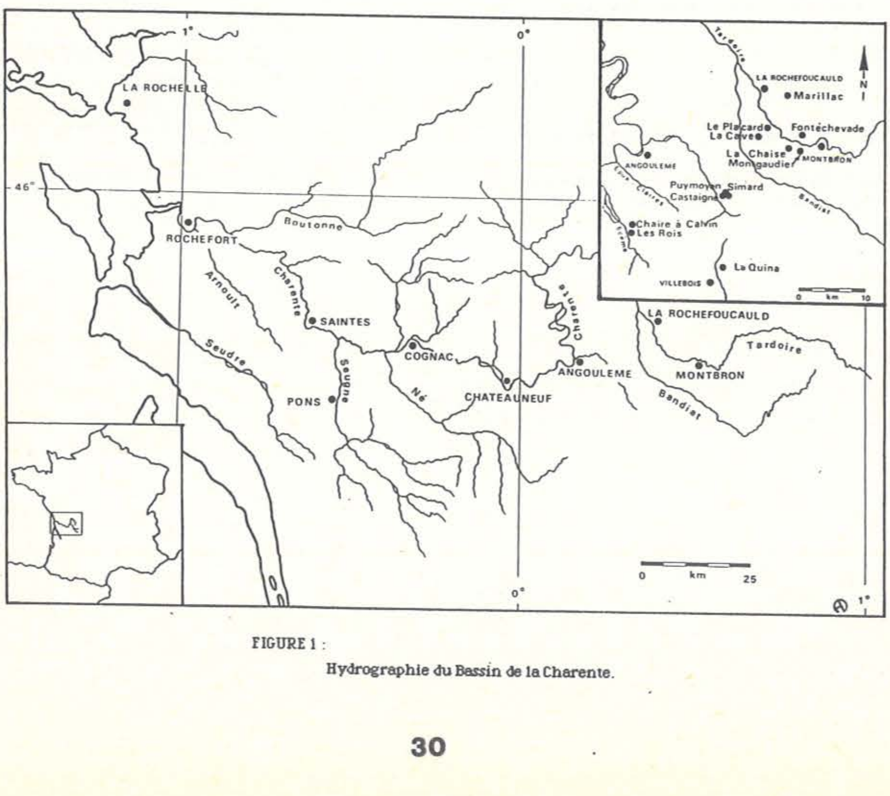

FIGURE 1 :

Hydrographie du Bassin de la Charente.

Dans son cours moyen et inférieur, la Charente coule dans des terrains qui appartiennent essentiellement au Crétacé et au Jurassique (figures 1 et 2). Alors que le Crétacé supérieur présente peu de phénomènes karstiques, le Jurassique se caractérise par un karst bien développé, principalement dans la région de La Rochefoucauld, où il a joué un grand rôle dans la mise en place des dépôts quaternaires des vallées de la Tardoire et du Bandiat. Les grottes et abris creusés dans ce karst ont constitué des lieux d'habitat privilégiés pour les hommes du Paléolithique, voire de l'Holocène. Les phénomènes karstiques de la région Montbron-Marthon-La Rochefoucauld sont déterminés par la tectonique complexe qui a affecté la bordure ouest du Limousin : entre le Plateau limousin à l'Est et le rebord de la côte turonienne au Sud-Ouest, les terrains jurassiques présentent deux surfaces déprimées : une dépression jouxtant le Massif central et un fossé étroit à l'emplacement de la Touvre. Entre elles, existe un secteur soulevé, correspondant sensiblement à la forêt de la Braconne. Selon H. Enjalbert (1947), "la plateforme jurassique a été disloquée et déformée par les accidents tectoniques qui forment un réseau articulé autour de l'extrémité ouest du Massif central".

Ce système karstique influe fortement sur le réseau hydrographique : les pertes des rivières sont nombreuses, principalement celles de la Tardoire et du Bandiat. Ces deux rivières ne confluant qu'exceptionnellement. Le Bas Bandiat est particulièrement caractéristique de ce que sont les pertes des rivières dans ce karst. Sur une vingtaine de kilomètres, de nombreux entonnoirs atteignant 10 m de diamètre et trois de profondeur jalonnent son cours, mais ces entonnoirs ne donnent pas accès au réseau souterrain, alors qu'à partir de Bunzac, on note de nombreux gouffres (12 sur deux kilomètres) dans lesquels la rivière se perd, tel le gouffre de Chez-Roby, donnant accès au réseau souterrain. La vallée du Bandiat peut être assimilé à un polié complet (Enjalbert, op.cit.).

Une importante partie des eaux ainsi perdues par ces rivières est en quelque sorte récupérées par les "sources de la Touvre", dont les résurgences sont les plus importantes en France après la Fontaine de Vaucluse.

1. LES GROTTES ET ABRIS DU BASSIN DE LA CHARENTE.

Les grottes et abris sont nombreux dans le Bassin de la Charente et sont souvent caractérisés par une intense occupation humaine préhistorique. L'opposition entre le domaine crétacé et le domaine jurassique se traduit par une différence sensible de la morphologie des cavités. Dans les terrains jurassiques, le type dominant est la grotte, alors que les terrains crétacés offrent des abris plus ou moins vastes.

Nous différencions les grottes des abris par le fait que ces derniers dépendent entièrement du milieu extérieur, alors que les grottes participent peu à ce milieu : leur participation se fait avec un décalage dans le temps par rapport à l'abri et avec une intensité moindre. Un second critère de différenciation nous apparait important, il s'agit du critère sédimentologique : les sédiments qui constituent le remplissage des abris proviennent essentiellement de la dégradation des parois et du plafond, alors que dans les grottes, le mode de remplissage est différent et ne fait pratiquement pas appel au thermoclastisme.

Les réseaux charentais de grottes s'enfoncent le plus souvent verticalement et les galeries atteignent un grand développement. Cet enfoncement vertical est bien caractérisé dans les environs de La Rochefoucauld (Fosse-Mobile, Gouffre de Chez-Rabaud, etc...). Presque toutes les grottes charentaises sont fossiles. La plupart d'entre elles se sont ouvertes sur l'extérieur par suite de l'évolution des versants qui les a recoupées (Fontéchevade, La Chaise, Rancogne), plus rarement par suite de l'effondrement du plafond entrainant la formation d'un aven dans lequel débouchent les galeries de l'ancienne grotte (Marillac).

Les abris s'ouvrent, à l'origine, à la limite de deux horizons pétrographiques différents dont l'un est plus gélif. Il se présente tout d'abord comme une sorte de moulure qui se creusera au fur et à mesure, donnant naissance à une cavité plus ou moins vaste dont la profondeur est en partie liée à l'épaisseur du plafond (figure 3).

Des exemples typiques de formation et d'évolution des abris se rencontrent dans la vallée des Eaux-Claires, non loin de Puymoyen. Cette vallée est ouverte dans les calcaires turoniens à *Radiolites lumbricalis* qui forment la pierre d'Angoulême (Coquand 1860). A la base de la falaise, s'observe un talus qui descend en pente douce vers la rivière et qui est constitué soit par des éboulis, soit par un niveau de calcaires se débitant en plaquettes. Les abris s'ouvrent à la limite de la falaise proprement dite et du talus dans une zone riche en végétation caractérisée par de nombreuses exudations d'eau où se creusera la moulure puis l'abri véritable. Il ne faut cependant négliger ni le rôle de la cryoclase, ni celui de l'érosion fluviatile dans la formation des abris. Le rôle de la gélivation s'exerçe principalement dans les zones de contact des bancs calcaires de natures différentes, les bancs marneux, plus gélifs s'excavant plus rapidement que les bancs compacts. L'érosion fluviatile a certainement un rôle plus modeste dont nous trouvons cependant des manifestations dans la vallée du Voultron, du Bruant ou de l'Antenne. Dans cette dernière vallée, le rôle de l'érosion fluviatile est indéniable (Debénath 1974).

De par la diversité morphologique de ses cavités et sa densité d'occupation humaine paléolithique, c'est plus particulièrement au karst de La Rochefoucauld (figure 4) que nous nous intéresserons ici et aux plus anciens témoignages de cette présence humaine.

2. L'OCCUPATION PALEOLITHIQUE DES GROTTES ET ABRIS DU KARST DE LA ROCHEFOUCAULD.

1. L'OCCCUPATION DES GROTTES ET ABRIS AVANT LA GLACIATION WURMIENNE .

Seules les grottes d' Artenac, La Chaise, Fontéchevade, et à degré moindre Montgaudier attestent de l'occupation antewürmienne du territoire charentais par les paléolithiques.

De Montgaudier, nous connaissons quelques artefacts accompagnés d'une faune probablement anterissienne (renseignement oral J.F. Tournepiche).

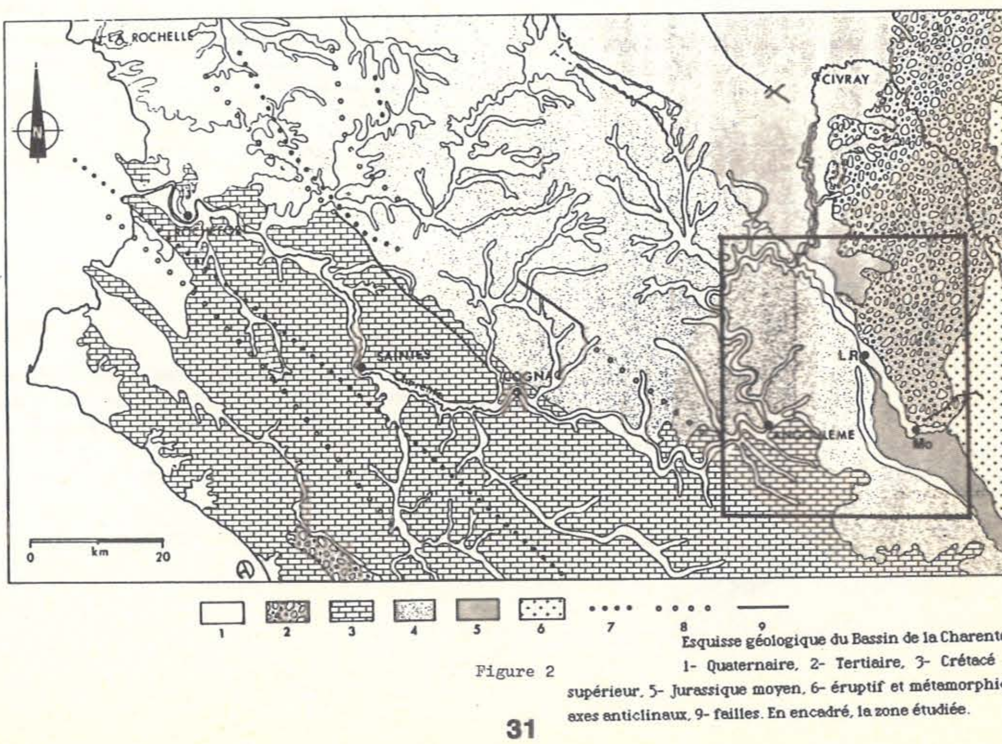

Figure 2

Esquisse géologique du Bassin de la Charente :

1- Quaternaire, 2- Tertiaire, 3- Crétacé supérieur, 4- Jurassique supérieur, 5- Jurassique moyen, 6- éruptif et métamorphique, 7- axes synclinaux, 8- axes anticlinaux, 9- failles. En encadré, la zone étudiée.

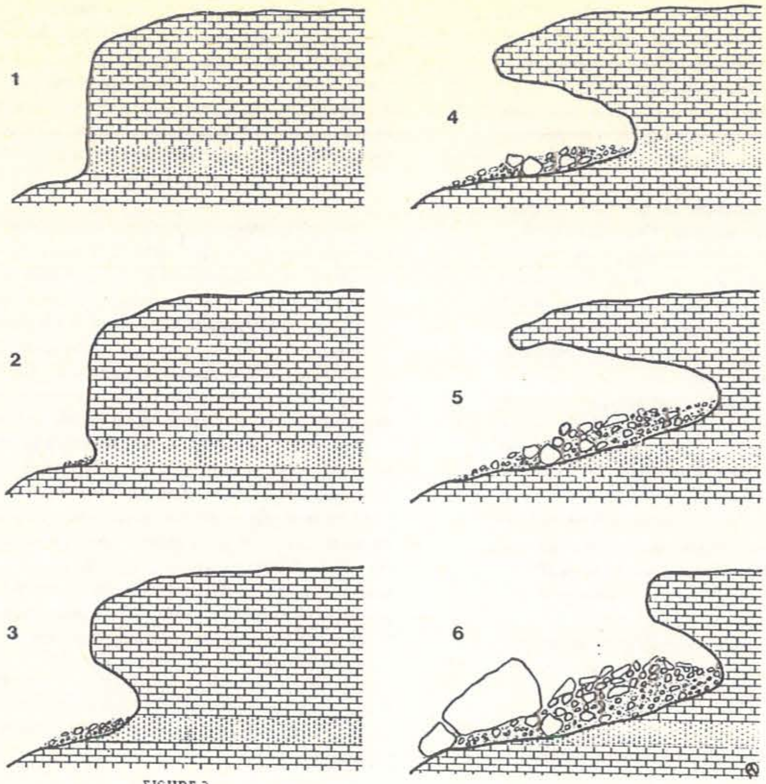

FIGURE 3.
Formation des abris:
1- falaise avant son évolution, 2- formation de la moulure, 3- évolution de l'abri jusqu'à l'effondrement du toit.

1.2. LA CHAISE -DE-VOUTHON

1.2.1. Les grottes :

De Montbron à Angoulême, la plateforme calcaire est caractérisée par une intense érosion souterraine et une couverture sableuse importante. C'est dans ce paysage que s'ouvrent les grottes de La Chaise, à hauteur du village de même nom. La rive gauche de la Tardoire est alors dominée par un puissant placage alluvial composé de sables et de galets de roches cristallines attribués au Quaternaire (Guillien et Vatan 1947) d'où émerge un hum bajocien tranché en falaise dans lequel on peut distinguer deux horizons : un horizon supérieur cristallin, saccharoïde, compact, très résistant, et un horizon inférieur plus gélif et plus détritique. A la limite de ces deux horizons, s'ouvre une série d'abris sous roches dominant le cours de la Tardoire d'une dizaine de mètres. Dans ces abris dont l'ouverture est orientée vers le Nord-Ouest, débouchent de nombreux conduits karstiques qui constituent les grottes de La Chaise (figure 5). Nous ne retiendrons ici que deux d'entre elles : les grottes Bourgeois-Delaunay et Suard dont les premières explorations remontent au milieu du XIX° siècle (Bourgeois et Delaunay, 1865). Elles ont fait par la suite l'objet de nombreuses fouilles plus ou moins systématiques dont celles de P. David et les notres.

1.1. ARTENAC.

Le gisement d'Artenac a été signalé pour la première fois en 1959 à la suite de la découverte d'une grotte sépulcrale qui donna son nom à une civilisation du chalcolithique : la civilisation d'Artenac.

Il n'en subsiste actuellement que le fond, tranché par l'exploitation des calcaires oxfordiens dans lesquels était creusé la grotte. Un gisement paléolithique y fut signalé en 1972 par J.F. Tournepiche. Des fouilles exécutées par B. Vandermeersch en 1974 provient un riche moustérien de type Ferrassie (Meignen et alii 1977).

J.F.Tournepiche (1983) distingue une séquence supérieure datée du Würm ancien, qui a livré le Moustérien et une séquence inférieure épaisse d'environ 10 m.

Un biface, un éclat et un racloir ont été trouvés dans la couche V de la séquence inférieure, associés à un machairodonte (*Dinoblastis latidens*), *Canis lunellensis*, *Ursus Deningeri* , *Equus mosbachensis* , ainsi qu'un canidé de grande taille. Ces éléments donnent à penser à J.F. Tournepiche que la couche V peut dater de la fin du Mindel ou au plus du Mindel-Riss.

La brèche de la couche II a été datée comme plus ancienne que 300 000 par U/Th (H. Schwarcz, *in litteris*).

Figure 4.

FIGURE 4 :
Le karst de La Rochefoucauld (d'après Enjalbert, modifié) :
1- horst de l'Arbre, B- dépression tectonique de La Rochefoucauld-Chasseneuil, C- synclinal de Puy-Bou, D- fossé du Bandiat, E- fossé de la Touvre, X- limite occidentale des terrains anciens, Ag- Agris, Ar- Artenac, LR- La Rochefoucauld, M- Merton, Ma- Mansle, Mo- Montbron, ST- sources de la Touvre.

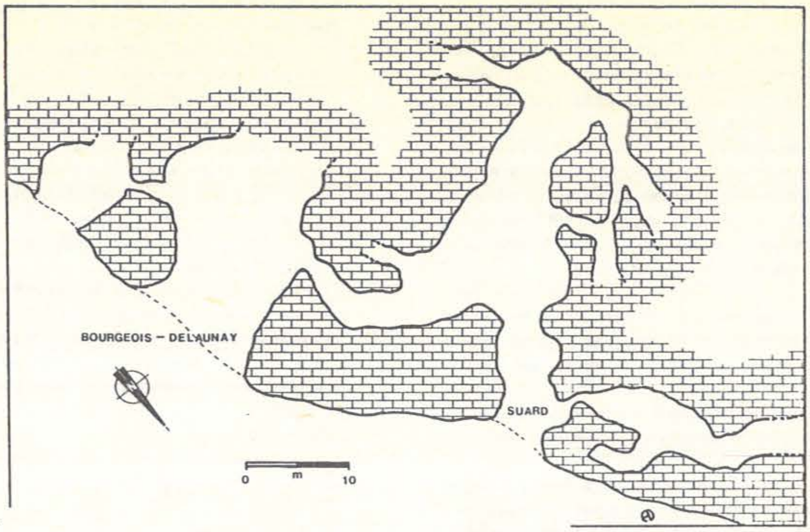

FIGURE 5 :
Plan des grottes de La Chaise, montrant le débouché des galeries karstiques dans les abris Bourgeois-Delaunay et Suard.

Ces grottes sont constituées de plusieurs galeries de sections irrégulières, dont le développement connu est de plusieurs dizaines de mètres et qui s'ouvrent sur l'extérieur par deux porches qui sont les abris Bourgeois-Delaunay et Suard. Le premier est large d'une douzaine de mètres à son entrée et profond, dans la zone fouillée d'environ 25 m. Il s'élargit vers le fond et semble se continuer sur au moins une vingtaine de mètres. Son plafond est sub-horizontal et ne présente pas de concrétionnement important. Il communique avec l'abri Suard par un couloir qui était comblé par des sédiments scellés par un plancher stalagmitique avant le début des fouilles David.

Toutes les galeries qui débouchent dans ces abris sont colmatées par des sédiments qui étaient eux aussi scellés par des planchers stalagmitiques qui sont conservés dans les parties profondes où ils n'ont pas été affectés par les fouilles anciennes. Ces galeries présentent de nombreuses concrétions stalagmitiques : stalagtites généralement tubulaires, stalagmites en cierges et colonnes. Il existe également en quelques points de la grotte Suard des coulées et, dans les parties profondes, des exentriques de petite taille, en harpons ou en ergots, de dimensions centimétriques. Les concrétions en chou-fleur sont rares et très petites. Nous n'avons jamais remarqué de perles des cavernes ni autres formes qui sont connues dans d'autres grottes du karst de la Rochefoucauld dans lesquelles les phénomènes de cristallisation sont plus développés.

Il existe un réseau inférieur, actuellement fonctionnel, totalement immergé et non pénétrable dont seule une cheminée d'équilibre est visible. Cette cheminée semble être en relation avec un ruisseau à éclipse, la Toulange, en relation avec la Tardoire.

Lors des premières fouilles, l'abri Bourgeois-Delaunay était comblé jusqu'à environ 1 m du plafond. On peut donc en conclure que son remplissage était puissant d'une douzaine de mètres.

Ce remplissage est constitué à sa base d'une épaisse couche de sables et argiles (environ 8,5 m) dans lesquels se distinguent quelques petites passées de graviers. Nous avons attribué cette formation à une phase rissienne (probablement le Riss II) (Debénath 1974). Elle est surmontée d'un mince niveau de blocs calcaires recouverts par un important plancher stalagmitique polygénique (Debénath, Raynal et Schwarcz 1980) attribué à l'interglaciaire Riss-Würm. Des séries de datations obtenues par la méthode Uranium/Thorium (Schwarcz et Debénath 1979, Schwarcz, Blackwell et Debénath 1983) indiquent que ce plancher s'est formé essentiellement entre 150 et 112 000 ans.

Puis vient une série de niveau attribués au début du Würm ancien, scellés eux aussi par un plancher stalagmitique et enfin des formations mises en place à la fin du Würm ancien et au début du Würm récent.

Les dépôts du Würm ancien sont très argileux, ils correspondent parfois à des dépôts de décantation en milieu humide calme (mare). Au fur et à mesure, le sédiment s'enrichit d'éléments caillouteux, pour atteindre un maximun à la fin du Würm ancien.

Les sédiments du Würm ancien renferment de nombreuses cristallisations ferro-manganifères, soit dans le sédiment où elles forment des niveaux bien distincts (confondus anciennement avec des foyers), soit en encroûtements autour des cailloux calcaires qui sont très altérés et n'existent parfois que comme "fantômes" au sein de la concrétion, soit encore en recristallisation dans les ossements fossiles, principalement les dents.

Les sédiments de l'abri Suard sont dans leur ensemble rissiens. Le Riss II est représenté par des formations sablo-argileuses qui rappellent celles que nous avons décrites à la base de l'abri Bourgeois-Delaunay. Ces sédiments sont séparés des éboulis cryoclastiques constituant le Riss III par un plancher stalagmitique daté par U/Th de 185 000 ± 10 000. Ces éboulis ont été scellés par des formations stalagmitiques contemporaines de l'interglaciaire Riss-Würm et sont surmontés par des couches dont la mise en place est contemporaine du début du Würm ancien. Les éléments caillouteux ne présentent pratiquement aucune altération et nombre d'entre eux sont gélivés en place et secondairement recimentés par des formations calcitiques. Ces phénomènes de concrétionnement affectent souvent la face inférieure des cailloux et se présentent alors sous forme de petits choux-fleurs de taille millimétrique.

Toutes les galeries qui débouchent dans les abris Bourgeois-Delaunay et Suard renferment un remplissage argilo-sableux de moins en moins riche en éléments calcaires au fur et à mesure que l'on gagne les zones les plus éloignées de l'entrée. Les planchers stalagmitiques qui surmontentt ces formations ont un âge de l'ordre de 9 ± 2 ka.

Il est intéressant de noter que la formation actuelle de plancher stalagmitique se poursuit dans les zones fouillées par P. David au début des années 50 et se manifeste par des petites plaques de calcite n'excédant pas un décimètre de diamètre et quelques millimètres d'épaisseur, et ce dans des zones en relation climatique avec l'extérieur.

1.2.2. L'occupation humaine :

Elle se manifeste sous forme d'artefacts et structures liées à l'habitat, de restes humains et de restes fauniques, ces derniers n'étant pas étudiés ici.

1.2.2.1. Les industries :

L'impression dominante que donnent les industries de La Chaise est une impression d'homogénéité qui fait place lors d'un examen plus attentif à une impression d'originalité qui est plus tenace. Cette originalité est sans doute liée à une facture dans son ensemble assez mauvaise des outils sur éclats et des bifaces, mauvaise facture provenant davantage de la matière première que des techniques utilisées.

La matière première est variée : silex divers allochtones, silex local du Bathonien-Bajocien (souvent gélivé), roches métamorphiques et éruptives diverses. Une partie importante de l'industrie (environ 30 %) est composée de galets bruts ou testés, ou d'éclats de débitage de ces galets de roches anciennes, provenant du Massif Central et recoltés dans les dépôts de la Tardoire.

Sur le plan technologique, les industries des couches inférieures de l'abri Suard sont de débitage faiblement levallois, avec un indice levallois voisin de 20. On remarque que cet indice diminue ensuite régulièrement dans les couches de la fin du Riss de l'abri Suard et durant le Würm ancien (sommet de l'abri Suard et abri Bourgeois-Delaunay). Nous ne connaissons pas à La Chaise d'industrie pouvant être rapportée à l'interglaciaire Riss-Würm.

Le facettage est bien développé , tant dans les séries rissiennes que würmiennes, avec un indice de facettage large compris entre 50 et 60. Le facettage strict est plus variable : son indice est inférieur à 50 dans les niveaux inférieurs de l'abri Suard et pendant le Würm ancien, alors qu'il est supérieur à 50 dans les derniers niveaux rissiens de l'abri Suard.

Le débitage est dans son ensemble peu laminaire, excepté dans les derniers niveaux rissiens où l'indice laminaire est supérieur à 10.

La caractéristique technique la plus intéressante est sans aucun doute ce que nous avions appelé (Debénath 1974, 1983) la *technique de reprise du talon* qui se distingue aisément de la préparation du talon. Il s'agit de l'enlèvement plus ou moins complet du talon et du bulbe de percussion par de grandes retouches le plus souvent oblique par rapport à l'axe de la pièce. Ces enlèvements sont peu abruptes ou très plats et obtenus au percuteur mou. Dans certains cas, cette reprise du talon sert de plan de frappe pour des enlèvements qui affectent la face *dorsale* de la pièce. Dans le premier cas, nous parlons de reprise *simple* ou partielle, dans le second de reprise *totale* . A cette reprise du talon est parfois associée une retouche plus ou moins écailleuse de la partie distale de la pièce, passant ainsi au couteau de Kostienki.

Nous avons retrouvé cette technique employée quelque soit le type de talon de la pièce support, à l'exception des talons naturels et aussi bien sur des éclats que sur des outils de types variés : racloirs, denticulés, pointes moustériennes, pièces à retouche sur face plane, grattoirs, couteaux à dos et encoches. Dans les couches inférieures du Riss III, elle atteint respectivement 14 et 18 % de l'industrie.

Par ailleurs, il existe de nombreux racloirs réalisés sur le talon de l'éclat : talon lisse formant avec la face ventrale de l'éclat un angle très aigu. Ce type d'outil ne peut être confondu ni avec une forme particulière de préparation de nucleus, ni avec un ravivage de racloirs de type Quina (l'indice Quina est pratiquement nul ou très faible dans tous les niveaux, mais il existe quelques objets présentant une retouche Quina atypique), ni avec une forme d'exhaustion d'un autre type de racloir.

Sur le plan de la typologie, la première remarque qui s'impose est de constater le petit nombre des bifaces et la mauvaise facture de ces outils qui sont le plus généralement atypiques, partiels et comportent souvent un dos. De plus, ils sont presque toujours de petite taille.

Les racloirs constituent le groupe d'outils dominant, avec une forte proportion de racloirs simples convexes. Les proportions de denticulés varient à l'inverse de celles des racloirs.

L'originalité typologique des industries de la Chaise réside dans la présence d'outils peu fréquents en Europe occidentale pendant le Riss final et le Würm ancien : outils pédonculés, pièces foliacées bifaces, nombreux couteaux de Kostienki, parfois atypiques. Il existe également une pointe de Chatelperron et de nombreux outils composites qui ne peuvent entrer dans le système de classification utilisé, principalement les racloirs.

Nous avons été conduit, sur la base de critères technotypologiques à différencier trois faciès industriels à La Chaise qui ont été définis par ailleurs (Debénath 1974, 1983).

Nous constatons une évolution sur place de ces différents faciès, du Riss III au début du Würm ancien : diminution de l'emploi de la technique levallois, diminution de la reprise du talon, variations des rapports entre denticulés et autres types d'outils, principalement racloirs et outils de type Paléolithique supérieur qui sont parfois assez bien représentés, apparition d'outils peu fréquents pendant cette période. Ces industries rissiennes évoluent vers une industrie moustérienne, assez mal définie de la fin du Würm ancien de l'abri Bourgeois-Delaunay.

Nous sommes donc ici en présence d'une industrie qui peut difficilement être comparée aux Acheuléens "classiques" et dont le caractère dominant reste un caractère moustérien.

1.2.2.2. Les structures d'habitat :

Une structure d'habitat de signification énigmatique a été découverte dans l'abri Suard. Il s'agit d'une accumulation de bois de rennes, certains de grande taille (figure 6). Ces bois, autant que l'on puisse en juger, étaient des bois de massacre, 13 avaient conservé leur meule et 8 d'entre eux étaient orientés de façon telle que la meule était dirigée vers le fond de l'abri. Ils avaient été disposés sur le sol alors qu'ils étaient entiers et les fractures se sont produites secondairement, sous la pression exercée par les sédiments. Les différents éléments étaient encore en connexion. L'ensemble affectait une forme grossièrement en arc de cercle. La partie centrale de la structure se caractérisait par sa richesse en éléments lithiques : outils, éclats, galets entiers ou fragmentés, nuclei.

Un percuteur se trouvait en dehors de la structure. Un gros galet de granite, peu altéré, était disposé entre les bois. Aucune manifestation d'action humaine n'est visible, ni sur les bois, ni sur ce galet. S'agit-il d'une réserve de matière première ? Cela est peu probable, puisqu'aucun bois de renne de ce gisement ne présente de trace d'utilisation, bien que leur conservation soit fort bonne. S'agit-il d'une structure liée à l'habitat ou à une activité particulière : protection contre les animaux, support destiné par exemple à faire sécher des peaux ou à constituer une sorte d'abri (coupe-vent ?). La question n'a pu être résolue.

Les os cochés sont pratiquement inconnus dans les industries rissiennes. Plusieurs specimens ont été trouvés à La Chaise. L'un d'eux est un fragment médian de côte d'animal de grande taille non déterminable specifiquement (Bovidé ou Equidé) qui se trouvait contre un des bois de renne constituant la structure ci-dessus évoquée. La face interne de cette côte présente 12 incisions profondes, parfois sur toute la largeur de l'os. D'une profondeur de 2 mm, elles ont une section en V dissymétrique. La face externe de l'os présente 4 incisions plus courtes et moins profondes. Une cassure, probablement obtenue par flexion, passe par l'axe longitudinal de l'une de ces incisions. L'espacement des coches, la netteté de leurs bords et la présence de fines stries provenant du glissement de l'outil utilisé pour les tracer, nous prouve qu'il s'agit de manifestations volontaires de l'activité humaine.

Ces os cochés semblent être une des plus anciennes manifestations connues d'une certaine forme "d'art paléolithique".

1.2.2.3. Les restes humains :

Les restes humains de La Chaise constituent l'une des plus importantes séries connues en Europe pour le Riss et la plus importante pour l'interglaciaire Riss-Würm. Près de 80 restes déterminables ont été mis au jour, tant dans les formations rissiennes de l'abri Suard que dans l'interglaciaire Riss-Würm de l'abri Bourgeois-Delaunay (Debénath 1977).

Ils appartiennent pour la plupart au squelette céphalique : quatre mandibules entières ou partielles, trois calottes crâniennes, plusieurs os isolés (pariétaux, frontaux, occipitaux et temporaux), un fragment de maxillaire portant encore ses trois molaires, fragments crâniens divers et nombreuses dents isolées.

Les restes appartenant au squelette post céphalique sont moins nombreux : diaphyses de péroné, de tibia et de fémur, côtes, scapulum, phalanges.

Il s'agit donc là de documents exceptionnels, remarquablement intéressants pour la connaissance de l'évolution humaine en Europe et pour l'étude des "anténéandertaliens" au sens chronologique du terme. Tous appartiennent à des individus très jeunes.

Ces vestiges présentent des caractères qui traduisent tantôt un archaïsme certain et tantôt annoncent l'homme moderne : le temporal est assez proche de celui des néandertaliens par son épaisseur, la position du trou stylomastoïdien, etc... Le réseau méningé domine dans la région antérieure, ce qui évoque également les néandertaliens. L'occipital est par contre beaucoup plus proche de celui de l'homme moderne.

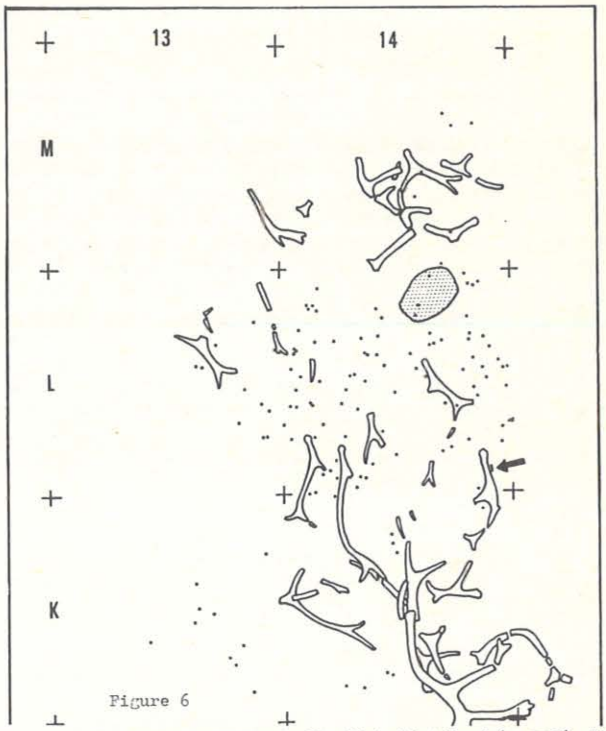

Figure 6

Structure d'habitat du Riss III de l'abri Suard (en grisé : bloc de granite), les artefacts sont signalés par des points. La flèche indique la position de l'os coché qui se trouvait dans la structure.

1.3. FONTECHEVADE.

A quelques kilomètres de La Chaise, s'ouvre la grotte de Fontéchevade, dans un contexte géomorphologique identique. Elle a fait l'objet de nombreuses fouilles depuis le début du siècle, dont les plus importantes furent celles conduites par G. Henri-Martin de 1937 à 1955.

L'entrée de la grotte est orientée au Nord-Nord-Est et la cavité "se présente actuellement sous la forme d'un vaste tunnel rectiligne dont l'entrée est en U renversé et le plafond presque horizontal" (G.Henri-Martin 1957) (figure 7).

Selon G. Henri-Martin (op.cit), deux cycles principaux ont été retracés, qui expliquent l'évolution de la grotte : dans un premier temps, un réseau de boyaux collecteur des eaux s'est formé, puis il a été libéré par suite de l'enfouissement des eaux. Dans un second temps, après abandon définitif du réseau par les eaux souterraines, une sédimentation d'abord argileuse, puis plus détritique par suite des actions du cryoclastisme a conduit au comblement de la cavité. Nous retrouvons ici des phénomènes proches de ceux que nous avons mis en évidence à La Chaise.

La grotte de Fontéchevade est particulièrement connue pour sa calotte crânienne attribuée anciennement à un *presapiens* (Vallois 1958) et par l'industrie tayacienne qui l'accompagnait. Des études récentes (Debénath 1974, Tournepiche 1985) montrent que les restes humains et le Tayacien de Fontéchevade sont plus anciens que ce que l'on pensait anciennement, essentiellement sur la base de données paléontologiques erronées.

Les industries tayaciennes se caractérisent par un débitage levallois qui devient de plus en plus important au fur et à mesure que l'on monte dans la série. Les talons sont en majorité lisses. Il existe dans les niveaux supérieurs des talons dièdres et facettés, mais en faible proportion.

Les choppers et chopping-tools forment la majeure partie de l'outillage.Il convient cependant d'être réservé sur l'analyse typologique de G. Henri-Martin. Il existe des grattoirs massifs et des encoches, celles-ci étant "presque toujours des ébréchures d'utilisation" ... ou des traces de concassage ! Les racloirs sont en petit nombre (environ 1 %). Il n'y a pas de bifaces.

2. L'OCCCUPATION DES GROTTES ET ABRIS PENDANT LA GLACIATION WURMIENNE.

Nous ne saurions terminer cette rapide étude de l'occupation de la zone karstique de La Rochefoucauld sans mentionner la présence humaine durant la glaciation würmienne. Cette présence s'est renforcée dans les grottes et abris de cette région durant tout le Würm, et sa présentation nécessiterait de longues pages. Les Moustériens ont colonisés largement l'abri Bourgeois-Delaunay et Montgaudier. Il sont également présents à Fontéchevade, où se rencontre un Moustérien probablement typique et un Moustérien de tradition acheuléenne, ce qui convient d'être signalée, cette civilisation étant davantage connue en plein air qu'en grotte dans le bassin de la Charente.

Si le Moustérien typique est mal connu, (peut-être est-il présent au Placard), nous voyons une vaste occupation des moustériens de type charentien : Moustérien Ferrassie à Artenac, Moustérien de type Quina à la Cave et à Marillac, Moustérien "intermédiaire" entre les types Quina et Ferrassie à Montgaudier (Debénath et Duport 1987).

Au cours du Würm récent, toutes les cavités seront occupées, par les Aurignaciens d'abord (La Chaise), puis par les Périgordiens (Le Bois du Roc) et surtout les Solutréens et les Magdaléniens (Le Bois du Roc, Le Placard, l'Ammonite, Montgaudier).

Tous les remplissages de ces gisements montrent que les phénomènes karstiques se sont poursuivis pendant la durée de l'occupation humaine : affaissements, aspiration de couches, injections d'argiles, formation de planchers stalagmitiques, etc...

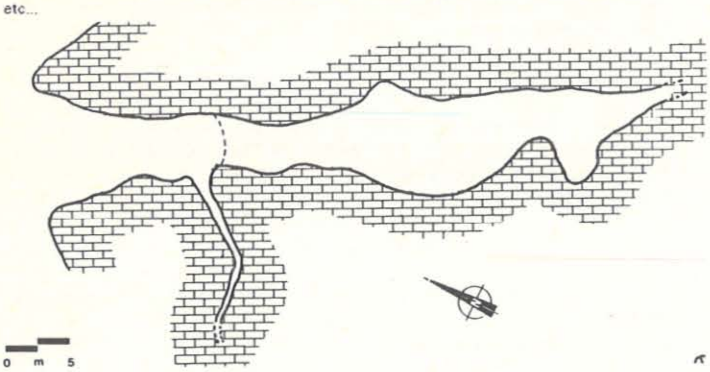

FIGURE 7 :

Plan de la grotte de Fontéchevade : galerie simple avec peu de diverticules.

3. CONCLUSIONS.

La karst charentais se présente donc comme une région particulièrement accueillante pour les paléolithiques qui l'ont habité durant de nombreux millénaires, pratiquement sans discontinuité. Cette occupation se poursuivra après les temps paléolithiques, puisque cette région montre de nombreux habitats holocènes, parfois dans des grottes à grands développements horizontaux, riches en nombreuses concrétions souvent de grandes dimensions : le Quéroy, Rancogne, les Duffaits, Agris. Dans le cas de cette dernière grotte, l'occupation s'est poursuivie, au moins de manière sporadique jusqu'au début du Moyen-Age (renseignement oral J. Gomez).

Les dernières prospections effectuées par les spéléologues charentais ont permis de mettre au jour plusieurs cavités dans lesquelles de nombreux animaux ont été piégés, ce qui permettra, au cours des années à venir d'avoir une meilleur connaissance des faunes paléolithiques de cette région et des compléments intéressants sur sa morphologie karstique.

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INTRODUCCION AL ESTUDIO DEL SANTUARIO ESQUEMATICO DE LA CAVERNA DE "PEÑA ESQUILLAS"

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THE FIRST IMAGES OF CAVE PAINTING IN LA RIOJA

Within the schematic cave painting in the northern Spanish plateau, we present a brief study of the paintings of this kind found for the first time in the autonomous comunity of The Rioja.

The importance of this study of schamatic cave paintings, situated timewise between the late Bronze and early Iron Ages, lies, apart from its being the first pictorel representation found in this regions in the fact that almost all the paintings housed in this cave, relate to a single theme - arboriforms, normally, this type of representation is found associated with other types within schematic art, being the first time that this theme receives priority in representation and forms a monothematic group based on a single sign and its variants.

In the brief study that we present, we make a description of each of the representations and their global assembly within Spanish schematic painting.

1.- Introducción.-

En los últimos años se ha producido, en España, una notable intensificación en los trabajos encaminados al estudio y descubrimiento de nuevos enclaves de arte rupestre, lo que ha supuesto un cambio considerable en el panorama y la concepción que sobre él se tenía. Tanto el número de descubrimientos, como la amplitud de temas y estilos, así como el hallazgo de santuarios en lugares hasta ahora considerados como estériles, hacen nacesario que cada poco tiempo, las conclusiones y planteamientos sobre el tema desvíen sus derroteros.

Uno de estos casos es el que aquí presentamos, constituyendo el primer centro rupestre de la Comunidad Autónoma de la Rioja. Si bien en provincias limítrofes (Soria, Burgos, Alava, Navarra) se habían descubierto desde antuguo representaciones en algunos abrigos y cuevas, no ocurría así en esta comunidad uniprovincial. Al menos desde un punto de vista teórico, esto carecía de lógica y las prospecciones efectuadas por la Federación Riojana de Espeleología, dieron por fin los frutos esperados, dentro de un ambicioso plan de investigaciones que se inició ya hace varios años.

2.- Situación y descripción de la cavidad.-

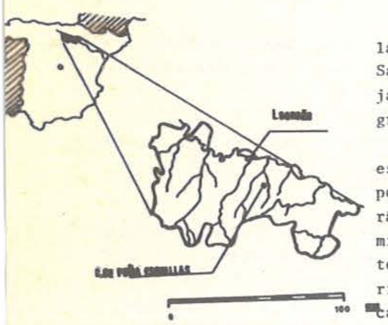

fig 1

Se encuentra esta cavidad en las proximidades del pueblo de Santa Engracia de Jubera (la Rioja), distante de la capital, Logroño) unos 25Kms (figura 1).

Su boca se abre a favor de una estrecha franja caliza de escaso potencial (correspondiente al Jurásico Superior) y casi nulo buzamiento, quedando delimitada, tanto en su parte superior como inferior, por materiales no karstificables (margas.

Las caracteristicas de este estrato calcáreo, hacen que la cavidad tenga poco desnivel y haya dado paso a una configuración laberíntica, con numerosas galerías, de diferentes dimensiones, que se entrecruzan (figura 2) siendo la nota predominante su escasa altura y la colmatación arenosa, que se observa de manera principal en el suelo, lo cual demuestra que en épocas pasadas actuó como surgencia.

3.- Descubrimiento y descripción de la galería de las pinturas.-

Dentro de labor de catalogación que lleva a cabo la Federación Riojana de Espeleología (F.R.E.) se encontró en esta cavidad un importante yacimiento paleontológico, en el curso de las actividades de exploración se localiza esta galeria, concretamente el 7 de febrero de 1987, denominandose a partir de este momento galería Arias en honor de su descubridor; es de escasas dimensiones, con una altura aproximada de 50cms, lo cual dificultaba claramente cualquier tipo de labor.

Por medio de la F.R.E. se consiguió cerrar la boca de la cavidad, contando con la colaboración de la dirección de Patrimonio de la Comunidad Autonoma de la Rioja, que concedió un permiso de prospección a un equipo formado entre otros por los firmantes de la presente comunicación. Una vez en posesión del mismo, se procedió a rebajar el suelo arenoso de modo que nos permitiese un trabajo mas comodo, a continuación realizamos un estudio fotográfico del techo por medio de infrarrojos.

4.- Las representaciones pictóricas. Caracteristicas y descripción.

El conjunto rupestre esquemático de Peña Esquillas, agrupa hasta el momento un total de siete grupos de figuras, todos ellos localizados en el techo del santuario. De los siete grupos, tan solo cuatro nos permiten individualizar las representaciones; pueden estar compuestos por una sola figura o bien por dos de ellas fácilmente individualizables. El mediocre estado de conservación en que se encuentran las representaciones, no permite diferenciar el resto, que se reduce a conjuntos indeterminados de pequeñas líneas y cortos trazos inconexos, a duras penas identificables.

Sobre el techo calizo del santuario se trazarón en su momento finas lineas de color negro que, unas veces claramente y otras muy veladamente, conformaban lo que conocemos como figuras vegetales o "arboriformes". Tales representaciones tienen unas dimensiones que oscilan entre los 23 y los 3,5cms., pudiendo aparecer diseñados sobre zonas lisas o en pequeños receptáculos o concavidades.

Podemos resumir la descripción del conjunto de esquematismos vegetales de la siguiente forma:

- grupo 1(figura 3): Es quizas el gruno mas llamativo de todos, esta formado por dos representaciones de tipo arboriformes presentando alternancia de trazos finos con otros gruesos y puntuaciones. Despues de su descubrimiento , este grupo fue dañado por desconocidos, tapandolo en parte con arena.
- grupo 2(figura 4): Conjunto de trazos que representan un arboriforme, el cual presenta ramificaciones en uno de sus dos lados, en el otro se aprecia una serie de puntuaciones y de lineas, pudiendo alguna de ellas tener relación con él.
- grupo 4(figura 5): Formado por un conjunto de trazos y puntos, aprovechando las oquedades de la roca soporte, configuración que podria corresponder a dos arboriformes, aunque su conservación impide asegurarlo cateforicamente.
- grupo 5(figura 6): Serie de trazos y puntos que forman un arboriforme, en la parte superior se observan unas lineas que podrian representar, igualmente, otro.
- grupo 5(figura 7): Conjunto formado por multitud de puntos y lineas de dificil interpretación. Se encuentra en una oquedad del techo.
- grupo 6(figura 8): Conjunto formado por trazos que representan una

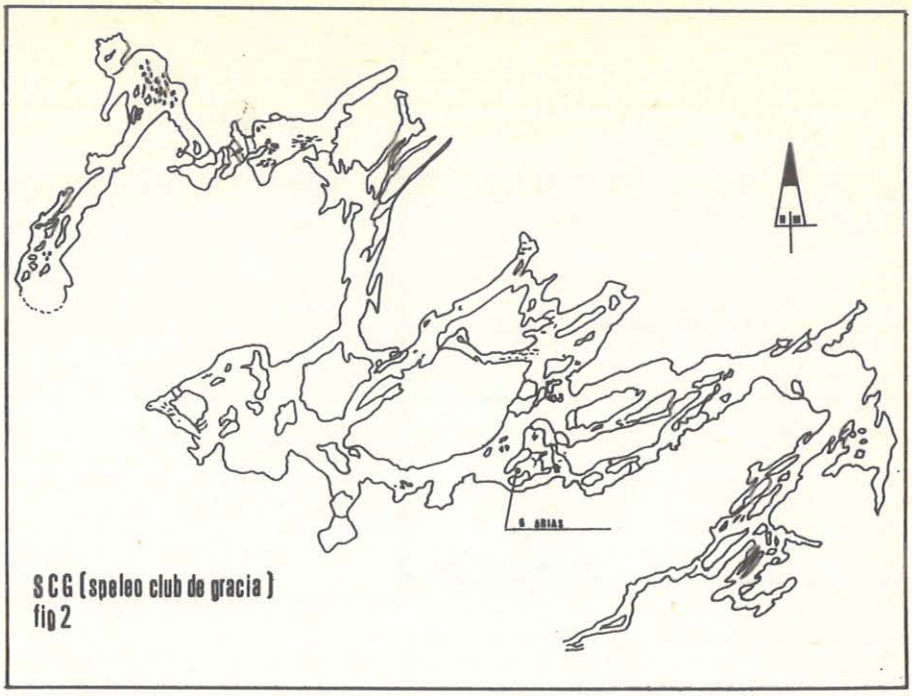

figura arboriforme, que podriamos incluir en los denominados laciformes.

- grupo 7(figura 9): Se encuentra en una pequeña oquedad del techo, representa un arboriforme, y para su realización se han usado las lineas de fisura de la roca soporte.

5.- Consideraciones finales.-

En esta, necesariamente, reducida síntesis final, queremos recalcar el carácter de santuario subterráneo donde se encuentran las las representaciones, y más concretamente, el hecho de que sitúen en un lugar apartado de la exterior, es decir en el interior de la cavidad. Este simple hecho nos sirve para enclavar geográficamente a Peña Esquillas en el grupo cantábrico de representaciones esquemáticas, basandonos en los últimos hallazgos y estudios. Tales estudios se encuentran en clara contraposición con algunos planteamientos antiguos, que negaban en los esquematismos la existencia de "provincias" o "grupos artísticos" de este tipo en la península. Las Comunidades Autónomas de Cantabria, País Vasco(Vizcaya y Alava), Castilla(Burgos) y ahora también La Rioja, poseen un tipo de arte esquemático que, en respuesta al resto de nuestra geografía donde se utilizan abrigos al aire libre, decora las galerías de sus cavernas, tal y como muy bien caracterizó el Dr. Apellaniz. Este tipo de santuarios pueden ser de nueva creación (Solacueva o Lazalday, en Alava; y ahora Peña Esquillas, por ejemplo), o bien una reutilización de santuarios paleolíticos (Arenaza, en Vizcaya o Las Monedas, en Cantabria). Se produce una utilización casi exclusiva del color negro, en líneas de diferente longitud que conforman figuras o simples trazos. Esta pintura, a veces se une a grabados que conforman santuarios más complejos, como es el caso de la Galería del Sílex en Cueva Mayor (Burgos).

Existe otro aspecto importante que, al menos de momeuto, proporciona una clara exclusividad a nuestra caverna en relación con la zona, y es el carácter monotemático de las representaciones. Los arboriformes o ramiformes, como también se les ha llamado, conforman un mismo tema que arranca desde etapas paleolíticas del magdaleniense (Altamira, Altxerri, Castillo,...), hasta la Edad del Hierro. Las representaciones, grabadas o pintadas, agrupan una gran variedad de formas, aunque el morfotipo característico consiste en una línea vertical en cuyos lados convergen o se cruzan, transversal u oblícuamente, series de líneas más o menos cortas y paralelas. Su disposición (invertída, inclinada,...) o bien los motivos con los que aparece o a los que aparece o a los que acompaña, suelen variar en número y tipo según el momento cronológico y/o la situación topográfica y geográfica. De momento no podemos establecer ninguna conclusión de carácter general en relación con este punto, ya que necesitaríamos un analisis mucho más extenso que plantearemos en futuras investigaciones.

fig 3

fig 4

fig 5

En cuanto a la cronología, obaservamos que el grupo de cavernas con esquematismos en el área cantábrica, ha sido enteramente fechado en el Bronce Final, tanto en el caso de cavernas reutilizadas como de nueva creación. Peña Esquillas, además de reunir las características vistas de esta zona geográfica, se nos presenta como un santuario unitario de carácter sencillo, en cuanto a técnicas e iconografía. Parece que todo él responde a una misma época, aunque como ha ocurrido en casos similares, no podemos precisar su extensión. En este caso puede ayudarnos el descubrimiento de un hacha de talón y dos anillos procedente de Lancia (León), con representación de un

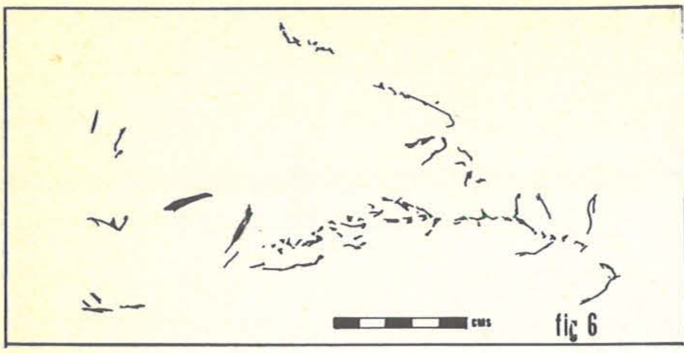

fig 6

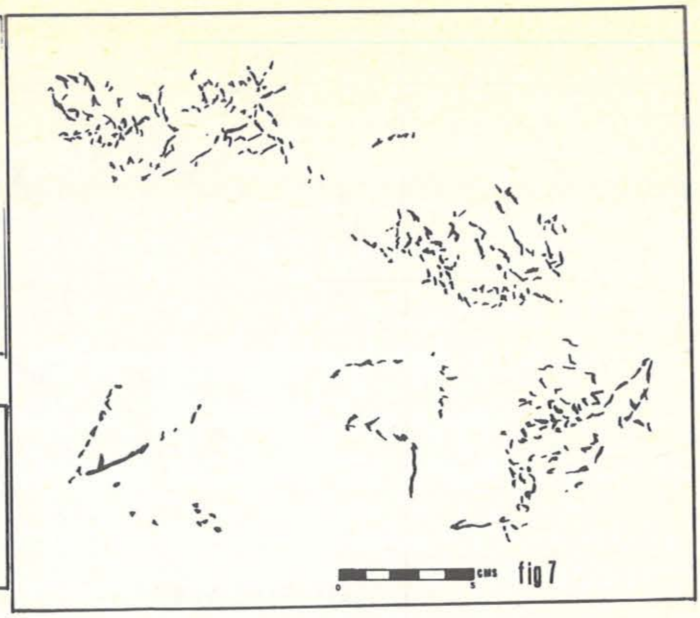

fig 7

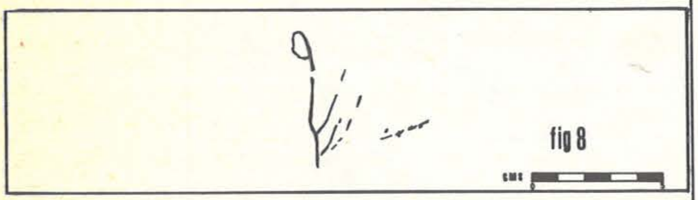

fig 8

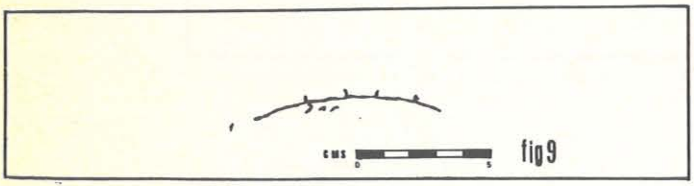

fig 9

arboriforme. Se han fechado en torno al año 1000 a.C.; si unimos esto a las pruebas de C-14 en Cueva Mayor (1100 a.C. aprox.), conseguiremos un mayor acercamiento a este fenómeno rupestre.

Finalmente, en cuanto al tratamiento de la interpretación de las representaciones, no queremos pronunciarnos de manera definitiva ante lo escabroso y delicado del tema. Ya desde que Breuil estudió el arboriforme con la figura humana. A esta hipótesis se han sumado después muchos autores y cierto es que, en los abrigos al aire libre del centro y sur peninsulares, parece existir una cierta relación. Por simbología, el árbol siempre se ha relacionado con la representación de la vida y la inmortalidad en su sentido más amplio. Actualmente, la interpretación de este arte esquemático se ha llevado al campo de lo conceptual pero, el "concepto", algo tan profundo y cambiante como inalcanzable para nosotros , por ley natural murió con los artistas.

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DATING OF GROWTH RINGS AND THEIR RELATION TO LATE QUATERNARY CLIMATIC CHANGES IN THE RYUKYU ISLANDS, JAPAN

ARAKAWA, Tatsuhiko

Late Quaternary climatic changes in the Ryukyu Islands, Japan were estimated from the analysis of many speleothem rings (Growth Rings : GRs) using the ESR dating method. A speleothem such as stalagmite, stalactite and column generically has many concentric layers in the same way as the tree rings. The formation of GRs and the thickness (or volume) of each layer of Gr are indicative of being influenced by climatic changes.

Many speleothems were collected from some limestone caves and they were cut into round slices. The samples were taken from the outer and inner edges and the centre of each ring in order to determine their ages from the beginning and end of the growth in each GR respectively. For example, in Yoron Island, the formation of GRs had been interrupted during 6 periods of climatic changes. These results are quite in agreement with the trend of the climatic changes that have been revealed in Japan and its vicinity.

The result of this study showed the new approach to the investigations into the relationship between the evolution of Karst landforms and the climatic changes during the Quaternary period.

LA DATATION DU DÉVÉLOPPEMENT DES ANNEAUX (GRs) ET LEUR RELATION AVEC LES CHANGEMENTS CLIMATIQUES À LA FIN DE L'ÈRE QUATERNAIRE AUX ILES RYUKYU, JAPON.

C'est à travers des ètudes qu'on a fait de beaucoup de "spèlèotherms" qu'on a su que le clime changes très tard à l'ère quarternaire aux Iles Ryukyu, pour cela a employé la mèthode R.E.S. Un "spèlèotherms" tel qu'une stalalgmite, stalactite et une colonne a beaucoup de couches pareilles aux anneaux d'un arbre. La formation de GRs et de l'épaisseur (ou volume) de chaque couche de GRs indiquent l'influence des changements climatiques.

Beaucoup de spéléothems furent recuellis de quelques cavernes calcaires et ils furent coupés en tranches. Quelques èchantillons furent pris de l'extérieur de l'intérieur et du centre de chaque anneau a fin de détermine leurs âges du commencement et de la fin de la formation dans chaque RGs respectivement.
Par example, à l'ile Yoron, las formation de RGs a èté interrompue pendant 6 pèriodes par des changements climatiques. Les résultats sont presque d'accord avec la tendance aux changements climatiques qui a été rèvélé au Japon et dans son entourage.

La resultat de cette étude a montré une nouvelle approche pour les recherches dans les relations entre l'evolution des formes Karstiques et les changements de climat pendant la périod quaternaire.

1. INTRODUCTION

Dating of speleothems has been investigated in many caverns, using several techniques, in particular, paleomagnetism, oxygen isotope and the U-series and TL. The ESR dating method also made it possible to determine the age of speleothems (Ikeya, 1975). Nevertheless, almost all of the investigations of speleothem dating tended not to analyze the speleothem itself but to determine the age of the cavern, terrace or past sea-level and to reconstruct the paleoclimates (e.g. Harmon et al., 1981: Henning, et al., 1983 etc.). Moreover, unfortunately, there are few reports about the formation of speleothems.

Many studies analyzing speleothems have reconstructed typical continuous paleomagnetic and paleotemperature records in some areas (e.g. Wendy and Wilson, 1968: Thompson et al., 1976: Harmon et al., 1978: Morinaga et al., 1985 etc.). These studies, however, regarded the growth of a speleothem as a continuous one in spite of the fact that the speleothem form had several concentric layers of unconformity.

On the other hand, there are many other effective approaches of researching the Quaternary climatic changes, for example; pollen analysis, diatom analysis, isotopic analysis etc., though these do not so readily reveal, the climatic changes during the Quaternary period in tropical regions, especially, on raised coral reef islands.

In this paper, speleothem rings (Growth Rings: GRs) were analyzed using the ESR dating method, and the results showed that a speleothem such as a stalagmite, stalactite and column, generically had many concentric layers in the same way as tree rings did.

2. STUDY AREA

The Ryuku Islands form an arc stretching from Kyushu to Taiwan, a distance of about 1,200 km.

Many studies have been reported investigating the Quaternary crustal movements in this area since this is where the Filipino-Sea plate strikes the Eurasian plate, hence it is an active area for such movements. But the Quaternary climatic changes have not been revealed in this area.

Yoron Island lies in the approximate centre of the Ryuku Islands and consists of seven raised coral reef terraces of Ryuku Limestone.

This island is divided into three areas by two major active faults running north-south and west-east. The northeastern area, in particular, clearly shows the raised coral reef landforms consisting of seven limestone terraces with limestone ramparts. Six cave groups have developed with different elevations well-matched with raised coral reef terraces.

3. SAMPLES

Twenty-two speleothems were collected from five different horizontal limestone caves, each from a different terrace, therefore a different cave group, in the area: one stalagmite was collected from Shinaha-Do Cave (10m A.S.L.), two stalagmites from Akasaki-Do Cave (25m), three columns and four stalagmites from Gushoka-Do Cave (18m), two stalactites and two stalagmites and two columns from Yago Cave (70m), and five stalagmites and two columns from Gokuraku-Do Cave (80m).

Cross-sections, 1cm thick, of these samples were taken. From the growth rings revealed, of 2-4mm in width, samples were taken from the outer and inner edge and the centre, in order to determine the dates of the beginning and end of the growth of each ring. The thickness (and volume), the growth rate and the percentage volume of each GR in a speleothem, were determined.

These samples were dated by the ESR dating method. Sampling procedures were performed according to Arakawa (1988), and ESR ages were determined using the theoretical calculation proposed by Ikeya and Miki (1984).

4. CONCLUSIONS

All ESR ages of GRs displayed less than 25,000 yr.B.P. except one GR which showed the exceptional age of 103,150 yr.B.P.. The formation of GRs had been interrupted during the following 6 periods:

23,600 - 19,800 yr.B.P.,	17,800 - 16,600 yr.B.P.,
10,600 - 9,800 yr.B.P.,	9,200 - 6,900 yr.B.P.,
3,500 - 2,900 yr.B.P.,	2,100 - 600 yr.B.P.,

On the other hand, many wide and clearly defined GRs had formed during the following periods:

19,000 - 18,000 yr.B.P.,	6,500 - 5,000 yr.B.P.,
5,000 - 4,000 yr.B.P.,	

These results clearly show that each speleothem had been formed, not successively, but with several interruptions during formation. It seems that they were caused by environmental changes i.e. climatic changes.

Also, the growth pattern of GRs in all the speleothems are very similar. As a result, the formation of GRs had been created not by individual factors but by the same factor. That is clearly the climatic factor; thus these results show undoubtedly that the formation of GRs had been influenced by climatic changes and that the growth pattern of GRs indicated the trend of climatic changes. This trend is quite in agreement fundamentally with the trend of the climatic changes that have been revealed in Japan and its vicinity.

The result of this study showed the new approach to the more detailed investigations into the relationship between the development of speleothems and the climatic changes during the Quaternary period. This new approach seems to be a useful method of revealing the Quaternary climatic changes in the limestone areas worldwide.

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THE DEVELOPMENTS OF LIMESTONE RAMPARTS AND LIMESTONE WALLS IN THE RYUKYU ISLANDS, JAPAN

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The Ryukyu Islands consist of Quarternary raised coral reef limestone, Ryukyu limestone (Yabe and Hanzawa, 193)), which have many interesting Karst landforms. ,The 'limestone walls' are, especially, known for their typical landforms (Flint et al., 1953). Although Flint et al. regarded them as two-dimensional landforms, in other works after Tujiomura (1965), they regarded them as three-dimensional landforms. These landforms are clearly convex ones.

The 'limestone walls' were re-investigated and they were divided into 2 different landforms: Limestone Ramparts and Limestone Walls. They were each classified into 4 sub-groups by origin, morphology and aspect. The distributions of Limestone Ramparts and Limestone Walls and two new developmental models of them were revealed from the results of field work carried out from the lithological aspect, from the investigation of underground water, from the comparison of other Karst landforms in the Ryukyu Islands and from the relating crustal movements.

LA FORMATION DE REMPARTS CALCAIRES ET DE MURS CALCLAIRES AUX ILES RYUKYU, JAPON.

Les iles Ryukyu sont un récif de corail de l'ére quaternaire (Yabe et Hanzawa, 1930) avec beaucoup d'intérèssantes formes Karstiques. "Les murs calcaires" sont bien connus à cause de leurs typiques formes. (Flint et al, 1953). Bien que Flint et al. les aient corriderès comme ayant deux dimensions, dans d'autres études apres Tujimura (1965), ils les corriderent comme ayant trois dimensions. Les formes sont mettement convexes.

"Les murs calcaires" ont été étudiés et ils ont été divisés en deux différentes formes: Remparts et Murs. Chacun de ses groupe par la suite a été classifié en 4 sousgroupes d'après l'origine, la morphologie et l'aspect.

Les distributions des Remparts et des murs calcaires en deux nouveaux models ont été corriderés d'aprés les résultats ens dancs les chantiers de travail, l'aspect lithologique, les investigations de l'eau souterraine et la comparation avec d'autres formes Karstiques aux Iles Ryukyu et par ce qui concerne aux mouvements de la croûte terrestre.

1. INTRODUCTION

The Ryukyu Islands, about 1,200 km in length, are an arc of islands between Kyushu and Taiwan. The islands have been considered to be unique in the Quaternary landforms and geology because of the distribution of living coral reefs and the Pleistocene Ryukyu Limestone. The limestone topography of the Ryukyus presents very distinctive Karst landforms with its lithological and geological features. These features are also attributable to the climatic condition of a sub-tropical island where the annual average temperature is about 22°C and the annual average rainfall is about 2,300 mm. The development of convex Karst landforms is especially remarkable in this region.

Among the Karst landforms formed in the Ryukyu Limestone, the "limestone walls" reported by Flint et al. (1953) are recognized as typical Karst landforms in the Ryukyu Islands. Some studies have been made concerning it. As a matter of fact, however, not even the distribution of "limestone walls" in this region is known, nor have its landforms and designation been clearly defined yet.

Although Flint et al. regarded them as two-dimensional landforms, in other Japanese works after Tsujimura (1956), they were regarded as three-dimensional landforms, thus, there are some differences between the landforms resulting from the way in which they were perceived. Therefore, it should be necessary to re-examine all those landforms.

Accordingly, the purpose of this paper is to order the studies that have so far been made and to attempt to clarify the morphology, classification, distribution and developments of Limestone Ramparts and Limestone Walls in the Ryukyu Islands.

As regards the method of this study, field investigations involving a groundwater survey, and measurement of the carbon dioxide and acidity in the residual soil, were made, based on distribution maps prepared from aerial photographs and topographical maps drawn on a scale of 1 : 1,000. 1: 3,000 1 : 5,000.

2. PREVIOUS STUDIES

The Flint et al. (1953) report on the morphological classifications and distributions of the "limestone walls" in Okinawa island was first discussed by Hoffmeister and Ladd (1945). According to Flint et al. (1953), "limestone walls" can be classified into the following four types; (1) along a fault, (2) along a marine terrace, (3) along a river, (4) around a doline. They are all considered to have been formed by case-hardening.

Later a number of views were presented regarding the origin of "limestone walls". These views can be broadly classified into the following four categories.

First, the origin of "limestone walls" is sought in secondary cementation (case-hardening), as explained by Hoffmeister and Ladd (1945), Saplis and Flint (1949), Flint et al. (1953), Flint et al. (1959), Tsujimura (1956). This origin is viewed as a result of climatic geomorphology because the formation of them is only possible under climatic conditions characteristic of sub-tropical and tropical regions.

Against such a theory, Tuchi (1971) classified the limestone walls in the southern part of Okinawa island as a cuesta, a type of structural landform.

On the other hand, Ota and Hori (1980) pointed out with respect to the origin of "limestone walls" that these landforms should be classified as tectonic landforms in view of the fact that the distributions of active faults and "limestone walls" equally overlap each other. Hanai (1959) also believed that many of the "limestone walls" in southern Okinawa is land consisted of groups of fault blocks and fault-angle basins.

Meanwhile, Nishimura et al. (1973) adopted the view of phreatic zone and vadose zone employed in the genesis theory of limestone caves. They approached from an altogether different point of view.

Various interesting theories about their development have been presented as described above, but each of them has a number of problems.

First, it is difficult to obtain from the theories of Flint et al. (1953) and others, who sought the origin of limestone walls in case-hardening, an explanation of the width of a wall ranging over 100 m, just in the recrystalization of the cliffs and steep slopes.

Also, the theory of Tuchi (1971) does not take into account the effects of active faults which Ota and Hori (1980) pointed out as being fundamental in development of limestone walls. However, the problem with the Ota and Hori theory is that it does not explain what directly brought about the formation of the embankment-like elevation.

The theory of Nishimura et al. (1976) is problematic in that it has employed the genesis theory of limestone caves as it supports the formation theory of Karst landforms above ground. At the same time this theory represents quite different levels of thought.

3. TERMINOLOGY

In this paper, Limestone Rampart will be re-defined as "rampart-like elevation of limestone formed by solution". The term used Limestone Wall, therefore, will be re-defined as "a wall-like landform of limestone approximately 2-10 metre and 1-3 metre in width formed by weathering".

4. CLASSIFICATION OF LIMESTONE RAMPARTS AND LIMESTONE WALLS

The limestone ramparts have been classified into the following four types according to their geomorphological location:

1 That which is located along a fault.

2 That which is located along a marine terrace.

3 That which is located along a river.

4 That which is located along a small tableland.

The limestone ramparts can be classified morphologically as follows:

1 Embankment - type.

2 Ridge - type.

3 Wall - type.

4 Cuesta - type.

These morphologically classified types, however, agree well with those classified by geomorphological location. Embankment-type ramparts are located along faults, rivers and marine terraces. Limestone ramparts, however, are located along rivers that have no limestone walls at their top face. The Ridge - type is found along marine terraces and the Wall - type along faults and tablelands. The Cuesta - type ramparts which are found in the southern parts of Okinawa island where there are several active faults also run parallel to each other.

The limestone walls can be classified into the following three types:

1 That which is located on the crest of a limestone rampart.

2 That which stands in a row on a slope.

3 That which is located around a doline.

4. DEVELOPMENTS

From the aforementioned morphological classification and distribution, limestone ramparts can be more broadly classified into the following two types. One, is the embankment-like type that develops along a river or marine terrace with no limestone walls on its crest. The other is the type that is found with some limestone walls, that has developed along a fault.

In limestone ramparts along rivers and marine terraces, ground water can be considered to flow down towards the base of the cliff. Because of this, the relative height to the ground water level increases as the edge of the cliff is approached. The Ryukyu Limestone is not yet concreted or semi-concreted, and is porous. Presumably, therefore, contrary to limestone in general, solution processes may diminish if the relative height to ground water level is excessive. This can be inferred from the fact that the Karst depression, particularly doline, in the Ryukyu Islands is of uniform shallow depth and presenting a tray-like feature. From such a viewpoint, solution is accelerated on the terrace surface and on the interfluves where the relative height to the ground water is small. The solution weakens near the edge of the cliff because a more and more accentuated and embankment-like elevation, is formed.

Meanwhile, deposition of residual soil continues on the terrace surface, on the interfluves, and under the cliff, which increases the acidity and promotes solution (Trudgwill, 1985 etc.). The wall of the scarp also hardens by case-hardening. This view is that such processes act to form limestone ramparts while affecting each other. However, it is believed in studies made so far on Karst landforms that solution process is accelerated as the amount of available relief become greater (Sweeting, 1972). This theory is altogether contrary to the idea presented in this paper. But in the Ryukyu Islands, a Pleistocene limestone area, such a theory that is contrary to Sweeting's theory is a very important one.

A limestone rampart along an active fault is tilted, so that the ground water should flow down toward the back slope. In limestone regions, such a knick point, once formed, hardly retreats at all in contrast with landforms in general, and solution proceeds from downstream of the ground water flow. In addition, limestone caves are formed near the ground water table which is close to the surface, and collapse occurs because of the shallow depth from the surface.

Moreover, according to the view described earlier, the solution process proceeds rapidly on the surface, and at an elevation where solution has not advanced, limestone ramparts are formed near the knick point, which the fault scarp hardens due to the presence of heat produced from fault activity and the climatic case-hardening process. This accentuates the wall. The parts remaining without undergoing solution as a result of such a process and the added action of hardening, are the limestone ramparts and limestone walls. Differences in morphology, such as the Embankment - type, Wall - type and Cuesta - type, are believed to arise in the process of development.

The above two theories are the presented views regarding the process for the development of the different types of limestone ramparts. The former theory, in particular, is applicable to limestone walls developing along marine terraces and also to limestone ramparts with no tilting developing along active faults.

Lastly, to describe the origin of limestone walls standing in a row on a gentle slope, it can be considered that these are formed when the initial landforms, the massive coral reef zones with the sandy deposit zones between them, is differentially eroded. Wide coral reef zone also remain without being subjected to the solution process, according to the former theory, mainly due to case-hardening. However, they are subsequently destroyed by physical erosion.

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THE AGES OF ONE CYCLE OF CAVE DEVELOPMENTS IN A SUB-TROPICAL RAISED CORAL REEF AREA: YORON ISLAND, THE RYUKYUS, JAPAN

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The Ryukyu Islands Arc is where the Filipino Sea plate strikes the Eurasian plate, hence it is an active area for such movements. Most of the Islands consist of Quaternary raised coral reef limestone. Therefore, it seems to be a suitable field to research cave developments.

Many speleothems were collected from five different horizontal caves, each from a different terrace, in Yoron Island. They were dated by the ESR dating method. Although, generally, the elevation of a cave floor indicates the underground water level at the time of its formation, all ages of speleothems displayed less than 25,000 yr. B.P. except one.

This result seems to show that many speleothems which had formed by that time had collapsed and disappeared with cave development. Because in a sub-tropical area like Yoron Island where limestone is very porous and soft and crustal movements have been active, limestone solution rate is more rapid, thus cave development is also quicker. Therefore, it is probable that the general limitation of speleothem existence, one cycle of cave development, is less than 30,000 yr. B.P. in the Quaternary raised coral reef limestone areas.

L'ÂGE D'UN CYCLE DANS LA FORMATION DE CAVERNES DANS UN RECIF DE CORAIL EN ZONE SOUSTROPICALE : LES ILES YORON, LES RYUKYUS, JAPON.

Les iles Ryukyus, se trouvent là oie la plaque de la mer des Philippines frappe la plaque Eurasienne, d'ou l'existance d'une zone active pour de tels mouvements. La plupart de ces iles sont un recif de corail de l'ère quaternaire. De là qu'il semble un terrain approprié pour faire des recherches sur la formation de cavernes. Beaucoup de "spéléothems" furent recueillis dans cinq différentes cavernes horizontales, chacune d'elles se trouvant sur une terrasse différente aux Iles Yoron. Ils furent datés par la méthode R.E.S. Bien que généralement, l'èlevation du sol de la caverne indique le niveau de l'eau sousterrain au moment de sa formation, tous les âges des "spèleothems" montrerent moins de 25,000 ans B.P. sauf un.

Cela parait montrer que beaucoup de "spéléothems" qui se sont formés à ce moment-là se sont écroulés et ont disparu avec la formation de cavernes. Car dans une zone soustropicale comme les iles Yoron où (the limestone) la prière calcaire est tres poreuse et tendre et les mouvements de la croute terrestre ont ètè trés actifs, la proportion de la dissolution calcaize est plus rapide, par consequent la formation de cavernes se dévèloppe plus rapidement aussi.

De là qu'il est probable que la générale limitation de l'existance des "Spèlèotherms", un cycle de la formation de cavernes, soit moins de k30,000 ans B.P. pour les zones d'un récif de corail quarternaire.

1. INTRODUCTION

The origin of limestone caverns has been discussed in many papers (e.g. Grund, 1903: Swinnerton, 1929: Davis, 1930: Ford, 1965 etc.), and studies have also revealed the stages of cave development (e.g. Sweeting, 1950: Malott, 1952: Kawano, 1980 etc.). Various attempts to estimate the ages of caves or the dates of their formation have also been reported.

The fact that limestone caverns have been developed mainly by erosion of groundwater flow and enlarged by roof collapse, especially along the lineaments or faults, has been confirmed. However, the age and manner of cavern developments have not been clearly revealed.

In this paper, the limitation age of one cycle of cavern developments in a sub-tropical raised coral reef area; Yoron Island, the Ryukyus was estimated from the dating of speleothems and travertines using the ESR dating method.

2. STUDY AREA

The Ryukyu Islands form a tectonically active island arc stretching about 1,200 km from Kyushu to Taiwan, where the Filipino Sea plate strikes the Eurasian plate, hence it is in an active area and has many raised coral reef islands consisting of several raised limestone terraces for such movements.

Yoron Island, which lies in the approximate centre of the Ryukyu Islands and consists of raised coral reef limestone. Ryukyu limestone shows clearly the raised coral reef landforms. Many limestone caves have developed in different altitudes and they are divided into 6 cave groups.

The Ryukyu limestone, compared to the Paleozoic limestone distributed in the main island of Japan, is very poorly cemented and displays high periability.

3. SAMPLES

Twenty-two speleothems were collected at random from five different horizontal limestone caves, which belong to a different cave group respectively.

Cross-sections, 1cm thick, of these speleothems were taken. Samples, of 2-4mm in width, were taken from some parts of the cross-sections, in order to determine the oldest age of the speleothems.

Many travertines were also taken at random from parts of the roofs and walls in these caves.

These samples were dated by the EST dating method. Sampling procedures were performed according to Arakawa (1988), and ESR ages were determined using the theoretical calculations proposed by Ikeya and Miki (1984).

4. RESULTS AND DISCUSSION

All ESR ages of speleothems and travertines displayed less than 25,000 yr.B.P. except one speleothem which showed the exceptional age of 103,150 yr.B.P.

Several interpretations can be made from this result. According to previous studies, for example, the absence of ages indicates the lack in the formation of speleothems and this absence may be regarded as a glacial period or a dry climatic period. But it seems to be doubtful, in this area, that the formation of speleothems had been so perfectly interrupted over such a long time (from 100,000 yr.B.P. to 30,000 yr.B.P.) even if it had been during a glacial period. In fact, the result of this study revealed clearly that, for the Last Glacial Stage (from 25,000 yr.B.P. to 10,000 yr.B.P.), speleothems had been actively formed.

On this island, there are 7 raised coral reef terraces and 6 cave groups sited at different altitudes. These terraces had been formed at quite different dates, hence it seems that the 6 cave groups had been also formed at different dates. The ages of these terraces are estimated from studies carried out on several islands located near Yoron Island, the highest one (T1) might have been deposited during the transgressions of oxygen isotope stages 16/15 and 14/13 (600,000 yr.B.P. or 500,000 yr.B.P.), T4 during the stages 6/7 (200,000 yr.B.P.), T5 during the stage 5e (120,000yr.B.P.), T6 the stage 5c (100,000yr.B.P.), and T7 the stages 4/5 (80,000yr.B.P.).

Accordingly, each cave must first have formed and developed during those terms, and then the speleothems formed in each cave during the same term, because it seems that none of the caves, travertines or speleothems had developed through some hundred thousand years or some ten thousand years. Also once each coral reef had been raised and each terrace had formed, each cave must have formed and developed near the groundwater surface, and then, the speleothems and travertines had grown.

The fact that the age of the speleothems and travertines did not correspond to the age of the terraces indicates that all the speleothems and travertines had disappeared due to the development of the cave and crustal movements. Since in sub-tropical regions like Ryukyu Islands where limestone is very porous and soft, limestone solution rate is more rapid, and crustal movement has been very active, the growth of the caves is also quicker. Some speleothems and travertines have not disappeared, because of their geographical and geomorphical siting, and this explains the existence of the exceptional one in this study.

Therefore, this result clearly shows that many speleothems which had been formed by that time had collapsed and disappeared as a result of the development of the caves and crustal movements or gravity. It seems that the general limitation age of speleothem existence must be less than 30,000 yr.B.P. in the Quaternary raised coral reef limestone areas.

This means that the way in which the cave develops is as if the inner roof and walls were being peeled out. Such a pattern of development has occurred many times over a period of years, each development is one cycle of the development of the cave and the period of one cycle is about 25,000 yr..

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PALEOKARST COLLAPSE FEATURES IN THE UPPERMOST MIOCENE OF MALLORCA ISLAND (SPAIN)

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Three depositional units build up the Upper Miocene of Mallorca: Calcisiltites with *Heterostegina* Unit, Reefal Unit and Santanyí Limestone Unit. The Santanyí Limestone Unit is formed by stromatolitic and oolitic facies and it overlies a wide Late Tortonian-Messinian coral reef platform; it corresponds to a shallow marine carbonate platform with sand bars and mangrove swamps.

In the south-eastern part of Mallorca island (Marina de Llevant) the contact between Reefal an Santanyí units shows some exposure facies, including collapse structures and breccia formations. These paleokarst features are abundant and well exposed on the sea-cliffs around Santanyí area.

Several types of collapse structures have been recognized in the Santanyí Limestone Unit and different types of karst-breccias are related to them. Breakdown processes on previously lithified oolitic beds and V-shaped plastic deformation on stromatolitic and mangrove layers are the result of karstic voids subsidence developed in the underlying Reef Unit.

Spatial distribution of these paleokarst features can be related to the facies distribution of the Reefal Unit suggesting that coral patch reefs dissolution have controlled the beginning of cavity growths. Breccia formation processes are involved in the cavity collapses and point out the great diversity of breccia types occurring in karstic environments.

CARACTERÍSTICAS DE LOS COLAPSOS PALEOKÁRSTICOS EN EL MIOCENO SUPERIOR DE LA ISLA DE MALLORCA (ESPAÑA)

El Mioceno superior de Mallorca está constituido por tres unidades deposicionales: la Unidad de Calcisiltitas con *Heterostegina*, la Unidad Arrecifal y la Unidad Calizas de Santanyí. La Unidad Calizas de Santanyí está formada por facies oolíticas y estromatolíticas dispuestas sobre una amplia plataforma carbonatada con facies arrecifales de edad Tortoniense superior-Messiniense y que corresponde a una plataforma marina carbonatada somera con migración de barras arenosas y presencia de manglares.

En la parte sud-oriental de la isla de Mallorca (Marina de Llevant) el contacto entre la Unidad Arrecifal y las Calizas de Santanyí muestra algunas características de exposición que incluyen estructuras de colapso kárstico y formaciones de brechas. Estas características de paleokarst son muy abundantes y presentan buenos afloramientos en los acantilados de la costa en las inmediaciones de Santanyí.

En la Unidad Calizas de Santanyí se han reconocido algunos tipos de estructuras de colapso y, relacionadas con ellas, varios tipos de brechas kársticas. Los procesos de fracturación sobre las capas oolíticas ya consolidadas y la deformación en forma de V sobre las capas estromatolíticas y de manglares son el resultado de la subsidencia causada por los vacíos kársticos desarrollados en los materiales subyacentes de la Unidad Arrecifal.

La distribución espacial de estas características de paleokarst se puede relacionar con la distribución de facies dentro de la Unidad Arrecifal, sugiriéndose que la disolución de los parches arrecifales de coral controlan el inicio del crecimiento de las cavidades. Los procesos de formación de brechas están relacionados con el colapso de las cavidades y ponen de manifiesto la elevada diversidad de los tipos de brechas que podemos encontrar relacionados con los ambientes de tipo kárstico.

1. GEOLOGICAL SETTING

Mallorca is the largest of the Balearic islands. It is located in the western Mediterranean and comprises two mountain ranges trending northeast - southwest. They are formed by folded Mesozoic sediments and they are separated and surrounded by a central plain filled by flat lying Upper Miocene to Quaternary deposits.

The Upper Miocene rocks of the western Mediterranean show well developed facies of reef and platform carbonates (ESTEBAN, 1979/80). In the sea cliffs outcrops of southern and south-eastern areas of Mallorca island, reefal, sand shoal and mangrove facies can be observed (figure 1). They form the Upper Miocene section of mallorcan stratigraphy (POMAR et al., 1985).

At the base, the Reefal Unit (POMAR et al., 1983) is lying unconformably over open platform calcisiltites (Calcisiltites with Heterostegina Unit) and it is mainly formed of echinoid rich calcarenites, with strongly bioturbed calcisiltites (containing coral boulders, Halimeda segments and other bioclastic fragments), coral framestones and rudstones -partially dolomitized-, reefal patches with calcarenites and oolitic and stromatolitic limestones. This unit conforms a depositional model of barrier-reef type with well developed reef front and a wide lagoon area with a well defined morphological zonation of coral masses.

Upwards an erosional and partly karstified surface forms the top of the Reefal Unit and, in southern Mallorca, it is covered by the Santanyi Limestone Formation (FORNOS & POMAR, 1984). This unit is formed by littoral carbonate deposits and oolitic limestones corresponding to mangrove and sand shoal environments. Due to its coastal character this formation presents a great variety of facies corresponding to local variations. Their vertical sequence has a transgressive trend, from a muddy criptalgal facies of a very protected marine environment to a high energy oolitic sand shoal with stromatolitic growths.

The upper levels of the Santanyi Limestone Formation are formed by stromatolitic facies and they register an important regressive event. Its top is truncated by an erosion surface covered by Pliocene deposits.

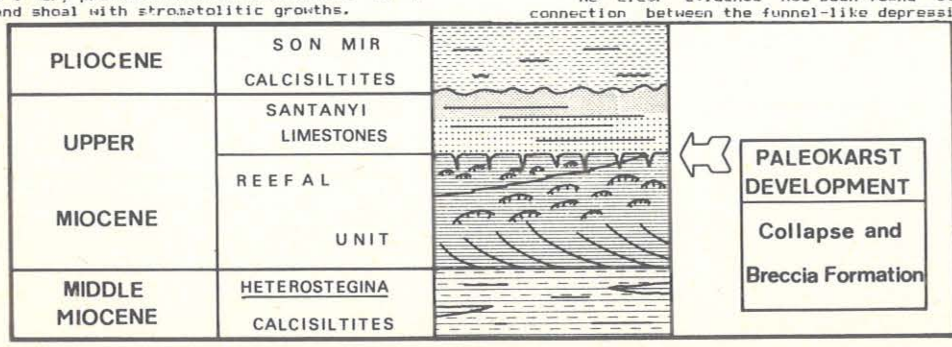
2. PALEOKARST DEVELOPMENT

Solutional subsidence features are conspicuous in the sea-cliffs around Santanyí, at the South-Eastern part of Mallorca Island. From Cala Llombards to S'Algar (near Porto Colom) repeated deformations, clearly observed from the sea, are outlined by the lower beds of the Uppermost Miocene rocks (Santanyi Limestone Formation). In detail these deformation-outcrops show also breakdown debris and setting features affecting frequently all the Santanyi Limestone Fm., specially the plastic mangrove beds. Even the upper Reefal Unit levels are locally deformed by these collapse processes.

Sedimentary and morphological data indicate a paleokarstic origin for this kind of hollow-like deformation of the beds, widely distributed along the coast following the contact between Reefal Unit and Santanyi Limestone Fm. In fact, collapse features disappears further away from S'Algar where sea-cliffs are mostly constituted by the Reefal Unit.

It seems likely that karstification of the coral patch reefs must be involved in the development of such collapse features. Voids resulting from solution of mainly aragonitic coral masses should trigger flow subsidence of plastic materials and promote, in some cases, the build up of secondary voids in the overlying beds. If these secondary cavities reaches a size several meters wide, sudden breakdown may occur causing chaotic piles of blocks and boulders that occupies near all the previous void.

No clear evidence has been found at present of direct connection between the funnel-like depressions of the beds and



epikarstic features as dolines, although in some exceptional cases underlying hollows development may achieved probably the surface as a result of their evolution. The absence of noticeable subaerial-exposure morphologies points out for a genetic model closely related with the concept of subjacent karst subsidence, as has been defined by JENNINGS (1971). In this model, a more soluble aptitude of the underlying reefal beds and suitable hydraulic gradients enhancing underground drainage towards the sea base-level have karstified preferentially the Reefal Unit; the Uppermost Miocene beds (Santanyí Limestone Fm.) having undergo only a passive behavior without evidences of significant karstification.

The age of the paleokarst development is difficult to establish with accuracy but its beginnings can be assumed presumably soon after the deposition of the Reefal Unit. Extensive growth of subjacent cavities must have continued at least until the Santanyí Limestone Fm. would be lithified in a certain degree, because deformation and even breakdown of the beds should be impossible as unconsolidated sediments. Progressive karstification during Pliocene and Pleistocene times cannot be disregarded.

3. COLLAPSE FEATURES

Deformation features of the Upper-Miocene beds are clearly related with the vicinity of the underlying Reefal Unit contact, as can be surveyed from the sea (figure 2a). In situ observations of the outcrops show a repeated similar pattern of collapse processes responsible for these deformations of the Upper Miocene levels, being near always characterized by the presence of funnel-shaped depressions as their most distinctive features. These bedding hollows are associated with setting subsidence of materials towards underlying voids developed in the Reefal Unit.

After careful examination of eighteen representative localities of such collapse structures some morphological and morphometrical data can be inferred. Morphologically three parts can be distinguished in the outcrops from base to the surface: 1) an irregular root-cavity located in the Reefal Unit and filled with subsident debris; 2) a generally narrow chimney without significant vault cantilever development; and 3) an overheading funnel shaped depression , always located in the Upper layers (Santanyí Limestone Fm.), that exceptionally are replaced by a confined area of fallen blocks localized where plastic deformation of the beds has been ineffective. In this manner, the collapse structure as a whole resembles a sandglass, but their upper cone becomes wider and gentler than the lower one. Only these funnel-shaped depressions are suitable for morphometrical analysis, certainly being the most conspicuous features in the sea cliffs. At the same time, they allow to the evaluation of the rock volumes involved in the paleokarst development.

The range of depression-diameters are usually between 25 to 90 meters, but some smaller collapse-features are less than 5 meters in width. Their depths are gauged from 3.5 to 14 meters. The side-dips of the depressions are comprised between 20° to 30°, but it increases near the inflexion of the beds where 45° to near vertical sides or even broken debris links gradually with the chimney part of the collapse structure.

Where in the littoral cliffs the Santanyí Limestone Fm. is present, only two-dimensional sections of the wide funnel-like depressions, nicely symmetrical and regular in shape, can be exclusively found (figure 2b). But, in some cases (specially where sea cliffs display good outcrops of the contact with the Reefal Unit), chimney-like voids appear located below the depressions and indicate vertical migration of plastic mangrove layers as well as subsidence of broken blocks and slabs from more resistent beds (figure 2c). It seems that the removal of support from underneath, due to the solution of the coral reef patches, should induced centripetal mass movement through localized weak points causing the development of narrow chimneys. They correspond upwards to the gentle funnel-shaped hollows. Finally, in other scarce cases, the downward migration of overlying materials as well as the adequate solutional growth of reefal voids below, have generated remarkable secondary cavities in the Upper Miocene levels great enough to the triggering of rigid breakdown processes. When these cavities occur, the funnel-depressions may be partially or totally disturbed and chaotic block piles -showing great interparticle porosity- can be found fulfilling the previous secondary cavities.

4. BRECCIA TYPES AND BRECCIA FORMATION PROCESSES

Breccia formation processes are related to solutional cavity collapses originating several breccia types resembling to those occurring in other karstic environments.

The types of karst breccias observed are dependent, both the genetical processes involved as well as the karst host rock features (Reefal Unit and/or Santanyí Limestone F.). Although there are several breccia types with minor variances, the more evident are collapse breccias generated by rock fall and by rock infilling.

Type A breccias, the first ones, are related with the breakdown of the upper levels (oolitic grainstones) of the Santanyí Limestone Fm.. The clasts, with sharp boundaries and varying in size -from few centimeters to more than one meter- show in some cases plastic deformation, and they are ever oligomictic. Normally there is any breccia matrix.

Type B. When the rocks involved in the collapse infilling are the lower levels of the Santanyí Limestone Fm. (mangrove facies), clasts present sharp to subrounded boundaries (with sizes no greater than few centimeters) and a breccia matrix formed by calcarenites to calcisiltites.

Type C breccias present Reefal Unit clasts of very variable size, ranging from centimeters to more than one meter. The clast boundaries are sharp to subrounded, and the presence of calcarenitic matrix is important.

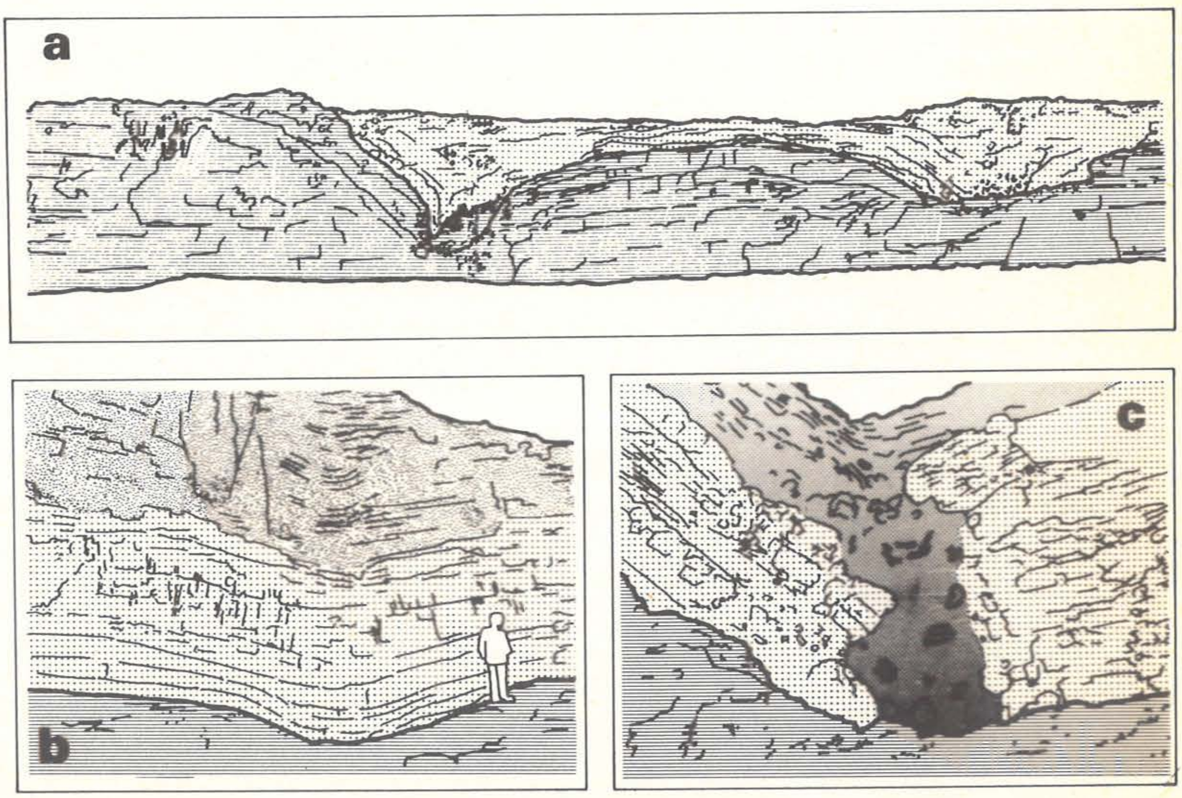


Fig. 2

All of this breccia types sometimes show the interparticle voids coated by calcium carbonate cement with several growth episodes.

In rare cases, red silts and clays make up the final cavity filling, that is not necessary to be contemporaneous with the breccia formation.

Type C breccias correspond to the breakdown of the karst host rock (Reefal Unit) after the void initiation and during the void development, while Type B breccias are related with the sedimentary infilling of a plastic collapse breakdown of the basal levels that cover the Reefal Unit. Type A breccias correspond to the sudden fragile breakdown of the upper levels of the Santanyi Limestone Fm. originated by the presence of underlying voids.

Breccia types described correspond to different stages in the evolution of karst collapses. The spatial distribution of these paleokarst features is directly related to the facies distribution, suggesting that coral patch reefs dissolution have controlled the starting and ulterior growth of cavities, which are finally responsible of paleokarst collapses described in this paper.

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Figure 1. Postorogenic Neogene Units outcroping in southern and south-eastern part of Mallorca.

Figure 2. Paleokarst collapse features in the Uppermost Miocene of Mallorca. a) Panoramic view from the sea; b) Funnel-like depressions in the Santanyi Limestone Fm.; c) Chimney-like voids infilled by subsident debris in the Santanyi Limestone Fm.

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PRELIMINARY STUDY OF THE CHEMICAL COMMUNICATION IN THE TROGLOBITE CATFISH PIMELODELLA KRONEI (RIBEIRO, 1907), FROM SOUTHEASTERN BRAZIL (SILURIFORMES, PIMELODIDAE)

TRAJANO, Eleonora

For vertebrate troglobites, chemical signals seem to play an important role in the social communication, which is involved in the reproduction and feeding.

Chemical communication was studied in the blind catfish, Pimelodella kronei, by means of a choice chambered apparatus with running water from aquaria containing conspecifics or pure water.

Social communication in P. kronei would comprise at least two kinds of chemical signals. Substances transported by water and perceived at distance would inform about the presence of conspecifics , but do not give detailed information on the sex or hierarchical position of the emitter. The response to these signals (attraction or repulsion) is variable. There would be also a chemical and/or mechanical signal, transmitted only after close proximity or contact, which allow individual recognition and leading the subordinate individuals to avoid the dominant ones. These substances probably adhere to the substrate, providing chemical marking of territories.

Olfaction is probably involved in this behaviour, and the pollution by detergents, which destroy the olfatory epithelium, could case serious disturbances in troglobite catfish population.

En los vertebrados troglobios, las señales químicas parecen de sempeñar un papel importante en la comunicación social, que está ligada a la reproducción y la alimentación.

Se estudió la comunicación química del bagre ciego Pimelodella kronei, mediante un aparato dividido en 2 cámaras recibiendo agua corriente de acuarios conteniendo ya individuos de la misma especie ya agua pura.

La comunicación social en P. kronei envolvería al menos dos tipos de señales químicas. Las substancias transportadas por el agua y percibidas a distancia informarían sobre la presencia de individuos de la misma especie, pero no dan información detallada sobre el sexo o la posición jerárquica del emisor; la respuesta a estas señales (atración o repulsión) es variable. Existiria también una señal química y/o mecanica, transmitida solo después de haber una gran proximidade o un contacto, que permitiria el reconocimiento individual y haría con que los individuos subordinados eviten los dominantes. Estas substancias probablemente se adhieren al substrato, marcando quimicamente los territorios .

El olfacto está probablemente relacionado con este comportamiento, y la polución por detergentes, que destruyen el epitelio olfativo, podría causar disturbios serios en las poblaciones de bagres troglobios.

INTRODUCTION

The recognition of conspecifics in total darkness is one of the problems faced by hypogean organisms. For cave vertebrates, chemical signals seem to play a central role in their social communication (Parzefall et al., 1980; Berti & Thinés, 1980; De Fraipont & Thinés, 1986).

Responses to chemical substances of conspecifics were studied in Astyanax mexicanus and Phreatichthys andruzzi (Characiformes) and Caecobarbus geertsi (Cypriniformes), which exhibit a generalized attraction to water coming from conspecifics (Berti & Thinés, 1980; Berti et al., 1982; De Fraipont & Thinés, 1986). Some variation related to sex, density of emitters, and previous experience was observed in the intensity or even in the response (attraction or repulsion), when the correlation between the response and the characteristics of both emitters and receivers of the chemical cues was studied, as in A. mexicanus and also the salamanders Proteus anguinus and Typhlomolge rathbuni (De Fraipont, 1987a,b; De Fraipont & Thinés, op. cit.; Parzefall et al., 1981; Bechler, 1986). P. anguinus requires body contact to recognize sex and hierarchical position (Parzefall et al., op. cit.).

Siluriforms are nocturnal, predominantly chemo-oriented fishes, clearly pre-adapted to the cave life. In the epigean American catfishes, Ictalurus spp., social communication, based on olfaction, allows the maintenance of pre-stablished hierarchy through individual recognition, the chemical memory lasting for four months (Todd, 1971).

The biology of the blind catfish, Pimelodella kronei, found in five caves from Southeastern Brazil, was studied by comparing them to their putative ancestor, P. transitoria. This study included their agonistic behaviour and response to chemical signals from conspecifics (Trajano, 1987). P. kronei is, like its ancestor, an aggressive, and territorial catfish (Trajano, op. cit.). They are expected to present a complex system of chemical social communication.

MATERIAL AND METHODS

Specimens of Pimelodella kronei were collected in the type locality, the Areias Cave, situated in the Upper Ribeira River Valley, SE Brazil (24° 35' S 48° 42' W), from 5 to 18 months before the tests on chemical communication. Eyed catfishes, P. transitoria, were collected in the Betari River Basin, tributary of the Upper Ribeira.

All catfishes were kept in darkness, isolated in (100 l tanks) or in pairs, each separated by a screen in (250 l tanks), in order to prevent continuous stress due to agonistic interactions. Observations were made under dim white light (15 lux at the water level), which does not stress the blind catfishes (Trajano, 1987).

Between January and June,1987, eight blind catfishes (5 males and 3 females) were individually tested as odor receivers in the choice apparatus shown in figure 1, which is a modification of the Y-labyrinth described in Barnett (1982). The other blind catfishes and one specimen of P. transitoria were used individually as signal emitters. Some tests were also done using as emitters rocks that were in the holding tanks, in order to do a preliminary study of the adherence of the chemical signals to the substrate.

The receiver catfishes were placed in the main aquarium 48 hs before the beginning of the tests. The control consisted of 60 or 70 min periods measured, by stopwatch, the times spent in the two chambers, both receiving pure water. Just after the control, the emitter was introduced at random in one of the receptacles. The tests started after a 60-90 min period, in order to stabilize the system. In each test, the time spent was measured in the choice chambers during a total of 100-120 min, distributed in 20 or 30 min per hour sessions; the time spent by the catfish in the connecting corridor was neglected. Each receiver & emitter pair was tested one time. Total number of tests was 56 P. kronei & P. kronei, 7, P. kronei & P. transitoria, and 6, P. kronei & rocks from P. kronei.

The results were evaluated statistically by the Wilcoxon's rank-sign test (Siegel, 1975). Parametrical test for the comparison of the variances of two populations was also applied (Daniel, 1978).

RESULTS AND DISCUSSION

The results are shown in figure 2. Blind catfishes were numbered according to their sizes, the latter being related with the hierarchical position: so, the individual n. 1 is the biggest and dominant over all the others and the n. 11 is the smallest and subordinate to the others (the specimens n. 5, 6, 9 and 12 died before the start of tests on chemical communication). The percentages of total time in the two choice chambers expressed as the differences between the times spent in the chamber receiving water from the emitter receptacle, respectively during the test and the control, are represented as percentages of the latter. Positive values mean attraction and negative ones mean repulsion.

Individuals of P. kronei do react to conspecific chemical signals transported by water. The fish behaviour usually changes after the introduction of the emitter: locomotory activity increases, inspection of the water outlets is frequent. The variance of the test times is significantly greater than the variance of the control times ($N=56$, $F=1,78$, $p<0.05$). Nevertheless, the response greatly varies, ranging from strong attraction to strong repulsion. In the set of blind catfishes, there doesn't seem to be a predominant kind of response to water transported substances, contrary to C. geertsi, P. andruzzi, A. mexicanus, and P. anguinus, which tend to polarize towards the water from conspecifics (Berti & Thinés, 1980; Berti et al., 1982; De Fraipont & Thinés, 1986; Parzefall et al., 1980).

In the case of P. kronei, some individuals displayed a generalized attraction to conspecifics: n. 4 ($N=7$, $T=0$, $p<=0.02$) and n. 7 ($N=7$, $T=0$, $p<=0.02$); others, a generalized repulsion: n. 3 ($N=7$, $T=0$, $p<=0.02$), n. 8 ($N=7$, $T=0$, $p<=0.02$), and n. 11 ($N=7$, $T=2$, $p=0.05$). The response varied from test to test for the three remaining catfishes: n. 1 ($N=7$, $T=8$, $p>0.05$), n. 2 ($N=7$, $T=5$, $p>0.05$), and n. 10 ($N=7$, $T=13$, $p>0.05$); the first two individuals showed some tendency to be more attracted than repelled by the conspecifics. These tests suggested complex social interactions, as in the Ictalurus spp. and the salamander T. rathbuni, to which the signal of response to water transported substances depends on several factors, such as previous experience and sex of both emitters and receivers (Todd, 1971; Bechler, 1986).

The sex and dominance relationships were analyzed trying to correlate the response signal to the characteristics of both emitters and receivers. Wilcoxon's test was applied to four groupings for the sex analysis: male receivers & female emitters ($N=15$, $T=46$, $p>0.05$); female receivers & male emitters ($N=15$, $T=56$, $p>0.05$); male receivers & male emitters ($N=20$, $T=83$, $p>0.05$); and female receivers & female emitters ($N=6$, $T=7$, $p>0.05$). There were no correlation between the signal of response and the sex of emitters and receivers. It can reasoned that either the chemical cues transported by water do not inform the sex of the emitter, as in P. anguinus, where the sex recognition depends on body contact (Parzefall et al., 1981); or, the reaction of blind catfishes to sexual signals transported by water is variable, depending mainly on other factors, such as size and previous experiences.

To study the agonistic behaviour (Trajano, 1987), the catfishes were paired off according to similar sizes. These pairings were done from a long time before the tests to just before the tests on chemical communication. So, in many cases, particularly that of individuals nearly equal size, emitters and receivers were known to each other and a dominance relationship already stablished. Since the P. kronei chemical memory of agonistic interactions seems to remain for 2-3 months (Trajano, op. cit.), Wilcoxon's test was applied to the group of known emitters and receivers which had their last encounter up to 3 months before the tests. It was not observed any correlation between the signal of response (attraction or repulsion) and the fact that the emitters were previously known ($N=11$, $T=26$, $p>0.05$).

I grouped these known individuals in two sets, and applied the Wilcoxon's test: emitters dominant over receivers ($N=6$, $T=3$, $p>0.05$), and emitters subordinate to receivers ($N=5$, $T=7$, $p>0.05$), in encounters accomplished less than 3 months before. There was no correlation between the hierarchical position of the emitter in relation to the receiver and the response signal of the latter. So, these aspects of previous experience - emitters being known, dominant over or subordinate to rêceivers in recent agonistic interactions, don't seem to determine the signal of response, attraction or repulsion, to chemical cues transported by water.

On the other hand, when allowed to get in touch, the subordinate individual recognized immediately the dominant one, avoiding it and taking the typical subordinate position at the top of the aquarium. The behaviour of the individual n. 2 was particularly illustrative: after the pairing with the individual n. 1, in which the latter was dominant after a long fight (140 min), ind. n. 2 was tested against the water from this ind. n. 1, reacting with attraction. But, when placed together, the ind. n. 2 avoided the n. 1 at the first touch, fleeing to the top of the aquarium, without any aggressive reaction. When paired with other individuals, the n. 2 engaged in aggressive interactions. These, and other data on the agonistic behaviour (Trajano, 1987), suggested the existence of a memory of the agonistic interactions in their near past, with individual recognition, at least by the subordinate fish (it is not clear whether the dominant recognizes the subordinate one), and all dependent on close proximity or even body contact.

If water transported substances does not inform on the characteristics of the emitters, the response to chemical signals from conspecifics will depend basically on the receivers (sex, age, gregariousness degree). As it can be seen in the figure 2, the eight blind catfishes form two size-related groups separated by some discontinuity between the n. 4 (standard lenght = 14,8 cm) and n. 7 (s.l. = 12,6 cm). Wilcoxon's test was applied to the two groups and it presented a tendency related to size. The four smaller individuals are significantly more repelled than attracted by their conspecifics, independently of the characteristics of the latter ($N=28$, $T=97$, $p=0.02$). For the four bigger ones, there was not a significant difference between the signals of response ($N=28$, $T=142$, $p=0.16$). Nevertheless, the Wilcoxon's T for this group is, in opposition to the smaller individuals group, the sum of the negative ranks, with near half the value of the sum of the positive ranks. So, big-sized individuals would tend to react more frequently with attraction than with repulsion to their conspecifics.

The correlation between the size of receivers and the signal of response is explainable when we consider the agonistic interactions in the cave habitat, which are relatively frequent (Trajano, 1987). Small individuals have more chances of meeting bigger ones and being chased away. A generalized repulsion could reduce the energetic cost of having to escape frequently. These chances decrease with growth, and the attraction to conspecifics may become advantageous, enhancing the probability to find sexual partners and food. The stronger attraction of A. mexicanus to larger groups than to smaller ones or isolated individuals is interpreted as an adaptation to the food-poor cave environment, as large groups would indicate a relatively abundant source of food (De Fraipont, 1987b). An increase of gregariousness in the bigger blind catfishes could favour their concentration in the slowmoving water, softbottom regions of the cave, where food is more abundant and where they could defend actively their territories (Trajano, op. cit.).

Other factors, such as sex and previous experience, could influence the response, specially of older individuals. For the larger group of blind catfishes, the females do not show a predominant response signal ($N=14$, $T=47$, $p>0.05$), but the males were significantly more attracted than repelled by their conspecifics ($N=14$, $T=6$, $p<0.01$). So, fully developed mature males tend to react positively to the water from conspecifics, a fact to increase the chances of finding sexual partners. These data support the assumption that attraction to conspecifics may be advantageous to larger individuals, for reproductive purpose, and suggest that, for P. kronei, the males play the most active role to locate sexual partners. On the other hand, it is very difficult to evaluate the role of all previous experience of the receivers considering chemical communication, since their individual history in the cave habitat is not known.

Character variability could also change their response to chemical cues. Other aspects of the behaviour of P. kronei, such as reaction to light and hiding habit, present individual variation, as well as morphological traits, like pigmentation (Trajano, 1987). Such a variability may be interpreted as a result of evolutionary tendencies in the making (Wilkens, 1986), P. kronei being considered a recent troglcoite (Thinès, 1969; Trajano, op. cit.). Character variability in the degree of gregariousness could account, at least in part, for the variation observed in the responses to water from conspecifics, and not related to size or sex. Some individuals could tend to be more gregarious (preferentially attracted by conspecifics), others, more solitary (repelled by conspecifics), and others, with intermediate behaviour. Evolution may lead to both tendencies of enhancing or

FIGURE 1

Choice apparatus used in the tests of reaction of P.kronei to chemical signals from conspecifics.

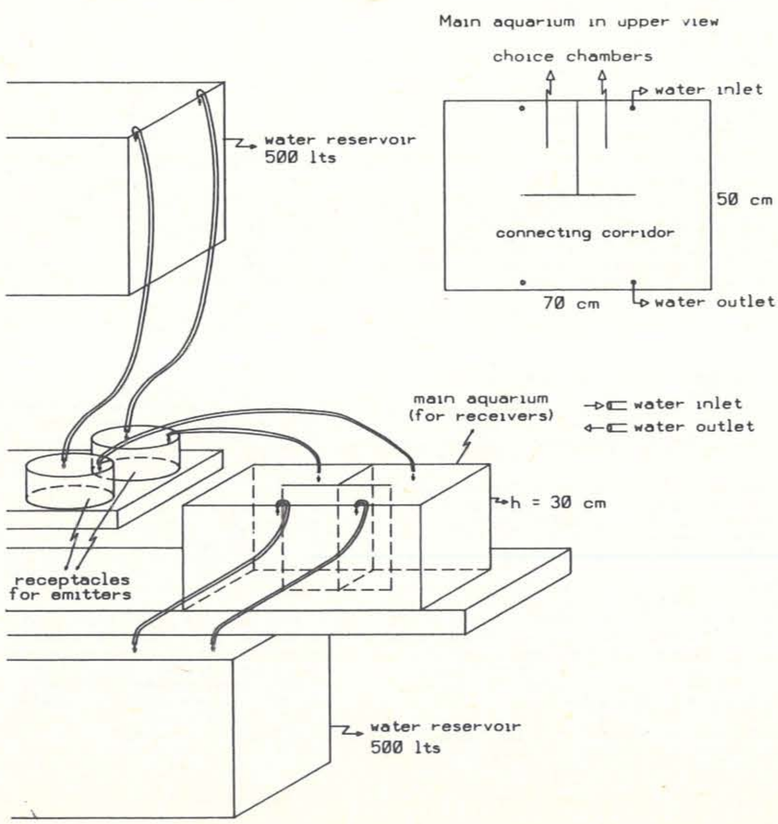
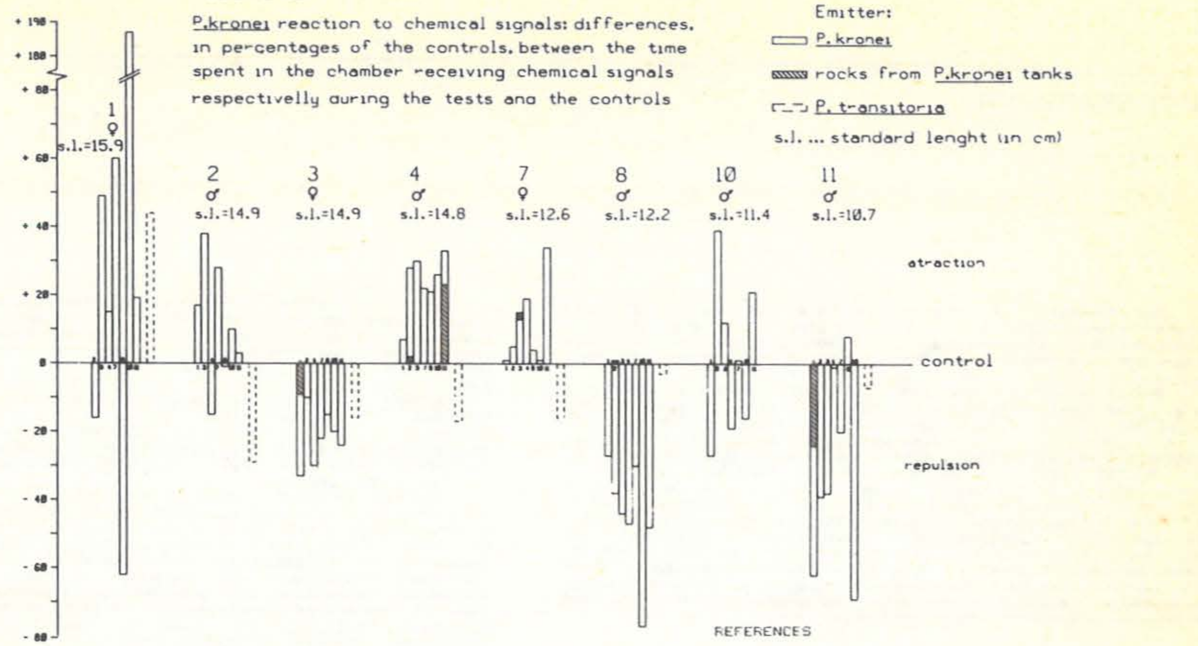


FIGURE 2

P.kronei reaction to chemical signals: differences, in percentages of the controls, between the time spent in the chamber receiving chemical signals respectivelly during the tests and the controls



reducing gregariousness. To test these two hypothesis, the response to chemical signals from conspecifics have to be studied in their putative ancestor (P. transitoria).

In conclusion, it is suggested that, like P. anguinus (Parzefall et al., 1981), the system of chemical communication in P. kronei comprises at least two kinds of signals, one functioning at distance and other dependent on close proximity or contact. Substances transported by the water and perceived at distance would inform about the presence of nearby conspecifics, but do not give detailed information on the emitters, thus not allowing individual recognition. The type of response to these chemical cues is variable, depending mainly on the characteristics of the receivers, such as size and sex, since most individuals reacted in the same ways (attraction or repulsion) to the substances from whatever were the conspecifics.

A second kind of signal, chemical and/or mechanical, would be transmitted only after close proximity or body contact, allowing individual recognition and leading the subordinate catfishes to avoid the dominant ones. One of its functions could be to maintain an established hierarchie without continuous fighting.

Although not conclusive or statistically significant (N=7, T=7, p>0.05), the tests using P. transitoria as emitters suggest that the distant chemical signalizer may be species-specific: except for the receiver n. 1, blind catfishes were repelled by the eyed one. This is particularly indicative in the case of the receivers n. 4 and n. 7, characterized by a generalized attraction to their conspecifics.

Tests using rocks from the holding tanks indicate that the chemical signals can adhere to the substrate. In five tests (receivers n. 2, n. 4 - two tests, n. 7, and n. 11), the response to substances from the rocks which were used as shelters by the emitters had the same signal as that of the response to the emitters themselves. In the sixth test (receiver n. 8 x rock from the n. 2), there was no response at all. These, and data on agonistic behaviour showing territorialism in P. kronei (Trajano, 1987), suggest chemical marking of territories.

In the catfishes, such as Ictalurus spp., chemical communication is based on olfaction (Todd, 1971). This is probably also true for P. kronei from Areias Cave, since the telencephalon tends to be more developed in this taxon than in P. transitoria, whereas the encephalic centers related to gustation are normally developed (Trajano, 1987). Which suggest that the olfaction may have a special importance for the blind catfishes. If that is the case, pollution by detergents, which destroy the olfactory epithelium, could seriously disturb the system of social organization, causing catastrophic damage to the blind catfish populations. Which being k-selected (Trajano, op. cit.), could have much difficulty in recovering from losses. This, and other kinds of pollution, are presently threatening several caves in the Upper Ribeira, including some where blind catfishes are found. At least in one case (Alambari Cave), it is possible that the blind catfish population has already been killed due to the pollution. Protective measures for these caves are in need not only for the blind catfishes, but for all the interesting fauna they support.

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FAUNA ASSOCIATED WITH BAT GUANO DEPOSITS FROM BRAZILIAN CAVES (A COMPARISON)

GRASPINI NETTO, Pedro

The diversity of feeding strategies in Neotropical bats offers an opportunity to compare three kinds of bat guano (that of insectivorous, frugivorous and hematophagous bats). This comparison is based on the survey of the taxa that have representative populations living in the guano.

Beside some taxa that occur in other substrates in caves (e.g. Oligochaeta, Diplopoda, Isopoda Oniscoidea, Collembola but Poduroidea, Ensifera Phalangopsidae), there are groups that seem to occur only in guano deposits (e.g. Collembola Poduroidea, Heteroptera but Reduviidae, Diptera Muscidae and Drosophilidae).

Whereas some of these taxa occur in more than one kind of guano, showing a low degree of selectivity, other seem to be restricted to certain types of guano. The last are exemplified by Chilopoda Lithobiomorpha, Isopoda Oniscoidea, Psocoptera, Ensifera Phalangopsidae (*Eidmanacris*), Heteroptera (Lygaeidae and Cydnidae), which have been found exclusively in frugivorous bat guano deposits; Collembola Hypogastruridae (*Acherontides* - great populations), Ensifera Phalangopsidae (*Endecous*), Diptera (*Fannia*, *Psilochaeta*, *Drosophila repleta*), in hematophagous ones; and Coleoptera Dermestidae, in insectivorous ones.

La diversidad de estrategias de alimentación en murciélagos neotropicales ofrece la oportunidad de comparar tres tipos de guano de estos animales (el de insectivoros, frugívoros y hematófagos). Esta comparación se basa en el levantamiento de los taxons que poseen poblaciones representativas viviendo en el guano.

Además de algunos taxons que ocurren en otros substratos en cavernas (como Oligochaeta, Diplopoda, Isopoda Oniscoidea, Collembola excepto Poduroidea, Ensifera Phalangopsidae), hay grupos que parecen ocurrir solo en depósitos de guano (tales como Collembola Poduroidea, Heteroptera excepto Reduviidae, Diptera Muscidae y Drosophilidae).

Algunos de estos taxons aparecen en más de un tipo de guano, mostrando un grado baso de selectividad. Otros parecen restrictos a determinados tipos. Este último grupo está representado por Chilopoda Lithobiomorpha, Isopoda Oniscoidea, Psocoptera, Ensifera Phalangopsidae (*Eidmanacris*), Heteroptera (Lygaeidae y Cydnidae), que fueron encontrados exclusivamente en guano de frugívoros; Collembola Hypogastruridae (*Acherontides* - grandes poblaciones), Ensifera Phalangopsidae (*Endecous*), Diptera (*Fannia*, *Psilochaeta*, *Drosophila repleta*), en guano de hematófagos; y Coleoptera Dermestidae, en guano de insectivoros.

INTRODUCTION

Bat guano is known as one of the most important sources of food in some caves. Some authors (e.g. Harris, 1970; Mitchell, 1970; Negrea & Negrea, 1971; Poulson & Culver, 1969), recognizing this importance, have studied the communities of cavernicoles that use bat guano as food supply.

Guano deposits vary according to the bat alimentary strategies. Bats that form guano deposits in Brazilian caves may me classified in three groups, according to what they feed on, and, of course, according to their feces.

Frugivorous. Their guano (F) may be constituted by little seeds not totally digested and big seeds with remains adhered. It has a particulate constitution.

Hematophagous. Their guano (H) is highly viscous and rich in nitrogenous compounds. Because of this it has a very quick fermentation.

Insectivorous. Their guano (I) is constituted by parts of insects and chitin remains. Its constitution is also particulate.

In Europe and USA there are basically insectivorous bats living in caves. So the works cited above study communities associated with insectivorous bat guano. There are in Brazil the three cited kinds. Then it can be noticed the great importance of the study of guano communities in countries like Brazil, where works can be done comparing the community structures associated to more than one kind of bat guano.

METHODS AND MATERIALS

Caves in different regions of Brazilian country were studied (see map 1), totalizing 21 caves. More than one type of bat guano deposits can be found in the same cave (F - 7 deposits analyzed from 5 caves; H - 19 deposits from 13 caves; I - 8 deposits from 8 caves).

The material was collected only in bat guano deposits with a surface area larger than 500 cm². It was noticed that smaller deposits are not good for the stablishment of animal communities, as did Holsinger & Culver (1988).

The collection was divided in three phases: a field sorting, in order to avoid a high mortality of specimens during transportation; a sorting at the laboratory; and, finally, the material collected was put through Tullgren/Berlese funnels. The samples were collected randomly, including material from the surface and from inside the dropping deposits.

The larvae collected were mantained in the laboratory in order to obtain the adults (that were used for identification). The specimens collected are stored at the "Departamento de Zoologia do Instituto de Biociências da Universidade de São Paulo".

RESULTS

Table 1 shows the relationship between taxa found and the three kinds of bat guano. This table includes data from Gnaspini Netto (1989), Trajano (1987) and new data from caves in Altamira region (Pará State).

Taxa	F	H	I
Oligochaeta	+	+	
Pseudoscorpionida	+	+	+
Opilionida Gonyleptidae	+	+	
Araneae Theridiosomathidae cf.	+		
Acarina	+	+	+
Isopoda Oniscoidea	+		+
Diplopoda	+	+	
Chilopoda Lithobiomorpha	+		
Collembola	+	+	
Psocoptera	+		
Thysanoptera			+
Ensifera Phalangopsidae	+	+	
Heteroptera	+		
Lepidoptera Tineidae	+	+	+
Diptera	+	+	+
Coleoptera	+	+	+

Table 1. Taxa registered in the analyzed bat guano deposits ((+) indicates occurence of the taxa in the specified bat guano deposit).

Due to the lack of specialists in many of the groups found, the identification was restricted in most cases to family level. This fact limited the comparison among the three kinds of bat guano.

Oligochaeta. Always populations with tens of specimens.

Pseudoscorpionida. Populations with few specimens (always less than 10, except for one deposit where there were more than 40). Perhaps an identification on genus level would lead to a better comparison among the kinds of bat guano.

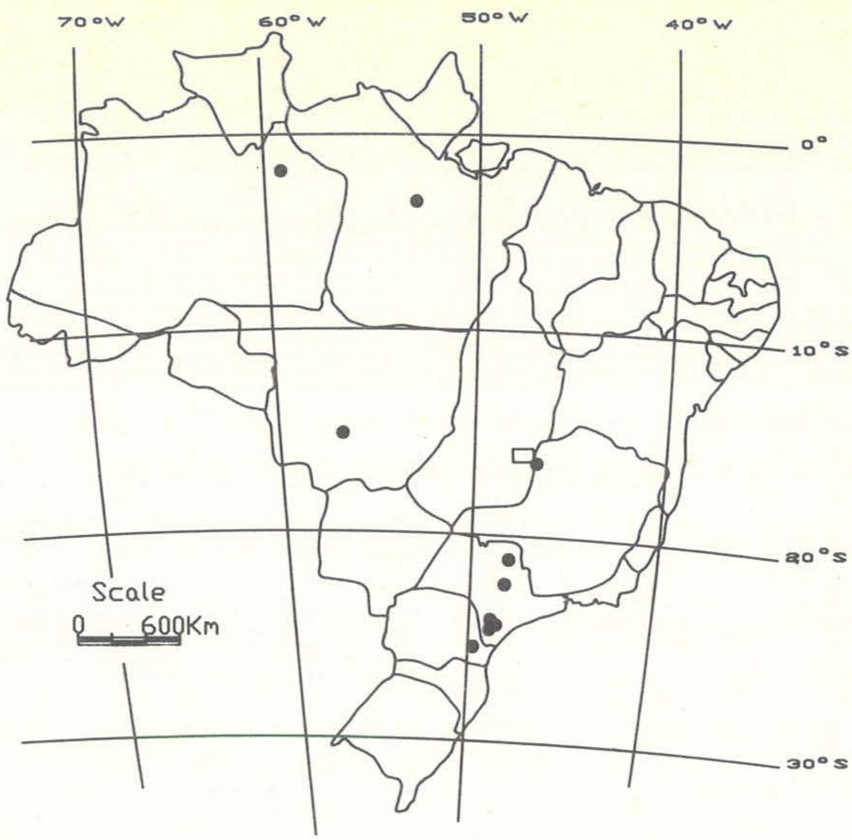
Opilionida Gonyleptidae. Few specimens feeding on guano, commonly only one specimen.

Acarina. Specimens of many families were found in the three kind of guano (see table 2). Due to the great diversity of mites associated with bat guano, a more detailed study of this taxon would present valuable data on the comparison of the three kinds of bat guano.

Isopoda Oniscoidea. Populations of tens of specimens, including juveniles and adults.

Diplopoda. Few specimens feeding on guano. Generally they are millipeds that are found commonly feeding on other substrata (dead and decaying organic matter, e.g. dead animals, dung).

Taxa			F	H	I
Acarina (undet.)			+	+	+
	Acarida	Acaridae (2 spp.)	+		
	Actinedida	Trombiculidae	+		
	Gamasida	Diartrophalidae	+		
		Eviphidiidae	+		
		Macrochelidae	+		
		Phytosseidae (2 spp.)	+		
		Polyaspidae (2 spp.)	+		
		Rhodacaridae	+		
		Macronyssidae		+	
		Haplomegistidae			+
		Laelapidae	+		+
		Uropodidae	+		+
	Oribatida	Gallumnidae	+		
		Oppiidae	+		



Map 1. Location of the visited caves in Brazilian country.

Table 2. Acarina associated with bat guano deposits.

Chilopoda Lithobiomorpha. Two populations of tens of troglomorphic specimens, including juveniles and adults, in (F), in two distinct caves. It is noteworthy that this is a taxon rarely found in caves in Brazil - only one pigmented specimen in plant detritus was found.

Collembola. Observed, always tens of individuals, in many deposits analyzed (see table 3). It must be noticed that there are some populations of thousands of specimens/m^2 of Acherontides sp. (Hypogastruridae), associated always with (H), in different caves.

Taxa		F	H	I
Entomobryoidea	Entomobryidae	+		
	Isotomidae	+		
	Paronellidae	+	+	
Poduroidea	Onychiuridae	+		
	Hypogastruridae	+	+	
Sminthuroidea	Arrhopalitidae	+		

Table 3. Collembola associated with bat guano deposits.

Ensifera Phalangopsidae. Very common in Brazilian caves, exclusively represented by the genera Eidmanacris and Endecous, which nevertheless are normally mutually exclusive. They were found also feeding on guano. It must be noticed, however, that specimens of the genus Endecous were found only on (H), while Eidmanacris were found only on (F).

Heteroptera. Populations with many specimens (always tens), including adults and nymphs. The Heteroptera are generally represented in Brazilian caves by specimens of Reduviidae (Zelurus spp.), but not in guano, where there are specimens of Lygaeidae or Cydnidae (observed in distinct caves).

Lepidoptera Tineidae. Many species occuring in many of the analyzed deposits, in the three kinds of bat guano. Except for one case in which adults were also present, there were always only larvae (kept in the laboratory) on the deposit.

Diptera. Observed in many of the analyzed deposits (see table 4). Generally there were not adults feeding on the droppings, except for Drosophila aff. repleta (Drosophilidae). Worthy of mention are the families Muscidae (genera Fannia and Psilochaeta), Phoridae, Milichiidae and Drosophilidae, the individuals of which may form great populations. The presence of Scenopinus fenestralis in (I) is without doubt related to the presence of larvae of dermestid beetles, which are its prey.

Taxa		F	H	I
Drosophilidae	(Drosophila aff. repleta)		+	
Muscidae	(Fannia spp. and Psilochaeta spp.)		+	
Milichiidae		+	+	+
Phoridae			+	+
Scenopinidae	(Scenopinus fenestralis)			+
Sphaeroceridae			+	
Stratiomyidae	(Hermetia ilucens)	+		

Table 4. Diptera associated with bat guano deposits.

Coleoptera. Few larvae and adults were found, including guanophagous and predators, in the three kinds of guano (see table 5). Great populations were formed by larvae of Dermestidae beetles (in (I)), and by adults and larvae of Leiodidae Catopinae beetles (in many deposits).

Taxa		F	H	I
Dermestidae	(larvae)			+
Histeridae				+
Lampiridae	(larvae)		+	
Leiodidae	Catopinae	+	+	+
Pselaphidae		+	+	
Scarabeidae	Aphodiinae	+	+	+
Staphylinidae		+	+	+
Tenebrionidae	Aleculinae			+

Table 5. Coleoptera associated with bat guano deposits.

The taxa listed above are similar to those presented as commonly associated with bat guano deposits in other countries (Ginet & Decou, 1977; Matile, 1970; Negrea & Negrea, 1971).

In the present study, Acarina, Collembola, Diptera and Coleoptera were found with high frequency in the analyzed deposits. The same was observed by Negrea & Negrea (1971), who defined them as "constants", in caves of Romania. Pseudoscorpionida and Lepidoptera Tineidae also occured with high frequency.

DISCUSSION

Restriction to guano deposits

Some taxa that were associated with bat guano deposits also were associated with other substrata in caves, and are generally more abundant in these other substrata. These taxa are Oligochaeta, Diplopoda, Isopoda Oniscoidea, Pseudoscorpionida, Opilionida, Collembola Entomobryoidea, and Ensifera Phalangopsidae.

However, there are other taxa that are most frequently or even exclusively found associated with bat guano deposits inside caves. They are:

Chilopoda Lithobiomorpha. Many troglomorphic specimens associated with bat guano against only one specimen in detritus.

Collembola Hypogastruridae (Acherontides sp.). Thousands of specimens associated with bat guano and very rare in other substrata.

Heteroptera Lygaeidae and Cydnidae. Exclusively associated with bat guano.

Lepidoptera Tineidae. Larvae frequently observed in guano deposits and rare on other substrata.

Diptera Drosophilidae and Muscidae (larvae). Exclusively associated with bat guano.

Coleoptera Dermestidae. Exclusively associated with bat guano.

Coleoptera Leiodidae Catopinae. Although few adults are found on other substrata, It was assumed that they were related to guano because they form great populations on guano deposits and because larvae were found only associated with bat guano deposits.

Relation between taxa and bat guano

From the tables presented above it can be noticed that some taxa can be used for comparing the three kinds of bat guano. Among them, some are restricted to one kind of guano, showing an affinity to this substrate. However, others occur associated with all kinds but one, hence showing not an affinity but an avoidance to one kind of substrate. Anyway, both types of relationships are good to determine that microclimatic and nutritional differences do exist among the substrata.

Taxa restricted to frugivorous bat guano:

Chilopoda Lithobiomorpha. Great populations, including juveniles and adults, found in distinct caves.

Acarina Acaridae, Trombiculidae, Diarthrophallidae, Eviphididae, Macrochelidae, Phytoseiidae, Polyaspidae, Rhodacaridae, Gallumnidae, and Oppiidae.

Collembola Arrhopalitidae, Entomobryidae, Isotomidae, and Onychiuridae. Tens of specimens.

Psocoptera. Few specimens.

Ensifera Phalangopsidae (Eidmanacris)

Heteroptera Lygaeidae and Cydnidae. Great populations, including adults and nymphs, found in distinct caves. Specimens of two species of Lygaeidae were found living in the same guano deposit.

Diptera Stratiomyidae. Few larvae.

Taxa restricted to hematophagous bat guano:

Acarina Macronyssidae.

Collembola Hypogastruridae. Although few specimens on frugivorous bat guano were found, it was assumed that they were restricted to hematophagous bat guano, because they form very big populations (thousands of specimens) on this substrate.

Ensifera Phalangopsidae (Endecous)

Diptera Drosophilidae, Muscidae and Sphaeroceridae. Populations of tens of larvae of Fannia spp. and Psilochaeta spp. (both of them could be found in the same guano deposit); few specimens of Drosophilidae (Drosophila aff. repleta) and Sphaeroceridae.

Coleoptera Lampiridae. Few larvae of different ages. It must be noticed that there were not any other "big" arthropod nearby, then they might be feeding directly on the bat guano.

Taxa restricted to insectivorous bat guano:

Acarina Haplomegistidae.

Thysanoptera. Only one specimen. This taxon is very rare in caves.

Diptera Scenopinidae. Larvae feeding on dermestid beetles larvae.

Coleoptera Dermestidae, Histeridae. Tens of larvae of Dermestidae and few adults of Histeridae.

Taxa that avoid frugivorous bat guano:

Diptera Phoridae.

Probably, these insects need lots of decaying matter, which is found in hematophagous and insectivorous bat guano, but is very rare in guano of the frugivorous bat. This might perhaps explain their absence in the last type of guano.

Taxa that avoid hematophagous bat guano:

Acarina Laelapidae and Uropodidae.

Isopoda Oniscoidea. Tens of specimens, including juveniles and adults.

This absence might be due to the very viscous nature of this kind of bat guano (contrary to the very particulate constitution of that of frugivorous and insectivorous bats), which could impair the mobility and even the survival of some taxa.

Taxa that avoid insectivorous bat guano:

Oligochaeta.

Opilionida Gonyleptidae.

Diplopoda.

Collembola. It is a very unexpected result.

Ensifera Phalangopsidae.

It is difficult to explain the absence of Oligochaeta and especially that of Collembola in the deposits analyzed. If they were present, they were missed when sampling and/or sorting the deposits.

CONCLUSIONS

From the above data, we can state that there is a clear relation (positive or negative, depending on the case) between the kind of bat guano and the communities associated with it, specially regarding some taxa. Additional data from new collection could clarify some suppositions and define better these relations.

As there is a relationship between the kind of bat guano and the associated taxa, and as Brazil is one of the few countries where there exist the three kinds of bats (frugivorous, hematophagous and insectivorous), and where one can develop works on the cited taxa, we must emphasize the necessity of protecting Brazilian caves against the predatory and destructive activities, which are presently destroying our caves.

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KARSTIFICATION OF COVERED PALEOKARST SURFACES DEPEND ON UNCOVERING

VERESS, Márton

In the Bakony - mountain /Hajog-Papod group/ the surfaces are constructed of Middle Cretaceous and Jurassic limestones. The surface are dissected by paleokarst uplifts and are significan y covered by unconsolidated sediments.

Erosion /or accumulation/ of these unconsolidated covering sediments result the migrating of rock-line and so the migrating of karstification as well, in the sides of paleokarst outlifts.

By observing of drilling cores and geomorphology we can typify the uncovered types which occur on horsts and the karstification itself belonging to these.

FEDETT PALEOKARSZTOS TÉRSZINEK KITAKARÓDÁSTÓL FÜGGŐ KARSZTOSODÁSA

A Bakony-hegységben /Hajag-Papod csoport/ a középső-kréta és júra korú mészkövekből felépitett paleokarsztos kiemelkedésekkel tagolt térszinek jelentős részben laza anyagokkal fedettek.

A laza fedőüledékek lepusztulása /vagy felhalmozódása/ a kőzethatár és igy a karsztosodás vándorlását eredményezi a paleokarsztos kiemelkedések oldalában. A fúrási és morfológiai megfigyelések segitségével tipizáljuk a rögökön előforduló kitakaródási tipusokat és az ezekhez tartozó karsztosodást.

I. KARSTIFICATION OF COVERED PALEOKARSTIC RELIEFS

In Bakony-Mountain /Dunántuli Block-Mountains/ the surface of the Middle-Cretaceous and Jurassic limestone blocks dissected by faults is a paleokarstic relief with protrusions - Hajag-Papod Mountain group area /Fig. I./ The loose deposits /pebble, clay, silt/ covering these reliefs of different heights can become redeposited. This process takes place inside the block /the block lurched/ or between the blocks /from the higher one to the lower one/. As the blocks were ascending and descending erosion and deposition could alternate on the same block.

In the case of erosion or filling up limestone protrusions rise over the relief covered by loose deposits. The rock-boundaries at the crossings of limestone protrusions and covered reliefs are the spots of karstification. Rainwater on covered reliefs reaches limestone at protrusions. Therefore recent karstification takes place on paleokarstic protrusions.

This karstification has the following characteristics:

-Karst phenomenons developed at rock-boundaries /when non-karstic reliefs are formed by impermeable deposits/ are termed sink-holes and swallet-dolines /when non-karstic reliefs are formed by permeable rock/. The swallet-doline /Veress, M. I982/ is a doline possessing a water channel and no separate and own catchment area. Namely it does not get enough water from surrounding reliefs covered with permeable rock. Infiltration can take place in a wide zone on reliefs covered with permeable silt /hidden rock--boundary/ so karstification developes also on a big area. As the silt becomes more and more argillaceous new and new karstic formations appear getting more and more water. It's sink-hole nature becomes more and more typical. When the impermeable rock appears by the erosion of the **silt the** karstic features undergo a transformation and new ones become sink-holes.

-Erosion or deposition of top sediments on a certain area results in shift of rock-boundaries downwards and upwards in the slopes of protrusions. In the first case inactive sink-holes, remnants /passages/ of sink-holes and in the second case filled up, buried karstic depressions mark the former rock-boundaries.

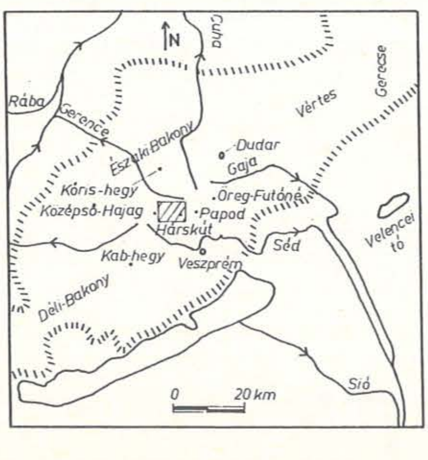


Fig. I. Investigated area
I. Mountain-boundary, 2. Water-course, 3. Peak, 4. Settlement 5. Examined area,

2. KARSTIFICATION FOLLOWING UNCOVERING TYPES

Mapping recent active karstic features and revealing the already inactive ones /drawing maps of covered bedrock using results of boring/ and comparing them to non-karstic formations some uncovering types followed by well confinable specific karstification can be discriminated on the surface of blocks. The nature of uncovering is determined by the size, the relative height, the location of the block and the morphology of it's relief.

2.I. Uncovering of a block of horizontal position

There is no river system on the surface when the block is of a small size. However erosion caused by the redeposition of top sediments is inhibited by the protrusions of the paleokarstic relief. Karstification begins at the top level of the protrusions of a bigger height when top sediments are permeable /hidden rock-boundary/. The height of protrusions decrease by karstification. It is followed by the erosion of top sediments so karstification can begin on a new protrusion of a lower top level. Therefore settlement of karstic features on the surface of the karstificating blocks is irregular so formations are small in size or filled up or become quickly inactive or more or less eroded.

If the block has large surface water courses may appear. The direction of valleys formed by water courses can correspond to the direction of the elongated and buried protrusions, rows of protrusions, or are perpendicular to that.

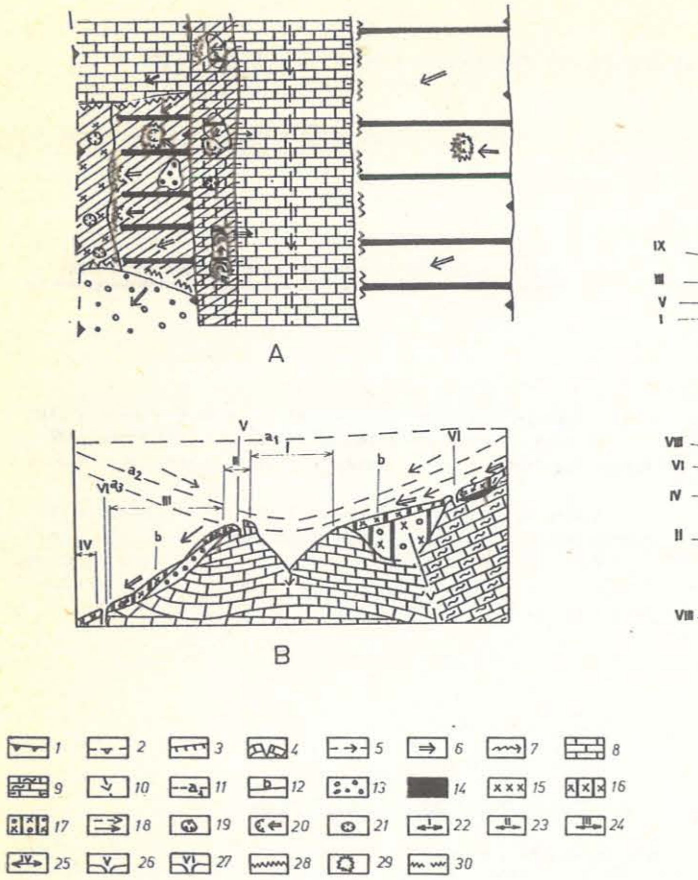
Therefore valley can develop in the loose material over the protrusions or between them. In both cases rows of karstic features appear along the axis of the valley.

When the valley deepens into the loose material covering the protrusions /Fig.2./ the rock-boundary appears at the top levels of protrusions. Karstic formations developed along the boundary line become inactive and only their stubs remain in the limestone because their catchment area is lost by the erosion of the loose material covering the slopes of protrusions.

The rock-boundary appears in the hillside of the valley and the protrusions when the valley sinks into the loose material between the protrusions. Gradual erosion of top sediments remained on the ridges between the valleys results in the shift of the rock-boundary in the hillside of the valley. Accordingly new and new karstic features can develop over the rows of karstic phenomenons becoming inactive.

The valley can develop perpendicular to the axis of protrusions as well. /Fig. 3./ In the previous case the karstification takes place on the top level of the protrusion cropping out at the valley--bottom. The catchment area of the karstic feature described above is represented by the area between the karstic formation and the valley-head.

/Karstification can begin at several spots of the valley-bottom when new protrusions are exposed./ Rock-boundary sinks lower and lower in the hillside as the material of the valley-bottom is transported into the karstic depressions. This results in formation of new karstic features. The denudating protrusions do not tower over their surroundings as their height dicreases because of recurring karstification. Karstic features appear in single or in groups on the valley-bottom. /The youngest one alone is active of the same group./



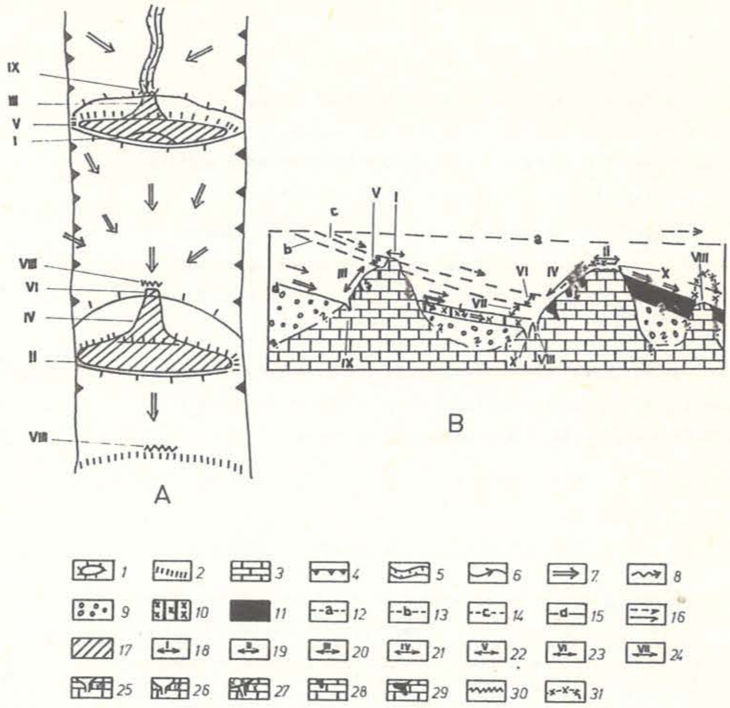


Fig. 2. Karstification on protrusions under the valley and along the axis of the valley /after the example of Hidegaszó-valley/ I. Hillside of a valley developed in loose sediment, 2. Former hillside of a valley developed in loose sediment, 3. Hillside of a valley developed in limestone, 4. Anticline valley from side-view, 5. Intermittent water-course, 6. Stream on the surface and over the impermeable layer, 7. Infiltration, 8. Upper-Jurassic limestone, 9. Middle--Cretaceous limestone, I0. Presumed fault, II. Former levels of pebble-cover /a_I; a_2; a_3/, I2. Recent surface, I3. Pebble, I4. Clay, I5. Silt, I6. Clayey silt, I7. Derived pebble, clay, silt mixture, I8. Former and recent resedimentation of top sediments, I9. Inactive sink-hole from top--view, 20. Swallet-doline from top-view, 2I. Collapsing doline, 22. Zone of totally desolated sink-holes, 23. Zone of inactive sink-holes and swallet-dolines, 24. Zone of swallet-dolines, 25. Zone of collapsing dolines, 26. Inactive sink-hole cave from side-view, 27. Active swallet-doline from side-view, 28. Rock-boundary, 29. Hidden rock-boundary, 30. Non-active rock-boundary A. top-view, B. side-view

Fig. 3. Karstification on denudating limestone protrusions perpendicular to the axis of the valley /after the example of the valley of sink-hole K_I and Klein-pusztai valley/ I. Limestone protrusion, 2. Boundary of the top level of the limestone protrusion, 3. limestone, 4. Hillside of the valley, 5. Sink-hole channel, 6. Water-course, 7. Stream on the surface and over the impermeable layer, 8. Infiltration, 9. Pebble, I0. Argillaceous silt, II. Clay /derived argillaceous silt, weathering products etc./, I2. Level of former pebble-cover, I3. Previous valley--bottom before silt-cover, I4. Former level of silt-cover, I5. Recent surface, I6. Former and recent resedimentation of top sediment, I7. Karstificated zone from top-view, I8. Zone of dissolved dolines, I9. Zone of collapsing dolines, 20. Zone of inactive sink-holes, 2I. Zone of inactive sink-holes and collapsing dolines, 22. Zone of inactive swallet-doline and collapsing dolines, 23. Zone of inactive swallet-dolines /former fossilized sink-holes/ 24. Zone of inactive swallet-dolines, 25. Active swallet--doline, 26. Active sink-hole, 27. Hidden sink-hole formation, 28. Choked water passage from side-view, 29. Fossil /filled up/ karstic depression from side-view, 30. Recent rock-boundary, 3I. Former surface of limestone eroded by karstification A. top-view, B. side-view

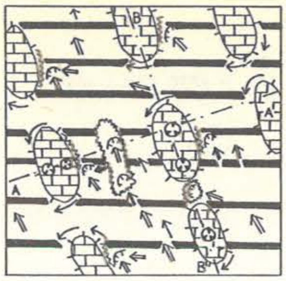
2.2. Uncovering of lurched blocks

Blocks can lurch in one or two directions. In the previous case protrusions form adjacent parallel ranges with longitudinal covered reliefs of a similar direction between them. Karstic phenomenons appear in rows on these protrusions where top sediment becomes thin. When a block is lurched in two directions /Fig. 4./ erosion of top sediments takes place also in two directions. Therefore protrusions crop out from the covering. There are covered reliefs dropping down towards the dip directions between the rows of protrusions. At the lower ending of the above karstic formations karstic formations develop the characteristics of which are considerably determined by covered reliefs. Development of small swallet-dolines is characteristic when the covered relief is of a small size and the majority of rainwater infiltrates before the rock-boundary. On such blocks new and new karstic depressions appear downwards in the hillside as a result of the erosion of top sediments. Karstification can begin at new and new places by the thinning of top sediments over protrusions inside covered reliefs /hidden rock-boundary/.

DISCUSSION

Remnant reliefs of former karstification process /positive formations/ karstificate along rock-boundaries since precipitation water flows to rock-boundaries on top sediments covering paleokarstic formations.

Uncovering of blocks with paleokarstic surface has different types that are followed by characteristic karstification.



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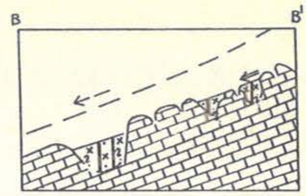

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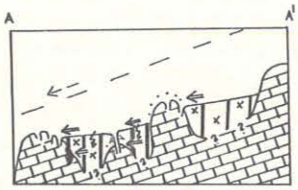

Fig. 4. Uncovering and karstification of protrusions of blocks lurched to two directions
I. Limestone protrusion, 2. Stream on the surface and over the impermeable layer, 3. Infiltration, 4. Former and recent resedimentation of top sediments, 5. Sections, 6. Middle--Cretaceous limestone, 7. Former level of silt-cover, 8. Silt with argillaceous laminated sandy intercalations, 9. Passages of former swallet-dolines and sink-holes from top-view, IO. Former surface of limestone eroded by karstification, II. Passages of former swallet-dolines and sink-holes from side-view, I2. Fossil /filled up/ karstic depressions, I3. Rock-boundary, I4. Hidden rock-boundary, A. top-view, B. side-view

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STUDIES ON ROVE BEETLES (COLEOPTERA, STAPHYLINIDAE) IN THE CAVES IN BULGARIA

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In the paper a great attention has been paid to the components of the Bulgarian rove beetle cave fauna, the locations and zoogeographical statute of the single kinds. Some data about the biology of the often met kinds are supplied. A survey of the known papers on the subject has been made. Expectations on eventual results of further profounds examinations on the subject are shown.

Исследования стафилинидов (Coleoptera, Staphylinidae) найденные в пещерах Болгарии

Иван М. Райчев

резюме

В докладе главное внимание обращается видовому составу болгарской стафилинидной пещерной фауны, местонахождения и зоогеографскии статут отделных видов. Говорится о некаторых данных биологии и экологии, каторые чаще всего встречаются. Делается обзор известной вышедшей до сих пор литературе по данному вопросу. Намечаются перспективы о евентуалных результатах на дальнейшие научные исследования в этом направлении.

The rove beetles are coleoptera, ordo Coleoptera, subclass Polyphaga of class Insecta (Invertebratae). In the last few decades there has been a consistent interest in them in many countries throughout the world. The different aspects of their biology and ecology as well as their genus diversity have been the object of investigation. As far as it concerns their genus diversity the cave coleoptera fauna represents a great interest. This is due to the fact that some of the rove beetles are apterous. Also the caves with their comparatively stationary living conditions are rather specific. This leads to the springing up of endemic forms especially of the species of genus Quedius and subfamily Aleocharinae.

Unfortunately the cave rove beetles are barely investigated not only in Bulgaria but in the whole world as well. The difficult penetrating into the caves and the difficulties arising with the collecting of the rove beetles are the probable main reasons for this.

For the first time we find information for the cave rove beetles in the Bulletin of the Bulgarian Society of Entomology, v. X, 1939, p. 153-154 where Burech I. in "Rapports et communications" reports 7 species as follows:

1. Philonthus cephalotes Grav. - Pirin, cave Kotela, 28.IX.1924, leg. Burech; cave Haidushcata peshtera, 1939, leg. Burech.
2. Ph. sordidus Grav.-Pirin, cave Kotela, 28.IX.1924, leg. Burech.
3. Gabrius nigritulus Grav. - Pirin, cave Kotela, 28.IX.1924, leg. Burech.
4. Quedius mesomelinus Marsh. - Pirin, cave Kotela, 28.IX.1924, leg. Burech; the precipice Ponora, near the town of Kotel, 9.VIII.1924, leg. Radev N.; cave of the vill. Beliakovetz, /Veliko Tarnovo/, 9.VIII.1928, leg. Tuleshkov.
5. Q. cinctus Payk. - cave Ponora, near the town of Kotel, 30.IX.1924, leg. Radev N.
6. Aleochara (Polychara) diversa Grav. - Pirin, cave Kotela, 28.IX.1924, leg. Burech.
7. Atheta spapaea Erâch. - cave Goliamata Podlistza /Velico Tarnovo/ 9.V.1928, leg. Tuleshcov.

There hasn't been been published data for the rove beetles from the caves in Bulgaria long after that. Only in "Essai sur la faune cavernicole de Bulgarie" - V.Gueorgiev, P. Beron, 1962-I; Beron P., Gueorgiev V., 1967-II and Beron P., 1972-III report 11, 8 and 12 species respectively, some of which are repeated in two of the publications.

During the investigations of the fauna in some caves in Bulgaria in the last few years, the following species were established (all leg. Borislav Garev, det. Ivan Raitschev).

1. Metocypus globulifer Geoff. - the Balkan range, reservation Northes Dzendem, recess the White wall, 4.IV.1984, 1 ex.
2. Philonthus pachycephalus Nordm. - vil. Resseletz, cave Temnata dupka, 20.I.1984, 2 ex.; vil. Musselievo, cave Nanin kamak, 12.X.1986, 4 ex.; vill. Sadovetz, cave Gininata peshtera, 19.X.1986, 6 ex.
3. Quedius (Microsaurus) ochripennis Menet. - cave Ovnarcata, near Karlukovo, region Zadanen dol, 20.I.1984, 2 ex.
4. Q.(M.) mesomelinus Marsh. - cave Svirtschovitza, near Karlukovo, 31.III.1984, 8 ex.; cave Haidushkata peshtera, vil. Devintzi, 17.V.1984, 4o ex.; cave Vodnata peshtera, 20.I.1986, 3 ex.; cave Gininata peshtera, near the of vil. Sadovetz, 19.X.1986, 2 ex.
5. Q. (Distichalius) punctatellus Heer. - cave Vodnata peshtera, near the vil. of Bochot, 29.VI.1984, 1 ex.
6. Neobisnius procerulus Grav. - cave Gininata peshtera, around the vil. of Sadovetz, 19.X.1986, 1 ex.
7. Atheta pilicornis Grav. - cave Vodnata peshtera, around the vil. of Bochot, 22.IV.1984, 26 ex.; cave Nanin kamak, vil. Museliavo, 12.X.1986, 3 ex.; cave Gininata peshtera, 19.X.1986, 6 ex.

After all these reports and investigation the catalogue of all known cave rove beetles in Bulgaria is:

(notes of the author - Philonthus sordidus Grav. = Ph. pachicephalus Grav.)

Fam. Staphylinidae

I. subfam. Staphylininae

1. Metocypus globulifer Geoff.
2. Gabrius nigritulus Grav.
3. Philonthus cephalotes Grav.
4. Ph. fimetarius Grav.
5. Ph. politus L.
6. Ph. pachicephalus Grav.
7. Neobisnius procerulus Grav.
8. Quedius (Microsaurus) fulgidus F.
9. Q. (M.) mesomelinus Marsh.
10. Q. (M.) ochripennis Menet.
11. Q. (Distichalius) cinctus Payk.
12. Q. D.) punctatellus Heer.
13. Q. (Sauridus) troglophilus Coiff.
14. Q. (S.) Gueorgievi Coiff.
15. Q. (S.) obliteratus Er.
16. Medon fusculus Marsh.
17. Paederus litorallis Grav.

II. subfam. Aleocharinae

18. Aleochara (Polychara) diversa Grav.
19. Al. (s.str.) sulcifrons Steph.
20. Atheta (Xenota) macroptera Bernh. var. dinarica J./J.
21. At. (Megistra) gramenicola Grav.
22. At. (s. str.) spalaea Erich.
23. At. trinotata Kr.
24. At. pilicornis Grav.
25. Platystetus arenarius Fourc.

Two from all these 25 species (13, 14) are endemic for Bulgaria and 5 species (marked in the catalogue with an asterisk) are recorded for the first time for the cave fauna in Bulgaria. Having in mind the great number and variety of the caves in Bulgaria we consider that the investigations could proceed successfully as far as it concerns the species from subfamily Aleocharinae which are comparatively difficult for defining.

We hope that the collaboration of the Cave Club and section Nature in the Historical Museum - Pleven will lead to considerable results in near future.

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THE MEASUREMENT OF KARST DENUDATION IN XIZANG (TIBET) AND ZHEJIANG, CHINA

ZHANG, Shouyue

ABSTRACT

The long-term observation of karst denudation for international comparative study by means of standard tablets was conducted in Xizang(Tibet) and Zhejiang.

The preliminary results are shown in the list.

Solutional lost of limestone tablets

Position	Xizang(Tibet) Lost(10^{-3} x mg/cm^2/day)	Zhejiang
1.5m above ground	0.52	12.02
Ground surface	-0.01	4.88
0.5m below ground	0.92	9.32

According to the documents of China and international comparative study, the influences of climatic zonality in latitude and altitude and soil cover on karst denudation are discussed.

The session of the Commission of Karst Denudation during the 7th International Speleogical Congress in Sheffield 1977 decided to carry out the joint research of solution in different environments in the world. The preliminary report of some collaborators is published. They are only some essential data. It is too early to come to the conclusions (Gams, 1981).

In China, the measurement of karst denudation has been done in Xizang (Tibet) Plateau and Zhijiang province near the East China Sea.

Many thanks for Prof. I. Gams providing the standard tablets.

RESULTS AND DISCUSSION

The preliminary results are shown in the table.

LOCATION, ALTITUDE	DAYS OF EXPOSURE	NUMBER OF TABLETS	POSITION (cm)	LOSS (10^{-3} $xmg/cm^2/day$)	PRECIPITATION IN EXPOSURE (mm)
Lhasa, XIZANG (TIBET) 3649 m	1080	3	+150	0.52	949
		1	0	0.27	
		3	-50	0.92	
Tonglu, ZHIJIANG 45 m	914	3	+150	12.02	4152
		3	0	4.88	
		3	-50	9.32	

1. Tonglu, Zhijiang belongs to subtropical humid climatic zone and southeast moonsoonal region.

Lhasa, Xizang (Tibet) is situated in the Qinghai-Tibet Pleatau arid climatic zone. The topography affects climate in the altitude of the Plateau.

Loss in wight of the standard tablets is widely different in various climatic zone. The loss in wight in humid climatic zone is higher than 10 to 20 times that in arid climatic zone. The lowest loss in wight is the tablet on the surface.

2. In humid climatic zone, the solution of tablets above the surface is the highest and higher than 2.5 times that on the surface and 1.3 times that in the soil.

3. In arid climatic zone, the solution of tablets in the soil is the highest and higher than 3.4 times that on the surface and 1.8 times that above the surface.

4. The difference of the solution of tablets in the soil between humid and arid climatic zones is less than that on the surface and above the surface between humid and arid climatic zones.

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SIMULATION TEST FOR DEVELOPING MODEL ON CAVE SYSTEM

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ABSTRACT

Caves, the most important underground karst form, has a complex process in its growing and development with comprehensive effect by a number of factors. It is of significane to reproduce the formation of a cave system by simulating test in lab. so as to discuss the basic rule of karst and direct the exploitation and utilization for underground water resources.

A testing device which can be changeable in size and can dismantle freely has been designed, including model system, hydraulic system and measurement system.

The geological model is made of gypsum and salt with different proportion. Made a model according to different geological structure and hydrogeological texture or other factors, the model laied into the device has an adjustable water head and flow by hydraulic system.

A series of observation, measurement, recoreds and composition in solvent can be taken from the beginning to the end of the test.

The model with different growing degree in the fracture and hydrogeological texture have been carried out and attained some results.

One work of great importance to the deepening of cognition on the karstification and its distributed regulation, the valuation and development on ground water and cave resources is to show directly the karstic formation, evalution and distribution in a geological body through simulating test.

A set of testing device has been designed and preliminary results have been obtained.

1. TESTING DEVICE

The main part of device is a corrosional trough. (Figure 1) It consists of cistern for supplying water, model room for infiltrating and drain trough for flowing out water.

The corrosional trough is made of organic glass with 1 cm in thickness, so as to be considered the bearing weight of geologic model and to be easily observed the corrosional phenomena. It can also be disessembled freely for adapting different size of model, but keep it sealed, never leak out the water.

2. TESTING METHOD

2.1. Model

The geological model is a homogeneous mixture mode from gypsum, salt and water, which are mixed with certain proportion, filled with film of rubber as a spacer to the aquiclude, pouring mixture which is made in advance into the model room and making the model form as what you planed, every layer of the model needs to dry till the whole model is well done.

2.2. Procedure

2.21 Make the decigned geological model in the model room.

2.22 Get ready for testing, including photograph, sketch and note on the model, checking the system of supplying and drainning water and hermetic seal of the infiltrating water system.

2.23 The test is started off with giving water.

According to the designed model, adjust the water table both in supply and drainage till the water table keep stable, measure and note down the room and water tempretures, the quantity of water in a cistern and drained water in a drainage trough, analyse corroded water timely.

2.24 Observe the changing model carefully during the test, taking the picture for some important phenomena and note.

2.25 The test is stopped by closing the water and drainning away from the model room, the model can be stripped layer by layer after drying for several days.

2.26 Sort out the data available for discussing the results.

3. RESULTS

Corrosional test for a massif between rivers with slow inclination in strata massif both in dense fissure and thin fissure have been carried out.

The test conditions are shown in table 1.

3.1. Model 1

3.11 There are difference in corrosional degree though the homogeneous massif. Figure 2 shows that the corrosional degree of NE-SW fissure is bigger than those of NW-SE.

3.12 The corrosional degree of phreatic aquifer is bigger than confined aquifer one. (see figure 3,4)

3.13 Corrosional action is always along the way of wide fissure. (see figure 4)

3.14 The collapsed degree for corrosion in confined aquifer is stronger than those of phreatic one, the whole model has fallen down about 3-10 mm.(Figure 5)

3.15 The corrosion of rock formation without structural fissure is mainly along the layer plane. (see figure 5)

3.2. Model 2

3.21 The beginning of a karst passage corrospond with distributed placement of the fissure. (Figure 6, 8)

3.22 The karst passage is formed at the bottom where the flow is concentrative.

3.23 The placement of fissure crosses on the surface is alco the seepage placement of concentrating flow, (Figure 7) so there is severe corrosion in the corresponding placement.

Table 1. Test conditions

	Model 1	Model 2
Model	Massif between rivers with dense fissure slow inclination in strata and impervious layer.	Massif between rivers with thin fissure slow inclination in strata.
Size	50 x 12 cm Layer thickness 2.5 cm Total thickness 27.5 cm	50 x 12 cm Layer thickness 2.5 cm Total thickness 7.5 cm
Dip angle	4°	4°
Fissure	X-type fissure 1-2 mm width, 3.7 fissures per 100 cm^2.	Continuous in upper part Non-continuous in lower part, 1.5 fissures per 100 cm^2.
Lasted hours	97.5	673
Water supply	Intermittent	Continuous
Water level of supply (cm)	H max = 24.8 H min = 22.7	H = 6.9
Water level of drainage (cm)	h max = 22.1 h min = 18.7	h max = 5.1 h min = 0
Yield of water (ml/sec)	Phreatic water 12-20 confined water 1-3	0.9
Room temperature (°C)	13.8	23.4
Water temperature (°C)	14.9	21.5

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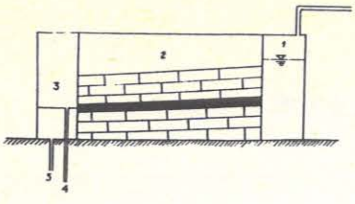

Figure 1 The corrosive trough
1 cistern 2 model room 3 drain trough
4 drainage and sampling of phreatic aquifer
5 drainage and sampling of confined aquifer

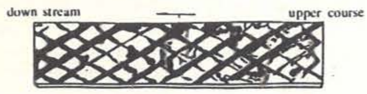

Figure 2 The corrosive degree of fissures of different position

Figure 3 The corrosive case of confined aquifer

Figure 4 The corrosive case of phreatic aquifer and development trend of underground passage

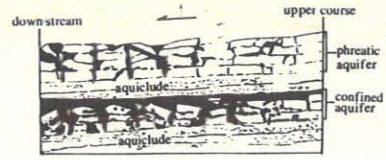

Figure 5 The corrosive case of model I in section

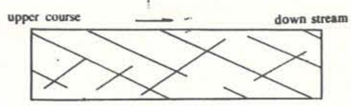

Figure 6 Distribution of fissures of model II

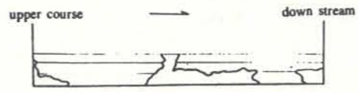

Figure 7 The corrosive case of model II in section

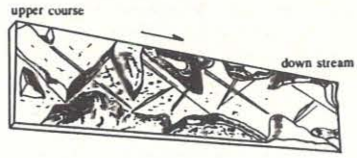

Figure 8 The embryo of underground passage of model II

CARBON DIOXIDE CONTENT OF CAVE SEDIMENTS AND CAVE AIR IN CHINA PRELIMINARY RESULTS

EK, Camille - GEWELT, Michel - ZHANG, Shouyue

Abstract.

Carbon dioxide measurements have been carried out in the atmosphere of Teng Long Cave (county of Lichuan, Hubei Province, China). They display very low contents : generally 300 to 500 ppm by volume in the galleries and fissures. This is attributed by the Authors to the huge dimensions of the galleries and the resulting important air circulation.

Analyses of the same gas in the soil air of the plateau and dry valleys surrounding the cave show much higher contents : from 1300 to 6500 ppm in clayey water-saturated soils.

At last, measurements of CO_2 content have been carried out - for the first time as far as we know - in the air of cave sediments. They show low values in sandy sediments (350 ppm) and moderate to high figures in clayey deposits (900 to 4000 ppm). This could explain possible present-day corrosional processes on limestone at the bottom of such deposits.

Résumé.- Contenu en CO_2 des sédiments souterrains et de l'air de grottes en Chine.

Des mesures de la teneur en CO_2 de l'air de la Grotte de Teng Long (Lichuan, Province de Hubei, Chine) montrent des valeurs très faibles dans les galeries et les fissures : de 300 à 500 ppm par volume. Les auteurs attribuent ces faibles teneurs aux grandes dimensions des galeries et à une importante circulation de l'air.

Les mesures du même gaz dans l'air des sols du plateau et des vallées sèches proches de la grotte ont fourni des valeurs bien plus élevées : de 1300 à 6500 ppm dans des sols argileux saturés en eau.

Pour la première fois à notre connaissance, des mesures de la teneur en CO_2 de l'air de sédiments de grottes ont été réalisées. Les valeurs trouvées sont faibles dans les sédiments sableux (350 ppm), mais nettement plus élevées dans les dépôts argileux (de 900 à 4000 ppm). Ces teneurs plus importantes pourraient expliquer des processus de corrosion actuelle du calcaire, en-dessous des dépôts.

INTRODUCTION

More than 79 measurements of carbon dioxide have been carried out in China in the atmosphere of caves, the soil and in the air of cave sediments of Tenglong Cave (Lichuan County, Hubei Province), Yaolin Cave (Tonglu County, Zhejiang Province) and Lingqi Cave (Jiande County, Zhejiang Province).

All measurements are done with a gas pomp detector (GASTEC). The gastec tubes (2LL or 2L) give a direct reading of the CO_2 concentration in the air (ppm/vol). The gastec pump system is more useful for field investigation: it is very light and only 2 or 3 minutes are needed for one measurement. The reproducibility of measurements is ± 10 per cent (Ek and Gewelt, 1985).

CO_2 DATA OF MEASUREMENTS

1. CO_2 data in the atmosphere of caves

CO_2 data in the atmosphere of caves were obtained for Tenglong Cave, Yaolin Cave and Langqi Cave (Table 1).

Table 1

LOCATION	CAVE SURVEY POINT	CO_2(ppm/vol)	REMARKS
Tenglong Cave			
main gallery	5	400	
" "	12-13	450	
" "	14	400	
" "	17	400	
" "	20	450	
" "	23-24	400	
" "	26-2	450	a nallow blind branch
	-3	600	"
	-4	1300	"
	-5	1400	"
	-6	1500	"
	-7	1400	"
yantangguan gallery	1	350	
"	2	400	a branch
yunudong gallery	1	350	
"	2	300	
yaowushan chamber		350	the highest point
longgongdong gallery		400	
longdengdong gallery		500	
qianfodian chamber and in the fissure		350	
baiyushilin gallery		350	on the top
"		400	On the botton
wind cave		300	exit
Yaolin Cave			
main gallery	1	500	
" "	2	1300	
" "	3	800	
" "	4	600	
" "	5	700	
" "	6	800	
" "	7	3000	end of the non-tourst gallery, groundriver sinking in
Lingqi Cave			
lingquan cave		400	
qingfeng cave	1	500	
	2	600	
aiyun cave		600	

2. CO_2 data in the soil of outside of the Tenglong Cave (Table 2).

Table 2

LOCATION	DEPTH BELOW SURFACE(cm)	CO_2(ppm/vol)	REMARKS
south side of the Xiaoyancao dry valley	-10	1300	tobaccofield
	-20	3000	" "
	-30	3800	" "
bottom of the Xiaoyancao dry valley	-35	6500	wet grass field
	-50	2600	maise field
Xiaoyancao village	-40	1400	on the lapie
Fen shuicao village	-30	1900	near the rice field

3. CO_2 data in the air of cave sediments of Tenglong Cave and Yaolin Cave (Table 3).

Table 3

LOCATION	CAVE SURVEY POINT	DEPTH BELOW SURFACE(cm)	CO_2 (ppm/vol)	REMARKS
Tenglong Cave				
entrance of main gallery	0	-30	1100	clayey deposits
main gallery	17	-40	900	" "
" "	19	-45	2300	" " near the water way
yunudong gallery	3	-28	350	sandy sediments
maojiaxia gallery	1	-20	3500	clayey deposits
		-30	4000	" "
" " near the exit	2	-13	1000	" "
		-33	2000	" "
		-50	5200	" "
Yaolin Cave				
main gallery	1	-20	1500	clayey deposits
		-30	1800	" "
		-50	3000	" "
" "	3	-20	1250	" "
		-30	1500	" "
		-50	1750	" "
" "	4	-20	1250	" "
		-30	1750	" "
		-50	2250	" "
" "	6	-20	950	" "
		-30	1200	" "
		-50	1500	" "
" "	7	-20	3700	" "
		-30	4000	" "
		-50	5000	" "

DISCUSSION

The carbon dioxide in the atmosphere of Tenglong Cave and Lingqi Cave display very low contents: generally 300 to 600 ppm by volume. This is attributed by the authors to the huge dimension of the galleries and the resulting important air circulation.

The Yaolin Cave is a tourst cave. The toursts breating out CO_2 is very important for the accumulation of CO_2 surrounding the tourst gallery (Zhang, 1985). The cave survey point 7 in Yaolin Cave is the end of non-tourst gallery with the highest air temperature (21.5°C), air CO_2 content and bad air circulation. In Tenglong Cave, the narrow blind branch is similar.

Analysis of the same gas in the soil air of the western Hubei Plateau and dry valleys surrounding the Tenglong Cave show much higher contents: 1300 to 6500 ppm in clayey water-saturated soils.

The measurements of CO_2 content have been carried out - for the first time as far as we know - in the air of cave sediments. They show low values in dryer sandy sediments (350 ppm) in Tenglong Cave and moderate to high figures in clayey deposits (900 to 5200 ppm) in Tenglong and Yaolin Caves.

Tamm and Krzysch(1963) found that 50 per cent of the variation in the CO_2 content of the soil was due to temperature and 20 per cent to moisture. Van Cleve and Sprague(1971) have also reported that temperature is two to five times as important as moisture in litter respiration (Brook et al, 1983).

The soil moisture plays an important role in same area and season on the surface and in the cave. The degradation of fine organic debris in the cave soil by bacteria, molds and fungi is the chief source of carbon dioxide in the cave.

The recharge of aggressibility for the vadose water in carbonate rock massif could explain possible present-day corrosional processes on limestone or dolomite at the botton of such deposits.

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CORROSIVE TEST UNDER ABNORMAL TEMPERATURE AND PRESSURE

JIN, Yuzhang - ZHANG, Shouyue

Deepkarst as an important karstification is greatly unknown for its growing and developing. It is not enough to explain deepkarst by description or an inference from surface phenomena, but the valuation on the leakage of a reservoir and dam at a high water head with large capacity, an utilization of underground water and damage, storage, transport of reservation of oil and natural gas are very closely related to the valuation of deepkarst.

The corrosive test under a condition of temperature, chemical and flowing fields to study the developmont of karstification was carried out, some results of the test are as follows:

All the dolomites have not been corroded under various CO_2 pressure at 100°C, most of them were corroded when high pressure CO_2 was applied at 50°C.

TH at 50°C is higher than those at 100°C under applied various CO_2 pressure.

Calcite marble could be corroded under CO_2 pressure of 15 bar at any temperature.

A comparison has been made between calcite marble and various dolomites, the corroded weight of marble is several times even tens times as high as various dolomite.

So far, there have been mainly accumulations or descriptions of the phenomena of deepkarst, but little study of the development of karst under a conditions of temperature field, chemical field, and flowing field.

As the valuation on the leakage of a water conservancy and hydroelectrical engineering at a high head of flowing with large capacity of a reservoir; an utilization of underground water and damage, storage, transport of reservation of oil and natural gas are very closely related to the valuation of deepkarst. For these reasons, a test on corrosion of deepkarst to different type of solvent which are artificial and natural and carbonate rocks at abnormal temperature and pressure has been carried out.

1. EXPERIMENTAL METHOD

1.1. Samples

Dolomite in various structures and limestone, calcite marble as a standard sample.

1.2. Solvents

Deep seated water sampling from oil field water with high mineralized of $CaCL_2$ and total hardness of 357 H°, Na_2SO_4 and $Na2CO_3$ solution.

1.3. T - temperature system from 25, 50, 100°C.
P - carbon dioxide pressure system from 5, 10, 15 bar.

1.4. Subjects to be determined

W (mg/cm^3) - sample's weight difference before and after testing divided by its own volume.

The composition of corrosive solution including pH S ($m\varrho^{-1}$) - electrical conductivity of solution, HCO_3^- (mg/l), total hardness (H°), Ca^{++}(mg/l), Mg^{++}(mg/l), SO_4^{2-}(mg/l), etc.

2. EQUIPMENTS (FIGURE 1.)

2.1. Type GD-05 high pressure cauldron.

2.2. Type GDK-4 temperature controller.

2.3. Type DDS-11 electric conductivity meter.

2.4. Digital pH meter.

2.5. Chemical analysis instruments and reagents.

3. METHODOLOGY

3.1. Voltage corresponding to various temperature in T. system condition is adjusted by temperature controller.

3.2. Under the 50°C, 15 bar condition, calcite marble is used as a standard sample ($CaCO_3$ = 99%) to interact with oil field water at a time system of 2, 4, 6, 8 hours (H), so as to choose the best interacting hours. Table 1. shows that over 4 hours the corroded weight of marble tended to be stable, therefore, 4 hours can be considered as a suitble reacting time.

TABLE 1.

H	pH	S($m\varrho^{-1}$) (25°C)	W (mg/cm^3)	HCO_3^- (mg/l)	Total Hardness (H°)	Ca^{++} (mg/l)	Mg^{++} (mg/l)
2	5.4	31	18.73	591,29	378.29	2329.6	228.0
4	5.7	53	41.37	709.54	392.56	2454.9	212.8
6	5.7	66	50.59	748.96	396.07	2429.8	243.2
8	5.6	54	46.13	729.25	394.66	2419.8	243.2

4. PROCEDURES

4.1. The unified standards of sample is made of 2 x 1 x 0.5(cm^3).

4.2. According to the volume of cauldron body, 150 ml water is enough.

4.3. Pretreatment

Samples need some cleaning, drying, weighing and measuring to obtain an exact volume V(cm^3) and weight W_1(g).

4.4. Suspend the pretreated sample in the centre of a heating champer, then inject the oilfield water of 150 ml.

4.5. After fixing the cauldron, expelling the air and supplying an amount of carbon dioxide, the reaction maintains for four hours(H) under stated conditions.

4.6. The reacted sample needs washing, drying and weighing again to get W2(g), the difference between W_1 and W_2 may be calculated as a corroded value W(mg/cm^3) on the sample.

4.7. Determine the corrosive solution for S($m\varrho^{-1}$).

Solution in any temperature(over 40°C) must not be measured until a drop in 40°C according to the instrument allowance except at 25°C condition at which it can be determined immediatly.

It is necessary for correcting S($m\varrho^{-1}$) value measured form various temperature value to 25°C standard condition.

pH value changing with temperature is so small that can be neglected.

5. RESULTS AND DISCUSSION

The results of corrosive test for dolomite in various structure and calcite marble interacted with deep seated $CaCl_2$ water in given conditions are shown in table 2.

Table 2.

Sample	Temperature (°C)	Pressure (bar)	Corroded Weight ±W(mg/cm^3)
Dolomite G	25	5	0.09
		10	0.63
		15	0.82
	50	5	0.26
		10	3.96
		15	5.23
	100	5	-1.16
		10	-1.01
		15	-0.89
Dolomite J	25	5	0.10
		10	0.58
		15	0.76
	50	5	0.37
		10	1.63
		15	3.58
	100	5	-0.68
		10	-0.20
		15	-0.30
Calcite marble S	25	5	6.02
		10	14.22
		15	19.03
	50	5	10.09
		10	25.48
		15	34.12
	100	5	-1.36
		10	-0.39
		15	1.36

The comparing results for limestone (Table 3) and dolomite (Table 4) interacted with deep seated $CaCl_2$ water, Na_2SO_4 and Na_2CO_3 solution respectively are shown as follows.

Table 3. Limestone

Temperature (°C)	Pressure (bar)	Corroded Weight ±W(mg/cm³) Na_2SO_4 solution	Na_2CO_3 solution	$CaCl_2$ water
25	5	13.27	7.01	7.36
	10	17.43	11.69	10.72
	15	21.07	16.94	14.17
50	5	25.36	12.75	17.17
	10	34.51	23.13	22.10
	15	42.32	27.01	43.14
100	5	39.03	4.92	13.33
	10	12.85	7.84	14.76
	15	88.60	12.73	25.68

Table 4. Dolomite

Temperature (°C)	Pressure (bar)	Corroded Weight ±W(mg/cm³) Na_2SO_4 solution	Na_2CO_3 solution	$CaCl_2$ water
25	5	2.23	1.95	-0.57
	10	3.61	2.39	-0.38
	15	4.00	1.81	0.57
50	5	6.91	2.45	-0.09
	10	9.87	4.45	3.89
	15	13.93	7.80	7.05
100	5	14.89	1.11	-1.32
	10	15.75	1.31	-1.95
	15	19.82	3.45	-1.97

According to the tables shown above

5.1. All the dolomites have not been corroded under various CO_2 pressure at 100°C, however, the weight of the samples increase because of separating out the ion in the solvent. At 50°C, most samples were corroded when high P.CO_2 had applied, but they separated out the ion with increasing weight when the CO_2 was 5 bar.

5.2. Calcite marble could be corroded under CO_2 P. of 15 bar at any temperature, the highest corroded weight was at 50°C, while the lowest one was at 100°C. Separating out of ions in the solvent might happen under 15 and 5 bar with a temperature of 100°C, the weight increased with the decreasing CO_2 pressure and the highest corroded weight was still at 50°C. Both had weight increased with an increasing CO_2 pressure when it was at 50°C and 25°C conditions.

5.3. A comparison has been made between calcite marble and various dolomites, it can be pointed out that the corroded weight of marble sample is several times even tens times as high as various dolomite sample, other than it is under 5 and 10 bar and at 100°C conditions.

5.4. Generally speaking, interaction of Na_2CO_3 and deep seated $CaCl_2$ water with carbonate rocks are of more corroded weight at 50°C and various PCO_2, especially with limestone.

5.5. In Na_2SO_4 solution, the corroded weight of carbonate rocks essentially increased with increasing temperature at various CO_2 pressure.

5.6. The highest corroded weight of carbonate rocks is in Na_2SO_4 solution amoung those water with different hydrogeochemical type at various temperature and CO_2 pressure.

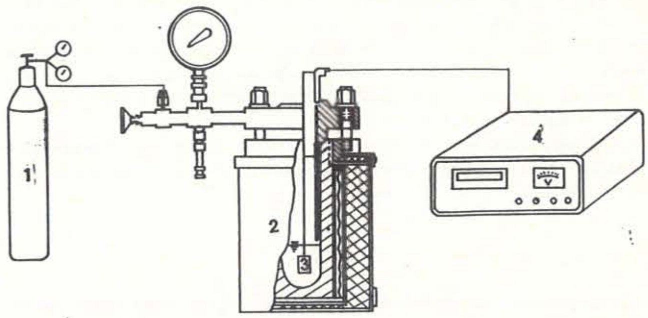

Figure 1. The device of corrosive test

1. Carbon dioxide
2. High pressure cauldron
3. The sample
4. Temperature controller

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LOCALISATION ELECTROMAGNETIQUE EN SURFACE DE DEUX GROTTES DE BELGIQUE

VANDENVINNE, Roger

RESUME

Dans la vallée de la Meuse sur le territoire de Lustin, deux cavités La Lucienne et le Solitaire, sont explorées depuis des décennies. Malheureusement le seul accès à ces grottes se fait par un tunnel réservé à l'exploitation du chemin de fer.

En raison de l'interdiction de passage décidé par la Société de chemin de fer, surtout après l'électrification de la ligne, il est devenu urgent de trouver une entrée plus appropriée. Aucune faille ni doline apparente dans le massif de Frênes ne permet d'engager des travaux d'ouverture nécessaires à une nouvelle percée.

C'est pourquoi une étude spécifique de repérage des grottes en surface a été entreprise. A l'aide de deux appareils identiques d'émission et de réception d'un champ électromagnétique on est parvenu à localiser en surface des points stratégiques de la grotte. Leur repérage a permis le forage d'un puits donnant ainsi un nouvel accès à ces cavités.

* * *

ELECTROMAGNETIC LOCATION FROM THE SURFACE OF TWO CAVES IN BELGIUM

ABSTRACT

The caves «la Lucienne» and «le Solitaire» are located in the municipality of Lustin, in the Meuse Valley (Belgium). The entrances of both caves are in a railway tunnel. Because of the electrification of the railway, the access to the tunnel is now forbidden, and the caves are thus left without any authorized entrance.

No fissure, no doline, no depression was apparent in the morphology of the overlying plateau, thus no hope of access.

A set of two transceivers of electromagnetic field was used to locate the cave from the surface. Electromagnetic emissions from definite points of the cave were clearly and occurately located at the surface. This allowed to dig a pit connecting the cave to the surface, and now used as entrance pit.

1.- INTRODUCTION

1.1.- Rappel de principe

Le repérage en surface de galeries souterraines est effectué par la détection d'un champ électromagnétique émis par le passage d'un courant alternatif dans une bobine toroïdale placée à l'endroit à repérer dans la galerie.

Dans cette méthode, les couches conductrices du sol constituent le secondaire d'un transformateur dont le primaire correspond à la bobine. Les lignes de force du champ décrivent des courbes se refermant autour du cadre émetteur. La captation de ce flux à l'aide d'un récepteur constitué d'une seconde bobine et d'un récepteur-amplificateur permet de déterminer sa direction et également son origine.

1.2.- L'appareillage

Il comprend dans la galerie une bobine d'un demi-mètre de diamètre, un émetteur-récepteur et une alimentation par batteries. Un second appareil identique au premier est utilisé en surface pour le repérage.

La fréquence d'utilisation choisie dans cette application a été de quatre cents périodes par seconde, avec une puissance d'émission de l'ordre de deux watts.

2.- LE TERRAIN

La région où se localisent les grottes faisant l'objet de cette étude, se situe dans l'axe de la vallée de la Meuse, sur sa rive droite, à mi-distance entre Namur et Yvoir. Elle est couverte par la carte topographique au 1/10.000e, numérotée 47/8. Les coordonnées Lambert de l'entrée artificielle sont : X: 186,090; Y: 118,855; Z: 125 mètres.

Les grottes sont situées dans les calcaires dévoniens supérieurs du massif des Rochers de Frênes, au flanc sud du synclinal de Walgraffe. Le massif fait affleurer la formation de base du Frasnien. Une coupe lithostratigraphique y a été décrite par COEN-AUBERT M. et COEN M. (1974) : la série débute par 40 centimètres de calcaires crinoïdiques, surmonté de 120 centimètres de dolomie foncée et grossière; par dessus, les calcaires massifs présentent une puissance de l'ordre d'une centaine de mètres. On y trouve une grande quantité de stromatopores.

Le réseau complexe de galeries et de salles qui parcourent le massif peut être rapporté au type du réseau hydrographique en treillis défini par MACAR P% (1946) dans les roches calcaires. Les grottes se sont développées en étages successifs au fur et à mesure de l'incision de la Meuse qui, à cet endroit, est profondément encaissée. Ces différentes étapes sont en relation avec les niveaux de terrasses développés aux flancs de la vallée de la Meuse. Nous sommes donc ici en présence d'une morphologie karstique caractéristique.

Pour terminer, signalons encore l'existence de limons éoliens, sur les plateaux environnants.

3.- DEROULEMENT DE LA RECHERCHE

3.1.- Première phase

Un repérage fut programmé en 1983, avec pour objectif la jonction avec la grotte du Solitaire qui, d'après la topographie, présentait les conditions les plus favorables. Malgré l'encombrement réduit de l'appareillage, il y eut quelques difficultés pour son acheminement dans la salle des Diaclases (voir plan), choisie pour ce premier repérage. La détermination du point en surface fut rapidement acquise, il était situé à une quinzaine de mètres de profondeur. A cet endroit, aucun caractère de surface n'était présent qui aurait pu faciliter le travail de désobstruction. Les responsables du club de spéléologues ont fait une confiance absolue à notre méthode de repérage.

En effet, il fallait des moyens professionnels pour réaliser le creusement d'un puits à cet endroit, soit par dynamitage, soit par forage dans le massif rocheux. Cette dernière solution fut retenue, car la firme Atlas Copco eut la complaisance de mettre un groupe compresseur à la disposition des membres du club. Un puits fut creusé à l'endroit déterminé par le repérage. Au delà d'une épaisseur de moins d'un mètre de calcaire délité, le forage rencontra un calcaire compact sur plusieurs mètres dans lequel apparut une fissure, qui servit de fil conducteur aux spéléos jusqu'au réseau des Diaclases. Enfin, le 4 mars 1984, l'accès à la grotte du Solitaire était ouvert sur le plateau.

3.2.- Deuxième phase

La jonction avec la résurgence «La Lucienne».

3.2.1.- Premier repérage

Il fut programmé au début de 1986, on plaça la bobine au lieu dit «La Baignoire» (voir plan). La détermination au niveau du sol ne put être affirmée en-deça d'une surface triangulaire de deux mètres de côté, par suite d'un phénomène de distorsion dans le flux magnétique. Malgré ce problème, ce lieu servit de direction pour les travaux futurs de désobstruction : L'intelligence des chercheurs fut de forcer un passage à partir de la grotte du Solitaire. En effet, un deuxième accès en surface aurait signifié un nouveau puits à creuser et surtout une nouvelle entrée à contrôler dans le futur.

La boue, le manque d'air et les difficultés d'évacuation des déblais rendirent les travaux de creusement très pénibles. Mais, après un travail acharné, une ouverture se dessina vers un réseau encore inconnu. C'est ainsi que furent découvertes la salle des Radicelles et la galerie de la Collaboration (voir plan). A ce stade, l'objectif n'était toutefois pas encore atteint, mais cette découverte insuffla un courage nouveau à l'équipe.

3.2.2.- Deuxième repérage

Un second repérage fut alors réalisé. La bobine d'émission fut placée au même endroit que précédemment (La Baignoire), mais le repérage s'effectua dans la nouvelle salle des Radicelles. Un point précis fut déterminé accompagné d'une mesure de profondeur. Ces paramètres connus, les travaux reprirent à partir de la grotte du Solitaire et après de nombreuses heures de travail, la jonction avec la Résurgence Lucienne fut effective le 29 novembre 1986. C'était l'aboutissement de six années de recherches acharnées.

4.- CONCLUSIONS

4.1.- Le premier point fut un repère précis. Si on se réfère au plan, le décalage de quelques quarante centimètres (dimensions du puits artificiel) est dû au placement de la bobine inférieure, décalée de cette distance vers la paroi de la galerie.

4.2.- Le deuxième point fut moins précis mais déterminant pour indiquer la direction à suivre. Ce repérage démontre les distorsions pouvant se produire lors des mesures. En effet, lorsque le flux magnétique traverse des milieux de densités différentes, en l'occurrence ici le calcaire et l'air, la vitesse de propagation des ondes varie, provoquant des distorsions au passage d'un milieu à l'autre (1). Selon le plan, la trajectoire entre les bobines d'émission et de réception passait dans ce cas par la salle des Radicelles nouvellement découverte, ce qui explique le phénomène observé.

4.3.- Quant au troisième point, le repérage ainsi que la profondeur furent déterminés avec précision.

5.- REMERCIEMENTS

Toute ma gratitude va envers les spéléologues et plus particulièrement Gérald Fanuel, Georges Châlon et Claude Daubresse qui ont fait confiance à mon travail de repérage.

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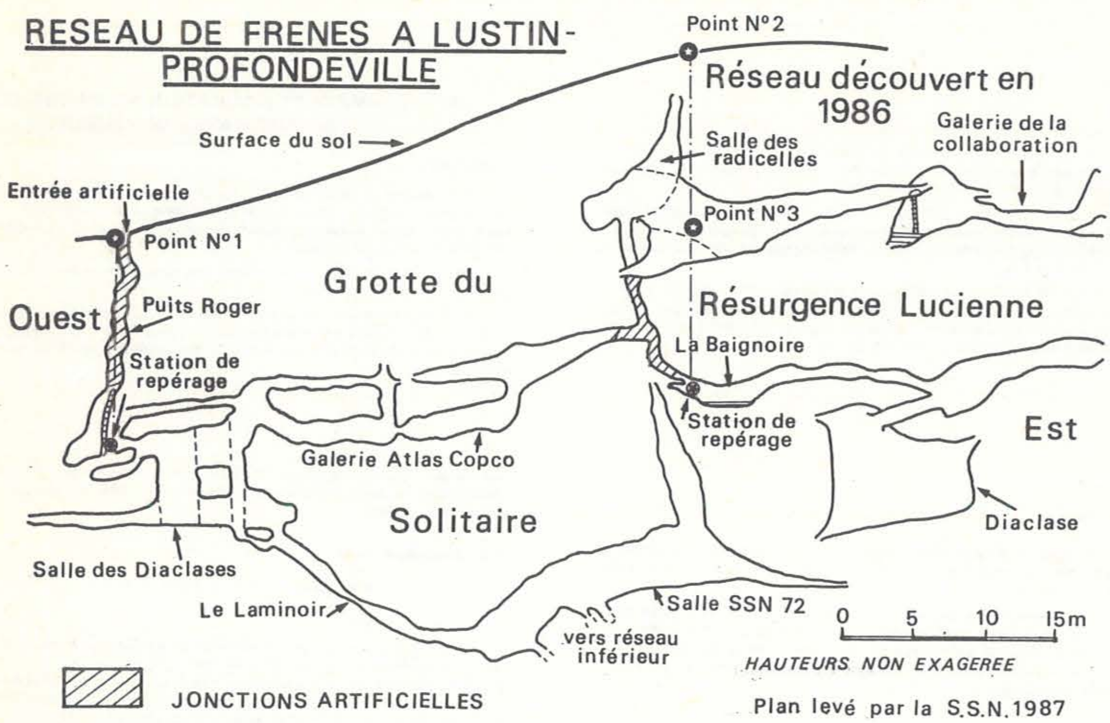
(1) Les vitesses de propagations des ondes E.M. (en km/sec) : eau douce 0,34; alluvions 0,6 à 12; couche superficielle meuble 0,2 à 0,6; air 0,34; calcaire 3 à 5.



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THE CUBIC CAVE PEARLS OF THE CORCHIA KARST SYSTEM (APUANE ALPS, ITALY)

FORTI, P. - PENSABENE, G.

ABSTRACT

During a recent exploration carried out by the Speleological Group of Lucca inside the Antro del Corchia karst system (Apuane Alps, Italy), some cubic calcite cave pearls have been found.

Similar speleothems have been previously reported in other caves of the world, but an explanation of their genesis has never given.

In the present paper a morphological description of these cave pearls is given and the internal structure is analyzed in detail. Following these observations, a genetical hypothesis is proposed which bases mainly upon the cinetic energy of the water, its normal level inside the pool and the steric impediment.

RIASSUNTO

In una recente esplorazione condotta dal Gruppo Speleologico Lucchese all'interno dell'Antro del Corchia (Alpi Apuane, Italia) sono state osservate alcune pisoliti di calcite di abito perfettamente cubico.

Pisoliti analoghe erano gia' state segnalate in altre parti del mondo, ma in nessun caso si era cercata una spiegazione della loro genesi.

Nel presente lavoro, dopo aver brevemente descritto morfologicamente le pisoliti del Corchia ed averne analizzato in dettaglio la struttura interna si avanza una prima ipotesi genetica basata sull'energia cinetica dell'acqua di alimentazione, sul livello normalmente raggiunto dalla stessa all'interno della vaschetta e sull'impedimento sterico.

INTRODUCTION

While exploring the Corchia cave system (Apuane Alps, Italy) in 1987, the Caving Club of Lucca found a calcite flowstone inside which some hundreds of peculiar cave pearls were cemented: all of them had a perfect cubic shape with rounded edges and were of the same dimensions (ranging from 2 to 8 mm). Owing to the strange shape of the pearls, cavers decided to take a small sample of these speleothems to allow a detailed study.

In the present paper, beside a brief overview on the other actually known occurrencies of cubic cave pearls in the world, an attempt of general hypothesis on the development of these strange speleothems is presented starting from the morphological analyses of the inner structure of the Corchia formations .

THE PREVIOUS OCCURRENCES

The first news about cubic cave pearls was given in 1964 by HUBART, who decribed a nest of such formations found in the Ramioul cave, Belgium: the pearls, some dozens with rounded edges, were found over a flowstone far from the direct flow of the water; they consited of pure calcite and their dimension ranged from 2 to 5 mm.

Twenty years later (ROBERGE & CARON, 1983) inside the Castelguard cave, Castelguard icefield, Canada, a nest was discovered with hundreds of cubic cave pearls with rounded edges cerating a natural mosaic. They were still of calcite and the nest was in a sufficiently calm place; the average dimension of the pearls was half centimeter and some of them was linked, even if only slightly, to the floor.

The last occurence of cubic cave pearls, before the actual one of the Corchia carst system, was in a cave of the Ardeche, France (RODET, personal communication): in this case, in a terrace, one meter above the floor of the corridor, 6 different nests were found containing cubic pearls, some of which linked to the floor (see fig.1): the dimension of these speleothems ranges from 5 to 7 mm and the inner structure, occasionally exposed by the corrosion/erosion processes (see fig.2), shows that the development of the pearls started with a "normal" spherical shape which was progressively transformed into cubic. In this case no mineralogic analyses was carried out on the pearls, but their external morphology may suggest they are still composed by calcite, or perhaps, more probably, by aragonite.

In all these occurencies the cubic cave pearls shown similar features: their shape between 2 to 7 mm and their growing environment characterized by a restricted precipitate supply, very regular packing and calm mode of deposition (HILL & FORTI, 1986).

THE CUBIC CAVE PEARLS OF THE CORCHIA SYSTEM

While exploring new branches of the Corchia karst system in 1987, the Gruppo Speleologico Lucchese discovered a flowstone containing an high number of cubic cave pearls, from 2 to 8 mm in size, were cemented close to the Portello shaft.

The place where the pisolits developed was protected from the direct dripping, therefore the feeding water had to be a laminar flow over the flowstone, whose growing finally cemented the pearls.

The pearls were linked each together and to the flowstone, but they may be easily released (see fig.3)

A small sample of these speleothems was taken to be analyzed.

Chemical and mineralogical investigations show that the cave pearls were made by pure calcite.

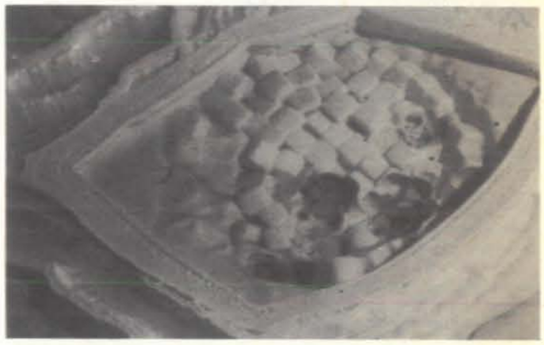

Fig.1 One of the nest of the cubic cave pearls of the Ardeche cave (France): the mean dimension of the pearls is 0.5 cm. (Photo P.Bayle)

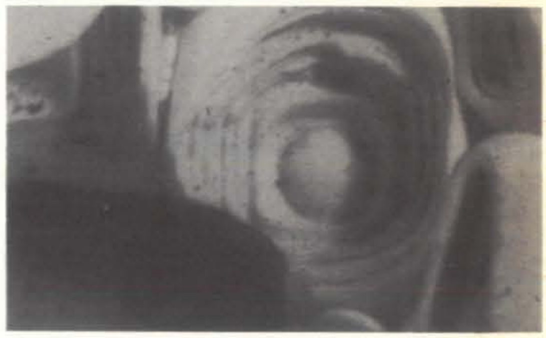

Fig.2- The inner structure of the cubic pearls of the Ardeche, where exposed, shows the passage from a spherical shape (up to 2 mm in diameter) to an cubical one. (Photo P.Bayle)

Some of the pearls were sectioned to expose their inner structure and the nucleus: all the analyzed pearls (about 50) have a very small nucleus (few microns in diameter) and their inner part was spherical in shape up to 2-3 mm in diameter, then changing its geometry to cubic in the same way observed in the cave of the Ardeche: each growing layer becomes thicker in the direction of the corners so transforming layer by layer the pearl into a cube with rounded edges.

In the larger elements cubic faces often presented a slightly hollow structure.

Microscopical analyses of the thin sections shown that, inside each layer, in the planar sections the calcite crystals were strictly confined inside the sheet, which was thinner than the rounded part of the layer, while along the thicker rounded edges they crossed unperturbed dozens of the layers (see fig.5): this fact suggests that the deposition along the corner directions was faster and underwent less stops than in the "planar" directions.

The accurate microscopical analyses cannot detect no kind of erosion features, even minimal, over the growing layers: thus

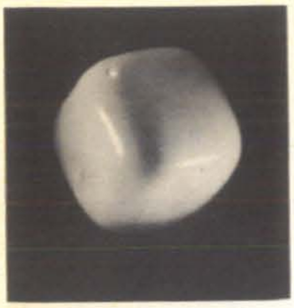

Fig. 3

Fig. 4

Fig. 5

Fig. 3 A cubic pearl of the Corchia cave (dimension 3 mm)(Photo P.Ferrieri)

Fig. 4 Section of a cave pearl: the passage from the spherical to the cubic shape is evident (Photo P.Ferrieri)

Fig. 5 Section of a cave pearl: the crystal structure close to the rounded corner where the calcite crystal cross unperturbed several layers is evident.

confirming that this kind of pearl develops in a rather different manner that the normal "polyhedrical" ones.

DISCUSSION

Several of the morphological features of the Corchia speleothems are similar to those of the previous mentioned cubic cave pearls observed in ther world: maximum dimension between 2 and 8 mm, rounded edges, inner sherical structure, etc.

Therefore it is reasonable to suppose that the genetical mechanism was the same for all of the actually known cubic cave pearls.

To define the development of the cubic pearls of the Corchia cave it has to be pointed out that all the data (position of the nest far from dripping, no inner nucleus larger than a few microns, no presence of erosional features) are in agreement with the conditions of low supersaturation degree and calm environment, requested in the previous occurrencies of such speleothems (HILL & FORTI, 1986).

It is evident that the low energy is a a condition which is necessary to develop cubic pearls, but, due to the rarity of these speleothems, clearly it is not sufficient alone.

To achieve the necessary conditions two more factors are fundamental in our opinion: the steric hindrance and the partial submersion of the pearls during long time intervals.

The steric hindrance may justifie the cubic development of the cave pearls after an initial spherical stage.

In fact, if we consider the growing of pisolites in a subhorizontal environment with definite boundaries and with low energy, they will organize themselves in a single bad. At a certain stage of their development the pearl will occupy all the place available; then the steric hindrance will control the further growth, which will be easier toward the interstices than along the contacts between the pearls (see

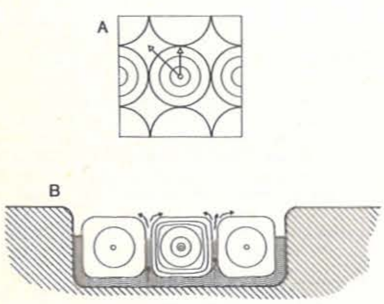

Fig.6 In an environment characterized by low energy, steric hindrance and single bad, when the pearls comes in contact each other (A), any successive growth will be faster toward the interstices than along the contacts, therefore asymmetrical layers will develop which transform the pearl shape from spherical to cubic. If the pearls are not copletely submerged for sufficently long intervals (B), feeding water supply of the upper part will be mostly via capillarity, and the water film on the top will control the flat development also of this part of the pearls.

Fig.6-A), the last requiring an higher energy.

This mechanism will progressively transform the growing layers from spherical to cubic.

It is obvious that there mustn't be a total steric hindrance, because in this case the deposition process will link the pearls together and to the floor and not allow them to develop into cubic forms.

A slight possibility to partially overcome this factor has to exist, at least in particular situations, and it is usefull also to explain the presence of cubic cave pearls organized in more than a single bad as in the Castelguard cave or in a single but perturbed one as in the Ardeche cave.

Even if the steric hindrance is present, it is still unexplained why the upper part of the pearls, which is completely free to mantain the spherical shape, remains flat.

This is the reason why we supposed the presence of a third condition: that is the necessity for the pearls to mantain their upper part out of the water for long periods. In this manner feeding water may reach the top of the pearls only through capillarity (see Fig.6-B) and the thin film of water, which is created in this manner, supports the flat development also of this part of the speleothems.

Indirect proof of this feeding mechanism is given by the slightly hollow shape of some of the upper faces of the largest cubic pearls.

Summarizing the development of cubic cave pearls is possible only if some conditions are simultaneously satisfied: very low cinetic energy and supersaturation degree of the water inside the nest, steric hindrance and partial emersion of the pearls.

These speleothems may therefore be regarded as "lower limit" for the "polyhedric cave pearls", whose development is controlled by the steric hindrance. In fact normally, the cinetic energy is sufficiently high and "normal polyhedric pearls" grow with variable shapes and evident erosional features, but where and only where also the other conditions are satisfied (low energy and partial emersion) will cubic pearls will logically develop.

CONCLUSION

The study of the uncommon pearls of the Corchia cave system and their comparison with the other worldwide occurrencies of such speleothems allowed to detect a gentical mechanism for the growth of rather cubic cave pearls.

The proposed way does not require peculiar crystal structures but only energetic and boundary conditions and therefore, if it is true, cubic cave pearls may theoretically consist not only of calcite, but also of aragonite or any other mineral.

In the near future it would be interesting to test if this genetical mechanism, surely active in the natural caves with calcite, should still be true whatever mineral is concreting.

We strongly belive that this last hypothesis is right, as it is probable that at least in one of the known occurrencies of the cubic pearls (the cave of Ardeche), the concreting mineral is aragonite, even if no experimental proof is available at present. Our idea is based upon the fact that in this cave well developed and whidespread aragonite speleothems are present and also the chromatic and texture features of the cubic pearls support this hypothesis.

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THE ROLE OF SULFIDE-SULFATE REACTIONS IN SPELEOGENESIS

FORTI, Paolo

ABSTRACT: In the present paper the speleogenetic role of the sulfur redox reactions have been analyzed from the chemical and morphological point of view. Moreover, the karstifying effect of the sulfate-sulfide reduction is here considered for the first time. The hyperkarstic effect of the biological cycle of sulfur is very large and brings both to the development of peculiar morphologies and to the deposition of plenty of speleothems, which are here shortly described. Lastly the necessity of studying the biologic reactions controlled by specific microorganisms in the near future is evidentiated: in fact they are increasing day by day their importance from the point of view of the speleogenesis.

RIASSUNTO: Viene analizzato sia dal punto di vista chimico che da quello morfologico il ruolo che le reazioni di ossidoriduzione dello zolfo hanno in speleogenesi. Inoltre viene per la prima volta dimostrato l'effetto carsificante delle reazioni di riduzione solfati-solfuri. L'effetto ipercarsico del ciclo biologico dello zolfo e' molto grande e causa sia lo sviluppo di morfologie peculiari sia la deposizione di un gran numero di speleotemi. Da ultimo viene evidenziata la necessita' di uno studio approfondito delle reazioni carsiche controllate da microrganismi: infatti l'importanza di questi processi in speleogenesi sta aumentando di giorno in giorno.

INTRODUCTION

Until recently there was a general agreement on the opinion that the development of the karst would be mainly controlled and directed by the chemical equilibria of the CO_2-H_2O-$CaCO_3$ system, and therefore the other mechanisms for the corrosion and/or the chemical deposition should be restricted to few and particular "hyperkarst" environments.

On the contrary, latest researches have clearly shown the importance of several other different karstifying reactions (FORTI & PERNA, 1986, HILL, 1987). Among them the whole set of the redox equilibria of the sulfide-sulfate system is surely the most active in cave environments, often producing noticeable speleogenetic effects, which are sometimes even higher than the normal one caused by the CO_2 dissolved in the metheoric seeping waters.

MOREHOUSE (1968) was the first who advanced the hypothesis that the sulfide-sulfate reactions may be the principal way of karst development: he presented his idea when analysed the speleogenesis of the Level Cervice Cave (Iowa, U.S.A.), a cavity developed at the boundary between limestone and sulfides orebodies. However his idea was not sufficently spread and the activity of the sulfide-sulfate equilibria was still believed to be confined in the minerogenetic field to justify the plenty of gypsum and other sulfates in caves (WHITE, 1976).

In the present paper the karst effects of the sulfide-sulfate equilibria are shortly decribed as well as the environments in which they may develop better causing the evolution of peculiar morphologies or speleothems.

Moreover, for the first time, it has been shown that not only the oxidation of sulfides, but also the reduction of sulfates are reactions which may cause karst corrosion. This fact is particularly important allowing the existance of a complete karst cycle totally based on the biologic cycle of sulfur.

EVIDENCIES OF SULFIDE-SULFATE SPELEOGENESIS

There are several reasons which suggested us to look at the sulfide-sulfate equilibria as very important karstifying agents, among them the principal ones may be grouped in the following 3 points:

1- Sulfates, despite their normally high solubility, are the most common and widespread spleothems (except calcium carbonate) and rapresent the largest cave minerals group

2- The amount of sulfate minerals is sometimes very high even if sufficient sources for the Sulfate ion cannont be detected

3- Several of the largest karst systems in the world contain a certain quantity of gypsum deposits

The fact that sulfates with 51 different compounds are the largest group among the cave minerals (FORTI & ROSSI, 1988) evidences the high reactivity that they have in a karst environment.

Moreover the abundance of cave sulfates is apparently in contrast with their relative high solubility, which would hinder their deposition and stability in caves, where a high degree of humidity and water flows are the rule. It may be justified only with sufficiently high and widespread sulfate deposition in order to exceed the reverse and parallel process of solution.

Thick solfate deposits, normally consisting of gypsum, are often found also in caves in which water chemistry has a low sulfate ions concentration, so that the precipitation of sulfate compounds is not justified. In these cases, if a great variation in the chemical composition of the waters is not probable during this time, then the only reasonable explanation is the possibility that some of the reaction involving sulfate ions may be restricted in places which cannot be directly reached or easily controlled: this is the case of the limestone porosity close to the boundary between the rock and the cave atmosphere or that of the deep phreatic waters.

But the active role of sulfide-sulfate in the karst corrosion is also strongly supported by the evidence that in nearly all the largest and deepest caves of the world a certain quantity of gypsum deposits or speleothems have been found: the Mammuth Cave and the Carlsbad Caverns in the U.S.A., the Lachambre system in France, the Antro del Corchia, Mt Cucco cave and Fiume-Vento system in Italy, the Cupp Coutunn cave in U.S.S.R. are some of the most prominent examples.

In our opinion, it seems unexplanable that in rearly all the very large caves gypsum or other sulfate deposits have been observed, while they are completely absent in several of the smaller cavities developed close to the principal karst systems.

In conclusion all these evidencies are consistent with the hypothesis of an important speleogenetic role for the sulfide-sulfate reactions in the evolution of limestone caves.

The main reason why the the karstifying effects of the redox reaction of sulfur have been up to day disregarded or at least underestimated was due to the general agreement, existing up to few years ago,on the fact that most of the karst corrosion develops only under phreatic conditions, while in the air filled zones only minor spleogenetic effects may take place, chemical deposition being the prevailing process.

But some of the sufide oxidizing reactions and the acid etch of limestone have the possibility to go on only in environments allowing gas excanges with the atmosphere (WHITE, 1976), therefore the obviuos conclusion was that to consider their speleogenetic effects negligible.

Only recently (CIGNA & FORTI, 1986) it was proved that the idea of the karstification strictly confined in the phreatic zone is ebsentially wrong: in fact, sometimes, the vadose zone, and even more that at interface, are much better to develop some speleogenetic processes. This is the case of sulfide-sulfate karst corrosion.

Once that idea was removed, it became possible to consider the sulfide-sulfate reactions and their possible speleogenetic effects in depth, in order to evaluate their importance in the cave evolution correctly.

THE BIOLOGIC CYCLE OF SULFUR AND THE SPELEOGENESIS

In nature the redox cycle of sulfur (see fig.1) is totally based on biologic reactions, controlled by bacteria and specific microorganisms (AA.VV., 1978).

The oxidizing reactions (see Tab.1), producing sulfuric acid, have just been taken into account as possible strong karst agents (MOREHOUSE, 1969; FORTI & PERNA, 1986). They may bring to the development of peculiar shapes, like the reverse gutters and the giant scallops (CHIESI & FORTI, 1987) or the corrosion bell shaped domes (CIGNA & FORTI, 1986) in caves close to sulfide orebodies, which allow the formation of a sufficiently high amount of sulfuric acids, or in caves in which the same acid cames from oil deposits (HILL, 1987).

On the contrary, till now the reducing reactions from sulfuric to sulfide acid have never been considered as potential strong karst agents. But at present it is clear that also the reducing processes cause speleogenetic effects.

These reactions are generally endothermic processes and therefore they need energy from the system, while it is unnecessary to the oxidizing ones which are all exothermic. Normally the energy feeding agent is the organic matter, which is oxidized to produce CO_2. It is just this additional carbon dioxide which makes the deep waters newly aggressive with respect to limestone (see Tab.1).

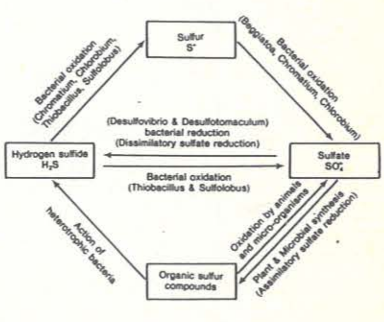
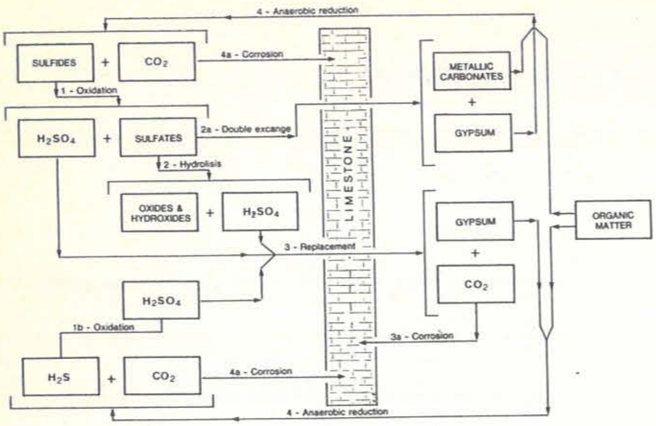


Fig.1 - The biologic cycle of sulfur

Fig. 2- Sketch of the karstifying effects developed during a biologic redox cycle of sulfur



From the stoichiometrical point of view the karst effect induced by the reducing reactions is equal to that of the oxidizing ones, but in this case, owing to the fact that the induced corrosion is caused only by the "organic" CO_2 produced in phreatic conditions, the resulting shapes cannot be distinguished from those caming from a "normal" karst process and therefore cannot be detected by a morphological analysis, however accurate.

Considering what has been said it is evident that each step in the redox porcess from sulfides to sulfates and back causes an additional karstification: but this fact has a great importance for the speleogenetic development because even in a short time several back and forth changes in the oxidation state of sulfur may occur.

In fact it was experimentally demonstrated, not only in the laboratory, but also inside the caves, that very often sulfur oxdizing bacteria live together with the reducing ones in the same place, and from time to time, those are active for which the environmental conditions are the most favorable.

As can be easily deduced from the reactions of Tab.1, 1 mole of H_2S which is firstly oxidized to H_2SO_4 and then reduced back to sulfide acid theoretically causes the karst dissolution of 4 moles of limestone and this obviously happens every full cycle.

In a karst environment the most common source for sulfide ions is the presence of metallic sulfides (principally pyrite): often they are disperded inside the limestone, but sometimes they may form orebodies.

The whole of the speleogenetic effects produced by the sulfur cycle referred to metallic sulfides may be outlined as in fig.2.

Tab. 1- Principal redox reactions for the sulfides-sulfates system and their speleogenetic effects

A- Oxidation:

1- $H_2S + O_2 \longrightarrow H_2SO_4$

2- $H_2SO_4 + CaCO_3 \longrightarrow Ca^{++} + SO_4^{--} + H_2O + CO_2$

3- $CO_2 + CaCO_3 \longrightarrow Ca^{++} + 2HCO_3^-$

B- Reduction:

4- $SO_4^{--} + 2(CH_2O) \longrightarrow H_2S + 2CO_2 + 2H_2O$

5- $2CO_2 + 2CaCO_3 \longrightarrow 2Ca^{++} + 4HCO_3^-$

The stoichiometric karstification produced by all these reactions is equal to 400 grams of calcium carbonate dissoved during the oxidation of 120 grams of pyrite (FORTI & PERNA, 1986). If we consider that the reducing process causes a corrosion of the same amount of rock, we obtain that a full redox cycle on a single mole of pyrite may karstify up to 800 grams of limestone.

To understand better the speleogenetic importance of this process, it is sufficient to think that in order to obtain an equivalent effect with the "normal" karst corrosion are necessary over 4000 liters of water with a carbon dioxide content of 250 mg/l (which is a medium-high value for cave waters).

RELATED FORMS AND SPELEOTHEMS

In the cave where they are prevalent, the hyperkarst processes based on the sulfide-sulfate equilibria lead to the evolution of peculiar forms and speleothems, which will be now shortly described and are also grouped in the scetch of fig.3.

In the submerged zone not far from the piezometric level, if a direct communication exists with the gas filled zone, giant pseudo-scallops (up to 1 m in diameter) may develop on the lodging walls, while domes or hollow half spheres on the ceilings and inverse gutters on both lodging walls and ceilings are formed. All these morphologies comes from the combined corrosion of the rock caused by the sulfuric acid and by the carbon dioxide consequentely formed.

The pseudo-scallops and, at least partially, the domes and hollow half spheres develop via convectional abseiling mouvements of the H_2SO_4 aggressive water (BINI & CAPPA, 1978; RUDNIKY, 1978; CHIESI & FORTI, 1987). Domes and half-spheres may grow also via gas buble corrosion (SZUNYOGH, 1982; FORTI, 1987).

In the air filled zone giant scallops, domes and half-spheres have the possibility to be formed when the hydrogen sulfide is oxidized in the gas phase or directly on the cave walls. In this case the sulfuric acid reaction on the limestone leads both to the deposition of gypsum and the immission of lage amount of carbon dioxide in the cave atmosphere. This condensates with water over the roofs, so causing the growth of bell-shaped domes and half-spheres partially overlapping each other (CIGNA & FORTI, 1986).

The development of reverse-gutter forms is strictly restricted to the submerged zone and my be active only if a large amont of bubbles of carbon dioxide is produced by the acid corrosion of limestone.

Shapes of giant-scallops, domes and half-spheres are well known therefore need not to be here described; on the contrary the reverse

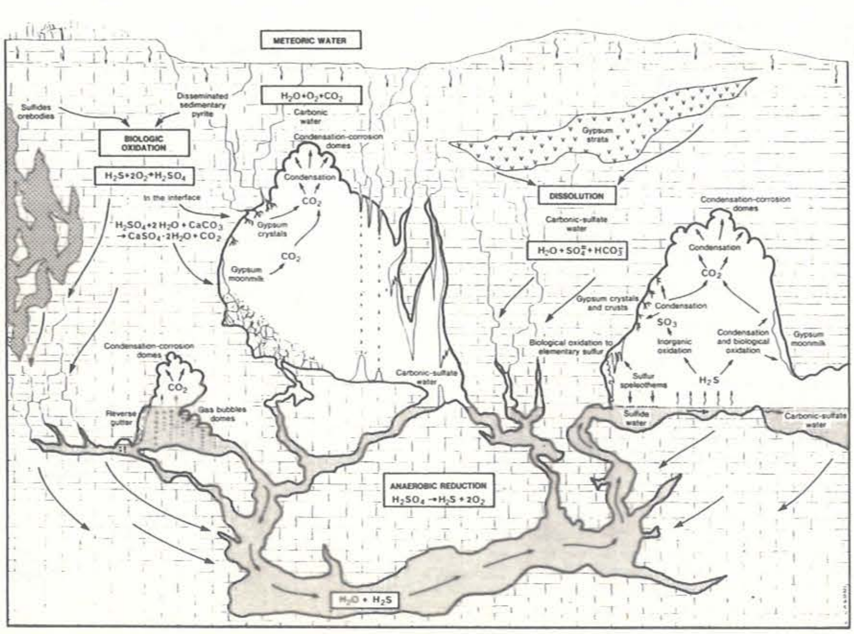


Fig.3 - Section of a theoretical cave in which all the speleogenetic mechanisms due to sulfur are active

gutters have been observed and described for the first time (CHIESI & FORTI, 1987) only in a cave of the Iglesiente mining distric and therefore are still commonly unknown, therefore they will be shortly described now.

The cave in which such peculiar morphologies have been firstly observed is developed just inside the biggest orebody of metallic sulfides (Galena and Sphalerite) of Sardina. The reverse gutters have been observed only on the lodging walls and small roof, while no evidencies of them have been found over the vertical or bended walls: their morphology closely resemble that of the small paragenetic galleries, but in the reverse gutters the horizontal parts may be followed by subvertical abseiling and also by short descending pathes. Their cross section is always an upset U and its depth is reverse proportional to the dip of the gutter.

Their genesis is explained with the presence of high quantity of gas bubbles (the carbon dioxide produced by the acid corrosion of the limestone in submerged condition), which going up toward the air filled zone follow preferential pathes along which the gas bubble corrosion becomes active (CHIESI & FORTI, 1987).

Anyway everse gutter are not a peculiarity of this cave: in fact, after their first observation they were discovered in several other caves and, in our opinion, this is the best proof of the fundamental role the sulfide-solfate reaction have in the spleogenesis of some karst systems.

The redox cycle of sulfur has been well known for a long time as a powerfull agent for the deposition of speleothems, therefore we do not describe all the numerous kinds of gypsum crystals and concretions as well as those of all the other sulfate minerals (HILL & FORTI, 1986); only the sulfur spleothems will be presented here, because they rapresent proof of the end of the redox reactons of the sulfur compounds in an interstage in which the value of the oxiding number is zero.

In natural environment the conditions in which the sulfur redox reactions may stop at that stage are not common, therefore, at least in the caves, sulfur speleothems are rare, even if recently several new occurrencies of this mineral have been done in the world.

In the karst environment most of the sulfur comes from the oxidation of the hydrogen sulfide, as for example the sulfur cave rafts over the sulfide rich river of the St.Ninfa cave in Sicily (FORTI, 1988) or the sulfur flostones and crusts of the cave inside the St. Cesarea thermae in Apulia (FORTI, 1983); but sulfur speleothems at least partially deposited by the reduction of sulfates (normally gypsum) are also known (FORTI, 1985).

CONCLUSION

At the end of this short outline on the peculiar morphologies, like the reverse gutters, or the high numbers of speleothems, whose genesis and development is controlled by the redox reaction of the natural cycle of sulfur, the prominent role that these reaction have in the speleogenesis is evident.

Once more, as usual in the last few years, it has been prooved that the "normal" karst development, based only on the CO_2-H_2O-$CaCO_3$ system, lowers its importance and loses part of the fields of its exclusive applicability in favour of the hyperkarst processes (CIGNA, 1981), which in turn are becoming the really normal speleogenetic mechanisms.

But the fundamental role of the biological redox reactions of sulfur in speleogenesis leads as consequence to put in a central position among the karst mechanisms the biologic processes and this, in our opinion, will have a noticeable influence in the development of the cave studies in the near furture

In fact till now the role of micro-organisms in the speleogenesis has been underestimated, if not completely disregarded mainly because the real difficulty to carry on such kind of research requiring wide interdisciplinary knowledges practicly hindered them to start with. Anyway it is evident that in the future it will be necessary to change the way to analyze such kind of problems in order to acheive a real knowledge of the karst processes.

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SPELEOTHEMS AND SPELEOGENESIS OF FAGGETO TONDO CAVE (UMBRIA-ITALY)

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ABSTRACT: Recent explorations inside the fossil galleries of the Faggeto Tondo cave (Mt Cucco, Umbria) led to the discovery of peculiar speleothems and cave minerals together with fluorine lenses.

Detailed analyses on the collected samples allowed to reconstruct the spelogenetic evolution the cave underwent: thermal phenomena caused the beginning of the karst process, which was mainly controlled by the sulfide waters flowing in vadose or in almost aereate conditions. At present only few metheoric and condesation waters with no traces of hydrogen sulfide are present inside the cave.

RIASSUNTO: La grotta del Faggeto Tondo (Massiccio di Monte Cucco, Umbria) presenta nella sua parte fossile particolari speleotemi (di calcite, gesso e celestina) nonche' lenti di fluorite.

L'analisi e lo studio di dettaglio dei minerali presenti nella grotta ha permesso di ricostruire lo sviluppo speleogenetico della cavita' basato in gran parte sulla presenza di acque solfuree fluenti in condizioni vadose o comunque prossime alla zona aereata.

Fenomeni termali sono stati alla base dell'evoluzione iniziale della cavita', mentre attualmente le poche acque circolanti sono di condensazione o di percolazione e non vi sono piu' tracce di acque solfuree.

INTRODUCTION

The Faggeto Tondo cave was recently explored (NOVELLI et al., 1985) in the W-slope of the Mt Cucco (Umbria, Italy) at about 1200 m a.s.l. It containes large, whidespread gypsum deposits and uncommon spleleothems, therefore a detailed mineralogical study of the cave was performed.

In the present paper, beside a geological sketch of the cave, all the observed speleothems are described and using the available data, a model for the cave development is presented.

GEOLOGICAL SKETCH

The Mt Cucco karst area consists of gently monoclinal fold with a N130 axis; the dip of the bedding is towards SW and ranges from 20 to 40 ; all the structure is interested by several NS transpressional faults.

The Faggeto Tondo cave (see Fig.1) is entirely developed inside the "Calcare Massiccio" Formation (Upper Lias), just close to the overlying "Bugarone" Formation (MENICHETTI, 1987),which has a very low permeability.

The "Calcare Massiccio" overlies the Anhydrites of the "Burano" Triassic Formation, which never outcrops, but it has been drilled for more than 1000 meters (GUZZETTI,1987).

Inside the "Calcare Massiccio" there are several fractures mainly oriented towards N30 and N50 and consisting of high angle joints; NS and EW fractures are also present; finally bedding joint planes exist at different level inside this sequence.

The structural settlement of the area, the high porosity of the "Calcare massiccio" and the overlying low permeability formations are the main factors which controlled the karst evolution in the whole area and in particular inside the Faggeto Tondo cave.

This cavity, over 3.000 m long and about 300 m deep, may be subdivided in two different parts. The upper one is completely fossil and consist of a pattern of rounded galleries following the dip of the strata: all the studied speleothems, mostly sulfate, have been collected in this part of the cave.

Some active flow is still present in the lower sector of the cave, where carbonate moonmilk is common and gypsum deposits quite absent.

SPELEOTHEMS AND CAVE MINERALS

The samples of rocks, speleothems and sediments were analyzed by X ray diffractometry and their thin sections studied with a microscope.

It is impossible to discuss in detail each sample and therefore they were grouped into three main groups (karstified rocks, speleothems and clastic deposits) and their mineralogical characteristic are summarized in tab.1.

The sistematic mineralogical investigation of the upper part of the Faggeto Tondo pointed out the presence of rare speleothems and cave mineralizations, which make this cave extremely important among the Italian karst systems.

Beside the normal calcite formations, there are speleothems, like the calcareous sand due to chemical sobstitution and the columns grown inside gypsum deposits: both originate from the reaction between the fresh (meteoric, CO_2 rich) seeping waters and the gypsum deposits (FORTI & PERNA, 1986).

The gypsum is far the prevailing among the cave minerals: it forms thick microcrystalline deposits, which often fill up the passages. Sometimes the sourfaces of such deposits show rounded fractures, which suggest their deposition from a semi-fluid (moonmilk-like) material.

Several of the gypsum deposits developed large rims (HILL & FORTI, 1986) in connection with fractures and tubes in the limestone floor, while along the walls the condensation and dripping pocesses caused the growth of big monocrystal stalactites, which were often deflected by the air flow;

Tab.1- Mineralogical composition of the samples of the Faggeto Tondo cave: Quartz and Feldspar have been omitted in the trace elements, due to their normal occurrence and low karst significance; the other minerals are not necessarily are present in all the gruped samples. A: halloysite; B: baryte; C: calcite; Ce: celestite; Cl: chlorite; F: fluorite; Fe: amorphous iron oxides; G: gypsum; Go: goethite; H: hematite; I: illite; L: lepidocrocite; M: montmorillonite; Q: quartz; R: rozenite; Rd: rodocrosite; S: strontianite

SAMPLE	MINERALS PREVAILING	ABUNDANT	TRACE
1- Karstified rocks			
C01	C		
R6	C		F
C04, C05, C09B	C	F	B
E1,C02	C/F		B/I/Cl/M
C03	F/C	S	B/R
R3, R4	F/C		B
R5,C012B	F	C	B
C06A	F	B	C
C012C	F		C
FA7,10,11, C09A	F		B
C06B	F/Go	Fe/H	L/Ro
2- Speleothems			
FA5, FA6, FA8, FA9	G		
FA12	G		Cl
C08	G		F
FA12-BU1	G		C/F
C07	G/C		F
C011, R7	C		
R2	Ce		
C010	Fe/Go		
3- Clastic deposits			
R1	Q/A	I	C/Ch/M

finally several deep and narrow conulites are present in the gypsum floors interested by dripping.

The present morphology of the gypsum deposits clearly indicates that they are fossil and where a small even amount of dripping is present they are dissolving and sometime changing at least partially into calcite formations.

Another cave mineral is celestite, which is present as aggregates of large (up to 2 cm) tabular hyaline crystals inside some of the gypsum depositis. The occurence of this cave mineral is uncommon and extremely rare in euhedral crystals. Beside the Crystal cave, Ohio (HILL & FORTI, 1986), the present occurence is the largest and the best in the world.

Both gypsum and celestite are products of chemical reactions, as their purity suggests. The dimension and thickness of gypsum deposits are incompatible with a genesis related to the oxidation of sulfide minerals which are present in low quantity inside the overlying formation; therefore their presence may be justified only with the flow inside the cave of sulfide waters, rising along the faults from the underlying Burano evaporites due to a low thermal activity.

A whidespread and deep (up to 1 m) chemical substitution is present along several of the exposed fractures in the cave walls and ceilings, where fluorine took the place of calcite (see Fig.2-B), without changing the macroscopical features of the rock: in fact some fossils remains (brachiopods, crinoids, gastropods) were sufficiently well preserved.

The fluoritized lenses are from grey to brown in colour and seem to follow, though not always, preferential directions, among which the NNE-SSW and E-W ones, related to the NS destral or EW sinistral strike-slip faults, prevail.

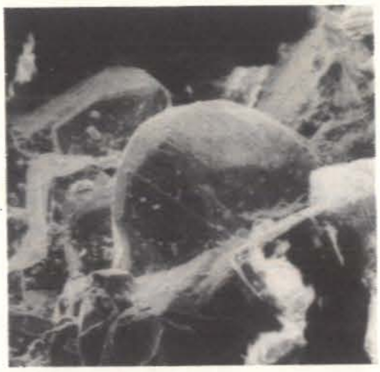
In the surface fluoritized lenses are still present, even if dolomitization processes are more common: anyway up to now it is impossible to define the spatial development of these chemical replacements.

Fluorite replacement of calcite had been gradual, as testified by some of the analyzed samples (C012A,B,C), and took place before the karst processes begun or in its early stages, therefore fluorite cannot be regarded as a true cave mineral.

Evident corrosional features over fluorite crystals (see Fig.2-C), developed in the later stages the cave, seem to confirm such an hypothesis. The deep-etching of fluorite is also testyfied by its presence as trace clastic material in several spleothems together with the occurrence of sufate minerals like rozenite and strontianite in the clastic filling of a fracture in a partially fluoritized wall (C03).

Amorphous or partially crystalline (Goethite, Lepidocrocite, Ematite), iron oxides, once associated with rodocrosite (C06B), are scarcely present: they form thin crusts or small filling along the tectonic or karst discontinuities of the walls. Their occurrence may be related to the weathering of metallic sulfides (mostly pyrite and marcasite), dispersed in the overlying formation.

Finally, an high halloysite content was detected inside a clastic greenich sediment at the top of a vertical pit (R1): this mineral is a well known cave mineral, whose occurrence testifies a strong acid environment (BERTOLANI et al., 1976), thus confirming the existence of an hyperkarst acid (sulfate) step in the cave development.



A

B

C

Fig.2- The Faggeto Tondo cave. A: gypsum crystal inside a corosion hole of the limestone wall (x160); B: fluorite crystals replacing the limestone (x350); C: corroded fluorite crystal (x1800) (Photo P.Ferrieri)

DISCUSSION

On the basis of the direct observations and of the analyzed samples, three different speleogenetic speps may be defined in the evolution of the Faggeto Tondo cave: they are characterized mainly by the physico-chemical parameters of the fluids flowing inside the karst system; moreover the first two steps seems to be strictly interconnected.

With the final emersion of the karst formation and its fracturation due to the late miocene tectonic, the first speleogenetic stage began, characterized by midum-high thermality, which caused the rising of fluids along the network of faults and joints: during this period a whidespread replacement of calcite, with fluorite (inside the cave) and with dolomite (in the sourface), took place.

The transition from the first to the second step was probably gradual, following the lowering of the temperature of the rising fluids: the second speleogenetic stage is in fact characterized by low thermality and sulfide waters rising from the evaporitc layers 800 m below the cave. The very high karst etch of these waters (FORTI, 1988) is responsible for the development of all the main cave passages, except the very recent vertical deepening. The deposition of the gypsum fillings in all the upper branches and locally of the other cave minerals (Celestite, Rozenite, Halloysite etc.) were caused by the same waters. All these minerals are a direct product of the reaction between sulfate ions and the wall rock, except halloysite, which is a weathering product of clay in strong acidic conditions (BERTOLANI et al, 1976).

Despite the large tubes morphologies suggest a phreatic development, the hydrologic conditions inside the cave cannot be completely saturated during this period: in fact it is well known that the karst action caused by the H_2S oxidation may fully develop only in aereate conditions and also the deposition of soluble minerals needs an active concentration process through evaporation. An additional proof is given by the presence of large celestite crystals, which is justified only if a lagoon condition was present, at least in some parts of the cave: in this manner the rising of the strontium content in the water, during the gypsum deposition, allows the achievement of the supersaturation degree with respect to celestite, even starting from very low Sr content. The presence of Strontianite in one of the analized samples(C03) is an additional proof of the existence of waters with a high strontium content.

At present the origin of this element is not sure: it may be dispersed as diadochy element in the karstified limestone or, more probably, it rose with H_2S from the underlying Burano formation, in which a low but constant presence of such an element is demonstrated (ROSSI, personal communication).

The occurrence of reverse gutters on the walls and of bell shaped domes in the ceilings (FORTI, 1988) perfectly agree with the hypotized

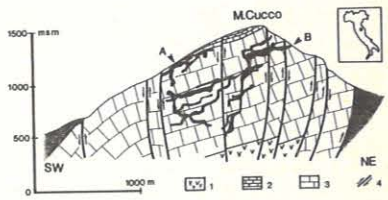


Fig.1- Geological skech of the Monte Cucco karst area: A- entrance of the Faggeto Tondo Cave; B- entrance of the Mt Cucco karst system; 1- the "Burano" Formation; 2- the "Calcare massiccio" Formation; 3- the "Bugarone" Formation; 4- fault

partially unsaturated conditions of the cave during this period.

As the rising of sulfide water stoped the third speleogenetic stage started, with the partial fossilization of the cave which is still going on. This last step is characterized by very low water supply as a result of meteoric infiltration and of condensation processes, the last being prevailing: in fact the low permeability of the overlying formation hinders the water seepage, except along the fractures. Where the percolation is allowed, as close to the entrance, a rapid evolution of sub-vertical branches, similar to the analogous ones of the Mt Cucco cave, is developing.

The growth of calcite speleothems started in this period, often enhanced by the partial simultaneous dissolution of gypsum (FORTI & RABBI, 1981), as the different calcite speleothems growing inside gypsum deposits testify. Thus the calcium carbonate formations are the younger chemical deposits of the cave.

FINAL REMARKS

Due to the presence in the Mt Cucco massive of the Faggeto Tondo cave with a rather complex evolution, the speleogenesis in the whole kast area. has to be reconsidered

The available data support a thermal event lasted over a long time, which is responsable not only of the fluorite and dolomite replacement in the limestone, but also of the deposition of thick gypsum deposits and other sulfate minerals caused by the rising of sulfide waters. Such an hypothesis, which cannot be restricted to the Faggeto Tondo cave, may be usefull to justify some speleothems (as the sulfate and phospate ones now under examination) and morphologies present inside the Mt Cucco karst system and in other cavities of the same area, like the Ferrata cave (FORTI & SALVATORI, 1989).

It seems to be highly probable and geologically reasonable that all the karst area underwent the same speleogenetic events, in particular those related to medum-high thermality, even if in the majority of the other caves the evidence of this period have been not yet discovered or, more probably, they have been completely destroyed or masked by the rapid development of the present day speleogenesis via fresh seeping waters.

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THE MAIN PRINCIPLES OF DEVELOPMENT AND DIAGNOSTIC CRITERIA OF A CARBONATE HYDROTHERMAL KARST

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ОСНОВНЫЕ ЗАКОНОМЕРНОСТИ РАЗВИТИЯ И КРИТЕРИИ ДИАГНОСТИКИ КАРБОНАТНОГО ГИДРОТЕРМОКАРСТА

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РЕЗЮМЕ

В докладе кратко изложены основные закономерности развития карбонатного гидротермокарста, установленные в результате полевого, экспериментального и теоретического изучения гидротермокарста СССР. Необходимым условием для появления продуктивных в отношении гидротермокарста систем являются: динамичность гидротермальных растворов; преобладание трещинной проницаемости пород; температура растворов менее 200°C; наличие растворенных электролитов (NaCl) и растворенной CO2.

Наиболее вероятными геологическими ситуациями появления гидротермокарста являются завершающие стадии развития геосинклиналей и этапы тектоно-магматической активизации платформ и складчатых областей. Наиболее вероятным механизмом при гидротермокарсте является активизация экзогенных вод тепловым потоком в зоне тектонических нарушений.

Рассмотрены особенности морфологии полостей, приведены данные об отложениях гидротермокарста в полостях и вне полостей. Предложен комплекс критериев диагностики гидротермокарста, включающий геолого-гидрогеологические, морфологические, минералого-седиментологические геохимические и косвенные признаки.

ABSTRACT

The paper shortly presents the main regularities of development of carbonate hydrothermal karst, as a result of field, experimental and theoretical study of hydrothermal karst of the USSR. With hydrothermal karst, the necessary conditions for development of productive systems are dynamism of hydrothermal solutions, predominance of rock fracture penetration, temperature of solution is less than 200°C, presence of electrolites (NaCl) in solutions and dissolved CO_2.

The most probable geological situations of hydrothermal karst appearance are completing steps of geosyncline development and stages of tectono-magmatic activization of platforms and fold regions. The most probable mechanism at hydrothermal karst is that of activization of exogenic waters by thermal flow in a zone of tectonic disturbance.

The paper provides the peculiarities of cave morphology, data on hydrothermal deposits in and out of caves. A set of diagnostic criteria is suggested for hydrothermal karst, consisting of geologo-hydrogeologic, morphologic, mineralo-sedimentary, geochemical and indirect signs.

The report is based on the field, experimental and theoretical investigations of hydrothermal karst. made in the USSR.

1. PRINCIPLES OF THE HYDROTHERMAL KARST DEVELOPMENT

1.1. Hydrodynamics of the process

This level is described by filtering properties of the rocks and by the hydrodynamical ones of the thermal waters. The water movement is mainly controlled by fissuration. layering and screening. The role of pore permeability is negligible. The solutions move in laminar mode. There are only local sites of attenuating turbulence These sites, which disturb a hydrodynamical picture of the flow, are the places, where individual caverns start to grow. One of the main principles of the big cavern formation is dynamics of the solutions sufficient for local turbulisation of the flow on the roughness of the fluid conducter walls. The turbulisation takes place under the following condition: $hU/\nu = 20\text{-}50$, where h - is the depth of roughness; U - is the flow velocity; ν - is the coefficient of kinematic viscosity. To form the small caverns, karstified zones and the collectors of thermal waters, oil and gas, the high dynamics of the flow is not necessary.

1.2. Thermohydrodynamics of the process

This level is described by interinfluence of heat properties of the rocks and ones of the flow. In general the temperature of the rocks themselves is controled by geothermal gradient. In some cases the heating of the rocks by the heat of cooling intrusive bodies is observed. It is not optional, however. The main characteristics at this level are the heat properties of the flow. The calculations show that heat equilibria in reaction zone is established during geologically negligeable time (about $n\cdot10^5 - n\cdot10^6$ s). Temperatures of hydrothermal karst solutions vary within broad limits. The temperature of 200-40°C is the optimum for carbonate hydrothermal karst development. Sometime the process goes at higher temperatures (300°C and higher). Under these conditions its development is not so extensive because of the reverse solubility of carbonates.

The formation and filling of hydrothermal karst caves go on the background of gradual decreasing of the temperature caused by space-time degeneration of hydrothermal system. This is well fixed when cave mineralization is studied by fluid inclusions method.

1.3. Physico-chemical dynamics of the process

This level is described by the substantial characteristics of the country rocks and hydrothermal solutions. The environment of hydrothermal karst development is mainly limestones. Thus, in the most theoretical works the system $CaCO_3$-CO_2-H_2O is used as a model. The foreign element influence on the process development has not been studied well enough. NaCl is usually present in hydrothermal karst solutions, more seldom there are KCl and $CaCl_2$ in different concentrations as well as CO_2. There is a tendency to oversimplify a salt composition and to reduce the concentration (from 25 to 0 mas.%) during evolution of the system.

The results of physico-mathematical modelling show, that in the geologically relevant conditions the main process of dissolutional cave formation is the diffusive transfer of substance through the boundary layer. The role of the real kinetics is negligible. As for the low temperature karst it is vice versa.

The country rock alteration is the substance rearranging related to formation of two physico-chemical zones, zones of $CaCO_3$ dissolution and precipitation. The substance is taken out from lower parts of carbonate section and precipitates in upper ones.

1.4. Geologo-hydrogeological dynamics of the process

The necessary condition for hydrothermal karst formation may have appeared in different times and in different geological environments through the whole geological history. At the final stages of geosyncline development as well as during tectono-magmatic activation of platforms and folded areas there is the highest probability of hydrothermal karst formation. As an example we can take hydrothermal karst of the Rodopes (the central massive of the geosyncline), the Crimea and the Tian-Shan (activized folded areas), the North American platform.

There are some data on karst age: Riphean and Cambrean (ore districts, USA: mine Sardana, USSR), Pre Middle Ordovician (ore districts, USA), Silurian-Devonian (the Sette-Daban, USSR), Carboniferrous - Early Permian (the Zeravshan, the Gissar, USSR), Jurassic (South Kirghizia), Cretaceous - Neogene (the Crimea), Pliocene-Pleistocene (the Caucazus), modern (the Rodopy). Given dating is based on the geological, paleogeographycal and paleohydrogeological reconstructions and, unfortunately, is not always reliable.

In fact almost all geologists recognize the polygenic origin of hydrothermal solutions. Since hydrothermal karst is usually connected with the latest stages of geological structure development, we can suppose that amagmatic waters predominate in it. For hydrothermal system to be productive in respect with hydrothermal karst formation, the following is necessary: 1 - great dynamical stocks of waters in the water-pressure system; 2 - availability of heat sources, among which the most important are the heat flows in the deep fault zones; 3 - water aggressivity due to CO_2 presence, higher temperatures and higher content of Cl-ion.

2. THE FORMS OF HYDROTHERMAL KARST OCCURRENCES

2.1. Hydrothermal karst caves morphology

Morphology of hydrothermal karst caves is in some way similar and in some way different to the morphology of low temperature karst caves. The following are the reasons for the similarity: 1 - the common physico-chemical process (i.e. dissolution) which results in the hydrothermal and low temperature karst caves formation; 2 - the common path of the hydrothermal solution and karst water movement. The differences result from the fact that the ascending movement of hydrothermal karst solutions is caused by water-pressure (non-gravitational) hydrodynamics.

Rather peculiar form of hydrothermal karst caves is a sphere. Caves-spheres are known in the Crimea, Kirghizia, Tadzhikistan and in other regions of the USSR. One may often find systems, which are made of some conjugated spheres. The diameters of distinct spheres are not usually greater than $n \cdot 10^1$ m. Another typical cave form is a dome-like one. Such caverns (caves-chambers) are characterized by a greater dimensions: their volumes may be by 1 or 2 orders greater than the volumes of caves-spheres. As an example the cave Carani (volume $1 \cdot 10^4$ m^3) in the Crimea and the Bakchardenskaia cave ($7{,}5 \cdot 10^5$ m^3) in Turkmenia can be taken. Besides dissolution, the breaking-down playes an important role in the formation of such caves.

Hydrothermal karst is usually gone under phreatic conditions. These conditions are reflected in the morphology of hydrothermal karst caves (see 3.2).

In hydrothermal karst caves one can find residual, breakdown and water chemogenical depositions. The most typical residual depositions are clays. They are usually found in hydrodynamical traps i.e. in the places, where the flow velocity falls. In the granulometric characteristics of the hydrothermal karst clays (in comparison with the low temperature karst clays) there must by a shift towards the pelite fraction. The most well-known residual deposition is the dolomitic sand.

Well described breakdown depositions of hydrothermal karst are the dissolution-collapse breccias (M.Sass-Gustkiewicz, 1975; S.Dzulynski, 1976).

Water chemogenical depositions are all minerals which precipitate in cavities during the hydrothermal system evolution. They can be divided into autochthone (which corresponds to the formula composition of the country rocks) and allohthone (related to the proper hydrothermal solution composition). For carbonate hydrothermal karst calcite, aragonite, ankerite and dolomite may be autohthone. The following minerals have been described in carbonate hydrothermal karst as allohthone ones: anhydrit, antimony, barite, celestite, chalcedony, chalcopyrite, chalcosine, cinnabar, cristobalite, fluorite, galena, goethite, gipsum, halotrichite, hematite, marcasite, metacinnabar, pickeringite, psilomelane, pyrite, quartz, realgar, rutile, sepiolite, spangolite, sphalerite, strontianite.

2.3. The hydrothermal karst formations, located outside the caves

In precipitation zone the $CaCO_3$ can precipitate not only in pre-formed soluton-made caverns, but also in fissure fluid conducters, the normal calcite veins being formed.

The hydrothermal solutions, when on the Earth surface, often contain plenty of CO_2 and $CaCO_3$, respectively. In this case the degasation of solution goes quickly,and there is an active precipitation of travertine.If the flow velocities are high enougn and there are sulphate rocks apart from carbonate in the geological section, then the formation of travertine may prevail on the vein calcite formation.

Another variant of the mineral formation on the Earth surface - is the formation of collumned radially-spread aggregates of calcite. The calcite, which precipitates from dilute thermal solutions is transformed in such aggregates.

3. THE DIAGNOSTIC CRITERIA OF HYDROTHERMAL KARST

The reliable diagnostics of the origin of dissolutional caverns is the necessary condition for the karstological researches. The problem of hydrothermal and low temperature karst distinction seems to be worth studied. This problem is especially important in ore geology (e.g. diagnostics of ore localization structures). This problem is mentioned in papers of S.Dżulynski (1976), V.Dublyanskiy (1980), E.Kutyrev and Yu.Liakhnitsky (1982).

3.1. Geologo-hydrogeological criteria

1). Non-obligatory relation of hydrothermal karst occurrences to continental interrupt. The presence of such interrupt is the necessary condition for the development of low temperature karst. As a result the fossil caves of low temperature karst are found near the stratigraphical unconformity surfaces.

2). The absence of relation to superficial feeding areas and base levels of erosion of the same age. Reliability of this criterion depends on quality of paleogeographycal and paleohydrogeological data.

3). Lack of stratification (for the hydrothemal karst within platforms). The karst, which is developed in platform conditions has clear stratification (R.Tsykin,1985).In the same conditions the hydrothemal karst gives non-stratified "azonal" formations. The hydrothemal karst of fault-fold mountain areas is likely to have analogous properties. Because of intensive block faulting and folding they are rather difficult to reveal.

3.2. Morphological criteria

4). The relation of morphology of the caves and their systems to non-gravitational hydrodynamics of ascending flows: a) spherical and dome-like caverns with great relative volume (greater than 100 $m^3 \cdot m^{-1}$, V.Dublyanskiy, 1980); b) bush-like systems consisting of spherical caverns with cupola upper terminations (L.Jacucs, 1977); c) cave systems with convexed upward (inversive) "equilibrium profiles" (E.Kutyrev, Yu.Liakhnitsky, 1982).

5). Predominance of phreatic signs in cave macro-, meso- and micromorphology. There are many special works dealing with the old phreatic condition diagnostics.

6). Unchangeable character of cave morphology with passage from one litological variety of carbonate rocks to another one (indication of diffusional regime of dissolution).

3.3. Mineral-sedimentological criteria

7). The presence of hydrothermal minerals in the caves. This is the most widely used criterion (S.Dżulynski, 1979; V.Dublyanskiy, 1980; E.Kutyrev, Yu.Liakhnitsky, 1982).

8). Less number of genetic classes of cave sediments. The residual, breakdown and water chemogenical sediments are found in the hydrothermal karst caves. Besides the water mechanical, cryogenical, organogenical and antropogenical sediments are found in the low temperature karst caves.

9). The presence of dissolution-collapse, hydrothermal explosions and hydraulic fracturing breccias (S.Dżulynski,1976). The clear distinguish criteria between hydrothermal and low temperature karst breccias are not elaborated, the usage of this criterion is complicated.

10). Predominance of mineral-sedimentological features indicating the open cavern filling under phreatic conditions: a) deposition of hydrothermal minerals as rhythmic-zonal coarse-crystaline drusy crust, uniformely covering cave walls; b) lack of differences between sediments on hanging and heading cave walls; c) crystal regeneration on the broken down drusy crusts; d) cockade structures in mineralized breccia bodies.

11). Space and genetic relationship between the caves, calcite veins and travertine bodies.

3.4. Geochemical criteria

12). The presence of mineralized thermal waters in the caves. This criterion can be used with the objects where hydrothermal karst is now in process.

13). The presence of country rock alteration and geochemical zonation syngenetic with karst.

The most part of proposed criteria are convergent. Therefore, using each single criterion one can not be confident in correctness of karst diagnostics. The possible complex space-time interrelationships between the hydrothermal and low temperature karst make the diagnostics difficult.

3.5. Indirect features

The following features indicate the possibility of detection of hydrothermal karst occurrences within studied area:

1. the presence of karst caves, with the age corresponding to one of the tectono-magmatic activation of this area;
2. location of studied occurrences within zones of hydrothermal activity (low temperature) manifestation;
3. their location within regional or global metallogenic provinces of the Hg, Sb, Pb, Zn, fluorite, baryte, calcite;
4. the signes of a hydrothermal activity with physico-chemical parameters which are favourable to hydrothermal karst development;
5. solution-made caverns in the non-karstifiable or poor karstifiable (under low temperature karst conditions) rocks.

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DATING OF CONTAMINATED TRAVERTINES

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Present techniques in U-series dating of dirty travertines demand that some allowance be made for contamination by common (detrital) ^{230}Th. Previous correction schemes have used ^{232}Th as monitor for ^{230}Th together with an assumed initial value for ^{2430}Th/^{232}Th. More sophisticated correction schemes use partial leaching techniques of which there are several. Whatever U-series correction method is adopted it is wise to augment the age-data with paleomagnetic, TL or ESR methods as a check for age concordancy. Examples are given from the early-man sites of Vertesszöllös (Hungary), Bilzingsleben (GDR) and Petralona (Greece).

La Datation des Travertines Contaminées

Là datation des travertines salées demand de tenir compte de ^{230}Th détritique (commun), parce'que autrement l'age derigé est trop vieille. Les méthodes précédents ont utilisés ^{232}Th comme une mésure pour ^{230}Th, avec une valeur initielle pour ^{230}Th/^{232}Th. Méthodes de correction qui sont plus avancées utilisés les téchniques de léssiver. Quel que soit la méthode du correction qu'on adopte, c'est prudent á augmenter le avec une méthode palaeomagnétique, thermoluminéscente ou de resonance paramagnétique áfin de vérifier l'âge. Nous donnerons quelques examples des places palaeoanthropologiques de Vertesszöllös (Hongrie), Bilzingleben (GDR) et Petralona (Grèce).

INTRODUCTION.

The U-Th method of dating pure carbonate depends on the observation that ^{238}U and ^{234}U are coprecipitated with the calcite, whereas insoluble ^{230}Th is not; ^{230}Th grows back toward equilibrium with its parents at a rate determined by its decay constant λ_o . Using alpha-specetrometry, the age can be computed from;

$$\frac{^{230}Th}{^{234}U} = \left(\frac{^{238}U}{^{234}U}\right)(1-e^{-\lambda_o t}) + \frac{\lambda_o}{\lambda_o - \lambda_o}\left(1 - \frac{^{238}U}{^{234}U}\right)(1-e^{(\lambda_4 - \lambda_o)t}) \qquad (1)$$

where λ_o and λ_4 are the decay constants for ^{230}Th and ^{234}U, respectively, and t is the age.

In carbonates contaminated by sediments and clays (detritus), however, an unknown amount of allogenic ^{230}Th is leached into the dissolved carbonate solution. The old method of correcting for this was to measure the activity of ^{232}Th in the thorium spectrum and then use an assumed initial value for ^{230}Th/^{232}Th. It was recognised that this procedure only worked for lightly contaminated samples and it could not take into account any ^{234}U or ^{238}U leached into solution.

A variety of other correction schemes have been proposed in which the isotope ratios of leachates and residues are plotted against each other on so-called isochron plots. Usually the activities are 'normalised' using ^{232}Th as a contamination index. Recently Ku and Liang (1984) have provided strict mathematical justification for isochron plots using leachate-residue (L-R) pairs. The isochron plots yield ^{230}Th/^{234}U and ^{234}U/^{238}U ratios of the carbonate end-member, and these are input into equation (1), as before, to derive the age.

SUMMARY OF THE 'LEACHATES-ALONE' METHOD.

The Ku and Liang, L-R method does not assume that the isotopes are in equilibrium in the detritus, but it does demand that there be no differential chemical fractionation (DCF) between the detritus isotopes during leaching. Schwarcz and Latham (1989) have shown that the use of leachates alone (the L-L method), from several aliquots of the same deposit, gets round the problem of DCF. Thus if the DCF is constant from leachate to leachate then its effect is merely to change the intercept of the L-L lines on the axes but not the gradients from which the age of the sample is derived.

The L-L method was subsequently tried by Przybilowicz, Schwarcz and Latham (1989) on five artificial calcite detritus mixtures, and they were able to recover the known calcite ages with good success.

It is now clear that variable DCF is recognisable by departures from the L-L straight lines. Experimental evidence from both the artificial mixtures and the Ku and Liang data show that the DCF changes most as the leach solutions become stronger. Consequently, the carbonate age data is best taken from that straight line section which utilises the weaker leachates. As yet, there is no agreed method of estimating the errors, but the most practical method appears to make use only of the scatter in the data points and ignores the individual error bars. This is because the error bars for weak leachates are artificially inflated by the decreasing value of ^{232}Th in the isochron plots. No doubt this problem can be resolved without too much difficulty.

CONCORDANCE CHECKS AND AGE LIMIT METHODS

Another way of checking U-Th age estimates on suitable material is to apply another independent dating technique, among the commonest of which are thermoluminescence (TL), electron spin resonance (ESR), ^{14}C and paleo- or archaeomagnetism. Unfortunately all these methods have their own problems and their reliability has to be judged on a case-by-case basis.

Nevertheless, for important archaeological dating of caves sites such concordance checks have proved invaluable, and we now give three examples.

VERTESSZOLLOS (Hungary).

The partial calvaria (which is possibly transitional between Homo Erectus and Homo Sapiens) and faunal remains from this site were found embedded in hot-spring deposits contaminated by wind-blown detritus, and a first attempt to date the deposits with U-series methods was made by V. V. Cherdyntsev (1965), who obtained ages ranging from 225 Ka to more than 250 Ka; and one age was quoted as being greater than 300 Ka. There was the possibility that they could even be older than 700 Ka. The travertines have variable quality from a dating point of view. Some samples are compact, whereas others are heavily contaminated with detritus and somewhat porous. Significant porosity in any sample serves as a warning that the isotopes may have been subject to open-system chemistry, and this is a more fundamental violation of the assumptions for reliable dating than is detrital contamination. Cherdynstev believed that the travertines conformed to close-system chemistry, and there are enough compact samples, above and below the cemented loess which contained the skull, for reliable age estimates.

Samples were found to be sufficiently magnetically stable that their magnetic polarity could be measured rapidly, and oriented samples were found to be normally magnetized. So the samples were certainly less than 720 Ka which is the recognised age of the start of the Brunhes Normal chron.

We next isotopically analyzed double leachates of two compact samples and a single leachate from a third. Without any Th corrections, they were all found to be either equal to or greater than 300 Ka in apparent age, as for some of the Cherdyntsev results.

We next assumed that the time period covered by the deposits was small compared with the overall age and plotted the isotope ratios on an isochron diagram. The L-L method, on these three samples taken together, gives straight lines whose gradients yielded a finite carbonate age of about 185 ± 25 Ka, which is somewhat younger than the Cherdyntsev results. Preliminary ESR dating by Hennig and Grun (1983) show ages ranging from 127 Ka ('Youngest' beds) to 210-250 Ka ('Older' beds) to 330-390 Ka (for the 'Basal' beds). For details see Schwarcz and Latham, (1984).

The next step in improving on the U-Th estimates will be to carry out multiple leaching of the samples separately in order, firstly, to decrease the estimated errors and, secondly, to see what kind of time range is spanned by the deposits. These could then be more meaningfully compared with the Hennig and Grun ESR estimates.

BILZINGSLEBEN (GDR). These are hot-spring travertines carrying varying amounts of detritus, and were isotopically analyzed by Harmon et al. (1980). They found ages ranging from 222 to 234 Ka, and the deposits had U concentrations of about 4.7 ppm. These analyses were in conflict with a pilot study by Latham and Schwarcz who found that compact samples gave ages from 319 Ka to over 360 Ka and U concentrations of only 0.18 ppm. Several more samples were analyzed and the Th spectra showed only low contamination by allogenic ^{230}Th, so Th corrections were not needed. Nevertheless concordance checks by ESR analyses were carried out by R. Grun, and these were in agreement with the newer results (Schwarcz, et al, 1988).

PETRALONA CAVE (N. Greece)

This is another important early-man site in which a skull (minus the lower jaw) was found cemented by knobbly calcite to a cave wall in a part of the cave called the Mausoleum. There is broad agreement that the skull probably represents a transitional stage between Homo Erectus and Homo Sapiens.

Unfortunately there have been several problems in ascribing an age for this skull (see eg. Wintle and Jacobs, 1982). The chief problem in dating the skull has been the uncertainty surrounding the exact stratigraphic relationship between the small amount of brown, knobbly calcite on the skull and the more easily datable calcite layers of the nearby floor. From arguments based mainly on colour, it seemed likely that the skull calcite did correspond to layer 10 (in the Poulianos notation).

Ikeya (1977) attempted to find a date by ESR on the calcite of nearby floor calcite layer 10. But without a direct measurement of the dose rate of the site itself, he had to assume a value taken from a Japanese site. His age estimates were as high as a 700 Ka.

U-series analyses on layer 10 (among other samples) were attempted by Schwarcz et al (1980) and they realised that the 5-10 cm thick layer 10 probably spanned the period from greater than 450 Ka to 260 Ka, and that there was a chance that the layer could be as old as 500 Ka. Liritzis (1982), used a leaching method to estimate an age for the layer 10 of and he also realised that this layer spanned a considerable time range.

The question of the relationship of the skull calcite to layer 10 was carried out by Hennig et al (1982) using trace element analyses on these two calcites and a third layer from another location in the cave. They showed that the skull calcite corresponded beyond reasonable doubt to the uppermost sublayer of layer 10. ESR dates on this layer and on fragments of the skull itself suggested an age between 130 and 240 Ka. Latham and Schwarcz in a U-Th reanalysis of the uppermost part of layer 10 found an age of about 160 Ka using the old Th type correction. They concluded that the probable youngest age for the skull was about 180 Ka.

Unfortunately, paleomagnetic analyses of various layers, including an excavated pit in the main part of the cave have been ambiguous. Preliminary results on soils by Bucha showed that there were significantly, viscous components present. In a more thorough analysis, Papamarinopoulos et al (1987) were unable to find good evidence for a reversed layer in Pit 1, and Latham and Schwarcz (1989) showed that both sediment and calcite layers in the excavated pit of the Mausoleum were magnetically unstable.

CONCLUSION

These results serve to show the desirability of using several methods to find the age of some of these problematic contaminated carbonate deposits. The new 'Leachate-alone' method shows that this method represents a significant advance over older methods in terms of increased accuracy and precision. It has been tested succesfully on artifical contaminated samples and on the contaminated travertines of Vertesszollos.

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MAGNETIZATION OF SPELEOTHEMS: DETRITAL OR CHEMICAL?

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Studies of speleothems from around the world have shown that their remanent magnetizations appear to be controlled only by the ancient field at the time of deposition. Sloping flowstones are free of any slope effect and the vertical sides of any stalagmite give the same paleomagnetic direction as the coeval horizontal drip cap. This is despite the observation that the magnetic load of most speleothems comes from cave floods and is thus detrital (Detrital remanent magnetization, DRM).

The presence of organics and known lack of detrital material, in other speleothems, argues for a chemical remanent magnetization (CRM) in which the magnetic grains grew in situ in the presence of the field.

Is it likely, in DRM-type speleothems, that the detrital material has become chemically reprecipitated and remagnetized, so as to give no depositional errors? Might bacteria also play a part in recrystallising magnetite? In some speleothems these are possibilities, but microscopic work shows that many of the observable detrital grains are still intact. The bulk of the magnetization is still DRM.

It seems that, for once, nature has conspired in every way to aid the scientist - but, as yet, by methods largely unknown.

Magnetization des Speleothems: Détritique ou Chemique?

Études des speleothems ont demonstrées que leurs magnétizations rémanents sont controllées seulement par le champ magnétique ancien quand ils sont deposités. Couches stalagmitiques sont librées d'effects du pendage et les côtes verticales des stalagmites possédes la meme direction palaeomagnétique que les couches verticales de même age. Cet observation est malgre que les mineraux magnétiques de plupart des speleothems derigés des inondations avec un chargement détritique. Donc, leur magnetizations rémanents naturels (MRN) est de type 'magnetization rémanent détritique' (MRD).

La presence des materiaux organiques et l'absence des materiaux détritiques, dans autres speleothems, suggère qu'ils tenaient un magnétization rémanent chemique (MRC) dans lesquels leur grains magnétiques ont formés, in situ, au presence du champ terrestre.

Est ce que c'est possible, dans les speleothems de type RMD, que les grains magnétiques détritiques sont reprécipités et remagnétisés d'un manniere sans erreurs de deposition?. Est-ce c'est aussi possible que bacterie jouent une part avec le récrystallization des grains magnétiques? Dans plusieurs stalagmites, c'est possibilite existe; mais èvidence microscopique manifeste que beaucoup des grains détritiques, qui les on observe, sont intacts. Le plupart de le magnétization des stalagmites est RMD.

Les magnetizations ne possèdaient pas des erreurs du deposition, et donc il semble, pour une fois, que la nature ont conspire en toute façon a aider le récherchеur - mais jusqu'a present - pour la plupart pars methodes inconnues.

INTRODUCTION

The principal aim of sediment paleomagnetism is to recover dated records of the past behaviour of the Earth's magnetic field. When magnetic particles settle through still water, they become aligned by the field against viscous drag, and this alignment is retained when the particles settle on the sediment bed. The resulting magnetization is known as a detrital remanent magnetization (DRM). However it is known that, on the average, magnetic particles rotate slightly on the surface of the bed so as to cause an apparent shallowing of the recorded magnetic inclination. The same effect can also be caused by subsequent compaction. If the bed is inclined then there may be an additional bedding error. If the water had an appreciable current then both the inclination and the declination may have been affected. Moreover, in the establishment of the final record, there are various sampling effects which may have to be taken into account (Verosub, 1977; Lund and Banerjee, 1979). Because of these problems, Latham and co-workers (eg Latham et al, 1979) investigated the magnetization of speleothems to see if it was possible to recover field records from them.

SUMMARY OF EXPERIMENTAL RESULTS

Oriented speleothems were taken back to the laboratory and cut up into 2 cm cubed specimens. The usual procedures of alternating field demagnetization or thermal demagnetization were used to magnetically clean the specimens. Measurements were made in a SQUID magnetometer. It soon became evident that some samples do have a measurable natural remanent magnetization (NRM) which was apparently unaffected by depositional processes. They found;

1) Pure white or translucent speleothems are magnetically very weak or have no NRM, as measured in a sensitive SQUID magnetometer.
2) Speleothems with the strongest NRMs acquired their magnetic grains from flood-laid detritus.
3) Some speleothems showed strong association between their magnetic content and the presence of organic material.
4) Spelothems which contained components derived from terra rosa generally have an unstable magnetic component.
5) A comparison of the magnetization directions of samples from vertical, horizontal and sloping sides failed to show up any effects that might be due to depositional processes, even when the magnetic grains were obviously of detrital origin.

Because it was already possible to date speleothems by the U-Th method, this last observation meant that reliable dated records could be produced from speleothems.

DISCUSSION

The problem then remained as to why speleothems should have NRMs which were free of depositional errors when sediments did not have such error-free NRMs. Latham (1981) suggested three modes of magnetization;

1) The magnetic grains grew, in situ, from iron held either by organics or by iron carrying bacteria - so producing a chemical remanent magnetization (CRM). Possible examples were the upper part of sample TS (Yorkshire, England) (Latham et al, 1979) and the inner core of SJHS (Chiapas, Mexico) (Latham et al, 1989).

2) The magnetic grains are detrital, from cave floods, and the NRM is some kind of DRM. Examples are VCCL, 82MS1 (Vancouver Island, Canada) (Latham et al, 1982; 1987); lower part of TS; SJLS (Mexico, Chiapas) (Latham et al, 1989) and others (Latham 1981).

3) The magnetization was detrital but has subsequently been modified in whole or part by chemical remagnetization (DRM plus CRM). Possible examples are DAS2 (San Luis Potosi, Mexico) (Latham et al, 1986) and the outer parts of SJHS.

Part of the evidence for CRM in some stalagmites also comes from the production of saturated induced magentizations (SIRMs) of pure stalagmites whose magnetite source could not have been cave floods. It is possible, though unlikely, that the small concentration of magnetic particles could have been air-borne. The SIRM experiments showed that the remanence carrier was magnetite.

In the ENF and BJTL samples from Canada (Latham et al, 1982) the magnetic material is strongly associated with organic material which has been identified by S-E Lauritzen (pers comm.) as probably having originated from decayed pine-forest litter (Figure 1). In these two cases it is not clear whether the organic material points to a detrital or a chemical origin for the magnetic component; it is probably both, since some organics are soluble and others are not. Rock magnetic studies showed that the particles are dominantly single-domained and the magnetization is hard.

Magnetotactic bacteria have been studied in a variety of aqueous environments (see Thompson and Oldfield, ch 15, 1986) and algae, having iron oxyhydroxide filaments, are common in some caves (eg. Long Churn Caves, Yorkshire, England). It is therefore quite probable that an NRM

FIGURE 1. Rhythmic layering of organic material in the BJTL flowstone from Crow's Nest Pass area, Canada. The magnetic material is submicroscopic and magnetically hard. The micrograph was taken with crossed polars and the darker portion ('brush' extinction) shows palisade crystals of different optical orientation to those of the light area.

component of some stalagmites will have been derived from bacterial or algal sources, but the exact magnitude or extent of such origins requires further study.

Whatever the method of production of a stalagmite CRM it is not difficult to see why such a magnetization should be free of any influences by its substrate or matrix. The grains simply grew in situ in the field and presumably became fixed at the same time as the calcite matrix was formed. Even in this case it is still possible to envisage a situation where the growing calcite crystals disturb the orientation of the newly forming magnetic grains. If this is the case, for CRM, then one can only suppose that it is a random effect about with no bias from the field direction, so resulting in a lack of measurable error.

DETRITAL REMANENT MAGNETIZATION OF SPELEOTHEMS.

The evidence for a detrital origin of remanence in some speleothems is;

1) Occurence of microscopic opaque grains concentrated along growth layers.

2) Opaque grains occur with quartz, feldspars and organic muck.

3) Some large opaque grains show exsolution features and spinel rods typical of titanomagnetites. Such grains have an exclusively igneous origin. (Figure 2).

4) after detritus has been laid on the stalagmite surface by floods, it is partially washed off the drip-cap area by the drips from the stalactite. The detritus is visibly concentrated around the slopes and vertical sides of the stalagmite - the 'wash-off' effect (eg. DAS2; Latham et al, 1986).

The NRM directions of ENF and BJTL showed no bias due to the dips of

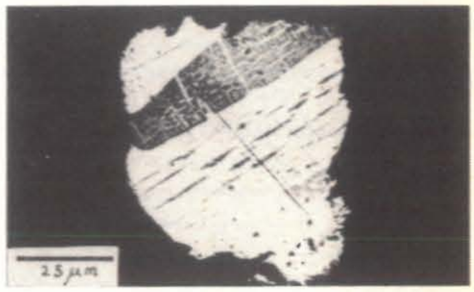

FIGURE 2. Reflected light micrograph of an opaque grain (oil immersion) from VCC1 (Vancouver Island, Canada). The phases are light-gray and brown-gray and it is probably a partially exsolved ilmenite grain. The Ti-Fe grains in many caves of Vancouver Island originated in basaltic dykes and sills within limestone beds.

these sloping flowstones (Latham et al, 1982). The coincidence of DRM directions from the horizontal drip cap to the vertical sides is well illustrated by specimens from the outer dirt rind of SJHS (Latham et al, 1989). The three horizontal drip-cap specimens have a direction of D = 351.7°, I = 19.1° and α_{95} of 0.8°. The side specimens incorporating the same growth layers have a direction of D = 354.8° and I = 19.4°. The combined five specimens have a direction of 351.9°, 19.8° with an α_{95} of 1.3°. (α_{95} is the half-angle of the cone of 95% confidence). This test has been checked positive for VCCL, 82MS1, DAS2 and others.

ERROR-FREE DRM - A POSSIBLE EXPLANATION.

The coercive force spectrum of most speleothems which carry an NRM shows that they generally have a range of grain sizes, from soft multi-domain (MD) grains to high coercivity single domain (SD) grains. The two exceptions are BJTL and ENF which have very high median demagnetization fields (MFDs) of greater than 40 mT. For ENF ratios of induced remanent magnetization at saturation to total induced magnetization J_{rs}/J_s were found to be greater than 0.45 indicating a high SD content. In most DRM-type stalagmites, however, there is usually a significant component of microscopically observable MD grains.

It is probable that if depositional processes play any role in affecting the orientation of magnetic grains, the MD grains will be the most susceptible to such effects. But because they are also magnetically soft, such grains may viscously decay and/or viscously acquire a magnetization in a later field, thus overprinting any possible depositiional effects. As with DAS2, VCCL and others, the softer magnetizations are usually viscous components having a direction close to the present Earth's field. As we have seen, however, the A-F or thermally cleaned directions, which are usually solely contained by the finer grains, have not been influenced by depositional processes - SJHS being a good example. This evidence leads us to suppose, therefore, that (1) even if the larger MD magnetite grains are affected by depositional processes their effect has not become evident because of later viscous overprints, and (2) the finer grains are not biased by measurable depositional effects.

Presumably the fine grains are free of depositional-effect errors because they are still free to rotate within their film of water until it evaporates. In addition, the magnetic grains are not subsequently affected by the way that calcite crystals grow from the underlying layer. In the case of DAS2 it was possible to show that the magnetization of these finer grains faithfully followed the ambient magnetic field throughout the 1200 yr growth period of the sample. (Unfortunately this property is frequently absent from sediments because pore spaces within the uncemented, non-magnetic matrix allow the finer grains to realign post-depositionally. Consequently, the fine-grain magnetization tends to follow later fields, until the sediment is dewatered, and this results in a post-depositional DRM.)

Further investigations of the nature of speleothem magnetism could include:

(1) The precipitation of calcite in a known field and under controlled conditions in which Fe is in a dissolved state in the feedwater so as to ensure that any resulting magnetization was unambiguously chemical.

(2) The precipitation of calcite in which various sized magnetite particles were incorporated in the feedwater. This series of experiments could be designed to find out at what grain size, if any, depositional effects began to be measurable. It is unfortunate that such experiments would probably take a few years to complete but, of course, they could be run concurrently with other work.

ACKNOWLEDGMENTS

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FEATURES AND HYDROLOGIC RUNNING OF THE KARST IN SIERRA SALVADA (ALAVA, BURGOS, VIZCAYA / NORTH SPAIN)

DE IPIÑA, Jesus Maria LZ. - PINEDO, Roberto

RESUME

Le Karst de Sierra Salvada comporte à la fin de 1.988 plus de 80 km. de galeries explorées dont la moitié correspondent au "Systéme Hayal de Ponata" (40.000 m./-350). Cette cavité, découverte et explorée depuis 1.983 par le Grupo Espeleológico Alavés (Vitoria-Gasteiz), est le principal collecteur de la zone.

On décrit le côntrole tectonique et lithologique du karst, et un premier modèle hypothetique d'écoulement souterraine appuyé dans le dispositif structurel, dans le positionement des surgences, les plus importants et dans les trajectoires des principaux rivières souterraines explorés.

RESUMEN

El Karst de Sierra Salvada comporta a finales de 1.988 más de 80 km. de galerías exploradas, de las cuales la mitad corresponden al Sistema del Hayal de Ponata (40.000/-350). Esta cavidad, descubierta y explorada por el Grupo Espeleológico Alavés (Vitoria-Gasteiz) desde 1.983, constituye el principal colector subterráneo de la zona.

Se describe el control tectónico y litológico del Karst y un primer modelo hipotético de circulación subterránea, apoyado en el dispositivo estructural del karst, en el posicionamiento de las surgencias más importantes y en las trayectorias de las principales corrientes subterráneas exploradas.

1.- INTRODUCTION

The Sierra Salvada is situated at the meeting point of the provinces of Alava, Burgos and Vizacaya, roughly 60 km. north-west of Vitoria-Gasteiz, capital of the Basque Country and has an extension of aproximately 70 Km2 (Fif. 1). The Sierra Salvada materials are composed of a thick package of limestone and dolomitic limestone, 200 m. in thickness, situated in a thick carbonate series, limited top and food by apparently impermeable marl facies.

The materials configure a Cuesta structure in the area, where the hard, resistant limestone stand out strongly, forming a vertical cornice whose height reaches 100-150 m. in the highest elevations.

The surface and underground morphologies as well as the orientation of the subterranean water courses are found strickly controlled by the fracturation, that has a strick E-W vector component.

This Karstic area, endoses (1989) more than 300 explored cavities, of which 9 are more than 1 km. in development. The "Hayalde Ponata Cave System" is the most important cavity of the karst, with 40 km. of explored galleries of a depth greater than 350 m..

Fig 1. Geographic location of Sierra Salvada.

The explorations in the area have been carried out by the Alava SpaeleologicalGroup (Vitoria-Gasteiz) in the "Jerea River System" and by the Edelweis Spaeleological Group (Burgos) in the "Pozalagua System".

2. STRUCTURAL AND LITHOLOGICAL CONTROL OF THE SUBTERRANEAN MORPHOLOGY

Sierra Salvada with its 80 km. of underground explored galleries constitutes a perfect area for constrasting fracture data obtained from the morphology of the cavities that perforate the carbonate packet (LZ. DE IPIÑA & PINEDO 1.986, 1.987).

The exokarst is characterized by the presence of structurally conditioned covered Karren.

In the case of endokarst, the structural and lithological control can be seen in two ways : firstly, in general, the realation between the directions of the different systems of joints present in the Sierra and the directions corresponding to the galleries of the cavities of this sector. This relation and the parallels between both can be seen in the diagram 2 .

Secondly, and on a different level, the control of the lithology and geological structure on the morphology. For example the dimensions of the galleries are related to the importance of the tectonic accident fron which they were formed. The biggest of these is the principal gallery of the "Hayal de Ponata System", conditioned by a breached fault zone , 40 m. wide. The variation in the chemical composition of the rock (gradual transition from limestone to marl-limestone) gives the galleries that traverse this zone a characteristic morphology, consisting of numerous blocks and slabs, fallen descomposed from the roof and walls as a result of great instability.

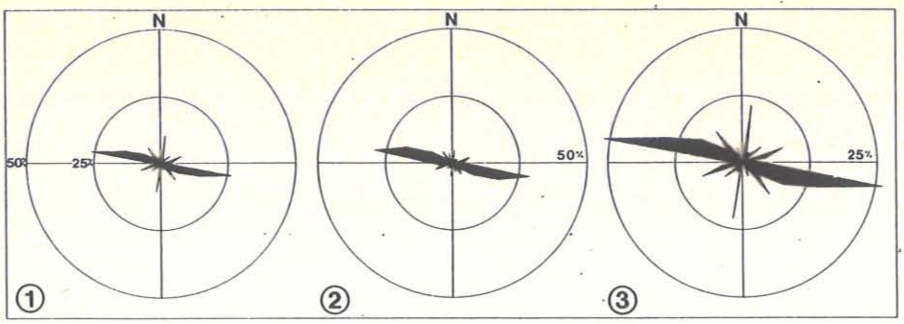

Fig. 2 Fracture orientation diagram; 1. % of joints number; 2. % of joints lengts; 3. % Orientation of the galleries.

The action of differential corrosion on certain areas of underground cavities creates distinc microforms whose origen lies in the compositional variation of the rock on which is formed the karst. It is characteristic of some cavities of the Sierra that such corrosion is produced taking advantage of the stratification layers, originating razored sections where the resistant material stands out in relief.

Lastly, indicating the rôle that the fracture density has in the underground morphology. In the areas where the density of the joints is low, the galleries accomodate themselves to the stratification layers giving squashed sections. On the contrary, in areas of high fracture density the galleries tend to the vertical accomodating themselves to the joints

3. HIDROLOGICAL HYPOTHESES

To the present (1989) 4 important underground water courses and some other secondary courses of lesser importance have been explored.

In the base of the structural dispositive of the Karst and the trajectory of these undergroundriver a first model can be configured of subterranean circulation area, estructured into three hypotetical basins: one of Mediterranean watershed ("Jerea river System") and two of Cantabrian watershed ("San Miguel el Viejo System" and "Pozalagua System") (Fig.3).

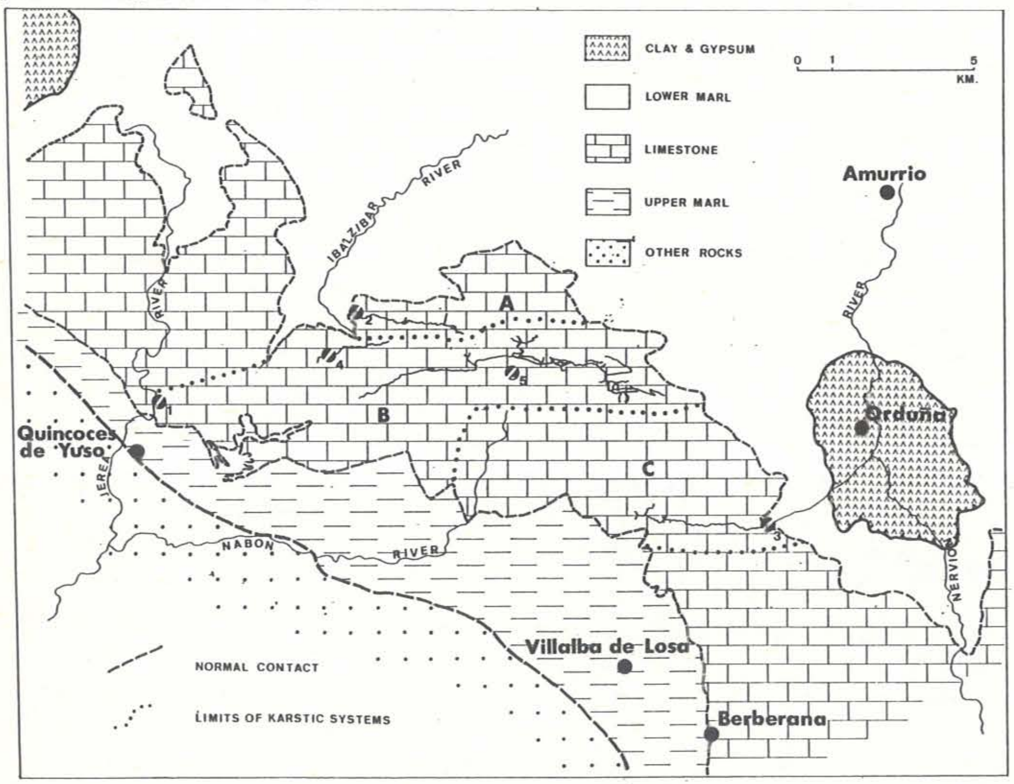

Fig. 3 Hydrogeologic diagram of the Sierra Salvada karstic area. A. San Miguel el Viejo System; B. Jerea river System; C. Pozalagua System. 1. Agua Cave (Burgos); 2. San Miguel el Viejo Cave (Alava); 3. Goba Haundi Cave - Perilde Cave (Burgos,Alava); 4. Marcenejas Cave (Burgos); 5. Hayal de Ponata Cave System (Alava, Vizcaya).

A. "San Miguel el Viejo System"

Hypotetically, this configures a recharging surface approximately10 km2, acting as a water collector the San Miguel el Viejo Cave (4.400 m.).

The discharge of the system is produced in the contac of the limestone and the inferior marl. The displacement of the underground water divisory to the north of the area limits the area of surface recharge of the system, and consecuently participates in the drainage of the nortern sector of the Sierra.

B. "Jerea river System"

Hypotetically the points of emergence of this unit, the most extensive of the three (32 km2. are situated on the rightbank of the Jerea River, near the contact with the impermeable top.

Continuing hypotetically, the discharge is effected through a series of springs with a flow estimated in low water at 20-30 l/s.

The Agua Cave is a intermitent resurgence that emits flows greater than 2 m/s water funcions as principal overflow of the system in high flow, conditioning its activity with the volume of discharge.

The situation of this discharge zone over the strongly fractured karst limestone and the proximity of virtual 'water level to the topographic surface, determine the infuence-effluence phenomena and the prevalent subaerial channels along the bed of the Jerea river, determining a displacement of the springs to the S. in time of low flow.

The principal collector of this unitwould be , hypotetically, the "Hayal de Ponata Cave System" (40.000 m. / -350) (LZ. DE IPIÑA & ALANGUA 1.983, LZ. DE IPIÑA & PINEDO 1.986) and secondly the Marcenejas Cave (2.700 m.). The flows transported in times of low water by this underground streams are estimated at 10-15 l/s.

C. "Pozalagua System"

Hypotetically, this individual unit has an area of 23 km2 , acting as a collector of the Goba Aundi-Cueva Perilde Complex (12.000 m.). An important part of the flow, drained by this complex filters in through the important network of drains situated in the high zone of the Range (Peride Cave, Albia Cave, Tejeras Cave).

The discharge is effected through the springs of the "Pico del Fraile" (AGORRETA 1.962) gully in the contact of the limestone with the inferior marl, the height of the point of emergence depending on the volume of the same.

In times of very low flow the discharge is effected on the gully- bed but at an lower level than the usual points of emergence.

3. CONCLUSIONS

A) The morphology of the cavities is controlled in two ways: One principal, the tectonic of the zone, on which the galleries or the different systems develop, and the other, relatively less important as it is the lithological variation of the carbonate package.

B) In the base of the trajectories of the explored subterranean streams, of the characteristic structures of the range and of the most importan springs which drain the karst, it is posible to delimit three karstic systems of parallel function.

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Num.	1	2	3	4	5	6	7	8	9	10
FILE	C.U.A.(*)	C.U.A.(*)	C.U.A.(*)	C.U.A.(*)	I.G.M.E.	OSAKIDETZA	I.G.M.E.	D.F.A.	OSAKIDETZA	OSAKIDETZA
DATE	04-12-81	21-12-82	06-07-83	01-09-83	13-01-84	17-09-84	02-10-84	13-02-85	24-09-85	29-06-86
pH	7,7	7,3	7,3	7,1	7,2	7,6	7,2	7,34	7,2	7,6
Conductivity	490	500	450	2100	2420		1171	690	820	920
CO3H-	253,5	251	230	391	168	400,7	346		450	
CO3--	0	0	0	0	0	0	0	0	0	
SO4--	130,4	46	16	83	62	77,6	68	51,25	73	74,4
Cl-	20	0	5,2	480	800	101,2	164	14,2	20,4	72,3
SiO2					10,0		9,7			
Ca++	115	155	87	270	300	165,1	131	116	140,20	105,6
Mg++	17	7	2,4	90	110	50	49	15,5	7,3	36,9
Na+	20	17,5	4,7	42	61		40			24,5
K+	1,6	0,4	0,2	2	3		1			1,02
NO3-	1	3	1,3	0,0	0,72	3,7	1	15,430	7,2	1
NO2-					0	0,048	0,06	0,02	0,1	NC
NH4+					0,03	0,32	0,16	0,283	0,19	+
S.S.		20	6	40					79,25	
PO4---					NC		0,01	1,4		NC
F-							0,4			
Iron	0,025	0,05	0,05	1	0,9		0,21	0,93		0,40
Manganese	0,066						0,06	NC		NC
Copper	0,025	0,025	0,025		0,01		NC	NC		NC
Zinc	0,005	0,05	0,025	0,3	0,01		NC	NC		NC
Hydrocarbons	+	+	+	+						
Cadmium							0,001	NC		NC
Lead							0,02	NC		NC
Nickel	0,025	0,1						NC		NC
Chromium	0,025	0,025					0,001	<0,05		
Mercury							NC			
Arsenic							NC			
Cyanide								0,053		

Table 1. Echávarri-Viña I well - Ground-water analyses. (All results, except pH and conductivity ($\mu S.cm^{-1}$), in mg./l.). (NC: non-content).

CONTRIBUTION TO STUDY OF GROUND-WATER POLLUTION IN THE APODACA KARSTIC AQUIFER (BASQUE COUNTRY, NORTHERN SPAIN)

DE IPIÑA, Jesus Maria LZ.

SUMMARY

The zone here studied constitutes an area about 40 km². located a few kilometers NW. of Vitoria-Gasteiz, the capital city from the Basque Country (Northern Spain). This zone constitutes the eastern-most edge of a wide acuiferous unit (Subijana Limestones) situated in the central-western Alava province.

The acuiferous materials are constituted by limestones and clayish limestones, largely fractured, with layers of compact marls. The age of this materials is Middle Coniacian - Lower Santonian.

On the basis of the data studied it is sketched the hydrogeological running of the unit. In the same way, the hydrochemical features, source and pollution processes affecting the zone are here described.

RESUMEN

La zona objeto de estudio es un área de unos 40 km²., situada al NW. y a escasos kilómetros de la ciudad de Vitoria-Gasteiz, capital del Pais Vasco (Norte de España), que constituye el extremo más oriental de una extensa unidad acuífera (Calizas de Subijana) desarrollada en el sector centro-occidental de la provincia de Alava.

En nuestro sector los materiales acuíferos están representados por calizas y calizas arcillosas, fuertemente fracturadas, con intercalaciones de margas compactas, de edad Coniacense Medio - Santoniense Inferior.

En función de los datos estudiados se esquematiza el funcionamiento hidrogeológico y se describen las características hidroquimicas, los focos y procesos de contaminación que afectan a la zona.

1.- INTRODUTION

The zone of study is an area of about 40 km²., located in the NW, few kilometres away from the city of Vitoria-Gasteiz (the capital of the Basque Country), that constitutes a small part of one of the widest aquifer areas of the Basque Country (Fig. 1).

In 1.982 a heavy industrial contamination was detected in a well for potable water supply of the area (Ecávarri-Viña I) attributed to an uncontrolled landfill whose contamination levels did not lessen during the period of time spent on the study (August 1.983) (MTZ. DE MUSITU et al. 1.983).

With these antecedents , in 1.987 the author made a preliminary study on the ground-water pollution of the aquifer. The aims were to define the characteristics and the operation of the aquifer as the basis of the pollutants dispersion in the area, the focus and the processes of contamination, and the temporal evolution of the contamination detected on the well Echavarri-Viña I. This paper represents a summary of this study.

2.- GEOLOGY CONTEXT

The karstic aquifer is developed in the carbonate levels of the Lower Coniaciens - Middle Santoniens (Upper Cretaceous) affected in this area by a smooth synclinal structure of NW.-SE. direction. In the NW. end the appearance of an diapiric nucleus, breaks the uniformity of the whole. In the materials described this structure has caused a strong fracturation assited by the development of an important karstification (Fig. 2).

The structural study of the area as well as the control practised by the tectonic in the position and geometry of

Fig. 1 Geographic location of the studied area.

karst can be found in ABALOS (1.986) and ABALOS, PINEDO (1.988). The general study of the karst and the description of the hypogean shapes had been inventoried by ERASO et al. (1.961).

3.- HYDROGEOLOGICAL FEATURES

The aquifer materials are composed of limestone and clay-limestone package of about 250 m. thick, strongly fracturated, which has compact marls inserted. The last ones determine confined aquifer levels and complicate even more the heterogenity of the karstic environment. These aquifer materials are limited to top and foot by impervius marl-formations.

The upper section of this unity functions freely, although the fore mentioned marl-levels determine confined aquifer levels. A main part of the ground-water flow in the upper section is found canalized preferably by the "Karstic

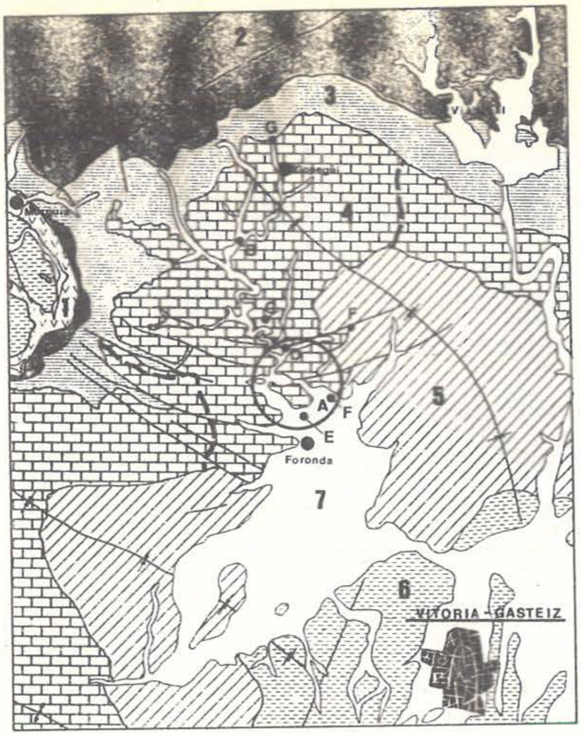

Fig. 2 Geologic and hydrogeologic contex. 1. Clay & Gypsum; 2. Sand-stone; 3. Lower marl; 4. Limestone (Karstic aquifer); 5 - 6. Upper marl; 7. Detritic materials of the river; A. Main discharge area; B. Bocarrón de Zaragua Cave - Main drain in the Zubialde bed-river; C. Zambolino Cave; E. Ugau spring; F. Industrial well (2,000 m³/day); G. Drains in contact with limestones; H. Echávarri-Viña I well.

System of Subialde River" (Bocarrón de Zaragua - Zambolinos - Pozos de Lendia - Ugau) (Fig. 3), determining a subaerial flow, the discharge of which joins two components: the discharge of the aquifer itself and the discharge of the afected flows collected by this system through important drains in the bed-river.

The transmissivity calculated in some of the wells studied, give us values between 3.7 and 11.7 m²./day which contrast with the high transmissivity of the main drainage system. The flows taken out from these wells are around 8-14 l./sec. with declines not excceding 70 m. which represents specific flows around 0.2 l./sec. m. .

The total recharge of the aquifer, which is the sum of the rainfall and the infiltrated drills of Subialde river and its tributaries, is about 54 Hm³./year. The discharge takes place in the S. end of the area through series of springs with a very irregular spectrum of the flows and the working of which is tightly controled by the oscillation of the piezometric level, which in this area is placed a few metres under the surface. The volume of this discharge is around 42.9 Hm³./year, which represents an average flow of 1,360 l./sec. . At present this descharge happens to be strongly influenced, especially in low waters, because of the pumping carried out by a nearby industry (2,000 m³./day).

4.- HYDROCHEMISTRY

The water of the aquifer is calcic bicarbonate and rarely calcic-magnesic (SHOELLER), which varies from an average hardness and notable mineralization to lighty mineralizated (NOISSETTE).

The relation r Mg^{++}/Ca^{++} is generally low, although certain values close to 0.6-0.7 point out a certain dolomitic content of the rock.

The presence of small levels of NO_2^- and NH_4^+ are in general indicators of reducer conditions of the aquifer. In the same way, the registration of iron levels associated with sulfurous odours in same of sampled wells (upto 400 μgr./l.), point out a solubility of the iron in reducer conditions starting from ferrous compounds appearing on the rock, especially sulphid.

In the continual analysis of the hardness parameter in two annual series, an outstanding hydrochemical heterogenety is detected (variation coefficients 17.1 and 17.9), which is understood as belonging to a karstic aquifer with well developed preferential conducts (SCHUSTER and WHITE 1.971).

5.- SOURCES AND PROCESSES OF GROUND-WATER CONTAMINATION

The potencial sources of contamination in the area, taking into account the low industrial activity, are only ones generated by urban, farming and livestock activities.

In our inventory we have taken into account nine

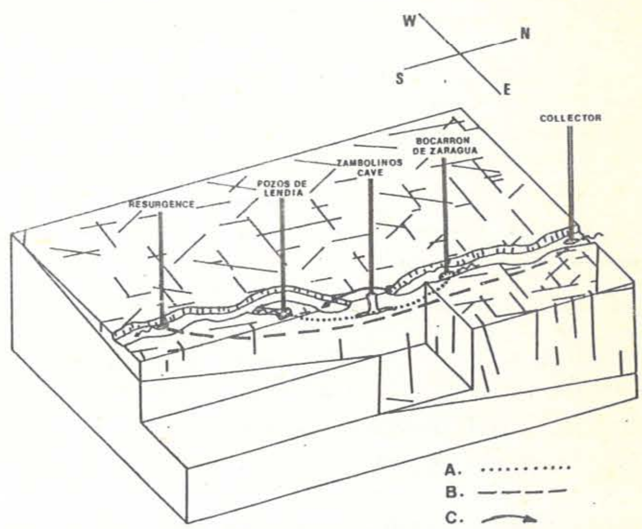

Fig. 3 Diagram of the karstic system functioning in the Zubialde river (ABALOS & PINEDO 1.988). A. High flow; B. Low flow; C. Flood seasons, strong overflows or thaws.

landfills that respectively include urban solid waste, ground and wreckage, dead animals, a codisposition of the former and in only one case industrial waste. Apart from the first ones, the others are either uncontroled waste-disposal and in some cases concerning ways of direct access to the network of subterranean flow.

According to the facts studied the quality of the ground-water, except the well made in Echávarri-Viña I, is only altered by the presence of microbiological indicators and

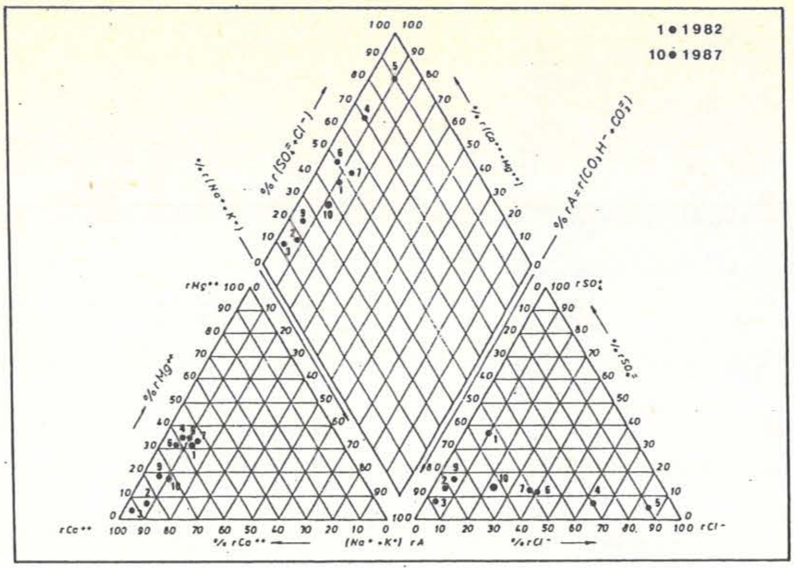

Fig. 4 Hydrochemical evolution of the water in Echávarri-Viña I well (Main constituents).

nitrite and amonium levels slightly higher than the legal limits.

The microbiological indicators mark the incidence over a wide group of local contamination samples of recent origin, surely related to the animals wastes used as fertilizer or to the effluents of septic tanks of the waste-water drainage system.

The detected concentrations of nitrites and amonium, point out a few reducer conditions in the aquifer and hardly ever organic contaminations.

The contamination detected in the well of Echávarri-Viña I is industrial in character and is noticed by the appearance of several pollutants and toxics.

Initially studied by MTZ. DE MUSITU et al. (1.982), these authors determined its relation with a landfill into which waste from industry, was thrown and injected (Lendia I).

High contents of material in suspension, essentially unsoluble silice and ferric hydroxid, reddish colourings caused by the colloidal particles of ferric hydroxid, high concentrations of dissoluted iron and lower concentrations of hydrocarbide, cyanide and heavy metals are the main signs of contamination. Such pollution is a cousequence of the leachates of the landfill Lendia I, as well as injections of liquid-waste from industry thrown into it. Even it the dissoluted-iron levels remain the same a progressive attenuation of the contamination can be seen.

There is also a secondary pollution of chlorides, coinciding with high levels of concentration in the more abounding constituents (Fig. 4), which responds to the subsequent cleaning and development proccess with acids used in the well. Such contamination is temporaly in character and goes back to normal in time, until the well recovers its initial levels.

6.- CONCLUSIONS

The dispersion of pollutants in the aquifer is strictly controled by the fracturation guidelines and the karstification developed in their favour. The existence in the karstic environment of routes and preferential channels of the subterranean flow, where the speed of transport is very high, can provoke a lapse of contamination from a long distance and in a short period of time. Such hydrogeologic features confer a high contamination vulnerability to the karstic aquifer of Apodaca, and in this way, the indicated heterogenity helps to create a great amount of local situations.

The focus and processes of the contamination detected in the groud-water are local character and derived from urban, farming, livestock activities, with a exception to that, which has been detected in the Echávarri-Viña I well.

In this case the contamination has an industrial origin which in the study period (1.982-1.987) partially attenuates. Nevertheless, the absence of a periodic control on the well prevents us from estimating whether the pluviometric contributions or additional gradient created once the well is pumped again, can mobilize pollutants that may have been kept on the surface or in the unsaturated area of the aquifer.

All in the waters of the aquifer are potable for human usage, but in some cases they demand normal treatments (clorination) in order to warrant the biologic potability. These waters are equally suitable for irrigation. For industry usage and due to their carbonated condition, they usually need softening processes because of incrustability problems that may result in industry process and circuits.

Finally the high vulnerability of this aquifer to contamination and the need of an effective protection of the ground-water based an a preventive strategy from a suitable arrangement of the territory should be underlined.

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A SEDIMENTAL STUDY OF DETRITAL MATERIALS IN THE HAYAL DE PONATA SYSTEM, SIERRA SALVADA, NORTH SPAIN

PINEDO, Roberto

RESUMEN

La Sierra Salvada se encuentra situada al NW. de la provincia de Alava (Norte de España) y está constituida por calizas y dolomías de edad Coniaciense. La sima del Hayal de Ponata con 40 Km. de galerias constituye el principal conducto de drenaje subterráneo de la Sierra. Los resultados de los análisis sedimentológicos y mineralógicos han demostrado la existencia de dos fases evolutivas bien diferenciadas, representadas por: un conjunto basal conglomerático sobre el que reposa el segundo nivel de menor granulometría. En este artículo se analiza la variación de tales conjuntos en un tramo de la sima.

SUMMARY

Sierra Salvada is located at NW. of the Alava province (Northern Iberian peninsula) and is constituted by limestones and dolomites of coniacien age. The HAYAL DE PONATA SYSTEM, with a gallery length of up 40 Kilometers is the main draynage channel of the range. The results obtainned from sedimentologic and mineralogic analyses indicate the existence of two well distinguished evolutive stages, representated by: a basal conglomerated ensemble overlayed by an upper unit with a smaller grain-size. In this work, the variations of such two ensembles is analyzed in a passage of the system.

GEOLOGICAL SETTING

The Hayal de Ponata System is situated in the Sierra Salvada. Since a lithological viewpoint this Range is part of the Subijana limestone formation dating from the upper-medium Coniacien , with a thickness varying between 150 and 200 m. The limestonecrops out over on area, of about 20 sq. km. Thelithology is essentially biopelmicrite, even though, localy, its dolomite content may increase. The analysis in thin section also reveals the presence of detrital quarz, pirite cristals and autigenic glauconite as chert nodes of varying dimension.

Tectonically this region is located between the biscayan anticlinorium and the Miranda syncline, forming a monoclinal area of slight dip (10º S). The direction of the packet coinciding with the great structures of the Basque-Cantabrian basin is N100-135ºE. Joints are the most outstanding structural feature. In general they are tension fractures, linked to the last phases of alpine orogenesis. The average density is 4.7 joint per sq. m.

Fig. 1

Among them there is a preferent system N90-100E corresponding to a longitudinal system which conditions in great measure the disposition of the internal karstic apparatus.

1. CAVE MORPHOLOGY

The Hayal de Ponata Systemhas an upper development at 40.000 m. and a drop at about 400 m. Up to now three entrances have been found, two in the area around the head of the head of the principal river and one around its middle area. The system show a great morphological variety, from meanderforms to sections in pin form in the highest areas, to clastic galleries of ample proportions (20 x 30 m.) . One part of the total development has a subterranean river with a low water at 10 l/s. The area where the majority of the detrital sediments are found coincides with the head of this river and the sedimentsmake up hanging terraces, situated at approximately 4 m. above the level of the present river. Sediments have also been studied in fossil galleries adjacent to the principals system.

3. DETRITAL SEDIMENTATION

3.1 Sediment levels

In carrying out this study 93 samples were taken from the system and submitted to granulometric and RX diffraction analysis.

The caracteristic detrital levels of this cavity are:

Botton Deposits. Consisting essentially of conglomerates of a typically autoctonous calcareous composition, together with lesser quantities of iron nodules, calcite boulders coming from the fragmentation of previous speleothems, as well as fragments of chert nodules. This is often interspersed with inferior granulometry(microconglomerates, sands or pebbles with mud-support structure), the result of the migration of the

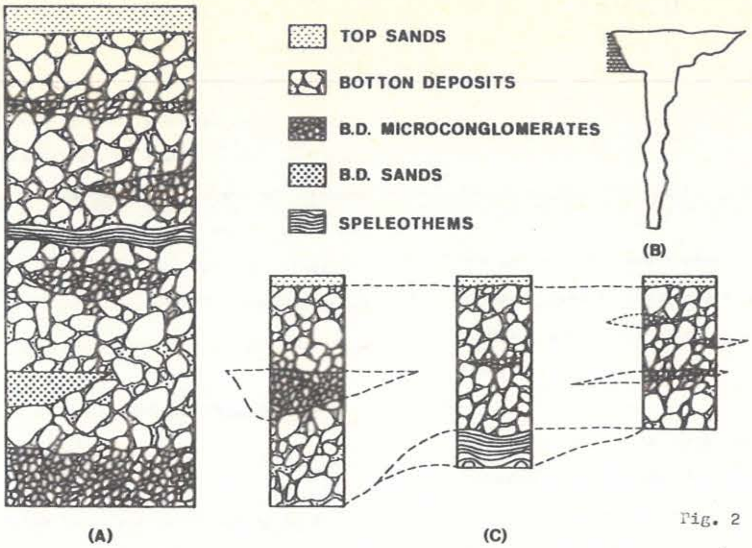


Fig. 2

principal channel from the sediment level or because of the formation of current structures, such as ripples,parallel stratification or dunes. Occasionally these discontinuous levels may be composed of up to 40% of iron nodules. Another of the caracteristic structures is the imbrication of- cantos-, which indicates a flow direction concordant whit the present. On occasion, these sotton deposits are cemented whit a thin sheet of carbonate.

Top Sands. The average granulometry is sand and gravel grade. As regards the composition, it differs from the ~~Botton Deposits~~ in the geater abundance of grains of quarz, in the absence of iron nodules and in the presence of thin needles of gypsum. The thickness is never more than 30 cm. , as distinct from the botton deposits which can extend up to 200 cm.

In the highest part of the principal axis of the system (the head of the principal river) the botton deposits are laid on a very decalcified bed, white in colour, even though absent in the rest of the cavity. In the same way, there are beds of lesser relevance among the botton deposits, better conserved than the last.

On other hand, between the basal level and that of the top there is a lack of conformity which cleary limits one stack from another.

3.2 Form and distribution of the particles

In general, grain-size is related with the form of particles. So, the biggest particles, always of a calcareous character, show a low sphericity (squased forms) and a higt degree of roundness: on the contrary, as the grain-size decrease , both sphericity and angularity increase.

The shape of the bigest clast (squashed) is conditioned by the jointed network of the Range. We find initial blocks in the form of match boxes, the edges of which rapidly wear off during transportation. As distinct fromthese, the smallest monocristaline particles have initially a more rounded form and come from a source closer to the cavity. The chert grains found are characterised by their pronounced roundness and sphericity.

The big limestone clast show at times, radial cracks provoked by the action of ice in the exterior of the Range.

Later they have been dragged along gullys into the endoKarst.

In so far as the relation between the parameters which characterise these detrital formations, it is worth pointing out the close relation between the head, the median and the sorting. This relation can be seen in figure 3, in which the farther we move away from the head, the lesser in size the grains become, both for the botton deposits and for the top sands.

Skewness values are fairly constant (between -0.5 and 0.25 phi) and Kurtosis (between 0.20 and 0.35 phi).

4. STAGES IN THE EVOLUTION OF THE SYSTEM.

The evolution of the Hayal de Ponata Sistem falls into several stages. The fist of these led to the formation of the preferential conduct of the drainage for the zone, first by means or forced, and later free circulation, which gave rise to just the type of morphology that we see today. At a second stage the basal bed was formed . In it we find some limestone pebbles, iron and chert nodules which are quite rounded and are probably the remains of the previous stage. On this bed, after the erosion of thespeleothems,the botton deposits are laid. These are characterised by an alternation in different episodes, some in which mechanical erosion is dominant and others in which chemical erosion dominates. This fact is supported by the presence of a greater percentage of iron nodules at certain levels, i. e. of insoluble limestone products. On certain occasions this stage is followed by another, the pebbles of the botton deposits are cemented with a thin coat of colada, never greater than 2 mm. This is followed by the sedimentation of the top sand deposits, characteristic of a calm current. This latter detrital sedimentation is followed by the next to presen layer in which both coladas and clastic sedimentation are produced, depending on the specific place.

Unfortunaly, the absolute dating of the different stages has not been possible up to now.

5.CONCLUSIONS.

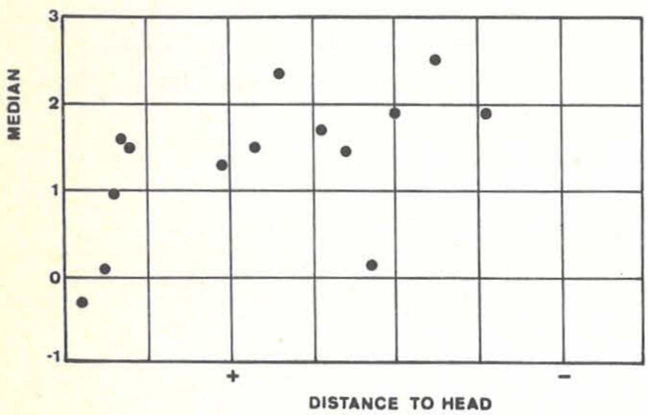
The detrital sediment sequences present in the Hayal de Ponata System lead to the following conclusions:

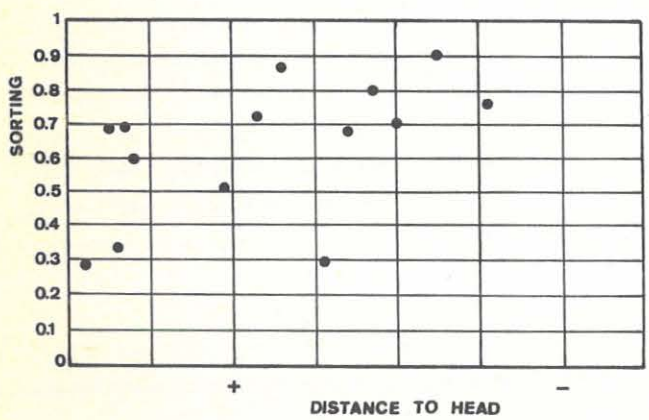
a.- Both sediment sequences, the botton deposits and the top sands are characteristic of a subenvironment stream passage (BOROZKA et al , 1983), both as regards grain-size and as regards the structure of the sediments such as ripples, dunes and imbrication.

b.- The source of the sediment material is twofold: one exterior, represented by calcareous clast and another internal consisting of fragments of calcareous beds or gypsum needles.

c.- It is possible to diferenciate two different types of chemical sediment, an initial carbonated type and a later gypsum type, although at present the chemical sedimentation is again carbonated.

d.- On the basis of the data obtained in the stratigraphic columns, it is possible to give a relative dating for the changes that have taken place in the Sistem. Roughly speaking these are three: the opening of a drainage chanel in the area, the sedimentation of the botton deposits accompanied by carbonated precipitation and the sedimentation of the top sands accompanied by gypsum precipitation.





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INVESTIGATION ON THE OLD VARIATIONS OF THE CLIMATE AND SOLAR ACTIVITY BY A NEW METHOD - LLMZA OF CAVE FLOWSTONE FROM BULGARIA

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Microzonality of luminescence of flowstones is the object of investigations with Laser Luminescent Microzonal Analysis (LLMZA). A correlation is found between the intensity of the rings of luminescence of the cave flowstones and the solar activity during the formation of corresponding layer of the flowstone. We suggests that the intensity of luminescence of rings in flowstones can be used as appropriate indirect index of solar activity. It was obtained time series of this index doumnwards to 25000 years (with resolution 10 years) in which Maunder and Spoerer minima are seen. A time series of this index downwards to 8000 years was obtained with a resolution about 2 months independent of what the absolute age of the zone is. The power spectral analysis of a part of this time series shows periods of 1, 11-12 and 24 years solar activity cycles. Larger periods are also seen. A time series of the index with a resolution of 3 days (150 px/a) was obtained in which the season cyclicity and the solar activity variations can be traced.

ИССЛЕДОВАНИЯ ДРЕВНИХ ИЗМЕНЕНИИ КЛИМАТА И СОЛНЕЧНОЙ АКТИВНОСТИ НОВИМ МЕТОДОМ ЛЛМЗА ПЕЩЕРНИХ НАТЕКОВ.

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Микрозональность люминесценции натеков является объектом исследованиям Лазерним Люминесцентним МикроЗональним Анализом /ЛЛМЗА/. Найдена корреляция между интензитетом зон люминесценции пещерных натеков и солнечной активности во время образования соответного слоя натека. Мы предложили использовать интензитет люминесценции зон в натеках как подходящий индиректний индекс солнечной активности. Получена временная серия этого индекса до 25000 лет назад /с разрешением 10 лет/ в которой видни Мауендеровий и Шпьореровий минимум. Получена временная серия этого индекса до 8000 лет назад с разрешением 2 месяца независимо от возрасти зон. Частотно-временний анализ части этой временной серии показывают периоды 1, 11-12 и 24 летных циклов солнечной активности. Регистрируются и длинновременние периоды. Получена временная серия этого индекса с разрешением 3 дня /150 точек в год/ в которой видни сезонние вариации климата и солнечной активности.

1. INTRODUCTION

The Laser Luminescent Analysis of Speleothems was proposed as a method for investigation of mineral forming conditions in [1,2].The Visual Luminescence Analysis was used in [3] as a method for investigations of climate changes during Quaternary. But those methods have a resolution which is insufficient to clarify the cyclisity of the short-time variations of the climate and solar activity (SA) which have caused them.For this purpose was proposed the method Laser Luminescent MicroZonal Analysis (LLMZA) with very hight resolution [4],which was applied in the present work.

The luminescence of the calcite speleothems is activated mainly by molecular admixtures [3,5], which are introduced by dissolving from plaing soils and sediments.Principal role in their dissolving is played by organic acids and the soil CO_2 all of them products of the life processes in plants [6],which are determined from the solar activity [7]. This quantity depends strongly on the solar activity and determines intensity of luminescence of the rings in speleothems.Therefore,curves of changes of the intensity of luminescence of flowstones along the axis of their growth present curves of changes of the SA versus the age of rings in the flowstone.Ut to now exist information for cycles of solar activity from direct measurements for 240 years and data from dendrochronology from 7400 years ago with resolution 1 yr. After calibration with this data,the method can be used for obtaining such information with higher resolution (up to 3days) from up to several milions years ago (the age of the oldest flow-stones).The experimental set-up used (scheme 1) is presented in [4].

The aim of this work is to study a new indirect index of the solar activity- the Intensity of Luminescence of the Microzones of Cave Flowstones.A time seria of this index can be obtained for a long period with high resolution(up to 125 px/yr),which allows research of either long or short time minima and maxima of the SA and general statistical conformities of the cyclicity of the SA (for which there are no time seria with sufficiently duration and good resolution).

1.1. Cyclicity of the Solar Activity

The main cycle of the SA,which was found as cycle of sun spots number, is 11-annual cycle.It is named solar cycle,because it is habitual for all phenomena of the SA [14].All indexes of the solar activity which affect on the frequency of solar phenomena show 11-annual cycle.Indexes of the solar activity which characterize power of the solar phenomena have double-peak,strongly deformed cyclic structure [15].

The discovery of the law of the changing of the polarity of the magnetic fields of the spots [16] allows physical interpretation of 22-years cycle.At transition of one 11-years cycle to the next,polarity of leading spots in the group in both hemispheres of the sun changes its sign.

The secular cycle was determined by [17].Accordingly [18] its mean duration is 79 years,in the boundaries between 30 and 120 years and is always multiple to 11-annual cycle,but not always to 22-annual.

Hypotesis of existance of double secular (189-yrs) cycle was proposed by [19].The possibility for existance of cycle with period of fifteen 11-annual cycles (165 yrs) was shown by [20]. Schove [12] confirmed this long cycle and discovered high activity in even centuries and low in odd.A cycle with duration of 600 yrs was determined (not very surely) on the base of Schove's time series and on some characteristics of 11-annual cycle [21,22].Its probable mean duration is 554 yrs [12].

It is difficult to determine convincingly existance of cycle of some centures only on the base of the data for the SA, which is measured only since 240 years.But using this cycles for prognosis [9.23] is very successful.

Long cycles of 600,900 and more years was confidently determined on the base of indirect indexes of the SA [24, 25, 26].

2. The Zonality of Luminescence of Cave Flowstones as Index of the Solar Activity

The method LLMZA and some its applications are given in [4, 8].Molecular admixtures in the flowstone luminesce at Laser irradiation of its polished section (scheme 1).If the growth rate of the flowstone is known,the curve of intensity of its luminescence in dependence of the distance from the surface will present a time series of the zonality of its luminescence.The time seria obtained are result of SA and Paleoclimatic variations.The intensity of the luminescence is determined mainly from the SA,because luminescent centres in flowstones are formed mainly on action of the solar radiation [4] penetrated through the earth atmosphere. Quantity of this radiation is strongly and directly correlated with the solar activity. The Paleoclimate determines mainly the width of the zones.After formation of the corresponding zone it is safed from further actions and safes information for the SA during its formation. It is confirmed by the series with resolution of 5 px/yr which show well pronounced 11-yrs cycles (fig.1) by which form can be obtained general properties of the 11-yrs cycle of the SA. This can be better seen at places with highest dynamics of the intensity of luminescence. As can be seen in fig.1 increasing part of 11-years peak is shorter than the decreasing; a critical point exists in the increasing part and cycles with higher maxima are shorter. Other known properties of the solar cycle [4,9] can be seen too.

Examples of time seria of the zonality of luminescence with resolution of 125 px/yr (fig.2), 4.7yr/px(fig.3) and 9.3 yr/px(f.4) are shown. Density of blackening of the emulsion of the negative, which is proportional to the intensity of luminescence is placed on the axis of ordinates, and the number of the measurements (pixels, by which can be determined age, because distance from the surface is proportional to the age of the flowstones and 1 pixel is a time step of the series) is placed on the abcissa axis. All time seria are obtained from a cave flowstone from Bulgaria.

2.1. Spectral Analysis of Time Seria of Luminescent Zonality.

To determine the periods of this climatic changes reliably and with the proper statistical accuracy, we regard the series of image density estimates as a time series (time dependent process) and use the methods of mathematical spectral analysis. The normalized smoothed estimates of the spectral density are calculated according to the formula:

$$S(\nu)=2\Delta[1+2\Sigma_{k=1}^{l-1} r(k)w(k)\cos\frac{\pi\nu k}{F}\Delta],\ \nu=0,1,\dots,F \qquad (1)$$

where r(k) is authocorrelation function, w(k)- the spectral window, Δ-discretization step, L- cut-off point, F is a number being 2-3 times greather than L, and ν the frequency (in Hertz). The inverse ν gives an estimate for the period T- of the periodic process. We have used the Bartlett's spectral window:

$$w(k)=\begin{cases}1-\frac{k}{l}, & 0\le k\le L\\ 0, & k>L\end{cases} \qquad (2)$$

which is a proper window being commonly used in similar research.

Fig.7 shows the spectrum corresponding to the scan shown in Fig.9. It is seen from that figure that the maximal value of the spectral density is abouth zero and the longest frequences, which corresponds to very large periods, not accurately determinable at the quantization step chosen (5 px/yr at L=300). There can be seen also two much longer peaks at 120 px (=24 yrs) and 60 px (=12 yrs). In order to investigate still shorter periodicities, we have filtered the source time series using a high-frequencies filter, namely that of the first differences:

$$Y_i = x_i - x_{i-1} \qquad (3)$$

The resultant spectrum is shown in Fig.8.

This latter result is rather interesting. It shows that we can reliably determine the annual rings in the sample using the proposed method at such magnificance [4].

The splittings of the 11-annual SA peak, observed in Fig.3, are due to the availability of binar, singular, three- and four-cyclic 11-years cycles with different length [4].

The time series from fig.3 has duration of 8000 yrs and resolution 5 yrs/px. As it is seen (fig.3) this index is in anticorrelation with the index "rate of increasing of ^{14}C " and in direct correlation with the SA, as in thermoluminescent time seria of sea sediment cores [28,29], but with possibilities for higher resolution [8]. In this time series can be seen very good long minima of Maunder and Spoerer, Medieval maximum and others. The power spectra (fig.5.a,b) of time series from fig.3 shows cycles with periods of 1180,590,425,310 and 22 years.

Power spectra from fig.6,7,8 demonstrate possibilities of the time seria of luminescent zonality for research of long and short time cyclisity of the SA. The spectra from fig.6.a,b was obtained for a time series with duration 35000 years (fig.4) and resolution 9,34yrs/px. It shows convincingly the reality of cyclicity with periods of 55,95,180,275,390,550,930,1170, 2340 and 3350 years. For existance of some of them there are data in time seria of other indirect indexes too [24,25].

Analysis of the thermoluminescence of the recent sediment cores shown four main periods: 137,7; 59; 12,06; and 10.08 yrs. Accordingly to [28] the beating of the too high-frequency components produce modulated wavetrain with carrier wave 11,4 yrs and amplitude modulation with period 206 yrs. Periods of 24, 12 (13.3; 10.4 and 8.8), 1 and 2 yrs were determined by power spectra (fig.7,8) of time seria with 5 px/yr (fig.9), and o,5,1 and 2 yrs in power spectrum (fig.10) of time seria with 125 px/yr (fig.2).

2.2. Flowstones for LLMZA investigations

Most suitable for dating by this method are the calcite polycristaline speleothems having strongly pronounced zonality of their luminescence. Best results are obtained from flowstones from the clousest to the surface parts of the caves with active air exchange, because climatic variations influence mostly on them. In speleothems from big depth only 350 years cycles of the solar activity and slow climatic variations could be traced, because climatic variations in depth are small and influence very weak on the flowstone growth [4]. The syngle crystal, the macrocrystal, the lake and aragonite speleothems are not suitable for the method for the same reasons. Flowstones with admixtures of luminescent metal ions

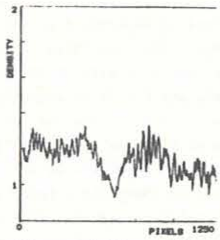

FIG.1. LLMZA curve with resolution 2.4 months (5 px/yr) obtained from photo 1.

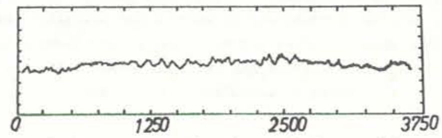

FIG.2. LLMZA curve of the season climatic variations with resolution 3 days (125 px/yr) [8].

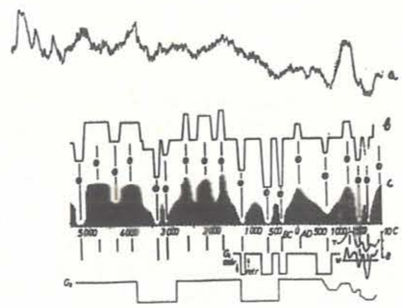

FIG.3. Curves of SA:-a.Luminescent curve [8], b-Persistent ^{14}C deviations by [27], c.-interpretation of (b) as SA envelope (of sunspot cycle), T-mean annual temperature in England, w-Winter severity index in London, G_1-times of advance and retreat of Alpine Glaciers G_2- same for worldwide glacier fluctuations.

(Mn^{2+}, Sn^{2+} and rare earth elements ions) are not suitable for application of this method, but they are exceptionally rare in speleothems, because they luminesce only in hydrothermal calcite [5]. Calcite with luminescence of uranil ion are also not suitable. Therefore it is necessary to indentify the spectra of luminescence of the sample according to [2,3,5], before applying this method. Taking in account, that the period of cyclicity of the solar activity is constant if the growth of the formation has been persistent from a certain period till now, this method can be used as method for dating from the number of rings due to cycles of the same type (as the dendrochronology) in this interval. However the accuracy of such dating is 1 year, independent from the age. Interruptions of the growth reflect in the curves as sharp places in the intensity of the luminescence of the sample[4]

3. Conclusions

Created method can be used for investigation of Climatic and Solar Activity Changes during Quaternary with high resolution (up to 3 days) and as method for dating of flowstones with accuracy of 1 year. This method allow preparation of time seria with different step Δt (time resolution). Minimal obtained till now step is 125 px/yr (less than 3 days). This resolution is unattainable for other applicable in caves methods. Another advantage of the method is that it do not need big quantities of matherial from the flowstone

Cycles of the Solar Activity with periods of 0,5; 1,2,11-12, 22, 55, 95, 180, 300, 400, 600, 900, 1200, 2300 and 3350 years are determined by LLMZA of Cave Flowstone.

4. Acknowledgements

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This work is a part of the **Internaional Programme of "Luminescence of Cave Minerals" of the Commision of Physical Chemistry and Hydrogeology of Karst of UIS**, and part of its National Subprogramme sponsored by Bulgarian Country Committee of Science.

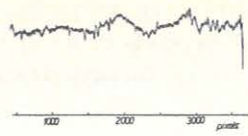


FIG.9. LLMZA time series with resolution 2,4 months (5 px/yr) [8].

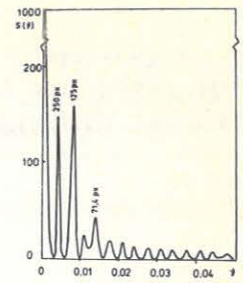


FIG.10. Power spectrum of the time series from fig.2.

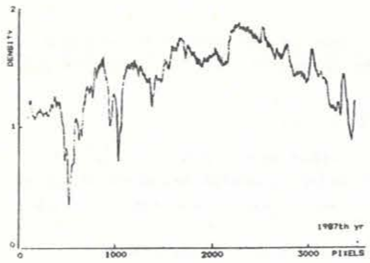


FIG.4.Luminescent time series with resolution 9,34 yr/px. (35000yrs)

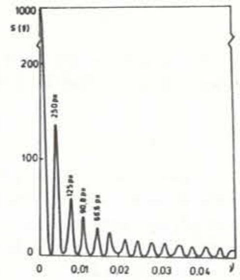
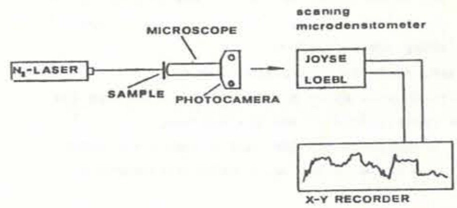


FIG.5.a.Power spectrum of f.3a



SHEME.1. Scheme of apparatus for LLMZA.

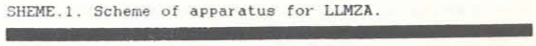


PHOTO.1.Microphotography of luminescence of part of Cave flowstone

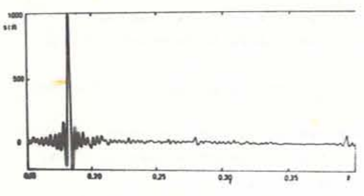


FIG.5.b. High-frequency filtered spectrum of fig.9 [8]

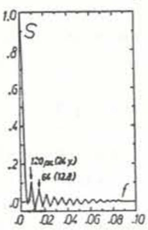


FIG.7. Power spectrum of the curve from fig.9 [8]

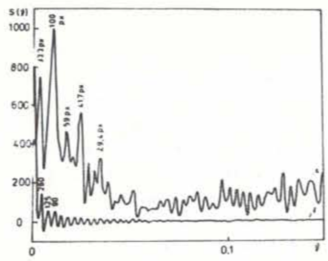


FIG.6. High-frequency filtered (a) power spectrrum (b) of fig.4.

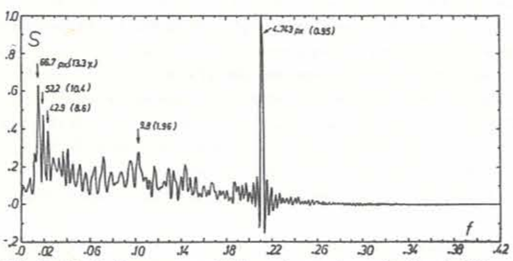


FIG.8. High-frequency filtered spectra of fig.9 [8].

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BASES AND STRUCTURE OF THE INTERNATIONAL PROGRAMME "LUMINESCENCE OF CAVE MINERALS" OF THE COMMISSION OF PHYSICAL CHEMISTRY AND HYDROGEOLOGY OF THE KARST OF U.I.S.

SHOPOV, Yavor

3 new special methods and 4 methodics for research of the luminescence of cave minerals are elaborated. The foundations of the International Programme of "Luminescence of Cave Minerals of the world" and mechanism of its working are described.

Advantages of this programme are possibilities for:

- easy nondestructive determination of objective information for mineral composition and luminescence of the speleothems.

- easy collection of information for the cave minerals and conditions of their formation in caves in the whole world from non-skilled cavers.

- easy access of every speleologist to expensive and complicated analytical methods.

Applications of this programme for obtaining principially new information in the field of geology, mineralogy, paleoclimatology, astrophisics and physics are shown.

Contemporary state and perspectives of the investigations of luminescence of cave minerals are shown.

ОСНОВИ И СТРУКТУРА МЕЖДУНАРОДНОЙ ПРОГРАММИ "ЛЮМИНЕСЦЕНЦИЯ МИНЕРАЛОВ ПЕЩЕР" КОМИССИИ ФИЗИКО-ХИМИИ И ГИДРОГЕОЛОГИИ ЮИС.

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/Болгария/

Разработани 3 новые специальние методи и 4 методики для исследования люминесценции пещерных минералов. Описани основи Международной программы "Люминесценция пещерных минералов мира" и механизм ее работи.

Достойнствами программы являются возможности для:

- легкого недеструктивного получения обьективной информации о минеральном составе и люминесценции вторичних образований пещер.

- легкого собирания информации о пещерных минералов и условиях их образования в пещерах целого мира неквалифицированними пещерниками.

- легкого доступа любово спелеолога к дорогой и сложной аппаратуре.

Показани приложения этой программи для получения принципиально новой информации в области геологии, минералогии, палеоклиматологии, астрофизики и физики.

Показани современное состояние и перспективи исследовании люминесценции пещерных минералов.

1. Introduction

Visual Luminescent Analysis (VLA) is the most commonly used in caves method [1].But accordingly to the most perfect monography of luminescence (L) of minerals [2], almost all data which can be studed with this method were obtained 30 years ago in [3],when several ten thousants mineral samples from nearly all mineral deposits of the world has been investigated.

Some disadvantages of this method are, that:

-obtained data are subjective (they are not measured with apparatus)

-determination of the activators of the luminescence is not possible. Attempts to determine activators of the luminescence with VLA and chemical analysis leads to erroneous results.The statement that Sr causes violet luminescence of carbonates and Cu- causes pale-green and blue luminescence of calcite and aragonite quoted in [4] are mistaken,because Sr-ions have not electron transitions in visible region and can not activate the luminescence of the carbonates,but Cu is known as quencher of luminescence of cations [2] Cu^{2+} can excite only infrared luminescence of some sulphides.

Slacik [5] has used simple apparatus with registration of total emitted light by photo cell with galvanometer, for quantitative evaluation of the intensity of luminescence at VLA (due to absence of necessary apparata).

The investigations of the spectra of luminescence accordingly to [2] reveals new possibilities for luminescent research in mineralogy:- for determination of the character of isomorphic substitution,the structural characteristics of the admixtures and defect centres and the typomorphycal peculiarity of minerals.

The conventional Luminescent Spectral Analysis (LSA) of minerals [2,6] needs expensive and complicated apparata and high-qualified spectroscopist, therefore it can be used only in large spectral laboratories. Therefore it has limited application in the Speleology.The luminescence of cave minerals (CM) of $CaCO_3$ at exitation with electron beem [7],N_2-LASER [8,9], Xe and Hg-lamp [10, 11] is measured with LSA. A disadvantage of this method is that it is destructive method and gives total spectra of luminescence of all sample and is inapplicable for research of fine mixed aggregates as moonmilk.

Conventional method for photography of luminescence (PL) is not adaptable for photography in caves,because it needs long exposition time (30-60 min) and a permanent electric sourse.The main disadvantage of this method is,that it always distores the colour of luminescence,because it is impossible to choose a pair filters which can absorb whole emission of the UV-lamp,without to absorb luminescence of the sample. Some photographers even don't use filters at all to absorb lamp emission,thus producing UV photos (as that shown in [4]) instead photos of fluorescence.

2. Special Speleological Methods and Methodics for Luminescent research

Described conventional methods and methodics for research of luminescence of minerals are proposed for work in laboratory conditions and are not adapted especially for the speleothems and for work in caves. This facts compeled the collective of section speleology of Sofia University to elaborate 3 methods (table 1),4 methodics (table 2) for research of speleothems and 3 apparata for their using directly in caves.They allows considerable enlargement of kinds and quality of the obtainable information and decrease to minimum of quantity of the samples necessary for laboratory measurements.

The most simple method for luminescent research,which can be used by every caver is IPP. Slides obtained by using this method can be developed by CSS for preparation of spectra of phosphorescence.CSS method was elaborated for determination of spectra of quick processes in astrophysics and spectraphysics.In speleology CSS is applied for preparation of spectra of diffuse reflectance and luminescence (at developing of slides obtained by IPL method) [18]. It is intended for research of widelines spectra,such as the luminescence of all speleothems formed at normal cave conditions (at temperature below 40° C). Only the L of the rare earth ions (which is observed exceptionally rare in the caves and occure only in some hydrothermal minerals as the fluorite) have sharp lines, which are broadened by the slide emulsion and are not reproduced realy at CSS.

This methods are foundations of the International Programme for research of "Luminescence of Cave Minerals of the World" of the Commission of Physical Chemistry and Hydrogeology of U I S.

The aim of this programme is the elaboration of a system for non-destructive express diagnostics of the Luminescent Cave Minerals with LSPA, by photographing its luminescence with IPP and obtaining the spectra with CSS. The determination of the spectra of L of all luminescent CM (which is the object of this programme) is necessary for this purpose. The LLMZA investigations are object of this programme too.

Advantages of this pragramme are possibilities for:

-easy non-destructive determination of objective information for mineral composition and luminescence of speleothems.

-easy collection of information for CM and conditions of its formation in caves around the world from non-skilled cavers and central development of the information with standartized technics.

-easy access of every speleologist to expensive and complicated analytical methods.

3. Structure of the Programme

First stage of the Programme is the preparation of slides of phosphorescence (P) of the CM (with IPP) in the caves. Every caver can participate in this stage, if he prepares slides of phosphorescence of speleothems (accordingly to applied instruction for IPP) directly in caves. Determination of typomorphic types of luminescence the of CM in caves will be produced.

Second stage- 1. Spectral development of slides by CSS method

-2. Indentification of obtained spectra by comparison with known spectra of luminescence.

-3. Receiving of sample of the mineral from the author, if the spectrum isn't known. Preparation of spectra of luminescence of the CM with different excitation and ESR spectra for determination of the luminescent centre.

-4. Perfect phase diagnostics of the mineral with X-ray diffraction and DTA, DTG and TG analysis. All data obtained from the samples sended from the speleologists will be mailed to them and they can publishe it with the help of the Leader of the Programme.

-5. Laboratory investigations on the changes of mineral forming conditions, climate and solar activity with LLMZA will be produced parallely.

Third stage- 1. Preparation of "Atlas of Luminescence of Cave Minerals" (similar to [6]) for diagnostics of CM with LSPA.

-2. Edition of the book "Luminescence of Cave Minerals of the World" including this Atlas. This book will containe Search Manual for diagnostics of cave minerals and reviews of investigations of the luminescence of the CM. In this book all materials will be clearly refered to their authors.

4. Conclusions

It is known that 49 from the 225 known CM luminesce in the mines, but luminescence of only 14 CM is observed in caves untill now. The determination of the luminescence spectra of all luminescent CM is necessary for the aim of this Programme. Therefore participation of as much as possible speleologists from all countries of the world in this Programme is desirable. It is especially impor tant for countries where this minerals have already been observed: - USA, South Africa, Australia, Italy and USSR.

Application of IPL and LSPA allowed to determine one New Mineral, finding of which by any other method was impossible [11]. Therefore probably some new minerals will be found in result of this programme.

5. Spectra of Luminescence of Cave Minerals

Minerals are not pure chemical substances and containe many admixtures. Usually some ions activate luminescence of the sample and the measured spectrum is a sum of the spectra of two or more ions. At excitation with UV-lamps, flashes, X-, β- or γ rays all this ions in the mineral luminesce. To determine the spectra of luminescence of each ion monochromatic exciting light is necessary. It can be obtained with double monochromator, or better with LASER [8,9,10 11]. At First spectra of excitation of the CM must be prepared using an exciting monochromator with standart UV- lamp. The sample must be excited with monochromatic light in its different bands of excitation. If this bands are due to different ions different spectra of L will be obtained (table 3). Some ions can luminesce at concentrations up to 10^{-5}% in the mineral. The determination of activating cations can be made by comparison of ESR and luminescent spectra of the ion in the sample [11]. Comparison with known data for electron levels of the ion in crystal field with the same symmetry is applicable too. Activating cations can also be determined by synthesis of mineral with admixture of investigated ion and determination of its spectra of luminescence [11].

Luminescence is the property of the CM most sensitive to the conditions of mineralforming [2]. Therefore it can be used for typomorphic indicator of this conditions. Luminescence of minerals formed at normal cave temperatures (0-40^{o} C) is due to molecular ions and sorbated organic molecules, because their luminescence is many times stronger than this of cations and covers their bands.

Luminescence of the hydrothermal minerals is due mainly to cations because molecular ions and molecules are destructed at high temperatures. Luminescence of cations can be used as an inditor of hydrothermal formation of the CM. Minerals formed by low-temperature hydrothermal solutions have short-life fluorescence(F) due to cations and long phosphorescence (P) of molecular ions. For example the orange-red L of Mn^{2+} in calcite sensitized by Pb^{2+} can be observed only in hydrothermal calcite, because Mn^{2+} has no strong bands of excitation and can luminesce only at availability of Pb^{2+} which absorbs Ultra Violet light and give up its energy of excitation to Mn^{2+} which luminesce. But Pb^{2+} have very big ion radius and can substitute Ca^{2+} only at high temperatures. If calcite has only orange-red short-time P it is formed by high-temperature hydrothermal solutions(>300^{o}C). If it has long-time phosphorescence too, it is low-temperature hydrothermal calcite.

TABLE 1. NEW METHODS FOR RESEARCH OF THE LUMINESCENCE OF CM

Method	Authors	obtainable information
I. Impulse Photography of Luminescence (IPL) 1. Photography of phosphorescence (IPP) 2. Photography of fluorescence & phosphorescence (IPFP).	Shopov, Tsankov (1984) Shopov, Grynberg (1985)	determination of minerals, registration of colour & zonality of fluorescence & phosphorescence and its spectra, UV-photography, extraction of single mineral samples, changes of chemism of the mineralforming solution. Climate and Solar Activities variations during Quaternary.
II. Colour Slide Spectrophotometry (CSS)	Shopov, Georgiev (1986)	widelines spectra of phosphorescence, fluorescence and diffuse reflectance of minerals, spectra of quick processes.
III. LASER Luminescent MicroZonal Analysis (LLMZA)	Shopov Y (1987)	Microzonality of luminescence, changes of mineralforming conditions, Climate & Solar Activuty variations during Quaternary (with resolution up to 3 days). Speleothem dating (with accuracy 1 year). Interruptions of speleothem growth.

TABLE 2. NEW METHODICS FOR RESEARCH OF THE LUMINESCENCE OF CM

Methodics	Authors	obtainable information
1. LASER Luminescent Zonal Analysis (LLZA)	Ugumori (1980)	Quantity of activating ion, zonality of luminescence of the speleothem
2. Direct Spectroscopy of Luminescence (DSL)	Shopov, Spasov (1983)	Kind of luminescent ion, changes of chemism of mineralforming solutions determination of genetic type of the deposit, selection of samples.
3. Direct Spectrography of Luminescence (DSGL)	Shopov, Tsankov (1984)	Registration of spectra of fluorescence & phosphorescence directly in caves, luminescent ion and its valency, coordination and local symmetry, diagnostics of CM & all from DSL.
4. Luminescent spectral Phase Analysis (LSPA)	Shopov, et al. (1985)	Determination of phase composition of the speleothem by spectra of its luminescence.
5. LASER Luminescent Spectral Analysis of Powders	Shopov, Kostov (1985)	Such as DSGL for collomorphyc aggregates of minerals and powders.

Application 1. Instruction for preparation of Slides of Phosphorescence of Cave Minerals.

I. Reflex camera with "M" or "FP" synhronizer for magnesian flash and curtain shutter is necessary to obtain slides of phosphorescence of CM. Modern cameras have not such synchronizer and need additional shutter delaier with delay of 0,003- 0,01 sec.

II. Electron flash(es) with leading number higher than 25 are necessary for the excitation of phosphorescence. The power of flashes has to be as high as possible. Several synchronized flashes can be used to increase light emission.

III. Colour slide daylight films with a speed as high as possible is necessary for this. Best films are sixemulsion slides of KODAC, FUDJI, or AGFA with speed 400-1000 ISO.

How to take the slides of phosphorescence

1. Put the camera on a tripod
2. Make usual photo of the sample, so that it fill in frame. Macrophoto with small exchange is preferable.
3. Put shutter rate in "B".
4. Connect flashes with synchronization jack "M" ("FP").
5. Put flash(es) as close as possible to the speleothem, but so that it will be fully lighted.
6. Set the lens stop to the openest possition and bring the mean

part of an image into focus.

7. Switch all the light off.

8. Make a control burst at closed eyes and after that quickly open eyes. Correct position of flashes if it is necessary for obtaining higher phosphorescence.

9. Exposure untill full extinction of light emission at fully opened lens stop and at lens stop 4 and 8.

10. Develope film in big photolaboratory with authomatic mashine development in big volume of developer.

11. Cut out 4 cm of black not-exposured end of the film and one good-exposured (numbered for each sample) slide of phosphorescence (over-exposured slides is not useful for spectral processing) and one usual slide of each photographed sample.

TABLE 3. SPECTRA OF LUMINESCENCE OF CAVE MINERALS

Mineral, excit.ion	Colour	Peak(nm)	Ref.	Origin
Calcite: CO_3	blue	430	(8)	infiltration
R_1	blue	450,470	(10)	infiltration
R_2	blue	475	(10)	infiltration
R_3	blue	490	(10)	infiltration
R_4	blue-green	500	(10)	infiltration
R_5	blue-green	518,471	(15)	infiltration
UO_2^{2+}	green	515,535,560	(20)	infiltration
UO_2^{2+} (magursilite?)	green	517,551,597	(20)	infiltration
PO_2^{2-}	yellow-green	525	(10)	infiltration
R_6	yellow-green	470,560	(20)	infiltration
R_7	yellow	560,510	(20)	infiltration
R_8	yellow	595	(21)	infiltration
Mn^{2+}	orange-red	630	(7,11)	**hydrothermal**
Aragonite: R	blue	450	(20)	infiltration
R_1	blue-green	440,508	(20)	infiltration
R_2	blue-green	485	(20)	infiltration
R_3	green	520	(20)	infiltration
R_4	yellow	562	(20)	infiltration
Vaterite: R	blue-green	515	(20)	infiltration
Huntite: R	blue	480,510	(15)	infiltration
R_1	yellow-green	530	(15)	infiltration
Hydromagnesite: R	green	460,520,550	(20)	infiltration
R_1	yellow-green	540	(20)	infiltration
Brucite	yellow-green	540	(20)	infiltration
Gypsum: R	yellow-green	540	(20)	infiltration
R_1	yellow	590	(20)	infiltration
Mn^{2+}	red	640	(21)	**hydrothermal**
Fe^{3+} fl.	dark red	700	(21)	**hydrothermal**
Purpurite: R	green-yellow	520	(20)	infilt.(guano)
$CaCO_3$-II: Pb^{2+}	ultra violet	370	(20)	**hydrothermal**
R	violet	400	(20)	**low-temper. h-t**
Mn^{2+}	dark red	660	(11)	**hydrothermal**
Fe^{3+} fl.	dark red-IR	710	(20)	**hydrothermal**
Quartz: AlO_4^{4-}	blue	470	(20)	**hydrothermal**
O^*_{Fe}	yellow	550	(21)	**hydrothermal**
Fe^{3+} fl.	dark red	685	(21)	**hydrothermal**
Hydrozincite: R	yellow-green	550	(20)	weathering
R_1	yellow	540,590	(20)	weathering

12. Make a list of slides (accordingly applied form) and mail them together to:

Y.Y.SHOPOV- BULGARIA 1408, SOFIA, DIMITAR MANOV 74 B.

FORM TO BE FULLFILLED FOR EACH CAVE.

1. Photographer: (name and full adress)

2. Photographic camera

3. Used films and speedy

4. Sample location: Country, Cave

5. Rock in which the cave is placed

6. Kind of cave mineralization (accordingly the Genetic Classification of Cave Minerals).

7. Temperature in the cave (^oC)

8. Mineral composition of each sample (if it is known)

9. Type of the speleothem for each sample

10. Possible additional data

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GENETIC CLASSIFICATION OF CAVE MINERALS

SHOPOV, Yavor

A checklist of all 225 known so far Cave Minerals is prepared. A successive genetic classification of cave minerals is proposed. It has following structure: - 1. TYPE of country rocks where cave are placed, 1.I. Class- genetic type of occurance of the mineral, 1.I.1. Subclass- chemical class of the mineral, 1.I.1.a. system(association) - physico-chemical conditions at mineral formation. Arrangement of chemical classes and of minerals in each association was made in dependence of frequency of occurance of the main ions contained in the mineral formula in the caves.

This classification allow very easy diagnostics and prognosis of cave mineral associations. The classification allow easy determination of the typomorphic indicators of the mineralforming conditions of cave minerals. Therefore it will be the working classification of the International Programme "Luminescence of Cave Minerals" of the Commission of Physical-Chemistry and Hydrogeology of karst of UIS.

ГЕНЕТИЧЕСКАЯ КЛАССИФИКАЦИЯ МИНЕРАЛОВ ПЕЩЕР.

ШОПОВ, Явор
/Болгария/

Составлен список всех известних /до 1988-мом году/ 225 минералов пещер. Сделана последовательная генетическая классификация минералов пещер. Она имеет следную структуру:

-1. ТИП вмещающей породы,

-1.I.Класс- генетичний тип месторождения минерала,

-1.I.1.Подкласс- химический класс минерала,

-1.I.1.a. система /ассоциация/- физико-химические условия образования минерала. Последовательность химических классов и минералов в каждой ассоциации сделана в зависимости от встречаемости в пещерах йонов входящих в химическую формулу минерала.

Эта классификация позволяет очень легкой диагностики и прогноз ассоциации пещерных минералов. Классификация позволяет легкое определение типоморфних индикаторов условии минералообразувания. Поэтому она будет работной классификацией Международной программой "Люминесценция минералов пещер" комиссии Физико-химии и Гидрогеологии ЮИС.

At the working of the International Programme of Luminescence of Cave Minerals of the Commission of Physical Chemistry and Hydro geology of Karst of UIS arose the necessity of a perfect genetic classification of Cave Minerals (CM), because the luminescence is the most sensitive to conditions of formation of CM property. Therefore the classification of the types of luminescence of the CM should be based on its genesis.

The using of the morphology of the speleothems for classification of CM is unsuccessful, because speleothems and CM are absolutely different and in most cases independent objects. Some speleothems can be formed by CM from all chemical classes & types of genesis (see application 1). The morphology or origin of mineral agregates (named speleothems in caves) are not used in any of the 25-th known classifications of minerals /2,3/. Unfortunately the classifications of the CM known so far are schematic, unsuccessive and incomplete (in the last classification /1/ 12 % of the described CM are not classified and 20% of the CM known up to now are not described). Accordingly to /2/ every good classification of minerals must be successive (to be based on principles universal for all classified minerals).

PRINCIPLES OF THE GENETIC CLASSIFICATION OF CAVE MINERALS

The aim of this work is an elaboration of complete and successive Genetical Classification of CM. Such classification will make easier finding and diagnostics of CM by prognosis of associations of the CM in any caves and rocks. This aim is solved by elaboration of a Genetic Classification improved with accordance to the cave conditions and processes (table 1) of the type of the famous classification of minerals of /2/. In this classification (table 2) are pointed minerals-indicators (i) of the genetic type of the mineral deposit. If some of them are determined in a cave, it can be determined using the classification, which known CM can be also found and should be searched in this cave. In this classification we use definitions of /1/ for "Cave" & "Cave Mineral".

All types, classes, subclasses and structural ions of the CM are placed in row by the frequency of their occurance in the caves Therefore most common CM are placed at the beginning and most rare in the end of the Classification.

The Classification has following structure:

The first sign of the Classification is TYPE of country rocks. It is subdevided to following types in dependence of the processes of the formation of the CM in different rocks by:

1. KARST ROCKS (limestones, marbles, dolomites, gypsum & halites)- particular redeposition of the rock from the soil waters & organic processes at temperature 0-30° C. - formed 100 CM.
2. KARST ROCKS WITH HYDROTHERMAL VEINS (rocks & caves contained ore)-hydrothermal processes or by weathering of hydrothermal minerals. -86/104/CM
3. ZONE OF THE CONTACT OF KARST AND NONKARST (INSOLUBLE) ROCKS (bauxites, limonites, shale & coal)- by reaction of the karst solutions & minerals with minerals of the nonkarst rocks. - 7/8/ CM
4. VOLCANIC ROCKS- by condensation or reactions of eruptive materials or weathering of volcanic rocks. -18/47/CM
5. SHALES-by weathering with the help of soil solutions and guano in tropical zone- 12/18/ CM
6. QUARTZITES & SANDSTONES-by weathering in tropical zone. -2/6/

The main types processes of formation of the CM can be classified as result of:

1. INFILTRATION (hydrocarbonate and soil-acidic formation and evaporation)-acting of soil solutions over karst rocks. -34 CM
2. BIOGENIC (anthropogenic, bacteriogenic, guanogenic & osteogenic)-living processes of organisms or by humans activity. They are most intensive in tropic zone. - 77/88/ CM
3. HYPERGENIC (weathering & metasomatoze)-weathering or substitution of detrial minerals by action of inorganic factors-86/99/CM
4. HYDROTHERMAL-deposition from hydrothermal solutions-26/31/CM
5. ERUPTIVE (fumarolic & magmatic)-reaction of detrial minerals and solutions with the gases and sublimation of the erupted substances. 11/22/ CM

CLASS-genetic type of the CM in dependence of processes leading to their formation, which are:

I. HYDROCARBONATE DEPOSITION of CM with participation of CO_2-17.

II. SOIL- ACIDIC REDEPOSITION with participation of the soluted in water acids. It is favoured by hot climate- 7 CM

III. EVAPORATION - supersaturation of solutions of high soluble minerals. It occures in dry caves. -10 CM

IV. WEATHERING-oxidation, carbonatization and hydratation of the detrial minerals- 69/87/ CM

V. ANTHROPOGENIC-formation of CM in result of the human activity. -1/2/CM

VI. BACTERIOGENIC-result of living processes of bacteria- 9/19/

VII. GUANOGENIC - at reaction of the animal excrements with the solutions & minerals in caves. - 65/73/ CM

VIII. OSTEOGENIC - at reactions of the solutions with bones in caves- 2/11/ CM

IX. HYDROTHERMAL -deposition of ore-associated CM by thermal solutions- 26/31/ CM.

X. METHASOMATIC -at reaction of karst solutions & minerals with nonkarstic.- 7/14/

XI. FUMAROLIC-at reaction of fumarole gases with minerals in the cave. Can be formed in caves in any rocks, but always are deal with volcanic activity.- 7/13/ CM.

XII. MAGMATIC -by condensation, hydratation & recristalization of magmatic substances.- 4/5/ CM.

In some cases one CM are formed by dehydratation of others, but this class has not typical representative and therefore isn't included in the classification.

Subclass-chemical class (anion group) of minerals. Accordingly to the frequency of formation of CM (with corresponding group) they are: -1. Carbonates, 2. Oxides & hydroxides, 3. Sulphates, 4. Chlorides, 5. Sulphides, 6. Phosphates, 7. Nitrates, 8. Organic, 9. Silicates, 10. Arsenates and Vanadates, 11. Fluorides and Bromides.

Association (system) - mineral association in dependence of the physico -chemical conditions of its formation. For example at 1.I.1.a. deposition of aragonite lead to increasing of the ratio Mg/Ca and to formation of the other minerals of the association. At 1.I.1.b availability of ice keeps up low temperatures and ensured existance of the unsteady at positive temperatures minerals of the association.

Inside the subclasses and associations minerals are placed accordingly to their structural cations in the row:- Karstogenic cations: -Ca, Mg, Fe, Mn, Na, Li, biogenic-K, NH_4, Si, ore-Ba, Sr, Cu, Zn, Pb, U, Hg, Ag, Sb and shiste-Ni. The hydrates with less molecules water are placed after those with more crystalization water, because usually are formed by their dehydratation.

102 CM formed coatings & crusts, 52(57)-stalactites, 23-moonmilk, 15-anthodites, 14-helictites, 7-coralloides & pearls, 6-balouns.

ASCKNOWLEDGEMENTS

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APPLICATION 1. SPELEOTHEM-BUILDING MINERALS

A. Minerals of coatings and crusts:-1.I.1.a-calcite, aragonite, dolomite, huntite, magnesite, hydromagnesite, 1.b-ice, monohydrocalcite, nesquehonite, II.-pyrolusite, ranceite, romanechite, todorokite, III.1-gypsum, bassanite, anhydrite, epsomite, hexahydrite, bloedite, mirabilite, 2-halite, VI.1.a.-goethite, maghemite, 1.b-birnessite, 2.sulfur, pyrite, VII.2-arcanite, aphtitalite, 4- monetite, F-apatite, OH-apatite, CO_3-F-apatite, whitlockite, newberyite, varishite, strengite, archerite mitridatite, niahite, schertellite, biphosphammite, 5-nitratite, darapskite, niter, 6-urea, 2.I.1-$CaCO_3$-II.siderite, rhodochrosite, strontianite, 3-barite, celestite, 4-cinnabar, metacinnabar, 5-opal, 6-fluorite II.1- dypingite, giorgiosite, artinite, pyroaurite, witherite, azurite, malachite, giorgeite, nacaurite, smithsonite, hydrozincite, cerussite hydrocerussite, rutherfordine, sharpite, zellerite, schroeckingerite, 2-wyartite, 3-melanterite, halotrichite, jarosite, chalcantite, posnjakite, brochantite, 4-arseniosiderite, olivenite, conichalcite, hewettite, calciovolbortite, vanadinite, descloizite, tyuyamunite, 5-chrysocolla, hemimorphyte, III- tintikite, leucophosphite, sampleite, 3.I.1-alunite, 4.I.1-misenite, voltaite, pottasium-alum, II.1-natron, thermonatrite, III.1-alunogen, 5.II.2-nickelalumite, 6.I-sveite, II-evansite

B. Minerals of stalactites: -1.I.1.a- calcite, aragonite (saponite), 1.b-ice (lansfordite), II.1-lithiophorite, romanechite, III.1-gypsum, epsomite, mirabilite, 2-halite, VI.1-goethite, 2-sulphur, marcasite, VII 2-aphtitalite, 4-brushite, monetite, OH-apatite, CO_3-OH-apatite, CO_3-F-apatite, variscite, archerite, biphosphammite (wavellite, diadochite), 5-nitromagnesite, nitratite, darapskite, 6-urea, 2.I.1-siderite, rhodochrosite, 2-hematite, 3-barite, 4-galena, 5-quatz, opal, II.1- artinite, malachite, smithsonite, hydrozincite, rosasite, cerrusite, 2-chalcophanite, atacamite, 3-melanterite, chalcantite, beudantite, 4-arsenate-belovite, spencerite, olivenite, descloizite, 5-hemimorphyte, IV-scholzite, 3.I-sphalerite (gibbsite), 4.III-allophane, 6.II-evansite.

C. Minerals of moonmilk:-1.I.1.a-calcite, aragonite, vaterite, dolomite, huntite, magnesite, hydromagnesite, baylissite, brucite, saponite, 1.b- monohydrocalcite, lansfordite, nesquehonite, barringtonite, III.1-gypsum, VI.2-sulfur, VII-monetite, F-apatite, taranakite, 2.I.2-hematite, II.1-hydrozincite, 4.III.2-allophane, 5.I.2-aluminite.

D. Minerals of anthodites:-1.I.1.a-calcite, aragonite, 1.b-ice, III.1-gypsum, bassanite, epsomite, mirabilite, 2- halite, VII- diadochite, darapskite, 2.I-opal, II-malachite, melantherite, 4.I-tamarugite, K-alum.

E. Minerals of helictites:-1.I.1.a-calcite, aragonite, 1.b-ice, III.1-anhydrite, epsomite, 2.halite, VI.1-goethite, 2-marcasite, 2.I.3-barite 4-galena, 5-quatrz, opal, II-malachite, 3.I.2-sphalerite.

F. Minerals of Angel hair:-1.III.1-gypsum, epsomite, hexahydrite, mirabilite, 2-halite, VII.5-nitrocalcite, nitratite, darapskite. 2.I.5-palygorskite, II.1-malachite, melantherite, 4.II.2-thenardite.

G. Minerals of coralloides:-1.I.1.a-calcite, aragonite, hydromagnesite, III-gypsum, VII.4-strengite, 2.I.5-quartz, opal.

H. Minerals of pearls-1.I.1.-calcite, aragonite, VI.1-goethite, VII.4-CO_3-hydroxilapatite, whitlockite, 2.II.1- smithsonite, hydrozincite.

J. Minerals of cave balouns:-1.I.1-calcite, aragonite, hydromagnesite gypsum, 2.I.5.quartz, opal.

Table 1. GENETIC CLASSIFICATION SYSTEM OF CAVE MINERALS by Y.Shopov

TYPE (country rocks)	CLASS (genetic type)	SUBCLASS (chemical class)	ASSOCIATION (SYSTEM) (ph-chem.conditions)
1.KARST	I.HYDROCARBONATE DEPOSITED	1.Carbonates	a. aragonite assoc. (Ca-Mg-CO_2-OH syst.)
			b. ice associated (Ca-Mg-CO_2-H_2O syst)
	II.SOIL ACIDIC	1.Oxides	
	III.EVAPORATED	1.Sulphates	
		2.Chlorides	
	IV.WEATHERING		
	V.ANTHROPOGENIC		
	VI.BACTERIOGEN.	1.Oxides & Hydroxides	a.Fe-oxides(Fe-O-OH) b.Mn-oxides Mn-O-H_2O
		2.Sulphides	
		3.Silicates	
	VII.GUANOGENIC	1.Carbonates	
		2.Sulphates	
		3.Chlorides	
		4.Phosphates	
		5.Nitrates	
		6.Organic	
	VIII.OSTEOGENIC		
2.HYDROTHERMAL VEINS	I.HYDROTHERMAL	1.Carbonates	
		2.Oxides & OH^-	
		3.Sulphates	
		4.Sulphides	
		5.Silicates	
		6.Fluorides & Br^-	
	II.WEATHERING	1.Carbonates	
		2.Oxides & OH^-	
		3.Sulphates	
		4.PO_4.AsO_4 & VO_4	
		5.Silicates	
	III.GUANOGENIC	1.Phosphates	
	IV. OSTEOGENIC		
3.CONTACT	I. METASOMATIC	1.Hydroxides	
		2.Sulphides	
		3.Silicates	
4.VOLCANIC	I.FUMAROLIC	1.Sulphates	
		2.Sulphides	
	II.MAGMATIC	1.Carbonates	
		2.Sulphates	
	III.WEATHERING	1.Sulphates	
		2.Silicates	
	IV.GUANOGENIC	1.Phosphates	
5.SHALES	I. WEATHERING	1.Sulphates	
	II.GUANOGENIC	1.Sulphates	
		2.Nitrates	
6.QUARTZITES & SANDSTONES	I. WEATHERING		
	II.GUANOGENIC		

GENETIC CLASSIFICATIONS OF CAVE MINERALS (BY Y.Y.SHOPOV)

1. KARST MINERALS

I. HYDROCARBONATE DEPOSITED MINERALS

1. Carbonates

a. *Aragonite associated* (Ca-Mg-CO_3-OH system)

123 4 5 6 7 8 9 10 11

1 calcite $CaCO_3$ (U.1609) 2.I.1,4.III, [1.III.1], Karlovy Vary,Cz

1 aragonite $CaCO_3$ Chromy(1927) 2.I.1,4.III,[1.III.1]Aragonite,Cz

1 vaterite $CaCO_3$ Baron(1959) 1.V,(2.I.1),[1.III.1]La Clamouse,Fr

1 dolomite $CaMg(CO_3)_2$ Pobeguin(1960) 2.I.1,[1.III.1,2] ,Fr

1 i huntite $CaMg_3(CO_3)_4$ Baron(1957) (1.III,1) de l'Herault,Fr

1 magnesite $MgCO_3$ Pobeguin(1960) [1.III.1],(2.I.1,4.III), Fr

1 hydromagnesite $Mg_5(CO_3)_4(OH)_2.4H_2O$ Davis(1957)[1.III.1]C.C.,US

1 brucite $Mg(OH)_2$ Filipov(1980)(2.I.2) Duhlata ! ,Bg

1 i baylissite $K_2Mg(CO_3)_2.4H_2O$ Shopov(1984) [1.III.1] ShCS ! ,Bg

1 i saponite $Ca(Mg,Fe)_3Si_4O_{10}(OH)_2.xH_2O$ Filipov(1979)Pepelyanka!Bg

[barringtonite, lansfordite, nesquehonite(rhodohrosite, manganite, pyrolusite)]

b. *Ice associated* (Ca-Mg-CO_3-H_2O system)

1 i ice H_2O Kittara(1850) Kungur cave USSR

p i ikaite* $CaCO_3.6H_2O$ Maximovich (1953) Aggtelk cave, H

p i pentahydrocalcite $CaCO_3.5H_2O$-? "Strubel(1982)" ?

p i monohydrocalcite $CaCO_3.H_2O$ Fischbeck(1971)Frankishe Schwein,WG

p lansfordite* $MgCO_3.5H_2O$ Harmon(1981)[1.I.1],Castleguard cave,C

p nesquehonite $MgCO_3.3H_2O$ Fischbeck(1971)[1.I.1]Frankishe Sch.WG

p barringtonite $MgCO_3.2H_2O$ "Hill,Forti(1986)" [1.I.1],(4.III) ?

[aragonite, calcite, hydromagnesite, (huntite)]

II. SOIL ACIDIC- DEPOSITED MINERALS

1. Oxides

p manganite MnOOH Kashima(1976)1.VI.1.b.1.VII(1.I.1)Naidena J.Yu

p pyrolusite α-MnO_2 Bragintsev(1963)1.VI.1.b.1.VII(1.I.1)K. USSR

p ranceite $(Ca,Mn)Mn_4O_9.3H_2O$ Richmond(1969)1.VI.1.b.1.VII.Mam.US

p lithiophorite $(Li,Al)MnO_2(OH)_2$ Urbani(1976)1.VI.1.b.1.VII.SM.V

p romanechite $BaMn_9O_{16}(OH)_4$ Bridge(1968)1.VI.1.b.1.VII.2.II.2 .A

p hollandite $(Ba,K_2)MnMn_7O_{16}.2H_2O$ Richmond(1969)1.VI.1.b.1.VIIUS

p todorokite $(Mn,Ca,Ba)_3O_{6-7}.1-2H_2O$ Fisher(1966)1.VI.1.b1.VII US

III. EVAPORATED MINERALS

1. Sulphates

l gypsum $CaSO_2.2H_2O$ (u.2200B.C)1.VI.3.VII;2.I.II;3.I.2.4.III..US

p i bassanite $Ca_2(SO_4)_2.H_2O$ Jude(1972) . R

l anhydrite $CaSO_4$ Diaconu(1974) (2.I.3) Diana cave. R

p epsomite $MgSO_4.7H_2O$ Lagni(1806)1.VI.3 .It

p i hexahydrite $MgSO_4.6H_2O$ White(1961) Wyandotte cave.US

p i kieserite $MgSO_4.H_2O$ Bernasconi(1962)Tana di Val Serata cave.It

p i bloedite $Na_2Mg(SO_4)_2.4H_2O$ Freeman(1973) Lee cave.US

l mirabilite $Na_2SO_4.10H_2O$ (u.2200 B.C)4.III.1(4.II..4.IV)Salt.US

[aragonite,baylissite,calcite,dolomite,huntite,hydromagnesite, magnesite,vaterite (glauberite)]

2. Chlorides

l halite NaCl Hovey(1896) 1.VII.3 (4.I) Salzburg cave.Au

l i carnallite $KMgCl_3.6H_2O$ Beltyukov(1969) Verhnekamsk.USSR

[dolomite,hydroxylapatite(chloromagnesite,sylvite)]

IV. WEATHERING MINERALS

p chloromagnesite $MgCl_2$ Cervellati(1976)(1.III.2.4.I)Pelogal.!It

\- fibroferrite $Fe(OH)SO_4.5H_2O$ Forti(1987)(I.VI.3)Ferrata cave!It

? stilpnomelane $(K,Fe,Mg)_6(Si,Al)_8O_{19}(OH)_9$ Forti(1986)Ferrata!It

V. ANTHROPOGENIC MINERALS

? i mellite $C_6(COO)_6Al_2.18H_2O$ Garavelli(1974) Romanelli cave !.It

vaterite (buetschlite,fairchildite,parahopeite)

VI. BACTERIOGENIC MINERALS

1. Oxides and hydroxides

a. *iron-oxides* (Fe-O-OH system)-by iron bacteria

\- goethite α-FeOOH Tower(1899) 2.I.2.2.II.2 Tintic Mine cave US

\- lepidocrocite γ-FeOOH Seeman(1979)2.II.2Dachstein-Mammothoh.Au

\- maghemite γ-Fe_2O_3 Urbani(1977) 2.II.2. Cueva la Milagrosa. V

\- magnetite Fe_3O_4 Seeman(1979)2.II.2.4.III.Dachstein-Mammoth..Au

(hematite)

b. *mangano-oxides* (Na-Mn-O-H_2O system) -by mineralazing bact.

? birnessite $Na_4Mn_{14}O_{27}.9H_2O$ Moore(1964)1.VII.(2.II.2) Weber.US

hollandite,lithiophorite,manganite,pyrolusite,ranceite,romanechite,todorokite.

2. Sulphides -by anaerobic suphur bacteria

? sulfur α-S Bielz(1884)4.I.2 Grotta della Zolfo.It

\- pyrite FeS_2 Tort(1964)2.I.4.3.I.2. Laubach cave.US

\- marcasite FeS_2 Maximovich(1969) 3.I.2.(2.I.4) Magiana .USSR

(hydrotroilite)

3. Silicates -by sulphuric acid bacteria

? i endellite $Al_2Si_2O_5(OH)_4.2H_2O$ Davis(1957) Carlsbad Cavern.US

epsomite, gypsum (aluminite, barite,fibroferrite,halotrichite, illite,stilpnomelane)

VII. GUANOGENIC MINERALS

1. Carbonates

p carboborite $Ca_2MgCO_3.B_2O_5.10H_2O$ Pajon(1986) C. de Ambrosio .Cu

p teschemacherite NH_4HCO_3 Dana(1868) SA

2. Sulphates

L i arcanite K_2SO_4 Martini(1984) Timbavati cave !.SA

p syngenite $K_2Ca(SO_4)_2.H_2O$ Dunkley(1967)4.I.1.Murra-el-elevyn!.A

p i aphthitalite $K_3Na(SO_4)_2$ Bridge(1973) Murra-el-elevyn. A

p i taylorite $(K,NH_4)_2SO_4$ Bridge(1973) Murra-el-elevyn !. A

p!i lecontite $(K,NH_4)NaSO_4.2H_2O$ Taylor(1858) !.Hon

3. Chlorides

l sylvite KCl Croissant(1972)4.II 4.IV(1.III.2) cave in Etna .It (halite)

4. Phosphates

p brushite $CaHPO_4.2H_2O$ von Rath(1879)IV.4. Skipton lava tube . A

p!i monetite $CaHPO_4$ Shepard (1882) Islands of Moneta and Mona.PR

l i fluorapatite $Ca_5F(PO_4)_3$ Hill(1972) New cave.US

p hydroxyl-apatite $Ca_5(PO_4)_3(OH)$ Duhn(1957)1.III. Windsor Gr..Ja

l CO_3-hydroxylapatite $Ca_{10}(PO_4)_3(CO_3)_3(OH)_2$ Duponi(1913)1.VIII.M

l carbonate-fluorapatite $Ca_{10}(PO_4)_5CO_3F_{1.5}$ $(OH)_{0.5}$Hammen(1956)Co

p i ardealite $Ca_2H(PO_4)(SO_4).4H_2O$ Schodler(1931) Cioclovina cave.R

L whitlockite $(Ca,Mg)_3(PO_4)_2$ Martinez(1953)1.VIII El Chapote.Mex

p bobierrite $Mg_3(PO_4)_2.8H_2O$ Ulrich(1870)4.VI.Skipton lava tube.A

l newberyite $MgHPO_4.3H_2O$ von Rath(1879) 4.IV.Skipton lava tube.A

p variscite $AlPO_4.2H_2O$ Machatschki(1929) 1.VIII. Drachenhohle. H

l wavellite $Al_3(PO_4)_2(OH)_3.5H_2O$"Maximovich(1976)"(2.II.4)W.F..US

p!i sasaite $Al_{14}(PO_4)_{11}(SO_4)(OH)_7.84H_2O$ Martini(1978)West Drief.SA

p crandallite $CaAL_3(PO_4)_2(OH)_5.H_2O$ Kaye(1959)1.VIII. Butler.US

p i woodhouseite $CaAl_3(PO_4)(SO_4)(OH)_6$ Wang(1982)Jade Lotus cave!Ch

\- phosphosiderite $FePO_4.2H_2O$ Axelrod(1952)2.III(2.II.4)Bomi H..L

\- strengite $FePO_4.2H_2O$ Axelrod(1952)(2.III) Bomi Hill cave.L

\- vivianite $Fe_3(PO_4)_2.8H_2O$ Balenzano(1974)2.II.4(3.I.1)Castel.It

\- diadochite $Fe_2(PO_4)(SO_4)(OH).5H_2O$ Becker(1925)(2.II.4.III).DDR

\- mitridatite $Ca_3Fe_4(PO_4)_4(OH)_6.3H_2O$ Martini(1978)Boons cave!.SA

\- i koninckite $(Fe,Al)(PO_4).3H_2O$ Kizaki(1983) ! .J

l purpurite $(Mn,Fe)PO_4$ Jones(1965) 4.IV. Gunong Keriang cave.M

p!i archerite KH_2PO_4 Bridge(1977) Petrogale cave.A

p i taranakite $H_6K_3Al_5(PO_4)_8.18H_2O$ Gautier(1894) Minerva cave .Fr

p!i francoanellite $H_6K_3Al_5(PO_4)_8 13H_2O$ Balenzano(1974)Castelana .It

p i minyulite $KAl_2(PO_4)_2(OH,F).4H_2O$ Martini(1978) Boons cave ! .SA

p!i phosphammite $(NH_4)_2HPO_4$ Bridge(1973) Toppin Hill cave. A

p!i.niahite $NH_4CaPO_4.H_2O$ Brigde(1983) Niah Grate cave !.M

p!i.mundrabillaite $(NH_4)_2Ca(HPO_4)_2.H_2O$ Bridge(1983) Petrogale !.A

p schertellite $Mg(NH_4)_2H_2(PO_4)_2.4H_2O$ MacIvor(1902)4.IV Skipton.A

p i stercorite $NaNH_4HPO_4.4H_2O$ Bridge(1977). Petrogale cave !.A

p i biphosphammite $(NH_4,K)H_2PO_4$ Dunkley(1967) Murra-el-elevyn.A

5. Nitrates

p i nitrocalcite $Ca(NO_3)_2.4H_2O$ Mitchell(1806) US

p i nitromagnesite $Mg(NO_3)_2.6H_2O$ Cutbush(1825) US

p nitratite $NaNO_3$ Bailey(1902) (4.IV) US

p i darapskite $Na_3(NO_3)(SO_4).H_2O$ Eriksen(1970) US

p i niter KNO_3 Davy(1821) Ce

p i nitrammite NH_4NO_3 Shepard(1857) Nickajack cave.US

6. Organic

p i weddellite $C_2CaO_4.2H_2O$ Bridge(1973) Toppin Hill cave ! .A

?!i uricite $CO(NH_2)_2$ Bridge(1974) Dingo Donga cave ! .A

? i acetamide CH_3CONH_2 Shopov(1987) Prilepnata cave !.Bg

?!i urea $C_4(NH)_2O_2C(NH)_2O$ Bridge(1973) Wilgie Mia cave .A

?!i oxammite $C_2H_8N_2O_4.H_2O$ Bridge(1977) Petrogale cave! .A

?!i guanine $C_4(NH)_3OCHNNH$ Bridge(1974) Murra-el-elevyn cave .A

birnessite,gypsum,hollandite,lithiophorite,manganite ,pyrolusite,ranceite,romanechite,todorokite (dittmarite,halite)

VIII. OSTEOGENIC MINERALS

p i montgomeryite $Ca_4MgAl_4(PO_4)_6(OH)_4.12H_2O$ Goldberg(1975)et-T..Is

ardealite,carbonate-hydroxilapatite,crandallite,variscite, whitlockite

2. MINERALS OF CAVES WITH HYDROTHERMAL VEINS

I. HYDROTHERMAL MINERALS

1. Carbonates

l!i $CaCO_3$-II $CaCO_3$ Shopov(1984) Shopovs cave system !.Bg

\- i siderite $FeCO_3$ Foster(1952) Poorfarm cave.US

\- ankerite $Ca(Mg_{0.67}Fe_{0.33})(CO_3)_2$ Maximovich(1970)3.I.2.Oht.A.Cz

l rhodochrosite $MnCO_3$ Shaub(1962) (1.I.1) !.Ar

l i strontianite $SrCO_3$ Shepard(1835) US

2. Oxides and Hydroxides

\- hematite α-Fe_2O_3 White(1962)2.II.2.4.III(1.VI.1.a)Wind cave.US

-!i H.T.FeOOH-? FeOOH Shopov(1984) Shopovs cave system !.Bg

\- i tenorite CuO Ransome(1904) Copper Queen Mine cave !.US

? i plattnerite PbO_2 Graeme(1981) Bisbee Mine cave.US

? i rutile TiO_2 Maximovich(1969) Magiana cave.USSR

3. Sulphates

l barite $BaSO_4$ Walker(1919)3.I.2.(1.VI.3) Madoc cave.C

l i celestite $SrSO_4$ Wright(1898) .US

4. Sulphides

\- i pyrrhotite Fe_7S_8 Broughton(1972) Playa Payaro cave.PR

\- i bornite Cu_5FeS_4 Shopov(1985) Shopovs cave system !.Bg

\- i galena PbS Peck(1979) .US

? cinnabar HgS Lazarev(1976) (4.II) Guadakskaya cave !.USSR

? metacinnabar HgS Lazarev(1976) (4.II) Guadakskaya cave !.USSR

? i stibnite Sb_2S_3 Maximovich(1969) Magiana cave.USSR

5. Silicates

l quartz α-SiO_2 Caublengh(1829) 6.I. .Br

l opal* $SiO_2.nH_2O$ Davy(1821)3.I.3.4.III.2.6.I. Doombera cave.Ce

? i sepiolite $Mg_4Si_6O_{15}(OH)_2.6H_2O$ Kaspar(1945) Zbrasovska cave .Cz

? palygorskite $MgAlSi_4O_{10}(OH).4H_2O$ 3.I.3.4.III.2.5.I.1.6.I.LS.NZ

? montmorillonite $Al_2Si_4O_{10}(OH)_2.4H_2O$ Bradlury(1959)(4.III.2).US

? illite $KAl_2(Si_3AlO_{10})(OH)_2$ Lazarev(1976)(1.VI.3)Gaudaksk..USSR

6. Fluorides and Bromides

l i fluorite CaF_2 Hovey(1896) . E

L i bromargyrite AgBr Graeme(1981) Bisbee Mine cave !.US

aragonite, calcite, dolomite, goethite, gypsum (akaganeite, anglesite,anhydrite,boehmite, brucite, cerussite,chalcopyrite, dickite,gibbsite,hemimorphite,epidote,lithiophorite,magnesite, marcasite,sphalerite,vaterite,witherite)

II. WEATHERING MINERALS

1. Carbonates

l i dypingite $Mg_5(CO_3)_4(OH)_2.5H_2O$ Shopov(1984)Shopovs cave syst!Bg

l i giorgiosite $Mg_5(CO_3)_4(OH)_2.5H_2O$ Shopov(1984)Shopovs cave s.!Bg

l i artinite $Mg_2CO_3(OH)_2.3H_2O$ Shopov(1984)Shopovs cave system !.Bg

\- i pyroaurite $Mg_6Fe_2CO_3(OH)_{16}.4H_2O$ Shopov(1985)Shopovs cave s.!Bg

l witherite $BaCO_3$ Rogers(1982) (2.I.1) Lilburn cave.US

\- malachite $Cu_2CO_3(OH)_2$ Tower(1899)5.I.1 .US

\- i azurite $Cu_2(CO_3)_2(OH)_2$ Ransome(1904) Copper Queen Mine cave.US

\- i giorgeite* $Cu_5(CO_3)_3(OH)_4.6H_2O$ Shopov(1984)Shopovs cave s.!.Bg

\- i nakaurite $Cu_8(SO_4)_4(CO_3)(OH)_6.48H_2O$ Shopov(1985)Shopovs c.s!Bg

l i smithsonite $ZnCO_3$ Whitney(1858) Hudson Bay Mine. C

l i hydrozincite $Zn_5(CO_3)_2(OH)_6$ Detrich(1960)Island Ford cave .US

\- i rosasite $(Cu,Zn)_2CO_3(OH)_2$ Graeme(1981) Bisbee Mine cave.US

\- i aurichalcite $(Zn,Cu)_5(CO_3)_2(OH)_6$ Northrop(1959)Blanchard m..US

l cerussite $PbCO_3$ Spencer(1908)(2.I.1) Broken Hill mine cave.Rh

p i hydrocerussite $Pb_3(CO_3)_2(OH)_2$ Shopov(1985)Shopovs cave syst!Bg

l i rutherfordine UO_2CO_3 Shopov(1985) Shopovs cave system ! .Bg
p i sharpite $(UO_2)_6(CO_3)_5(OH)_2.7H_2O$ Shopov(1985)Shopovs cave s.!Bg
p i zellerite $CaUO_2(CO_3)_2.5H_2O$ Shopov(1985)Shopovs cave system!.Bg
l i schroeckingerite $NaCa_3(UO_2)(CO_3)_3(SO_4)F.10H_2O$ Shopov(1985)s!Bg

2. **Oxides and Hydroxides**

\- akaganeite β-$FeOOH$ Shopov(1983)(2.I.2)Shopovs cave system !.Bg
\- cuprite Cu_2O Graeme(1981)(2.I.2) Bisbee Mine cave ! .US
\- atacamite $Cu_2Cl(OH)_3$ Bridge(1978)4.I..5.I.1.2 Jingemia cave. A
? i chalcophanite $ZnMn_3O_7.3H_2O$ Graeme(1981)Bisbee Mine cave .US
p i wyartite $Ca_3U_7C_2O_{22}(OH)_{16}$ Shopov(1985)Shopovs cave system !.Bg

3. **Sulphates**

\- melanterite $FeSO_4.7H_2O$ Young(1915)3.I.2.Wilson cave .US
p pickeringite $MgAl_2(SO_4)_4.22H_2O$ Franco(1961)4.I.III.d. Zolfo.It
\- halotrichite $FeAl_2(SO_4)_4.22H_2O$ Bellini(1901)4.I.III(1.VI.3).It
p i kalinite $KAl(SO_4)_2.11H_2O$ Bielz(1884) Turia cave !. R
\- jarosite $KFe_3(SO_4)_2(OH)_6$ Stringham(1946)3.I.2.5.I.1.4.III.1.US
\- i chalcanthite $CuSO_4.5H_2O$ Mitchell(1921) .US
\- i posnjakite $Cu_4SO_4(OH)_6.H_2O$ Shopov(1985)Shopovs cave system!.Bg
\- i brochantite $Cu_4SO_4(OH)_6$ Northrop(1959)Blanchard mine cave .US
\- i devilline $Cu_4Ca(SO_4)_2(OH)_6.3H_2O$ Forti(1985)Monte Rosso .It
\- i cyanotrichite $Cu_4Al_2SO_4(OH)_{12}.2H_2O$ Norhrop(1959)Blanchard m.US
\- i spangolite $Cu_6Al(SO_4)Cl(OH)_{12}.3H_2O$ Northrop(1959)Blanchard!US
l anglesite $PbSO_4$ Rickard(1924) (2.I.3)Ahumada mine cave .Mex
\- i beudantite $PbFe_3(AsO_4)(SO_4)(OH)_6$ Dietrich(1960)Island Ford!.US

4. **Phosphates, Arsenates and Vanadates**

p hopeite $Zn_3(PO_4)_2.4H_2O$ Spencer(1908)2.III.Broken Hill mine .Rh
p parahopeite $Zn_3(PO_4)_2.4H_2O$ Spencer(1908)2.IV(1.V)Broken H. .Rh
p! spencerite $Zn_4(PO_4)_2(OH)_2.3H_2O$ Walker(1918)2.IV.Hudson Bay m.C
p tarbuttite $Zn_2(PO_4)(OH)$ Spencer(1908)2.IV.Broken Hill mine .Rh
? i arsenate-belovite $Ca_2Mg(AsO_4)_2.2H_2O$ Feraud(1976) .Fr
\- i arseniosiderite $Ca_3Fe_4(AsO_4)_4(OH)_6.3H_2O$ Smolianiniva(1970)USSR
-!i strashimirite $Cu_8(AsO_4)_4(OH)_6.5H_2O$ Mincheva(1968)Zapachitsa!Bg
\- i olivenite $Cu_2AsO_4(OH)$ Tower(1899)Tintic mining distr. cave!.US
\- i conichalcite $CaCuAsO_4(OH)$ Graeme(1981) Bisbee Mine cave !.US
? i mimetite $Pb_5(AsO_4)_3Cl$ Graeme(1981) Bisbee Mine cave !.US
p i hewettite# $CaV_6O_{16}.9H_2O$ Nenadkevich(1909)Tuya-Muyun cave!.USSR
\- i calciovolborthite $CaCuVO_4(OH)$ Nenadkevich(1909)Tuya-Muyun.USSR
l i vanadinite $Pb_5(VO_4)_3Cl$ Spencer(1908) Broken Hill mine cave .US
p i descloizite $(Zn.Cu)PbVO_4(OH)$ Smolianinova(1970)Tuya-Muyun.USSR
l i tyuyamunite $Ca(UO_2)_2V_2O_8.8H_2O$ Nenadkevich(1912)Tuya-Muyun.USSR

5. **Silicates**

? i clinochlore $Mg_5Al(Si_3Al)O_{10}(OH)_8$ Forti(1985)Monte Rosso ! .It
\- i shattuckite $Cu_5(SiO_3)_4(OH)_2$ Graeme(1981) Bisbee Mine cave !.US
\- i chrysocolla $Cu_{2-x}Si_2O_5(OH)_3.xH_2O$ Smolianinova(1970)TyuyaM!USSR
? hemimorphyte $Zn_4Si_2O_7(OH)_2.H_2O$ Spencer(1908) 2.IV(2.I.5)B.H.US

goethite, gypsum, hematite, lepidocrocite,maghemite,magnetite, romanechite,vivianite(allophane,birnessite,chalcoalumite, diadochite,gibbsite,halotrichite,lonecreekite,natrojarosite,phosphosiderite,wavellite)

III.GUANOGENIC MINERALS

-!i tintikite $Fe_6(PO_4)_4(OH)_6.7H_2O$ Stringham(1946)Tintic m.cave!.US
\- i leucophosphite $KFe_2(PO_4)_2(OH).2H_2O$ Axelrod(1952) Bomi Hill. L
\- i sampleite $NaCaCu_5(PO_4)_4Cl.H_2O$ Simpson(1952)5.I.1. Jingemia. A

hopeite,phosphosiderite,stercorite (diadochite,strengite)

IV.OSTEOGENIC MINERALS

p i scholzite $CaZn_2(PO_4)_2.2H_2O$ Dietrich(1960)Island Ford cave !.US

hemimorphite,parahopeite,spencerite,tarbuttite

3. Minerals of caves at contact between karst and other rocks

I.METASOMATIC MINERALS

1. **Hydroxides** (at contact of limestones with bauxit. or limon.)

l gibbsite $Al(OH)_3$ White(1959)4.IV(2.I.2.II.2)Hineman cave. US
l boehmite $AlOOH$ Seeman(1973)(2.I.2) Dachstein-Mammonthohle ! Au
p alunite $KAl_3(OH)_6(SO_4)_2$ Boye(1977)5.I.1.6.I(4.III.2)Fourgas.FG

(mitridatite,vivianite)

2. **Sulphides** - (at contact of coal with limestone rocks)

\- chalcopyrite $CuFeS_2$ Maximovich(1969) (2.I.4)Magiana cave. USSR
l sphalerite ZnS Orlov(1972) (2.I.4) . USSR

ankerite,barite,gypsum,jarosite,marcasite,melanterite,pyrite

3. **Silicates** - (at contact of limestones with shiste rocks)

? dickite $Al_2Si_2O_5(OH)_4$ Wiehman(1981) (2.I.5) Iza cave !. R
? i benitoite $BaTiSi_3O_9$ Wiehman(1981) Iza cave !. R

[opal]

4. Minerals of Volcanic caves

I.FUMAROLE MINERALS

1. **Sulphates**

l glauberite $Na_2Ca(SO_4)_2$ Andreichuk(1988) (1.III.1)Kungur !.USSR
p tamarugite $NaAl(SO_4)_2.6H_2O$ Zambonini(1907)4.III.1.G.d.Zolfo!It
p! misenite $H_6K_8(SO_4)_7$ Bellini(1901)4.III.1.Grotta della Zolfo!It
\- i voltaite $K_2Fe_5Fe_4(SO_4)_{12}.18H_2O$ Scachi(1850)Grotta del.Zolfo.It
p pottasium alum $KAl(SO_4)_2.12H_2O$ Davy(1821) 4.III.1. 5.I.1 .It
\- metavoltine $Na_6K_2Fe_7(SO_4)_{12}O_2.18H_2O$ Bellini(1901)4.IIIZolfo!It

2. **Sulphides**

L i oldhamite CaS Chirvinskey(1947) Syukseevskaya cave .USSR
\- hydrotroilite $FeS.nH_2O$ Andreichuk(1988) (1.VI.2)Kungur !.USSR

halotrichite, pickeringite, potassium-alum, syngenite, sulfur atacamite (chloromagnesite,natrojarosite)

II.MAGMATIC MINERALS

1. **Carbonates**

l natron $Na_2CO_3.10H_2O$ Harter(1973) 4.III. Pisgah lava tube .US
p thermonatrite $Na_2CO_3.H_2O$ Seeman(1979)4.III.SalzburgerschachtAu
p trona $Na_3H(CO_3)_2.2H_2O$ Harter(1973)4.III. Pisgah lava tube.US

2. **Sulphates**

l thenardite Na_2SO_4 Bertolani(1958) 4.III.1.Gr. delle Argille.It

sylvite (cinnabar,halite,metacinnabar,mirabilite)

III.WEATHERING MINERALS

1. **Sulphates**

p i alunogen $Al_2(SO_4)_3.17H_2O$ Bellini(1901) Grotta della Zolfo.It
p i basaluminite $Al_4SO_4(OH)_{10}5H_2O$ CRGMJ(1983) Tateishi Syonyn-do.J

2. **Silicates**

i allophane# $Al_2Si(OH)_{10}$ Bartrum(1930) (2.II.5) .NZ
\- epidote $Ca_2(Al.Fe)_3Si_3O_{12}(OH)$ Del Monte(1983)(2.I.5) Santo.It

aragonite,calcite,gypsum,halotrichite,hematite, jarosite, magnetite,metavoltine,mirabilite,misenite,natron,palygorskite,pickeringite,pottasium-alum,tamarugite,thenardite,thermonatrite, trona,tschermigite(alominite,alunite,barringtonite,hydromagnesite,magnesite,montmorillonite)

IV.GUANOGENIC MINERALS

1. **Phosphates**

p i struvite $NH_4MgPO_4.6H_2O$ Ulrich(1870) .A
p dittmarite $NH_4MgPO_4.4H_2O$ MacIvor(1887)(1.VII.4)Skipton lava !A
p i hannayte $Mg_3(NH_4)_2H_4(PO_4)_4$ MacIvor(1887) Skipton lava tube. A

bobierite,brushite,gibbsite,newberyte, purpurite, schertelite, sylvite(mirabilite,nitratite)

5. Minerals of Shale Caves

I.WEATHERING MINERALS

1. **Sulphates**

p aluminite $Al_2(SO_4)(OH)_4.7H_2O$ Martini(1980) (1.VI.3.4.III) !.SA
p i apjohnite $MnAl_2(SO_4)_4.22H_2O$ "Bauer(1985)". Alum cave !.US
\- natrojarosite $NaFe_3(SO_4)_2$ Martini(1984)(2.II.3.4.I.1)Jungle.SA
\- chalcoalumite $CuAl_4SO_4(OH)_{12}.3H_2O$ Martini(1980)(2.II.3)Mb.M!SA

alunite,atacamite,jarosite,malachite,palygorskite

II.GUANOGENIC MINERALS

1. **Sulphates**

p tscermigite $NH_4Al(SO_4)_2.12H_2O$ Cody(1978)4.III.1.Ruataru cave.R
-!i lonecreekite+ $FeNH_4(SO_4)_2.12H_2O$ Martini(1983)Lone Creak Fal!SA
-!i sabieite+ $NH_4Fe(SO_4)_2$ Martini(1983) Lone Creak Fall cave !.SA
-!i clairite+ $Fe_3(NH_4)_2(SO_4)_4(OH)_3.3H_2O$ Martini(1983)Lone Cr.F.!SA

2. **Nitrates**

-!i hydrombombomkulite+ $NiAl_4(NO_3)_2(OH)_{12}.13\text{-}14H_2O$ Martini(1980)SA
-!i mbombomkulite+ $(Ni,Cu)Al_4[(NO_3)_2.(SO_4)](OH)_{12}.3H_2O$ Mar(1980)!SA
-!i nickelalumite+ $(Ni,Cu)Al_4[(NO_3)_2.SO_4)](OH)_{12}.3H_2O$ Mart(1980)!SA

atacamite,sampleite

6. Minerals of Quartzitic and Sandstone caves

I.WEATHERING MINERALS

p!i sveite+ $KAl_7(NO_3)_4Cl_2(OH)_{16}.8H_2O$ Urbani(1977)Autana cave ! . V

alunite,opal,palygorskite,quartz

II.GUANOGENIC MINERALS

p i evansite# $Al_3PO_4(OH)_6.6H_2O$ Van der Hammen(1956) .Ce

Table 2. Genetic Classification of Cave Minerals (by Y.Y.Shopov)

Each CM is placed in the group corresponding to the most common origin of occurance of this mineral in caves. The other origins of the mineral are pointed by the number of the corresponding group. CM which occured with the minerals of the present group, but have other origin are placed in [].CM which are formed at such conditions inside of caves,but in caves have other origin are placed in() The names & the chemical formula of minerals are given accordingly

The names & the chemical formula of minerals are given accordingly /4/.The amorphous & the new minerals are given accordingly:-"*"/7/ "-"-/6/."+"-/1/."#"-/5/.The data contained in the table are:-1.Luminescence-the minerals with known luminescence are pointed by "l" CM with luminescence obserbed only in synthetical samples- "L". CM which probably luminesce-"p".CM which may be can luminesce- "?".CM which can't luminesce- "-". 2.Minerals found for the first time in cave-"!".3.CM-indicators,which have only one possible origin- "i". 4.Mineral name.5.Chemical formula,6.author who first found the mineral in the caves.7 year,8.paragenesis,9.cave of the first finding of the CM.10. CM found only in one cave.11.Country:- A-Australia.Ar-Argentina.Au-Austria,Bg-Bulgaria. Br-Brazile. C-Canada. Ce-Ceylon,Ch-China. Co-Colombia. Cu-Cuba. Cz-Czechoslovakia. DDR-East Germany.E-England,FG-French Guiana,Fr-France,H-Hungary, Hon-Honduras. It-Italy. Is-Israel. J-Japan.Ja-Jamaica.L-Liberia,M-Malaysia. Mex-Mexico. NZ-New Zeeland. PR-Puerto Rico. R-Rumania.Rh-Rhodesia. SA- South Africa. V- Venezuela. Yu- Yugoslavia. WG- West Germany.

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EVOLUTION OF TROPICAL KARST AND CAVES IN THE RED RIVER DELTA REGION

SZENTES, George

SUMMARY

The tropical cone and tower karst nearby the Red River Delta in Vietnam is closely connected to the vast karst regions of SE Asia. The neotectonic activity from the Pleistocene to the recent days affects mainly the karstification.

To the east and southeast of the delta a comperatively recent lowering can be observed, which has resulted a low elevated cone and tower karst landscape and the archipelago of Ha Long Bay. Several hundred fossil caves appear in the limstone cliffs.

To the west of the delta a general uplift formed continuous cone and tower karst ranges. Blind valleys, dolines, sinkholes and remains of old phreatic caves are marking the karst rejuvenation in response to the uplift.

ZUSAMMENFASSUNG

Der tropische Kegel- und Turmkarst in der Umgebung des Red - River - Deltas ist eng verbunden mit den ausgedehnten Karstgebieten Südostasiens. Die Verkarstung wurde beeinflußt durch die von dem Pleistozän bis heute stattfindenden neotektonischen Aktivitäten.

Östlich und südöstlich vom Delta zeigt sich eine verhältnismäßig rezente Senkung, die eine abgesunkene Karstlandschaft und den Karstarchipel der Ha Long Bucht gebildet hat. Zahlreiche fossile Höhlen befinden sich in den Karstkegeln und Türmen.

Westlich vom Delta formten sich durch die allgemeine Anhebung zusammenhängende Gebiergszüge aus Karstkegeln und Karsttürmen. Infolge der Hebung eine Rejuvenation der Karstlandschaft, mit blinden Tälern, Dolinen, Wasserschlingern und Resten alter phreatischer Höhlen zu erkennen.

1. GENERAL CONDITIONS OF THE KARST AND CAVE DEVELOPMENT

The karst that, surrounds the Red River Delta (Fig. 1.) is an integral part of the vietnamese karst, which is closely connected to the karst of Soth China, North Laos, Thailand and Burma, and forms one of the largest and most spectacular tropical karst region of the world. In addition to the other landscapes the area comprises some special and exeptional phenomena due to its peculiar geologic and tectonic situation.

In the Red River Delta region, as in Vietnam generally, the the tropical humid climate is characteristic, which is strongly influenced by the interactions of the monsoons. This, so called Indochinese Intertropical Climate has created the conditions of the tropical karstification.

Paleoclimatological studies proved that, those conditions were more favourable during the initial phase of the karstification in the Tertiary and early Pleistocene times, when the tropical climate extended in larger area. Later the climate changed, so that at present the tower karst occurs outside that climatic zone, too.

The karstic limestone was deposited almost continuously in the large Lao - Vietnamese Geosyncline during the Devonian - Permian period. The geosyncline took place in the northern region of the country and is noted for its numerous, very typical limestone sediments, which are found together with conlomerates, schists and coal bearing strara.

The Devonian limestone is thickly bedded, well crystallized and gray to dark gray in colour. It is overlain by the conformable, dark Carboniferous - Permian Fusulina limestone series. The formation varies from being medium bedded to thinly laminated, with frequent intercalations of limy shale. The whole series is covered occasionally by the light gray to pink unconformed Permian limstone.

Following a short Triassic sedimentation since the Upper Norian stage the country was under the continental regime. In this time clastic sediments in the limited continental basin were deposited.

The limestone series has undergone several phases of tectonic deformations. Numerous generations of folding and faulting appear as abundant evidence of the orogenies. The younger tectonic activity exerts important influence on the karstification, particularly on the karsts around the Red River Delta. The fault system of the Red River Valley and Delta marks a mobile, repeteadly reactivated tectonic belt along the bordfer region of the Indochinese Geosyncline and the South China Plateau.

The formation of the Red River Delta can be traced since the Tertiary through the several hundred meter thick loose sediments, which have accumulated in the time of the sinking. Concurrently with the lowering an intense karstification occured along the rim of the delta. The former continuous limestone plateaux underwent a strong tropical karstic denudation, which resulted scattered groups of karst cones all over the region.

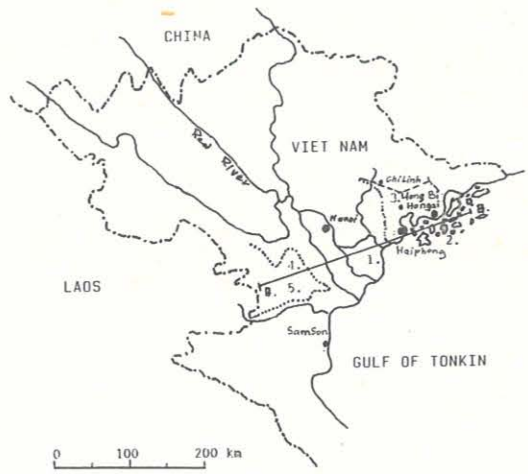
Several phases of cave development can be found in the cones, which are giving proof of the various stages of the karst evolution.

The recent feature of the karst is the consequence of the modifying effect of the neotectonic activity from the Pleistocene to the recent days. East and southeast of the delta a comperatively recent lowering can be observed, while to the west and southwest of the delta a general uplift appears (Fig. 2.).

2. THE LOWERING KARST LANDSCAPE TO THE E AND SE OF THE DELTA

2.1 The karst between the towns Chi Linh and Uong Bi

Obvious evidence of the lowering the cone and tower karst along the eastern rim of the delta between the towns Chi Linh and Uong Bi. In a length of 40 km the extensive karst erosion has resulted in 150 - 200 m high cones or cone groups, which are separated by intermontane plains. These alluvial plains represent the erosion base level, which is only 1 - 3 m above the sea. Tidal waves from the sea, and frequent floods from the mainland have caused a brackish swamp, which is zigzagged by artificial dykes and canals.



faulty limestone-granite contact

boundary of the karst and the delta

A —— B section line(see Fig.2)

1 Red River delta
2 Ha Long Bay
3 The karst between the towns of Chi Linh and Uong Bi
4 Huong tich (Perfume Pagoda)
5 Cuc Phuong (Ancient Forest)National Park

Fig. 1 Location of the study area

Caves are appearing in almost each cone, but their length rearly exceed the 10 m. They are the remains of an early stage of cave development.

Granite mountains have tectonic contact in the north and east with the limestone. Geoelectrical investigations have been carried out in the area in order to study the deep aquifer. The resistivity soundings show the presence of saline water as deep as 2000 m beneath the karst surface, while under the granite range, fresh water bearing aquifer appears. The interpretation suggests that, the fresh water recharge is blocked by the faulty granite - limestone contact and deep percolation of sea water occurs in the cavernous karst aquifer.

2.2 The karst archipelago of Ha Long Bay

The continuation of the karst range southeastward forms a karstic shore line and the large karst archipelago of the Ha Long Bay.

The karst archipelago occupies a 2500 square kilometer area between the towns Haiphong and Hongai. More than 4000 limstone cliffs of varying heights rise from 50 to 15o m above the sea, forming the most spectacular karst island sea of the world. Some of the islands appear as a cluster of cones, whilst others culminate in a single summit. Between the islands the sea is 5 - 40 m deep.

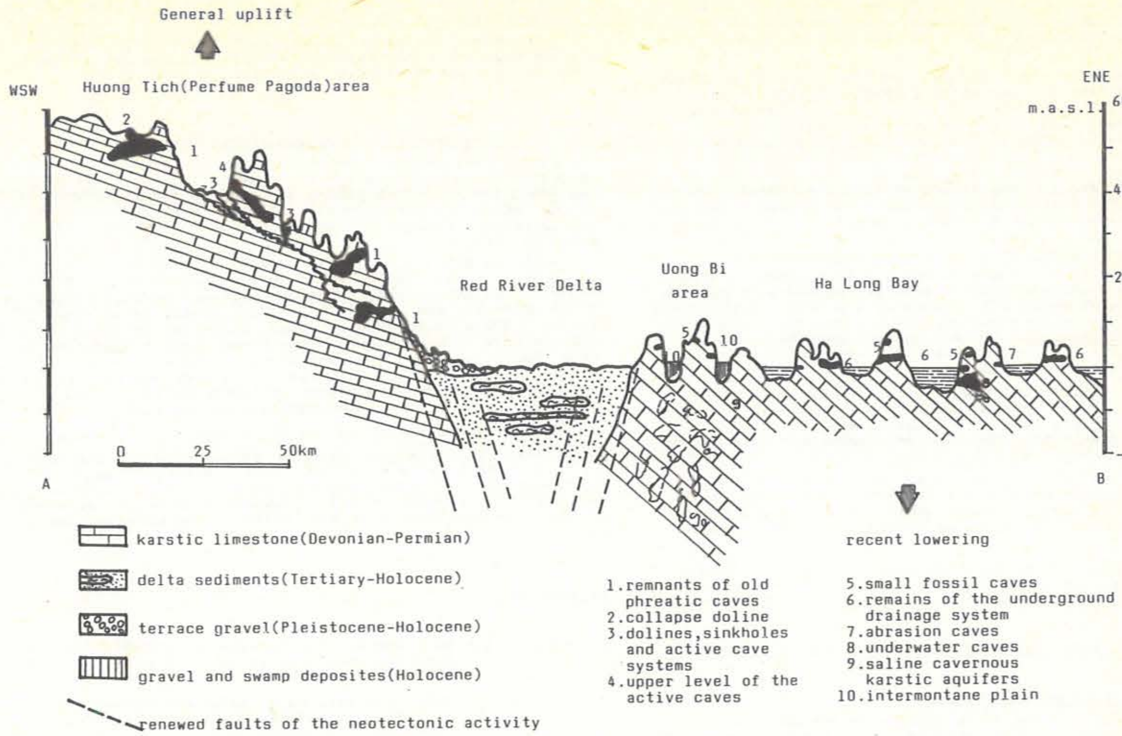


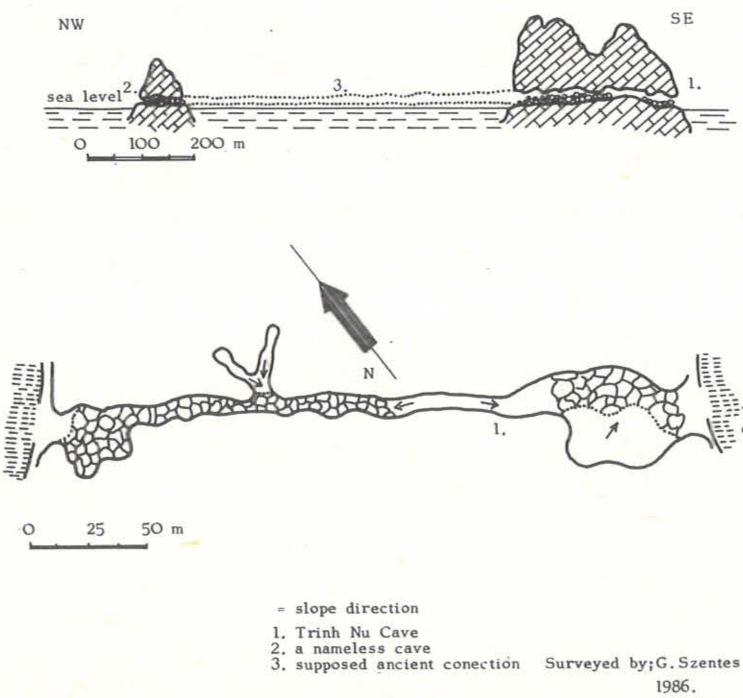
Fig.2.Geological section through the Red River Delta showing theoretically the main phases of karst and cave development.(The horizontal and vertical scales are not applicable for the projected caves and karst formations)

The islands are composed chiefly of medium bedded, dark grey to grey Carboniferous Fusulina limestone, which is occasionally overlain by the thin laminated Permian limestone. In some places the underlaying Devonian limestone crops out. The general dip is 50 - 60°.

The cliffs are undercut by abrasion 2 - 4 m in height and 3 - 4 m in depth. This height corresponds with the average 2,5-3,0 m height of the regional tide. Recent landslides are abundant along the dip slopes of the limestone, where thin clayey shale intercalates.

The archipelago has undergone a complex geological - tectonical evolution. The submergence of the cone karst, which has a long time development since the Tertiary period, is certainly related to the neotectonic movements along the Red River and its delta, which have caused the general lowering of this region.

However the recent base of the towers, on average -20 m, is the result of the complicated rising and falling changes of the base level. For instance, marine terraces appear up to +15 m on the mainland shore and in some caves. It is also thought that during the formation of this extensive archipelago glacioeustatic fluctuation of the sea level occured, which could explain those phenomena with less tectonic deformation.



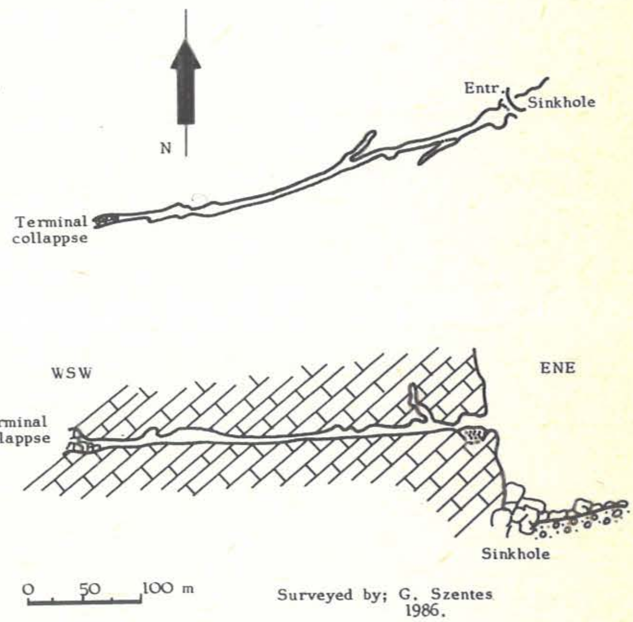


Fig. 3.; Trinh Nu /Virgin/ Cave in the Ha Long Bay. The map of the cave and a longitudinal section along the supposed ancient connection.

Fig. 4.; Map and longitudinal section of the Hang Tien Su/Prehistoric Cave in the Cuc Phuong /Ancient Forest/ National Park.

Several hundred caves exist in the islands. The majority are only a few meters in length, though same large chambers and passages hundreds of meters long which lead through the island can also be found.

Two types of caves can be distinguished from their development, abrasion caves, and fossil caves which formed concurrently with the tropical karstification. Abrasion caves are less significant, mainly hollows a few m long in the ancient and modern abrasion levels. Some impressive natural bridges represent spectacular phenomena of this type of cave development. The remains of the large underground drainage system on this once continuous karst plateau which has gradually been dissected from the begining of the tropical karstification until the recent submergence, appear in the different levels of the island cones. There are also extensive underwater caves.

The Trinh Nu (Virgin) Cave is an interesting tunnel like passage. This passage is 3 - 5 m wide and 5 - 10 m high, is decorated with flowstone, and marks an ancient stream bed with erosion levels. It ends in a chamber, which opens at sea level on the other side of the island. On another island, 600 m away, and facing the entrance of Trinh Nu Cave is a 100 m long cave passing through a small cone. The similarity between the two caves suggests that this is the same system which has became separated (Fig. 3.).

A few km to the west is an island containing the Bo Nau Cave. The tufa curtain decorated entrance is a 20 m wide and 10 m high arch. Behind this lays a single 30 m diameter chamber. The Surprise Cave has nearly the same size and appearence on a neighbouring island.

On the western end of the island sea, the Hang Dan Go (Pelican Cave) is a 100 m long chamber divided into several sections by large collapses. From this chamber short, flowstone decorated passages form a labyrinth. On a nearby island is the much smaller Dinh Cave.

On the eastern edge of the bay, the nicely decorated Giau Go Cave contains a series of large chambers, which are also the rest of a larger, ancient cave system.

3. UPLIFT INFLUENCED KARST DEVELOPMENT TO THE W AND SW OF THE DELTA

3.1 The Huong Tich (Perfume Pagoda) area

In the western part of the delta meandering streams cut into the alluvial plains leaving detectable terraces which mark a general uplift. Further to the west of the delta continuous ranges of cone karst dominate the landscape. This rugged terrain shows karst rejuvenation in response to the intense uplift. Blind valleys with dolines and sinkholes have been formed which drain the water to the intermontane plain.

As a result of the uplift the remains of old phreatic caves are abundant from the base level to the summit of the cones at 650 - 700 m above the sea level. These phreatic chambers and tubes vary from 10 m to several hundreds of meters in length. The longest is the Huong Tich (Perfume Pagoda). At about 600 m above the sea level a large collapsed doline opens just a few meters below the peak of the cones. It is 50 m in diameter , about 30 m deep and leads to a large phreatic chamber, from where a 200 m long passage which gradually narrows can be followed. Massive, mainly dead stalactites and columns decorate the cave. In the large chamber Buddhist altars have been erected.

unexplored active system, and is terminated by flowstone cemented collapse blocks.

The described karst areas around the Red River Delta, like the other vast karst regions of Vietnam, hide temendous possibilities for further speleological exploration.

3.2 Cuc Phuong (Ancient Forest) National Park

One hundred kilometers southwest of the Red River Delta extensive ranges of Devonian limestone form clusters of karst cones and towers along the NW - SE trending geosyncline axes. The area is known as Cuc Phuong (Ancient Forest) National Park. The name derives from the dense rain forest growing on the cones, some part of which are primeval forest.

From the delta a gradually ascending landscape reaches the local erosion base level, which is situated on the base level of the wide, alluvium covered valleys between the cone ranges some 300 m above the sea level. This height of the karst rises gradually 700 - 800 m above the sea level. Dissected plateaux and blind valleys have been developed between the cones, suggesting an elevated karst landscape. The water sinks into well developed sinkholes and there is no doubt that large, still undiscovered caves have been formed. The average height of the cones is 2 - 300 m and above the sinkholes dry cave passages can be found.

The longest dry cave is the 500 m Hang Tien Su (Prehistoric Cave) (Fig. 4.). The cave entrance is 5 m wide and 3 m high and is 50 m above a large sinkhole. In the entrance chamber the remains of prehistoric man have been excavated. A 4 m wide and 10 m high passage leads further in and is decorated by brilliant flowstones. It marks an inactive river bed, which is the uppermost part of the

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A TYPE OF VERTICAL CAVE CONSIDERED AS A "VERY DEEP KARRENFELD"

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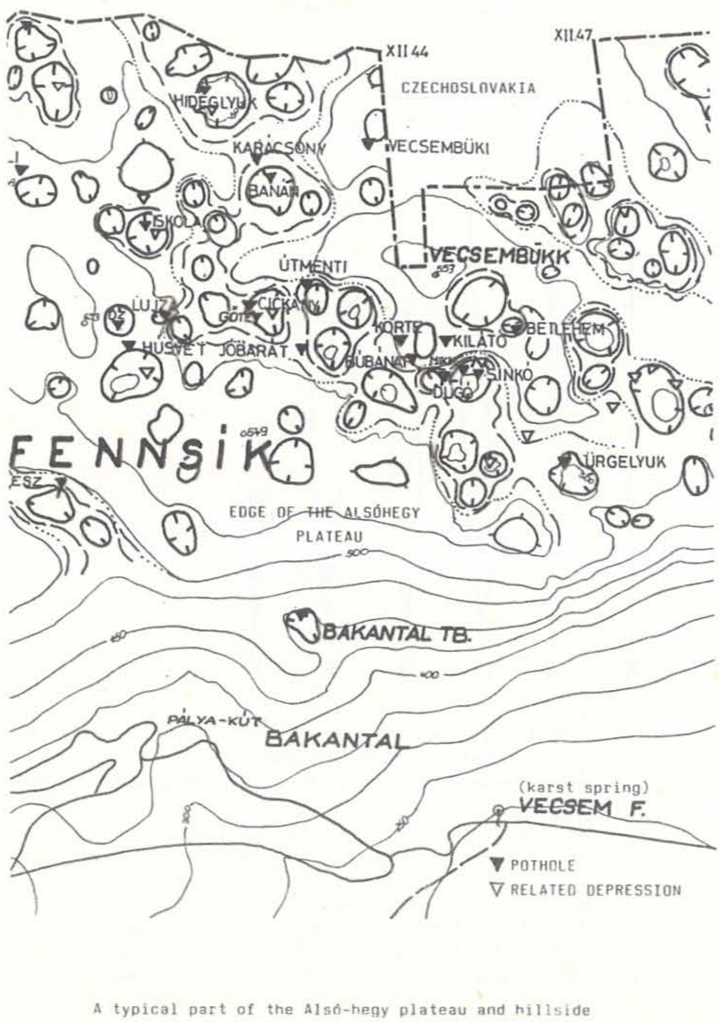
The exploration of a Hungarian-Czechoslovakian karst plateau (Name,Hungarian:Alsó-hegy,Czech:Dolny Vrch) has been carried on for almost eighty years.Vertical caves (potholes) discovered and mapped during that period now offer an insight of about 2.5 kilometers to the karst in a rather small area of only seven s q u a r e k i l o m e t e r s.The origin and hydrologic role of the unique phenomenon has been discussed during the many years by contradictory theories,all of them holding some pieces of the truth.The jigsaw puzzle may fit together now.It can be surprising that these potholes - their average depth 30 m,24 of them deeper than that,the deepest of them 240 m - can not be considered else than a very deep karrenfeld.More exactly their role in the karstic drainage equals that of the surface in magnitude,they lack any direct relationship to any specific karst spring.Still - obviously these potholes were made by the percolating karst water.

Az Alsó-hegyi zsombolyok,mint "nagyon mély ördögszántás".

A Magyar-Csehszlovák határon fekvő alsó-hegyi fennsík kutatása csaknem nyolcvan éve folyik.Az időközben feltárt és feltérképezett 89 zsomboly mintegy 2,5 km össz-mélységű betekintést enged a karsztba néhány négyzetkilométernyi területen.A különös jelenség keletkezését,hidrológiai szerepét sok ellentmondásos elmélet taglalta a sok év során,mindegyik az igazság néhány elemét magában hordozva.A kép talán mostanra összeállt.Meglepő,hogy hidrológiai szerepüket tekintve ezek a barlangok - átlagos mélységük 30 m,ennél mélyebb 24, a legmélyebb 240 m - mindössze igen mély ördögszántásnak tekinthetők.Pontosabban vízszállításuk nagyságrendjében a karsztos felszín bármely helyével egyenlő,közvetlen kapcsolatuk valamely kitüntetett forrással nincs.Természetesen létrejöttüket a leszivárgó karsztvíz okozza.



A typical part of the Alsó-hegy plateau and hillside

LOCATION

The "potholes" or the vertical caves in subject are located on the Alsó-hegy plateau,North-East Hungary,South East Czechoslovakia at a distance of about 20 kilometers East of Aggtelek. ($48^{0}35'$N $20^{0}40'$E)

FACTS TO THE POTHOLES

The potholes of theAlsó-hegy plateau (Made of Triassic limestone) represent a very special type of vertical caves that haven't been reported from elsewhere their character is as listed:

- They occur in a very dense concentration,88 of them(in 1989 and that's a growing number) and many depressions probably related to the potholes occur confined to only about 3.0 kmsq, a relatively small area.

- All of them follow a tectonic pattern in shape,they consist of one or more joint controlled pits

- They have no any known continuation,most are choked by debris,but those pits that have no opening to the surface have muddy bottom.

- None of them function as water swallows but the deeper they are the wetter theybecome with depth.

- Almost all potholes open in the upper parts of doline-funnels.

THEORIES OF ORIGIN

There were many theories discussing the origin of the Alsó-hegy potholes since their exploration began in 1911.Here we describe the most important theories in brief:

- H.Kessler stated in 1933 after several years of exploring the deepest Alsó-hegy potholes that these vertical caves were avens developed by the cave-in of large chambers of horizontal caves themselves choked by the debris when the aven finally reached the surface.He based his theory on such a well known example as the Padirac in France.His theory was strongly opposed even in the days of its birth.Some said (e.g.L.Schönviszky) that the potholes were a result of pure corrosion.

- The Author with the members of the Budapest METEOR caving club has conducted an extensive mapping activity from the late fifties. By the late sixties evidences strongly contradicted the "mechanical theory" of pothole development. The emerging big number of discoveries and depths varying from several to 245 m excluded the logical existence of a "mother cave".

Based on facts of cartography, morphology and hydrology the author said (1968) that the potholes were a product of the solution of infiltrating water that was drained by the vertical fissures. The infiltrating water broadened the fissure, until it was wide enough that mechanical forces take over and open up the cavity to the surface. Discoveries of fissures that had no surface entrances and had muddy bottoms with no debris, potholes that were dug out on the surface in the bottoms of small depressions seemed to support the idea. Once open the potholes slowly fill up their entrances ever broadening.

- I.Sárváry suggested it 1970 and worked out a theory with P.Müller in 1973 that the potholes were a product of pure corrosion and they developed in unision with the dolines that they have their entrances in. They offer convincing calculations that the solution effect of the infiltrating rainfall only was enough to be responsible for the "missing limestone mass", the cave volume. The dubious part of their theory is the emphasized doline-pothole relation because there wasn't ever discovered an example that would support it and the simile of the high mountain karst is not convincing.

- I.Szenthe stated in a lecture (1971) that the potholes were ancient water swallows developed at the retreating edges of a now completely missing impervious pyroclastic cover. Nothing but minute amounts of these pyroclastics found in pothole and doline fills support the idea that has never been published in detail

MORE FACTS TO THE POTHOLES

P.Müller found based on his stratigraphic studies on the surface and in the potholes of the Alsó-hegy that the beds of limestone stand on their edges due to a fold and thus the bedding planes are vertical.

Four water tracings were performed, two in Hungary in 1969(Sárváry 1971) and two in Czechoslovakia (VITUKI/Maucha,1976) at the middle of the plateau including the deepest of the potholes, the Vecsembükki-zsomboly. The tracing was made by water transported in tnks to the plateau. The results were curious because the tracers emerged in more than one karst springs at the hillfoot from each source and two of the potholes distributed the traced water brotherly to Hungarian and Czechoslovak springs prooving that the potholes have no hydrological relations to any one particular karst spring.

Paleomagnetic tests of some pothole fills proved that these caves are the earliest ones in the Aggtelek karst having been there in the Pliocene.

WHAT THE POTHOLES ARE NOT?

Facing the above facts and theories it must be screened out what the potholes are not thus to get a clearer picture of what they really may be.

The potholes are not made by the cave-in of any deep horizontal caves by a purely mechanical way. The shape of the cross sections of the potholes is not round but elongated, fissure shaped. Also the potholes are too deep to have been developed the way rock mechanics describes - details omitted here. On the other hand if there was a "mother cave" some traces of it would have been discovered, but all efforts to find it were in vain.
The potholes are not ancient water swallows because many of them have just recently opened up, many pits that have access from neighbouring shafts are not and have never been open to the surface. Most important of all clues are the results of the water tracings. Any sinkhole, that ever sinks concentrated quantities of runoff is related to one and only one karst spring. The potholes conducted water to two-three springs thus they can not be any swallets ancient or other.

The Alsó-hegy-type potholes are closely related to dolines as are many vertical alpine caves. The climate of the Alsó-hegy is a relatively mild continental climate, there are no great accumulations of snow the meltingof what is responsible for the origin of alpine dolines and caves that also function as true swallets. The potholes are in no way kin to the alpine caves.

WHAT ARE THE POTHOLES?

It must be emphasized again, that here we talk about the potholes of the Alsó-hegy and not about those anywhere else. Also it is not excluded that somewhere else the same type of cave exists.

The described theories in spite of some wild assumptions hold the seed of truth in parts of them.

H.Kesslerwas right that it is the mechanical forces that finally open the potholes to the surface.

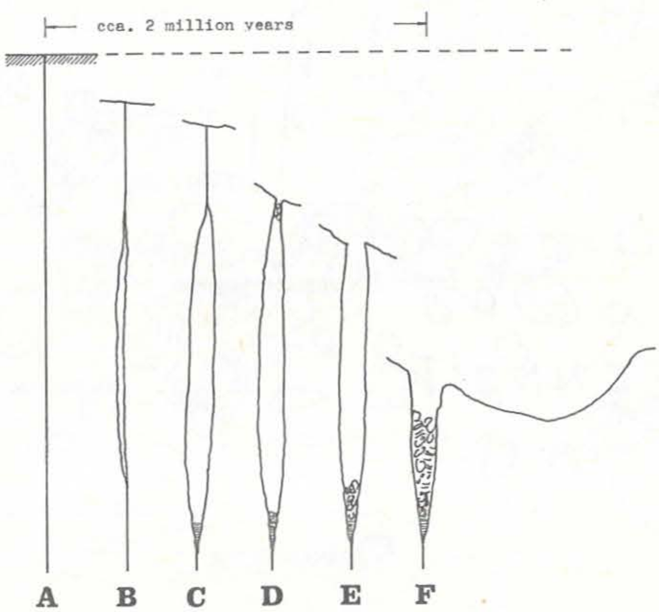
Müller and Sárváry were right with their computation prooving that concentrated runoff was not needed to the development of potholes but seepage was enough through about two million years.

I.Szenthe was right to put in the element of hitherto missing surface denudation.

And the Author was right in his theory of 1968 because the following water tracings, computations and continued exploration proved what he said but he was wrong putting together some facts and missing the element of surface denudation.

Let him try it again.

On the figure a sequence of sketches illustrate the most important phases of pothole development.



A. shows a fissure under an original surface that is reduced to a lower elevation by each sequence.
B. Descending waters drained by the fissure starting at a depth of about 50-60 meters develop an initial slot of a cave. The suggested depth comes from observations, potholes start to conduct considerable amounts of seepage not above this depth.
C. Solution widens the fissure and clay is deposited to the bottom. This state of development can be observed at the bottom of the lower levels of multilevelled potholes. The potholes develop not only in width but in the length of the fissure too thus separate fissures meet in many cases. These are usually not exatly in the same phase of development. At phase C.

the fissure may stop draining enough seepage to further development being not deep enough any more under a denuding surface.

D. Denudation brings down the surface close enough to the pothole that mechanical forces brake up the top of the fissure and debris start to fall on the bottom until

E. the plug in the entrance falls completely in,debris cobers the original mud deposit completely and the entrance becomes larger - the cave is now bisected by the lowering surface at a lower,wider section.

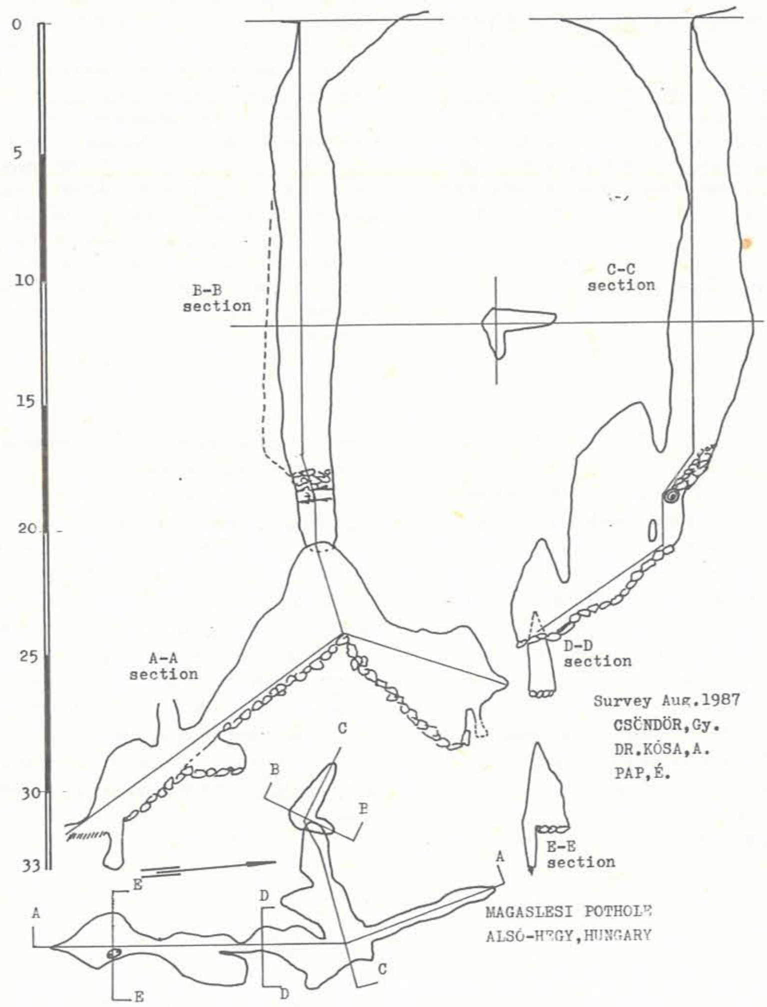
F. Denudation fills the pothole,that is now a gaping shallow depression.

This is the story of a single pothole.Until the final peneplenization of the limestone plateau the show will go on initial cavities developing in the deep,gaining size,joining others to make multilevelled systems of fissures,going dry,open up and fill in.

Surface denudation is quickest at the dolines and no wonder, that almost all pothole entrances can be found in the doline-slopes.The dolines and the potholes may not more relations than that since the majority of dolines do not contain potholes.Quite possibly the relation is a more intricate one and other than very systematic geodesic and hydrologic survey and data processing will not reveal more than we know now.

CONCLUSION

The Alsó-hegy type potholes are made solely by the solution of of infiltrating water.They are deep and numerous thanks to the very accented vertical fracturing that was helped by the limestone beds standing on their edges.They are deep but speaking in the terms of hydrogeology they play as much role in karstic runoff as any point of the karstic surface. Deep the potholes are but in one respect we can consider them as only very deeply developed grooves of a karrenfeld.



One of the Alsó-hegy potholes in an E state of its development

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HOW DO BATS RESPOND THE ENVIRONMENTAL FACTORS?

KOVATS, Nóra

The main effort of this research was to state which environmental factors were crucial for cave-dwelling bats and to study how the animals responded to them. It primarily had a nature conservancy purpose: protection of the biotop (here caves providing the requirements of bats) is needed to conserve the particular species.

Of environmental factors temperature, relative humidity and CO_2-level were measured. Other, not measurable factors, e.g. shape of the roost and position of bats were investigated as well.

Bats turned to be much more "adaptable" than they had been supposed before. It can be caused by two reasons: first, no environmental factor has an effect by itself. A given set of them determines the occurrence (or absence) of the animal, so a "more adequate" factor can modify the effect of a "less adequate" one. Secondly, the species could develop certain behaviour mechanism that ensures better capacity for survival than it would be expected considering merely physiological properties.

Human disturbance, being a new environmental factor, is the most crucial, as no defensive mechanism has been developed by bats.

Wie reagieren die Fledermäuse auf die Umwelteinflüsse?

Die Zielsetzung der Forschung war erstens die Bestimmung der kritischen Umwelteinflüsse auf die höhlenbefindlichen Fledermäuse, zweitens die Untersuchung der Reaktion von Tieren auf diese Faktoren. Die hat einen wichtigen Naturschutzaspekt: man muss das Biotop (hier: die geeigneten Höhlen für die Fledermäuse) behüten, wenn wir die Art schützen wollen.

Unter den Umwelteinflüssen untersuchten wir die folgenden: Temperatur, relative Luftfeuchtigkeit und CO_2-Gehalt. Daneben studierten wir auch solche unmessbaren Faktoren, wie die Form der Ruhestätte, die Lage der Fledermaus usw.

Die Fledermäuse hatten eine grössere Anpassungsfähigkeit gezeigt, als es früher angenommen wurde. Das hat zwei Gründe. Erstens: die Umwelteinflüsse wirken nicht selbst. Das Vorkommen (oder der Mangel) eines Tieres wird durch eine gegebene Menge der Faktoren bestimmt, also die Faktoren können einander gegenseitig modifizieren. Zweitens: die Art kann einen Verhaltungsmechanismus entwickeln, was eine grössere Aussicht für die Fortdauer sichert, wie man aus physiologischen Kennzeichen erwarten kann.

Die menschliche Störung ist ein neuer, gleichzeitig der gefährlichste Umweltfaktor, weil dagenen die Fledermäuse noch keinen Schutzmechanismus entwickeln konnten.

1. INTRODUCTION

Most European countries, including Hungary, strive to protect bats and their habitat or certain details of it. First of all it would require to get more information about the habitat (e.g. roost, feeding habitat) itself. Studying the ecological requirements of bats we can understand how they choose their roosts, so places providing these requirements can be protected more efficiently.

Aggregates of cave-dwelling bats have been investigated for five years (aggregate of every bat of a cave referred to as population; that of individuals belonging to the same species referred to as colony).

Here I mainly deal with hibernation as it is the most crucial period for survival of the individuals. Species occurring most frequently or being the most abundant in individual number were as follows:

Rhinolophus ferrumequinum (Greater horseshoe bat)
Rhinolophus hipposideros (Lesser horseshoe bat)
Myotis myotis (Mouse-eared bat)
Myotis blythi (Lesser mouse-eared bat)

2. SOME QUESTIONS OF ENERGETICS OF BATS

Most of the recent bat species are tropical. Number of species decreases towards the north, as the circumstances become less favourable. Several mechanisms had been evolved by temperate bats enabling them to survive under relatively extreme circumstances. One of these adaptation mechanisms is their special thermoregulation, that differs from that of other mammal taxa. Bats are heterotherm. It means that they are normally able to maintain constant body temperature but in unfavourable parts of the day or even season their body temperature falls to that of the ambient, by a slowing down of breathing, heart--beat and other body systems.

Temperate bats can become torpid in both summer and winter. Winter torpor is referred to as hibernation. It is caused by lack of food, its length depends mainly on the species itself and the weather.

Summer torpor (referred to as daily torpor) is different. These species encounter a constant energy deficit, as food intake (insects available) does not provide enough energy for bats to remain continuously at high body temperature (40-41°C). Peak deficits may occur during pregnancy and lactation. Going to the north difference between body temperature and that of the ambient grows, thus energy deficit would increase as well.

Bats can not raise the food intake: first, flying (thus hunting itself) is very energy consuming. Secondly, quantity of insects depends on the weather. On cold, rainy days there is a food shortage, so food intake of favourable days has to cover the energy costs of unfavourable periods. In addition, bats have to prepare for hibernation. Most mammal can do it by increasing the food intake in autumn, but bats can not, as it follows from the above.

It is clear that there is only one possibility to reduce this energy deficit, namely to reduce the energy costs. By becoming torpid bats can save energy, because they do not need to maintain continuously high body temperature. This daily torpor makes it possibile to survive unfavourable periods, to build up energy reserve for hibernation and to give birth to the babies. Whatever energy-saving solution this is, most of the temperate bats can bring up only one young.

3. VULNERABILITY

We can see that energy stored as fat is very limited, that is why these animals can be especially vulnerable. In winter fat deposit is just enough to make it possible for the animal to respond to the changes in environmental factors (e.g. decrease in temperature). In these cases the bat can wake up and look for other, more appropriate roost. This response is very energy-consuming: on one hand, body temperature raises from that of the surrounding (e.g. a cave) to 40-41°C, causing significant loss of energy. On the other hand, remaining at this high body temperature requires extra energy as well.

These awakenings seem to be calculated evolutionary, under normal circumstances the fat reserve lasts till the end of winter, when insects appear. Problem can arise if something unusual happens to the population, for example a too long and cold winter. It may also occur that bats have to wake up too often (especially because of human disturbance). In both cases they use up the fat deposit too early and die of starvation.

The other reason of vulnerability of these animals is their rather narrow ecological tolerance. First, most of the insectivorous bat species feeds exclusively on given taxa of insects. Secondly, bats must select their roosts very carefully. (Int this point of view there is a quite significant difference between the so-called "tree-bats" and "cave-bats": the former group can olerate greater extremes, while the latter one requires more constant environment.)

Purpose of this study was to find out how bats choose their roosts: what environmental factors could be the most crucial; between what extreme values of these factors the given colony or population ocurred and, finally, it was expecially interesting to investigate how the animal itself reacted upon its environment. Optimum values of the environmental factors were determined as well, on the basis of quantitative occurrence.

4. ENVIRONMENTAL FACTORS

In our case, as well as in course of any other ecological fieldwork, the main difficulty was to answer the first question, namely to find environmental factors having the most significant effects on the aggregates. Both measurable and not measurable factors were investigated. The first group of the factors involved for example temperature, relative humidity and CO_2-level. Shape and location of the roost belonged to the second group.

Here we deal with temperature and relative humidity, both were chosen on the base of physiological respects.

Temperature of the roost should be suitable for maintaining the slowed down metabolism. Therefore there is a (theoretical) optimum, where the metabolic rate is the most favourable, and there are a lower and an upper limits. Of course, these values differ a little bit in case of each species.

The other factor being crucial considering the metabolism is the relative humidity. This, as well as temperature, especially concerns the period of hibernation. If relative humidity is very low at a certain place, water loss can be very significant. It means that the animal has to wake up to drink very often, causing considerable loss of energy in case of each awakenings.

Relationship between these factors is very close: on one hand, temperature has a direct effect on relative humidity and, on the other hand, they have indirect effect on each other. For instance, metabolism and water loss may grow when temperature increases. If relative humidity is low at the same time, water loss can be more crucial and dehydration can be faster than they would be considering merely one unfavourable factor.

There are two possibilities to study the role of these environmental factors and to determine the tolerance of a given aggregate. First, measurements can be made in one cave and then we can compare the spatial and temporal distribution of bats to values measured. Secondly, investigation can be carried out in several caves and we can compare these results. The latter method can be advantageous when values of a certain factor do not show significant variation within one cave.

Cave used as a sample is the Létrási-Vizes Cave (Bükk Mountains). Results of measurements made here are compared with those of other Hungarian and Polish caves.

5. RESULTS

On the basis of observation made in the Létrási-Vizes Cave it can be said that temperature preferences of the investigated species have showed clear differences. (Here ecological requirements of Myotis myotis and M. blythi are discussed together, since they usually formed groups together and identification could not have been made without disturbing the bats.)

Temperature preference was determined on the base of temporal (Fig. 1.) and spatial (Fig. 2.) distribution of bats. Greater horseshoe bats preferred the warmest places, occurred most frequently at temperature of 6.4 - 8.0°C. Once I observed a specimen at extremely low temperature (3.8°C) as well. Upper extreme value agreed with that of the optimum (8.0°C) as it was near to the maximum temperature of the cave (8.2°C).

Optimum of Lesser horseshoe bats was between 5.5 - 7.5. Extreme values of its occurrence were 3.2 and 8.1°C.

Mouse-eared and Lesser mouse-eared bats were the most abundant in individual number at temperature of 3.0 - 7.0°C. Lowest and highest extreme values were 2.2 and 8.0°C.

There is a significant difference between values measured in this cave and those of mentioned in literature. For example Schober and Grimmberger (1987) give the following characteristic values of winter roosts:

Greater horseshoe bat: 7.0 - 10.0 °C
Lesser horseshoe bat: 6.0 - 9.0 °C
Mouse-eared bat: 7.0 - 12.0 °C /!/
Lesser mouse-eared bat: 6.0 - 12.0 °C /!/

Furthermore, in course of most of my measurements made in other caves the two horseshoe species were found at higher temperature, between 8.0 - 10.0°C.

Measuring the relative humidity such a significant variation could not be observed. On the basis of values measured in both the Létrási-Vizes Cave and other caves bats can be said to prefer high relative humidity, near 100 %.

6. CONCLUSIONS

This significant difference between thermopreferendums of aggregates of the same species can be explained as follows: first, certain behaviour patterns may help the animal to cut free more or less from ambient temperature. In case of Mouse-eared and Lesser mouse-eared bats the most important behaviour pattern is to form colonies: the lower the temperature, the more individual bunch together (Fig. 3.). In this way energetics is much more advantageous, making it possible for the colony to occur at such a low temperature that would be impossibile for a single individual, regarding merely physiological respects. This pattern can be observed in horseshoe bats as well.

Secondly, no environmental factor can be studied in itself. Interactions between the factors, even between the animal and its environment should be taken into consideration to obtain reliable and useful data.

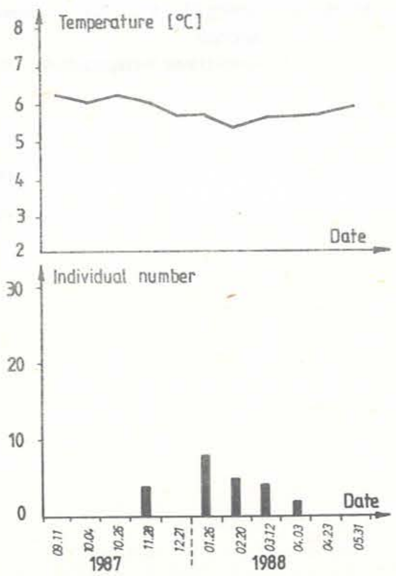

Fig.1a.Temporal distribution of Rhinolophus ferrum-equinum and R.hipposideros at a given station of the cave

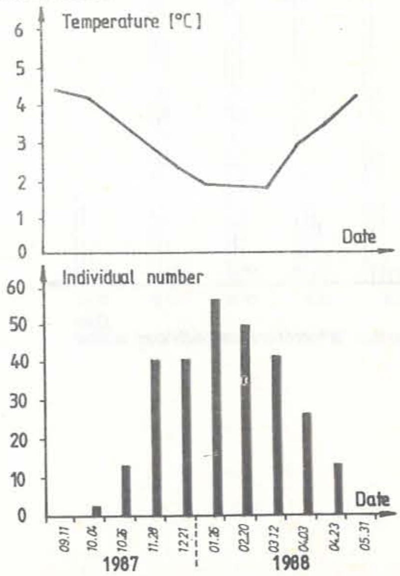

Fig.1b.Temporal distribution of Myotis myotis and M.blythi at a given station of the cave

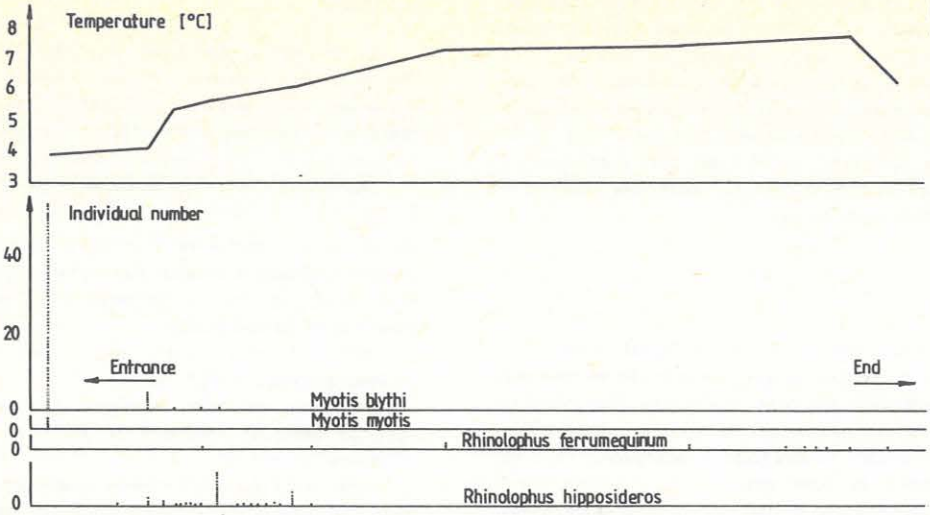

Fig. 2. Spatial distribution of bats in the Létrási-Vizes Cave

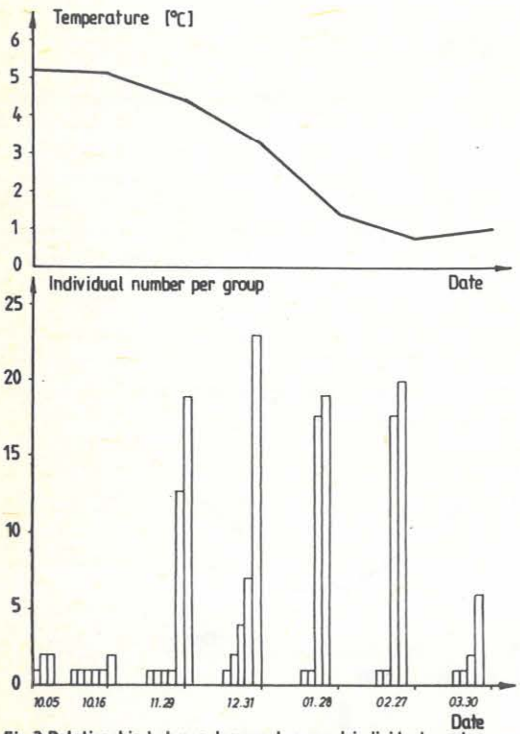

Fig. 3. Relationship between temperature and individual number of groups

Each cave has its own "individuality", possesses given set of environmental factors. It is very important to understand: a certain population has adopted to a certain cave, to certain set of the environmental factors, not to caves in general. That is why it is essential in bat conservation to protect the accustomed roost of each population.

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PURPOSES AND NECESSITY OF GRID MAPPING

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The first (and so far very often neglected) step of nature conservation must be to estimate what we possess (namely the recent status of natural resources). For example, having exact faunistical data there is a possibility to state any changes in plight of the given taxon. These changes probably indicate environmental problems, so getting exact information about the symptom (e.g. decrease in individual number or even disappearance of a whole population) can help to reveal the reasons.

Grid mapping, as a method, enables an up-to-date data processing to be made. Usually 10 x 10 km sized squares are used, but they can be divided into subsquares. Each square has a code consisting of 2 letters and 2 numbers. To demonstrate how data collection and data processing should be made in a particular case we surveyed caves used by hibernating bats in a given 5 x 5 km sized subsquare in the Bükk Mountains.

We should like to call attention to the difficulties of grid mapping of migratory species (bats are involved here as the winter and summer roosts of a colony are different). In these cases two estimations of the population must be made.

Ziele und Notwendigkeit der Rasterkartierung

Der erste Schritt des Naturschutzes ist notwendigerweise eine Abmessung der Kostbarkeiten, die zur Beurteilung des ursprünglichen Umweltzustandes noch heutzutage zur Verfügung stehen. Bisher war das zum Teil vernachlässigt. Wenn wir beispielsweise genauere faunistische Daten haben, dann gibt es eine Möglichkeit zur Bestimmung jeder Veränderung im Status eines gegebenen Taxons. Wahrscheinlich zeigen diese Veränderungen die Umweltprobleme an, so tragen die genauen Informationen von Erscheinungen (z.B. die Verminderung der Exemplare, oder die Verschwindung der ganzen Population) zu der Aufdeckung der Ursachen bei.

Die Rasterkartierung, als eine Methode, sichert die Möglichkeit einer zeitmässigen Datenverarbeitung. Man braucht gewöhnlich die Quadrate mit 10x10 km, aber die kann weiterteilen (sog. Subquadrate). Jedes Quadrat hat einen Kode mit zwei Buchstaben und zwei Nummern. Zur Demonstration des Sammeln von Angaben und der Datenverarbeitung zeigen wir in einem Subquadrat mit 5x5 km auf dem Bükk-Gebirge die Höhlen, welche eine Aufenthaltsstelle für Fledermäuse im Winterschlaf geben.

Wir verweisen darauf, dass die Rasterkartierung von Zugtieren auf Schwierigkeiten stossen kann. (Zu den Zugtieren kann die Fledermäuse auch eingeteilt werden, weil das Quartier im Sommer und Winter gewöhnlich unterschiedlich ist.) Gegebenenfalls müssen zwei Aufnahmen durchgeführt werden.

1. PURPOSES OF GRID MAPPING

The first and most important step of any kind of nature conservation should be to estimate what we possess (namely the recent status of nature). Neglecting this step we can not follow with attention to what extent certain plant and animal populations are damaged by different problems of environmental protection. This question can be approached from the other side as well. Az occurrence (or absence) of living organisms always indicate something, decrease in individual number of a given population or even disappearance of the whole population can be regarded as a symptom, that presumably indicates a certain negative effect. Albeit not often, but its opposite can also occur: re-appearance of a population or increase in its individual number may indicate positive alteration in environmental factors.

We have to think of that the later such a data-base is created to estimate the status of natural resources the smaller chance we have to solve the problem by recognizing the symptom.

Grid mapping accepted in whole Europe seems to be the most adequate method to collect, to process and to publish data. We would emphasize that grid maps in themselves provide rather little information, so a computational data processing should complete it. On one hand, during grid mapping there is no possibility to record certain elements of data (locality and date of collection, name of the collector). These are all essential elements of any faunistic/floristic data. Exact record of the locality is needed when certain localities have to be arranged by different administrative units or topographical lot numbers. Date of collection is primarily important because of seasonal bahaviour of the species. Finally, knowing the name of collector makes it possibile to control the data and guarantees their authenticity.

On the other hand, grid maps do not strive for quantitative representation. Classical form of grid mapping enabled only a two choice selection to be made (the species occurred or not). It has turned out that presentation of quantitative properties should be necessary, that requires a supplementary data-base.

2. PRACTICAL APPLICATION OF GRID MAPPING

Grid used in European survey is of UTM (Universal Transverse Mercator) system. It consists of main squares of 100 x 100 km^2. These are encoded alphabetically, 2 letters form the code of each main square. It results from the peculiarity of this projection that at every sixth longitudinal circle a so-called convergent zone can be found to equalize area diminution caused by spherical shape of the Earth.

National surveys normally use squares of 10 x10 km^2. These are encoded by numbers from 0 to 99, within each main square of 100 x 100 km^2. In this way each square has an alphanumerical code consisting of two letters and two numbers. The letters refer to the main square, the numbers to the square itself.

To survey smaller areas within the country (e.g. counties, natural reserves, national parks, etc.) further division is needed. Two possibilities are avilable, both are wide-spread. First of them is when the square of 10 x 10 km^2 is divided into subsquares of 5 x 5 km^2 and they are encoded alphabetically. Then each subsquare is divided into four parts again. Subsqares of 2.5 x 2.5 km^2 formed in this way are encoded numerically. The second possibility is to divide the square of 10 x 10 km^2 into subsquares of 1 x 1 km^2, they are encoded numerically from 0 to 99. This procedure agrees with dividing the main square of 100 x 100 km^2 into squares of 10 x 10 km^2.

In each square occurrence of the species is shown, using certain symbols (here ●) Separate maps should be made for each species, for the sake of clearness.

To make the foregoing lucid, a factual example is to be described here. In the Bükk Mountains (Hungary) a subsquare of 5 x 5 km^2 of the square of 10 x 10 km^2 was chosen for this survey (Fig. 1.). Taxon investigated was Chiroptera (bats). These animals have special seasonal behaviour: summer and winter roosts of the same colony are different. As this survey was especially made to demonstrate the practical application of grid mapping, species hibernating in caves were investigated, during the period of hibernation (subject of our paper agrees with that of the conference at this point).

Square investigated is situated at the edge of the Bükk Plateau. Our choice was made by the facts that it could be easily approached and number of caves of this area was quite high, according to the register of the Ministry for Environmental Protection and Management of Water Supplies was as much as 62 (Fig. 2.). The investigation was carried out in the winter of 1988-89.

Hungarian bats belong to suborder Microchiroptera, to the families Vespertilionidae and Rhinolophidae. Among the 24 species occurring here the following ones were observed:

Rhinolophus hipposideros (Lesser horseshoe bat)

Fig. 1. The investigated subsquare of 5×5 km^2 (DU62D) within the square of 10×10 km^2

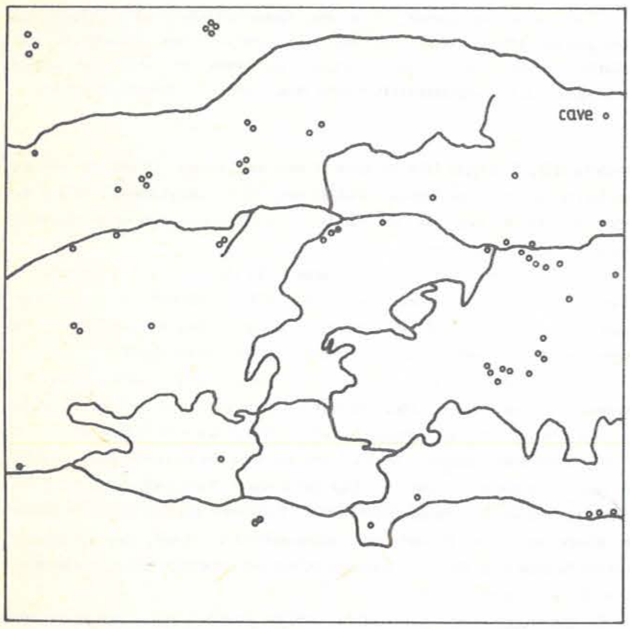

Fig. 2. Distribution of caves in the DU62D subsquare

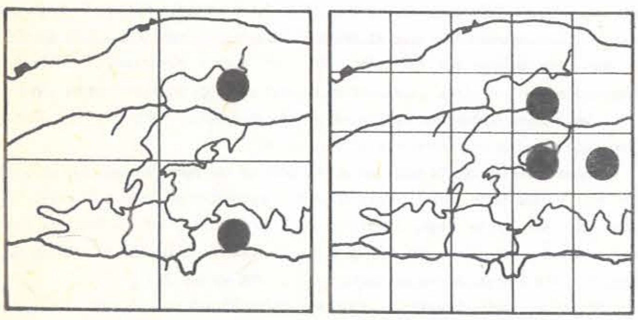

Fig. 3. Distribution of Rhinolophus hipposideros in the DU62D subsquare

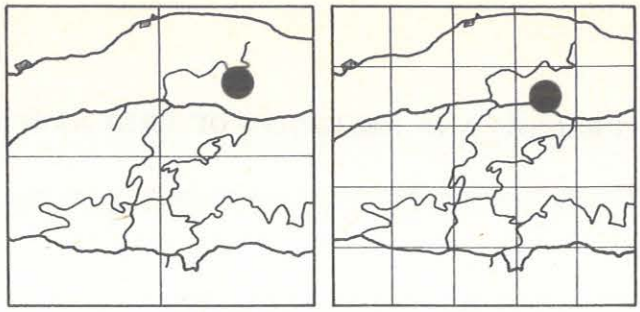

Fig. 4. Distribution of Rhinolophus ferrumequinum in the DU62D subsquare

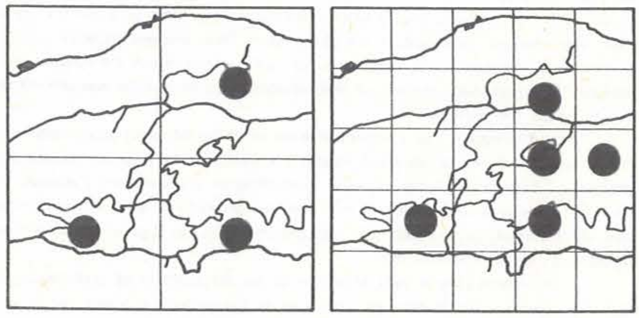

Fig. 5. Distribution of Myotis myotis in the DU62D subsquare

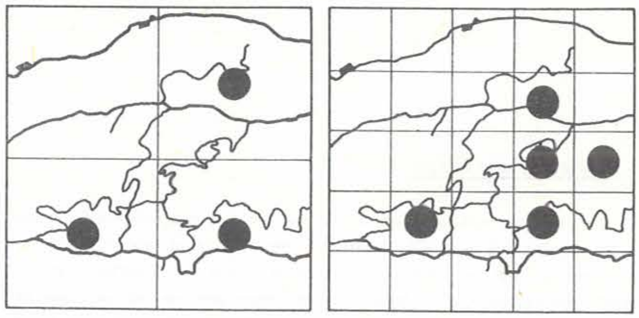

Fig. 6. Distribution of Myotis blythi in the DU62D subsquare

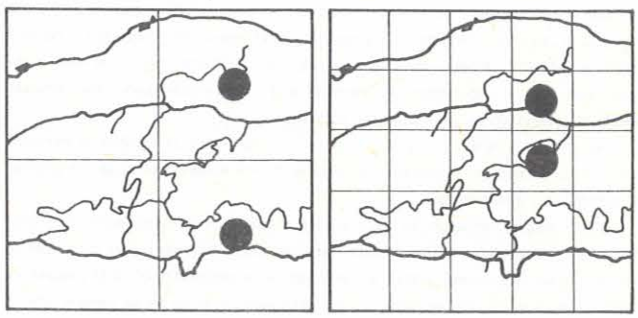

Fig. 7. Distribution of Myotis nattereri in the DU62D subsquare

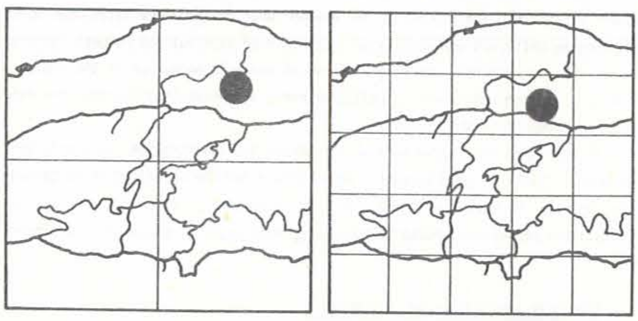

Fig. 8. Distribution of Myotis mystacinus in the DU62D subsquare

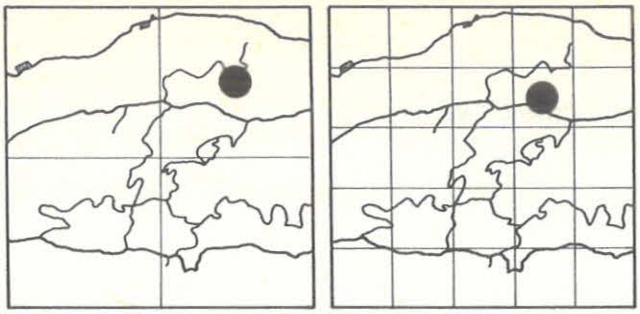

Fig. 9. Distribution of Barbastella barbastellus in the DU620 subsquare

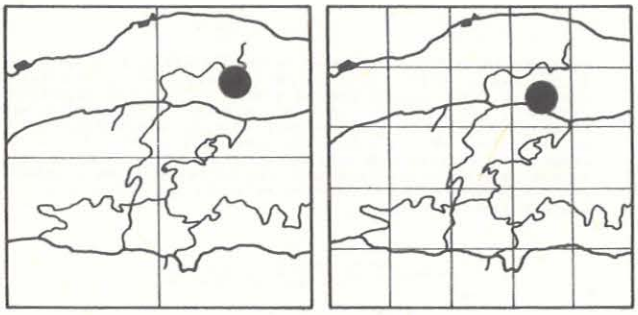

Fig. 10. Distribution of Pipistrellus pipistrellus in the DU620 subsquare

Rhinolophus ferrumequinum (Greater horseshoe bat)
Myotis myotis (Mouse-eared bat)
Myotis blythi (Lesser mouse-eared bat)
Myotis nattereri (Natterer's bat)
Myotis mystacinus (Whiskered bat)
Barbastella barbastellus (Barbastelle)
Pipistrellus pipistrellus (Pipistrelle)

Occurrence of these species are shown on grid maps (Fig. 3-10). The subsquare of 5 x 5 km^2 is divided in two ways, for the sake of comparison. It can be seen that the two different methods (dividing into subsquares of 2.5 x 2.5 or 1 x 1 km^2) may give different pictures. As it can be expected, the latter provides more exact result, but requires better maps and more precise field-work.

3. DIFFICULTIES OF GRID MAPPING

Experiences of almost 30 years of European grid mapping show that in case of both collecting and processing data several difficulties can arise. Among them only two are described here, we have encountered them most frequently during our investigation.

One of the most important problems results from the method itself. Essence of grid mapping is a continuous observation of the status of the objects of nature, here species, so data collecting can never be finished. Old data can be used only to compare the former and present status.

In case of bats the seasonal behaviour mentioned above, namely different summer and winter roosts of one colony, enlarges this difficulty. For these species two grid maps should be made, one would show the winter, the other the summer occurrence.

It results from the foregoing that the other main problem of both grid mapping and creating a computational data-base is whether an appropriate network is available for supplying of data. This network should not be based exclusively on specialists: role of amateurs and amateur groups in nature conservation is growing as the problems increase.

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SHEAR, TENSION OR BOTH - A CRITICAL VIEW ON THE PREDICTION POTENTIAL FOR CAVES

LAURITZEN, Stein-Erik

Abstract

There are general problems of distinguishing between tension and shear planes on the collective and individual level. In many cases, real distributions of tension and shear fractures cannot be distinguished. In these cases, general assumptions that either of the two types of fracture exclusively controls caves on the collective level become meaningless. Shear fractures are most often recognized individually as guiding fractures, and cave passage trends often correlate well with them. Beta analysis (intersection) of bedding planes and fractures seems like a promising <u>directional</u> approach for the analysis of structural control in caves.

INTRODUCTION

From the theory of speleogenesis it follows that cave conduits are formed from pre- existing fractures. Therefore, the history of brittle deformation is essential for determining the geometry of a karst system. Generally, fractures can be of two basic types, shear or tension, depending on their angle with the principal axes of stress, Figure 1a. A widely held view, which often occur in textbooks, is that tension fractures are better conveyors for groundwater than other fractures. This view might seem intuitively conceivable, but as we shall see later, a unique distinction is difficult to prove.

In the following we shall use the term *Tension Plane* about fractures generated by tension, and *Shear Plane* about all fractures generated by shear forces, i.e *both* true faults and incipient faults (Shear Joints).

As brittle shear zones evolve, they will distort the stress field in their vicinity. Secondary shearplanes may therefore develop at acute angles to the primary shearplanes; these secondary shearplanes may further develop a new set of tertiary shears, Figure 1b. Such multiple generations of shear planes are often named Riedel shears, and it follows immediately that the ***scale of observation*** is important for the identification of the stress field. A stress field which is "unimodal" on a larger scale would develop into several sub-sets with decreasing scale of observation. In some cases, the regional stress field may be deduced from small scale slip-vectors by means of statistical analysis of a large sample (Angelier 1975).

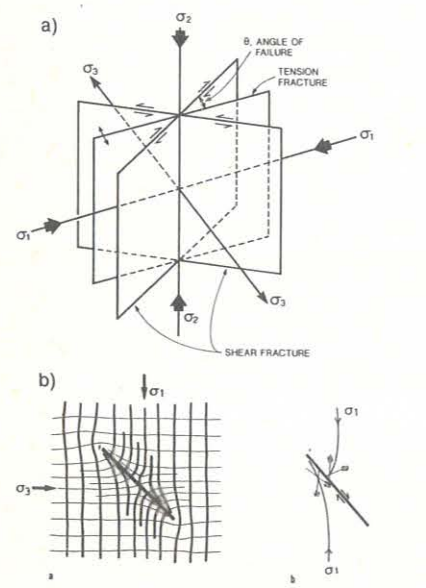

Figure 1.
a) Shearplanes and tension fractures related to the principal axes of stress, σ_1..σ_3. *b) Distortion of the stress field around fractures. σ_1 and σ_3 may rotate up to 90°. From Bles and Feuga 1986.*

NON- DIRECTIONAL DATA
Resolution of shear and tension planes

There are several problems connected to the analysis of the collective properties of shear and tension fractures, i.e. when they occur in populations. First, when we try to decompose slip- vector data of the scale of cave passages into principal stress axes, we will almost always get multimodal distributions. Second, the maximum available angle for the distinction between tension and shear fractures is the angle of failure, θ, which is dependent on the strain rate and the internal friction in the material. θ is commonly in the range of 20 - 40°. In practice, each set of fractures display a distribution around a mean, which may sometimes exceed ± 30°. Therefore, genetically related sets of shearplanes and tensionplanes may overlap, and a distinction between them on the collective level may become difficult. From this, we will also realize that there is an upper limit to the number of clusters that can be resolved on a sphere; the number depends on the relative position and the distribution of each cluster.

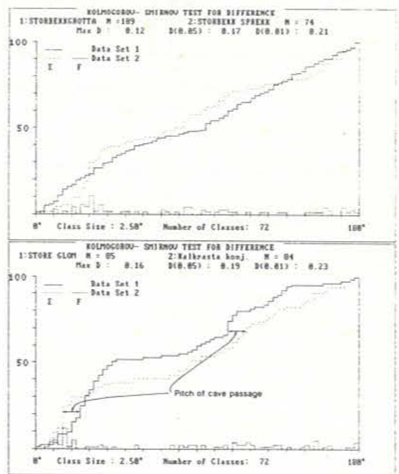

Figure 2.
The strike of shearplanes compared with cave lineament trends. The deviation observed may be explained by the pitch of the cave passage in the guiding fracture.

Fracture planes as such are non-vectorial, i.e. they are trends. It is common practice to constrain the statistical treatment of planes to their projection in the horizontal plane (the strike). Being trends, they can only be resolved within the range of 0-180°. With a slip angle of about 30° and a dispersion of 30° (Fisher distribution), more than two sets of stress axes (four sets of shearplanes) can hardly be resolved with confidence on a semicircle. The corresponding tension planes would bisect the angles between each conjugate set of shearplanes, and the question is whether they can be resolved from them as a separate population.

These problems of resolution can be demonstrated on samples where the association of shearplanes, tensionplanes, or both allows determination of the slip- vector, and subsequently, the stress axes (see general texts like Davis 1984, Ragan 1968, Ramsay and Huber 1987). These techniques can easily be implemented on a microcomputer which allows the processing of large amounts of real and simulated data sets. For the purpose of further research into the 3- dimensional analysis of caves and fractures, a menu- oriented program: ***"Sigma 123"***, has been written in Turbo-Pascal code (Borland 1988, Lauritzen 1988). Several approaches have been applied to the problem of comparing samples of spherical data (Fisher et al. 1987). An annoying problem is that we have no good method for statistical testing of multimodal distributions on a sphere; it is suggested to carry out the tests in the horizontal and in the vertical plane separately. Several approaches may be taken, either a direct comparison of rose diagrams by means of non-parametric statistics (Kolmogorov-Smirnov, Kuiper), or by a Quantile-Quantile plot which is sensitive both to the shape of distribution and to the position of the means (Fisher et al. 1987). For the sake of brevity, we shall only consider the application of the Kolmogorov- Smirnov statistic here.

So far, more than ten samples of conjugate shearplanes (n= 25 - 100) have been analyzed and compared with the corresponding tension planes and with axes of cave systems in their immediate vicinity. All data sets were also tested for randomness and uniformity; data sets which could not be distinguished from random or uniform distributions were rejected.

Tension planes vic. Shear Planes In most cases, the Kolmogorov- Smirnov test was unable to distinguish between the distribution of tension planes and the distribution of the corresponding shear planes.

Tension planes vic. Cave Passage Trends In some cases the test rejected the null hypothesis that the caves could be explained by the distribution of tension planes, in other cases not.

Shearplanes vic. Cave Passage Trends In most cases, cave trends and shearplanes could not be distinguished. Moreover, it was usually possible to explain the slight mismatch between two maxima by the fact that a cave passage would represent a pitch in the plane of the guiding fracture, and thus deviate from the strike of that plane (Figure 2).

It is generally difficult to suggest unique solutions to the problem, simply because ***lack of difference is not a sufficient criterion for unique identity***. For example, it is possible to "predict" the distribution of lineament trends of the Pierre St. Martin System from a set of shearplanes (faults) that can be extracted from geological maps of the area. Using a sample of about 100 lineaments in each group, the two sets cannot be distinguished as different by the Kolmogorov- Smirnov statistic, Figure 3. This result is obtained by using the ***opposite null hypothesis*** of Eraso (1986). Based on the assumption that caves are guided by tension planes alone, he predicted the PSM system from synthetic tension planes.

Direct Observations Accepting that the collective treatment of potential guiding fractures do not always yield unique solutions, we may turn to the individual level of Conduit/guiding fracture association and try to identify their origin. In most of the cases that have been investigated, the guiding planes that allowed analysis were shearplanes. Other guiding fractures which could not be analyzed with confidence, were however, often parallel with other shearplanes. Generally, larger elements of conduits seemed controlled by shears, whilst some of the most effective shortcuts, could be tension planes. The most striking example is perhaps Castleguard Cave in the Canadian Rockies, where most "bedding planes" turned out to be low

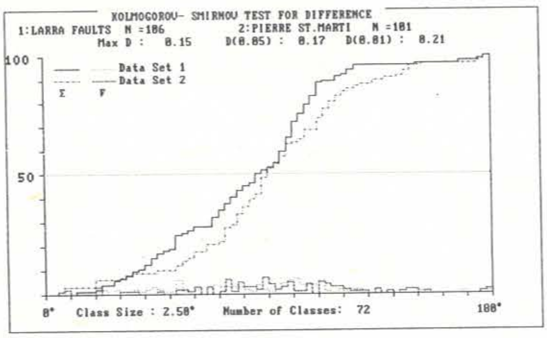

Figure 3.
Lineaments in the Pierre St. Martin System "predicted" from shearplanes, measured as mapped faults of the area. The two distributions cannot be regarded as different.

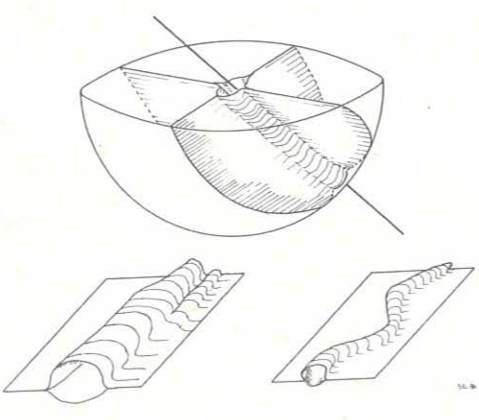

Figure 4.
Cave conduits are controlled by planes, or by the lines of intersection between them. The dip direction of cave conduits may be modelled by beta analysis of planes that supposedly control them. From Lauritzen 1986.

angle thrusts, and many of the vertical elements (shafts) were guided by faults. We may, however identify tension fractures as guiding fractures in the case that fractures may experience secondary tension from geomorphological reasons, i.e. loading and exfoliation close to steep surface gradients.

A possible explanation for the observed preference of shearplanes as guiding fractures may be that shearplanes (faults) tend to be more extensive than tension planes, which also tend to be mineralized. The more extensive a fracture plane, the higher is the probability for intersecting other fractures, thus allowing throughflow.

DIRECTIONAL DATA
Beta Lineation Analysis
The problem of fracture genesis may be avoided if we consider the general observation that cave passages are almost always guided by the line of intersection between two planes, Figure4. Using this approach, we may try to predict caves by constructing lines of intersection (beta analysis) between bedding plane/fracture, or fracture/fracture (Lauritzen 1986, 1988b). The resulting lines are trends in space, but as they possess a dip direction, they are directional in the two-dimensional domain. We therefore have the possibility to consider the dip *direction* of cave conduits, and utilize the full circle in our analysis. For vadose conduits, the dip direction would also be the direction of flow. In most cases, it was possible to model the axial trends of cave surveys by beta analysis of fractures and bedding planes, and the goodness of fit between the observed and predicted ***dip directions*** were in some cases highly acceptable, Figure 5. The corresponding beta- plot of fracture/fracture intersections do not explain much of the cave pattern. In contrast, dolines are often believed to be controlled by fracture intersections.

CONCLUSIONS
1) It is difficult to make general distinctions between tension and shear planes on the collective level.

2) The trends of cave passages may be predicted from tension planes ***and*** from shear planes. This investigation suggest that shearplanes often give the best goodness of fit of the two. Small deviations between the modes of shearplane strike and cave lineaments may sometimes be ascribed to the fact that the cave often represent a pitch in the guiding plane.

3) Close inspection and analysis of individual guiding fractures in caves most frequently reveal them as shear planes. Tension planes are much less common as guiding fractures.

4) A non-genetic, directional model for cave lineation dip direction is suggested. It models the lines of intersection between bedding planes and fractures. In some cases, this approach may produce highly acceptable results.

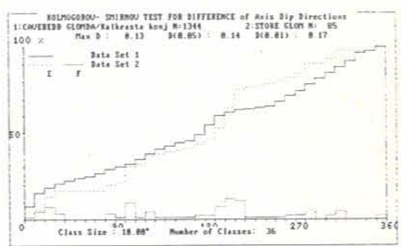

Figure 5.
Dip direction of a cave compared with beta analysis of fractures of bedding planes. This approach allows testing in a full circle, directional domain.

5) These conclusions need further testing before general validity can be claimed. Future studies should follow this approach:

a) Sufficiently large (N = 50- 100), non-random and non-uniform samples should be used.

b) The null hypothesis must be tested against all alternative hypotheses before we can make inferences about unique identity.

c) To reveal the true structural control of a cave, the origin of single guiding fractures should be investigated and analyzed statistically and compared to the collective properties of other structures.

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THE SIRIJORDA KARST AQUIFER, NORDLAND, NORTHERN NORWAY

OVSTEDAL, Jarl - LAURITZEN, Stein-Erik

Abstract: The Sirijorda karst aquifer is an allogenic multi-input system recharging into one main spring. Connections between 3 major inlets and the spring were proven through qualitative dye tracing. Flood responses are found over a range of 100 times baseflow, indicating well developed conduits. Conductivity ranges from 34.3 to 119.2 μScm^{-2} and total hardness from 5.6 to 21.9 ppm Ca^{2+}. One infiltration-fed conduit displayed very little variation in discharge (0.3 L/sec), conductivity (190 μScm^{-2}) and total hardness (39 ppm Ca^{2+}) The aquifer was further characterized though recession analysis, hydrochemistry and water tracing.

INTRODUCTION:
The purpose of this work is to study the mechanisms of response on a typical conduit aquifer in a stripe karst setting. This study is still in progress; we will present only tentative and general results here.

Geographic and Geological Setting:
The study area is situated in Eiteràdalen, North Norway, Figure 1. The karst is developed in a band of almost vertically dipping calcite marbles. The carbonate strata are approximately 100 m thick, and the underground drainage routes are strongly strike- controlled. Allogenic water sinks at 3 discrete inlets (A & B, Figure 1), of which one (B) is an intermittent overflow from a small polje west of the border of Figure 1. There is only one resurgence (C). The cave (EFGC) constitute a vadose streamway between the spring and the main sump (E). An infiltration-fed tributary (E, "Twin Ducks") enter the upstream part of the cave.

Qualitative dye tracing proved the connection AEC. Moreover, the underground streamway was found through a small cave in the SE edge of the main depression, indicating that the conduits follow a marble/mica schist contact from A to B.

Instrumentation and Sampling:
Discharge is gauged in all inlets by flügel or salt dilution techniques. V-notch veirs are mounted in A, B and C and monitored by means of pressure transducers and data

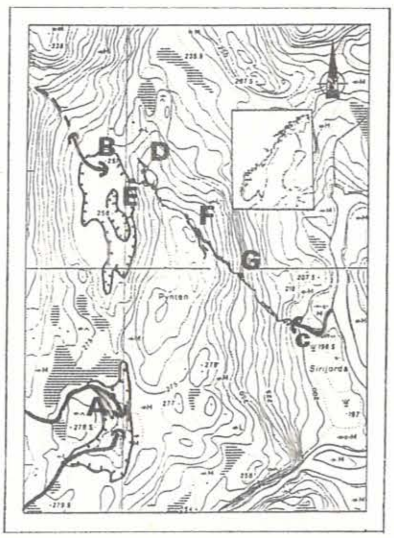

Figure 1.
Location of Sirijorda. A,B : inlets; C: resurgence; D,E,F,G: sampling sites within the cave. D is an infiltration- fed tributary ("Twin Ducks passage"). Cave survey after Faulkner (1979).

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logger (C), chart recorder (A), or manual records (B). Temperature and conductance is monitored continuously in the resurgence (C), as well as air temperature and local precipitation.

Water samples were drawn by a water sampler at 24 h intervals at (C); in periods of field attendance, "simultaneous" series of samples were drawn from A, B, C, D, E, F, G in order to map the hydrochemical state of the system at different water stages. All samples of water and precipitation will later be analyzed for stable isotopes.

Conductivity, temperature, pH and alkalinity was determined either immediately or within a few hours of sampling, other main constituents were subsequently determined titimetrically (total hardness), by ICP (Ca,Mg,Na,K,Fe,Al) and ion chromatography (Cl^-,$SO_4{}^{2-}$).

The work was commenced by July 1988, and is still in progress. A programme of quantitative dye traces will be carried out in the 1989 season.

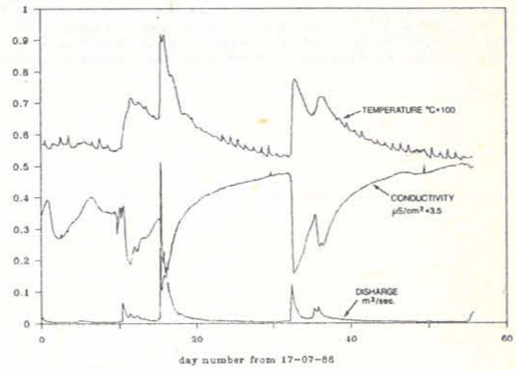

Figure 2.
Variations in discharge, water temperature and conductivity in the resurgence during 60 days from July 17th, 1988.

PRELIMINARY RESULTS

Discharge
Baseflow in the resurgence (C) is about 3.5 L sec^{-1}. Very rapid flood responses attain up to 512 L sec^{-1}, i.e. about 150 times baseflow (Figure 2). The rapid peak response to recharge confirm the observations of large vadose conduits, 1- 2 m diameter, in the cave.

Recession analysis is not yet completed, but long-term baseflow recession yielded a decay constant of 7.31 x 10^{-7} sec^{-1}. The corresponding flood and baseflow volumes during the large flood (Figure 2) were 36,500 m^3 and 1,540 m^3, respectively.

Temperature and Conductivity:
Temperature responses in the resurgence are rapid and parallel discharge and conductivity. The abrupt changes represent the arrival times for high temperature, low conductivity surface waters at the resurgence. Conductivity and temperature are therefore intrinsic tracers which reflect piston- flow and exchange between storage of different types within the aquifer. The events of august- september 1988 do not show any pulse of increased in conductivity at the commencement of floods,- which might represent the fissure storage ejected by piston flow. This observation seems to harmony with the extremely low recession volume representing baseflow (see above), suggesting that fissure storage is low.

We would expect rapid exchange of thermal energy between the allogenic water and the conduit walls. From these reasons, we should expect the thermal wave to be delayed relative to the conductance wave; i.e. temperature would display a shorter penetration length than solute concentrations (X_0 of Wigley and Brown 1971). According to Wigley and Brown (1971):

$$X_0{}^* = 16.4\ X_0 \qquad (1)$$

where $X_0{}^*$ and X_0 are the relaxation lengths for solutes and temperature.

The arrival time of temperature at the large flood of Figure 2 was 108 minutes, whilst conductance dropped after only 30 minutes. This corresponds to a piston volume of 7,780 m^3 and 1,350 m^3, respectively. In both cases, the storage is apparently flushed out of the system before peak discharge is reached.

These preliminary results needs to be tested for reproducibility in future flood events. More studies of this kind is in progress where we shall compare travel times of different types of tracers (dyes, stable isotopes) with the response characteristics of the system.

Estimates of X_0 for temperature
Temperature measurements in A..G, (Figure 1), may help us to estimate X_0 (temp) of the conduit system. According to the theory of Wigley and Brown (1971) water temperature of a tubular conduit will decay exponentially with travel length:

$$T_L = T_a + (T_0 - T_a) * e^{-K*L} \qquad (2)$$

where T_L and T_0 are water temperatures at length L and at the entrance; T_a is the asymptotic temperature of the surrounding rock walls, L is the travel length and k is a decay constant. Analogous with the concept of half-life, we may introduce a length constant, X_0, that is the length after which the original temperature difference is reduced by 1/e. The expression of X_0 in Wigley and Brown (1971) can be rewritten:

$$X_0 = 167.8 * Q^{0.17} * r^{0.83} \qquad (3)$$

where Q is in $m^3 sec^{-1}$ and r (conduit radius) is in meters. X_0 was determined as the slope of L (m) vic. $\ln((T_L - T_a)/(T_0 - T_a))$ (^0C). Knowing X_0 and Q, we may estimate r, according to (3).

X_0 depend on the T_a used. Using the temperature of the infiltration- fed inlet (D in Figure 1) as T_a, discharges in the range of 3.6 - 4.7 $L^3 ec^{-1}$, yield X_0 = 2000 ± 400 m, corresponding to average passage radii of approximately 0.1 m. X_0 is longer than the underground conduits (about 950 m), which is conceivable with the fact that diurnal input variations (of T_0) penetrate the system at moderate and low discharges (Figure 2). Exploration has revealed the streamcourse as essentially vadose, interrupted by shorter phreatic loops. At a discharge as low as 3 L sec^{-1}, an average radius of about 0.1 m seem conceivable. At this discharge, the water would twinkle inbetween gravel and boulders in the streambed. If we use the conduit volume at high discharge, as determined from conductivity travel time, we may calculate a flood radius of 0.67 m, which, as expected, for vadose transit, is larger than the low discharge radius.

Water Chemistry
Conductivity ranges from 34.3 to 119.2 μScm^{-2} and total hardness from 5.6 to 21.9 ppm Ca^{2+}. The infiltration-fed conduit (D: Figure 1), displayed almost invariable discharge (0.3 L/sec), conductivity (190 μScm^{-2}), and total hardness (39 ppm Ca^{2+}).

CONCLUSIONS
Our preliminary study suggest that the Sirijorda karst comprise a conduit- dominated, allogenic aquifer. Groundwater storage appears to be relatively minor, as most of the available fissure water is flushed out before flash floods reach peak discharge. Penetration distances for temperatures and for solutes appear longer than the conduit system. Further work will test the reproducibility of the reported observations and extend the studies to dye tracer experiments.

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SCALLOP DOMINANT DISCHARGE

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Abstract. The problem of scallop dominant discharge relative to seasonal flow variations and long-term duration is investigated. Hydrochemical process studies in a cave conduit suggest that the highest rates of wall retreat occur at flood discharges of a duration of 20 % or less. Scallop dominant discharges determined by cave diving and combined with up to 50 years' hydrograph records, reveal that the scallop dominant discharge occur at the highest discharges of 2-15% duration. There appears to be a linear relationship between the scallop dominant discharge and drainage area, which raises the prospect of reconstructing not only paleo-discharge, but also paleo-watersheds from fossil scalloped conduits.

Introduction.

There is a well established relationship between morphometric properties of scallops, the flow direction and the velocity of the corrosive fluid that formed them (Curl 1974, Blumberg and Curl 1974, Lauritzen 1981, 1986a). This relationship has wide implications for paleocurrent reconstructions (Pizarowicz and Maslyn 1981, Lauritzen 1982, 1986b). Scallops usually form unimodal, well sorted log- normal distributions (Lauritzen 1982), and therefore allude to a constant rate of flow, or that one discharge is dominant. However, in nature, the discharges in springs and in cave conduits varies with the recharge of the aquifer. We should expect scallops to represent the discharges that provide the most effective rates of wall retreat. Corrosion rates are generally proportional with flow rate (Dreybrodt 1988), and hence the highest discharges should intuitively become the "Scallop Dominant Discharges".

Duration of flow and corrosion.

Continuous runoff data and systematic hydrochemical data have been gathered from the natural laboratory (Jordtulla) of the underground outlet of Lake Glomdal, Northern Norway (see detailed description in Lauritzen et al. 1985). Solute concentrations were measured practically simultaneously in the inlet and outlet of the 580 m long phreatic system. Sufficient data were gathered to estimate a transfer function between discharge and rate of wall retreat. The transfer function used was of the type :

$$R_Q = R_{max}(1-Q^k) \qquad (1)$$

Where k and R_{max} was estimated to -0.52 +/- 0.31 and 1.76 (+4.65/-1.27)*E-6 mMoles cm^{-2} sec^{-1}, respectively. The rate estimate is done by assuming the cave's inner surface as a straight, smooth cylinder.

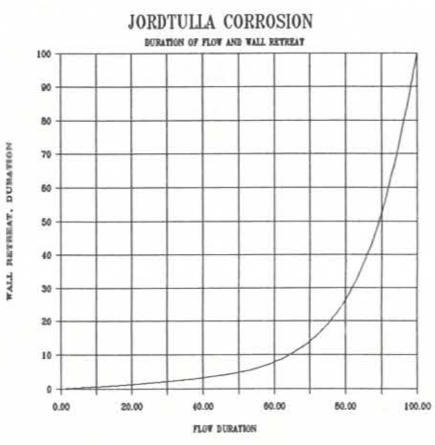

Figure 1. Relative duration of flow rate and rate of wall retreat for two years in the Jordtulla system, North Norway.

The "true" estimate of wall retreat rates are dependent of an accurate estimate of the reactive surface area of the cave walls. This is a fractal problem and may be solved as such. Measurements in dry phreatic cave galleries reveal the ratios between $A(\delta=10^0\ cm)/A(\delta=10^3\ cm)$ for marble caves to be in the range of 2 -10. The fractal dimension of conduit surface areas are in the range of D = 1.07 -1.25 (Lauritzen in prep). However, when discussing the duration of rates relative to the duration of flow, the surface area becomes a constant which we do not need to know.

In Figure 1 the normalized duration of flow vic. duration of wall retreat rates are shown for two years of observations in Jordtulla. From the graph we may infer that 80 % of the solutional work is performed by the highest discharges which occur only at less than 25 % of the time.

Hence, wall retreat rates appear more effective at the higher than the lower flow regimes, and hence we should expect scallops to reflect the highest rates of flow.

Direct estimates of scallop dominant discharge.

We may now turn to catchments which drain through phreatic caves and try to estimate scallop discharges from in situ measurements and compare them with long-term hydrograph records. The requirements for this analysis is:

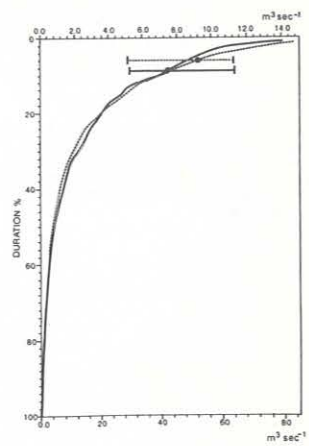

Figure 2. Long-term flow duration for two allogenic springs in Norway. Scallop dominant discharge as determined by scallop morphometry and cave diving is shown. The scallops correspond to the 2- 15 % upper flow regimes.

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1) The catchments must have been stable for a time long enough to allow equilibrium between scallop size and the existing flow regimes. A scallop relief of say, 2 cm would then require some 20 -200 years to be completely replaced by another pattern, assuming a maximum attainable rate of wall retreat of 1.0- 0.1 mm/a.

2) Hydrological records should cover as long time as possible, preferably 30 years or more.

3) All water from the catchment must drain through the spring, or the gauging station itself must be placed into the spring.

4) The spring must be accessible by divers and preferably consist of a single conduit with a sufficiently simple (circular or elliptical) geometry.

Fortunately, we have numerous water stage stations in Norway which have almost continuous discharge records from the 1930's and earlier, providing excellent data bases for duration curves (*Directorate of water Resources*). Moreover, at least 4 of them represent rivers which drain through allogenic cave systems, of which 2 have been investigated so far. Scallop discharges represent the upper 2- 15 % of duration for them, Figure 2. A third conduit, Fosshølet, which have only two year's of discharge records, gave the same result. Direct morphometry of scallops in active springs do therefore support the process observations, that a scallop pattern represent the upper 2 - 15 % of flow.

Drainage Area and Scallop Dominant Discharge.

Scallop dominant discharge and the corresponding drainage area of four scalloped, active phreatic conduits are shown in Table I and plotted in Figure 3.

Table I
Scallop Dominant Discharge and Drainage Area.

Location	Drainage Area, km^2	Discharge, m^3s^{-1}
Fosshølet	2	0.38
Jordtulla	27.7 (160)	26.2
Landbru	59.8	8.6
Plura	342	42.8

The yet limited data set suggests a linear relationship between scallop dominant discharge and the corresponding drainage area.

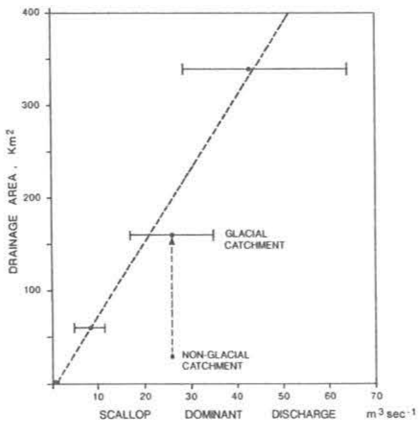

Figure 3. Scallop dominant discharge vic. catchment area for 4 active phreatic conduits in Norway. The Jordtulla data (see Table I) are shown for non-glacial and glacial catchments. The scallops represent periods of glacial influence in the system. The remainder of the data are from non-glacierised catchments.

The Jordtulla data are ambiguous for two reasons. First, from historical records, we know that the Jordtulla drainage area has changed dramatically during the last 30 -50 years because of retraction of the nearby Svartisen icefield. Second, the glacial drainage into the system was diverted by a tunnel in 1959. To-day, the extent of the glaciers are such that the tunnel would not affect the drainage area of Jordtulla, which therefore is in its "natural" state of an ice-free period, but the scallop distribution of the conduits, would then correspond to discharges that were affected by glacial drainage (Lauritzen et al. 1986). Correcting for this, the Jordtulla data fit well into the remainder of the data of Figure 3.

The apparent linear relationship suggests an area-specific scallop dominant discharge. Each of the areas of Figure 3 possess rather different specific mean runoff. The scallop data then suggest that long-term area-specific flood discharges may be regionally less variable than the corresponding mean specific runoff.

Provided that this trend can be verified or modified through more observations, we may have a powerful tool for reconstructing not only paleodischarge, but also paleo-watersheds from scalloped fossil conduit fragments. Please note that the data are from a rather restricted climatic region; it is therefore evident that future studies in other climatic zones would be extremely valuable.

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THE SEDIMENTOLOGY OF SIRIJORDA CAVE, NORDLAND, NORTHERN NORWAY

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Abstract Sirijorda cave is approximately 1400 m. long with a vertical range of 90 m. The cave is situated in a glacially sculptured valley. The cave has been the object for excavation, which has revealed an interesting biostratigraphy. It was therefore of interest to investigate other sedimentological facies in the cave, and to relate these to external conditions. The sediments were studied through sections, cores, paleomagnetism and other general sedimentological methods. Sirijorda cave exhibit a complicated mixture of facies: fluvial, backflooding/ stagnation, slumping, eolian, scree. Fluvial sequences are dominated by erosive hiatii; cut and fill structures are often as large as the passage itself, making lateral correlation difficult. Sediment structures in a side annex, with 25-30 degrees floor dip, are strongly disrupted by slumping. This phenomenon is not found in annexes/galleries with lower floor gradients.

Die Sedimentologie der Sirijorda Höhle, Nordland, Nord-Norwegen. Die Sirijorda Höhle ist ca. 1400 m lang und besitzt eine vertikale Höhe von 90 m. Die Höhle liegt in einem glazial geprägten Gelände. Ausgrabungen in der Höhle haben interessante biostratigrafische Ergebnisse ergeben, daher war es von interesse andere sedimentologische Facies zu untersuchen, und diese zu ausseren Bedingungen zu beziehen. Die Sedimente wurden an Hand von Sektionen, Kernen, Paleomagnetismus und andere generelle sedimentologische Methoden untersucht. Die Sirijorda Höhle zeigt eine Reihe von komplexen Faziesmixturen: Fluviale, Stagnation, Eolische, Gehängeschutt. Die fluviatilen Sequensen sind durch erosive Hiatii ausgezeichnet; die "cut and fill" Strukturen sind häufig so gross wie den Hölengang und erschweren daher die laterale Korrelation. Die sedimentstrukturen in einer seitliche Gallerie mit 25 bis 30 Grad Gefälle sind stark durch Rutshungen gestört. Rutschungen sind nicht in anderen Seiten Gallerie und annexen gefunden, die geringeres Gefälle aufweisen.

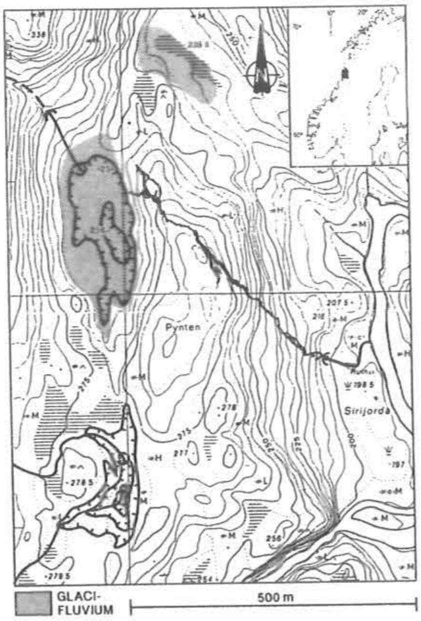

Figure 1: Location of the cave. Sirijorda is situated in Eiteråndalen south of Mosjøen, North Norway.

INTRODUCTION

The Sirijorda cave is situated in Nordland, northern Norway, (Fig. 1). Systematic excavations of a bone-baring talus deposit of the Moose Shaft (Figure 2) was performed in the years' 1985 -1988 (Lauritzen and Østbye, unpublished). A large amount of bones have been extracted; the oldest ^{14}C dating of bone so far is about 6,000 years B.P. It was of interest to investigate the total sedimentology of the cave system and try to correlate the deposits with surface events.

This paper consider the different sedimentological facies of the cave , which is found throughout the cave, and present tentative conclusions on the timing of deposition and relation to external conditions.

OBSERVATIONS

Distribution of erratic boulders

Erratic boulders ***(lag)*** seem to be a facies that can be found widely spread throughout the cave. The deposits display a wide range of grain sizes. We may hypothesize that the mean size of such clasts along the cave passage would decrease downstream of the points of injection. A sudden increase in size of allogenic clasts would then indicate the position of a paleoinlet. The measurements were done on the largest, rounded to subrounded erratic boulders, found in separate locations. The measures of boulders > 60cm are not as accurate as the others because there are less stones to measure, and the possibility of misinterpreting is greater.

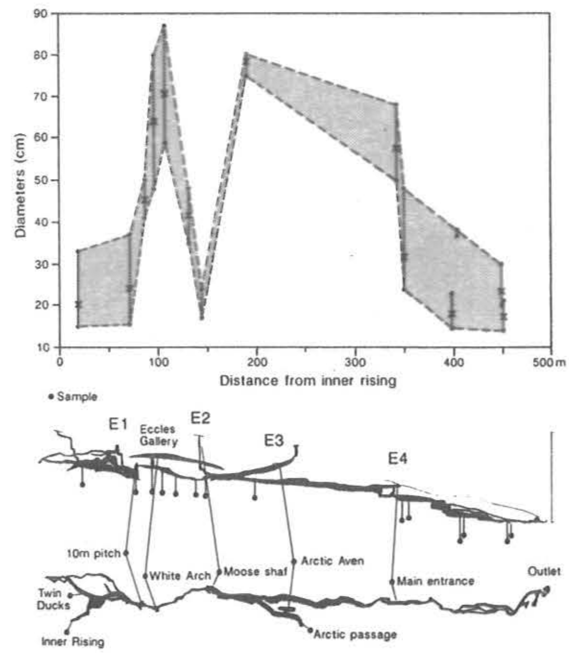

Figure 2: Top: Grain sizes of large, erratic boulders as a function of the horizontal distance within the cave.
Below: Names of places in Sirijorda cave. Survey from Faulkner (1980)

Cut and fill facies

Arctic Aven (Figure 2) contain a sediment deposit which display a complex history of erosion and deposition (Figure. 3). It is possible to separate five events of erosion and deposition (hiatii), where the grain size is changing from clay to gravel. Laterally, the fluvial/glasifluvial sand disappears further up Arctic passage and is replaced by a more or less laminated clay sediment and a diamictic sediment.

Other fluvial/glasifluvial sand facies

Fluvial sand facies are most common in the inner part of the cave, upstream of the 10 m pitch. Most frequently, the sands display horizontal lamina; cross lamination has been detected in one section at Twin Ducks (Figure 2). The cross laminations are of a coarser material and are deposited in a reversed direction (upstream).

Fluvial sand with cross laminations was also found, on a ledge on the top of the 10 m pitch (Figure 2). The cross laminations correspond to a downstream paleocurrent direction. The top level of the deposit can be traced through several erratic sand deposits which are still in place on ledges further upstream in the passage.

Stagnating facies and slump facies
The occurrence of laminated clay is restricted to the upper part of Arctic Passage. The clay strata display internal disturbances due to slumping. The slumping has also caused faulting and folding of the deposit; less disturbed sections is found where the slope of the cave floor is less than about 25 degrees. In some instances the clays are brecciated and deposited as clasts in a coarser complex of gravel and sand.

In Arctic Aven, it is possible to identify four 2-4 cm thick clay beds, which can be traced laterally for 2-2.5 m. They are separated by 1-3 cm thick layers of sand (Figure. 2); the deposit is truncated in both ends by erosion.

Eolian facies.
In the inner part of the cave, at Twin Ducks, there is a thin, dark brown, silty sediment without any internal structure. The sediment veneer is laterally very extensive and envelopes other sediments and rock surfaces. The deposit do not seem to have any distinct upper level of deposition, but it can be seen sticking to the cave walls, making horizontal lines and vermiculations. We therefore interpret this deposit as eolian; further investigations will reveal whether it is a chemical deposit or a corrosional residue.

Scree facies
The only location where scree material can be formed today is in the Moose Shaft, and such material has only been found here. The shaft is a vertical fissure with a vertical drop of 30 m from the surface. It continues as a large paragenetic gallery partially filled with scree and diamictic sediments. The section has a top layer of angular boulders, then a layer of soil, bones and blocks. In the soil layer and between the boulders there are literally tens of thousands of bones from moose, wolf, wolverine, goats, birds, rodents and amphibians. Except for scattered, recent casualties of starved rodents around in the cave, this is the only deposit known so far with a distinct biostratigraphy.

Clayey Diamicton
Underneath the scree layer of the Moose shaft there is a sharp contact to a clayey diamictic sediment with occasional sapprolithic boulders. The diamicton is more than 3 m thick and rests on the bedrock floor. The diamicton appears absolutely devoid of bones.

Just upstream of the Moose shaft is a large phreatic -or possibly paragenetic- gallery that is choked with sediment (White Arch Passage, Figure 2). The choke is located only a few meters away from the Moose shaft deposit, and further excavations may show whether they are continuous. The White Arch fill is post-dated by speleothem deposits.

TENTATIVE CONCLUSIONS
Erratic boulders:
Figure 2 shows the grain size distribution of large clasts along the cave. When considering the largest observed clast in each section, there is a main peak just downstream of the large ceiling shafts (E1) in the upstream part of the cave, and another peak at the Moose Shaft (E2). The clasts decrease in diameter downstream of the two paleoinlets. From the present data, neither Arctic Passage (E3) nor the lower entrance (E4) can be identified as paleoinlets for large clasts.

In detail, clasts with diameters > 40-50 cm disappear when the Moose Shaft is approached and reappear after the Moose Shaft entrance, so there must have been a new input from somewhere. The Elk shaft would have been an obvious choice, but we must also consider the possibility of a connection from White Arch trough to the bottom of Moose shaft. As discussed above, sediments and close location could hint at a connection. In this case we need only to infer one paleoinput for the clasts; the high level galleries (Eccles Gallery) at the very back of the cave. This is fully compatible with the general topographic setting of the karst system.

In order to move these large boulders (up to 1m in diam.) we must infer extremely high discharges at least over shorter time intervals. One obvious condition for such a hydraulic facies is the "flushing lavatory" facies that are associated with deglaciations (Ford, 1979).

History of Deposition:
Arctic passage:
The magnitude of erosion as displayed in the sections in Arctic Aven is often of the same magnitude as the passage itself. Sediment deposits are therefore rarely extensive, making lateral correlation difficult. However, large changes in the hydrological regime must have ocurred, from the depositional environment of clay (in stagnant water), to the deposition of gravel accompanied with erosion in older deposits.

Higher up in the passage the typical fluvial sediment disappears and is replaced by more or less disturbed laminated clay and gravel layers. The extensive slumping is also evident from the surface of the deposits, which display depressions and miniature landslides.
The laminated clay must have been deposited when the cave was filled with water; the slumping occurred some time after a fall in the water table, when the water logged deposits were exposed to air. Later, seepage water could possibly trigger slumping.

The sediments were probably deposited through a passage extending southwards behind Arctic Aven, now filled with sediments. The proximity of glaciers on the outside would provide an on and off signal of damming effects (clay) and increased hydraulic gradients (cut and fill and deposition of sand and gravel). Such oscillations could well exist within one cycle of deglaciation.

So far, we have no chronological control of the sedimentation (Paleomagnetic measurements are in progress). We may tentatively associate the sediment sequences in Arctic passage with the last glacial cycle, possibly the last deglaciation.

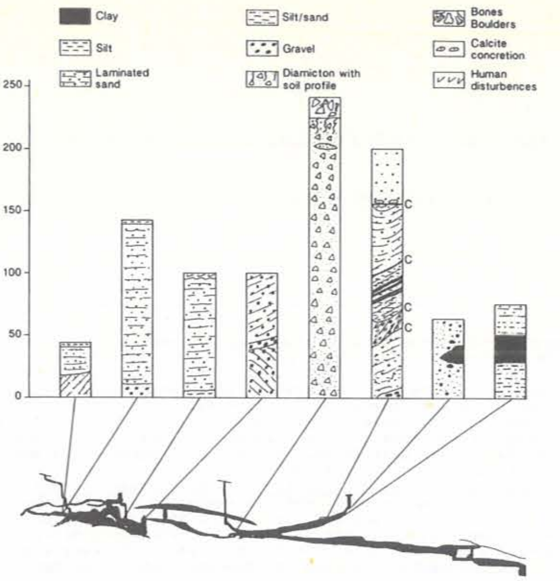

Figure 3: Sediment sections in different locations of the cave. The four first columns represent the inner parts of the cave, the fifth is the diamictic deposit in The Moose Shaft, and the last three are from Arctic Passage.

Moose shaft:
So far, the bone material in the talus deposit have given Holocene dates. Since we have a sharp, possibly erosional boundary towards the clayey diamicton, which is devoid of bones, we tend to believe that the Moose Shaft did not exist as an open shaft which could trap contemporary fauna when the diamicton was deposited. The shaft shows uphill scalloping, demonstrating that water flow was reversed up through the shaft at some time. This corresponds well with a paragenetic enlargement of the passage above the diamicton. The high clay content and fabric suggests that the diamicton is an injected till, and the sapprolithic state of the clasts within the diamicton suggests a considerable age.

We may therefore suggest that White Arch passage and the bottom of Moose shaft was initially continuous with no surface connection. The diamicton was then injected from a glacier (either from upstream or through Arctic Passage). The paragenesis and subsequent reversal of flow may have opened the incipient Moose Shaft under ice- contact conditions. If this sequence took place during the last glaciation, it would explain the restricted range of Holocene dates we have obtained from the bone deposit.

Inner part of cave (inside the 10m pitch):
One section of the fluvial sands in Twin Ducks passage display reversed cross laminations. This could indicate a gross reversal of flow, or a local eddy. A gross reversal of flow would be compatible with ice contact, where englacial hydraulic gradients were superimposed onto the cave conduits (Lauritzen 1984). The reversed scallops in the Moose shaft supports this view.

The top level of several sand deposits allude to synchronous deposition under a common watertable. The level of this watertable would most likely be controlled by surface conditions, i.e. ice contact.

The brown, silty sediment covering the other sediments in Twin Ducks strongly suggest an eolian origin. The thickness increases towards Eccles gallery, making this a possible point of input for the material. Further studies (SEM, XRD, etc.) are in progress.

In general we can say there are much more sediments in the upstream parts of the cave than elsewhere. This may be due to a proximity to the source (the sediment-filled depression above the cave) or that this part of the cave has been less susceptible to flushing events.

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VLF METHOD FOR SURVEYING CAVES

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After numerical modeling VLF measurements were made in an open pit of limestone over a known cave and its environment. The applicability of the method was tested by drillings. It can be stated that applicability depends on

- the angle between the structural and the transmitter direction
- the geological situation determined by the depth, height and width of the cave and the apparent resistivity contrast between the cave and its environment.

VLF-Methode zur Höhlenerforschung

Nach numerischer Modellierung haben wir VLF-Messungen über einer bekannten Höhle und ihrer unmittelbaren Nähe in einer Tageskalksteingrube durchgeführt. Zur Kontrollierung der Anwendbarkeit der Methode wurden Bohrungen abgeteuft. Die Anwendbarkeit der Methode hängt von

- der relativen Position der Struktur und der Richtung des Senders
- der gegebenen geologischen Umgebung, die durch die Tiefe unter der Oberfläche, die Breite und die Höhe der Höhle, sowie durch den spezifischen Widerstandskontrast zwischen der Höhle und ihrer unmittelbaren Umgebung bestimmt wird, ab.

1. INTRODUCTION

The increasing need for protecting our environment has led to the application of geophysical methods. The given problem determines what geophysical methods are suggested to solve it. Cave surveying requires various methods depending upon the geological situation. The applicability of the VLF (very low frequency) electromagnetic method for surveying caves is analyzed in this paper. After numerical modeling VLF measurements were made in an open pit of limestone at the surface over a known cave and its environment. The results of numerical modeling have to be taken into consideration for practical use.

2. THE ESSENCE OF THE VLF METHOD

It is a passive method in the sense that a distant power source - not under the control of the person making measurements - is used as a transmitter. This transmitter station is a vertical electric dipol or monopol carrying alternating current. Transmitters are operating in the 15-25 KHz frequency range. The electromagnetic energy is propagated between the earth's surface and the lower ionosphere (sky wave), and along the earth's surface (ground wave). In the place of the measurement this primary field can be treated as plane wave because of the large distance from the transmitter. The primary magnetic field lines from the transmitter are at right angles to the direction of the station. The primary field penetrates into the ground and if there are inhomogeneities within the penetration depth there will be secondary fields radiating from them. For this reason the superposition of the primary and secondary fields can be measured at the surface. Because of the penetration the electric field component of radial direction (E_R) can be detected. The higher frequency is used the shallower the penetration depth will be (skin effect). A commercial instrument Geonics EM-16 registers the secondary vertical magnetic field component (H_z) to the horizontal azimuthal magnetic field component (H_φ) and Geonics EM-16R measures the apparent resistivity (ϱ_a) from the ratio of the radial horizontal electric field component (E_R) to the azimuthal magnetic field component (H_φ) and their phase angle (φ_{E_R,H_φ}) as well. The earlier field studies suggested that the VLF method can be used as a fast not too expensive measurement for gaining geologic information or for geologic mapping from the depth not greater than the penetration of the electromagnetic wave [1]. It can neither be used if there is a transmission line in or close to the exploration area (which can be treated as a "secondary" transmitter), nor in the case of surface or buried metal objects near the surface (their effects are stronger than the geologic response).
At the same time VLF measured data are affected by the topography of the exploration area and the topographical effect appears first of all in H_z response.

3. VLF NUMERICAL MODELING FOR CAVE SURVEYING

It is obvious that a cave has a three-dimensional extension. However, if a cave has a structural direction which coincides with its length the cave can be approximated by a two-dimensional geologic structure. The longitudinal direction of the cave is called the strike direction. In every two-dimensional medium any linearly polarized wave independent of its angle of incidence at the surface can be decomposed into two waves having purely E or purely H polarization. The most important equation governing this electromagnetic phenomenon is the time independent Helmholtz's partial differential equation which can be derived from the Maxwell's equations [2]. For example E polarization Helmholtz's equation has the following form (similar to H polarization):

$$\frac{\partial^2 E_y}{\partial x^2} + \frac{\partial^2 E_y}{\partial z^2} = k^2 E_y$$

where y denotes the structural strike direction and k denotes the wavenumber. In this case E_y, H_x, H_z components exist in contrast with the H polarization case where the components are H_y, E_x, E_z. Discretization of (1) over a rectangular net covering the two-dimensional structure containing the cave results in a linear finite difference equation system for both polarizations. Although the two polarizations have similar forms of Helmholtz's equation, the finite difference equations are different because the E polarization differs from H polarization in boundary conditions. In our numerical modeling the number of complex unknowns was 2000 for each polarization because the grid used consisted of 40 columns and 50 rows.
The linear system was solved with iterative method (successive overrelaxation). The questions to be answered by the numerical modeling for VLF are as follows:

- which polarization will bring a better response to the same geologic situation,
- what effect does the apparent resistivity contrast between the cave and its environment have,
- what is the depth from which a cave can be located at the surface.

Our numerical experience is summarized in the first four figures. Figure 1. illustrates VLF resistivity responses over caves which are weak conductors for H polarization. In this case the electric field (the direction of the VLF transmitter) is at right angles to the strike direction of the cave which has a height of 5 m and a width of 20 m and the cave is situated in different depth. Figure 3. shows VLF resistivity responses over strong and weak conductors for E polarization. In contrast to the H polarization the same caves with low conductivity do not show effect. If the conductivity of the cave is much higher than that of its environment the computed apparent resistivity does not result in such strong response which was experienced in the case of H polarization (Figure 2.). Using a VLF resistivity equipment for surveying caves the greatest anomaly can be registered if the cave is at right angles to the direction of the transmitter.

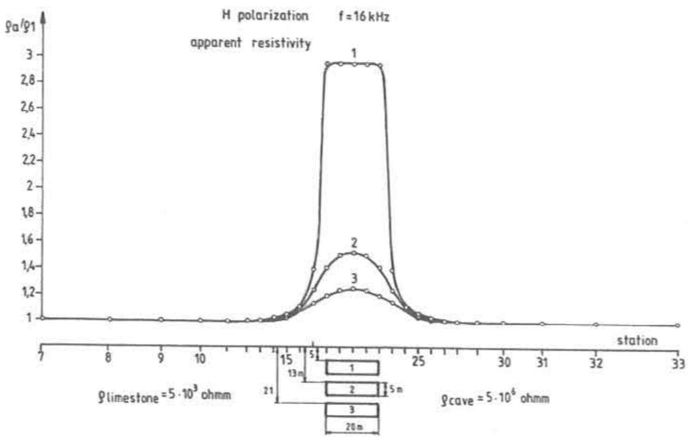

Figure 1. VLF resistivity responses for H polarization over a cave of low conductivity situated in different depths

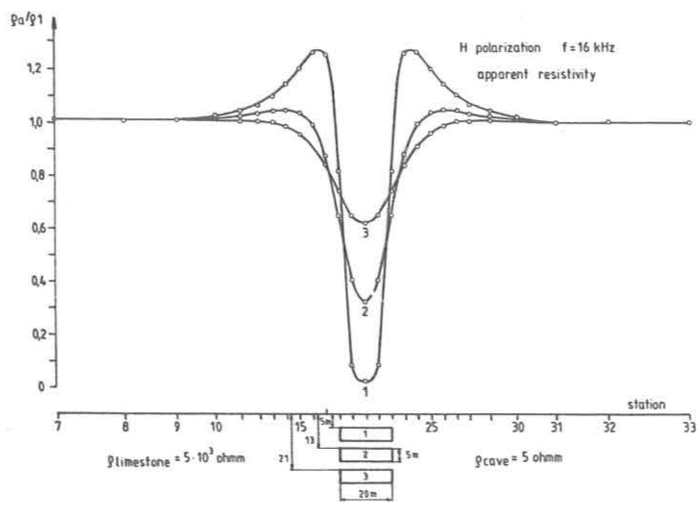

Figure 2. VLF resistivity responses for H polarization over a cave of high conductivity situated in different depths

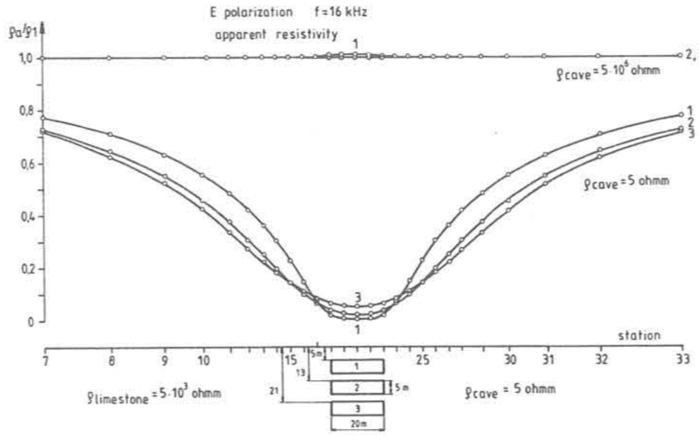

Figure 3. VLF resistivity responses for E polarization over a cave of low and over a cave of high conductivity in different depths

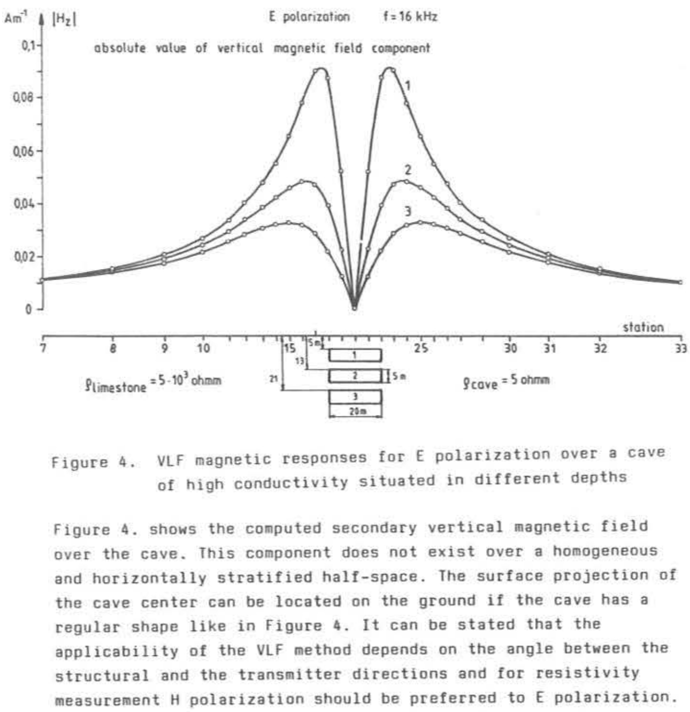

Figure 4. VLF magnetic responses for E polarization over a cave of high conductivity situated in different depths

Figure 4. shows the computed secondary vertical magnetic field over the cave. This component does not exist over a homogeneous and horizontally stratified half-space. The surface projection of the cave center can be located on the ground if the cave has a regular shape like in Figure 4. It can be stated that the applicability of the VLF method depends on the angle between the structural and the transmitter directions and for resistivity measurement H polarization should be preferred to E polarization. At the same time the more perpendicular the strike to the transmitter direction is the less H_z response can be expected.

4. A CASE HISTORY

There is an open pit of limestone not far from Aggtelek, Hungary. The hill is called Esztramos. In the course of mining activity caves, holes, slits can be found and may simultaneously be destroyed. The cave named after prof. Földvári is close to the exploration area. There was a little cave (with a length 15 m, a width of 10 m, a height of 2 m and its distance from the surface is 13 m.

The question originating from the Programoffice belonging to the Ministry of Environmentprotection and Water Economics (in the frame of G-10 pronram) was the following: has the 1/1988 cave any continuation or are there any other caves in the exploration area [5]. We tried to solve the problem using VLF EM 16/EM 16R. H_z component could not be measured because of pylons and metal objects. Figure 5. shows the VLF apparent resistivity map over the 1/1988. cave. In order to get H polarization case the transmitter used by us was GBR (Rugby, England). The VLF apparent resistivity response over the cave is greater than anywhere (the cave did not contain clay or water, it can be treated as non-conductor, it is in agreement with our numerical modeling, see Figure 1.) The maximum and minimum zones were drilled (F1,F2,...,F10 see Figure 5.), some of them crossed holes, but there is no connected cave near the surface within the depth of 12 m. Radio frequency experience gained by us over known caves showed that there is an indirect relationship between the measured components and caves [3], [4]: the fault zone along which the cave formed can be located instead of having a direct effect of the cave.

5. RECOMMENDATION FOR FUTURE WORK

In order to get more information about the structural direction or directions the measurement of the electromagnetic fields of other VLF stations can be suggested. They are as follows: UMS (Moscow, U.S.S.R.), FUO (Bordeaux, France), NAA (Cutler, U.S.A.), JXZ (Helgeland, Norway). The frequency range of this kind of measurement can be enlarged as well [1]. In this manner the exploration (or penetration) depth can be controlled. This is only one geophysical method and it can be completed by other geophysical methods like magnetic surveying, gravitational method, direct current electrical methods with different electrode arrangements, reflection and refraction method of seismic prospecting. It is obvious from the above that cave surveying is a compleceted problem. Taking into consideration both all geological information and the interpretation of the geophysical measurements we can make progress in cave surveying.

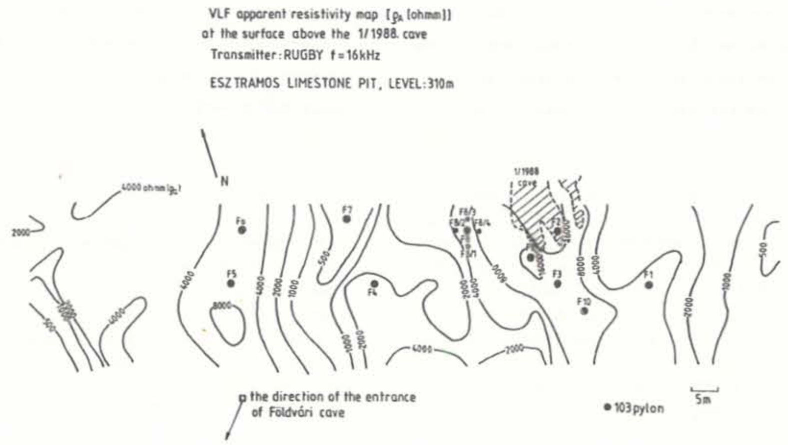

Figure 5. VLF resistivity map over a cave

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EXPERIMENTS IN TRACING KARST UNDERGROUND WATERS WITH BROMINE USING NEUTRON ACTIVATION ANALYSIS

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Bromine was used as water tracer and it was quantitatively determined by means of the instrumental neutron activation analysis. 20 ml of water from each sample were evaporated in cups maid by foloed thin (about 10 microns) aluminum foil. Then the cups were further folded to form small samples for irradiation in a nuclear reactor. After an appropriate cooling time the samples were measured on a semiconductor gamma-ray spectrometer without any chemical or other preparation. For each sample four bromine and one gallium gamma-lines were recorded for further computer processing. Gallium, being uniformly mixed in aluminum served as an internal standart for the neutron flux. An experiment was carried out in a Bulgarian cave and conclusions were made about the movement of the water in that cave.

Our group, united around the speleological club "Akademic", Sofia has beeng developing during the recent years water tracing in karst regions using quantitative determination of the tracers by means of neutron activation analysis [1] The advantages and difficulties of this method as well as it's area of application are discussed elsewhere and we will not discusse them now. We give the results of an experiment, carried out in a Bulgarian cave putting an emphacise on some developments of the methods.

A cave river was traced using KBr in amount about 4-5 kg for a flow of several tens of liters per second. At several points along the stream samples were collected each amounting to 180 ml. The time intervals varied from 1/2 to 1 hour. About 250 samples totally were collected and brought to the laboratory. Then from each sample 20 ml. were evaporated in small cup made of folded aluminium foil 15 μm thick which original dimensions were 8x7 cm^2.

The evaporation was performed in laboratory driers at temperatures below the boiling point of the water. It took usually 6 to 10 hours. Along with the samples standard samples with diffent concentrations were prepared by adding appropriate amount of KBr into distilled water.

The foil with the dry remnant on it was folded further to forme a specimen 1x2 cm^2 and 1,5 mm thick. Up to 60 such specimens were sealed in a polythene penal and put into the nuclear reactor for irradiation during 6 hours at a thermal neutron flux of 5.10^{12} $n/cm^2.sec$. After 3 days cooling the so called instrumental neutron activation analysis was performed. The γ-ray spectrum of each specimen was taken without any preliminary chemical or other treatment. We used a high-resolution and high efficiency semiconductor γ-ray spectrometer. Five minutes were enough to obtain good statistical accuracy- the standart deviation beeing equal to 5 % for the lowest bromide concentrations measured and equal to 0,6 % for the highest concentrations. We summed the intensities of the four of the most intensive γ-lines of bromine (with energies from 554 to 828 KeV) and also the intensities of two lines of Ga^{72} with energies 630 and 834 KeV. Galium contaminates in small amounts aluminium, being chemically analogous with it. This fact gives us a chanse to use it as internal standard to monitor for the neutron fluence that has been irradiating each specimen. Our Al-foils weighted around 240 mg. The half life of Ga^{72} is 14,1 hours and of Br^{82} -35,5 hours. After 3 days of cooling we obtain for 5 minutes for the sum of the two Ga γ-lines 12000 counts $^+_-$ 1,5 %. For the bromine we have from 4000 to 100000 counts. These figures show that Ga standard can be utilized in our case. We could not extract all the advantages out of it, because we did not know the exact weight of each Al-cup, but our measurements show that their weights differ within 4 % and the Ga intensities differ within 11%. This result indicates that an ununiformity of the neutron flux field exists within several percents. The proper use of Ga internal standard could reduce an additional sprread of the results, due to that ununiformity.

All the results were obtained using least squares fitting programs. Using IBM-PC-type computer it takes less than 5 minutes to fit all 6 lines for a specimen, which permits to do simultaniously measurement and fitting.

The results, shown at the fig.1 point out how the tracers passes through two measuring points. Along y-axis we have pointed the concentration of KBr in the water at given point. The squares are for a spring, appearing beneath a rock, and the crosses are for the main river, coming out through the cave entrance. The specimens were not thrown away after the measurements, but saved althow rather carelesly: they were jammed into a lead container and left to themselves. Four years later the same specimens were irradiated in the reactor again and all the measuring and fitting procedure was repeated. Fig.2 shows the results. It deals with the spring under the rock. The solid line is the same as in fig.1, left, and the triangles are the results of the latest measurements Two

fig.1.

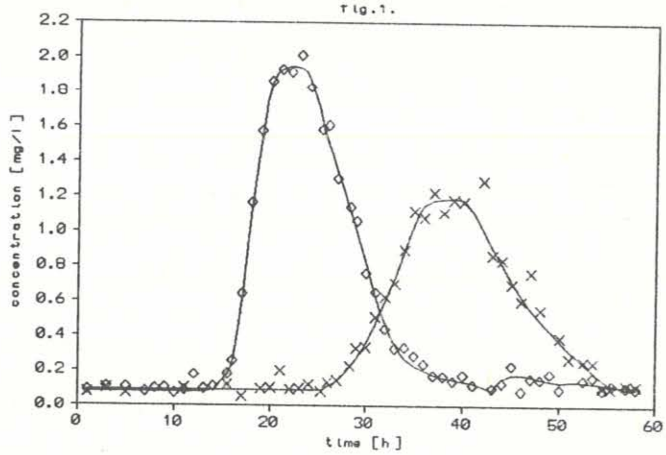
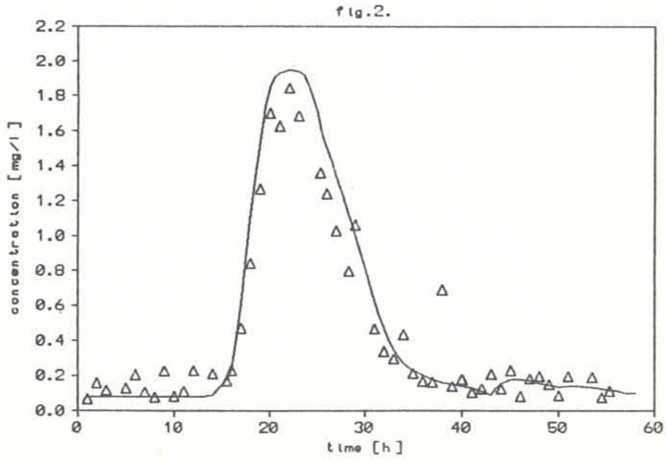


fig.2.



conclusions can be made:

1. After 4 years the specimen still keep the information.

2. Additional measures must be taken for proper storage of the specimen; otherwise some of the bromide is lost and deposited on other specimens.

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CARE OF ASTHMATIC CHILDREN IN THE HOSPITAL CAVE IN TAPOLCA

MUCSI, János - HORVATH, Tibor

We have dealt with treatment of chronic obstructive pulmonary diseases in children since 1983. Our intention was to educate the children suffering from a psychosomatic disease with a strong social handicapp, help them to become healthy adults. Now our group consists of 38 patients.

Their therapy is a complex prophylactic-rehabilitating care programme including the following:

1. elimination of allergens that are responsible for the hypersensitivity of children
2. correct administration of prophylactic drugs
3. physical therapy /kinesitherapy and sport activities/
4. climatotherapy
5. psychosociotherapy

The regular programme: on Tuesdays they perform complex activity in the cave utilizing its special climatic condition. This programme involves exercising of breathing rhythm, expiration and relaxation training, vertebral- and chest wall correction gymnastics, etc. all of these in playful form. On Saturdays they do swimming.

In every summer they take part in a summer camp in the mountains. We are in close connection with their family and school, so we can control all of moments of their private life.

They produce a substancial improvement. Their clinical status, general condition, physical and psychic tolerance are improving, while the number of days spending in hospital or absent from school as well as the request for medicines are decreasing.

Accordingly, this is a complex programme for influencing their way of life. The cave is a very important space in this activity, its special microclimate improves the effect of several non-specific respiratory rehabilitation method, what is more, it is a very strong positive helping us in the psychosomatic control of these very problematic patients.

Ärztliche Betreuung der an Asthma leidenden Kinder im Krankenhaus-Höhle von Tapolca
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Wir beschäftigen uns seit dem Jahre 1983 mit an obstructive chronische Atmungsorgane Kranken Kindern. Unser Ziel war, dass wir von den psychosozial und physikalisch geschädigten Kindern gesunde Erwachsenen erziechen können. Unsere Gruppe steht von 38 Personnen zusammen.

Wir möchten eine profilaktische Therapie fortsetzen, die die Folgenden in sich fassen sollen:

1. Die Elimination deren Allergenen, daran die Kinder empfindlich sind.
2. Richtige Betreuung von profilaktischen Medikamenten.
3. Physische Therapie /Bewegungstherapie und Sporttätigkeit/
4. Klimatherapie
5. Psychosoziale Therapie

Wir treffen mit den Kindern wöchentlich zweimal. Am Dienstag leisten wir Atmungsübungen im Höhlenklima. Die asthmatischen Kinder erlernen leibverbessernden Übungen und an Blasmusikinstrumenten zu spielen. Je am Samstag werden sie schwimmen mitgebracht.

Wir sind mit den Eltern und den Schulen in einem engen Kontakt und kontrollieren wir die Sporttätigkeit und das häusliche Verhalten von Kindern.

Die Mitglieder der Gruppe nehmen im Sommer an einem zweiwöchentlichen Lager unter Bergen teil. Sie bekommen eine erhebliche physische Belastung, verschaffen sich Selbstbeherrschung und gewöhnen sie an den gesunden Rhytmus des menschlichen Lebens.

Unsere Kinder haben nur einige Tage im Krankenhaus verbracht. Sie blieben nicht so oft von der Schule fern, wie es früher war. Sie verbrauchen weniger Medikamenten.

Wir sind der Meinung, dass eine Grotte für die Betreuung der asthmatischen Kinder ein optimaler Ort ist. Die Heilwirksamkeit seines Klimas kann die Wirkung der konventionellen Behandlung der chronischen an der Atmungsorgane Krankheiten zu verbessern.

The number of chronic aspecific respiratory diseases shows a marked increase. There is the same tendency in childhood. Only the close unity of the prophylaxis, treatment and rehabilitation can be successful on a fight against these psychosomatic diseases.

There is a curative cave under the Municipal Hospital of Tapolca. We have dealt with treatment of chronic obstructive pulmonary diseases for 16 years. We had collected the asthmatic children in Tapolca and in the neighbourhood of the town 6 years ago assuring them the medical treatment since then.

Our intention was educate the children suffering from psychosomatic disease with a strong handicap, help them to become healthy adults within the bounds of possibility.

Our team involved 3 doctors, 1 gymnastic trainer and 2 teachers attends to the children. Now our group consists of 38 patients.

Their therapy is a complex prophylactic-rehabilitating care programme including the following:

1. elimination of allergens that are responsible for the hypersensitivity of children.
2. correct administration of prophylactic drugs
3. physical therapy /kinesitherapy and sport activities/
4. climatotherapy
5. psychosociotherapy

We keep in permanent touch with the families. We guarantee them the satisfying medical background and treatment as well as help them to form a normal relation between the children and the parents.

We are in close connection with the schools. The teachers and we discuss all of the problems connected with the children. Our aim is - among others - to avoid their release from physical education as well as to ensure the regular, intensive and adequat physical training to them.

Once a week our asthmatic children perform complex activity in the cave utilizing its special climatic condition. This programme involves exercising of breathing rhythm, expiration and relaxation training, vertebral and chest wall correction gymnastics, etc. all of these in playful form.

Once a week they do swimming. It is of importance to pick up the correct rhythm of breathing and the swimming helps on development of the chest wall and the breathing muscles. The fresh, humid and clear air above the water surface is similar to the air in the cave and useful for the purifying of the respiratory tracts.

Every summer they take part in a summer camp in the mountains.The woodland air, walking tours and the intensive sporting programme improve their physical condition. Furthermore the camping can enhance the team spirit and decrease the sense of illness.

Before the beginning of our care programme every child was in hospital on the average once a year. In the last six years altogether four children spent a few days in hospital.

Before 1983 16 children took regularly bronchodilatators, antibiotics or corticosteroids besides protective medicines. 9 children received corticosteroid administration. And now 6 children take regularly bronchoprotective drugs and neither of them took habitually bronchodilatators and none of them received any corticosteroid in the case of the last six years.

The incidence rate and the term of the absence from school decreased significantly. The average in the earlier years was 17,5 days a year individually and now it is just 7,3 days for a child.

Their physical condition improved remarkably. Before the taking care the half of the children was exempted from physical education and now none of them, in fact, 12 are registered players.

Considerable improvement can be observed in their psychical condition as well as in the development of the familiar and school relations. Their sense of illness decreased and the social integration performed in perfect order.

Our observations show that a complex prophylactic-rehabilitating programme can significantly improve the condition of asthmatic children. The cave is the optimum space in this activity, its special microclimate improves the effect of several non-specific respiratory rehabilitation method, what is more, it is a very strong positive helping us in the psychosomatic control of these very problematic patients.

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UNDERWATER EXPLORATION OF DRAGON'S BREATH LAKE (1987)

MAXWELL, Charles

In July 1986 a team of speleologists from the South African Speleological Association (SASA) discovered a large underground lake in the dolomite region of northern Namibia (approximately 19,0 deg. S. and 17,5 deg. E.)

The lake was reached via a number of pitches with a final 20 metre drop into the middle of the lake. The surface of the lake was surveyed and found to have an area of 1,9 hectares (18984 square metres). According to the Guinness Book of Records, this is the largest underground lake in the world.

The cave was named "Drachenhauchloch" or "Dragonsbreath Cave" due to the fact that warm air flowed from the cave entrance.

As no cave diving equipment was available during the initial expedition and in view of the remoteness of the cave site, no diving was done during 1986. In 1987 a team of 40 cave divers and speleologists returned to Dragonsbreath to explore and survey the lake underwater. The cave diving team was lead by the author. The problems encountered in getting the diving and safety equipment to the lake and details of the underwater survey methods and results are discussed in this paper.

L'EXPLORATION DE LA GROTTE DE L'HALEINE DU DRAGON

En juillet 1986 des spéléologistes de l'Association Spéléologique de l'Afrique du Sud ont trouvé un grand lac souterrain parmi la région dolomitique du nord de Namibia (app. 19.0 S., 17.5 E.).

On a atteindu le lac par quelques degrés avec une dernière 20 metre chute dans le milieu d'un lac. On a arpenté l'étendue du lac, et s'est assuré une étendu de 1,8984 hectares. Selon le Guinness Livre des Records, c'est le plus grand lac souterrain de la monde.

On a appelé la grotte "Dragons Breath" ou "Drachenhauchloch" ou "de l'Haleine du Dragon" parce que de l'haleine chaude a soufflé de l'entrée de la grotte.

Parce qu'il n'y avait pas de l'équipage de plongeur spéléologique pendant la pemière expédition, et parce que la situation de la grotte est éloignée, on n'a pas plongé pendant 1986. En 1987 40 plongeurs spéléologiques ont revenus à la grotte de l'Haleine du Drogon pour l'exploration et l'arpentage du lac sous l'eau. L'auteur a dirigé l'expedition. On discute les problèmes rencontrées pendant le transport des équipages des plongeurs et de la sûreté au lac, et les détails des méthodes de l'arpentage sous l'eau, et les résultats, dans cette étude.

1. INTRODUCTION

In July 1986 a team of speleologists from the South African Speleological Association (SASA) discovered a large underground lake in the dolomite region of northern Namibia (approximately 19,0 deg. S. and 17,5 deg. E.). At the entrance to the cave a strong, humid updraft could be felt, caused by the immense mass of warm water and air that lay silently beneath the ground. The cave was therefore named "Drachenhauchloch" or "Dragon's Breath Lake".

The water was reached via a number of pitches with a final 20 metre drop, through a fissure in the roof of a huge chamber, into the middle of the lake, 60 metres below ground level. The entrance and upper levels of the cave consisted of dolomite breccia and chert fragments while the final pitch and main chamber occurred in massive dolomite. The surface of the lake was surveyed and found to be just over 200 metres long and between 80 and 105 metres wide, having an area of 1,9 hectares (18984 square metres) (1).

According to the Guinness Book of Records, the largest known underground lake in the world prior to 1986 was the Lost Lake of Tennessee, with a surface area of 1,8 hectares (2). The 1986 survey therefore suggested that Dragon's Breath Lake is the new world record holder in this category. As no cave diving equipment was available during the initial expedition and in view of the remoteness of the cave site, no diving was performed in the lake during 1986. However, the slope of the walls at water level indicated that the lake was far larger underwater and it was therefore decided that an underwater survey should be conducted.

The Author, in his capacity as Cave Diving Officer for SASA, was responsible for leading a diving team to explore and survey the lake underwater in July of the following year. Besides the exploration and survey of the lake underwater, the other objectives of the 1987 expedition were to ascertain whether the cave contained any cave dwelling aquatic fauna, to estimate the volume of water, to investigate the underwater geology, to find any indication of previous water level fluctuations, to investigate the cave's potential for tourism and to locate a suitable place for the land owner to sink a bore hole for irrigation purposes. A documentary film was also to be made of the expedition.

2. PREPARATION

A team of experienced divers was picked and given training in specific caving techniques, specialised equipment was collected, a quick and efficient method of underwater cave survey was devised and sponsors were sought. The traditional method of cave survey, using a survey tape for distance measurement, was dispensed with and a special combination flow meter, compass and depth gauge swim board, of a similar design to that commonly used in scuba competitions, was built and calibrated (3).

The possible existence of further chambers, either water-filled or with air spaces, leading off from the main lake, was added incentive to explore the cave in a methodical manner. As the diving work would be predominantly deep and would be done in total darkness, each diver needed helmet-mounted diving lights. All dives would be done on life lines, using specially constructed light-weight diving reels. A team of film makers, led by Swiss speleologist Gerald Favre, was invited to make a documentary television film of the expedition. While the diving plans were being formulated, the non-diving speleologists were

DRAWINGS OF DRAGON'S BREATH LAKE

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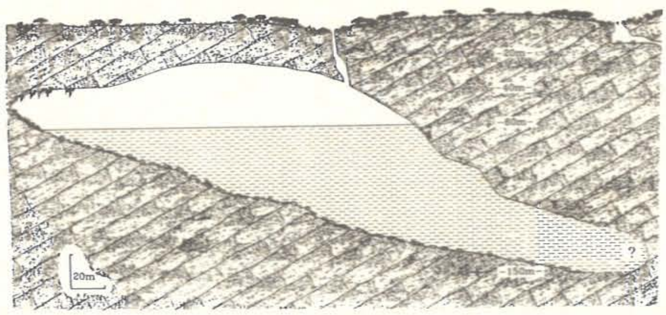
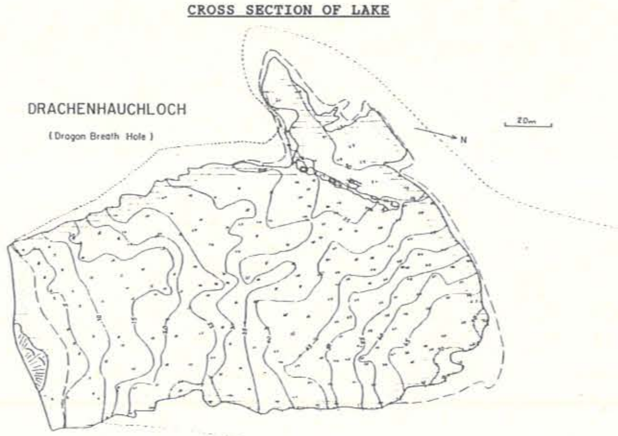
1986 AND 1987



CROSS SECTION OF LAKE



PLAN OF LAKE SHOWING BOTTOM CONTOURS EVERY 5 METRES

busy planning the rigging of the cave above the water, designing the three diving platforms and organising the catering and other campsite matters.

Shortly after arriving at the farm the cave was rigged and the diving rafts, telephones, oxygen resuscitators, diving equipment and inflatable boats were lowered to the lake and assembled. As the expedition consisted of nearly 40 cave divers and speleologists, it was important that the cave was suitably rigged to allow for the smooth flow of people continuously moving in and out of the cave. Therefore, both SRT (Single Rope Technique) and conventional caving ladders were rigged on all the pitches and telephones were installed at various levels. In spite of the enormous amount of equipment that had to be lowered through 60 metres of near-vertical shafts, the operation went comparatively smoothly due to the well thought out system of pulleys, hoists and Tyrolean cables installed especially for this purpose.

One of the most important items of equipment that was at our disposal was a 150 metre length of high pressure hose, complete with fittings and pressure gauge, that enabled the divers to fill the diving cylinders on the rafts from the two diving compressors outside the cave. This avoided the immense task of taking the cylinders to the surface after each dive. Four powerful surface lights and a submersible mercury vapour light were installed, illuminating the entire cave and thereby giving the divers a better idea of the immensity of the subterranean chamber.

3. THE UNDERWATER ENVIRONMENT

The roof of the chamber under which the lake lay was magnificent; a near perfect unsupported dome of massive dolomite, giving one the impression of being in a Gothic cathedral. The walls carried on down into the blue-tinted water. In some places there were crevices and fissures, in other places extensive overhangs awaited exploration. At one end of the lake there was a steeply sloping beach, decorated with calcite formations. A paddle around the lake gave one a feeling of isolation and tranquility.

The first dive in Dragon's Breath was a memorable occasion. There was a weighted SRT rope hanging into the water from the top of the final pitch but it was impossible to see where the air gave way to water, so still and clear was the water. Even during dives in excess of 80 metres, the submerged mercury vapour light could be clearly seen through some 200 metres of water. The water temperature was 24 degrees centigrade all the way to the bottom of the lake, affording the divers adequate thermal protection, even in 3mm surfing wetsuits.

The bottom of the lake sloped from the beach on the southern end of the chamber towards the north, where the deepest point reached by the divers was 90 metres below the water surface, or 150 metres underground. At the Northern end of the lake the divers discovered an impressive overhang where the domed roof continued to sweep below the water. With horizontal penetrations of over 100 metres, the survey showed that the divers were working directly under a nearby cave. This cave was aptly named "Small Beginnings" as it was explored first, the day before Dragon's Breath was discovered. In speleological terms, this was very exciting as the overhang could lead into another large cave system.

One of the most interesting areas that was explored underwater was situated near to the beach, where the submerged roof was covered by small stalactites. As these formations can only form in air, their presence was a good indication of previous water levels in the cave. These particular formations were found as deep as 15 metres below the surface of the water. In this area the bottom of the lake was strewn with broken formations, the pure white calcite contrasting with the dark, silt-laden background. The resulting effect was to give one the impression of a strange and alien landscape in this crystal-clear water.

The bottom of the lake was littered with massive dolomite boulders, measuring as much as 5 metres across, that had fallen from the roof of the chamber. These boulders were covered by a thick layer of fine silt in which a new species of subterranean freshwater amphipod was discovered. This amphipod has been named Trogloleleupia dracospiritus (4), after the lake itself (draco = dragon, spiritus = breath). This crustacean is large for the genus, being up to 20 millimetres long, white, totally blind and well equipped with sensory hairs. A colony of Sundevalle's Leaf-Nose bats (Hipposideros caffer) frequented the cave and the guano from these animals, together with debris washed into the cave during the rainy season, supplies the amphipods with their required organic food input (5).

4. UNDERWATER SURVEY EQUIPMENT AND TECHNIQUES

Due to the large proportions of the lake, a method of underwater survey had to be devised, which was accurate to within reasonable limits while remaining both quick and safe to use. Furthermore, it had to be borne in mind that the divers would be working at depths in excess of 50 metres, at which depth nitrogen narcosis would become a complicating factor. As the days progressed, it became apparent that the underwater survey would end with some unsurveyed areas, due to the excessive depths and horizontal distances under the overhang which were being encountered at many of the underwater profiles surveyed.

The flow meter used to measure distance consisted of a plastic four-digit counter, similar to that used in a tape recorder, attached directly to a four bladed plastic propeller taken from an anemometer. Once assembled, the device was calibrated by a diver in a swimming pool under controlled conditions and over a known distance. During extensive testing of the instrument, the accuracy was found to be better than 5%. The counter was mounted between two "wings" cut from plastic sheeting, joined by two wooden handles. On the bottom wing were mounted an accurated oil-filled yacht navigational compass and a depth gauge. The top wing was used to hold sheets of plastic drafting paper suitable for making notes underwater with a pencil. The complete system looked rather like an olden days bi-plane but it proved to be very stable and maneuverable in the hands of a diver.

During a survey of the lake perimeter, the walls of the lake were premarked with biodegradable paste at 20 metre intervals at water level. The divers were split into two teams, each with their own raft, and the cave was sytematically surveyed underwater, one point at a time. Each team was again split into pairs consisting of a "lead diver" and a "survey diver". The lead diver would attach the life line to a weighted decompression line, hanging beneath the diving raft, and swim under the overhang in a pre-arranged direction, while the survey diver would clip his buddy line onto the life line and follow, taking note of any change in direction, depth and distance.

To enable the divers to concentrate on surveying the cave walls and overhangs, an echo sounder was used to perform a bathymetric survey of the lake floor. The resulting contoured plan of the lake floor proved useful in understanding the formation of the cave. The echo sounder transducer was also aimed horizontally in an attempt to ascertain the extent of the overhanging areas, but this method proved unsuccessful due to the wide beam angle of the transducer.

While the divers worked below, a surface gravimetric survey was conducted to ascertain the extent of the cave where the divers could not venture. The results of this survey did not indicate that the cave system extended past the point to which the divers had penetrated but, as the instrument was working through solid rock of up to 150 metres in thickness, the possibility of the system carrying on could not be overlooked. However, no evidence was found to substantiate the theory that the numerous known water-filled caves in the area are inter-connected, although there may be a very slow percolation of water between some of them. The positive identification of identical cave dwelling aquatic fauna in two adjacent cave systems would have been an indication of a hydrological connection, but such a discovery has not been made to date.

5. SAFETY PRECAUTIONS AND EMERGENCY CONTINGENCY PLANS

As it was impossible to get the decompression chamber near to the lake and the divers were performing deep repetitive dives, extreme care was taken to keep the chances of the divers getting decompression sickness to a minimum. Lifting a bent diver through 60 metres of sheer drops and tight cracks before getting him to the decompression chamber may well have caused more harm than good. Even if a diver surfaced and felt fine, what adverse effect would the heavy exertion of the climb out of the cave in the hot, humid environment have on him? As hard work and dehydration after a deep dive can encourage the onset of decompression sickness, the divers were required to relax on the raft for at least an hour before climbing out.

In accordance with Carl Edmonds' Australian wet therapeutic oxygen tables (6), a diver showing any signs of decompression sickness upon surfacing would be sent straight down to 9 metres on pure oxygen for 30 minutes (60 minutes for more severe cases) and would then be brought up very slowly at a rate of 12 minutes per metre, switching to compressed air for 5 minutes every 30 minutes. This was quicker and safer than trying to get the diver to the decompression chamber at ground level. Two large oxygen cylinders were therefore rigged on the main diving raft with reducers and hoses to a boatswain's chair at 9 metres, where a second diver, breathing compressed air could keep a careful watch on the patient. Thanks to the generosity of one of the sponsors, an unlimited supply of oxygen was on hand. Also on the raft were an oxygen resuscitator and a diving First Aid kit that included a number of the standard diving emergency drug packs (Valium 10 mg., soluble asprin 600 mg., ascorbic acid 500mg. and Medrol 32 mg).

Thankfully, the one-man portable decompression chamber was never used "in anger" but it was re-assuring to know that it was there as, while wet treatment would have been used in the event of any symptoms having become apparent before the diver left the lake for ground level, the decompression chamber was equally important in the event of the symptoms only manifesting themselves once the diver was outside the cave. The decompression chamber could also have been used to transport a patient, under pressure, by helicopter to the closest therapeutic decompression chamber with lock-on facilities that was situated on the Atlantic coast, some 650 kilometres away. During the entire diving operation, a helicopter and a medical practitioner, trained in the treatment of decompression sickness, were on standby in the closest town.

The use of life lines was mandatory at all times, as well as the standard cave diving rule of 1/3 air in, 1/3 air out and 1/3 air for reserve. All the main diving cylinders were fitted with separate bail-out cylinders with their own regulators and contents gauges. It is accepted practice in cave diving circles to give preference to self-help in an emergency rather than to place too much reliance on the buddy system. Nonetheless, both divers were at all times connected to the surface of the water as the lead diver's life line reel was clipped onto his arm and the survey diver was clipped onto the life line by a buddy line. The divers could therefore easily locate each other or the first decompression stop under the raft.

6. DECOMPRESSION METHODS

As the surface of the lake was at an altitude of 1550 metres above sea level, the standard decompression tables had to be adjusted using the Cross Correction Method (7). For example, the deepest dive done on compressed air in Dragon's Breath was to a depth of 81 metres but this dive had to be treated as if it were to a depth of 101 metres at sea level, increasing the decompression time considerably. Stage decompression, using either the U S Navy Air Decompression Tables, or diving computers based on the Swiss tables calculated by Professor A. A. Buhlmann of the University of Zurich (8), was used. Specially devised decompression tables were used for the tri-mix dives.

It was found that, by using diving computers in preference to decompression tables for diving on compressed air, the time spent decompressing could be safely shortened when complex dive profiles were used. This was particularly apparent when diving beneath an overhang when a large percentage of the dive time was spent in a gradual descent and ascent with a sudden drop-off to the maximum depth (9). Two large oxygen cylinders, equipped with reducers and low-pressure hoses were connected to regulators and were available for decompression after long or extra deep dives or in case of an emergency. Spare compressed air cylinders were hung below the raft in case they were required to complete the decompression schedule.

7. CONCLUSION

The merging of two specialised disciplines, that of vertical speleology and deep diving, was done to obvious advantage. As far as the future of Dragon's Breath is concerned, a good relationship has been established with the land owner who is fully aware of the dangers of allowing inexperienced people into his cave. Perhaps one day the cave will be opened to tourists and the echo of excited voices will again reverberate from the very heart of this subterranean world or perhaps the cave will be left unspoilt, visited occasionally by the privileged few. In the meantime, a controlled volume of the valuable water will be pumped to the surface to irrigate the crops on the dry and dusty land above, but always with the conservation of the cave in mind.

The surface area of Dragon's Breath Lake is only 1000 square metres greater than that of the Lost Lake of Tennessee. Due to the cross section of Dragon's Breath Lake, immediately above and below the present water level, the surface area could increase or decrease significantly with a few metres fluctuation in the water level. Speleologists, familiar with the hydrology of the area, have reported fluctuations in the water level in other caves of over 20 metres in the space of 7 years (10). If, for example, the water level in Dragon's Breath was to drop, the surface area of the lake would increase in the areas where the roof overhangs but decrease in the beach area. An interesting phenomenon may therefore occur, whereby these two underground lakes alternate as the largest in the world, depending on long-term weather cycles.

As for the method used for the underwater survey, some problems were experienced with the handling of the survey equipment underwater and with the interpretation of the results. When working at depth, in total darkness, in a large void with little to use for orientation, the divers experienced difficulty in holding the flow-meter perpendicular to the line of the survey. This was partly due to the lack of a suitable local training venue for the divers prior to departure for Dragon's Breath. The resulting survey was therefore graded as a British Cave Research Organisation (BCRA) grade 2B instead of the anticipated 3C. While the accuracy of the underwater survey was disappointing, it served as a means of exploring the cave in a methodical manner and a worthwhile survey drawing of the cave was produced.

Considering the fact that the 3 week expedition was done on the low budget of approximately $200 per person, including equipment, transport, food and accommodation, the operation can be considered a great success, all the objectives having been achieved.

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LEAD MINING OF CAVES IN THE DRIFTLESS AREA OF SOUTHWEST WISCONSIN AND NORTHWEST ILLINOIS, U.S.A.

REEDER, Philip P. - DAY, Michael J.

During the Wisconsinan stage of the Pleistocene in North America, the "Driftless Area" of the Upper Midwest probably was not glaciated, hence preserving the pre-existing geology, including the Middle Ordovician Galena Dolomite, which was a host rock for paragenesis of lead deposits. From hydrothermal solutions mixing with groundwater, crevice lead sulfide ores were deposited along lines of weakness resulting from bedding, collapse of breccias, and preferential dissolution of joints. Lead has been mined in the Driftless Area since antiquity, with greatest activity in the mid-nineteenth century. The earliest gathering of surface (float) deposits progressed to shallow digging and to removal of ore from caves which were uncovered during excavation or which had natural entrances. Historical records show that several Driftless Area caves, including those in the Cave Lead District of Illinois, were mined extensively. The Atkinson Mine Cave, in Grant County, Wisconsin, was entered in 1856 and was mined through 1880, with about 40,000 tons of ore removed. Remnant evidence of mining includes drill holes, mining tools, spoil piles and modified passages.

BLEIABBAU IN HOEHLEN IM PLEISTOZAEN-EISFREIEN GEBIET SUEDOESTLICHES WISCONSIN UND NORDWESTLICHES ILLINOIS, U.S.A.

Waehrend der Wisconsin (Wuerm) Vereisung in Nord Amerika war das sogenannte pleistozaen-eisfreie Gebiet ("Driftless Area") im nordoestlichen Mittelwesten aller Wahrscheinlichkeit nach nicht vergletschert. Das hat dementsprechend die vor-pleistozaenen geologischen Verhaeltnisse praeserviert, einschliesslich des Mittel Ordovicium Galena Dolomits, welcher als Gastgestein fuer die Paragenese von Bleivorkommen bekannt ist. Spalten-Blei Sulfiderze (crevice lead sulfide ores) wurden vorwiegend durch Mischung hydrothermaler Loesungen mit dem jeweils vorhandenen Grundwasser transportiert und entlang von Schwaeche- und Bruchlinien bzw. Spalten abgelagert, die wiederum entweder durch Brecchienkollaps oder durch praeferenzielle Loesung schwacher geologischer Schweisszonen entstanden waren. Blei ist in dem Untersuchungsgebiet schon in vorkolumbianischen Zeiten abgebaut worden. Der frueheste Abbau erfolgte durch Sammeln exponierter Erze, spaeter durch Graben in leichter Tiefe sowie in Hoehlen, deren Eingang kuenstlich oder auf natuerlichem Wege freigelegt waren. Seit europaeischer Besiedlung zeigen historische Dokumente, dass mehrere Hoehlen im Untersuchungsgebiet (Driftless Area) einschliesslich des Hoehlen Blei Distrikts von Illinois (Cave Lead District of Illinois) systematisch ausgebeutet wurden. Die Atkinson Bergwerk Hoehle im Grant County, Wisconsin wurde von 1856 bis einschliesslich 1880 ausgebeutet und erzielte 40 000 Tonnen Erz. Bohrloecher, zurueckgelassenes Handwerkszeug, Hoehlendurchbrueche und andere Stollen sowie Abraumhalden zeugen noch heute von der einst lukrativen Bergwerkstaetigkeit in diesen Hoehlen.

Introduction

Mining of lead in the Upper Mississippi Valley began around 1815 and induced permanent settlement in the region (Figure 1). Lead ore was gathered from residual surface deposits or was removed from shallow excavations that often encountered joint-like fissures or crevices in the bedrock filled to varying extents with galena (the predominant lead ore of the area). These galena-lined caves were the main source of mineable ore in the region.

Ore-bearing crevices sometimes extended to the surface and natural cave entrances were utilized to gain access to deposits. Ore was gathered in caves from residual deposits mixed with sediment, predominantly loess transported into the crevice by descending meteoric water or clays resulting from weathering of the host rock. Sometimes lead deposits lining the cave walls were removed with primitive mining tools. Once the most accessible deposits were removed, intersecting tributary crevices were excavated. Eventually labyrinths of interconnected crevices, both natural and those modified by excavation, were developed.

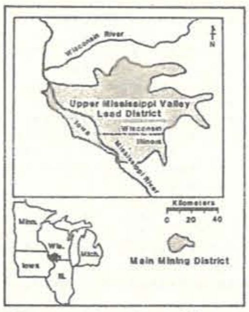

Figure 1 - Location of the Upper Mississippi Valley Lead District.

The mining of lead was most prevalent in the Upper Mississippi Valley from 1825 to 1870, with peak production occurring in the 1840's. An almost uninterrupted decline in lead production occurred from 1850 to the present, and no active lead mines currently operate in the region.

Geology of the Upper Mississippi Valley Lead District

Covering much of the north-central United States is a layer of glacial drift varying in thickness from a few centimeters to several hundred meters. This drift is a mixture of stratified and unstratified silt, clay, gravel and boulders (Knox, 1985). Glacial transport and deposition of this material in the Pleistocene obliterated and/or buried the former landscape.

Lying well north of drift covered areas (which extend as far south as the Missouri and Ohio Rivers), and surrounded by glaciated terrane, is a region which differs markedly from the surrounding landscape. This "Driftless Area" comprises approximately 16,000 square kilometers of the Upper Mississippi Valley, mostly within Southwest Wisconsin, but including portions of Minnesota, Iowa, and Illinois. The Upper Mississippi Valley Lead Mining District is entirely within this Driftless Area.

The most widely exposed rock unit in the lead region is the Middle Ordivician aged Galena Dolomite, with the older Decorah and younger Mequoketa Formations exposed to a lesser degree (Figure 2). Principle lead deposits are restricted to the Galena Formation (Heyl and others, 1970).

The carbonate rocks in the lead region are progressively more dolomitized away from the central portion of the region, mainly in a northeasterly direction. Karst topography is mainly confined to the limestone units, and diminishes with dolomitization (Heyl and Others, 1970). The Galena Dolomite is granular, crystalline, coarse-grained and porous, and weathers into exceedingly rough, irregular forms (Grant, 1909).

Figure 2 - The geology of the Upper Mississippi Valley Lead District.

The Galena Formation contains well-developed vertical and inclined joints which are tracable for up to 3 kilometers horizontally and 90 meters vertically. Regional tectonic deformation in the Paleozoic produced these joints as well as folds and faults, which were later accentuated by dissolution and slumping of the beds before and during mineralization of ore deposits (Agnew, 1963).

Lead ore bodies were grouped into 5 classes by Calvin and Bain (1899). 1) Vertical sheets were deposited between crevice walls perpendicular to bedding. If the host rock was dissolved by groundwater circulating around the ore deposit, the crevice was partially open or was filled with sediment mixed with ore (Calvin and Bain, 1899). 2) Flat deposits were sheets parallel to the bedding, 3) Pitches, represented connections between vertical sheets and flats. 4) Disseminated deposits were formed where the rock was broken or rendered porous by dissolution (karstification) and brecciation. 5) Cave deposits, the largest and richest sources of ore, were usually abundant because concentrated in caves was all the ore originally deposited in the rock mass and later altered by dissolution. In caves a large surface area is available for lateral segregation of ores and accumulation of disseminated ore bodies and sheet deposits. Chimneys (vertical shafts formed by descending groundwater) along crevice cave passages sometimes produced substantial amounts of ore. An idealized cross-sectional diagram of the various types of ore bodies is depicted in Figure 3.

Origin of Ore Deposits

Numerous hypotheses have been proposed to account for the development of the Upper Mississippi Valley Lead deposits. Consensus dictates that these ores were deposited by rising solutions which moved laterally and chiefly upward through pre-existing dissolutional features which may have been formed by an aggressive pre-ore phase of ascending hydrothermal fluids moving through the fracture system (Hedges and Alexander, 1985). The fractures were further modified when meteoric water was drawn into the system, diluting the solutions and eventually flushing the concentrated brines out of the district to leave behind ore deposits (Heyl and Others, 1970).

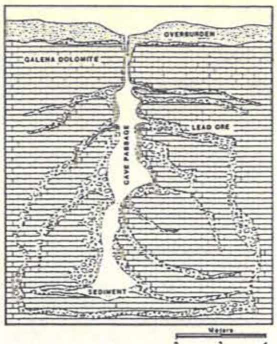

Figure 3 - Idealized cross-section of a typical ore bearing zone in the Galena Dolomite.

Mining Techniques

Early lead mining techniques were extremely crude by present standards. Miners would dig a pit to bedrock and then prospect out in all directions, dragging the galena to the center of the excavation. If a prospect pit struck the "soft ground" of an open crevice, the crevice was followed in an attempt to locate ore. Often, numerous shafts were sunk along the extent of a crevice and, if a crevice intersected the base of a bluff or hill, an adit (horizontal entrance) was excavated into the hillside.

Figure 4 illustrates a cross-section of a lead mine as depicted by David Dale Owen in 1839. Miners are removing lead ore from a galena-lined cave and are hoisting it up a shaft to the surface. The presence of cave formations (stalactites) in this illustration attests to the firm link between caverns and lead mining. Owen (1844) noted that the ceilings of subterranean chambers were commonly adorned with large stalactites which concealed the lead ore which they encrusted. The altering of caverns by mining lead-bearing crevices expanded passage widths and heights considerablely.

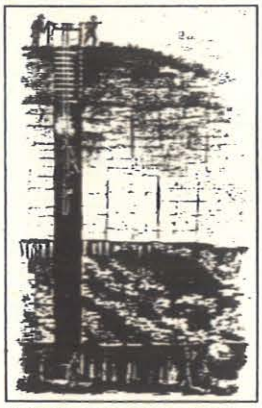

Figure 4 - Cross-section of a lead mine as depicted by David Dale Owen in 1839.

Mining of Lead Ore From Caves in Wisconsin

One of the earliest known lead mines in the Upper Mississippi Valley was Snake Cave (St. John's Mine), which has the largest entrance of any cave in Wisconsin (Figure 5). Evidence of mining in Snake Cave includes rocks excavated in the pursuit of lead piled along the sides of the passages, and pillars and support walls left behind to buttress the ceiling. Unaltered cave passage in Snake Cave is indicated by the presence of massive flowstones which would have been destroyed if this section of the cave had been mined.

Some of the earliest mining in Southwestern Wisconsin consisted of removing ore deposits from the walls of solution caves and cavities (Paull and Paull, 1977). Lapham (1846) noted that ore was being removed from crevices ranging from 15 meters wide down to thin cracks. Large chambers (cave rooms) located along the crevices sometimes had walls lined with lead ore in thicknesses ranging from about 2 centimeters to over 0.5 meter.

Many of the caves south of the Wisconsin River were investigated by 19th century lead miners. The "Big Spring" at Castle Rock in Grant County flows out of a rocky cave with appreciable volume and force (Schafer, 1932). This cave, because of the size of the spring issuing from it, was probably investigated for lead deposits, although no written account of such an investigation exists. North of the Wisconsin River, Bogus Bluff Cave was excavated in part in search of lead ore, although the date of this is unknown (Day, 1986).

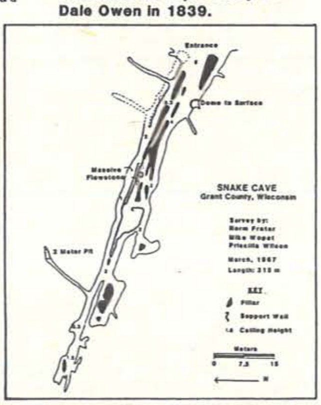

Figure 5 - Snake Cave (St. John's Mine), Grant County, Wisconsin.

The Beetown Lead District, which was the most westerly district in which any productive mines were worked in Wisconsin, had numerous cave lead deposits. Around 1840, lead ore was discovered in Dudley Cave. Also in the Beetown District, numerous mines were located around the Muscalunge Diggings, where many of the deposits mined were cave deposits. Arthur and Company Mine Cave was discovered when a 27 meter shaft located a 20 meter high crevice from which ore was subsequently removed. About 1 kilometer from Arthur Mine Cave is Cherry Tree Shaft, which is one of two access points into the now water-filled Brown and Turley Mine, from which crevice ore deposits were removed (Anonymous, 1966).

The largest producer of lead ore at the Muscalunge Diggings was the Atkinson (Adkinson) Diggings. From 1862 to 1877 over 900 metric tonnes were removed from Atkinson Mine Cave (Figure 6). Entry to the cave was first gained through a 20 meter discovery shaft. Eventually 2 more shafts were dug and an adit was excavated as the true extent of the ore body was realized. This adit can still be used to enter Atkinson Mine Cave, where over 3 kilometers of 1 to 5 meter high passage comprise the mined-out cavern. The deposits lined the walls of long linear crevices which existed as open caves, clay-filled caves, or simply as areas of partially dissolved, vuggy rock.

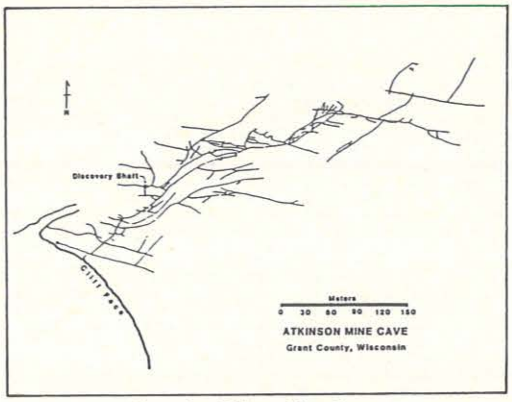

Figure 6 - Atkinson Mine Cave.
Source: Peterson, 1969

Evidence of passage alteration by mining is found throughout the cave. Many passages are lined with piles of broken rock which was not removed from the cave with the ore, and drill holes used to break this rock away from the walls are still in evidence.

The deposits of the Atkinson Range (a range denotes a single or several sub-parallel crevices containing ore), trended northeast and were frequently intersected by smaller east-west trending crevices (Figure 7). In contrast to Atkinson Mine Cave, where crevices were partially filled with ore, some other crevices were completely ore filled and did not take on a cave-like appearance until the ore was removed.

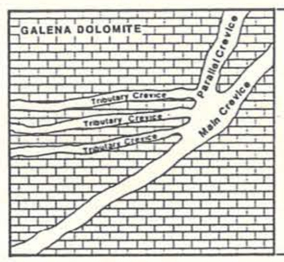

Figure 7 - Main and tributary crevices in Atkinson Mine Cave, Grant County, Wisconsin.

Source: Chamberlin, 1877

In a roster of caves of Wisconsin compiled by Cronon (1971), some of the previously discussed mine caves were listed. In addition to Bogus Bluff Cave, Castle Rock Cave, Arthur and Company Mine Cave, Atkinson Mine Cave and Dudley Cave, Cronon further listed Brown Thomas and Company Mine Cave, Buster Mine Cave, and Shullsburg Mine Cave.

Illinois Mine Caves

Although the largest portion of the Upper Mississippi Valley Lead District is in Wisconsin, the mining of lead ore from caves was not exclusive to Wisconsin. Lead deposits were also removed from caves in Northwestern Illinois.

The Royal Princess mine was focussed upon an east-west crevice at about the center of a series of crevices known as the California Diggings. These crevices were originally sediment-filled with the ore deposited on the cave walls or mixed with sediments during a later episode of deposition (Bretz and Harris, 1961).

The Marsden Mine was discovered in 1854 during excavation of a spring. After excavating the spring for 6 meters, cave passage 6 to 9 meters in diameter was encountered containing large amounts of ore. Stalagmites, bearing galena on their summits were reputedly found here (Cox, 1914).

Smith (Mount Carroll) Cave was located when miners excavated a narrow sediment-filled joint for 6 meters before encountering cave passage that narrowed at some points and was excavated in search of ore. The crevice that determined the development of the cave is actually a complex of sub-parallel joints whose curved courses made divergences and convergences along the strike of the beds and therefore produced considerable variation in cave widths.

In Herman Smith Mine Number 1 ore was deposited in a 3 meter wide zone of closely-spaced crevices. The crevices were entered via an inclined adit or a 30 meter shaft 150 meters west of the adit. The ore deposit was approximately 3 meters wide and 1.5 meters high; cave passage above the ore-bearing zone was typically 1.5 meters high, although passage height was as much as 15 meters where enhanced dissolution carved a cave above the ore deposits (Bradbury, 1959).

Located 1 kilometer north of Herman Smith Mine Number 1, is Herman Smith Mine Number 2. Originally only subordinate deposits of galena were mined from the original crevice, but about 100 meters west of the entrance, along the original crevice, a cave was encountered that was lined with a thick sheet of galena. This type of deposit was cited by Bradbury (1959) as a type example of crystal-lined cave deposits.

Summary

From 1825 to 1870 the Upper Mississippi Valley Lead District was one of the most important lead producing regions in the World. Originally, ore was removed from caves with natural entrances or from shallow excavations that often encountered crevices in the bedrock which intersected ore-lined caves. Shafts were sunk into many of these crevices to further facilitate ore removal.

Caves proved to be the most important source of lead ore in the region. Throughout the lead mining period in the Upper Mississippi Valley, cave lead deposits sustainded the industry. Ore deposits continued to be removed from caves well into the 20th century and today the cultural and physical landscapes of the region still bear evidence of the lead mining activity.

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NORTH CAROLINA GRANITIC CAVES: VALUABLE SPELEOLOGICAL RESOURCES

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In the southern Appalachian Mountains of western North Carolina, U.S.A., a variety of granite caves have proven to be of value in the areas of local history, archaeology, mineralogy. biology, as well as sport caving and tourism.

En el oeste de Carolina del Norte, Estados Uindos Estan situados los Montes Apalaches y eu el sur de estos Montes hay una gran variedad de euevas de granito, que prueban ser de gran valor en las areas de historia, arqueogia, mineralogia, biologiá, asi como el deporte de cávernas y turismo.

North Carolina is located in the southeastern United States. In contrast to such neighboring states as Virginia, Georgia, and Tennessee, our state lacks an abundance of cave-forming carbonate rocks. The ancient crystalline rocks, the granites, gneisses, and schists of North Carolina do hold considerable speleological promise. In fact, of the more than 1000 caves in this state, most are found in these older formations. The Blue Ridge escarpment of the southern Appalachian Mountains is a particularly rich area for such caves. Some are extensive enough to be in a world class category. The variety of cave types include rock shelters, caves formed by water action and piping phenomena, talus caves, and numerous fissure and tectono-talus caves.

Shelter caves are fairly numerous in our mountains and are formed by a variety of processes including frost wedging and exfoliation, honeycomb weathering producing large tafoni pockets, and the abrasive cutting action of streams and waterfalls. Though generally limited in size, often measuring greater in width than in length, many of these features nevertheless served as convenient campsites and shelters for early nomadic Indian tribes and were occasionally used for the same purpose by early settlers as well. Today they are important archaeological sites.

Historically, these caves have been used for practically everything imaginable. Indians, pioneers, runaway slaves, criminals, war deserters, musicians, moonshiners, prostitutes, hoboes, and hermits have all sought refuge in them at one time or another. Many have been used to store food, building supplies, farm equipment, animals, and one even served as the site for local church services.

Running water has played an integral role in the formation of some of our granite caves. Boone's Cave, for example, is a 200' long granite-gneiss cave located on the banks of the Yadkin River. The cave was formed due to the river water enlarging a pre-existing crack in the rock. Daniel Boone, famous frontiersman, reportedly hid in this cave once to escape an Indian attack. Granite, being composed primarily of quartz, feldspars, and biotite mica was once considered relatively unaffected by the action of water. Quite the contrary, it has been found that some of the feldspars are broken down into kaolin (clay), and the biotite is transformed into vermiculite. The remaining quartz is then carried away by the running water.

Two of our state's caves, Devil's Den and Stiller's Cave, were formed by piping phenomena in a decomposed granite. Both contain small streams flowing along several hundred feet of passages whose profiles strongly resemble solution caves in limestone.

Even though it is believed that the Pleistocene glaciers failed to reach as far south as North Carolina, the southern Appalachians were still locally affected by snow, ice packs, and frost heaving action. This is evidenced today by the presence of many boulder fields at the base of cliffs and in stream valleys. Block creep caves and talus caves, some of considerable extent, are often found in such areas. These are fairly abundant not only in the mountains, but also in the piedmont sections of the state. Generally characterized by multiple entrances and small to moderate size passages, some of these North Carolina talus caves extend for many hundreds of feet beneath the boulder piles. Occasionally underground streams along with sandbars and varves add to the interest of exploring these features.

Closely related to talus caves, and often found in conjunction with them are the fissure (tectonic) caves. An excellent example of this relationship is the Campbell Cavern-Amazing Bat Cave complex. With over 1000' of passage and approximately 80' of vertical relief, the upper portion of this cave consists of a talus maze connecting by way of a 50' drop to the lower fissure component developed along an enlarged joint plane. This cave harbors five species of bats in the winter months, and a new species of amphipod crustacean has been discovered in one of its pools.

The Rumbling Bald Mountain system is a similar example of a tectono-talus cave in gneissic rocks and is still being explored. Two of its major entrances are located at either end of a massive detached flake of rock which dropped and landed against the cliff face forming a block-creep cavern. The passage within this block creep cave segment can then be followed into an impressive fissure cave which penetrates the mountain at right angles along an extensive system of joints. These caves were reportedly used by Tories hiding out during the Revolutionary War. During the late 1800's a series of earthquakes and ominous rumbling noises terrorized the locals of the area. One modern theory for the rumbling sounds is that of huge boulders falling within the caves and the sound reverberating through the large passages and out into the valley below. It has been said that the large block-creep flake acted as a sounding board, amplifying the noises. Even today, explorers have to contend with unstable rocks in this system.

Several of our fissure caves including Jingle Hole, Ice Shaft, Smokehole of the Dismals, and Tombstone Drop exceed 100' in depth and provide sporting opportunities for the vertical caver.

The Bat Cave System is our premier world class fissure cave. Developed in Cambrian age augen-gneiss, the cavern is 192' in depth, and over a mile in length. The cave has a rich and varied history, including having once been used to hide runaway Negro slaves as part of the so-called "Underground Railroad". Three new species of invertebrates, one endangered bat species (the Indiana Bat), and the elusive and unusual Crevice Salamander make these caves their home. In addition to the main cave system, over a dozen smaller satellite caves are found on the same mountain.

The Bat Caves are under the jurisdiction and protection of the North Carolina Nature Conservancy which manages a 93 acre preserve surrounding the caves.

Also located in the same Henderson granite-gneiss formation is nearby Moonshiner's Cave. Though smaller than the Bat Caves, it has been a popular tourist attraction since the turn of the century. Recent improvements in the cave including an all new lighting system allow visitors to see more cave than had previously been shown

Many of our granitic caves have been of interest to biologists in that a considerable number of new species of invertebrates have been discovered within these non-carbonate voids. It may be of interest to note that some of the more interesting life forms have been observed in rather small caves. The state's first subterranean water slater (an asellid isopod) was found in a cave less than 100' in length. A half dozen new species of planarians (flatworms), and an equal number of undescribed amphipods of the genus Stygobromus have been found in caves of modest length. New arachnids and millipeds have also been discovered.

Mineralogy is another field of interest in our granite caves. Unlike the barren ugly rock passages totally devoid of formation envisioned by some individuals, many of our caves actually do contain speleothems. Gypsum deposits occur in some of the passages developed in a staurolite-micaschist. In other caves, opal speleothems occur in a variety of forms including thin white crusts, small stalactites and draperies, flowstone with delicate microgours, helictites, stalagmites, and several types of cave coral. Some clastic deposits such as mud and silt stalagmites have also been noted. In the winter months well-developed ice deposits transform even the plainest of passages into veritable ice palaces.

On a more practical note, knowledge of the presence of certain tectonic caves helped provent the ill-planned installation of a low level nuclear waste dump in one of our pseudokarst areas just a few years ago.

Many more discoveries are yet to be made in the often overlooked granitic caves, not only in North Carolina, but also in other areas of the world. Other significant granite caves have been documented in the northeastern United States and in several western states including Texas and California.

Australia, Sweden, and several other countries have numerous granite caves of great importance. We would encourage speleologists everywhere to search beyond their limestones, gypsums, and lava fields, for significant caves can and do occur in granitic rocks as well.

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GEOCHEMISTRY OF THE SECONDARY PHOSPHATE MINERALS FROM JAPANESE ISLANDS

KASHIMA, Naruhiko

Abstract

This paper is focussed on the geochemistry of the secondary phosphate minerals(hydroxyapatite, variscite and vashegyite) collected from the caver and insular environments. The major-elements and trace-elements as Nb, Zr, Y, Sr, Rb, Pb, Zn, Cu, Ni, Co, Cr, Ba, V, S and Ga were analysed.

The difference of the chemical composition of secondary phosphate minerals in caver and insular environments is related to two factors, the climatic parameters and the geochemical conditions.

Zusammenfassung

In der vorliegenden Arbeit werden die Geochemischen von sekundär Phosphatemineralien(Hydroxyapatit, Variscit und Vashegyit) aus Höhlen- und Insular Ümvelter. Haupl-Elemente und Winzig-Elemente wie Nb, Zr, Y, Sr, Rb, Pb, Zn, Cu, Ni, Co, Cr, Ba, V, S und Ga Analysieren wurden.

Der Unterschied die Chemish Komponente von sekundär Phosphate Mineralien in Höhlen- und Insular Ümvelter werden durch zwei Fakoven bedingt, Klimatisch-en und Geochemishen Bedingungen.

Introduction

According HILL & FORTI(1986), thirty-six spelean phosphate minerals have been reported in the world. In Japan, eight spelean phosphate minerals (ardealite, brushite, hydroxyapatite, koninckite, sasaite, taranakite, variscite and vashegyite) occur in calcareous and volcanic caves(KASHIMA, 1987), and are usually associated with the bat guano deposits.

Early geochemical analyses data of the spelean phosphate minerals from Japan were given by MAKI & KASHIMA (1977). SAWAMURA & MOMOI(1983) examined the guanos and minerals from Kyusen-do Cave, Ose-do Cave and Odamachi-do Cave,

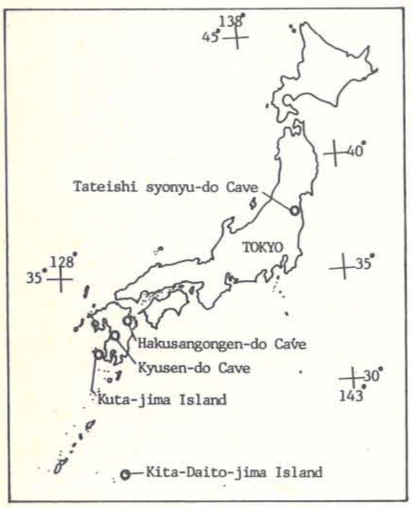

Fig. 1. Location map of sampling sites.

and performed chemical analyses. Trace elements of phosphate minerals were not recorded.

On the other hand, mineralogical and geochemical studies on the insular phosphorites are quite numerous(e.g. ALTSCHULER, 1973). In Japan, YAMANARI (1935) described an insular phosphorites from Kita-Daito-jima Island, Okinawa Prefecture. KANESHIMA(1957 ; 1964) reported that the phosphate ores in the Ryukyu Islands contain a considerable amount of Zinc and Strontium and are associated with Arsenic, organic matter and amino acid.

In the present study, three secondary phosphate minerals(hydroxyapatite, variscite and vashegyite) collected from caver and insular environments(Fig. 1) were analyzed for major and trace-elements.

The purpose of the paper are 1) to report the result of major and trace-elements study and 2) to bring out the geochemical significance leading to the different environment of mineralization.

Samples studied

The following six specimens were used in this study.

Hydroxyapatite

1) NK 385. White leaf-like flaky specimen from Hakusangongen-do limestone cave, Oita Prefecture.

2) NK 474. Brownish to yellowish veins or crusts from closed insular phosphorite mine in Kuta-jima Island, Kagoshima Prefecture.

Variscite

1) NK 463. Pale brown with black outer rind scoriacerous specimen from KKyusen-do limestone cave, Kumamoto Prefecture.

2) NK 590. Brownish high grade hard specimen from Kita-Daito-jima Island, Okinawa Prefecture.

Vashegyite.

1) NK 697 White, powdery and fine-grained specimen from Tateishi syonyu-do Cave, Fukushima Prefecture.

2) NK 587. White and cream-coloured earthy specimen from Kita-Daito-jima Island, Okinawa Prefecture.

Experimental methods

X-ray powder diffraction analysis(XRD)

XRD was carried out with RIGAKU instruments under ordinary operating condition. The $< 2\mu m$ size fructions collected from each specimens were oriented on the glass slide with aceton.

X-ray fluorescence analysis(XRF)

Quantitative bulk chemical analysis of specimens was performed in a Philip PW-1450 automatic sequential spectrometer. Major elements are determined on fusion discus using the heavy absorbed fusion technique, minor and trace-elements are routinnely determined on pressed powder pellets.

Scanning electron microanalysis(SEM)

SEM was carried out with a ISI DS-130 research instrument equipped with PGT EDX analyzer. The bulk specimens were mounted on brazen stub and coated with Au in a Hummer VI Sputter coater.

Electron probe microanalysis(EPMA)

Thin sections of hydroxyapatite specimen were analysed for Ca, P, Ba, Sr, Cl, F and O by JXA-8600 JEOL electron microprobe.

Results

A detailed chemical composition of hydroxyapatite, variscite and vashegyite from caver and insular environments in Japan were determined by XRF(Table 1). From the data presented in Table 1, it is clear that hydroxyapatite NK 474 specimen and vashegyite NK 697 and NK 587 show extremly high SiO_2 contents.

XRD examination of specimen NK 474 gave strong peaks of hydroxyapatite and quartz. Although, at specimen NK 385, quartz peaks cannot be observed.

SEM image maps of Ca, P and Si at specimen NK 385 and of Ca, P, Si, Fe, K and Al at specimen NK 474, showed the occurrence of silica minerals or clay minerals filling materials within the interspaces zoning platy hydroxyapatite crystals(NK 385) or small pockets in hydroxyapatite matrix and crystals(NK 474).

By EDX analysis, the surface of euhedral crystal of vashegyite is found to consist of Al, Si, P and Fe elements.

The results of EDX analysis of the elemental values of Ca and P for zoning hydroxyapatite crystal(NK 385) are significant vary which are the inside and the outside of crystal. The Ca/P ratio are lower in the inside than the outside. Besides, the elemental distribution of Al and Si are recognized only the outside of the section(NK 385) and the surface of specimen NK 474.

The EPMA data of specimen NK 385 were averaged 39.52% CaO, 32.19% P_2O_5, 0.02% SrO, 0.05% Cl and 0.42% F. Specimen NK 474 composition averaging 45.06% CaO, 32.36% P_2O_5, 0.09% SrO, 0.69% Cl and 0.72% F. The CaO/P_2O_5 ratios in specimen NK 385 varies between 1.07 and 1.34 among 39 points and averaging 1.20. The specimen NK 474 have CaO/P_2O_5 ratios between 1.33 and 1.52 among 13 points and averaging 1.40, which are distinctly greater than the NK 385 values.

Fifteen trace-elements, Nb, Zr, Y, Sr, Rb, Pb, Zn, Cu, Ni, Co, Cr, Ba, V, S and Ga, were determined for specimens of hydroxyapatite, variscite and vashegyite. The highly concentrated trace-elements in hydroxyapatite NK 385 are Y, Sr, Zn, Cu, Ba and S. Variscite specimen NK 590 has high Sr and S contents with low Cr and V as compared with NK 463. Vashegyite specimen NK 587 has high Sr, Zn, Cu and Ba contents as compared with specimen NK 697.

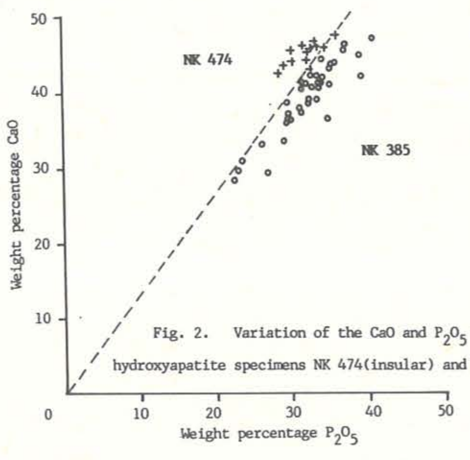

Fig. 2. Variation of the CaO and P_2O_5 weight percentages of hydroxyapatite specimens NK 474(insular) and NK 385(spelean).

Conclusive remarks

The present study has shown that the environmental differences in the chemical composition of secondary hydroxyapatite, variscite and vashegyite, within were previously not recognized, can now be revealed.

XRD reveal that the silica mineral(quartz) and clay mineral includes accessory minerals of hydroxyapatite and vashegyite. The concentraction of SiO_2 at XRF is essentialy due to the presence of mainly silica mineral(quartz) and clay mineral. However, the silica occurs as finely dispersed throughout the specimen. And silica mineral occurs as infill materials within the interspaces and small pockets of hydroxyapatite crystals and crystal surfaces of vashegyite. This contamination of silica and clay minerals are generally due to the effect of depositional and weathering processes.

In the two hydroxyapatites, the spelean specimen(NK 385) and the insular specimen(NK 474), most interesting result of the variation of CaO and P_2O_5 weight percentage, a plot of CaO vs. P_2O_5(Fig. 2) shows a linerly positive trend. This result suggests that the insular hydroxyapatite(NK 474) acquired highly CaO/P_2O_5 ratios from the meteoric waters which were reflect the terrestrial weathering of the limestone bed and the guanos in origin.

For comparison, according to WHITE(1976), the caver environment, at constant temperature and invaded by percolating solutions carry various substances, forms an excellent environment for the slow deposition of minerals. The spelean hydroxyapatite specimen NK 385 seem to precipitate from mixing two solutions, calcium-salt rich vadose-phreatic solution and phosphoric acid solution from bat guano or urine.

On the other hand, F and Cl contents of the spelean(NK 385) and insular (NK 474) hydroxyapatites are sharply different that the latter specimen characterized by higher F and Cl contents can be reduced by sea-water scattering or storm waves.

Details of the trace-elements of variscite and vashegyite seems to be different between the spelean(NK 463 and 697) and insular(NK 590 and 587) environments, that is to say, the analytical results of trace-elements demonstrate that the elements Sr and S concentrate more in insular phosphates than in spelean one.

Phosphorite deposits on Kita-Daito-jima Islands occur in residual red clay deposits with weathered pumices. Kuta-jima Island, hydroxyapatite occurs in the fissures and bedding plains of altered-guanitized chert and limestone beds. The Sr and other high content elements probably arose from chemical weathering products, and/or from seawater on the surface of island.

Table 1. XRF-whole mineral analysis of hydroxyapatite, variscite and vashegyite specimens.

	hydroxyapatite		variscite		vashegyite	
	NK385	NK474	NK463	NK590	NK697	NK587
SiO_2	0.18	8.96	0.67	0. 49	7.37	3.93 (wt%)
TiO_2	0.01	0.07	0.05	0.12	0.16	0.49
Al_2O_3	0.04	2.04	30.8	29.1	23.1	25.4
Fe_2O_3	0.12	0.69	0.04	1.25	2.10	3.86
MnO	0.01	0.01	0.01	0.01	0.01	0.07
MgO	0.01	0.72	0.01	0.28	0.13	0.16
CaO	51.0	43.2	0.12	0.55	0.30	3.35
K_2O	0.12	0.43	0.16	0.22	0.27	0.40
P_2O_5	41.4	32.5	42.7	41.5	29.4	28.7
Na_2O	0.05	0.75	0.02	0.40	0.01	0.42
LOI	7.31	10.5	25.3	25.9	36.8	32.6
Total	100.3	99.9	100.3	99.9	99.7	99.9
Nb	5	10	3	6	3	9 (ppm)
Zr	15	10	5	19	28	9
Y	18	70	9	17	20	27
Sr	140	460	18	664	78	3159
Rb	16	10	1	1	9	13
Pb	3		12	17	7	23
Zn	171		238	213	42	175
Cu	48		128	138	31	123
Ni	7		1	3	6	49
Co	5		5	5	5	16
Cr	5	10	254	94	84	70
Ba	65	60	3	61	71	219
V	5		814	118	65	79
S	612		263	1516	1240	2635
Ga	1		4	1	1	7

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THEORETICAL CONSIDERATIONS FOR THE ORIGIN OF EDWARDS AQUIFER CAVES IN THE BALCONES FAULT ZONE, TEXAS, USA

OGDEN, Albert E. - COLLAR, Paul D.

ABSTRACT

Pumping (aquifer) test data and well logs show that the highest transmissivity (T) values and the most caves (intersected by wells) occur just inside the confined-unconfined boundary of the Edwards Aquifer due to "mixing corrosion." Most ground water moves through fault-controlled caves. The interior of the fault blocks have lower T values and less cavern development. Caves also form above impermeable strata in the unconfined zone. Pocket caves form where evaporitic layers have been removed by dissolution. Time-series hydrochemical data from the three largest springs and data from 90 wells show that the water is usually undersaturated with respect to calcite except during severe drought condition. A three-dimensional diagram of the calcite saturation data from wells show lower values along the major faults and photo-lineaments. Therefore, cave growth is occurring faster along zones of structural weakness within lithologically favorable strata.

RESUMEN

Pruebas de bombeo y perfiles litológicos indican que las areas de trasmisividad mas altas y la mayoría de cuevas (intersectados por pozos) ocurren inmediatamente adentro del limite artesiano del acuifero Edwards por causa de "corrosion de mixtura." La mayor parte del agua subterranea fluye a través de cavernas controladas for fallas. En el interior de bloques de roca separados por fallas, la transmisividad es más baja y hay menos desarrolo de cavernas. Cuevas tambien ocurren encima de strata impermeable en la zona no artesiana. Huecos pequenos interconectados ocurren donde capas de anhidrita han sido disuelto. Data hydroquímica a través del tiempo de los tres manantiales más grandes del area y data de 90 pozos indican que el agua esta debajo de la saturación de calcita excepto durante una sequía severa que ocurrió durante el ano del estudio. Un diagrama de saturación de calcita en agua de pozos, elaborada en tres dimensiones, muestra bajos indices de saturación coincidentes con fallas grandes y fotolineamientos. Consecuentemente, el desarrollo de cuevas está ocurriendo más rápidamente en zona de debilidad estructural dentro de strata litlógicamente favorable.

INTRODUCTION

The Edwards Plateau of central Texas, U.S.A. can be divided into two components: an uplifted plateau to the west and a dissected plateau of lower elevation to the east. This paper will concentrate on cavern development in the lower dissected plateau which is known as the Balcones Fault Zone. In the elevated western Edwards Plateau, the water table is at great depth; thus numerous air-filled caves are known within the Cretaceous-aged limestones and dolomites (Texas Speleological Survey, 1961 to present). However, in the Balcones Fault Zone, ground water is much closer to the surface or occurs under confined (artesian) conditions. Therefore, caves are often totally filled with water (Smith, 1965).

Discharge from the Edwards Balcones Fault Zone Aquifer occurs from large, first-order springs. Recharge to the springs can occur from over 100 miles away. Theoretically, as undersaturated water moves towards a discharge point, more and more carbonate rock is dissolved until saturation occurs (Jacobson and Langmuir, 1970). Abbott (1977) calculated the saturation indices of calcite (SIC) and dolomite (SID) for a one-time sampling of nine wells and five springs in the Edwards Aquifer and concluded that the waters were generally undersaturated. For the spring waters, this is demonstrated by the lack of travertine deposits downstream from the outlets. He concluded that both spatial and temporal saturation data were needed to adequately investigate flow conditions in the Edwards Aquifer and the development of caverns. The chemical data used in the collection of saturation indices collected between 1981 and 1985 were published in reports by the Edwards Aquifer Research and Data Center (Ogden et al., 1985a and 1985b). This paper will model saturation indices to test whether the ground water becomes more saturated along its pathway to the springs and the Bad Water Zone and will shed light on some factors controlling the state of saturation. In addition to hydrochemical data, geological and hydrologic factors affecting cavern development will be discussed.

LOCATION, AND GEOLOGY OF THE STUDY AREA

The study area is located along the Balcones fault escarpment in Hays and Comal counties, Texas (Figure 1). The Edwards Limestone Aquifer is composed of a group of Cretaceous carbonates that have a total thickness of approximately 450 feet (137 m) in the San Marcos area. The Edwards Aquifer is composed of the Comanche Peak Limestone, Edwards Limestone, and Georgetown Limestone. Rose (1972) raised the Edwards Limestone to group status in central Texas and divided it into the Kainer (lower) and Person (upper) members. The Edwards Aquifer was later divided into hydrostratigraphic units by Maclay and Small (1983) through a detailed analysis of cores and geophysical logs. Lithologically, the Edwards Aquifer consists of rudist limestones, burrowed tidal-flat wackestones, grainstones, dolomite, nodular chert, solution-collapse breccias, and weathered, honeycombed beds.

DeCook (1963) performed the first detailed analysis of the ground water resources of Hays County. The occurrence of ground water within the hydrostratigraphic units of the Edwards Aquifer has been described by Maclay and Small (1983). The differing solubilities of the hydrostratigraphic units have had a profound effect on transmissivity and porosity.

Recharge to the aquifer occurs through losing streams located primarily to the west and south of San Marcos and New Braunfels. Surface water moves across the impermeable rocks of the Glen Rose Formation (Drainage Zone, Figure 1) until the Edwards Aquifer is encountered at the Balcones Fault Zone. Most of this water generally moves in an east/northeast direction, where it discharges at the Comal, Hueco, and San Marcos springs. Complex "down-to-basin" faulting causes the Edwards Aquifer to lie deeper and deeper below the surface as one moves in a southeast direction. The Bad Water Line represents the eastern edge of the aquifer where poor circulation has caused the water to have a high TDS (>1000 mg/l) and be non-potable.

The San Marcos Springs are the second largest spring group in Texas with an average historic flow of 161 cfs (4.50 m^3/sec). They are located in the city of San Marcos in Hays County and are owned and operated as a tourist attraction by Aquarena Springs, Inc. The spring orifices are now under up to 40 feet of water due to a dam originally created for hydroelectric power. Water issues from six major orifices along the base of the Balcones Escarpment at the San Marcos Springs as well as from numerous smaller openings.

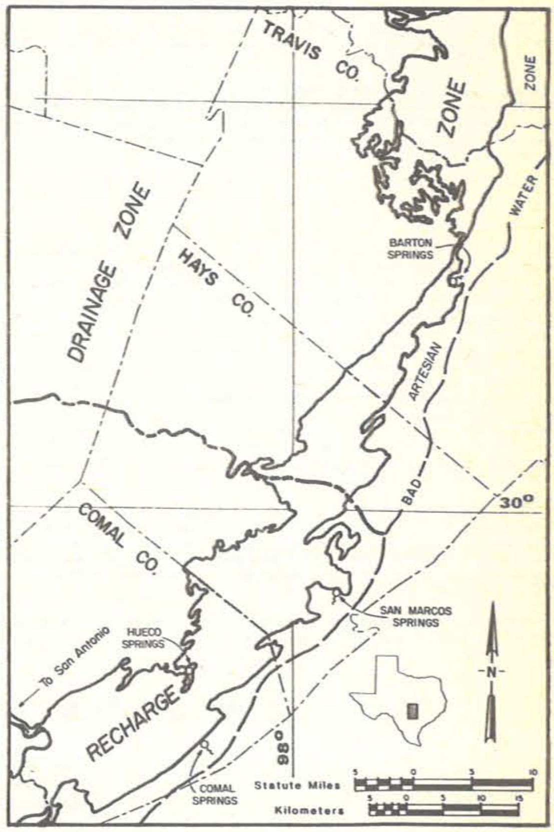

Figure 1. Location of the Study Area in Texas.

The effects of the intense faulting on ground water movement in the Edwards Aquifer was discussed by Maclay et al. (1985). Kastning (1977) studied faults and their influence on conduit enlargement throughout the Edwards Plateau, as well. He found that faults can have either positive or negative effects on cavern development. Beck (1968) also noted that faulting has an effect on cave development and growth in Comal County, which lies just fifteen miles south of San Marcos. A comparison of fault, joint, and photo-lineament orientations around San Marcos was made by Rothermel and Ogden (1989). A broader-scale analysis of photo-lineaments was recently made by Woodruff et al. (1989).

METHODS

Water samples were collected twice a month by divers from the six orifices of the San Marcos Springs. Discharge was recorded at the time of sampling.

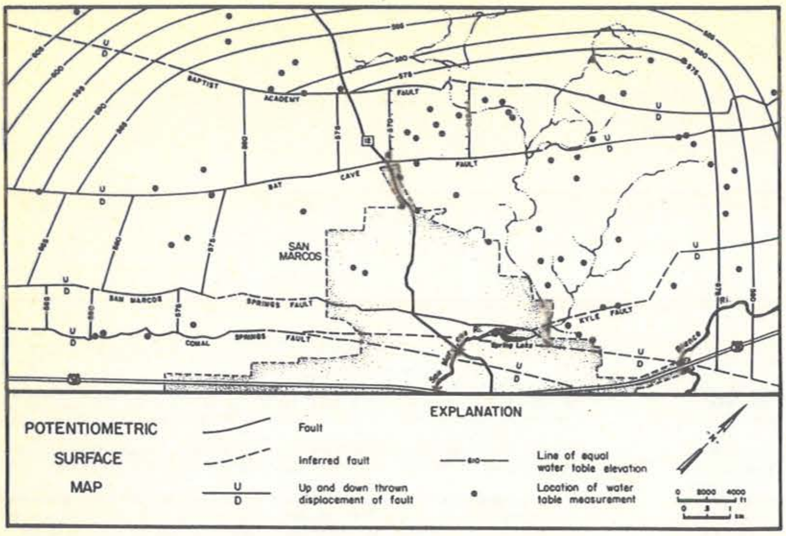

Figure 2. Potentiometric Surface Map Showing the Location of Sampled Wells.

Samples and static water levels from ninety wells were collected during a three week period February 21, 1985, and March 14, 1985 (Figure 2). All samples were collected in one quart containers from the water faucet closest to the well. Temperature, dissolved oxygen, and pH were measured in the field. Samples were then placed in a cooler with ice and brought to the laboratory for further analysis. Time-series plots of the chemical parameters measured were published previously by Ogden and Quick (1985) and Lunsford and Ogden (1985).

The USGS WATEQF program was used to calculate the saturation indices of calcite, dolomite, and gypsum. The input requires measurements for calcium, bicarbonate, pH, magnesium, sulfate, and temperature. Ionic strength was calculated by the Debye-Huckel method.

Finally, single well pumping tests were performed utilizing the methods of Jacob (1963) for calculating approximate values of transmissivity. Water well logs were obtained from the Texas Department of Water Resources to determine the stratigraphic occurrence of caves within the hydrostratigraphic units of the Edwards Limestone Group.

RESULTS

Figure 3 summarizes the structural and stratigraphic occurrence of caves within the Recharge Zone and Artesian Zone of the Edwards Aquifer. Cavern formation in the Balcones Fault Zone is controlled by a complex interaction of hydrologic, lithologic, structural, and paleo-erosional factors. Pumping (aquifer) test data and well logs show that the highest transmissivity (T) values and the most caves (intersected by wells) occur just inside the confined-unconfined boundary of the aquifer due to "mixing corrosion" (Bogli, 1964). High transmissivity and sulfur values just within the Bad Water Zone suggest that some caves are forming due to "sulfuric-acid" corrosion, similar to the theory for the origin of Carlsbad Caverns in New Mexico (Egemeier, 1987). Sulfur reducing bacteria feed on hydrocarbons found in the Bad Water Zone and are responsible for the production of hydrogen sulfide gas. This phenomena produces aggressive water within a transition zone between the Artesian and Bad Water zones. The process appears to cease deeper within the Bad Water Zone since transmissivity values rapidly decrease downdip.

Second in importance to these boundary contacts for cavern formation are the abundant faults that trend primarily in a northeast direction. Most ground water moves through fault-controlled caves with the interior of the fault blocks having lower transmissivity values and less caves. Caves have also formed at the Edwards Limestone-Georgetown Limestone unconformity boundary where an initial permeability was formed by subaerial erosion.

Also important are lithologic controls. The Regional Dense Bed member and chert horizons perch water in the unconfined zone causing caves to form in the overlying beds. Caves also form in the Leached and Collapsed Member and Kirshberg Member where evaporitic layers have been removed by dissolution. These caves are small "pocket caves" that occur randomly throughout the hydrostratigraphic units. Another lithologic control is the presence or absence of honeycombed beds. The honeycombed layers allow water to move in a nearly "homogeneous fashion" similar to porous media, and thus caves are not formed. The manifestation of the dissolution processes in the honeycombed beds is the occurrence of large interconnected megapores. The Marine Member and Basal Nodular Member of the Edwards Limestone contain few caves due to the low solubility of the clay and dolomite-rich beds.

Figure 4 shows a comparison of discharge of the San Marcos Springs to calcite, dolomite, and gypsum saturation. As discharge increased in 1983, the waters became less saturated. Essentially no recharge took place during a nine month drought period in 1984. As a result, the waters became super- saturated with respect to calcite and dolomite, but gypsum saturation levels remained relatively constant. This suggests that significant amounts of local recharge must occur from the Blanco River and Sinking Creek during wet times, but during the drought only old water which had moved great distances in the aquifer emerged from the springs. Also, during drought conditions, the ground water moves much more slowly allowing more time for dissolution to take place. This was demonstrated by two dye traces to the San marcos Springs during different water table conditions (Quick and Ogden, 1985). During high flow, ground water moved at 1500 ft/day (457m/day, but during low flow the trace between the same sites moved at only 300 ft/day (95m/day).

Another factor that might cause undersaturated conditions during normal flow periods is the precipitation of calcite before reaching the springs. Water table fluctuations associated with mixing of ground waters with different PCO_2 levels could cause calcite precipitation and new aggressiveness (Bogli, 1964). This possibility is suggested by calcite-filled vugs seen in cores taken about two miles upgradient of the springs.

Gypsum saturation levels were unaffected by the reduced volume of water during the drought. The low levels of gypsum saturation and its uniformity through time suggest that anhydrite beds within the aquifer have long since been removed by dissolution.

Figure 5 shows the distribution of calculated SIC values for ninety wells. There is a marked lack of uniformity of the data and no apparent evolutionary trend between the Recharge Zone and the Bad Water Line. The intersecting "valley and ridge" topography of the plot is thought to reflect zones of high and low transmissivity corresponding to solutionally enlarged faults and fractures and the occurrence of caves. Due to faster ground water flow along such open fractures, water would be expected to be more undersaturated than slower moving water in the unfractured rock. Some lineations of highly undersaturated waters (troughs) correlate with known faults and photo-lineaments.

ZONES OF CAVERN DEVELOPMENT IN THE EDWARDS AQUIFER

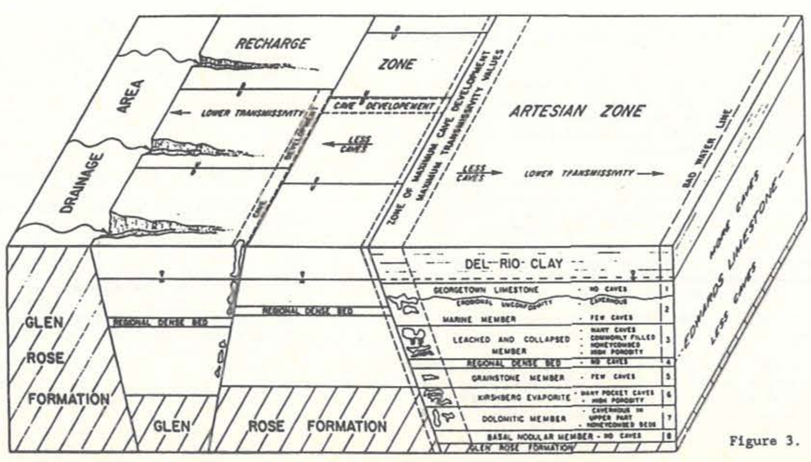

Figure 3.

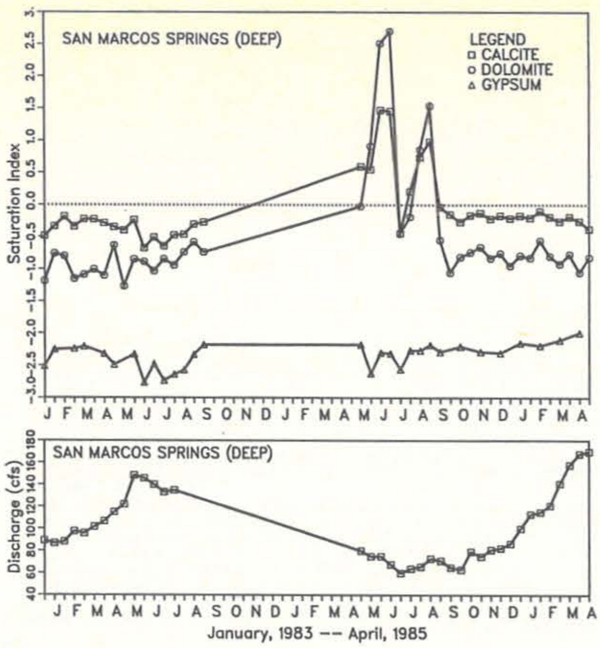

Figure 4. Comparison of Discharge versus SIC, SID, and SIG at the San Marcos Springs.

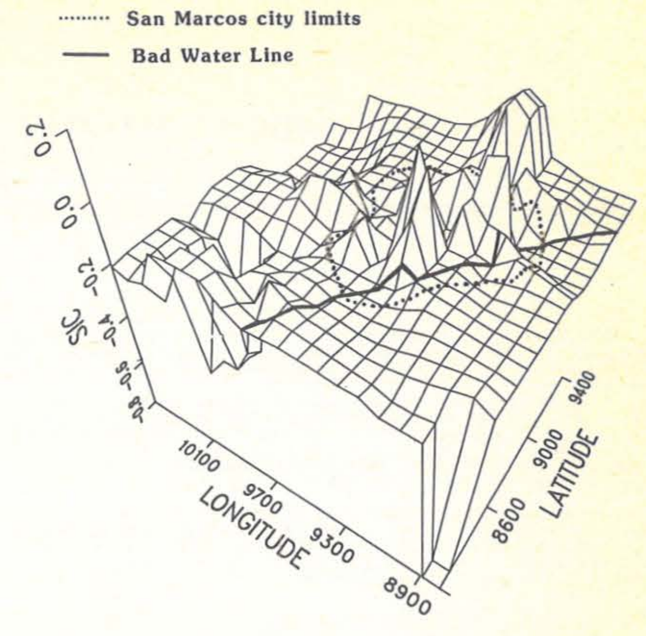

Figure 5. Distribution of SIC Values in the Edwards Aquifer in the Vicinity of the San Marcos Springs.

CONCLUSIONS

Ground water in Edwards Aquifer wells and springs throughout Comal and Hays counties during the study period was always undersaturated with respect to calcite, dolomite, and gypsum except during extreme drought conditions. Gypsum saturation values are particularly low except in the west/northwest portion of the study area where leakage across faults from gypsum beds in the Glen Rose Formation is thought to occur. No evolutionary trend in saturation of well water occurs between the Recharge Zone and the Bad Water Line, as anticipated. Instead, undersaturated waters occur along faults and fractures where the ground water moves faster, is affected more greatly by recharge events, and where there is less water/wall rock contact due to greater cave development. Mixing of local recharge waters of different PCO_2 concentrations and the precipitation of calcite before reaching the springs are believed to contribute to the undersaturated conditions, as well. Thus, cavern development throughout the Edwards Aquifer is actively occurring despite long distances between recharge and discharge areas. The growth of caves is probably growing faster along the faults within the more soluble hydrostratigraphic members. "Mixing corrosion" appears to be responsible for the high density of caves along the unconfined-confined boundary of the aquifer system. Finally, the "sulfuric-acid" theory of cave origin may be applicable at the Bad Water Line, but transmissivity values and cave development rapidly decrease in a down-dip direction, deeper within the Bad Water Zone.

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CAVE SALTPETRE: CHEMICAL, HISTORICAL AND MINERALOGICAL ASPECTS

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Saltpetre caves in Spain, France, West Germany, and Virginia, USA were visited to study the nature of saltpetre occurrences. The earliest saltpetre history is reported at Sophienhöhle (West Germany), which was visited in 1490. Forty-six efflorescent wall- and floor-crust samples and 35 sediment samples were collected from ten caves. Nitrate minerals, which are deliquescent, were found only in crust samples from Peery Saltpetre Cave, USA. Niter [KNO_3] and nitromagnesite [$Mg(NO_3)_2 \cdot 6H_2O$] formed by the evaporation of leachates from the cave sediments of Sophienhöhle and the six American caves. Data from chemical analyses of the leachates indicate that 12 specimens from the American caves have nitrate (NO_3^-) concentrations greater than 10,000 mg/L. From cation and anion compositions it can be inferred that with lower humidity 19 sediment leachates would have yielded the highly deliquescent mineral nitrocalcite [$Ca(NO_3)_2 \cdot 4H_2O$]. Chemical evidence confirms that all ten caves contain saltpetre.

HÖHLEN-SALPETER: CHEMISCHE, HISTORISCHE UND MINERALOGISCHE ASPEKTE

Salpeter-Höhlen in Spanien, Frankreich, der Bundesrepublik Deutschland und den USA (Virginia) wurden hinsichtlich der Art iher Salpetervorkommen untersucht. Die früheste salpetergeschichte ist von der Sophienhöhle (Bundesrepublik Deutschland) bekannt und reicht bis in das Jahr 1490 zurück. Sechsundvierzig Proben von Wand- und Bodenausblühungskrusten sowie 35 Sedimentproben aus zehn Höhlen wurden untersucht. Leicht zerfliessliche Nitratminerale wurden nur in Krusten aus der Peery Salpeter Cave (USA) gefunden. Niter [KNO_3] und Nitromagnesit [$Mg(NO_3)_2 \cdot 6H_2O$] bildeten sich durch Lösungsverdunstung aus Sedimenten der Sophienhöhle und der sechs Amerikanische Höhlen. Chemische Analysen dieser Lösungen ergaben, dass 12 Proben aus den Amerikanische Höhlen Nitrat (NO_3^-)-Konzentrationen von über 10 000 mg/L aufwiesen. Aus der Ionenbilanz ergibt sich, dass bei geringerer Feuchtigkeit 19 Sedimentwasser das leicht zerfliessliche Mineral Nitrocalcit [$Ca(NO_3)_2 \cdot 4H_2O$] gebildet hätten. In chemischer Hinsicht enthalten alle zehn Höhlen Salpeter.

1. INTRODUCTION

Saltpetre was obtained from caves in Europe and the southeastern United States of America primarily during times of war, when imports were restricted and there were great demands for saltpetre for the manufacture of gunpowder. Mining efforts were most intense during the European conflicts (into the 1800s) and the American Revolution (1775-1783), the War of 1812, and the Civil War (1861-1865) in the USA. Petre dirt (saltpetre earth) was leached of its nitrates and the resultant leachate was titrated with a leachate from wood ashes. The decanted liquor was boiled until KNO_3 crystallization occurred. Identifications of nitrate minerals in early reports have not been verified by modern techniques (Hill, 1981a), because nitrate minerals are deliquescent and do not normally crystallize in the high-humidity environments found in most southeastern American (Hill, 1981b, p. 127) and European caves. The identity of the nitrates in the saltpetre earth of these caves is still unclear. The composition of the saltpetre in six of Virginia's 76 known saltpetre caves was studied by Hubbard and others (1986). In 1986, saltpetre caves in Spain (1), France (2), and West Germany (1) were visited and samples were collected to determine if nitrate minerals were present and to identify the saltpetre constituents in leachates of the cave sediments (Figure 1). This paper presents a comparison of the chemical, historical, and mineralogical aspects of saltpetre in the six American and four European saltpetre caves.

2. CAVES SAMPLED

Cova del Salnitre (SP) is in the province of Catalonia, Spain, in Paleocene to Eocene limestone pebble conglomerate. This 549 m long cave was first worked for saltpetre in the 1500s. Mansuet Buxo Xalavia, a guerrilla fighting Napoleon's army, used the cave as a base of operations and produced gunpowder from the cave (José Ma. J. Raventòs, 1988, written communications).

Grotte d'Enfer (GE) is near Les Eyzies, France, in Cretaceous limestone. It is essentially an abri (shelter cave) with a small stream. The cave was worked for saltpetre in 1793 (Lartet and Christy, 1864, p. 242).

Grotte de la Salpêtrière (GS) is located on the Gard ou Gardon within 150 m of Pont du Gard, France, in Upper Jurassic limestone (Créac'h, 1967, p. 93). Also refered to as Abri de Prehistorique, it is a shelter cave. Cave sediments are dated 15,000 years before present (Belot, 1977, p. 175). No information on the saltpetre history of this cave was found.

Sophienhöhle (SH) is near Bayreuth, Bavaria, West Germany, in Jurassic dolomite. Although the cave is about 465 m long (Kempe and others, 1982, p. 102), saltpetre workings were confined to a mazy entrance area. The cave was visited in 1490 by Hans Breu in search of saltpetre (Cramer and others, 1935). Saltpetre was mined at the cave, according to the cave manager, but the date of this activity was not determined. Evidence of the removal of saltpetre earth was found in small wall and ceiling alcoves. *Ursus spaleous* remains have been removed from the entrance area.

Johns Cave (Jo) is in Frederick County, Virginia, USA, in limestone and dolomite of the Rockdale Run Formation (Ordovician). Evidence of the mining of saltpetre earth was found throughout this 100 m long cave and includes diggings, old sediment levels on walls, and four mounds of petre dirt thought to be the remains of leaching vats or their spoils. A number of inscribed names or initials dating from the 1780s and 1790s occur in the vicinity of the sediment mounds. The cave has been cited as "remarkable only for its production of saltpetre, and preserving fresh meats in hot weather" (Kercheval, 1833, p. 319).

Madisons Saltpetre Cave (Ma) is in Augusta County, Virginia, USA, in limestone and dolomite of the Conococheague Formation (Cambrian). The cave contains about 490 m of passage, although 90 m are under water. Diggings, names and dates, and old sediment levels on the walls comprise evidence of saltpetre mining. Wall inscriptions are dated as early as the 1770s and include the name of one known supplier to the Continental Army (Revolutionary War), two names dated 1813 (War of 1812), and an inscription by "Greenlee Davidson" in 1863. According to his diary, Captain Davidson collected samples of earth from this cave for analysis of saltpetre in 1862. Hovey (1897, p. 291) reported Jedekiah Hotchkiss, General Stonewall Jackson's map maker, to have said, "Madison's Cave was mined for saltpetre during the three great wars, of the revolution, of 1812, and of the rebellion - probably the only cave on the continent of which that can be said."

Clarks Cave (Cl) is located in Bath County, Virginia, USA, in the Devonian Licking Creek Limestone. The cave contains 9.1 km of mapped passage (Collings, 1988, p. 26), a third of which was worked for saltpetre. "Evidence indicates that this cave was worked for saltpetre as early as 1740. Mr. (Grady) Clark, who owned this property for many years, reported that his grandfather (Samuel Clark) worked in the cave during the War of 1812" (Faust, 1964, p. 42). Saltpetre mining occurred during the Civil War (Douglas, 1964, p. 152) when this cave was possibly a part of Horner's niter works (Smith, 1987, p. 22). The extensive saltpetre workings contain abundant evidence of mining, including tally marks, artifacts, excavations, fills and other passage modifications.

Witheros Cave (Wi) also is located in Bath County, Virginia, USA, in the Licking Creek Limestone (Devonian). Approximately one third of this 3297 m long cave (Simmons, 1981, p. 11) contains evidence of saltpetre mining. The most recent mining activity was probably during the Civil War era.

Peerys Saltpetre Cave (Pe) is in Botetourt County, Virginia, USA, in limestone and dolomite mapped as the Cambrian Conococheague Formation (Spencer, 1968). The cave is reported to be over 400 m long (Douglas, 1964, p. 188) and contains evidence of mining activity throughout. "This cave is very likely the place where, it was reported in 1775 that, Charles Lynch had found 'many rocks of GENUINE SALTPETRE'" (Faust, 1964, p. 45). Mining operations during the Civil War were reported by the cave's owner, Mrs. Mary Goodwin (Mansfield and Boardman, 1932, p. 97).

Curve Saltpetre Cave (Cu) is located in Giles County, Virginia, USA, in limestone and dolomite of the Ordovician portion of the Knox Group. Evidence of saltpetre mining is found throughout this 200 m-long cave. Workings reportedly date from the Civil War (Douglas, 1964, p. 226; Holsinger, 1975, p. 91), but inscribed dates associated with diggings indicate that some work was carried out before the Civil War.

3. METHODS

Mineral and sediment samples were collected at each of the ten saltpetre caves. Fourty-six mineral samples consisting of efflorescent crusts were collected in vials from sediment and rock surfaces of the cave floors, walls, and ceilings. Thirty-five sediment samples were collected from cave areas with evidence of saltpetre mining. Typically, well aerated, nearly dry, spongy sediments with little organic material were sampled.

Sediment samples were air dried for approximately one week until they attained a constant weight. A 700 g subsample, excluding charcoal and large rock fragments, was mixed with 500 mL of distilled water in an inverted 1000 mL polyethylene bottle with its bottom removed and with a glass cotton filter in the neck of the bottle. After 24 hours, the subsample mixture was allowed to drain through filter paper into an Erlenmeyer flask. After an additional 24 hours, the mixture was vacuum filtered for additional leachate yield. The leachate constituents were precipitated by allowing approximately 10 mL of leachate to evaporate from a watch glass.

Mineral and sediment samples and chemical compounds precipitated from the leachates were identified by X-ray diffraction and optical microscopy. Sediment leachates were filtered an additional time through a 0.45 μm filter and then split. Half of each leachate was acidified with concentrated HNO_3. The acidified leachate was diluted and analyzed by atomic absorption for Ca^{2+}, Mg^{2+}, Na^+, and K^+ using an Instrumentation Laboratories model 751 dual-beam spectrophotometer. The unacidified leachate subsamples were

Figure 1. Locations of the four European saltpetre caves discussed in this paper: 1. Cova del Salnitre; 2. Grotte d'Enfer; 3. Grotte de la Salpêtrière; 4. Sophienhöhle. Locations of the six American saltpetre caves can be found in Hubbard and others (1986).

diluted and analyzed for Cl^-, NO_3, SO_4^{2}, and PO_4^{3} using a Dionex Ion Chromatograph.

4. RESULTS

The minerals identified from the 46 mineral samples are summarized in Table 1. Only two of the samples contained nitrate minerals. Crusts Pe 7B and Pe 7C (Peerys Saltpetre Cave) were identified as niter (KNO_3). The niter occurred as white, kinky, lint-like fibers approximately 1 cm in length on the top and side of a small ledge (site Pe 7B) and as white, silky, hair-like fibers up to 2 cm long on the top and sides of a small ledge (site Pe 7C).

The mineralogical compositions of the 35 sediment samples are summarized in Table 2. Only the major minerals were identified by whole-sample X-ray analysis.

Precipitates formed by evaporation of leachates of the sediment samples are reported in the "Evaporated Leachate" column of Table 2. Halite precipitated from leachates of sediments from the four European saltpeter caves, but not from the six American saltpetre caves. Gypsum was usually the first and most prevalent precipitate from all of the leachates. Niter precipitated from leachates of Sophienhöhle (SH 4 and SH 5) and Curve Saltpetre Cave (Cu 2 and Cu 3), but was conspicuously absent from the precipitates of Peery Saltpetre Cave leachates. Nitromagnesite [$Mg(NO_3)_2 \cdot 6H_2O$] was observed to form only when the humidity of the X-ray laboratory was reduced to the low-thirty to mid-forty percent range. At these lower humidities, niter and nitromagnesite were identified from 16 leachates, which include representatives of each of the six caves of Virginia and Sophienhöhle. Twenty-two leachates did not fully evaporate and no nitrocalcite [$Ca(NO_3)_2 \cdot 4H_2O$] was identified. No nitrate compounds were found upon complete evaporation of five leachates (GS 1, Jo 2, Jo 4, Wi 1, and Wi 5).

Cation and anion analyses of the leachates are tabulated in Table 3. Nitrate (NO_3^-) concentrations range from a high of 36,210 mg/L, 2.6 percent by weight, (Madisons Saltpetre Cave, Ma 2) to a low of 6 mg/L (Grotte de la Salpêtrière, GS 1). Twenty-one leachates, including representatives of all six of the caves of Virginia and Sophienhöhle, had nitrate concentrations greater than 3000 mg/L. Phosphate (PO_4^{3-}) was below detection limits in the dilutions used for the American leachates and was not analysed for the European leachates.

Table 1. Mineralogical composition of efflorescent crusts

Sample[1] Name	Composition[2]	Sample[1] Name	Composition[2]
SP 1A	taranakite	Ma 3A	gypsum, tr. quartz
SP 2A	apatite group	Ma 3B	gypsum, tr. quartz
SP 3A	brushite	Ma 4A	apatite, tr. unknown
SP 4A	brushite		
SP 5A	apatite group	Cl 1A	gypsum
		Cl 2B	epsomite, tr. calcite
GE 1	calcite, tr.[3] weddellite	Cl 2C	epsomite
GE 2	calcite	Cl 3A	gypsum
GE 3	weddellite		
		Wi 1A	epsomite
GS 3A	gypsum, muscovite,	Wi 1B	epsomite
	kaolinite, tr. quartz	Wi 1C	epsomite
GS 4A	gypsum, calcite,	Wi 1D	epsomite
	muscovite, tr. calcite	Wi 1E	epsomite
GS 5A	calcite, min. quartz	Wi 2A	gypsum or brushite
		Wi 2B	gypsum or brushite
SH 1A	gypsum, dolomite	Wi 4B	calcite
SH 2A	gypsum	Wi 4C	gypsum, tr. quartz
SH 6A	dolomite		
		Pe 2A	epsomite
Jo 2A	calcite, dolomite	Pe 3A	nesquehonite
Jo 2B	calcite, dolomite	Pe 7B	niter
Jo 3A	calcite, dolomite	Pe 7C	niter
Jo 3B	calcite, dolomite		
		Cu 1A	nesquehonite
Ma 2A	calcite, quartz,	Cu 4A	gypsum
	kaolinite, chalcedony	Cu 4B	amorphous powder
Ma 2B	amorphous, quartz	Cu 4D	calcite
Ma 2C	gypsum, tr. quartz	Cu 5A	gypsum

[1]First two letters refer to cave name
[2]Identification by X-ray diffraction
[3]tr. indicates trace amount

Table 2. Mineralogical composition of sediments and evaporated leachates identified by X-ray diffraction

Sample[1] Name	Sediment	Evaporated Leachate	Evaporation[2] State
SP 1	qtz, tarnk, ill, ps. lcphs	gyp	moist
SP 3	qtz, tarnk, ill, ps. lcphs	gyp	moist
GE 4	calc, qtz, dtr. tour	gyp, hal, calc	wet
GE 5	calc, qtz	hal, gyp, calc	moist
GS 1	calc, qtz, ill, tr. kaol	hal, calc	dry
GS 2	calc, qtz, ill, tr. kaol	gyp	moist
SH 3	dol, qtz, tr. kaol	gyp, nitrmag	moist
SH 4	qtz, dol, mn. kaol	gyp, nitr, hal, calc	dry
SH 5	qtz, dol, mn. kaol	nitr, calc	dry
Jo 1	qtz, ill, tr. kaol, sp. dol	gyp, nitrmag	wet
Jo 2	qtz, ill, tr. kaol, sp. dol	gyp, hexhyd	dry
Jo 4	qtz, ill, tr. kaol, sp. dol	amrph, calc	dry
Ma 1	qtz, mn. ill, mn. kaol, mn. mcrcl	gyp	wet
Ma 2	qtz, mcrcl, tr. ill, tr. kaol	gyp, nitrmag	moist
Ma 3	qtz, mn. kaol, mn. mcrcl, tr. ill	gyp, nitrmag	moist
Ma 4	qtz, mn. mcrcl	gyp	wet
Cl 1	qtz, ill, sp. albt	gyp	wet
Cl 3	qtz, ill, gyp, sp. albt, tr. kaol	gyp, nitrmag	dry
Cl 4	qtz, ill, tr. kaol	gyp	wet
Cl 5	qtz, ill, tr. gyp, tr. kaol	gyp	wet
Wi 1	qtz, gyp, tr. ill	gyp, hexhyd	dry
Wi 3	qtz, ill, sp. albt	gyp	wet
Wi 4	qtz, gyp, tr. ill, sp. albt	gyp, nitrmag	wet
Wi 5	qtz, ill	gyp, calc	dry
Pe 1	qtz, dol, ill, tr. calc	gyp, nitrmag	dry
Pe 4	qtz, ill, kaol	nitrmag	dry
Pe 5	qtz, kaol, tr. ill	nitrmag	dry
Pe 6	qtz, ill, tr. kaol	nitrmag, gyp	wet
Pe 7	qtz, ill, dol, tr. kaol	gyp, nitrmag	moist
Pe 8	qtz, ill, kaol, tr. dol	gyp	moist
Pe 8B	dol, qtz, kaol, ill, tr. calc	unkn	wet
Cu 1	qtz, ill, sp. dol, tr. kaol	gyp, nitrmag	dry
Cu 2	qtz, ill, tr. kaol	amrph, nitr, epsmt	dry
Cu 3	qtz, ill, tr. kaol, sp. dol	nitr	dry
Cu 5	qtz, ill, tr. kaol, sp. dol	gyp	wet

albt: albite, **amrph**: amorphous, **calc**: calcite, **dtr.**: detrital, **dol**: dolomite, **epsmt**: epsomite, **gyp**: gypsum, **hal**: halite, **hexhyd**: hexahydrite, **ill**: illite, **kaol**: kaolinite, **lcphs**: leucophosphate, **mcrcl**: microcline, **mn.**: minor, **nitr**: niter, **nitrmag**: nitromagnesite, **ps.**: possible, **qtz**: quartz, **sp.**: spot pattern indicates specimen contained only a few grains, **tarnk**: taranakite, **tour**: tourmaline, **tr.**: trace, **unkn**: unknown

[1]first two letters refer to cave name
[2]Evaporation state at relative humidity of mid-forties

5. DISCUSSION

There are considerable differences between the European and the American saltpetre occurrences compared in this paper. The European caves occur in younger rocks (Lower Cenozoic and Mesozoic), while the American caves are in Paleozoic rocks. The saltpetre deposits in three of the European caves were located in the entrance areas whereas all of the American caves tended to contain more extensive distributions of saltpetre earth. The only nitrate mineral found in the saltpetre caves was niter (Table 1, Peerys Saltpetre Cave), however, niter and nitromagnesite did precipitate from the leachates of sediments of Sophienhöhle and all six of the caves of Virginia (Table 2). Data from chemical analyses of the leachates (Table 3) indicate that 12 specimens, all from American caves, have nitrate (NO_3^-) concentrations greater than 10,000 mg/L.

After nitromagnesite had precipitated from a number of the leachates, a thick viscous slurry was observed even at relative humidities in the low-thirty to mid-forty percent range. A similar leachate slurry was considered a solution of calcium nitrate by Maxson (1932). All 15 of the American leachate subsamples which did not fully evaporate (damp or wet on Table 2) initially contained over 3000 mg/L of NO_3^- and high calcium concentrations (Table 3). These leachates should yield nitrocalcite upon complete evaporation (Hubbard and others, 1986). Six of the nine European leachate subsamples did not fully evaporate under similar low relative humidities. Five of the subsamples initially contained over 500 mg/L of NO_3^- and over 400 mg/L of Ca^{2+}. The sixth subsample only contained 14 mg/L of NO_3^-, but an American specimen (Cu 3) with only 42 mg/L of NO_3^- precipitated identifiable niter. A very small amount of highly deliquescent nitrocalcite may be capable of bonding with enough moisture to maintain a state of dissolution at the relative humidities and temperatures found in our laboratory in Virginia.

Hill (1981b, p. 131) ranked the nitrate minerals in decreasing order of deliquescent stability in the cave environment as niter, soda-niter ($NaNO_3$), ammonia-niter (NH_4NO_3), nitromagnesite, and nitrocalcite. Considering this ranking and the data presented by Hubbard and others (1986) and this paper, the composition of cave saltpetre in the six American caves is probably a mixture of nitromagnesite and nitrocalcite with local concentrations of niter. Although the four European caves appear to have much lower concentrations of nitrates, we believe that the composition of the saltpetre is probably nitrocalcite. Nitromagnesite is apparenty an important constituent where a source of magnesium is available, such as the dolomite rock at Sophienhöhle. Niter is probably only locally concentrated in some caves in Virginia. The possibility that darapskite [$Na_3(NO_3)(SO_4) \cdot H_2O$], unranked by Hill (1981b), is present in saltpetre caves in Europe or Virginia cannot be discounted. Seasonally, extended periods of cold, low-humidity weather (January-February) can result in low cave humidities, especially in the European abris. We postulate that in addition to niter, nitrocalcite and nitromagnesite may occur seasonally in some saltpetre caves in Europe and Virginia.

Table 3. Cation and anion concentrations in leachate (mg/L)

Sample[1] Name	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Cl^{-}	NO_3^{-}	SO_4^{2-}
SP 1	806	88	40	99	153	1493	1562
SP 3	636	75	18	50	82	868	1644
GE 4	1141	75	667	233	1309	2220	141
GE 5	239	17	346	51	1089	14	61
GS 1	55	3	16	4	60	6	40
GS 2	422	49	130	27	294	566	872
SH 3	1806	925	163	414	483	7930	2510
SH 4	49	44	43	139	110	290	206
SH 5	27	41	32	145	56	350	58
Jo 1	2705	2315	100	183	222	22250	383
Jo 2	201	85	10	86	2	301	778
Jo 3	24	25	7	3	3	36	32
Ma 1	3926	612	59	76	253	12980	1037
Ma 2	9345	1450	630	2240	195	36210	871
Ma 3	4246	857	60	279	10	19620	773
Ma 4	3224	852	70	31	13	15190	676
Cl 1	1712	280	174	24	187	4544	924
Cl 3	1118	803	257	26	178	4580	1780
Cl 4	5350	1270	620	89	344	25290	481
Cl 5	2713	706	122	104	419	11580	1066
Wi 1	788	1783	546	34	508	3824	2034
Wi 3	5285	411	115	72	83	18790	773
Wi 4	1417	703	299	58	83	4544	1469
Wi 5	684	64	36	34	10	67	1592
Pe 1	2425	1725	267	214	237	16430	2041
Pe 4	676	1426	116	35	236	4652	77
Pe 5	43	78	28	22	26	345	164
Pe 6	2925	1725	354	234	419	21070	383
Pe 7	2265	3130	559	512	919	22670	1554
Pe 8	1561	469	44	54	81	4406	614
Pe 8B	3102	918	79	118	83	14010	968
Cu 1	504	546	45	46	50	3032	735
Cu 2	64	41	21	121	9	483	103
Cu 3	13	5	4	58	3	42	27
Cu 5	716	319	94	47	314	3500	340

[1] First two letters refer to cave name

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PINLIKE "PEASTONE"-SPELEOTHEMS AS INDICATORS OF DRAUGHT IN CAVES

LORBERER, Arpád - RÓNAKI, Laszló

The paper discusses on pisolitelike speleothems developed with condensation from vapour with $CaCO_3$-aerosols of the way-out currents of air in caves (Photo 1). These "peastones" develope mostly in narrow lithoclases and in flow-shades of jutting edges, in consequence of the local decrease of the partial vapour-pressure of air. For the exploration works of caves these speleothems can be related to the existing draught of air, that can indicate the existence of unexplored parts of caves, too.

The successfully excavated lithoclases in the Mecsek Mountains (S-rn Hungary, e.g. Photo 2) and the lots of pinlike "peastones" in the narrow tubelike parts of the main galleries of high-mountainous shaft-caves verify the speleological importance of these concretions.

Knöpfchensinterbildungen, als Indikatoren der Luftströmung

Es handelt von Knöpfchensinterbildungen, mit - von kaltas Karstwasser stammenden - Kalzitmaterial, die von - aus dem Kondenzwasser der von Höhlen ausströmenden Luft ausscheidenden - $CaCO_3$ Aerosolen entstehen (Abb. 1). Derartige Bildungen entwickeln sich infolge der Verminderung parziellen Dunstdruckes in engen Höhlengängen und an Stellen der Wirbelbildung. Diese Bildungen sind von Hinsicht praktischer Höhlenentschliessung darum interresant, weil ihre Vorkommen in engen Höhlengängen weisen an weitere, unerschliessene Höhlensysteme hin. In Mecsek Gebirge weisen das mehrere erfolgreich freigelegte Spalten (Abb. 2) und in den engen Verbindungsgängen der hohegebirgischen Schachthöhlen befindliche, nadelartige, kleine Knöpfchensinter anschaulich an.

Nyeles borsókő-képződmények, mint huzat-indikátorok

A tanulmány a barlangokból kifelé áramló levegő kondenzvizéből kiváló $CaCO_3$-aeroszolokból keletkező, hidegvizes kalcit-anyagú borsókőképződményekkel foglalkozik (1. ábra). Az ilyen képződmények a barlang szük járataiban és örvényképződési helyeinél fejlődnek ki a parciális páranyomás csökkenése következtében. A gyakorlati barlangfeltárás szempontjából ezek a képződmények azért érdekesek, mert előfordulásaik a szük járatokban további, feltáratlan üregrendszerekre utalhatnak. A Mecsek-hegységban több sikeresen kibontott hasadék (2. kép) és a magashegységi zsombolyok szük összekötő járataiban található tüszerü apró borsókövek ezt szemléletesen igazolják.

The pisolitelike carbonatic speleothems, forming cauliflowerlike concretions or formations similar to the clusters of grapes are named in general "peastones" in Hungary - independently of mineralogical respects. The greater part of this speleothems are constructed from aragonite - and from thermalwater originated calcite-minerals, but there may be found concretions of coldwater calcite-minerals too. The single elemental sphericities can develope one by one with or without pinlike neck on the limestone- or dolomitewalls of caves, but mostly - especially in the hydrothermal karstic caverns - in greater mass, forming several pisolitic and pisolitelike concretions. The latter speleothems of typical hydrothermal origin was named by CHOLNOKY, J. (1944) as "resostones", however this genetic differentiation is very rarely in use. Certain authors (e.g. GÁNTI, T.: 1957, 1962) put also the true pisolite (i.e. the cave-pearls) and some fungoidic concrecions among the peastones (after GRADZIŃSKI,R. UNRUNG,R.:1960). The present paper discusses further on pisolitelike speleothems of condensational origin only, developed in several active stalactite-caves and shafts with cold karstic waters (e.g. underground streams) in close connection with the aerodynamic conditions of this caves.

As it is well-known, there are two different types of condensational waters in the undergound holes and caves. (JAKUCS,L. - KESSLER,H.: 1962, KUŇSKÝ,J. 1960).

The water condensed from the air of breeze cooled under temperature adequate to the maximum saturation with vapour, into the inner parts have a corrosive effect on the surfaces of carbonatic rockwalls and speleothems of the caves. This condensed water has not any dissolved solids, but composes agressive carbonic acid with the CO_2-content of the air and therefore several characteristic secondary corrosive mikroforms (e.g. karrlike little furrows, corroded stalactites, etc.) could develop on these surfaces. The insoluble contaminations of corroded rocks (silicates, clay-minerals,etc.) could be left over some places, forming gradually thickening soft platings (e.g. concretions of "Blotne zamki" - "Muddy-castles" in the Mie tusia cave, W-rn Tatra Mountains, Poland). These corrosive condensational waters can exert their effects mainly in the near-entrance parts of karstic caves.

The other type of condensational waters is originating from the "karstwater-vapour" saturated air of currents occuring from the inner pants toward the entrances of caves. The vapour of karstic water have some $CaCO_3$-aerosole content, which have been getting into the air-space of caves by mechanical processes with the water-drops falling off the roof and the stalactites and being dispersed at the ground or stalagmites (CSER,F.-MAUCHA,L.:1968). The formation of the little coldwater-calcite sphericities adhered to the pinlike branches is derived from that type of condensational waters (MURRAY,J.W.:1954, JAKUCS,L.-KESSLER,H.:1962).

One can form a more exact idea of the developing process of these speleothems, considering the places of its appearance and the local aerodynamic conditions in the karstic caves. Namely these pinlike pisolitic speleothems can be found mostly in the narrow lithoclases or tubelike galleries where they are making more difficulties by creeping through these sections of caves. Therefore there are known also different speleologic nicknames of thie "pinlike peastones" (e.g. in hungary: "ruhaszaggatók" = dress-tearers. In poland: jaskiniowe jamniki = cave-dachshunds, etc.).

Taking into account the stable air temperature and saturation with vapour in the inner parts of caves, the air currents toward the entrances may be considered as quasi-stationary ones. According to the BERNOULLI-equation-having validity in case of stationary volume-flows - the decrease of the cross-section cause increase in the flow velocity and decrease in the pressure of the flowing medium. As a consequence of the decrease of the partial vapour pressure in the air local supersaturations will occur and the surplus of vapour will condense together with the $CaCO_3$-aerosols on the surface of cave-galleries. The separated solid aerosols will develope pinlike pisolitic speleothems directed by the air-currents. The air flowing further into the larger caverns is able to become saturated with "karstwater-vapour" again.

From the aerodynamic point of view the karstic caves and shafts are irregular systems with many possibilities for turbulent currents and forming of whirls. No wonder then that also in the flow-shades of jutting edges there are frequently this type of little "pinlike peastones". The excentric stalactites (i.e. the helictites) having a similar $CaCO_3$--aerosole origin develope mainly also in the lateral, blind caverns; in the vicinity of galleries with intensive air--currents (CSER,F.-MAUCHA,L.:1968).

From the cave-explorational point of view it is essential, that these "pinlike peastones" having condensational origin can he related to the existing (or during a long time existed) draught of air. It also can indicate the existence of unexplored parts of cave. This connection of pinlike pisolitic speleothems with the draught was first recognized empirically in the course of exploration works on active caves of the Mecse-Mountains (SE-transdanubia Hungary), it has been used successfully in the speleological practice for about two decades (RÓNAKI,L.: 1961-80). Recommendation was given for practical application of the phenomenon observed and published in 1963 (RÓNAKI,L.: 1980). As an example it is represented by photos 1-2. These are indicators of draught in the "Korallzsomboly" cave.

The clearest examples for the genetics and development of this pinlike speleothems are abounding in the typical alpine (i.e. high-mountainous) shaft-caves, having otherwise rather few concretions. The $CaCO_3$-aerosols originating from the air-space of larger caverns or shafts with very high "karstwater-vapour" content (e.g. deeper parts with underground streams of waterfalls) are separating with the condensed water in the narrow lithoclases or tubelike galleries of the way out, as by the "great shafts" in the wysoka- and Ptasia-caves in the W-rn Tatra Mountains (S-rn Poland), in the Spluga della Preta (N-rn Italy) or cave of Winds (Vintului) in the Bihar-Királyerdő (S. Craiului) Mountains (Transsylvania, Rumania).

In Hungary the average temperature in caves is + 10 C°. The temperature in caves mentioned above is lower. We tried to observe the phenomenon in tropical karst terrain, therefore we studied several caves in Cuba in 1988. Unfortunately we have not found any aerosol formations. It does not mean that they cannot occure in the case of 24-26 C° air temperature of caves, however, further examination is needed. The precipitation of peastones in cave-basins filled with stagnant water was a very interesting observation (Piñar del Rio, Viñales; Cueva San Thomas). These formations on walls no longer covered with water were similar to peastones known in hydrothermal caves of Buda Mountains.

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SCULPTURES ET GRAVURES RUPESTRES AL'ILE DE NAXOS DEPUIS L'EPOQUE PREHISTORIQUE JUSQUE A NOS JOURS

PETROCHILOU, Anna

RESUMÉ

Naxos est la plus grande et la plus remarquable île des Cyclades, connue pour son paysage, aussi que pour son art qui date des l' epoque néolithique.

Les habitants qui ont vécu dans les grottes, ou en pleinair, ont laissé les traces de leur vie, et plus tard, ces de leur civilisation connue sous le nom de la "civilisation Cycladique".

Nous allons mentionner ses fameuses gravures rupestres qui representent le zodiaque et des scènes de leur vie quotidienne, et aussi des statuette en marbre, qui sont devenus celèbres dans tout le monde.

Des fouilles realiseés à Naxos ont mis au jour de temples, des tombes, des vases et d'autres oeuvres d'art, parmi lesquels les statues des Kouroi sont les plus connues.

On y trouve encore aujourd'hui inachevées en pleinair, près des carrieres de marbre, ces statues abandonnées à leur someil éternel.

SUMMARY

Naxos is the biggest and most important island of the Cyclades famous for its landscape and its art.

The prehistoric habitation of the island y'prooved from the archaeological survey and the excavations reconvered many elements of that period. The incisions on the rocks found near Apiranthos and representing scenes of every day life, and also tools of obsidien are some of these indications.

Later the famous idols of marble are the most important signs of the so called "Cycladic Civilisation" while the big Kouroi of the archaic period proved the continuity of art and civilisation during many Centuries.

L'île de Naxos est la plus vaste de l'archipel des Cyclades,et se présente comme la plus remarquable tant en belle nature qu' en préhistoire et histoire.

A cette île on été découvertes des traces des hommes préhistoriques qui ont vécu dans les grottes ou en plein air. Des outils en obsidienne, des vases, des idoles, des gravures rupestres, etc.

C'est à Naxos que parut et prospera la civilisation cycladique, parallelement à la civilisation minoenne en Crète, depuis 40 ciècles avant notre ère.

Mais tandis qu'en Crète la civilisation minoenne s' efface au XIVe siècle av.J.C., à Naxos la civilisation cycladique continue à un niveau remarquable jusque au 1100 av.J.C.

De fouilles effectués à Naxos ont mis à jour des aglomerations de maisons, des outils, des ustensiles, des tombeaux, des armes et autres oeuvres d'art.

Les matériaux utilisés étaient: l' obsidienne, la pierre, la terre, le marbre, les métaux.

Il est bien connu que les plus anciens ustensiles en terre, des hommes primitifs étaient faits à la main et plus tard au tour. A Naxos aussi, les ustensils en terre étaient cuits aux rayons du soleil et plus tard au feu.

Pendant la moyenne époque cycladique (2000-1400 av.J.C.) l'usage de la terre est influencé par l'art minoen tandis que plus tard (1400 -1100 av.J.C.) par l'art mycénien predominant en crète.

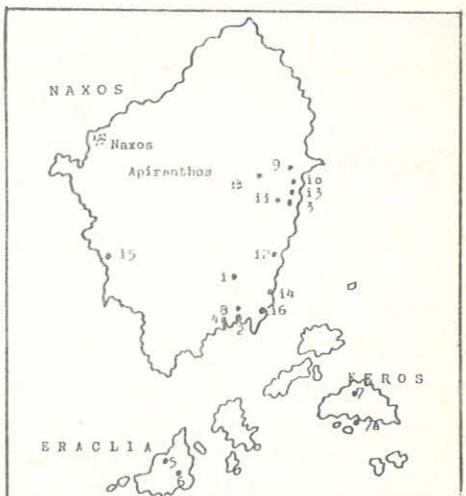
Pendant la période mycénienne, la ville de Naxos, était considerée comme la plus importante de la mer Egée.

L'homme néolithique avait pris conscience des beaux arts. En utilisant pour ustensiles des pierres dures et aiguës a réussi de graver sur les roches ou sur des blocs de pierre des scènes de leur vie quotidienne, comme la chasse, la pâture des animaux, le transport maritime par des barques primitives etc.Dix pierres ont été incorporées dans le mur sur la colline "Corfi d'Aroniou". De même, en accord avec leur fantaisie de présenter le char du soleil, le zodiaque etc., ce qui prouve qu'ils avaient assez de connaissances astronomiques, depuis, 6.000 ans av.J.C. Fig.1a, 2, 3.

Tous ces blocs de pierre gravés ses trouvent au musée d'Apiranthos de Naxos, lequel a été créé par feu Michel Bardanis, membre de la S.S.G.

Sur les roches ils ont gravé les saisons de l'année: l'été, le jour long la nuit courte, et le contraire pour l'hiver, de plus le soleil et toute autre figure que leur fantaisie concevait.

Plus tard l'esprit artistique des Naxiens s' évolue vers la scul-



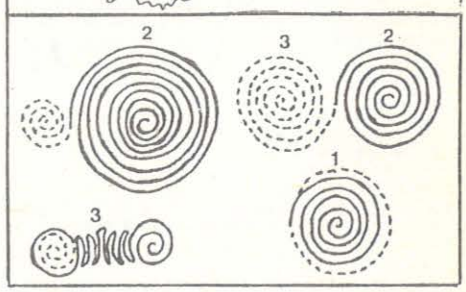


Fig. 1. Les regions ou ont été trouvées de gravures sur de rochers immobiles.
1) Chimaros, 2) Panormos, 3) Amodi, 4) Spedou, 5) Agios Athanasios, 6) Agios Mamas, 7) Rachidi, 7a) Dascalio, 8) Vouda, 9) Agia Trias, 10) Liaridia, 11) Vilanou, 12) Psili Amos, 13) Sténou, 14) Driti, 15) Athalasou, 16) Korfi t'Aronioy.

Fig.1a. 1) Le spiralls représentent le soleil aux diverses saisons: 2) Le grande avec une petite formée de fossettes, c'est l' été, le contraire c'est l'hiver. 3) De dimantions moyennes, le printemps ou l'automme. Le nombre total du cercle dans les deux spirales, que est toujours douze, represente les douze mois de l'année.

pture.

Sur le marbre blanc de l'île, ont été sculptées unique pour les statues, les premières anthropomorphes statues de la Grèce.

Il ya des idoles datant, d'après l'opinion des spécialistes, du 3ème millénaire av.J.C., Leur hauteur est de deux centimètres à 1,50 m. et leur forme se presente raide et sans mouvement.

Les plus anciennes statues, manquent de beauté et de symétrie et leurs visages sont plats, ovales et arrondis et toujours inclinant vers l'arrière.

Il y a d'autres têtes sculptées allongées en hauteur de sorte que le visage prend la forme d'une triangle.

En général les sculptures ont le cou très long, petites protuberances à la place des mains, le torse très grand, les pieds courts et gros, toujours unis l'un à l'autre, les doigts tendus, de sorte que la statue semble s'y appuyer. (Fig.4)

Au fil des années les statues deviennent plus artistiques avec une certaine symetrie, toujours le cou très long, et avec les signes du sexe au thorax. Les mains toujours se réposent sous la poitrine, la main droite sous la main gauche.Il y a des statues, dont les pieds sont séparés, mais toujours unis aux plantes et appuyés aux doigts. (Fig.5.). Seulement aux idoles assises les pieds sont totalement séparés.

Et l'évolution artistique continue dans l'ile de Naxos.

Les statues, en marbre blanc de l'île sont plus longues (plus qu' un mètre), les analogie du corps plus symetriques. Au 7ème siècle

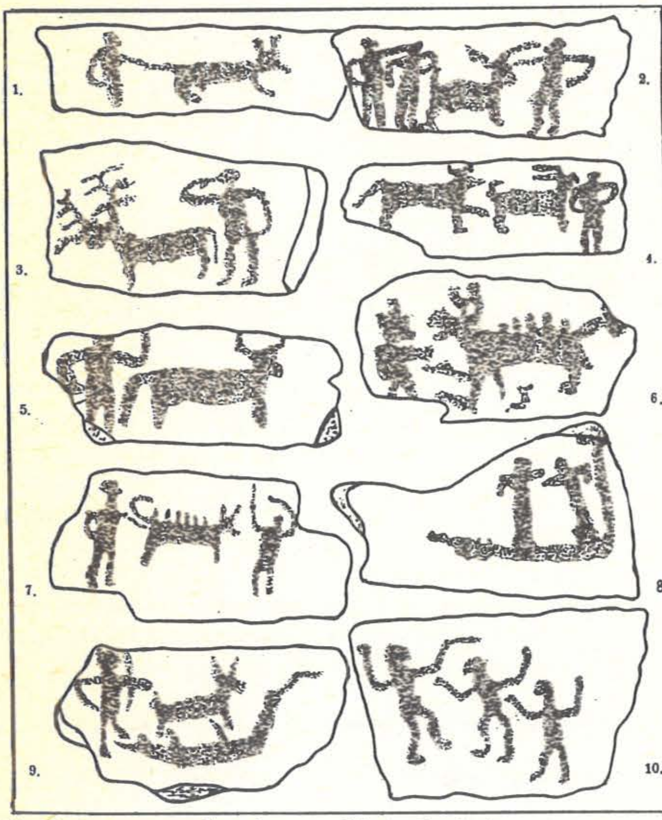


Fig.2. Gravures sur les pierres mobiles présentent:
1, 2, 6, 7 Scènes de chasse.
3, 4, 5 Scènes pastorales
8, 9 Scènes au barque
10 Scène de danse.

Ces pierres ont été découvertes sur la colline Corfi d' Aroniou.Elles se trouvent actuellement au Musée d'Apiranthos à Naxos.

av.J.C.nous rencontrons sculptés sur des énormes blocs de marbre,les Kouros, dons le corps moins raide est d'une certaine symétrie.

On trouve encore aujourd'hui en plein air, près des carrières de merbre, trois Kouros du 7ème siècle av.J.C.Les spécialistes ont l'opinion que ces statues ont été abandonnées inachevées.

Le premièr, se trouve à une altitude 100 m., au village Apollon, parce que la statue - dit on - était consacrée au Dieu Apollon. Les dimensions: 10,40 de longueur, plus qu' un mètre de largeur. Les mains sont unies au corps jusq'aux coudes et se tournent après verticalement sur une courte longueur, parce que l'épaisseur du bloc de marbre, ne permettait pas plus de longueur. Les pieds sont totalement

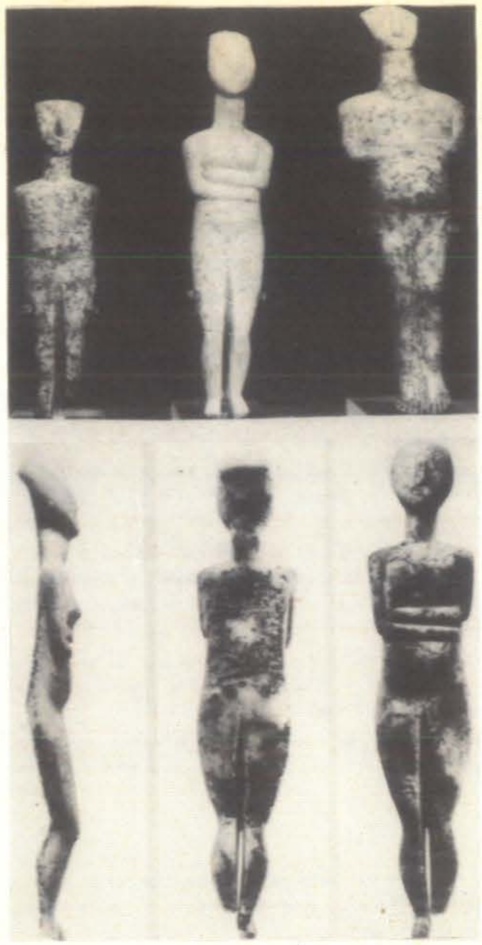


Fig. 4-5. Idoles du 3me millenaire a.J.C.Musée de Naxos.

Fig. 6. La colline "Corfi d'Aroniou" ou ont été decouvertes dix pierres gravés, incorporées dans le mure sur la colline.

Fig. 7. Kouros au village Apollona, près de carriere de marbre inachevé, est d'une longueur de 10,40m.

Fig. 8. Kouros au village Kournochori au site Melanes, est d'une longueur de 6,50m.

Fig. 9. Kouros au pied de la colline Nyfiotissa, est d'une longueur de 5 m.

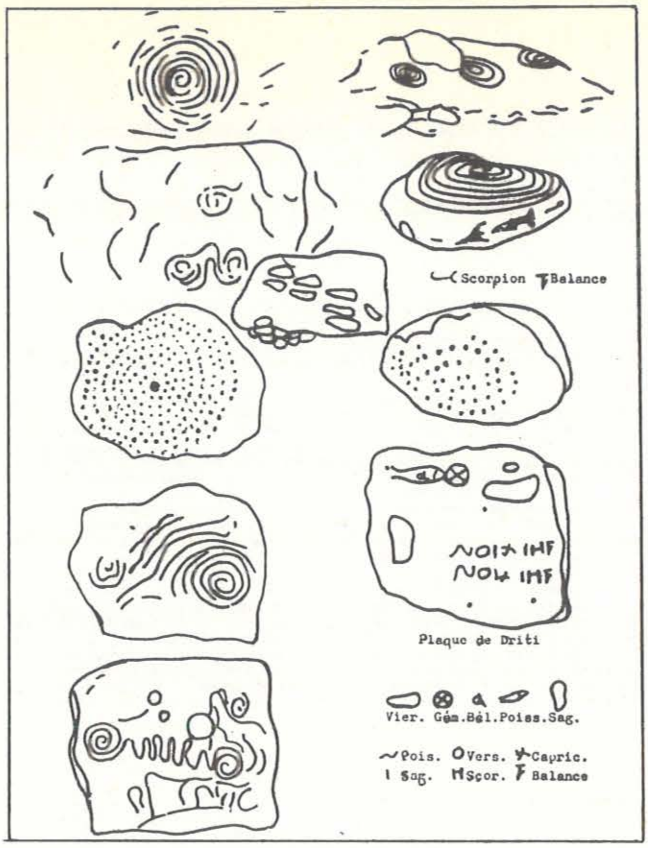


Fig.3. De rochers immobiles et pierres mobiles gravées, représentent le soleil et les constellations.
Les pierres mobiles se trouvent au Musée d'Apiranthos à Naxos.

unis. On ne peut pas dire si l'artiste se proposait de les separer après. (Fig.7).

Le deuxième Kouros se trouve près de la source d'eau du village Kournohori, au site Melanes. Il est long 6,5 m.On le considère inachevé, mais pourtant il a plus de symétrie et les pieds sont separés, arrondis et présentent une souplesse en leur formation. Les mains, avec les coudes loin du thorax, ne touchent pas le corps. Les pieds sont totalement séparés, les plantes arrondies. On peut dire que ce Kouros Iaisse l'impression qu'il se repose, (Fig.8).

Le troisième Kouros inachevé aussi, se trouve au même site,plus haut que le deuxième, près de Kinidaro au pied de la colline Nyfiotissa. Ses pieds sont amputés et la longueur actuelle de la statue est de 5.00 m.(Fig.9).

Ce Kouros se présente plus artistique et moins raide que les deux autres. Plus caractéristique est la différence à la forme du thorax, lequel présente un abaissement au centre, par contre aux deux autres Kouros, où le thorax se présente plus presenté au centre, avec des legères saillies aux flancs. L'intention de l'artiste était, sans doute, de présenter un corps féminin.

On admet que cette statue représente l'Ariadne endormie. Suivant la mythologie, Theseus, retournant de la Crète avec Ariadne, l'abandonna dans l'île de Naxos. Dionysos l'y trouva endormie et d'elle fit son épouse.

Les Kouros de l'île de Naxos sont considerés comme les précurseurs des fameuses anciennes statues hélleniques, lesquelles se trouvent actuellement tant aux musées grecs qu'aux musées d'autres pays.

Dans le territoire sacré de l'île Delos, où Dieu Apollon naquit, l'édifice des Naxiens était le plus ancien et le plus remarquable. La se trouvait la colossale statue d'Apollon, oeuvre des artistes Naxiens du VIIème siècle av.J.C.

La statue était 8,5m. de hauteur. Aujourd'hui il ne reste que sa base, 5,11 m. de longueur, 3,50 m.de largeur et 0,80 m. de hauteur.

Près du sanctuaire d'Artemission se trouvent le torse et une pièce du bassin de cette statue colossale.

Aussi remarquable tant en grandeur qu'en symétrie artistique est la statue de Nikandra (Naxiotissa) dy VIIème siècle av.J.C.dont la hauteur est de 2 m., consacrée au sanctuaire d'Artémis. La statue se trouve actuellement dans le Musée National d'Athènes.

Les 9 lions en marbre dans le territoire de Délos, qui sont considerés comme les gardiens du site sacré, sont aussi des oeuvres des sculpteurs Naxiens.

La perfection d'art glyptique des Naxiens est demontrée par la finesse de la statue "Couros de Naxos" du VIème siècle av.J.C.d'une hauteur de 1,20m.

La statue se trouve dans le Musée d'Etat de Berlin EST.

En résumé, ce bref exposé vise à démontrer que le berceau des artistes grecs en sculpture et glyptique se trouve à Naxos, depuis l' époque néolithique avec une évolution continue et de là, l'art s' est répandu dans toute la Grèce.

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THE CANGO CAVES OF SOUTH AFRICA: HAS GOVERNMENT CONTROL BEEN BENEFICAL?

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The Cango Caves north of Oudtshoorn in the Cape Province have always enjoyed Government ownership and control since their discovery in 1780. As early as 1821 regulations were drafted for their preservation, with provision for fines for offenders. However until 1891 the Caretaker lived three hours ride from the Caves. Therefore supervision was unsatisfactory; numerous graffiti were written and formations removed. No one has been prosecuted for damaging the Caves.

At Union in 1910, ownership of the Caves passed from the Cape Colonial Government in Cape Town to the Union Government in Pretoria. The latter Government had no interest in the Caves, and attempted to pass its responsibility to the Cape Provincial Administration. That Administration was at first unwilling to accept the Caves because of the expense involved. After the Oudtshoorn Municipality had agreed to manage the Caves, control was vested in that Municipality in 1921. Although the then Administrator of the Cape stated clearly that the Municipality was to make no profit from the Caves, and that any surplus was to be spent on the Caves or used to reduce the entrance fees, the Oudtshoorn ratepayers have, especially during the past 25 years, benefitted considerably.

LES GROTTES DE CANGO DE L'AFRIQUE DU SUD: EST CE QUE LE CONTROLE DU GOUVERNEMENT ONT ETE SALUTAIRE?

Le Gouvernement toujours a possédé les Grottes de Cango nord d'Oudtshoorn dans le Département du Cap depuis qu'on les a trouvées en 1780. En 1821 le Gouverneur a réglé pour leur conservation, avec des amendes pour leur violations. Cependant jusqu'à 1891 le Concierge demeurait une promenade à cheval de trois heures des Grottes. Donc leur soin était mauvais; on a écrit beaucoup des graffiti et a transporté des formations. On n'a poursuivi personne en justice pour endommager les Grottes.

A Union en 1910, on a transferé les Grottes du Gouvernement Colonial du Cap dans la Ville du Cap au Gouvernement Union dans Pretoria. Ce Gouvernement la ne s'intéressait rien aux Grottes, et a essayé transférer son responsabilité au Département du Cap. Initialement ce Département la s'a refusé agréer les Grottes parceque la dépense. Après la Municipalité d'Oudtshoorn s'avait accordé à diriger les Grottes, on les a investues de la Municipalité en 1921. Bien que l'Administrateur du Cap a dit évidemment que la Municipalité ne doit pas se profiter des Grottes, et doit dépenser quelque surplus sur les Grottes ou pour diminuer le prix d'entrée, les contribuables d'Oudtshoorn s'ont profités beaucoup, particulièrement pendant les 25 ans derniers.

The Cango Caves are a well-known tourist attraction situated in the Swartberg foothills about 27 km. north of Oudtshoorn in the Cape Province of South Africa. At the time of their discovery, 1780, the Caves and the surrounding land were owned by the Dutch East India Company[1]. It is most unlikely that the officials of the Company knew about the Caves. Access was controlled by the surrounding tenant farmer. The roads were so bad, and the population of the Cape Colony so sparse, that visitors were few and far between. The political changes during the next forty years:

1795: First British Occupation;
1803: Batavian Republic;
1806: Second British Occupation

had no effect on the management of the Caves. The tenant farmer continued to pay his rent to the same local Field Cornet who forwarded it to the same office in Cape Town.

During the Second British Occupation the system of land tenure was changed. The sitting tenant was permitted to buy his land from the Government. Accordingly on 10 January 1820 the land surrounding the Cango Caves passed into private ownership. However the Governor, Lord Charles Somerset, had inserted into the title deeds a servitude reserving the Caves for the public in perpetuity:

"........ on condition that he (van der Westhuizen) and the future proprietors of the place Combuis shall have no right whatever to that part of the ground where the Mouth of the Grotto is situated; that the same shall be left perfectly free and undisturbed and be considered as public property; that he shall at any future period suffer a road to be cut across the land to the said Grotto ...."

On the following day he instructed the local Magistrate to inspect the Caves and to draft regulations for their preservation, then sailed for England. His successor, Sir Rufane Donkin, had no interest in the Caves.

It was a further 18 months before the Magistrate prepared his *"regulations for the preservation of the Grotto in the Cango"*. Inter alia, he provided for the imposition of fines on people who might deface the Caves, and appointed the local Field Cornet ex officio Caretaker. For this additional duty the Field Cornet received no extra salary, but was permitted to charge visitors 10 rix dollars (equivalent to R1-50 or 15s. - an enormous sum of money in those days) for his own account. This part-time minor Government official therefore legally acquired a potentially valuable monopoly at the expense of the owner of the surrounding farm, whose grazing was eaten by the draught animals of the visitors[2].

For the next half century successive Field Cornets lived three hours ride away from the Caves which were fitted with no gate. Therefore visitors were unwilling to ride for a further six hours to request permission to visit. The Caves slowly deteriorated with numerous graffiti being written on the walls, and formations being removed, by the unsupervised visitors. Although successive surrounding landowners complained to the Magistrate, and requested that a gate be installed, no action was taken by the Government[3].

By the 1880s. communications had improved sufficiently for there to be a noticeable increase in the numbers of visitors. No accurate figure is available because the Field Cornet had a vested interest in under-reporting the numbers of visitors. If he were seen to be making a large income from the Caves, the Government could be expected to appoint a Manager and to keep the income for itself. At that time the Outshoorn Divisional Council was responsible for the maintenance of the access road, but received no income from the Caves. The Councillors saw that the Field Cornet, who by then lived nearer the Caves, was enjoying a comfortable extra income therefrom. They therefore applied to the Colonial Government several times during the next 30 years for the servitude (and therefore the income) to be vested in the Divisional Council[4].

With the exceptions of the Magistrate and of the Member of the Legislative Assembly, the Divisional Councillors were peasant farmers whose standards of education were so low that the Government believed that they were incapable of managing the Cango Caves. The Government did however terminate the monopoly of the Field Cornet in 1891, and substituted that of the surrounding farmer who was appointed Caretaker. The farmer received no remuneration, but was permitted to charge visitors 5s. for his own account in lieu of salary. At the same time a substantial gate was erected at the entrance to the Caves[5]. The gate did not prevent further damage to the Caves because the increasingly large numbers of visitors could not be effectively supervised by the Guide.

In terms of the South Africa Act of 1909, at Union on 31 May 1910 the servitude was transferred to the Union Government in Pretoria - about 1600 km. to the north. That Government, understandably, was concerned with more important matters than distant caves, and asked the Cape Provincial Administration to assume the responsibility for their management. The Provincial Administration, having no money available for the Caves, declined. The practice of paying the entrance fees to the Caretaker ensured that no capital was accumulated to pay for the necessary improvements for visitors.

At that time the only facilities at the Caves were the gate and a few ladders. Otherwise the Caves were, apart from the vandalism, more or less in their original state. There was no shelter, toilet, ablutions, restaurant, running water, electric light, easy path or other comfort for the visitors. Lighting was by candles, flaming torches and magnesium ribbon, all of which produced clouds of smoke, soot and ash to the detriment of the formations. It would require a large amount of money to provide those improvements at the Caves. In those days before deficit financing became fashionable, such money was unavailable from Government sources. In 1911 some Oudtshoorn businessmen, who were aware of the facilities which had been provided by private enterprise at the Government-owned Jenolan Caves in Australia, applied for a 50 year lease of the Caves so that they could effect the necessary improvements. This would have required an Act of Parliament but, although the enabling "Cango Caves Preservation Act, 1912" was prepared, it never reached the Statute Book because of pressure of more important business.

It was these Oudtshoorn businessmen who realised that one day the Cango Caves would become profitable. They were largely educated men, who, having realised that the Government was unwilling to relinquish control, turned their attention to the Oudtshoorn Town Councillors. These Councillors were better educated and more articulate than their Divisional counterparts, and successfully persuaded the Provincial Administration that they were capable of managing the Caves at no cost to the Province and Union. Having received this assurance from the Municipality, the Provincial Administration accepted responsibility for the Caves from the Union Government in 1915.

Although the financial position of the Oudtshoorn Municipality was no better than that of the Provincial Administration, the latter transferred control and management to the former in 1921[6]. However, the Province did retain the right to approve the entrance fees and all expenditure of the revenue. The Administrator stated clearly that the Oudtshoorn Municipality was to make no profit from the Caves; any surplus was to be spent on the Caves and to be applied to the reduction of the entrance fees - 50% of which was paid to the Caretaker in lieu of salary.

The Oudtshoorn Municipality acquired no land with the Caves - that remained in private ownership. The surrounding landowner refused to sell because he wished at some time in the future to erect a tea room for the use of visitors. The Administrator refused permission for the Municipality to expropriate the required land. In later years the Municipality overcame this problem by building the tea room under the overhang at the entrance - legally it was inside the cave[7], and by building the generator house for the electric lights within the proclaimed road reserve.

The 1920s. were not prosperous years, and the income from the caves was not as large as had been hoped. The first priority of the Municipality was the provision of electric lighting at a cost of £5000. The Municipality had so much difficulty in raising this sum that the South African Railways and Harbours attempted to take over the Caves, arguing that it had the necessary finance, technical experience and publicity resources. Although the Municipality was struggling on all three issues, it was sufficiently well-connected politically to defeat the Railways. It solved the financial problem by borrowing from one of its Councillors! The electric lights were switched on in 1928[8]. The staffing requirements of the Caves by then necessitated the employment of salaried staff; and the services of the surrounding farmer were terminated.

The Cango Caves continued to struggle financially during the Depression of the 1930s. and during the 1939 - 1945 War, though business began to improve after the War. The increasing numbers of visitors were responsible for the limited facilities at the Caves becoming hopelessly inadequate as early as 1947[9].

The Oudtshoorn Town Councillors for the next ten years discussed possible improved facilities at the Caves, but had to wait for the appointment in 1956 of Mr. M.C.T. Schultz as Town Clerk before the final plan was effected. The tarred access road was financed by the State Government. The 400000 Rand cost of the large car park, terminal building, mains electricity, concrete paths, passage widening and artificial entrance was partly financed by a 25-year loan. Since these facilities were opened in 1967, they have enabled up to 190000 visitors to see the Caves in a year. Despite temporary recessions due to large increases in the price of petrol and its limited availability, there has been during the past 20 years a healthy surplus of income over expenditure.

It has always been the policy of successive political masters of the Cape since 1820 that the Cango Caves are a national asset which shall be conserved. However, successive Government servants have been unable or unwilling to enforce that policy. The management of the Caves has, for reasons of convenience, always been in the hands of the Oudtshoorn local residents who have regarded them as a local asset to be exploited for their benefit. The Oudtshoorn Municipality has always been sufficiently politically well-connected to persuade the Provincial Administration to bend, and in 1971 to change, the rules, and to permit the expenditure of large sums of money from the Caves on items unconnected with the Caves. The ratepayers and tradesmen of Oudtshoorn have benefitted from the Caves as follows:

1) Attraction of visitors, with their money, to Oudtshoorn.
2) Substantial cash payments to General Revenue.
3) Creation of employment, both at the Caves, and indirectly through the expenditure of the visitors' money in the town.
4) Financing of most of the Municipal publicity expenditure.
5) Numerous minor payments which, by any other Municipality, would have been debited to General Revenue or not made.
6) Four tourist camps / caravan parks.
7) Maintenance of Arbeidsgenot (a cultural museum).
8) Substantial contributions to the following major amenities:
   a) C.J. Langenhoven Memorial Library & Cultural Centre.
   b) Arnold de Jager indoor and outdoor sports complex.
   c) Cape Adventure Training & Environmental Study Centre.

Against these benefits, all of which have been financed out of income or by loans, must be debited the following substantial expenditure towards which the Municipality has been required to make no contribution:

1) The cost to the Province of administration and supervision of the Municipality's management of the Caves.
2) The cost to the State of construction and maintenance to National Road standards of the road to the Caves, less that of constructing and maintaining a similar farm road to lower standards.

It is, unfortunately, impossible to quantify the total nett benefit which the ratepayers and tradesmen of Oudtshoorn have derived from the Cango Caves. It represents, however, an excellent return on an undertaking which has required no capital investment, and which has involved no commercial risk.

The 1984/85 accounts revealed the following figures which confirm the profitability of the Cango Caves:

Total income	R563947-68
Operating surplus for the year	R 96184-99
Accumulated surplus	R176456-18
Profit on Trading account	R 35360-61
Accumulated surplus Cultural fund	R 20698-63
Book value of Cango Caves and tourist camps	R830698-89

Whether or not Government control of the Cango Caves is considered to have been beneficial depends on which side of the fence the observer sits. From the point of view of the Oudtshoorn ratepayer it has been an unqualified success. To the conservationist (and it must be remembered that conservation has been the policy of all the political masters of the Cape since 1820) Government control has been disappointing. In 1972 and 1975 were discovered Cango II and Cango III respectively; the quantity and quality of their formations give a very good impression of the condition of the show cave (Cango I) two centuries ago. Most of the remaining formations in Cango I are dead[10]; many are disfigured with graffiti and lampenflora.

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SPELEOGENETIC AND SEDIMENTOLOGICAL INVESTIGATIONS IN BEARS CAVE - BIHOR MOUNTAINS

HADNAGY, Arpád

The Bears Cave, discovered in 1975 in Măgura Hill, near Chişcău village, became the most attractive touristical point of the Bihor Country through its ornamental abundance/stalagmite of „candle" type, minute basins, aragonitical helictite/ and its bear fossil abundance. It represents the most extensiv cavern/1,5 km length/ from karstic complex that formed in white marble of Bihor autochton. The results of the petrographic-sedimentological analyses corroborated with the paleontological, geomorphological and geological known dates directed us to stabilize the evolutive sense and rythm of the cave. Then it was determined that it functioned in Pleistocen as a sidewise ressourgence. The aboverânged galleries and underground terraces was formed singenetic with the t_4, t_3, t_2 and t_1 terraces of the principal collector -Crăiasa Valley- under the general tecto-climatogenetical effect of subsidance of the Black Criş basin.

The detritical autochton material of the superior fossile galleries presents in preponderance carbonatically/also appears trigonolites/the well corroded fragments being included in an residual real clayey mass, that represents 80% from the cave deposit. The chemical and mineralogical character of this clay demânstrate us a possible allochton origin feldspar mica limitrophe, nonkarstificable, distributive areas. The heavy mineralogical paragenesis kinds as:-garnet, cyanite, staurolite;-hornblende, pyroxene, spinel, zircone, magnetite seems to be enough convincing to sustain this hypothesis. Allitical ooids, anatase, corundum, leucoxene, and well rolled rutile, tourmaline indicates us in exchange an bauxitical allochton source for the detritical material, and the magnetical spherules - a possible participation of the cosmical material.

SPELEOGENETISCHE UND SEDIMENTOLOGISCHE FORSCHUNG IN DEN BÄRENHÖHLE - BIHOR GEBIRGE

Die Bärenhöhle, entdeckt im Jahre 1975 am Fusse des Berges Măgura neben Chişcău Dorf/Kreis Bihor/ erregte grosse aufmerksamkeit sowie turistische anziehungskraft durch ihre merkwürdige Ornamentik: kerzenförmige Stalagmiten, kleine konkretions Becken, aragonitische Heliktite, usw., und mit ihren fossilen Funde. Aus kristallinen weissen Kalkstein des Autochton Bihor gebildet repräsentiert diese Höhle eine unvergleichliche Crossraum/1,5 km länge/ aus dem Bihor Autochton.

Die Resultate sedimentpetrographischer Analysen befestigen mit bekannten geologischen, geomorphologischen und paleontologischen Daten liessen uns die Richtung sowie Rhytmus der Höhlen evolution erkennen. Man stellte also fest dass im Pleistozän diese Höhle war eine abhänger unterirdische Lauf. Die unterirdisch-übereinanderliegenden Galerien und Terassen formten sich singenetisch mit den Terassen t_4, t_3, t_2 und t_1 des Hauptsammelbeckens Crăiasa Tal unter dem tekto-klimatologischen einfluss die bodensenkung des Crişul Negru Beckens.

Das einheimische detritische Material der oberen fossilen Galerien ist hauptsächlich karbonatisch/es kommen auch Trigonolite vor/die gut korodierten Fragmente sind in eine tonige rote residuale Masse eingeschlossen welche 80% der Ablagerungen ausmacht. Die mineralogische sowie chemische Natur der Ton weist auch auf eine mögliche allochtone abstammung, aus Feldspat und Glimmer, der umgebenden unkarstisch verteilung Gebiete hin. Die Paragenese der Schwermineralle des Typus:-Cranat, Disten, Staurolith;-Hornblende, Pyroxen, Spinell, Zirkon, Magnetit sind überzeugende Argumente für die wahrhaftigkeit dieser Hypothese.

Die allitischen Oolithen, Anatas, Korund, Leukoxen, gut gerollt Rutil und Turmalin weisen jedoch auf eine allochtone bauxitische Quelle des detritischen Materials hin, und die magnetischen Kugelchen sind sogarein beweis möglicher kosmischer beteiligung.

Introduction

Bears Cave accidentally discovered in Autumn 1975, offers an unusual ornamental richness. But it become famous for its abundance of fossil rests, especially of Ursus spelaeus, that could be find in all the galleries known today. The cave appears thus before the visitors eyes like a real museum natural build and ornamented.

1. The General Geographical, Geomorphological and Hydrographic Frame

The cave is situated at the east-southeastern end of Chişcău Village, Pietroasa commune, Bihor District, in the west piedmont hills area of the Bihor Mountains. Măgura Hill, that cantons this karstic complex, culminates with the Brusturii Peak/ +770m/ and it is morphological and tectonical limited to the west by the Peşterii brook and the Spring of the Izbuc brook, to the east by Brusturi brook, to the south by the Vîrtoape dolinar valley and to the north by Crăiasa Valley, that is the principal hydrographic collector of the entire basin Juleşti-Chişcău in the same time.

The active water course, which drains the lower level of the cave, appears as a slope resourgence tributary to Crăiasa Valley, that is the right affluent of the Crişul Negru river in its turn, the river that drains the entire Neogen basin of Beiuş.

The morphology of the karstificable area on the Măgura Hill has some particular aspects, with a great richness of forms: lapieses, dolines, dolinar valley, ponors, emergencies and dry valley.

2. The Geologo-strucural Frame

The north-western sector of the Bihor Mountains and the area of Chişcău inclusively is characterized by an accentuated tectonism and a participation of two break-thrust units, near the Bihor autochthon: Arieşeni nappe and Ferice nappe.

The autochthon, as a structural basic unit, consists of a detrital Liasic on the entire edifice of the western part of the Bihor Mountains, unkarstificable in facies of Gresten and Neo-Jurassical carbonatic formations. The Tithonic limestones, in which it is cantoned the karstic complex, appear as recrystallized under the thermometamorphic effect of the Pietroasa granodioritic massif. The calcareous stones autochthon, from the Brusturi drainage basin, also appears as a little tectonic window in the frame of Arieşeni nappe formation.

The Arieşeni nappe appears in disjunctive relations and occupies considerable areas aspecially to the east and south of the Măgura Hill karstificable area. The sediments of the unit are exclusively detritic/sandstones, microconglomerates, a.s.o./of Permian age. The Ferice nappe occupies the western part of the Măgura Hill under a dolomitic facies and black calcareous stones with silicious accidents.

The ancient of the major disjunctive systems, which appear in the investigated area, are faced NNW-SSE direction, the line on which the Banatites/magmatic rocks/were placed lenghtwise, respectively where the Bears Cave itself was formed as a rectilinear cavity.

3. The Morphology of the Deepkarst

This cave is ranged in three main levels, the net being typically of subhorizontal one generally faced north-south.

The Chişcău underlying karst complex consists of two large cavities: The Bears Cave extends on 625m, and 1500m long, and "The Chişcău Cave", 148 m long. The other cavities called: "Trăienuţ Cave", "The Little Cave", "The Cave under Gruiu" and "The Cave from Prusturi Valley" have extents of only some metres.

The visitors acces begins at a medium level, called "The Acces Gallery" which is continued with the "Intersection Room", from which "The Candles Gallery" is ramified to the upper level and from which another secondary superior level is ramified "The Twisted Gallery"/+21m/. The Intersection Room is also ramified to the south through "E.G.Racoviţă Gallery" and "The swallets Gallery". The iferior level, 375 m long, appears uneven from Racoviţă Gallery/16m long/, being in the same time only active level, with an underground discharge of 2-10 l/s. I met here a series of suspended terraces with graded bedding, allochthon, detritic material. The meandred flow suggests a supersolicitation of the permanent capacity of the water, the line valley intensity being of only 2-3 m/100 m.

4. The Types of the Cave Sediments

Under the different physico-chemical effects of the existing sedimentogenetical surrounding, in Quaternary, many types of sediments could arise in the Bears Cave.

4.1. Calcareous - Concretionary Sediments

Almost all the active and fossil galleries abound in stalactites and stalagmites as a result of the dissolving and the supersaturation of waters in $CaCO_3$, through the water of percolation fallen from the roof of the cave, in the large majority of the galleries a stalagmitic floor tens cm. thick is formed.

Maintaining the hypothesis according to which the degree of solubility of the karstificable rocks it will depends on the phisico-chemical characteristics of the affected rock, on the one hand and the acidity, temperature and the pressure of the solvent, the richness and quantity of the concretionary forms -formed very probably at the end of the Pleistocene - on the other hand, shows us the existence of an interstadial epoch with a rich vegetation and a ground having plenty of CO_2 on the Măgura Hill.

The cave pearls appear as white little balls in the small ornamental lake/speleomouth/ and little basins of the stalagmitic floor, with a concentric interior structure/alternations of aragonite in preponderance with calcite/. Helictites appear much more rarely and they usually adorn the walls of the active inferior galleries.

4.2. Mangano - ferriferous Sediments

The sediment of the insoluble MnO_2 is observed especially on fossil rests, on brute detritic fragments found under the stalagmitic floor. The involving of the Mn^{2+}, Fe^{2+}, Fe^{3+} ions thus took place more rarely in the evolutive transition periods from a wet climate to a dry one. The relation Fe^{2+}/Fe^{3+} is very variable and thus difficult to determine. Spheroidal manganous nodules appear rarely and especially in the detritic sediments of The Inferior Gallery.

4.3. Detrital Sediments

With the view of recognition and wishing to reconstitute the speleosedimentary environment the greatest attentions was given to the karstic detritus. To define this speleosedimentary medium I tried to determine the majority of physic, chemical and biological characteristics of the whole sedimentary complex. Our samples noted on the graphs/fig.1 and fig.2/with P_1, P_2, P_3 and P_4 were collected from the prospecting well nr.I. of The Acces Gallery. The micromineralogical correspondent of these raw samples was noted with m_1, m_2, m_3, m_4 and the corresponding depths of these samples were: 1 = 0,0-0,25m; 2 = 0,25-0,45; 3 = 0,45-0,75/from the superior red clayey horizon/, respectively the samples nr.4 was gathered from the depth of 0,75-0,90 from the yellowish clayey horizon. The total mineralogical samples were thus noted: M_1 - The Acces Gallery, M_2 - The Intersection Room and M_3 - The Candles Gallery. The whole ensemble of detrital and residual material was amply granulometrically, morphoscopically and mineralogically analysed; the brute fractions and the fine ones/under 2mm in Ø/ respectively those light were studied apart from those heavy. The graphic aspects of the grain size curves built for the brute psephito-psammitic fraction and the heavy minerals can be noticed on the fig.1-2.. If the simple frequency curves of the brute detritus presents itself with an obvious polymodality, with modulus for the sub-classes 1-2 and 32-64mm, at the heavy fraction these curves present themselves unimodally, with the modulus culminating in the sub-class 0,063-0,125 mm.

Owing to the closing aspect of the cumulative curves built for the brute fraction, the Folk&Ward parameters couldn't be calculated, this being possible only for the association of heavy minerals in the cave. So if the values Mz, for the brute fraction, oscillate between 1,52-5,77 mm, for the concentrates of heavy minerals these values were always sub-milimetrical 0,09-0,73mm.

Seeing the graphic aspect of the cumulative curves of the heavy fraction, we notice/fig.2/that these have two truncated points, one corresponding to the 0,125mm diameter, and the other to 0,25mm. The "saltation" line-sector presents a great inclination :70-80°, while "the rolling and traction" population line sector a much more gentle: 40-50°. They can deduce from these aspects the exclusion of "the suspension" population existence in the heavy minerals field, the energy and the speed of the transport courses becoming lower, and very variably, the hydroenergetic maximum levels being able to transport heavy minerals with the specific weight between 3-5 and diameters between 0,125-0,25 mm through saltation.

According to the standard deviation parameter/σ_{G1}/the spelean heavy minerals appear "poorly" and "moderately", the values σ_{G1} being over 1,11, from which we deduce that the transport of this material was effected in very different hydraulic conditions, that couldn't permit the realization of perfect sortations of this detrital material.

Looking at the symmetry of grain size distribution, through the skewnes -Ski-values, especially in the situation of drawed samples from the well nr.I/m_1, m_2, m_4/we see the realization of a perfect symmetry, while at the other samples collected from wells M-II and M-III it has a weak negative skewed, that proves a super domination of a coarsely material in comparison with that fine one. Having in view the values of the inclusive graphic kurtosis -K_{G1}-, the value of this parameter indicates, at the residual and light fraction, platykurtic forms, while the heavy fraction offers lepto-and mesokurtic curves, presenting a better sortation of the central part of distribution.

The commonest heavy minerals, met in the Bears Cave, in an order of the increasing dimensional frequency, can be thus enumerated: zircon, rutile, tourmaline, kyanite, staurolite, garnets, epidote, psilomelane, magnetite and limonite. Carrying on it has been found mineralogically an enrichment in quartz and feldspath from coarse sandy classes to those fine, from 2-3% in the coarsely sandy class up to 10-40% in the siltic class. In coars sandy classes the presence of the prismatic, and hipidiomorfe aragonite, becomes an habit, but this autochthon mineral disappearig in the fine sandy class and the siltic one.

The light detrital allochthon fraction is dominated, in all the cases, by a concretionary argillaceous material, having a brown-reddish colour, excepting the sample P_4, of the inferior yellowish clayey horizon, in which a calcareous autochthonous detrital and calcitic frost weathered material appears. From a petrographic point of view, the allochthone brute detrital elements, have a certain source from the crystalline schists and clastic sedimentary formations of the nappes, in karstificable neighbourhood of the Măgura Hill.

4.4. The Residual Sediment

The result of the grain size analyses effectuated on these sediments indicates, rather than a pure clay/see fig.4/but a clayey silt, small sandy. The frecvency curve/fig.3/appears unimodal in the favour of the siltic sub-class 0,05-0,025mm. The allochthone nature in preponderence, of the clayey material could be determined through its mineralogic composition in which the illite dominates, being followed by kaolinite and only in a tiny part by montmorillonite, material resulted from the alternation of feldspars and micas unkarstificable rocks, situated to the east from the Măgura Hill.

5. Evolutive Sense and Rhythm of the Cave and of the Residual detritual Sediments

The existence of three antithetic main levels and a secondary one in The Bears Cave, as well as of other suspended, underground, alluvial terraces represent abvious arguments that the evolution of the deepkarst, as of shallow karst, was dominated and controlled by the total geological evolution of the entire Beiuş basin. Resorting to the paleogeographical image of the investigated area we know the fact that after the sedimentary of tithonical calcareous, in Neo-Jurassic, this territory both in Cretaceous and Neozoic age remained in exundation. At the end of Cretaceous era in this part of Europe was dominated by a warm tropical-subtropical climate which favoured the repeated and fast formation and destruction of a luxuriant vegetation, which that time made easy the formation of a soil rich in CO_2.

After the karstification, in the swallets and hollows of the jurassic rocks, could gather an ante-Jurassic detritogen material, respectively a material resulted from the residues of the Triassic calcareous, situated to E-SE/from the actual Padiş area/. The effectuated micromineralogical analyses, through the described mineralogical spectrum, proved that the siltic-clayey-sandy sediment/fig.4/ and an important part of the coars detrital material/fig.1/gave rise both from the terrigenous material of Bihor Autochthon and from the Arieşeni and Ferice nappes.

In Neogen period al the Măgura Hill suffered an impregnation in aquifer conditions. The galleries of the cave, belonged to an phreatic aquifer ,submitted to a slow and permanent dissolution. The knowledge of the general karstic denudation speed, in the Bihor mountains area, the palaeontological proofs found here in abundance, and not at last the results of the sediment-petrographical analyses, permitted us to make out the evolutive rhythm and the stages of the cave. The climatic changings of the Pleistocen, as well as the balancing with different intensities both the mountain frame, and the Beiuş basin, the creation of same local subsidence area in the basin, influenced the rhythm and the erosive and sedimentary intensity and they intervened in the same time in the repeated changings of the granulometrical distribution of the forming sediments.

In the middle and superior Pleistocene in the Beiuş basin was formed the medium alluvial terrace $-t_5-$, in the karstic complex of Chişcău and the insourgence-resourgence direction was established, with the resourgence localized at the end of The Twisted Gallery. Durring Mindel-Riss interglacial age the activity of another resourgence began - The Candle Gallery, time in which The Twisted Gallery activates as superabundance. In the $Würm_1$-$Würm_2$ interstadial, corresponding in time to the formation of the river terrace $-t_4-$ from the basin, another resourgence activity will begin in the Măgura Hill- Trăienuţ Cave and the Acces Gallery appear.

In the W_2-W_3 interstadial the terrace $-t_3-$ from the basin is activated in the same time with The Inferior Gallery/this resourgence localized in the Chişcău Cave/, and the superior galleries pass to an inactive regime.

Taking into account the fact that the presence of the Ursus spelaeus, species characterizes and indicates the Mousterian in this part of Europe, and in the superior red clayey horizon abound the fossil rests of this mammal, this seems to be a certain argument for the pre-existence of the superior galleries in the Riss stage and for the begining of the sediemnt's formation and especially of the clayey residue in the Würm interstadial stages.

In Holocene all at once with the formation of the terrace-t_2- in the karstic complex analysed the actual capture from the entrance in the Chişcău Cave is produced and in the Bears Cave it gets the actual configuration. The fact that the frost riving played a less important part in the detritus formation, in Pleitocene age, can be argued first through the morphoscopical aspects of the detrital autochthone elements and explained through the relative reduced altitude of the cave/under 800 m/.

On geological scale, the evolutive sense, from now, on will certain lead to the total disappearance of the cave, through the colmatage with alluvial deposits and heavy falls.

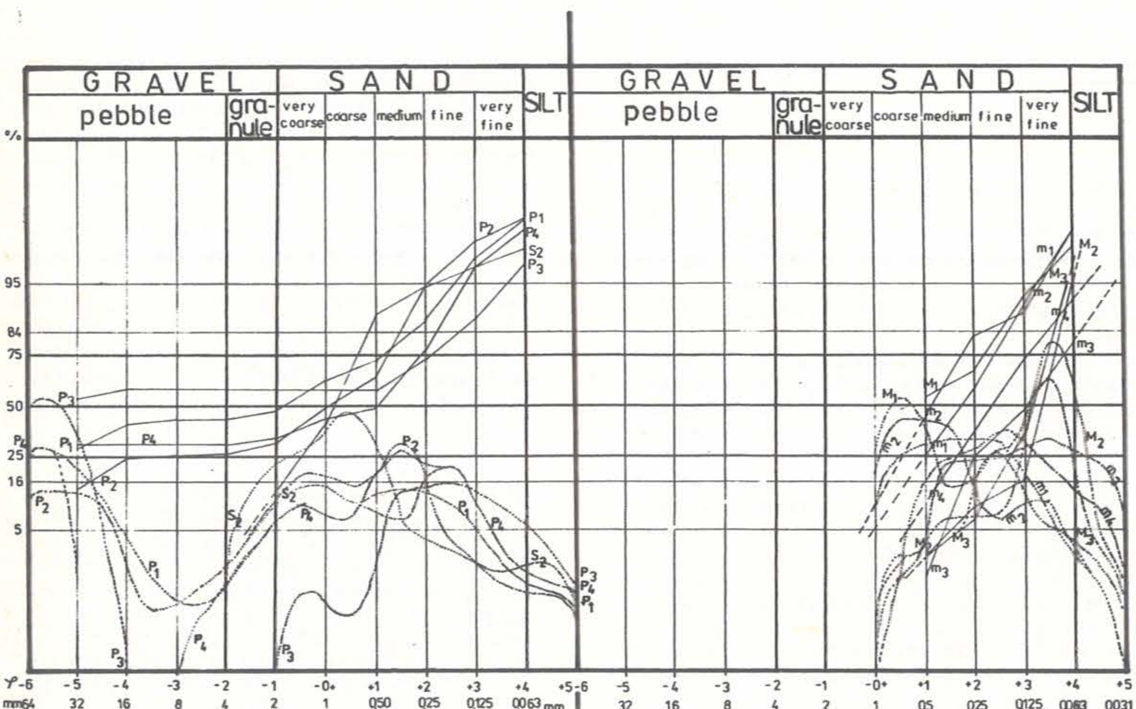

FIG.1. FIG.2.

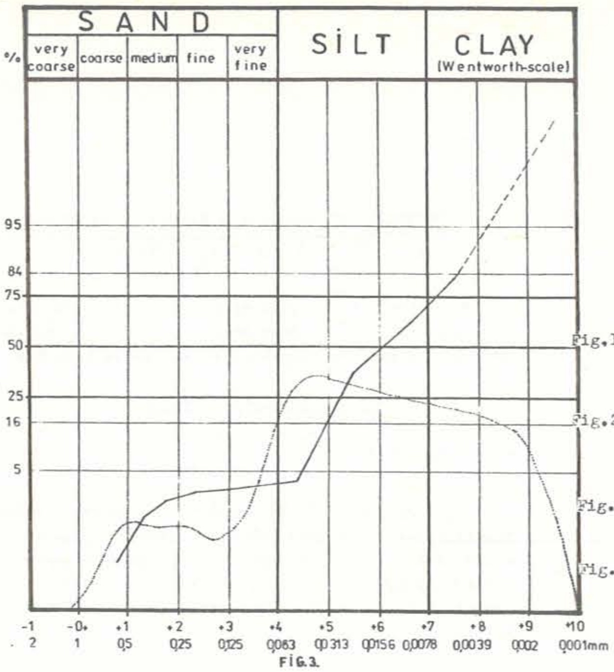

FIG.3.

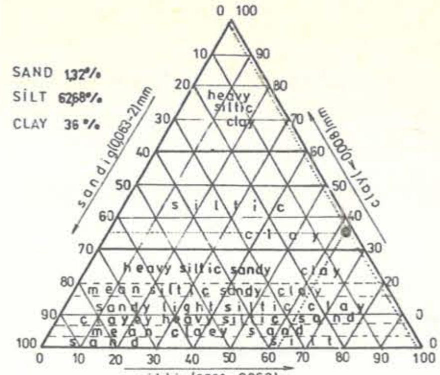

FiG.4.

The Figures List

Fig.1. The graphic aspect of the simple grain size frecvency curves and cumulative curves built for the brute detrital fraction/the pit-I with the samples F_1-F_4, the pit-II with S_2/.

Fig.2. The aspect of the simple frecvency and cumulative curves of the heavy fraction afferent to the prevailed samples from the pit-I/m_1-m_4/and the pits M-II/M_2/, M-III/M_3/and M-IV/M_4/.

Fig.3. The frecvency and cumulative grain size curve built for the residual sediment of the superior red clay ,collected from the dept of 0,8m.

Fig.4. The ternary diagram for the granulometrical classification of the residual sediment in the Bears Cave.

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CARTOGRAPHIC REPRESENTATION OF THE EXTENSION OF KARSTIFICATION - A PROPOSAL -

VERESS, Márton - PÉNTEK, Kálmán

We produce a function which unambigously characterizes Karstic cavities. Investigating the areas bordered by level lines of the cavities according to depth we can get the function:

$$T : x \longrightarrow \pi \cdot \left(\frac{1}{M} \cdot \ln \frac{x}{L}\right)^{\frac{2}{K}} \qquad (0 < x \leq L)$$

K, L, M parameters of a function are characteristic for Karstic cavities. By statistical and cartographical describing of parameters there is a possibility for morphological and genetical comparison of the investigated Karstic regions.

FÜGGVÉNYTANI MODELLEK ALKALMAZÁSA KARSZTOS TERÜLETEK VIZSGÁLATÁRA ÉS ÖSSZEHASONLITÁSÁRA

Karsztos mélyedéseket egyértelmüen jellemző függvényt állitunk elő. A mélyedések szintvonalai által határolt területeket a mélység függvényében vizsgálva kapjuk a

$$T : x \longrightarrow \pi\left(\frac{1}{M} \cdot \ln \frac{x}{L}\right)^{\frac{2}{K}} \qquad (0 < x \leq L)$$

alakú függvényt.

A függvény K, L, M paraméterei a karsztos mélyedésekre specifikusak. A paraméterek statisztikus, valamint térképi ábrázolásával lehetőség nyilik a vizsgálatba bevont karszterületek /Bakony-hegység, Bükk-hegység, Alsó-hegy, Padis-fennsik/ morfológiai, és fejlődéstörténeti, karsztosodási összehasonlitására.

1. FORMATION OF THE FUNCTION NECESSARY FOR THE PRODUCTION OF PARAMETER K

Informations related to karstification are represented by dolines developed on a certain karstic area. Therefore representation ofparameters of dolines denoting karstification enables the demonstration of geographic extension of karstification. For this reason we determine functions of dolines as the parameters of the function will indicate the karstification of an area with dolines.

Examining karstic geomorphological units we find that contour lines representing depressions of different heights above sea level are of different absolute value. To avoid this karstic depressions are transformed to a so-termed reduced 0 level by vertical translations. All contour lines of all karstic depressions are determined in relative values compared to the limit contour line.

We determine the total area of all karstic depressions on a certain karstic area represented by contour lines of the same relative value. In accordance with the above we try to find a connection between the $\{x_i\}_{i=1}^{n}$ relative depth of the contour lines and the total areas demarcated by locally closing contour lines.

Our purpose is to find a proximate function that is analitically easy to use. It's parameters carry obvious geomorphologic information. The curve of the function fits to points related to $\{(x_i, T(x_i))\}_{i=1}^{n}$ with small varience.

Let's describe T total area demarcated by closing contour lines of the same value as the function of x depth related to the reduced level 0 and the measured $\{T(x_i)\}_{i=1}^{n}$ values related to $\{x_i\}_{i=1}^{n}$ points. The localisation of the points obtained show decreasing tendency on every observed area. Looking for the explicit form of function $x \mapsto T(x)$ $(0 < x \leq L)$ by examining several possible formulas it's advisable to use the following form:

$$T : x \mapsto \pi \cdot \left(\frac{1}{M} \cdot \ln \frac{x}{L}\right)^{\frac{2}{K}} \quad (0 < x \leq L) \tag{1}$$

where L means the appearing maximal depth related to the reduced level 0. We make the meaning of parameters $M < 0$ and $K \geq 1$ clear later.

Parameters L, M, K, of function $x \mapsto T(x)$ are determined by the least squares method considering the $\{(x_i, T(x_i))\}_{i=1}^{n}$ measured points. Let's use the described procedure for a single karstic depression. Using the Cavalieri-principle let's make a volume preserving topological transformation to get an axisimmetrical figure where the T(x) area of the original and the transformed figure is of the same value at any $0 < x \leq L$ depth. We termed the result ideal karstic depression. Turning the curve of function $x \mapsto \mathcal{K}(x)$ around the axis we obtain the ideal karstic depression. The above function is termed the characteristic function of the examined original karstic depression. The explicit form of the characteristic function can be easily determined since

$$T(x) = \mathcal{K}^2(x) \cdot \pi \tag{2}$$

when $0 < x \leq L$. Using (1):

$$\mathcal{K} : x \mapsto \left(\frac{1}{M} \cdot \ln \frac{x}{L}\right)^{\frac{1}{K}} \quad (0 < x \leq L) \tag{3}$$

According to this K and M can be interpreted as a geomorphological parameter.

According to fixed L and K comparing two ideal karstic depressions with parameters $M_1 M_2$ $(0 > M_1 > M_2)$ using (3) the result is $\mathcal{K}_1(x) > \mathcal{K}_2(x)$ from the characteristic functions $\mathcal{K}_1(x)$ and $\mathcal{K}_2(x)$. Therefore parameter M determines the horizontal dimension of a karstic depression so the closer parameter $M < 0$ is to 0 the wider the object is.

Examining the effect of parameter $K \geq 1$ first after fixing L and M we determine the inflectional point of characteristic function $x \mapsto \mathcal{K}(x)$. The locus of the inflectional point can be calculated simply:

$x_* = L \cdot e^{\frac{1}{K} - 1}$, its value is $\mathcal{K}(x_*) = \left(\frac{1-K}{M \cdot K}\right)^{\frac{1}{K}}$ and its proportion related to the maximal depth is $\lambda = \frac{x_*}{L} = e^{\frac{1}{K} - 1}$.

It's clear when $0 < \lambda \leq 1$ and $K \mapsto 1$ then $\lambda \mapsto 1$ and when $K \mapsto \infty$ then $\lambda \mapsto \frac{1}{e}$

The value of K descibes the shape of the doline when L and K are given. In the case of bigger K value the inflectional point of the depression gets further and further from the deepest point.

If we fix the value of M and K and compare ideal karstic depressions of L_1 and L_2 parameters where $L_1 > L_2 > 0$ then according to (3) the result is $\mathcal{K}_1(x) > \mathcal{K}_2(x)$ when $0 < x \leq L_2$ from $\mathcal{K}_1(x)$ and $\mathcal{K}_2(x)$ characteristic functions. Therefore parameter $L > 0$ determines the vertical dimension of the karstic depression so the bigger $L > 0$ is the deeper the formation is.

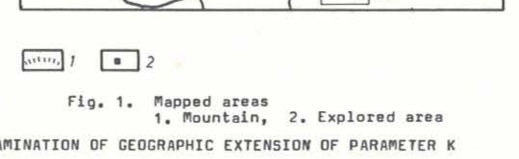

Fig. 1. Mapped areas
1. Mountain, 2. Explored area

2. EXAMINATION OF GEOGRAPHIC EXTENSION OF PARAMETER K

We start from the fact that the increase of parameter K -as a result of the increase of a karstic feature - depends on the age of development or the speed of evolution in a given case. When parameters K are obtained by using data of dolines that are localized on a small area the different speeds of development are probably not considerable as the conditions determining evolution do not show notable deviation as well. Therefore doline-spots of different parameters K represent different periods of karstification.

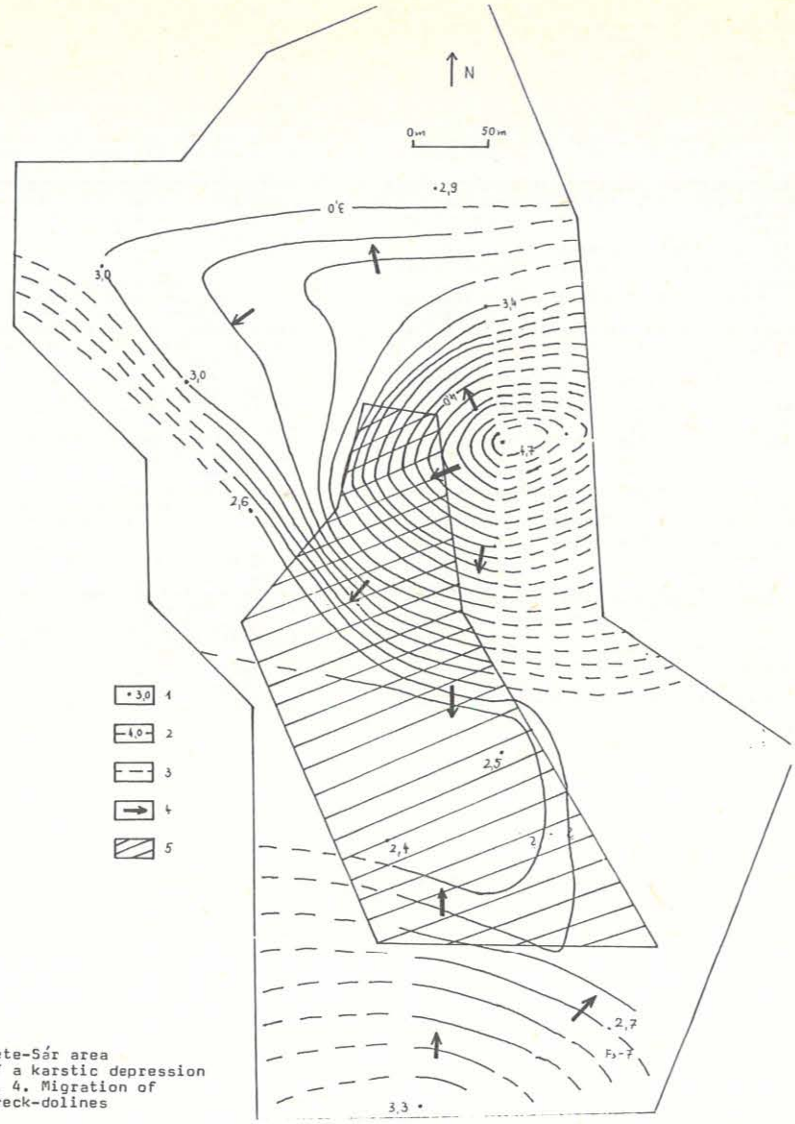

Fig. 3.

Isoline map of parameter K of Fekete-Sár area
1. Localisation and parameter K of a karstic depression
2. Isoline K, 3. Presumed isoline K, 4. Migration of karstification, 5. Area of old wreck-dolines

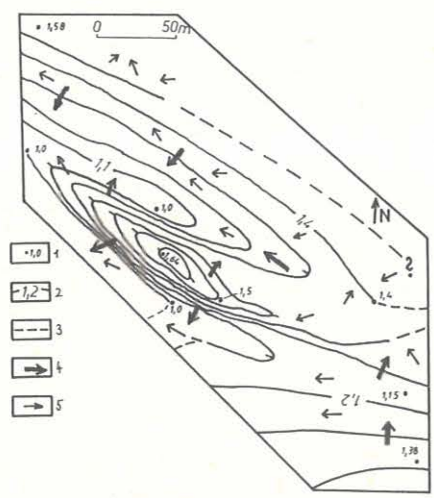

Fig. 2. Isoline map of parameters K of a Mester-Hajag area
1. Localisation and parameter K of a karstic depression
2. Isoline K, 3. Presumed isoline K, 4. Migration of karstification, 5. Direction of inclination of the surface

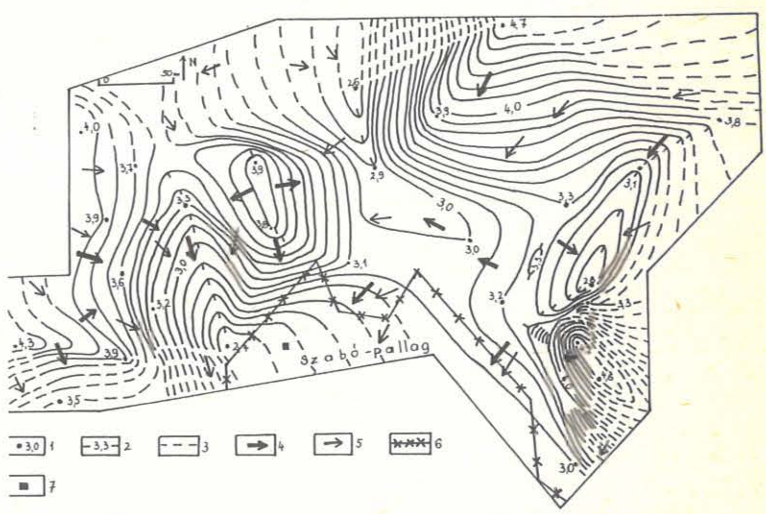

Fig. 4. Isoline map of parameter K of an Alsó-hegy area
1. Localisation and parameter K of a karstic depression
2. Isoline, 3. Presumed isoline, 4. Migration of karstification, 5. Direction of inclination of the surface, 6. Timber-line, 7. Ranger's cottage

In order to obtain a graphic image of karstification of different periods of an area we drew isolines using parameters K /numerical value of K was related to the deepest point of the doline/.

In the direction of isolines of smaller values K karstification is younger on a map constructed by the above. In the case of unchanging conditions of karstification essentially the map shows the direction of the spread of a feature.

K maps /Fig.1,2,3,4/ were drawn after accurate mapping of three areas characterised below: functions and parameters K of 46 depressions /9 on Mester-Hajag, 10 on Fekete-Sár, 27 on Alsó-hegy/ proved to be definable.

Reliefs covered with loose sediment karstificate on the lurched block of Mester-Hajag /Bakony-Mountain/. Karstification takes place where protrusions of rough karstic limestone bedrock crop out or where top sediments are thin.

Depressions are usually 1-2 metres in diameter and are of similar depth and are karstic features often with passages formed partially in the top sediment.

On the territory of Fekete-Sár /Bükk-Mountain/ a bare limestone surface with no outlet karstificates. Dolines big in diameter and often complex dolines /uvala/ are characteristic on a bare relief. Actually inactive older dolines dominate in the central part of the area. Their side-wall is sometimes totally absent /wreck-doline/. The original surface between them remained in the form of narrow ridges.

A bare limestone relief of wavy surfaces karstificates on the territory of Alsó-hegy /Aggteleki-karst/. The dolines are of a rather big size occasionally developed far from each other or side by side.

Comparing the K maps of these areas we find that karstification on Mester-Hajag is initiative and advanced on Alsó-hegy. Fekete-Sár is in a transitional stage of karstification between the two areas.

We can see that isolines form a rough "surface". Roughness indicates anomalies of karstification of an area.

In the followings we try to find a connection between isolines and the inclination of the surface.

We find that direction of inclination of a surface and direction of karstification are usually perpendicular to each other. Inclination of a surface does not have marked direction on Fekete-Sár.

Covered reliefs sloping towards NW and expanding towards NW-SE are characteristic on Mester-Hajag. Several rows of covered reliefs can be observed from SW towards NE at a greater and greater height. Redeposition of sediments along such a relief is of such an extent that karstification can begin at some spots where sediments become thinner. Erosion and deposition could alternate corresponding to the direction of inclination on these reliefs. Therefore more or less eroded parts / otherwise the top sediment could thin sooner or later / can alternate in the direction of inclination. Owing to this in the direction of inclination the age of karstification / value of K / decreases then increases and decreases again.

As erosion towards NW can equally proceed on covered areas of different heights areas by each other could become uncovered at a similar speed. Hence the rate of their karstification is also similar. Therefore K isolines enclose a big angle with the direction of inclination of a surface. The angle between the two directions can be smaller as well since resedimentation can proceed towards SW too from the higher covered reliefs to the lower ones.

On Alsó-hegy the cause of the similarity of the two directons is that the top sediment was eroded sooner from the higher reliefs. During the ascending of the area new and new territories have lost their top sediments in the direction of inclination of the limestone surface so karstification spread in the same direction. /Fig. 4./ Therefore areas of nearly the same height - uncovered simultaneously - are linked by the isolines.

On the territory of Fekete-Sár karstification is younger and younger towards the center of the area where the oldest dolines can be seen. The explanation of the above is that uncovering started in the center and was spreading towards the edges followed by karstification too. Isolines of the map represent recent condition following the above process. It is characterized by a younger karstification in the center and by an older one on the edges. Clearly karstification spreaded towards the edges and from here towards the central parts again. Here after recurrent karstification just wrecks of older dolines remained.

DISCUSSION

Different stages of karstification ofdifferent areas and illustration of relative ages of karstification within an area is represented by a map drawn of parameters K of functions of karstic depressions.

Shapes of K isolines represent not only the anomalies of karstification within an area but the characteristics of the erosion of top sediments. Uncovering of karstic surfaces could be simultaneous where the decrease of values K correspond to the direction of inclination of the surface and it is of a different age when values K do not correspond.

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CLIMATE AND SPELEOGENESIS IN MOUNTAINS (THE GREAT CAUCASUS AS AN EXAMPLE)

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Speleogenesis is defined mostly by the peculiarity of physical geographical conditions and climate in particular in mountain calcareous regions.

The vertical morphoclimatic zones are vividly singled according to karst and speleogenesis conditions on the Southern Slope of the Great Caucasus. 1. Low-mountain and piedmont karstic massifs with favourable hydroclimatic conditions for speleogenesis (the altitude 900-1000m).,2. Calcareous middle mountain zone covering the vast territories of silvan belt (from 900-1000m up to 1700-1800m) with abundant (4-5) moisture; 3. Subalpine and alpine belt, the zone (from 1700-1800 up to 2750m) of the Alpine bare and covered karst with severe climate and traces of the late quaternary glaciation.

In the mentioned regions the development and intensity of karst speleogenesis differ from each other. This is specified by different regimes of recent tectonic movements and relief energy as well as by different hydrogeological and climatic conditions. Variation of climatic conditions in Quaternary period, alternation of glacial and interglacial epochs are of great importance for the speleogenesis of calcareous regions of the Great Caucasus.

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КЛИМАТ И СПЕЛЕОГЕНЕЗ В ГОРАХ
(на примере Б.Кавказа)

Спелеогенез в горных известняковых регионах во многом определяется особенностями физико-географических условий и, в частности, своеобразием климата.

На южном склоне Б.Кавказа по условиям карсто- и спелеогенеза четко выделяются вертикальные морфоклиматические зоны: I.Низкогорная и предгорная (до абс.отметок 900-1000 м), с благоприятными для спелеогенеза гидроклиматическими условиями; II.Известняковое среднегорье, охватывающее обширные территории горнолесной полосы (от 900-1000 до 1700-1800 м), с избыточным (>4-5) увлажнением; III.Субальпийский и альпийский пояс (от 1700-1800 до 2750 м) - зона высокого голого и задернованного карста, с суровым климатом, со следами позднечетвертичных оледенений.

Ход и интенсивность карсто- и спелеогенеза в отмеченных зонах отличаются друг от друга, что обусловлено как неодинаковым режимом новейших тектонических движений и энергией рельефа, так и различными гидрогеологическими и климатическими условиями в каждой из них. Изменениям климатических условий четвертичного периода, в особенности же чередованиям ледниковых и межледниковых эпох, нами придается важное значение в спелеогенезе известняковых районов Б.Кавказа.

In mountainous calcareous regions, the speleogenesis is defined mostly by the peculiarities of physical geographical conditions and climate in particular. This problem has been widely considered in Soviet publications (Gvozdetsky, 1968,1972; Sokolov, 1972 et al.) as well as abroad (Trombe,1952; Corbel, 1959; Jakucs, 1970; Pulina, 1971 et al.).

On the Southern slope of the Great Caucasus the following vertical morphoclimatic zones are vividly singled out according to the conditions of karst and speleogenesis: I. Low-mountain and piedmont karstic massifs (up to 900-1000m above s.l.) with hydroclimatic conditions favourable for speleogenesis all the year round. II.Calcareous mid-mountain zone, covering the vast territories of silvan belt (from 900-1000m up to 1700-1800m) with abudant (4-5) moisture and hydrometeorological conditions extremely favourable for speleogenesis, and III. Alpine bare and covered karst zone (from 1700-1800 up to 2750m) with severe climate and traces of the late quaternary glaciation with irregular march of karstification during climatic seasons of a year. The intensity of karst speleogenesis is different within the mentioned regions. This is specified by various regimes of recent tectonic movements and relief energy as well as by different hydrogeological and climatic conditions in each of them.

According to L.Yakuch,1973, in Alpine, periglacial and moderate climatic zones the ratio of different aggresive agents is the following:

Agents / Zones	Alpine and periglacial	Moderate humid
CO_2 of atmospheric origin	45	7
CO_2 of inorgenic origin	5	9
Biogenic CO_2 (in soil)	30	54
Inorgenic acids	5	5
Organic acids	15	25

The investigations carried out by the authors during many years confirm that the activity of karst processes depends on the regime of atmospheric precipitations as well as on temperature variation of the air and soil. Thus, the temperature regime of the air affects the hydrological regime, defines solid and liquid precipitations fall, influences snow cover melting, causes thawing and ground freezing. Thus the bare apical surfaces of the calcareous massifs in Georgia suffer sharp diurnal variation of temperature in early spring and late autumn, when positive day temperature is drastically changed by negative temperature at night.

During warm season, at the Gagra range, at the absolute height of 1640m the ground is warmed up in day time sometimes up to 50°C, while at night it is cooled down to 5-7°C due to intensive radiation. On some hot days the temperature of calcareous surfaces is higher than that of the air by 30-35°(VI.1967; VI. 1968; VII.1969 et al.see Loladze, 1965). Under such conditions the mechanical weathering becomes highly intensive- that is one of the main reasons of jointing. Thus, in the secular coarse of modification of the volume of bare karstifiable rocks the temperature and mechanical forces destroy easily even such monomineral rock, as the limestone is.

The major part of surface forms distributed on the bare territory is embedded and developed in the weathering joints. Just these joints completely absorb the atmospheric precipitations and couse the aridity of karstified surfaces.

In the karst belt of Georgia the precipitation amount increases with the height, as at the Gagra massif. Thus, on the territory of Gagra resort the mean perennial precipitation sum is 1524 mm. While at the Gagra range it is 2281 mm, i.e. up to 1600m the average amount of precipitations increases by 45 mm per 100m.

On the slopes of sea-oriented low mountain calcareous massifs precipitation increase is the highest at 300m. Here the annual value of rain-gauge gradients fluctuates from 10 to 400m. Higher, the precipitation amount decreases , while from 1000m up to 2000m increases again. The leveled apical surfaces of calcareous massifs (abs.height 1800-2000 m) are recognized as the critical heights for precipitation growth and are characterized with very strong karstification.

According to the obtained data the calcareous massifs of Georgia almost the whole year are supplied with abudant precipitations that is particularly noticeable in the karst belt of Abkhazeti, where their total annual value, at the low massifs as well as at the high ones is rarely below 1500mm.

No sharp difference is felt in their seasonal distribution, with few exceptions. In the annual sum of precipitations at the piedmont areas the liquid precipitation prevail, in comparison with the apical surfaces of high massifs.

Probably under estimation of atmospheric precipitations influence upon the calcareous surfaces one is to proceed not from the absolute value of precipitations, but from the part that remains after evaporation. As it turns out the annual dispense of evaporation from the sea level up to 3000m varies from 815 to 470mm, i.e. with height the evaporation decreases. Comparing the amount of atmospheric precipitation with the evaporation data it can be concluded that the moisture balance within the karst belt of Georgia is quite sufficient for the active karstification processes during the whole year.

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According to morphological peculiarities of surface karst relief on the southern slope of the Great Caucasus one can state that with precipitation increase the intensity of karst proccesses is rising. On the other hand the evaluation of intensity of karst denudation in different climatic zones is still debat - able problem. On this point two main theories have been brought out and discussed. According to J.Korbel (1959), the denudation of karstified rocks is much stronger in cold climate. According to other authors (Lemann,1964; Jakucs,1970) the limestone denudation is quicker in the areas with edaphic soil cover in warm climate, where biogenic production of carbon dioxide is higher. D.J.Smith and T.C. Atkinson (1976) tried to settle this problem finally. They generalized all available data in tables and schemes and to their great surprise were to agree with J.Corbel: the rate of limestone erosion in cold climate was higher. The authors added, that the rate of process is directly proportional to intensity of annual discharge. Besides, the surface erosion is not the only way of rock erosion. Underground erosion of limestone may amount 40% of total erosion.

Solid atmospheric precipitations e.i. their volume, thickness of layer, duration of snow cover and conditions of its melting play special part in the speleogenesis of subalpine and alpine regions. At certain air temperature (thawing, persistent low temperatures) the snow cover may accelerate or impede the activity of karst processes. According to observations of many years, the snow cover at the Gagra calcareous massif gradually increases from the third decade of September and reaches its maximum in the third decade of March, The thickness of snow cover exceeds 1,5m almost in each decade of a cold season with few exceptions. With height the thickness of snow cover will increase and vary whithin fairly large limits depending on the slopes exposure and the protection of the separate elements of relief. This refers primarily to the apical levelled glacial-nival karst surfaces at the high calcareous massifs of Arabika, Bzibi, Okhachkue, Askhi, etc. Their macro, mezo and micro elements of karst relief are buried during the whole winter under the solid snow cover. The snow cover over 1 m lasts from the first decade of January up to the third decade of April even at hypsometrical level of meteorological station (1644 m) at the Gagra range. At the height of 1800 m snow cover lasts 182 days; at 2200m-196 days, while at 2500m- 222 days. In winter the meteorological conditions favour the formation of steady solid snow cover on the surfaces of mountain massifs, i.e. within the range of 1600-1800m the air temperature of the coldest month - January is -3°, -5°C, while during 4 months the mean temperature is below 0. In winter, during 2-3 months the mean air temperature is negative even at 13 o'clock. Within the range of 1800-2100m in January the mean temperature is -5,-7°C, and for 4-5 months mean daily temperature is below 0. Above 210 m (the apical surfaces of calcareous massifs of Georgia) the mean temperature of the temperature of the warmest months- July and August is 7-9°. (Kordzakhia, 1961).

The following important conclusion can be made on the bases of presented climatic data: Almost during the whole cold period (XI-III) at the hypsometric levels above 1600m the karstification processes almost stop and has no essential effect due to absence of liquid run-off. (Tintilozov, 1976).

It's worth mentioning, that today the caves in zone of high karst are formed under the influence of the local , incidently originated abudant dispersed run-off especially in Spring due to melting of the whole snow cover. On this account the karstification processes within the boundaries of high massifs are so strongly developed, that have no analogues. among the other speleological regions of Georgia.

Recently, in the subalpine and alpine zones the karst forms of relief are developed under the influence of rain and snow melt water, since there are no permanent watercources in the zones. However, it doesn't mean at all, that in the past under the different geomorphological and hydrographical conditions, the permanent water absorption didn't take place at the apical surfaces of high massifs. Thus, the majority of investigated large vertical caves (Sneznaya- Mezhennogo, Pantukhina, Arabika etc.) were developed in former cycles and passed the long and complecated way of development since embedding up today.

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What are the climatic conditions and speleogenesis peculiarities at the calcareous middle mountain zone on the southern slope of the Great Caucasus?

Forest microclimate noticably differs from the climate of subalpine and alpine karst regions. The fluctuation of the air and ground diurnal temperatures and very strong winds at the apical surfaces become very week under the forest cover. Therefore, the processes of physical weathering are practically extinguished at the depth of 10 centimetres. Besides, the snow cover is evenly dispenced and lasts for a longer time in the forest zone. Snow melting period in forest is twice longer than in the open areas (Sokolov,1962).

The precipitation amount noticeably increases in silvan zone on account of fog, hoarfrost and ice storm. Thus, the fog increases the total precipitation amount for 25-30% and sometimes even exceeds the total annual volume of precipitations. The hoar frost and ice storm precipitations are also very perceptible. The silvan zone of mountainous Crimea acquires 22% of the total sum of atmospheric precipitations (Ved, 1968).

One can assume that in the karst belt of Georgia, where silvan massifs occupy larger areas, the amount of precipitations is much higher than in the mountainous Crimea.

The decaying forest bedding gives rise to aggressive waters. The role of silvan belt in retaining the atmospheric precipitations and their gradual expense is very great. Thus, at Gagra range (local meteorological station) during the third decade of January (1941) the height of snow cover in the open area came to 269 cm, water resources 780mm while in the forest the same data were 337 cm and 977mm. During the third decade of February (1941) the data for the open area was: 196cm and 723 mm; in the forest 259 cm and 1063 mm. In some years (III-1941, II-1945) the height of snow cover was up to 3 metres and over.(Loladze,1965), Moreover, the vegetation roots and the forest itself play an active part in karstification processes as well as protect the soil and control the ground water run-off. High discharge karst streams of Georgia (Mchishta, Rechkhi, Tsathkhura etc.), which basins probably contain the large cave systems, exist mainly on the account of woody massifs.

Abudant precipitations (vertical and horizontal) falling on the slopes of woody massifs, inversed towards the Black Sea, along with favourable temperature and biochemical conditions, specify the intensive karstification processes during the whole year.

The existence of comperatively low-powered carbonate rocks and high density of karst caves is common for the piedmont karst regions, situated at the zone of low-intensity late Cainozoic movements. Unlike the high karst massifs, the lower regions are characterized with large flooded cave systems with well developed stages connected with concentrated powerful water streams formed by transit underground run-off. Speleomorphogenetic significance of these watercources is that they favour the development of hydrostatic and hydrodynamic pressure in karst caves, which involves their intensive growth.

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Karst relief of the southern slope of the Great Caucasus even before the Late Pleistocene glaciation suffered strong erosional destruction and dissection simultaneously with the origin of water absorbing elements (clints, lapie, pits, shafts,etc). During glacial epochs the intensive march of erosional-corrosional processes standing out against intensive raising tectonic movements slowed down or even stopped, while the karstified surfaces were preserved due to the absence of the liquid run-off. Thus, we attain the great importance to the variation of climatic conditions of Quaternary period, especially to the succession of glacial and interglacial epochs in the speleogenesis of mountainous calcareous regions of the Great Caucasus. The abudant glacial waters released during inter glacial phases due to inflow and seepage caused extensive wash-out on surface and underground. The existence of mountainous deep karst caves in the depths of mountainous calcareous regions (Pantukhina- 1225 m, Ilukhina -1225 m, Sneznaya-Mezhennogo- 1370m, Arabika-1110 m etc.) confirms the essential role of glacial run-off and floods in the speleogenesis of mountainous countries. The great wash-out abiliy of fluvioglacial waters is testified by molasse deposits carried down from high mountain massifs by temporary and permanent floods (rivers Bzibi, Khipsta,Aapsta etc), such is 20-30 m stratum of calcareous conglomerates of the Duripshi plateau in Abkhazeti,etc.

Thus the process of karstogenesis is greatly influenced by climatic conditions and is strongly depended on the ratio of heat and moisture.

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CAVE EXPLORATION IN THE CANADIAN ROCKY MOUNTAINS

YONGE, Charles J.

Cave and karst exploration in the Canadian Rockies proceeds on two fronts: on the one hand, the helicopter has proved invaluable in reaching remote and/or inaccessible karst areas (see for example, volume 2, pages 258-263 of the 9th International Congress of Speleology, Spain 1986) and on the other, known areas yield new caves or extensions to existing ones.

Recently, two new karst areas have been investigated around Mount Ball (Kootenay National Park) and Mount Bastille (Cariboo Land District), both in British Columbia. Preliminary exploration has turned up a number of short caves but the presence of remnant large caves and impressive karst in each area suggests much more remains to be found.

Of known caves and karst, the Crow's Nest Pass (Southern Alberta/BC boundary) continues to yield new caves in addition to new passage in existing caves. Moon River Cave (Cariboo Land District) has finally been explored. Difficulties there in exploration involve following a river that flows under a remnant glacier prior to flowing underground in a series of pitches. In the Bow Valley east of Banff National Park, the small well-known Rat's Nest Cave has been extended while under study (see "The Rat's Nest Cave Project" in these proceedings). It is now placed among the 10 longest caves in Canada.

L'EXPLORATION DES GROTTES DANS LES ROCHEUSES CANADIENNES - RESUME

L'exploration des grottes et du karst dans les Rocheuses du Canada se poursuit sur deux fronts: d'une part, l'hélicoptre s'est révélé inestimable pour atteindre des régions karstiques reculées et/ou inaccessible (voir par exemple, vol. 2, pages 258-263 des Actes du "9e Congrès International de Spéléologie, Espagne 1986") et d'autre part, de nouvelles grottes ont été découvertes dans des regions déjà connues, ou de nouveaux passages ont été exposés dans des grottes déjà explorées.

Récemment, deux nouveaux plateaux karstiques en Colombie Britannique ont été prospectés aux alentours des Mont Ball (Parc National de Kootenay) et Mont Bastille (Cariboo Land District). Une première exploration a révélé l'existence de petites grottes, mais la présence de karst impressionnants dans chacune de les regions suggère qu'il en reste encore beaucoup à découvrir.

Parmi les grottes et karsts déjà prospectés, le Col du Crow's Nest (Sud de l'Alberta, à la limite de la Colombie Brittanique), continnue à se révéler une source de nouvelles grottes et de nouveaux passages. La grotte Moon River (Cariboo Land District) a enfin été explorée. Il s'agissait la de trouver un moyen de suivre une rivière qui coule sous un reste de glacier avant de se jeter dans une suite de puits souterrains. Dans la vallée de la rivière Bow à l'est du Parc National de Banff se trouve la grotte de Rat's Nest, de petite dimension mais bien connue lors des études qu'on y poursuit (voir "Le Projet de la Grotte Rat's Nest" dans ces Actes), on a fait la découverte d'autres passages. La grotte se place maintenant parmi les dix grottes les plus longues du Canada.

1 INTRODUCTION

The Canadian Rockies comprise considerable masses of paleozoic limestone that extend mainly along the continental divide. The sphere of interest to the Alberta Speleological Society (ASS) stretches from the US border in the south up into the North West Territories. Most activity is concentrated in the southern portion where areas are accessible to the major population centres. For example, the Crows Nest Pass 100km north of the US border has yielded several caves, the longest being 10km to date. Accessibility of the karst results in two levels of exploration. One to the closer areas involving weekend trips usually on foot and occasionally with help from four-wheel drive vehicles, and the other to remote karst terrains, utilizing helicopters or float planes. On the latter excursions, very often the karst areas are unexplored and new cave discoveries result; closer to civilization, it is in the known caves that discoveries are usually made. However, the first example below, is a relatively accessible area which had been missed and where new caves have just been found.

2 RECENTLY EXPLORED KARST AREAS

2.1 The Karst of Mount Ball

This karst lies on the western flank of Mount Ball (3312m) in Kootenay National Park some 130km due west of Calgary. Caves are developed in a limestone unit (Fairholme Reef Complex of Devonian Age) split by an impermeable slatey/quartzitic boundary at around 2,400m ASL. Above the impermeable boundary some horizontal caves have developed along the boundary and may be found in residual, glaciated ridges. Remnant and active vadose canyon caves have been found with dimensions up to 8m high by 3m wide in fossil passages and 4m high by 1m wide in active passages.

The Silver Sands system (Fig 1) receives water from snow fields on Mount Ball. The main route is developed along the strike and sumps after 140m, whereas the tributary route (Silver Sands Cave) can be followed updip at 3^{o} for 300m to a sinkhole entrance, beyond the breakdown of which, it appears to continue. The sink entrance is found in a heavily glaciated bench and the cave trends into a ridge where the water resurges. Further along the ridge and downdip, Canyon Remnant Cave and other sections of fossil passage can be found which suggests scouring by repeated glacial advances or sequential melting back of one glacier.

The main portion of the karst lies in a broad flat-bottomed valley that hangs at its "downstream" end. Here the the limestone has been eroded down below the impermeable boundary leaving an impressive glaciated karst pavement exhibiting numerous shafts and a variety of karren. The upper end of the pavement is lapped by a text-book example lateral moraine which delivers streamwater to active shaft sinks on the limestone. A number of the shafts around the perifery of the pavement appear to be sinks of this kind.

The caves in this lower portion of the limestone are thus of a vertical nature but punctuated by horizontal sections (Fig 2) with a depth potential of 500m. Passages are typical of alpine karst, active streams target on older, fossil passages. Of interest is that portions of these older passages contain massive redissolved speleothems and calcified sediments suggestive of an interesting glacial history. Permission from the Park Service is being sought to pursue such studies.

Many of the shafts on the pavement are developed on mineralized joints and in Provenance Cave (Fig 2), the first sighting in a Canadian Cave of the asbestiform mineral attapulgite was observed on such a joint.

2.2 Northern Karst Regions

Some karst areas have been investigated around 100km NW of Jasper in the Hart Ranges and these have yielded a number of significant caves.

2.2.1 Close To The Edge

The cave is named after its spectacular entrance shaft, remarkable in the Canadian Rockies (Fig 3). Although presently fed by a small stream, the shaft is remnant and perched in a ridge 1km above the main valley floor. The shaft descends as a free drop for 253m with an average diameter of 15m (the greatest continuous drop in the Americas outside Mexico). A futher 30m drop leads to a blocked rift taking a massive draft. A large spring 700m directly below the cave suggests a route for the cave water although most of the spring water likely flows from a karstic valley adjacent to, but lower than the cave.

2.2.2 Karst of Bastille Mountain

Bastille mountain straddles the continental divide, flanked by an icefield to the east and an extensive, glaciated karst ($15km^2$) to the west. Karst pavements rise northwards with the dip from 1700m to 2200m and large resurgences a few kilometers to the south appear as ponds in muskeg in a major valley system at 1200m. Other resurgences have been seen to the NW which may drain a small portion of the karst.

The pavements are developed on highly fossiliferous Devonian limestones with some indication of thrust faulting. Evidence of glacial activity is very fresh, exhumed coral heads and millstones litter the surface; some patterned ground can also be seen. Shafts and shaft sinks are the most common cave feature encountered, the latter draining small, remnant icefields. Probably only half of the 500 or so shafts (many blocked with rubble) in the area have been explored.

Some down-dip, canyon passage was found including a major fossil canyon system (Tier Duct Cave, Fig 4) whose dimensions reached 4m wide and over 30m high. Mapped for 0.6km, it has the potential to traverse some 5km of karst terrain.

2.2.3 Moon River Karst

Like a lunar crater, this area is marked by a $10km^2$, barren basin containing a sinking lake (Moon River) on its western side and studded by shafts and depressions on its eastern side. It lies 40km NW of the Bastille karst. The basin is divided north-south by a vertical limestone/quartzite contact which explains the confiuration of shafts and lake. Two principal caves are formed on the contact: Moon Valley Cave is a canyon system that trends towards the middle of the basin and contains some well-developed passage. Moon River Cave (Fig 5), is the sink for the 0.5km diameter lake perched on the quartzite. The sink-hole is massive and is capped by a remnant glacier. The river, flowing below the glacier, enters the cave and cascades down several pitches before entering a siphon. An overflow, phreatic route above the siphon has been explored for several hundred meters in the direction of Jarvis Lakes, the likely resurgence point 4km northwards and 450m lower.

3 EXTENSIONS IN KNOWN CAVES

3.1 Rats Nest Cave

Two other papers in these proceedings by Yonge deal with specific aspects of this cave; only a general description is given here.

The system is situated on Grotto Mountain close to the town of Canmore (site of the Nordic events at the 1988 Olympic Winter Games). The cave has been well known locally for around 15 years but was never systematically explored. Mapping and exploration of the system by the Alberta Speleological Society has now realized over 4km of passage (before, it was thought to be less than 1km) and exploration is continuing. It is now the sixth longest cave in Canada.

Contained within the Livingstone formation of Devonian Age, the cave is almost completely fossil-phreatic in nature. The entrance was once a spring and most passageways lie below it. The system is developed along a major thrust fault which can be traced westwards across Grotto Mountain to Cougar Creek 4.5km distant. The cave was likely fed from subglacial streams in the Cougar Creek valley during glacial times which suggests a major portion of the cave remains to be found. Exploration is continuing both westwards and eastwards along the fault; the lower, eastern section through siphons via diving.

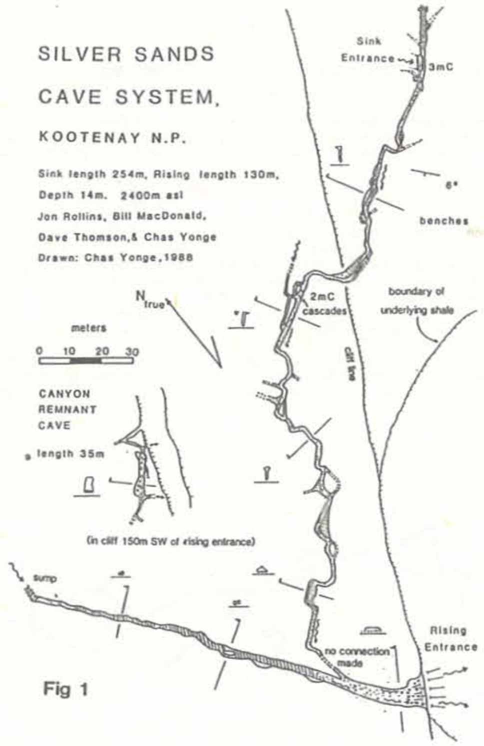


Fig 1

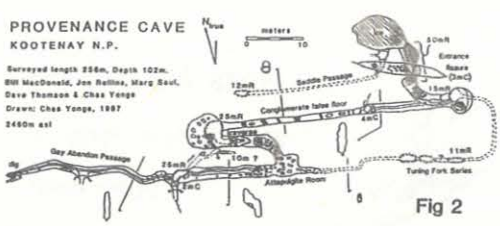
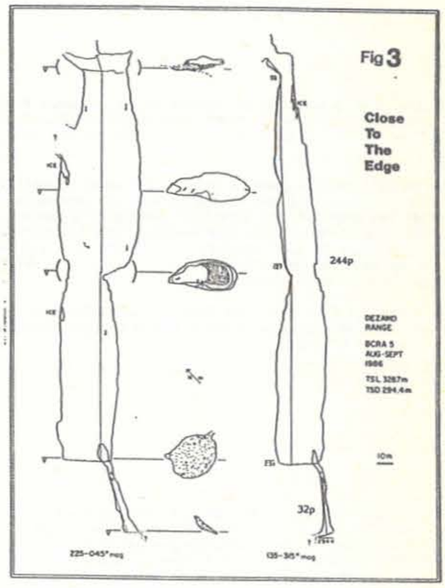
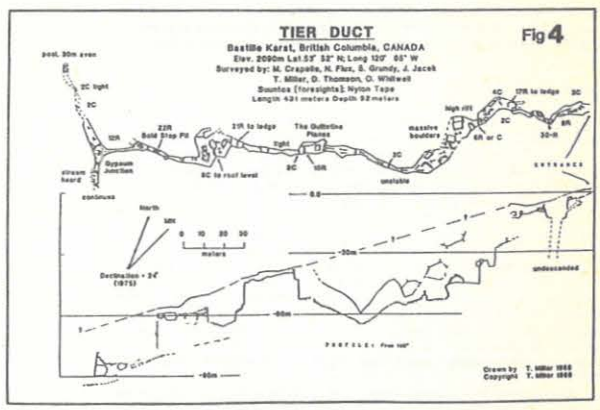
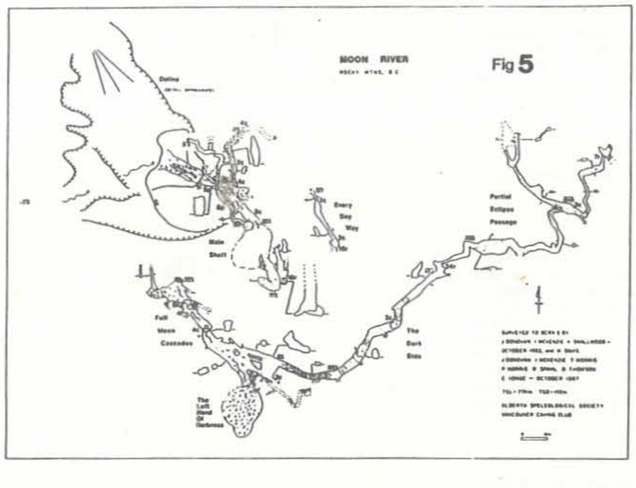


Fig 2







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THE RATS NEST CAVE PROJECT

YONGE, Charles J.

Rat's Nest Cave, over 3 km long, is situated in the Canadian Rocky Mountains 25 km east of the town of Banff in Banff National Park (close to Canmore, site of the nordic events at the 1988 Winter Olympic Games).

The cave has recently been designated a "Provincial Historic Resource" to protect it from local quarrying and vandalism. With the designation, a course of study has been put into effect to investigate a number of aspects of the cave; these include: paleohydrology and speleogenesis, hydrology, speleobiology, the cave atmosphere and radon, the bone bed (Holocene) and the paleoenvironment (see "Isotope Studies of Speleothems from Rat's Nest Cave" in these proceedings).

The ultimate aim of the Rat's Nest Cave Project is to establish the cave as a natural underground laboratory in which studies like the above can be pursued in the years to come.

LE PROJET DE LA GROTTE "RATS NEST" - RESUME

La grotte "Rat's Nest", qui fait plus de 3 km de long, est située au milieu des Rocheuses Canadiennes, à 25 km à l'est du Parc National de Banff (elle est à proximité de la ville de Canmore, où se sont récemment deroulés les épreuves de ski nordique des Jeux Olympiques d'hiver de 1988).

La grotte a reçu la désignation officielle de "Resource Provinciale Historique" qui la protege contre toute activité d'extraction minière et contre tout vandalisme. De concert avec cette désignation, une série d'études a été entreprise qui examine un certain nombre d'aspects de la grotte: par exemple, des études de paléohydrologie, de spéléogénèse, d'hydrologie, des études de la faune, de l'atmosphère et du radon, d'un gisement d'os de la période Holocène et du paléoenvironnement (voir "Etudes Isotopique des Échantillons de Spéléothèmes de la Grotte de Rat's Nest sur ces Actes).

Le but ultime du projet de la grotte Rat's Nest est de faire de cette derniere un laboratoire souterrain natural dans lequel des études telles que celles mentionnées ci-dessus pourraient être poursuivres dans les années a venir.

Rats Nest Cave (Fig 1) has been chosen for protection and study. It has required special conservation measures because it was both threatened by quarry concerns (fig 2) and, being accessible to large population centres, vandalism. The cave is extensive and contains many interesting features, notably wide-spread formations and a Holocene bone bed at its entrance.

The project was put in place when Alberta Culture took an interest in the cave system and requested specific information about the cave and its contents. Subsequently, the author received a grant of $10,000 to study the cave; the work to date is described below.

2 THE CAVE (Fig. 1)

Rats Nest Cave is situated on Grotto Mountain in the Canadian Rocky Mountains near the town of Canmore (site of the nordic events at the 1988 Winter Olympic Games). It is 10km east of Banff National Park and 90km west of Calgary (population, 600,000). The cave has been known in recent times for a few decades but the last 15 years has seen most of the caving activity.

The cave system at the time of writing exceeds 4km in length. Contained within the Livingstone Formation of Devonian age on Grotto Mountain (2670m), it is almost entirely fossil phreatic in nature. The entrance appears to have been a spring and most of the passageways lie below it. While siphons are encountered in the lower portions of the cave, wide-spread phreatic conditions probably relate to past glacial activity in the adjacent Bow Valley and one of its tributaries, Cougar Creek. Grotto Mountain is cut by a major fault along which the cave is developed; the fault intersects Cougar Creek at its NW termination and Gap Lake at its SE termination. The Cougar Creek Valley, 4.5km distant, appears to have have been the source of water for the cave in glacial times, while presently Gap Lake and an adjacent resurgence, 1.5km distant, represent modern day outlets.

The cave is currently the sixth longest in Canada and contains speleothems throughout its length. At its entrance, a shaft contains over 2m of bone deposits dating back to the most recent glaciation. Details of these deposits and other aspects of the cave are described next.

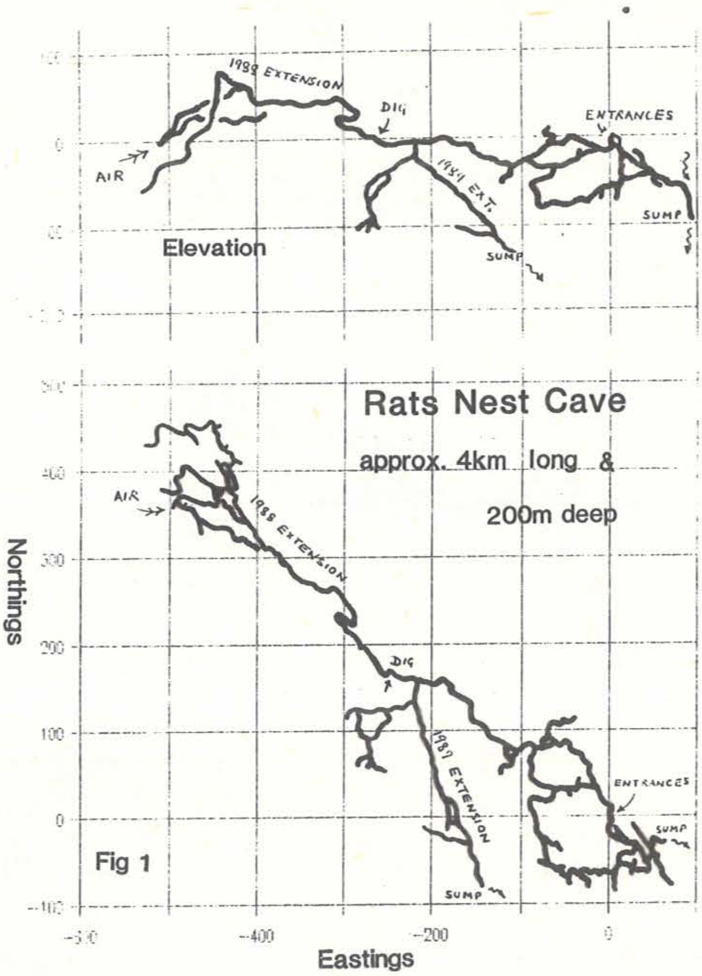

Fig 1

3. THE STUDY

The study has been divided into 5 sections as depicted in Fig. 3, these comprise:

3.1 Determination of the Extent of The Site

Apart from wanting to know how extensive the cave is and where it is located in respect of surface features, it was also felt important to define a zone of protection around the system in respect of industrial concerns. The cave has been mapped to 4km but survey work continues as more passage is found. A cave radio, designed locally by ASS members, Ian Drummond and Julian Coward, is being used to pin-point the position of the cave with respect to the surface. In the lower reaches of the cave, dives made through a number of siphons has extended passages eastwards. Continued exploration of open passages and some digging is currently extending the cave westwards.

3.2 Speleobiology Inventory

Work in the entrance shaft bone bed is continuing with Jim Burns of the Provincial Museum. The 31 different mammal species he has identified have been ^{14}C-dated back to 7,600 years BP so far. Some of these mammals are locally extinct, otherwise all are represented somewhere in North America today. The entrance appears to have been occupied by a variety of carnivores that brought carcasses to the site at various times. Hence, the variety of bones including elk and bison. Presently pack rats (bushy-tailed wood rats) live at the entrance and, prior to caving activity, mountain sheep sheltered there during storms. Little brown bats have been observed in the cave but their roosting site has yet to be found. Study of the smaller forms of life within the cave, eg. over-wintering harvestmen, amphipod worms etc., has only just begun and no results are reported here.

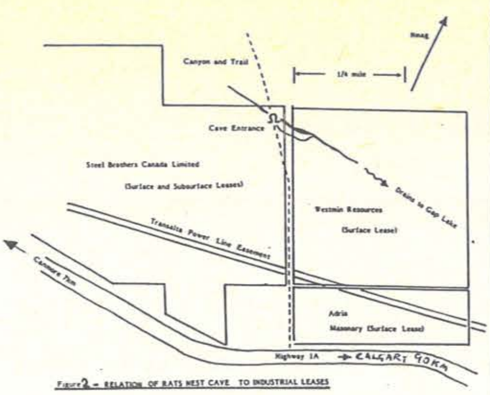

Figure 2 - RELATION OF RATS NEST CAVE TO INDUSTRIAL LEASES

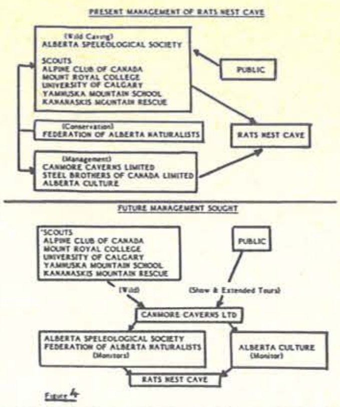

Figure 4

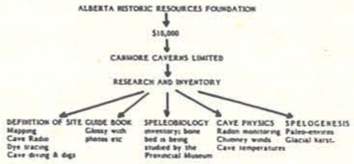

Figure 3

was likely coupled to Bow Valley glaciations and the cave sediments should yield information on that glacial activity.

3.5 Guide Book

All aspects of the knowledge gleaned from the cave is being compiled in a "popularised" guide (being written by Dave Thomson of Banff). The Albertan public is not aware of cave resources in the province and it is hoped that the book will provide an understanding of the importance and fragility of these sites. When a portion of the system is opened as an interpretive site, as is hoped, the guide book will provide specific information about the cave to the visitors.

MANAGEMENT OF THE SITE

While there are many people caving in Alberta, many do not belong to an organised group. As a result, there is little understanding of the delicacy of the cave environment in the province and some vandalism has occured at Rats Nest: eg,. breaking and even removal of formations. In addition, the cave has been under the threat of quarrying. After considerable government negotiations, the cave was declared a Provincial Historic Resource, thereby placing it under a protection order from the government.

To provide access to the cave, a preliminary management plan was put into affect based on public interest and the findings of the cave study. Liaison was established between the lease holders (Steel Brothers of Canada Limited), Alberta Culture and various interested public groups. The management plans, both present and future can be seen in Fig 4. Persons not attached to the 7 interested groups listed there are expected to contact the Alberta Speleological Society (ASS) for information and possible membership. Subsequent trips into the cave are then regulated by the management group (yet to be ratified by the monitoring parties). An important, external influence on the management plan is the Federation of Alberta Naturalists (FAN) whose main concern is conservation of the site.

3.3 Cave Physics

Preliminary measurements have been made in the cave on temperature, humidity, wind velocity and radon. In brief, the results are as follows: temperature (5.0 +/- 0.1°), relative humidity (97-100%) and wind velocity (a range between +/- 1m/s). Activated charcoal was used to collect radon and measurements from the entrance area near the bone bed give 2.2 +/- 0.1 WL (working levels). This value is rather high for caves and may be due to the siting of the detector close to the bone bed. Further, detailed measurements are being pursued on the parameters described above.

3.4 Speleogenesis and Paleoclimatology

See also "Isotope Studies of Speleothems from Rats Nest Cave by Yonge and Ford" in these proceedings,

Speleothems and clastic sediments have been removed for isotope and paleomagnetic studies respectively. Isotope analyses comprise U-series dating (Ford, McMaster University) and stable ^{18}O, D and ^{13}C measurements (Yonge, Calgary University). The cave is in a strategic location for investigating past glaciations, being at the point where the Bow Valley (which contained a massive glacier in Quaternary times) breaks out into the foothills and adjacent to the celebrated "ice-free corridor" which may have allowed people to migrate into the Americas from the north. Furthermore, the cave

A future plan then involves developing a portion of the cave for public tours by Canmore Caverns Limited (a company set up for the cave development) and this company would (and does) seek to gain the leases from the current lease holders. In this case, the interested groups would set up a wild cave tour schedule with Canmore Caverns and the company's activities would be monitored by the ASS, FAN and Alberta Culture.

The ultimate goal of the Rats Nest Cave Project is to set up a cave institute in Canmore funded in part from the financial assets of the show cave. The institute's goals would be education and research; the cave would continue to be used as an underground laboratory and studies would be extended to other, more remote, karst regions of the Canadian Rocky Mountains (see for example, Cave Exploration in the Canadian Rocky Mountains by Yonge in these proceedings).

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EIN THERMODYNAMISCHES MODELL VERTIKALER HÖHLEN VOM TYP "AVEN"

ŠČUKA, Julius - RODA, Stefan Jun. - RAJMAN, Ladislav - RODA, Stefan

THERMODYNAMIC MODEL OF VERTICAL CAVES OF "AVEN" TYPE

The aim of our contribution is to evaulate the research of time and space changes of microclimatic parameters from five chosen vertical caves of "Aven" type in the Slovak Karst.

From the results of the experiment made on the base of nomeric and statistic parameters of microclimate there was documented dependence on

- external synoptic situation
- geographical position and influence of vegetal cover of the mouth of exploring objects
- morphology of objects
- and on the course of the curve of geothermic gradient.

The research showed that the main factors changing the microclimate of exploring objects are

- the influence of external synoptic situation
- the influenee of geothermic gradient
- and the influence of phasic water changes

According the analyze of results there is made the thermodynamic model of the system with the existence of three thermodynamic sones. The first sone of the system, from the thermodynamic point of view, is mainly influenced with the external synoptic situation. The influence of geothermic energy is prevalent for the third zone. The second zone is the place the thermodynamic compensation of energetic influence of the first and the third zone with the main influence of phasic water changes.

Einleitung

Zu den grundlegenden physikalischen Methoden der Erforschung des unterirdischen Karstphänomens gehört das Studium der zeit- und raumgebundenen Veränderungen von Faktoren des Mikroklimas.

Mit dem Ziel solche Veränderungen der mikroklimatischen Parameter in Höhlen des Typs "AVEN" zu untersuchen, haben wir in den Jahren 1984 - 1985 experimentelle Messungen der Lufttemperatur, der relativen Luftfeuchtigkeit, des Luftdrucks und der Richtung der Luftströmung in fünf Objekten des Slowakischen Karsts durchgeführt. Bei der Wahl der Objekte wurden folgende Gesichtspunkte berücksichtigt:

- die geographische Lage der Mündung des Forschungsobjekts,
- die Morphologie des Objekts /mit einem Tiefenlimit von mindestens -50 m/ und
- die Vegetationsdecke an der Mündung des Objekts.

Die Messungen wurden vierteljährlich in den einzelnen Jahreszeiten, bei annähernd gleicher synoptischer Situation in der äusseren Atmosphäre durchgeführt.

Die Temperaturmessungen der Höhlenluft im vertikalen Profil der Objekte wurden mit einem Messgerät eigener Konstruktion mit einem Messchritt von 5 m realisiert. Der Messfühler /Thermistor/ wurde am Kabel installiert um den Einfluss des Subjekts auf die Temperaturmesswerte auszuschliessen. Die anderen verfolgten mikroklimatischen Parameter wurden mit einem Messchritt von 20 m mit angeseiltem Operator ermittelt.

Die Messwerte wurden statistisch numerisch und graphisch mit dem folgenden Ziel verarbeitet:

- Bestimmung der Abhängigkeit mikroklimatischer Veränderungen in den untersuchten Objekten von der äusseren synoptischen Situation,
- Bestimmung der Abhängigkeit des Mikroklimas von geographischen und morphologischen Faktoren und
- die Verfolgung von Veränderungen thermodynamischer Parameter in den untersuchten Objekten.

Ergebnisse des Experiments

Anhand der gewonnenen Ergebnisse wurde nach der statistisch-numerischen Verarbeitung der mikroklimatischen Parameter deren Abhängigkeit von

- der äusseren synoptischen Situation,
- der geographischen Lage und dem Einfluss der Vegetationsdecke der Mündung des Versuchsobjekts,
- der Morphologie des Objekts und
- dem Gradient des geothermischen Typs dokumentiert.

Die Forschungen haben gezeigt, dass der Einfluss der äusseren synoptischen Situation und der Gradient des geothermischen Typs mit den damit zusammenhängenden Veränderungen des Aggregatzustandes des Wassers den dominierenden Faktor der Veränderungen des Mikroklimas in den untersuchten Objekten darstellt.

Der Einfluss der äusseren synoptischen Situation auf die Veränderungen der mikroklimatischen Parameter wirkt sich am intensivsten am Temperaturverlauf und der Luftfeuchtigkeit in Abhängigkeit von der Tiefe, der Vegetationsdecke der Mündung und der Morphologie der untersuchten Objekte aus. Die grösste Temperaturamplitude in bezug auf die Tiefe weisen die Eingangszonen der untersuchten Objekte von der Mündung bis zu etwa -40 m auf. Der Verlauf der Temperaturamplituden wird durch den Jahreszeitwechsel ausgeprägt beeinflusst. Im Frühjahr und im Sommer ist eine Abhängigkeit der Temperaturmesswerte von der äusseren synoptischen Situation nur bis zu einer Tiefe von etwa -25 m zu verzeichnen. Im Herbst und im Winter können wir anhand unserer Messwerte eine solche Abhängigkeit bis zu einer Tiefe von ca -40 m nachweisen.

Die Mündungen der Versuchsobjekte befinden sich in einer Höhe von 455 bis 677 m ü.d.M. Da der Einfluss der geographischen Lage auch eine Funktion der Vegetationsdecke der Mündung der untersuchten Objekte ist, müssen wir diese Problematik komplex behandeln. Zum Teil spielt auch die Grösse der Mündung des Objekts eine beeinflussende Rolle.

In bezug auf die geographische Lage können wir die beschriebene Abhängigkeit anhand der Durchschnittstemperaturen für die Tiefenintervalle von 0 - 50 m, 0 - 70 m sowie auch aus dem extrapolierten Wert des Gradienten des geothermischen Typs für die Tiefe von 0 m dokumentieren. Für den Einfluss der geographischen Breite und der Seehöhe stehen diese Werte aus den untersuchten Objekten in guter Übereinstimmung zu den aus der Beziehung nach Choppy /1984/ berechneten Werten:

$$t = 54,3 - 0,9.L - 0,006\ Z,$$

wo L - die geographische Breite und Z - die Höhe über dem Meeresspiegel in Metern bedeutet.

Der Einfluss der Vegetationsdecke der Mündung kommt in der Verminderung des Anteils des Einflusses der äusseren synoptischen Situation zum Ausdruck. Die Vegetationsdecke an der Mündung des Objekts vermindert die Einwirkung der direkten Sonnenstrahlung und vermindert auch die Intensität der Strömung der atmosphärischen Luft. Aus den genannten Gründen lässt sich der Einfluss dieses Faktors auf den Temperaturverlauf in den untersuchten Objekten nur bis in eine Tiefe von -10 m dokumentieren.

Die statistisch verarbeiteten Messwerte weisen bei minimalen morphologischen Veränderungen nur geringe Abweichungen von der Gradientkurve des geothermischen Typs auf, welche 1 % nicht überschreiten. Ein wesentlicher Einfluss der Morphologie tritt bei umfangreicheren Höhlenräumen in grösseren Tiefen in Erscheinung. Dieser Faktor verursacht eine Abweichung vom Verlauf der Gradientkurve des geothermischen Typs in Tiefen von mehr als -65 m. Bei geringeren Tiefen der Forschungsobjekte und bei sich vergrösserndem Querschnitt wird der Einfluss der Morphologie der Objekte durch den Einfluss der äusseren synoptischen Situation überdeckt.

In allen untersuchten Objekten wurde ein Temperaturgradient vom geothermischen Typ /Choppy J., 1984/ dokumentiert. Allgemein konnte diese Abhängigkeit für unsere Forschungsobjekte durch die nachstehende Beziehung definiert werden:

$$\Delta t_h = 0{,}02\ h + t_o,$$

wo: Δt_h - Temperatur in der Tiefe h in °C
h - Tiefe in Metern
t_o - Temperatur in der Tiefe 0 m, gewonnen als Schnittlinie mit der Achse der Temperaturskala.

Diese Erscheinung dominiert bereits in Tiefen ab -40 m, was den im vorliegenden Modell des Systems diskutierten Gleichgewichtsbedingungen entspricht.

Das thermodynamische Modell des Systems

Anhand des Modells des thermodynamischen Systems der untersuchten Objekte können wir die Einflüsse der einzelnen beschriebenen Faktoren in drei vertikal gegliederten Zonen modellieren und auswerten. Der Endzustand /s. Abb. 1/, d.h. die gesamte energetische Bilanz ist durch die Energiesumme der in den Prozess eintretenden Medien gegeben. Aus dieser Sicht ist das Mikroklima des Modells nur eine Widerspiegelung energetischer Vorgänge.

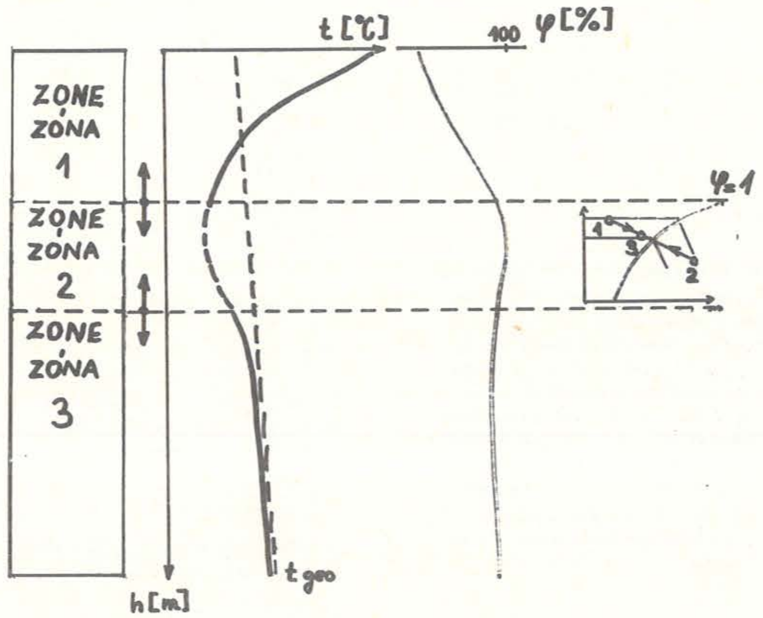
Für Veränderungen der mikroklimatischen Parameter in der ersten Zone sind isochronische Geschehen mit Energiezufuhr aus der äusseren Atmosphäre charakteristisch. Die der ersten Zone des Modells zugeführte Energie erreicht in den Frühlings- und Sommermonaten positive Werte. Diese Energie wird dann durch Energieumwandlungen in der zweiten und dritten Zone des Modellsystems kompensiert.

Für die zweite Zone des Modells sind isothermische Geschehen charakteristisch und der energetische Zustand dieser Zone mit parabolischem Verlauf des Temperaturgradients ist das Ergebnis der Umwandlung des Aggregatzustandes des Wassers. Hinsichtlich der in Abhängigkeit vom Wandel der Jahreszeiten kompensierten Energiemenge kommt es zu äquivalenten Volumenveränderungen der zweiten Zone.

Für die dritte Zone ist ein geothermischer Verlauf des Temperaturgradienten charakteristisch. Dieser Zustand entspricht den Gleichgewichtsbedingungen einer normalen Schichtfolge der Höhlenluft unter den jeweiligen Temperatur- und Druckverhältnissen. In energetischer Hinsicht ist für diese Zone eine adiabatische Kompression bzw. Expansion charakteristisch.

Das so definierte thermodynamische Modellsystem ermöglicht die Simulierung mikroklimatischer Parameter im System für einen bestimmten Zeitpunkt mit gegebenen Ausgangsbedingungen. Durch Variieren der Ausgangsbedingungen für verschiedene Zeitintervalle erhalten wir ein den experimentell festgestellten Tatsachen nahes dynamisches Modell.

ABB. 1.
OBR. Č. 1.



KARST DEVELOPMENT IN ITS INITIAL STATE: A MODEL OF SPELEOGENESIS

DREYBRODT, Wolfgang

We present a theoretical model, based on the chemistry of dissolution kinetics of limestone, by which solutional widening of initially 20 μ wide fractures under the action of calcite aggressive water, subject to hydraulic gradients above 0.01, is calculated as a function of time. The model assumes that above a saturation level of 90% there is a change from first order kinetics (1) to slow fourth order kinetics (2). As a consequence solutional widening of small fissures to geologically feasible sizes over large distances is possible in a time scale of several 10000 years. This resolves the long debated question on the initiation of karst systems and shows that mixing-corrosion plays only a supporting role in the initiation of karst systems. Field observations which support our model will be discussed.

Wir stellen ein theoretisches Modell vor, durch das die Aufweitung von ursprünglich 20μ weiten Klüften durch kalkagressives Wasser unter hydraulischen Gradienten oberhalb von 0.01 als Funktion der Zeit berechnet werden kann. Die Annahmen in diesem Modell sind, daß für Kalk-Sättigungsgrade des Wassers oberhalb 90% eine Änderung der schnellen 1. Ordnungslösungskinetik (1) zu einer langsamen 4. Ordnungskinetik (2) stattfindet. Als Folge daraus ist die Aufweitung enger Klüfte auf geologisch relevante Dimensionen und über große Entfernungen innerhalb einer Zeitskala von 10000 Jahren möglich. Das Modell trägt zur Lösung der seit langem diskutierten Frage über die Initiationsphase von Karst bei und zeigt, daß Mischungskorrision nur eine unterstützende Rolle spielt. Feldbeispiele, die unser Modell unterstützen, werden vorgestellt.

1. INTRODUCTION

Primary permeability of carbonate rocks results from an interconnected network of small fissures and cracks comprising joints, bedding plane partings and eventually also faults. Initial apertures are about $1\cdot10^{-2}$cm (Motyka and Wilk, 1984). Once by some geological event an input-output configuration for surface water is given, which supplies an hydraulic head h driving surface water through the percolating net of fractures to an output, solutional attack of the CO_2 containing water starts to widen the fractures and secondary permeability originates. Fig. 1 shows this. Some of the many small fractures constitute a percolating pathway from a point input to a point output, and by solutional widening a conduit arises which is also shown. This process generally known as

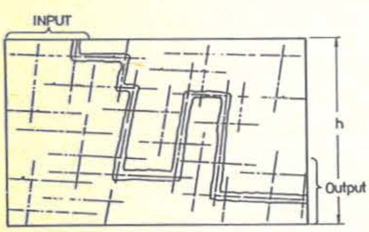


Fig. 1: System of fractures with percolating pathway. By solutional widening a cave conduit is created along this pathway.

karstification is intimately connected to the chemical kinetics of the system H_2O-CO_2-$CaCO_3$ (Dreybrodt,1987,1988). If dissolution proceeds very fast the calcite aggressive H_2O-CO_2 solution very quickly attains equilibrium and thus cannot penetrate deep into the rock without losing its solutional power. Therefore only surface denudation should be expected. On the other hand, if dissolution rates were extremely small water can penetrate deeply into the rock but solutional widening is then extremely slow and it may take geologically unrealistic times until an aquifer, typical for carbonate rocks develops. It is known (Mylroie and Carew, 1986, Bakalowicz 1982) that minimum times of about 10000 years are required until such an aquifer develops to maturity. It is of interest to model the development of carbonate aquifers since new land use programs of limestone terrains provide human impact onto these systems and a deeper understanding of their development may prevent damage.

2. THE MODEL

The basic question to answer is: Provided the hydraulic gradient between input and output stays independent on time, what is the time dependence of the flow rate of water Q(t) driven through the percolating pathway? How does this rate depend on geometrical parameters such as the length l of the pathway, its average aperture a and the magnitude of the hydraulic head h between input and output? And furthermore, how does this system depend on chemical parameters as saturation concentration c_{eq} and chemical rate laws describing dissolution. To give answers to these questions the percolating pathway is simplified to an initially uniform fracture of rectangular shape with an aperture a_o and breadth b_o. By solutional activity this initial apertures will not stay constant along the length of the fracture but will become functions of x, the coordinate along the length. Fig. 2 shows a part of the fracture, between x and x+dx. The concentration of dissolved calcite, given as $c = (Ca^{2+})$ at the inflow x is c(x) and at x+dx it is c(x+dx) = c + dc. The flow velocity is v(x). Finally dissolution proceeds by a rate law F(c). Mass balance now requires

$$F(c)P(x)dx = v(x)A(x)dc \tag{1}$$

This states simply, that the amount of calcite dissolved from the wall with perimeter P(x) is equal to the amount of calcite transported away by flow through the cross sectional area A(x).

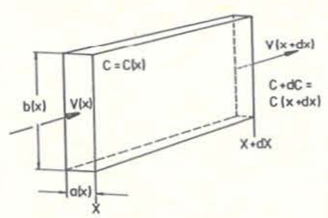


Fig. 2: Fracture along the flowpath between positions x and x+dx. Concentration of inflowing solution is c. At the outflow concentration has increased by dc.

Now from the equation of continuity we have a constant flow rate Q along the conduit:

$$v(x)A(x) = Q \tag{2}$$

Integrating Eq. 1 yields

$$Q\int_{c_0}^{c} dc/F(c) = \int_0^x P(x)dx \tag{3}$$

Thus one obtains the concentration c as a function of x along the pathway. To calculate Q one uses the equation of Hagen-Poiseuille for laminar flow (Beek and Mutzall, 1975). From this a flow resistance R can be defined

$$R = \frac{12\eta}{\rho g}\int_0^{\ell}\frac{dx}{a^3(x)b(x)} \tag{4}$$

η is the dynamic viscosity, ρ density of water, g earth's acceleration. The flow rate Q then results as

$$Q = h/R = I\ell/R;\ I = h/\ell \tag{5}$$

h is the hydraulic head and I the hydraulic gradient along the flowpath.

To calculate now Q(t) as a function of time, one starts with the initially uniform fracture from which R_o = R(0) can be easily calculated. Then with this value eq. 3 is integrated numerically and the dissolution rates are obtained as a function F(x). Using this function one obtains for the fracture aperture a(x,t) and the fracture breadth b(x,t) a recursion formula

$$\begin{aligned} a(x,t+\Delta t) &= a(x,t) + \gamma\tilde{F}(x)\Delta t \\ b(x,t+\Delta t) &= b(x,t) + \gamma\tilde{F}(x)\Delta t \end{aligned} \tag{6}$$

γ is a factor converting dissolution rates from mol/cm^2·s into retreat of bedrock in cm/year and Δt is a suitable time increment. Thus by iteration a(x,t), b(x,t) and Q(t) can be calculated.

3. DISSOLUTION KINETICS OF LIMESTONE

Dissolution rates of $CaCO_3$ for a H_2O-CO_2 solution flowing laminarly in a completely waterfilled fracture of given aperture are reported by Dreybrodt (1987, 1988) and Buhmann and Dreybrodt (1985). The dissolution rate is given by

$$F^{(1)}(c) = \alpha(x)(c_{eq} - c); \quad \alpha(x) = \alpha_0 \left(1 + \frac{\alpha_0 a(x)}{6D}\right)^{-1} \tag{7}$$

The kinetic constant $\alpha_o = 2.5 \cdot 10^{-5}$cm/s can be regarded as constant for most situations encountered in karst areas. The correction term results from the fact that for aperture width a(x) > 1 cm mass transport becomes dominantly controlled by molecular diffusion of Ca -ions. D is the corresponding coefficient of diffusion ($D = 7 \cdot 10^{-6}$ cm^{2}s^{-1}). For pure calcite this rate law holds up to saturation. For natural limestone, which usually contains a few percent Mg^{2+}, however, close to saturation a change in the reaction occurs and dissolution rates follow a higher order rate law (Plummer and Wigley, 1976).

$$F^{(4)}(c) = \beta(c_{eq} - c)^4; \quad \beta = 1.2 \cdot 10^{13}\,\mathrm{cm^{10}mol^{-3}s^{-1}} \tag{8}$$

In our model calculation we use $F^{(1)}(c)$ for $c < 0.9c_{eq}$ and $F^{(4)}(c)$ for $c \geq 0.9 c_{eq}$. This implies and abrupt drop of dissolution rates at $c = 0.9c_{eq}$ by two orders of magnitude, which in nature will be smooth.

4. RESULTS

In the following calculations, unless otherwise specified, the parameters used are $a_o = 0.01$ cm, $b_o = 100$ cm, $l = 20000$ cm, $I = 0.1$, $c_{eq} = 2 \cdot 10^{-6}$ mol/cm^3 and α_o, β as given by eqs (7), (8). We call this standard condition.

Fig. 3 shows the profile of a fracture with these parameters as it develops in time. Note that the scale of a(x) is logarithmic. In the early stage of evolution, i.e. for times below 2000 years, $c = 0.9\,c_{eq}$ is attained quickly and dissolution proceeds in the slow 4th order kinetics along almost the entire length of the fracture, which therefore increases slowly in width. Consequently the throughput Q(t) increases slowly. At a time of 2000 years a region of first order kinetics starts to penetrate into the fracture for a few meters and with increasing time a zone of fast dissolution migrates through the fracture with increasing speed until it reaches its end. This marks breakthrough time T_B, which is characterized by a dramatic increase in Q(t), as shown in Fig. 4.

After breakthrough has occured dissolution proceeds in first order kinetics along the entire length of the fracture and solutional widening is several 10^{-3} cm/year for laminar flow. At breakthrough, however, in most cases the width of the aperture is at least about 1 cm and turbulent flow sets in. Then due to the influence of an increase in diffusion by turbulence solution rates are in the order of 10^{-2} cm/year. (Dreybrodt, 1987,1988).

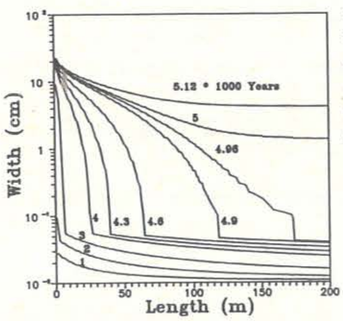


Fig. 3: Evolution of the width of a fracture along its length. The widths are plotted in logarithmic scale. Numbers on curves give the time needed for the evolution of the corresponding profile in 1000 years.

The evolution of the fracture widths as depicted by Fig. 3 shows clearly a concerted action between two regimes of dissolution kinetics. Slow 4th order kinetics first is effective over almost the entire length, widening the fracture to increase throughput. The regime of the action of first order kinetics at the entrance penetrates into the fracture to a distance L_p given (Dreybrodt, 1988) by

$$L_P = 1.15Q(t)/(\alpha b) \tag{9}$$

This shows that with increasing Q(t) the region of first order kinetics increases until breakthrough is achieved.

If one assumes, however, that first order kinetics is effective until saturation and no 4th order slow kinetics exist at all one finds that for the example of figs. 3 and 4 breakthrough is achieved at a time $T > 10^9$ years. This means that karstification would not exist at all. This has been first realized by White (1978) and Palmer (1984), who both claimed a region of slow inhibited

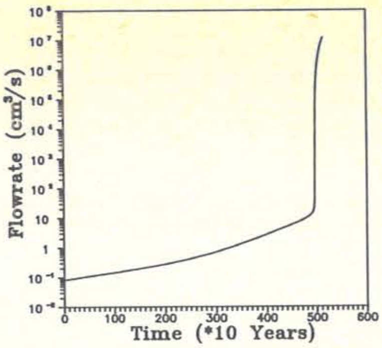


Fig. 4: Flowrate through the fracture of Fig. 3 as a function of time. The steep increase in flowrate marks the event of breakthrough at breakthrough time T_B.

dissolution kinetics close to saturation to account for the fact that karstification does in deed exist.

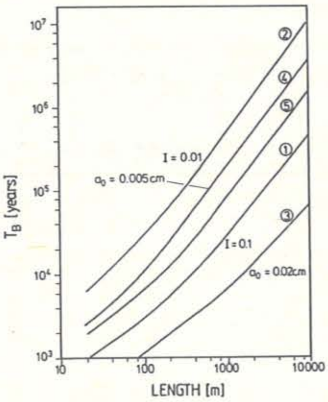


Fig. 5: Breakthrough time as a function of fracture length l for hydraulic gradients of 0.1 and 0.01 with initial width $a_o = 0.01$ cm, curves 1 and 2. Curves 3 and 4 show the situation for $a_o = 0.005$ cm and $a_o = 0.02$ cm subject to a hydraulic gradient of 0.1. Curve 5; $a_o = 0.02$ cm and $I = 0.01$. All other values are standard conditions.

To further eludicate karstification from our model we have calculated the breakthrough times in dependence of the geometrical parameters a_o, l, and I and left all the other parameters as defined in the standard condition. Fig. 5 shows the breakthrough times in dependence of the length of the aperture. This length models the length of karstified pathway. The numbers on the curves indicate the parameter values, which have been changed from the standard condition.

Curves 1 and 2 give karstification times (breakthrough time) for an initial aperture of 0.01 cm subject to a hydraulic gradient of 0.1 and 0.01 respectively. Note that curve 1 corresponds to the set of standard parameters defined above. These are realistic numbers for natural conditions (Ford, 1980; Motyka and Wilk, 1984). From this one can see, that for dimensions in the order of several hundred meters karstification from the initial to the mature state is effected within several ten thousand years. Minimum times of several 10000 years for the development of large karst caves are observed in the field (Mylroie and Carew, 1986; Bakalowicz, 1982). Karstification on large scale of several kilometers under low hydraulic gradients, $I = 0.01$ is effected in the range of several million years in accordance to field observations (Villinger, 1987).

Curves 3 and 4 show karstification times at $I = 0.1$ and initial fracture widths which are double or half compared to the standard run (curve 1). Curve 5 shows the breakthrough times with $a_o = 0.02$ and $I = 0.01$. It is obvious from these data that karstification times depend heavily on the initial joint width a_o and also hydraulic gradient I.

So far we have observed large scale features with l> 50 m and low hydraulic gradients. There are karst features, however, with dimensions below 100 m subject to high hydraulic gradients above 0.1 to about 1.0. This is the case in the formation of dolines or shafts. Karstification at even higher hydraulic gradient may occur also at sites of artificial water reservoirs and dams.

Fig. 6 shows breakthrough times for standard conditions and varying hydraulic gradients and length of the karstifiable pathways with lengths between 10 to 100 meters. Times of karstification range now from several 10 to several 100 years. Especially at high hydraulic gradients times of below 100 years are obtained for fracture lengths of several 10 meters.

This is in accordance with field observations by Gunn and Gagen (1987) who observed sinkhole development over limestone quarry margins, which had been abandoned 50 years before. Furthermore the data of fig. 6 predict development of shafts connecting the surface to already existing vadose caves below in a time of about 1000 years. The results of our model also shed some light to the importance of building dams or artificial water reservoirs only in areas of suitable geological settings with respect to primary permeability and also

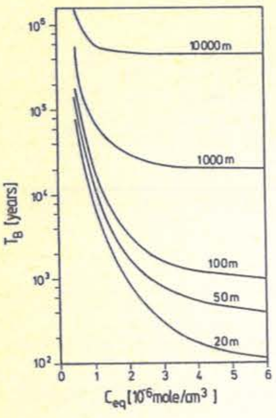


Fig. 7:
Breakthrough times as a function of calcite saturation concentration. The numbers on the curve denote the fracture lengths. All other parameters are standard conditions. There is a steep increase in karstification time for low concentrations. This increase is particularly significant at small fracture lengths.

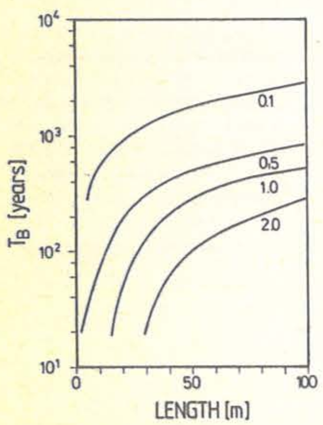


Fig. 6:
Breakthrough times for small scale features of karstification as a function of fracture length. Numbers on the curves indicate hydraulic gradient. All other parameters are standard conditions.

stresses the importance of careful grouting.

A further interesting topic is to study the dependence of breakthrough times in dependence on the chemical parameteres α_o, β and c_{eq}. Here we report only the main findings. Detailed results will be published elsewhere. For large scale features (cf. fig. 5) one finds that breakthrough times compared to the standard values of α_o change by no more than a factor of 2 for α_o varying between 10^{-4} cm/s to 10^{-6} cm/s . There is also a similar behaviour in dependence on β. Changes compared to the standard value of β are no more than by a factor 2 for $10^{-12} < \beta < 10^{-15}$. This is an important finding. It explains why karstification is such an ubiquitous phenomenon and does occur in such a wide variety of different kinds of limestone rocks. The dependence on c_{eq}, which is related mainly to the initial CO_2-content of the water and to a much less extent on temperature is significant. Times of karstification increase for several orders of magnitude if one lowers c_{eq} from $2\cdot10^{-6}$ mol/cm^3 to a value of $0.5\cdot10^{-6}$ mol/cm^3. The change becomes increasingly significant with decreasing fracture lengths. This might explain the high intensity of karstification in tropical karst, such as tower karst in Guilin, China, where foot caves of short length connect surface water to the karst water level (Zhu, 1988) and CO_2-content in the soil during rain time is high. Details will be discussed elsewhere.

On the other hand the steep increase in stimes for breakthrough for $c_{eq} > 1.5\cdot10^{-6}$ mol/cm^3 which corresponds to soil CO_2-pressures below $3\cdot10^{-2}$ atm at 10° indicates that karstification is inhibited if CO_2 is lacking. The curves indicate a threshold for karst initiation for $c_{eq} < 5\cdot10^{-6}$ mol/cm^3. In this region the differences between karstification for large scale and small scale features are diminishing and range all into time scales of several hundred thousand years. This shows that karstification in the initial state depends heavily on vegetation and renders to be impossible in areas of bare rock.

5. CONCLUSIONS

We have presented a model which explains karstification from the initial state to maturity. The concerted action of fast first order dissolution kinetics far from equilibrium and slow fourth order kinetics close to saturation is the key in understanding karstification. The results of the model are expressed in terms of times for karstification, which are necessary for the evolution of waterleading flow conduits, such that dissolution proceeds in fast first order along the entire flowpath. Further development of these flow conduits to mature channels is effected from then on with dissolution rates in the order of several 10^{-2} cm/year retreatment of bedrock.

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THE EFFECT OF $MGCO_3$ TO THE SOLUBILITY OF CALCITE: ENHANCED AGGRESSIVENESS?

DREYBRODT, Wolfgang

We have reinvestigated the influence of $MgCO_3$ to the solubility of $CaCO_3$ in the system $MgCO_3$-$CaCO_3$-H_2O-CO_2. In contrast to the findings of Picknett and Stenner (Trans. British Cave Research Assoc, 5, 1978) we have not found any evidence for enhanced solubility of $CaCO_3$ in solutions containing between 0-11% $MgCO_3$ related to the saturation concentration of $CaCO_3$. Our experimental points follow closely the thermodynamic theory of the common ion effect. We therefore doubt the existence of $MgCO_3$ enhanced calcite solubility and its speleological implication suggested by Picknett and Stenner.

Wir haben den Einfluß von $MgCO_3$ auf die Löslichkeit von $CaCO_3$ im System $MgCO_3$-$CaCO_3$-H_2O-CO_2 untersucht. Im Gegensatz zu Picknett und Stenner (Trans. British Cave Research Assoc, 5, 1978) haben wir keine erhöhte Löslichkeit von $CaCO_3$ in $MgCO_3$ enthaltenden Lösungen zwischen 0-11% $MgCO_3$ gefunden. Unsere experimentellen Daten stimmen mit der thermodynamischen Theorie des "common-ion effects" überein. Wir bezweifeln daher die Existenz der Erhöhung der CalzitLöslichkeit durch den Einfluß von $MgCO_3$ und damit auch die speläologischen Konsequenzen, die von Picknett und Stenner vorgeschlagen wurden.

1. INTRODUCTION

In order to explain speleogenetic processes mechanisms have been invoked from which renewed aggressiveness of calcite saturated solutions results. The most known is mixing corrosion as proposed by Bögli (1980). Although nowadays one agrees that speleogenesis is also possible without this process, it may well be important for the development of certain structural elements of caves (Dreybrodt 1987,1988). Another mechanism was advocated by Picknett (1977) and Picknett and Stenner (1978). They claimed from their experiments that upon addition of small amounts of magnesium carbonate to calcite containing solutions the solubility of calcite is enhanced. Fig. 1 shows their results (Picknett and Stenner 1978). The calcite solubility (ordinate) is measured in units of the calcite saturation concentration of a pure $CaCO_3$-H_2O-CO_2 solution. The abszissa gives the molar ratio of the concentrations of $MgCO_3$ added to the solution to the $CaCO_3$ contained in this saturated solution. Thus the open circle at (0.04; 1.12) tells us that upon addition of 4% $MgCO_3$ calcite solubility is enhanced by 12% with respect to a saturated pure $CaCO_3$ solution. The full line is a curve drawn through the experimental points (open circles). No explanation of this "unknown effect" was given by Picknett and Stenner and they agreed that thermodynamic equilibrium calculations should yield the dashed curve showing a decreasing solubility with increasing addition of $MgCO_3$ due to the common ion effect (Picknett 1977).

From these experimental findings they derived speleological implications: When water passes through pure limestone initially, it will become saturated with calcite. If later it enters into beds of magnesian limestone, upon dissolution of magnesium carbonate rejuvenated aggressiveness originates. Therefore the junction of two different limestones with these properties will be a site of cavern enlargement. Another mechanism of renewed undersaturation is similarly to mixing corrosion due to the nonlinearity of the solution curve and results when two saturated calcite solutions with different contents of $MgCO_3$ mix. These speleogenetic implications have meanwhile entered into the textbooks Jennings (1985), Trudgill (1985), and Bögli (1980).

In a recent series of experiments dealing with the influence of Mg^{2+} onto the dissolution kinetics of calcite we also have done similar experiments as Picknett and Stenner under very well defined experimental conditions. We have found, however, no evidence of enhanced calcite solubility. We therefore doubt the existence of rejuvenated aggressiveness and consequently its speleological implications.
Dissolution of calcite proceeds in teflon vessels (1). The solution, containing analytical grade $CaCO_3$ is stirred by teflon stirrers (2) with 150 rpm. The solution is open to a CO_2-atmosphere of defined composition, with $p_{CO_2} = 5 \cdot 10^{-3}$ atm, which is enclosed by an outer vessel (5). This vessel contains 4 identical teflon beakers (1) for the dissolution experiments. In each of these a conductivity electrode (3) measures the progress of dissolution. The outer vessel is thermostated at a temperature 20 ± 0.02 C. The CO_2-atmosphere is

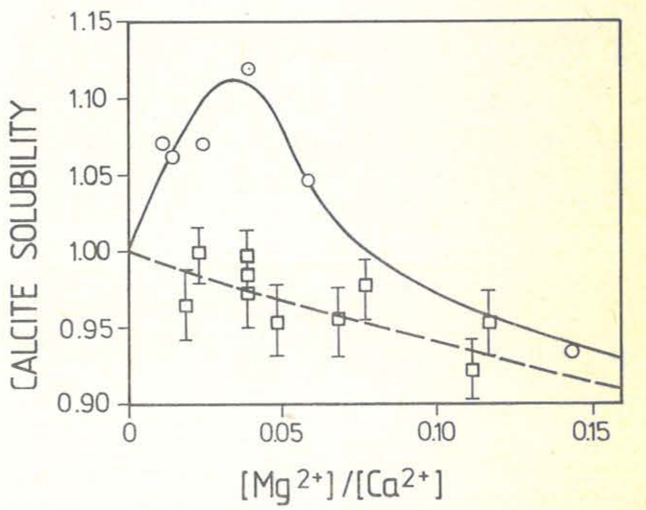

Fig. 1: Equilibrium concentrations in units of the equilibrium concentrations of a pure H_2O-CO_2-$CaCO_3$ solution versus molar ratio of $MgCO_3$ to $CaCO_3$ in the solution. Open squares; our data. The dashed line shows the result of thermodynamic calculations.

provided by first evacuating the outer vessel and then flushing it with the gas of 0.5% CO_2 and 99.5% N_2. By monitoring the conductivity of a pure stirred water sample without $CaCO_3$, we find that the solution equilibrates with respect to CO_2 in about 10 min, a short time compared with the time needed for equilibration with respect to calcite (10 hours).

In one experimental run we measure simultaneously three samples of varying $MgCO_3$-concentration in the solution and one pure sample. Each vessel contains 120 mg $CaCO_3$ (Baker Analyzed Reagent). 60 ml of bidistilled water are added to obtain the pure calcite solution. The $MgCO_3$ containing samples are prepared by adding 60 ml of a $MgCO_3$ containing solution of known composition (reagent grade $MgCO_3$ 99,999%, Ventron) into the corresponding vessels. Concentrations of $MgCO_3$ were between $2 \cdot 10^{-5}$ up to $1,5 \cdot 10^{-4}$ mol/l, corresponding to molar Mg^{2+}/Ca^{2+} ratios between 2% to 11%. The Mg concentration was analyzed by titration before adding the solution to the beakers. It was also analyzed after the experiment was completed. The good agreement between these two values shows that no Mg containing carbonates did precipitate during the experiment.

After the vessels have been filled with these reagents, the container was evacuated for a very short time (1 min) and then flushed with the CO_2-containing atmosphere such that a p_{CO_2} of $5 \cdot 10^{-3}$ atm was established. Then it was sealed vacuum tight to the outer atmosphere. As required by Picknett and Stennen this guarantees

2. EXPERIMENTAL PROCEDURE

Fig. 2 shows the experimental set up used in our experiments.

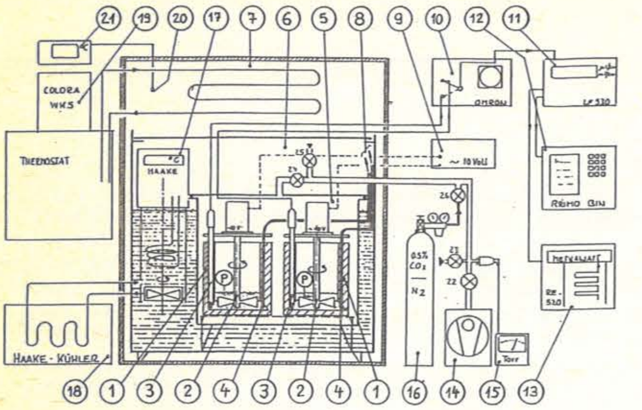

Fig. 2: Experimental set up.
(1) Teflon vessels
(2) Teflon stirrer with motor
(3) Conductivity electrode
(4) Capillary for extraction of solution without opening outer vessel
(5) Outer vacuum-tight vessel to establish defined p_{CO_2} for the dissolution process
(6,7,8,17,18,19,20,21) Components of thermostating the outer vessel in a water bath
(10,14,15,22,23) System for evacuating outer vessel (5)
(16,24,25) System for filling outer vessel with defined CO_2-atmosphere
(10,11,12,13) System to record conductivity

experimental conditions such that dissolution in all four samples proceeds in contact to the same CO_2 atmosphere and the results are therefore comparable. Furthermore our experimental set up keeps the different solutions reliably separated and prevents contamination of the samples.

3. RESULTS

The dissolution process is monitored by registrating the conductivity. Fig. 3 shows a typical plot versus time. Saturation is assumed, when the conductivities of all samples vary by no more than 0.5% within 24 hours. This is generally achieved after a time of two days. The asterisks in fig. 3 show the measured values of conductivity in arbitrary units during a typical experiment lasting for 2 days. The full line is a fit to the data using an exponential function $C(t) = c_1 \cdot (1-\exp(-t/\tau)) + C_2$. The good agreement shows that equilibration to 99% is achieved in about 10 hours. Nevertheless in the first experiments run times of 10 days were used, to be sure that the sample had come to equilibrium.

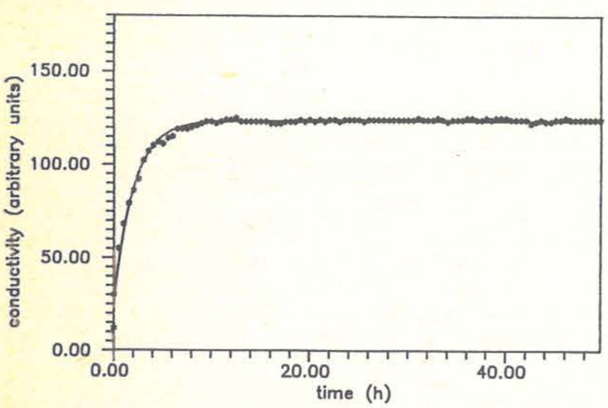

Fig. 3: Evolution of the solution towards equilibrium. The experimental points are fitted to an exponential given by $C(t) = 99.01 (1-\exp(-t/2.011)) + 24.58$. The data show that equilibrium is reliably obtained after 2 days.

When equilibration was reached liquid samples of the solution were extracted from the vessels via a cappilary without opening the outer container. These samples were filtered by use of a 0.45µ filter and immediately analyzed for pH, alkalinity, Ca-concentration and total hardness, to obtain Mg-concentration. Titrations for Ca and total hardness were performed using EDTA (Titriplex III, Merck) 0.002 m and calconcarbon acid or Merck indicator tablets for Ca and total hardness respectively. Alkalinity was titrated using HCl and methyl orange as indicator. 20 ml of sample were used and titration was performed with a high precision (0.2%) digital burette (Brand).

Ca	Mg	HCO_3^-	SI_C	P_{CO_2}
1.36	0	2.85	0.004	$5 \cdot 10^{-3}$ atm
1.30	0.05	2.70	- 0.06	"
1.34	0.11	2.79	- 0.02	"
1.25	0.13	2.70	- 0.08	"

Table 1: Results of concentration measurements at equilibrium. HCO_3^- is measured as alkalinity. Concentrations are in 10^{-3} mol/l. SI_C is saturation index with respect to calcite as calculated from WATEQ2 (Ball et al., 1979). Error of concentration measurements is about 3%.

The concentrations of alkalinity, Ca and Mg as well as CO_2-pressure where used as input parameters for a chemical equilibrium programm (WATEQ2) and saturation indices SI_C with respect to calcite were calculated, to confirm for equilibration. Since WATEQ2 does not accept p_{CO_2} as an input parameter, we used the pH-value as input parameter instead and adjusted this value until the p_{CO_2} calculated agreed with $p_{CO_2} = 5 \cdot 10^{-3}$ atm. The pH-value thus obtained is slightly higher than the measured one. This is due to CO_2 degassing from the sample, when it is analyzed.

In Fig. 1 we have plotted the data of our experiments (open squares). All the points lie close to the theoretical curve for the common ion effect and there is no increased solubility due to the presence of $MgCO_3$ in the solution. In our experiments we have met the basic requirements as demanded by Stenner and Picknett (1978), i.e. equal conditions for the dissolution process for the pure and Mg containing samples for direct comparison.

We have found no evidence for enhanced calcite solubility. We conclude from our experiments, the results of which are in agreement with the thermodynamic theory, that one has to doubt the experimental findings of Picknett and Stenner and also accordingly speleological implication related to this effect.

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DOCUMENTATION OF CAVES AND KARST IN REDWOOD CANYON, KINGS CANYON NATIONAL PARK, CALIFORNIA, USA, WITH APPLICATIONS TO SINKHOLE SEDIMENTATION

BOSTED, Peter E. - TINSLEY, John C.

Lilburn Cave is a complex maze with over 16 km of passages mapped. This complexity leads to over 300 simultaneous survey loops which have been closed by a specially-developed computer program. A multi-layered approach has been used to portray a plan view of the cave in an Atlas format. Computer color graphics has also been used to portray the relationships between the different passages, with the passage sizes being taken into consideration. Photographs of the color graphics screens have been used to make stereo pairs of slides.

Photographs have been taken to illustrate the interesting geologic and minerologic features of this cave formed in banded marble. Photographs have also been used to document the scientific research projects being conducted both underground and on the surface.

La cartographie et photodocumentation de Lilburn Cave, California

Lilburn Cave est un labyrinthe tres complex avec plus de 16 km topographié a ce jour. Cette complexité nessecite un programme d'ordinateur speciale pour regler les plus de 300 boucles topographiques toutes jointes les unes aux autres. Pour le desin du plan, un format a plusieurs niveaux a été employé pour produire un Atlas de la cavité. Un ordinateur a aussi été employer pour produire des projections en couleurs sur un ecran, tout en tenant compte de la largeur des passages. Photos de ces projections ont permi de faire des paires de diapositifs qui donnes l'impression de trois dimensions.

Des photos ont èté pris dans la cavité a fin d'illustrer les aspects geologiques et minerologiques de cette grotte formé en marbre bandé. D'autres photos montrent divers aspects des projets scientifiques conduites.

1. INTRODUCTION

Lilburn Cave is a complex maze cave formed in a long narrow lens of marble located under Redwood Canyon, in Kings Canyon National Park, California, U.S.A. Part of the Redwood Mountain roof pendant terrane of the Sierra Nevada range, the marble lens is located at an altitude of about 1500 m and comprises a body of rock approximately 4 km long, 500 m wide, and at least 200 m deep. The cave follows the NNW to SSE trend of this isoclinally folded, steeply dipping marble unit [1]. Although concentrated in an area of only 1000 m by 200 m, the cave has over 16.5 km of passages mapped to date. Surface outcrops of the marble are rare, but collapse of cave passages has created at least sixty sinkholes of varying sizes. A surface stream, Redwood Creek, sinks at several points near the contact with the marble, appears in Lilburn Cave approximately 2 km downstream, can be followed through the lower reaches of the cave, and finally sumps at the downstream end of the cave, reappearing 1 km down-canyon at Big Spring, thence via Redwood Creek to the Kaweah River. The unusual feature of Big Spring is ebb-and-flow discharge during periods when discharge exceeds 12 cubic feet per second [2,3].

We summarize several methods used to document salient features of the Redwood Canyon karst as well as results of selected research projects conducted here. As the number of research projects is large, we cannot be comprehensive, but rather will focus on a single representative project that is related closely to the cartography of this karst system.

2. CARTOGRAPHY

2.1 Survey Methods

For most surveys, whether above ground or in the caves, readings are taken in both the forward and backward directions using either a Brunton compass or a Suunto compass/inclinometer pair. If the readings disagree by more than 2 degrees (or 1 degree if above ground), they are repeated until agreement is reached. On some occasions agreement to better than 5 degrees cannot be achieved, even with the same person reading in both directions and all sources of extraneous magnetic fields removed. These situations are ascribed to local deposits of magnetic material in the bedrock and, fortunately, are rare. Distances are measured with a fiberglass tape. The notetaker makes a running sketch of the survey at the same scale as the final map, using a protractor and ruler to accurately plot the survey points on the page. This practice has been found to help in reducing blunders and in speeding up the transfer of the sketches to the working maps. Cross sections are shown whenever a passage's characteristics change significantly. Survey stations at junctions (which occur on the average every 20 m in Lilburn Cave) are marked with small metal disks fastened to the wall with pop rivets and marked with the station number. Disks are sometimes placed between junctions when they are separated by longer than average distance. These tags provide a permanent yet relatively unobtrusive way of marking the survey grid for use by various research projects (IE locating biological traps, monitoring flooding, sediment levels, and sediment migration, mapping of joints, etc.).

2.2 Data reduction

The survey data, and the passage dimensions at each station, are typed into a computer file. The stations are grouped into survey legs, which are sequences of consecutive stations joining two junctions or going from a junction to a dead end. The computer program determines which legs are part of the network of interconnected legs and which simply go to dead ends. For the legs that are in the network, the program does a least-squares minimization fit to determine the best set of correction vectors that will simultaneously close all the loops. This is done separately for each of the three dimensions that determine the position of the junctions. The quantity minimized is the sum of the squares of the ratios of the corrections divided by the expected errors for each leg. The expected errors for each survey leg are calculated assuming that each compass and inclinometer reading has an error (sigma) of 1 degree and each length measurement has an error of 5 cm. If the actual errors were in agreement with this estimate, then the distribution of relative corrections should have a mean value of 1. That this is indeed the case for the over 290 interconnected legs in Lilburn Cave can be seem graphically in Figure 1, which shows roughly an exponential shape with a "decay width" of about 1.

2.3 Survey blunders

When serious blunders occur for stations that are part of the interconnected loop network, corrections much larger than expected are generally found by the loop closing program. As can be seen in Figure 1, most of the corrections fall on the smooth exponential curve, but a few have very large corrections (greater than 5). The latter are likely to contain blunders.
The procedure used for correcting blunders is to allow the program to input as large a correction as it likes onto the suspect leg by setting the expected error to a large value. A close examination of the size and magnitude of the correction vector in many cases allows quick identification of the error. The most common errors found have been: a) reversing back- and fore-shots for either compass or inclinometer, b) transposition of digits on the distance, c) compass readings off by 100 degrees, d) reading inclinometer in percent instead of degrees, e) wrong station name for first or last station in a leg, and f) compass reading systematically in error owing to the way the compass is being read. The 28 legs in the network that still have a squared relative correction greater than 5 are consistent with small blunders (resulting in less than 50 cm errors) that have yet to be identified

The computer program uses a sparse matrix inversion routine to solve the system of simultaneous linear equations resulting from the least-squares minimization. About 10 seconds is required to correct the 290 interconnected legs in Lilburn Cave, running on a mainframe-type computer.

2.4 Portrayal

Several methods are especially useful for portrayal of the cartographic information. The first is a large plan view map of Lilburn Cave depicting all of the passages at a scale of 1:240. This map shows passage detail such as drops, floor material, major survey stations, formations, and streams.
Due to the three-dimensional complexity of most of the cave, offsets of selected areas are made to the side of the main passages. To avoid cluttering, no cross sections are shown. Similar plan and profile maps are being made of the two smaller caves in the area: Cedar Cave and May's Cave.

To show the full complexity of the cave, the cartography project is making an atlas of Lilburn Cave. The cave is divided into quadrants, and for each quadrant as many levels are drawn on separate sheets as necessary (up to four sheets). The task of dividing the passages into different levels is not easy as there are almost as many connections vertically as horizontally. For each quadrangle, a special section is reserved to show cross sections and elevations for all the major passages shown. Station names at junctions are identified, as are the names of passages and prominent features. Eventually, it is planned to overlay the different levels, which the level being portrayed shown in dark black, and the other levels in light grey.

A third way of portraying the cave is with computer graphics. A program has been written that displays the passages in various colors according to their elevation. The passage dimensions are drawn by interpolating the dimensions entered at each survey station. The cave can be enlarged or shrunk to show various portions in greater or lesser detail, and it can be rotated about vertical and horizontal axes. Photographs of the video terminal have been made to make color prints showing both plan and profile views of the cave. In addition, by rotating the cave appropriately about an imaginary fixed point, pairs of slides have been taken that, when viewed through a stereo viewer, impart a realistic three-dimensionality. The program draws the passages that are closer to the viewer on top of the ones that are further away, which enhances the realism of the image. Black-and-white renditions of the computer-generated plan and profile views are shown in Figure 2. In order to distinguish the various passages, their dimensions have been reduced to the width of the lines, resulting in standard "line-plots" of the cave.

3. DOCUMENTATION OF SINKHOLES AND HILLSLOPE EROSION RATES

3.1 Overview

The surveys showing surface karst features, including sinkholes, trails, cave entrances, and sinking tributary streams, are plotted onto a topographic map of the area at 1:4800 scale, using a 15 m topographic contour interval. Sources of data include fragmentary, cartographic efforts that supported topical karst studies in past years. These are augmented by new surveys of trails, streamcourses, and geomorphic features of the Redwood Canyon area. Although most sinkholes located upstream of Lilburn have been charted, only a portion of those that lie above Lilburn Cave have been included so far. When this work is completed, it will be possible to try to correlate the surface sinkholes with deposits of granite boulders that are often found plugging upper level passages. As the only natural entrance to Lilburn is in the bottom of one of the sinkholes, comparisons of sinkholes and in-cave blockages of boulders may allow identification of other entrances that once were open to the surface.

Figure 3, a generalized map, depicts principal features of the Redwood Canyon karst area. The array of sinkholes, sinking streams and Big Spring resurgence roughly delimits the latitudinal extent of the marble lens. Lilburn Cave occupies about 25% of the length of the marble, chiefly between Mays Creek and Pebble Pile Creek. The sinkhole arrays situated north of Lilburn Cave are the small basins used to study rates of soil erosion, a study described briefly below. All cave features shown have been located using surface surveys; the forest canopy precludes effective use of visible spectrum aerial photography.

Transport of earth materials from slopes to sinkholes and caves are important in the evolution of karst basins; however, opportunities to estimate rates of soil erosion and slope degradation in karsts of the western United States under conditions of natural vegetation are seldom realized. In Redwood Canyon, a 700-year old silicic volcanic ash was blown in from the eastern Sierra Nevada and subsequently blanketed the mantled karst; this tephra deposit today forms a discrete horizon in selected sinkholes and provides a stratigraphic basis for calibrated, volumetric estimates of post-tephra sediment eroded to the sinkholes. The data we present are preliminary yet reflect an effective means to document caves and selected karst-related processes.

3.2 Nature of sinkholes and sinkhole sediments

The sinkhole sediments are composed chiefly of gravel, sand, silt and clay derived from the granitic and metamorphic rocks which frame the canyon, and from alluvial terrace deposits along Redwood Creek and its tributaries. Drainages tributary to Redwood Creek typically sink at or near the contact of Redwood Canyon's marble and the adjacent granitic and non-carbonate metamorphic rocks. The white, powdery tephra, identified by its distinctive trace element chemistry as a product of the Deadman Dome vent in the Inyo Craters volcanic chain located south of Mono Lake in eastern California [4], is easily recognized in the field using soil augers or slit trenches. This tephra has been dated at about 700 radiocarbon years before present in the meadows of the Sierra Nevada and near the eruptive center [5]. In favorable geomorphic situations, the tephra was eroded from hillslopes, rivulets, and gullies and was deposited in the sinkholes. The most favorable setting for these sedimentation studies requires sinkholes which are plugged with sand and silty sediment. The sinkholes must lack efficient conduit-related drainage, but must be slowly permeable to water. Persistence of a seepage-dominated hydrologic regime means that the sediment-plug effectively traps fine sediment, including tephra. The trapped sediment is accreted vertically to that sinkhole's sedimentary record. In contrast, sinkholes drained by open conduits usually transmit most of the fine-grained sediment (and volcanic tephra) directly to the cave system below. Such sinkholes preserve little record of the ash and are not useful for this study. Sinkholes located on forested terrain where slopes measure less than about 8 degrees typically did not receive tephra or sediment rapidly enough to produce a reliable stratigraphic record. Exposures in shallow trenches indicate scattered pockets of tephra are preserved in burrows; apparently bioturbation occurring on the forest floor destroys the tephra layer. Where the sinkholes have not collapsed or formed stratigraphic leaks into the cave during the post-tephra time period, the tephra is effectively isochronous, having been erupted, transported, and deposited within a very short span of geologic time. This marker bed establishes age equivalence among deposits in widely separated localities. The Redwood Canyon karst is a convenient laboratory wherein rates and processes of slope erosion can be appraised, owing to the tephra "clock" preserved in many sinkholes.

3.3 Methodology

In each sinkhole, an array of 15 to 30 borings are dug using a hand-powered soil auger. The respective thicknesses of tephra and post-tephra sediment are measured in each hole. Surveys using compasses-and-tape as described above are conducted to chart the auger holes in the sinkhole, the basal perimeter of the sinkhole, the drainage basin area of the sinkhole, and the area of the drainage basin wherein the slopes exceed 8-10 per cent. The respective volumes of tephra and post-tephra sediment are estimated using standard planimetric and isopach techniques. The quotient of the tephra volume (or post-tephra sediment volume) divided by the area of the drainage basin draining into the sinkhole yields an estimate of the vertical thickness of tephra (or post-tephra sediment) eroded into the sinkhole from the drainage basin, provided the sinkhole has indeed trapped sediment and has not leaked appreciable sediment into the cave system. From comparisons among several sinkholes and drainage basins, we expect to be able to learn how the estimated erosion rates vary as functions of basin size, slope, aspect, vegetation, etc. The estimated erosion rates would be applicable to the mixed coniferous forest ecosystem under conditions of climates which prevailed during the past 700 years. Only by comparing results from a number of well-plugged sinkholes can we obtain stable estimates of average sediment yield.

3.4 Preliminary Results

Twenty-two sinkholes have been examined and ten sinkholes have been augered as of 12/31/88. Hillslopes of less than 10% tend to retain at least part of the mantle of volcanic ash, which then becomes mixed with the soil owing to biological and physical processes. Slopes steeper than about 10% generally shed their ash mantle readily into the sinkholes and are more efficient contributors of sediment, especially coarse sediment, than their more gently-sloping neighbors. The tephra blanket apparently ranged in thickness from 1 to 5 cm thick in the Redwood Canyon area. Erosion rates of the soil mantle measured in this way range from 0.5 -1.5 cm/yr during the past 700 radiocarbon years.

4. PHOTODOCUMENTION

Photography has been used extensively to document the natural resources of Redwood Canyon as well as the ongoing research. Among the interesting underground natural features are the very photogenic banded marble, a variety of passage shapes from tubes to keyholes to canyons and crawlways, deposits of silt and clay rhythmites, the streams and waterfalls, and unusual cave minerals [6] such a blue copper-bearing flowstone and stalactite deposits, a large calcite cave pearl, and orange, carrot-shaped stalactites. Above ground, noteworthy karst features are the sinkholes and Big Spring. Among the research projects that have been captured on film are: installation of monitoring equipment at Big Spring, installation of a telephone line to monitor water levels in the cave and correlate them with flushing of the spring, collection of sediments and biota, the ongoing surveying, the measurement and survey of volcanic ash (tephra) deposits in sinkholes, and various dye-tracing and water chemistry projects. A new, rigorous photomonitoring effort is recording the evolution of a very large sinkhole that opened up in Pebble Pile Creek above the south end of Lilburn Cave (between October 12, 1987 and March 31, 1988) and the resulting dramatic changes in sand levels in the passages below.

5. CONCLUSION

Documentation of the Redwood Canyon karst proceeds along several diverse but complimentary avenues. These include depicting the principal caves at three different levels of scale and detail and providing cartographic support for a diverse array of scientific investigations.

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Figure Captions

Figure 1: Distribution of squared survey correction vectors divided by expected magnitudes of interconnected survey legs in Lilburn Cave.

Figure 2: Plan and profile view of Lilburn Cave.

Figure 3: Map showing surface and subsurface karst features of the Redwood Canyon karst area.

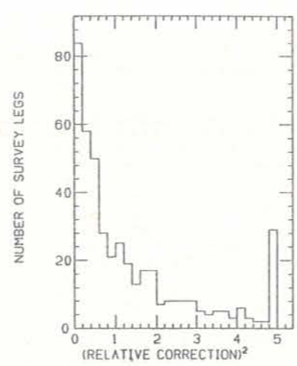

Figure 1

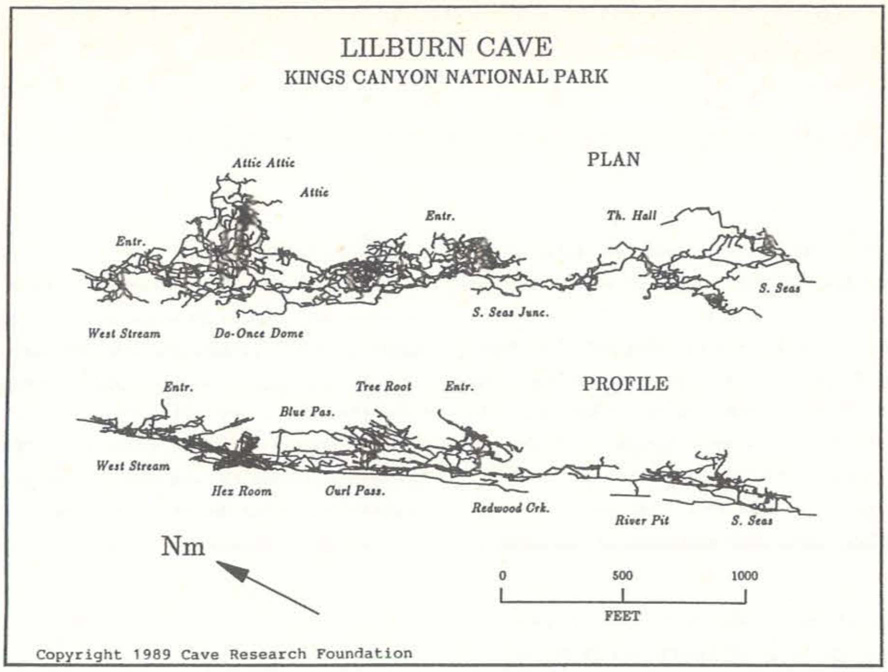

Figure 2

REDWOOD CANYON AREA

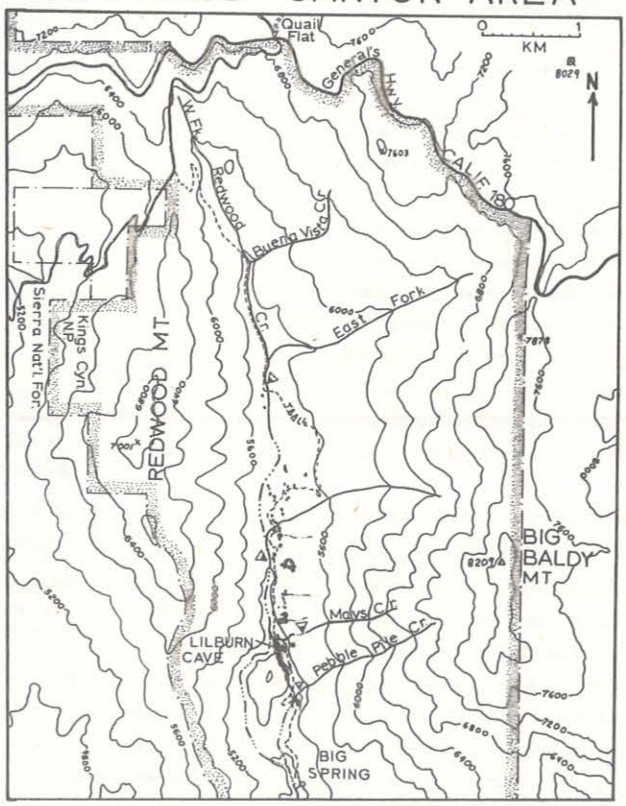

FIGURE 3. MAP SHOWING THE REDWOOD CANYON KARST AREA

Principal sinkpoint	Mapped cave
Sinkhole	Paved highway
Field station	Unpaved road
Resurgence	Elevations in feet

Generalized from the USGS Giant Forest 15' topographic map (1956 ed.)

CAVE SITE SEL-UNGUR AND PALEOGEOGRAPHY OF UPPER PLEISTOCEN IN SOUTHERN TIEN-SHAN

SGIBNEV, Valentin V.

In mountain regions of Middle Asia are known cave sites related to Mousterian. The new cave site Sel-Ungur (Obishir valley) is notable for eventful of its geological section.Two horizons corresponding to different sedimentational situation have been described. The lower horizon is psephytic,uniform, with numerous artifacts and bony material. This horizon is genetically associated with accumulation of talus in lower part of cave In upper horizon there are nine rhythms of combining layers of aleuropsammites and strongly humusic aleurits. Up the layer turbidid fragments, cryogenic textures, planes of slipping are shown. Bony artifacts in the upper horizon do not are found.

Geomorphological correlation shows that settling of cave site Sel-Ungur was occured in stage of stabilization of Pleistocen subaridic climatic optimum. The climatic unstability of intermediate stage in late Upper Pleistocen and appearance of Lower Holocen terraces that took place under nival gumidization of region compeled man to leave the cave. Migration of man from submountain region of Southern Tien-Shan can explaine the interruption in settling of cave sites from Upper Mousterian to Late Paleolith.

For Quaternary geology of Middle Asia the problem of paleogeographic reconstruction are of great importance. It is associated with limited possiblities of traditional methods for this region . Geomorphological correlations are braked by unsynchronal development of fragments of mountain structures and intermountain areas and, as a result, by different altitudinal position of coeval relief forms. Quaternary sections of Southern Tien-Shan have complex structure, contain many sedimentation interruptions and extremely few paleontological material. Unsufficient level of stratigraphic studies both faunistic and absolute explaines the existence of considerable blanks in paleogeographic reconstructions.

First of all this observation is related to Upper Pleustocene. In this connection the cave deposits that contain stratified artifacts and bony material are of especial interest.

In Middle Asia caves and grottos are known whose sections can be related to Upper Pleustocene in accordance with containing material. Among them there are caves Amankutan, Obirachmat, grotto Teshik-Tash and others. In this cavities many artifacts have been found: flakes, scrapers, knifes, nucleus etc. In the past two decades the reach bony marerial has been collected and precessed (Batyrov, Batirov, 1988). All data are indicative of wide and mass settling of man during Upper Pleustocen in submountaine region of Southern Tien-Shan. From the point of view of modern-day lithologic-paleogeographic studies the active assimilation of natural refuges, namely caves and grottos, also had negative consequences. The cave sections have been strongly altered by antropogenic factor, they are badly interpreted, contain much added material. Thus the cave deposits that had been affected by anthropogenic influence, have now exterretorial character, reflect paleogeographic situation of considerably distant places of hunt, collection and, perhaps, exchange. In this connection the cave Sel-Ungur is of exceptional interest for our investigations.

The cave Sel-Ungur discovered by A.P. Okladnikov in 1955 is disposed in Obishir valley in spurs of ridge Katrantau. In recent years archaeologists from many regions carry out active

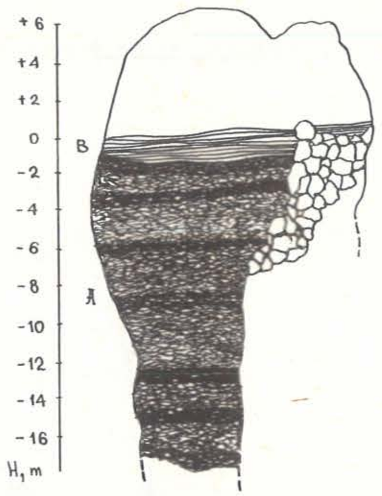

Fig. 1 General view of Quaternary section of cave Sel-Ungur. A- gruss-debris horizon with Paleolithic material; B- steril aleurolithic horizon.

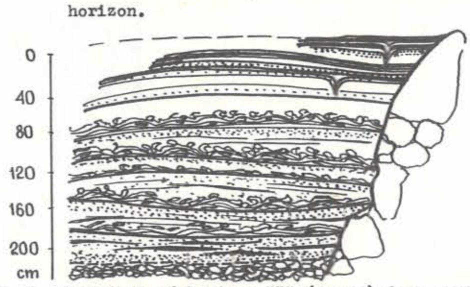

Fig. 2 Structure of horizon "B" (upper) from section of cave Sel-Ungur.

studies here. Till present time a section of cave deposits that has more than 15m in thickness and contains two large lithological horizons has been studied (fig. 1). The lower one is psephytic, homogenous with numerous artifacts and bony material. This horizon is genetically bound with accumulation of talus in lower part of known cave volume. From data of Islamov (1988) the main part of this horizon relates to Acheulian. According to Ranov (1988) the age of this horizon cannot be more

Fig. 3 Interrelation of cave Sel-Ungur and hydrothermokarst system in various stages: 1- before Upper Quaternary; 2- after Upper Quaternary.
- hydrothermal water in Obishir cave system.

200 Ky. For this horizon the palynologic data are obtained (Velichko et al, 1988) that indicate, in author's view, the xerophility of paleolandscape. All above data are related to lower debris-loamy horizon underlyining the sterile upper horizon.

Possibly, this horizon didn't attract attention until present time becouse of its archeological and faunistic sterility but its content is of exeptional value. In upper horizon nine rhythms of combined aleuropsammitic and strongly humic aleuritic interlayers (fig. 2). form a very substantial section about 1,5m in thickness. From base of this horizon up the layers the turbidite fragments are shown and in the top part of it the cryogenic textures and slide planes are found.

Thus, it is obvious that two climatic stages correlate with two horizons of cave section. The prolonged xerophilic epoch corresponds to the lower psephitic horizon. For a large duration of this epoch the climatic conditions favour to man assimilation of areas ajacent the cave. It is necessary to point out that the xerophility of surrounded landscape was determined not by lithological studies but by data of pollen analysis (Velichko et al, 1988). The humid-subnival stage corresponds to upper aleuropsammitic horizon. Becouse of severe conditions the zone of man settling has been mooved aside to the valley. The stratigraphic position of the boundary between two horizons can be related to early Mousterian.

The questions about stratigraphic position of the age of a cave settling and correlation between lithological composition and paleogeographic situation are disputable.

For their solving it is necessary to determine the age of appearance of cave entrance. The ambiquity of such question is obvious becouse of regional specifity of karst evolution. The multistage superposition of cold-water karst and gravitational caves on the hydrothermal paleokarst matrix is genetical peculiarity of karst in this region. The cave Sel-Ungur illustrates this scheme with exeptional clearness. At the same massiv several caves with superpositional hydrothermal mineralization have been opened. The water temperature in the cave reach 35°C that indicates the uncompleteness of hydrothermal stage of karst evolution. The cave Sel-Ungur is located in the roof hydrokarst system and is an integral part of it (fig. 3).

Our scheme allows to understand a history of the cave site evolution and the reasons of its leaving by man during Pleustocene. The settling of cave Sel-Ungur occured uncertainly long ago, but in that time the cave was directly bound with hydrothermal karst system. During this period the monotonous gruss-debris section with loamy filler has been formed. This horizon doesn't reflect the climatic state of landscape out of the cave. It may be only pointed out that the low humidity of region and the weak flooding of roof of karst massive is characteristic of this horizon. The weak lithification of lower horizon is bound with such conditions and it is not characteristic of cold-water caves of this region during Quaternary (Abdudjabarov, 1970). Also it may be supposed that the entrance into the cave was narrow enough and this limited the climatic interrelation between the cave and the surface.

An appearance of modern arch entrance took place during evolution of Obishir valley slope in Quaternary. The evolution of valley slope didn't only climatically bind the cave and surrounded area but also coincided with stage of ice sheet development in Tien-Shan. This event opened the cave for cold air and the cave ceased to be warm and dry. The man leaved it. In this period man migration to warmer regions is characteristic of the all mountain belt of Tien-Shan. Thus an interruption in settling of cave sites from Upper Mousterian to Late Paleolith for this landscape belt of Southern Tien-Shan in explained by development of Upper Pleustocene ice sheet and intensive humidification of region.

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ZONATION OF KARST IN TIEN-SHAN AND PLATE TECTONICS

SGIBNEV, Valentin V.

Principles of zonation of karst in Tien-Shan are remained a matter of discussion for many years. For Tien-Shan the separation of small karstic taxons is based on lithology-tectonic foundation. Under this it is supposed that karstic province of Tien-Shan is a part of karst country of Siberia and Middle Asia. We draw attention to two principal theses. In first place, forming of mountain structures of Tien-Shan was occured for Alpine stage of tectogenesis by interaction of Indian and Asian plates. In the second place, the tectonic regime of the whole Tien-Shan for Quaternary is synchronal. Analysis of spreading of karst forms in rocks of various composition and genesis that carried out in conformity with scheme of intersecting morphostructures of Tien-Shan allowed to make the follows conclusions:

- karst country of mountain structures in Middle Asia is structurally isolated from Siberian karst country;
- by morphology, placing and stages of development of cold-water Quaternary caves the Tien-Shan is integral region that identical with karst province;
- the hydrothermal cavities of South Tien-Shan inherritedly mapping the active fragments of Asian plate.

The principles of karst zonation in foldmountain structures are remained a matter of discussion for many years. The karst zonation of Tien-Shan, the largest mountain structure of orogenic belt of Southern USSR is a great part of this discussion. Starting from studies of Maximovich (1953) the karst region of Tien-Shan is related to karst country of Siberia and Middle Asia (Gvozdetsky, 1972). Previously this position didn't raise doubts.

According to the views adopted the geotectonic and geostructural zonation lies in the basis of separation of karst taxons. The separation of smaller taxons is based on lithologic-tectonic and climatic zonation. At our glance zonation of non-carbonaceous karst and karstomorphous phenomena is predetermined by tectonics only to a small extent. Here the lithology and the climate are dominating factors. In this study we consider position of subregional and regional zonation of carbonaceous karst in connection with scheme of global tectonics (fig. 1).

Recent studies have shown that the combination of two vectors of tectogenesis - the horizontal one and the vertical one - is characteristic of Tien-Shan (Litosfera...., 1986). To south-west from Talas-Fergansky fault the horizontal displacement dominates that is conditioned by an approach of Indian and Asian plates. To north-east from this fault the vertical uplifts prevail. The correlation between this regions is shown on fig. 2. We have studied a genetical bond of large karst taxons and two vectors of tectogenesis.

In Tien-Shan more than 300 caves are known in carbonaceous rocks (Sgibnev, 1979), mainly of Lower and Middle Paleozoic. Three types of caves are genetically prevail: gravitational-erosional, corrosive-erosional and hydrothermal. Their spatial interrelation brightly reflects the features of structural-tectonic division of Tien-Shan. In regions of dominant vertical rise the great part of caves is related to gravitational-erosional type. This caves are associated with gravity fissures and small openings of dicission. The caves of corrosive-erosional type are less known. They are associated with zones of weakness along river drainage or with paleofragments of the latter. To the second type we can relate the caves Agala-Tas 1 (Sgibnev et al, 1977). and Kastan'e. Besides above, in the region of horizontal displacement the hydrothermal caves are fully presented. The caves of corrosive-erosional type don't only widespread in this region but also have large dimentions and thick sinter crust. For that caves the correlation between levels of karstification and drainage system is characteristic of (Sultanov, 1972) within the limits of Pleustocenic-Holocenic stage of tectogenesis. The caves of gravitational-erosional type are distributed rather uniform in the landscape belt.

Morphology of caves have ben studied is closely connect with their genesis and reflects the degree of correlation of karstic and tectonic factors. The gravitational-erosional caves have small dimentions, contain either clastic deposits or don't have residial material at all. This caves have simple contours in a plan and many linear elements. The lenght of corrosion - erosional caves mounts to hundreds metres (cave Chil-Ustun). Sometimes this caves have several feebly marked levels. In

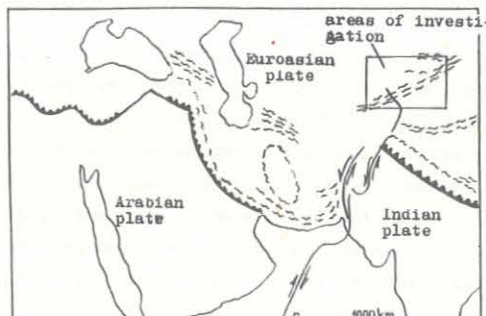

Fig. 1. Position of studied area in general scheme of global tectonic elements (was used the base of A. Michard, 1987 with additions of authors).

this caves allochthonous and autochthonous deposits are combined. Autochthonous material is carbonaceous-argillaceous, often with thick sinter crust. Allochthonous material is represented by sandy-argillaceous, rarely sandy-gravely deposits.

For hydrothermal caves the avialability of crystallitic crust is also usual. Among them the minerals of epithermal association such as antimonial-mercurial, barit-calcitic and rare-earth (Sgibnev, 1981) are met. Such as above associations is usual for cave deposits of Zeravshan-Hissar karst.

The genetical types of caves are also varied from one another by temperature of karst water. In corrosion-erosional caves a water has temperature lower 14°C, in hydrothermal - above 20°C with reaching 35-40°C (Abdudjabarov, 1979).

Fig. 2. Scheme of interrelation of interseding morphostructures in Tien-Shan (after "Litosfera....", 1986 /B.I.Makarov, O.K.Chediya/) and areas of hydrothermal karst (Sgibnev, 1981).
· - hydrothermal areas; - transorogenic fault
/ - axes of structural higs in Southern Tien-Shan and Chu-Ili massif

The available evidence allow to make some generalizations. Tectonic history of evolution of individual fragments of Tien-Shan has an effect on genetic content of karst landscape. The gravitational-erosional caves are mainly azonal concerning the large tectonic elements. First of all their position is controlled by lithologic-landscape factors. The corrosion-erosional caves is their evolution are closely, first and foremost stratigraphically, bound with tectogenesis. This bond is conditioned by stage evolution of river drainage and synchronous development of karst systems, in the first place within the limits of Pleustocenic-Holocenic stage. More old synchronization doesn't has sufficient factual ground till present time. The most close bond with regional tectonic structure is observed for hydrothermal karst. Spatial position of hydrothermal karst is limited by submontane frame of southern slope of Fergana valley. More rarely such caves are found in the northern-eastern peripheral part of this valley and carbonaceous masses of Northern Tien-Shan. Practically all karst places and districts adjoin to axis of transversal uplifts (fig. 2).

The foregoing observations must be coordinated with two principal considerations. In the first place, forming of mountain structures in Tien-Shan and contiguous mountain plexus took place during Alpine stage of tectogenesis by interaction of Indian and Asian lithospheric plates. In the second place, tectonic regime of whole Tien-Shan during Quaternary was synchronal according to majority estimations.

Summarizing our analysis, we would like to propose the following conclusions:

- Karst country of mountain structures in Middle Asia is structurally isolated from Siberian karst country. Accordingly, it is necessary to distinguish this karst country as independent taxon unit;
- In accordance with morphology, placing and stages of evolution of cold-water corrosion-erosional caves during Quaternary, Tien-Shan is an integral karst region identical with karst province. This allow to study the cold-water caves of Tien-Shan as an integral genetic totality independently of subregional factors. This conclusion directs futher investigations to peculiarites of manifestation of local lithologic-landscape features and demands the stratigraphic foundation of karstologous studies for this cave group outside Quaternary;
- Hydrothermal places and districts cannot be regarded in genetical bond with cold-water karst taxons. The hydrothermal caves of Southern Tien-Shan are placed in regions with prevalence of horizontal movement of earth crust, and this caves are genetically bound with large tectonic structures. In this connection such caves may be regarded as a stable indicators of mobile fragments of lithospheric plates.

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TECTONIC BOUNDARIES AND STAGES OF KARSTIFICATION IN TIEN-SHAN

SGIBNEV, Valentin V.

In orogenic belts it is of great interest the correlation of stages of tectonic activity and karstification. The tectonic structures of Tien-Shan with widespread karst and karstomorphic phenomena are arisen as a result of stage interaction of Indian and Asian plates. This staging causes the essence and evolution of karstification in region. Sections of hydrothermal caves in Tien-Shan contain hydrothermal and cold-water depositions. The hydrothermal superposition corresponds to completive stages of Hercinic tectonic activity of region (K-Ar 230-236 Ma). In present the level of cold-water caves associated with position of surface stream flows are formed. It is characteristic of to the region the following evolution of karstification:

- during the periode of tectonic stability the karst cavities associated with surface water stream flows are formed. Under tectonic activity the karst drainage system is destroyed and part of caves is become a collectors of hydrothermal solutions;
- during the following stable period the base of new karst drainage system is formed, a superstructure of paleokarst fragments is added electorally and a complex systems with stage hydrothermal remaking and mineralization are formed.

In fold-mountain structures the study of interrelation of tectonic activization stages and karstification is of great interest. This is conditioned by dominative role of tectonic factor in spatial localization of various carbonaceous karst types in Pamir - Tien-Shan region. For this region the influence of tectogenesis on stratigraphic stages of karstification is remained uncertain. In present study we analyzed the role of tectogenesis stages of Tien-Shan and its paleofragments in forming of hydrothermal and cold-water karst in carbonaceous rocks.

As a methological base of our work we use the tectonic position of Tien-Shan in fold-mountain belt of Southern USSR. In recent years it was shown that tectonic structures of Tien-Shan have been arised from interrelation of Indian and Asian lithospheric plates (Litosfera ..., 1986). Our findings indicate that stage character of this interrelation causes the stratigraphic content of karst evolution in studied region.

To the full the stage character of tectogenesis has been shown in stage evolution of cold-water karst caves in karst regions of Southern Tien-Shan and Zeravshan-Hissar. Four large fragments of cave Kievskaya (-950m, plateau Kyrk-Tau; Lobanov, 1978)correspond to four stages of Pleustocenic-Holocenic tectogenesis. The caves of Southern Tien-Shan are disposed on the four levels. This levels are synchronous with terrace levels at altitude intervals on 650, 375, 75 and 6m above modern fluvial planes (Sultanov, 1972). Accordingly, the age of caves is determined as Early, Middle and Upper Quaternary and Holocene. In variant of local stratigraphic scale the age corresponds to Soh, Tashkent, Golodnostep' and Syr-Darya complexes accordingly. V.I. Kucheryavih (1970) noted that caves of Southern slope of Chumkar-Tau are coordinated with Zeravshan river terraces or synchronal terraces of lateral affluents. Thus, for cold-water karst caves and their systems is characteristic of the close bond between stage character of evolution and stages of tectonic activization of region during Quaternary.

The question about stratigraphic correlation of tectogenesis stages and stage character of evolution of hydrothermokarst systems is solved less synonymously. The hydrothermokarst cavities and their systems are widespread in karst regions Zeravshan-Hissar and Southern Tien-Shan. Their studing is associated with industrial development of postkarst hydrothermal deposits. The most detail stratigraphic description of hydrothermal mineralization have been obtained for antimonial-mercurial depositions of Southern Tien-Shan.(Barvinkova, 1975). It was determined that hydrothermal superposition of mineralization on karst systems has been occured 230-236 mln years ago during final phase of Late Hercinic tectogenesis stage of Southern Tien-Shan (Berger, 1979). This data allow the hydrothermal karstification on the antimonal-mercurial depositions to be related to the boundary beetwen Hercinic and Alpine tectonic cycles. The study of barite-calcitic mineralization of Fersman system permits to mark out the Pliocenic-Pleustocenic boundary of hydrothermal reworking of karst system. Thus, we can suppose that activization of hydrothermal karst processes coinsides with large-scale tectonic boundaries in evolution of Tien-Shan and its paleofragments.

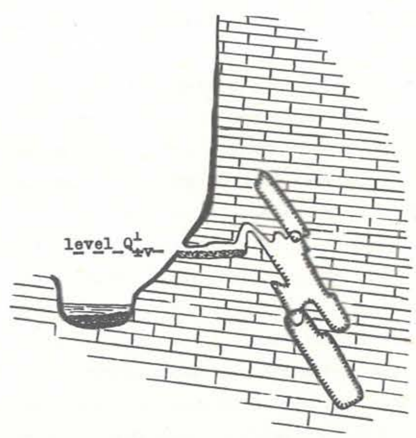

Fig. 1 Combination of hydrothermal cave and cold-water erosion-corrosional passage in Fersman massif.

It is, of exceptional interest to study the correlation of cold-water and hydrothermal stages of karst processes in polygenetic systems. This is associated with determination of genetic content of initial karst matrix and its evolution. Let us to regard two tipical examples. System Surpriz-Petrova of Fersman massif shown the correlation of cold-water and hydrotermal processes (fig. 1). The hydrothermal cave, which is reveted with trigonal scalenohedrons $\{21\bar{3}1\}$, in a great part of its volume is disposed lower and higher of present river level. This system had been opened during Lower Holocene by erosion-corrosional passage. At present the passage is disposed above the river level on 7-8m. Its floor along the whole lenght is covered with river coarse sand. Thus, the system with Pliocenic-Holocenic hydrothermal mineralization is complicated by Low Holocenic cold-water fragments. In karst system of Obishir valley an another variant of combination of cold-water and hydrothermal processes has been met (fig.2). Laminated sandstone from coarse-grained to dust-like is squeezed in lower part of

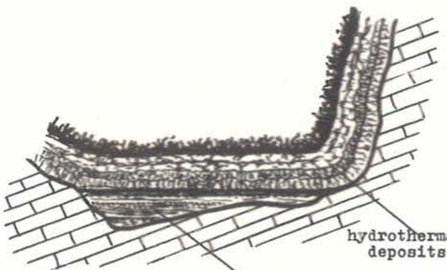

Fig. 2 Combination of hydrothermal and cold-water deposits in system of Obishir massif.

cave between the hydrothermal margin and the bedrock. In this case we observe deposits of cold-water karst which are older than 250 mln years. Hence, the cold-water karst system was being developed during Hercinic cycle in epoch of tectonic stability.

Summarizing our analysis we would like to propose the following redefinition of the stages of karst evolution:

- In regime of tectonic stability the karst cavities associated with surface water-streams are formed. During the period of tectonic activization at the boundary of epoches the karst drainage system is destroyed or is divided into parts and part of caves is become a collector of hydrothermal solutions.

- During the following stable regime the new karst drainage system is led. The drainage system inherits a paleomorphological pattern and at the same time the individual cavities are electorally added. In such a way the complex system such as Fersman or Kan-I-Gut are formed.

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FEDERAL CAVE PROTECTION IN THE UNITED STATES: THE FEDERAL CAVE RESOURCES PROTECTION ACT OF 1988

HUPPERT, George N. - THORNE, Janet B.

Caves on Federal lands have had limited protection under a variety of laws. Prior to 1988, no Federal laws specifically addressed caves as a unique environment. On October 21, 1988, both houses of the United States Congress passed legislation to protect caves on Federal land. The Federal Cave Resources Protection Act of 1988 is the culmination of a concerted effort by supporters that started in 1982.

The Act is a compromise between the wishes of its supporters, largely in the speleological community, and the, perhaps more practical, desires of those in the Federal agencies that will administer it. One compromise in the law is that it will only be applied to 'signficant' caves rather than all caves on Federal land. A precise definition of 'significant' has yet to be determined.

Speleological organizations have been invited to become involved in working with Federal agencies in a nine month formulation period. During that period, the criteria for 'significance' will be defined, and other regulations will be drafted. Such regulations will be challenging to write because they must be strong enough to require careful watershed management, but simultaneously be flexible enough to tailor the management to the unique ecosystem of each cave. In addition, the first list of 'significant' caves will be produced. This will be an open list, so that it will be possible to add other caves to it in the future.

PROTECTION DES GROTTES FÉDÉRALES AUX ÉTATS-UNIS: LOI DE 1988 RELATIVE À LA PROTECTION DES RESOURCES SPÉLÉOLOGIQUES FÉDÉRALES.

La protection des grottes sur le territoire fédéral était jusqu'à présent limitée par toute une série de lois. Avant 1988, aucune loi fédérale ne portait particulièrement sur cet environnement unique que sont les grottes. Le 21 octobre 1988, les deux Chambres du Congrès des Etats-Unis ont legi legiféré sur la protection des grottes sur territoire fédéral. La loi de 1988 relative à la protection des ressources spéléologiques fédérales a couronné l'effort concerté de ses défenseurs depuis 1982.

La loi est un compromis entre les souhaits de ses partisans, principalement dans la communauté spéléologue, et les désirs, peut-être plus pratiques, de ceux qui devront l'appliquer au niveau des agences fédérales. L'un des compromis de cette loi est qu'elle ne concernera que les grottes "importantes", et pas toutes les grottes sur le territoire fédéral. Il reste à définir le terme "important" plus précisement.

Des organisations spéléologiques ont été invitées à collaborer avec les agences fédérales pour une période de neuf mois pour tenter de définir ce terme. Pendant cette période, les critères d'importance seront établis, et d'autres règlements redigés. Ces règlements seront particulièrement difficiles a rédiger puisqu'ils devront à la fois demander une gestion minutieuse des plans d'eau, et garder une assez grande flexibilité pour répondre aux besoins uniques de l'écosystême de chaque grotte. Enfin, il sera conçu une première liste des grottes "importantes". Ce sera une liste ouverte, à laquelle il sera possible d'ajouter d'autres noms dans l'avenir.

1. A BRIEF HISTORY OF THE ACT

Late in 1988 events of monumental importance for federally owned caves occurred in the Congress of the United States. On October 21 the U. S. House of Representatives passed the Federal Cave Resources Protection Act of 1988. President Reagan signed the Act into law on November 18, 1988 as Public Law 100-691.

While there have been a number of federal laws that could be used to protect some caves (i.e. the Antiquities Act, the Clean Water Act, the Endangered Species Act, the Federal Archaeological Resources Protection Act, the Historic Preservation Act, the Wilderness Act, and many others), none of them specifically mentions caves. Additionally, only a limited number of caves could be covered by the provisions of these Acts (Huppert, 1979 and 1986; Huppert and Wheeler, 1986). These shortcomings allowed caves to be ignored by federal managers. This was usually due to the lack of knowledge of the presence of caves or of their significance, rather than deliberate exclusion. Many states have recognized the uniqueness of caves by passing legislation providing for some protection. More than half of the states now have enacted state cave protection laws, the most recent of which are Kentucky and Alabama. While these acts carry the force of law on federal land, they are rarely applied.

The signing of Public Law 100-691 caps an effort that lasted more than six years. In 1982 the National Speleological Society Board of Governors passed a resolution that set the Society on a course to seek a cave protection law at the federal level. Other conservation groups joined the fight during the succeeding years. The American Cave Conservation Association quickly added its support and resources into getting a resolution introduced into the United States Congress.

Several Representatives and Senators were approached to sponsor the proposed act. Unfortunately, caves are generally not a newsworthy item, are not well understood, and are not considered significant by most of the public. Therefore finding a committed sponsor to be dedicated to the passage of a law that would have little political value at election time was not an easy task. Eventually Congressman Rick Boucher (with Tim Johnson and Larry Craig) introduced the resolution into the House of Representatives, and Senator Tom Daschle was the Senate sponsor. House Resolution 1975 and Senate 927 were presented to their respective chambers on April 7, 1987.

The original drafts of the Act were written by a variety of individuals. Speleologists, cavers, federal agency personnel, legislators and their environmental aides, and conservationists all had significant input into the language of the Act prior to its introduction. Once the resolutions were introduced, the real work began. The bills were remanded to the appropriate committees for study, testimony, revisions, and a decision for future action (i.e., returning them to the House or Senate for a vote or rejecting them in committee).

An important task was to get enough support for the proposed law within both of the legislative bodies, to be able to acquire affirmative votes. Again, this was not an easy task. Caves and their contents are not emotionally appealing issues to the average American voter. Slowly, co-sponsors to the bills were found in Congress. While there were never many, they were a dedicated and persistent group. Support from conservation groups outside the caving community was sought and many responded favorably. Some of the more active groups were the Audubon Society, the Defenders of Wildlife, the National Wildlife Federation, The Nature Conservancy, Outward Bound, and the Sierra Club. Affected federal agencies (the Department of Interior and the Department of Agriculture) generally supported the concept of the proposal. However they all voiced concerns on the administration, interpretation, and enforcement of various aspects of the proposed law. As a result the draft version of the law was over a year in committee under debate and revision.

The resulting legislation is a compromise among all parties concerned. The various federal agencies involved had enough influence on the process so now only "significant" caves will be protected. A positive outcome is that all lands administered by the Departments of Agriculture and Interior are included in the law, compared to the draft version which proposed to exempt National Park Service and Indian lands. Unfortunately, this still leaves considerable federal properties free from the provisions of the Act. Two federal agencies which control considerable land of speleological significance are the Department of Defense and the Tennessee Valley Authority. Cave protection on units of the Department of Defense has been sporadic and generally not good. The Tennessee Valley Authority, an independent agency of the U.S. Government, has worked over the years to protect the caves they manage and has established a good track record. However, fiscal retrenchment may change this.

2. PROVISIONS OF PUBLIC LAW 100-691

The Federal Cave Resources Protection Act requires that the involved federal agencies publish regulations concerning the management of "significant" caves within their jurisdiction. The regulations will detail the various criteria for defining what "significance" means, as related to caves. This process has already started. On March 14, 1989 federal agency personnel and representatives from conservation groups met in Washington, D.C. to consider the criteria for "significance." Within one year after the regulations are published in final form, a list must be produced of "significant" caves on lands of the Departments of Interior and Agriculture. This list will undergo periodic revision as more information is provided to the agencies.

The Act specifically calls for participation by those who use caves in determining the management practices for the caves on the list. It insures that these caves will not be ignored in land management plans drafted by the agencies. It will also regulate cave access, prohibited activities (such as damage to speleothems, biota, etc.), the assessment of penalties (up to $10,000 USD), and the appeals process for persons charged with violations.

What the law will not do is force a change in any existing mining agreements or leases, nor will it supercede any established land management plans. In addition, it will not alter any rights or legal agreements made with respect to water, nor remove the states' responsibilities related to fish and wildlife.

Until the regulations are published, what will happen to the management of caves is somewhat vague. Hopefully, all land managers will follow the directive issued by the Bureau of Land Management (Robison, 1989) wherein all of the Bureau's caves will be considered "significant" and managed as such until more specific regulations are effective. Apparently the Forest Service has issued a somewhat weaker directive which requires that only the more important caves on their lands be protected until the regulations define "significance."

3. REFINING THE LAW

The agencies, together with speleological, conservation and other interest groups, must first define the criteria which make a cave "significant." However, provision should be made so that this definition can be modified, if a future need arises. Meetings in the spring of 1989 will produce these documents. The most obvious criteria are those based on size, depth, mineral deposits, unique biology, critical habitat, archeology, paleontology, historical values, unique geology or hydrology, recreational values, and minimal evidence of negative human impact (Anon., 1988; Thorne, 1988; Wilson, 1989). Of course, this list does not contain all of the possible criteria. The "significant" caves will be required to meet at least some, but probably not all, of these criteria. These will be more precisely refined as the 1989 meetings progress.

Secondly, the U.S caving community will play another important role. Cavers and other knowledgeable individuals will provide the agencies with a list of caves that meet the criteria for significance. A preliminary list has already been produced (Thorne, 1989). The list of "significant" caves will remain open so that later additions can be made. This procedure will be a great challenge to cavers and speleologists as any particular cave cannot be considered "significant" if it is not on the list. Cavers will have to overcome their, sometimes warranted, fears of informing agencies of the status of caves on agency lands.

According to the National Speleological Society (1987), more than 4,200 caves may be affected by this Act. The speleological and caving community in the United States has the chance to have a great impact on the management of many of our underground treasures for generations to come. The great mobilization of effort that resulted in the passage of the Federal Cave Resources Protection Act of 1988 will now be directed toward interpretation, administration, and enforcement of the Act. This success story is continuing and is a good example of how a relatively small group of individuals can influence a nation's lawmakers and land managers.

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102 STAT. 4546 PUBLIC LAW 100-691—NOV. 18, 1988

Public Law 100-691
100th Congress

An Act

Nov. 18, 1988
[H.R. 1975]

To protect cave resources on Federal lands, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

Federal Cave Resources Protection Act of 1988.
Minerals and mining.
Conservation.
16 USC 4301 note.

SECTION 1. SHORT TITLE.

This Act may be referred to as the "Federal Cave Resources Protection Act of 1988".

16 USC 4301.

SEC. 2. FINDINGS, PURPOSES, AND POLICY.

(a) FINDINGS.—The Congress finds and declares that—

(1) significant caves on Federal lands are an invaluable and irreplaceable part of the Nation's natural heritage; and

(2) in some instances, these significant caves are threatened due to improper use, increased recreational demand, urban spread, and a lack of specific statutory protection.

(b) PURPOSES.—The purposes of this Act are—

(1) to secure, protect, and preserve significant caves on Federal lands for the perpetual use, enjoyment, and benefit of all people; and

(2) to foster increased cooperation and exchange of information between governmental authorities and those who utilize caves located on Federal lands for scientific, education, or recreational purposes.

(c) POLICY.—It is the policy of the United States that Federal lands be managed in a manner which protects and maintains, to the extent practical, significant caves.

16 USC 4302.

SEC. 3. DEFINITIONS.

For purposes of this Act:

(1) CAVE.—The term "cave" means any naturally occurring void, cavity, recess, or system of interconnected passages which occurs beneath the surface of the earth or within a cliff or ledge (including any cave resource therein, but not including any vug, mine, tunnel, aqueduct, or other manmade excavation) and which is large enough to permit an individual to enter, whether or not the entrance is naturally formed or manmade. Such term shall include any natural pit, sinkhole, or other feature which is an extension of the entrance.

(2) FEDERAL LANDS.—The term "Federal lands" means lands the fee title to which is owned by the United States and administered by the Secretary of Agriculture or the Secretary of the Interior.

(3) INDIAN LANDS.—The term "Indian lands" means lands of Indian tribes or Indian individuals which are either held in trust by the United States for the benefit of an Indian tribe or subject to a restriction against alienation imposed by the United States.

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(4) INDIAN TRIBE.—The term "Indian tribe" means any Indian tribe, band, nation, or other organized group or community of Indians, including any Alaska Native village or regional or village corporation as defined in, or established pursuant to, the Alaska Native Claims settlement Act (43 U.S.C. 1601 et seq.).

(5) CAVE RESOURCE.—The term "cave resource" includes any material or substance occurring naturally in caves on Federal lands, such as animal life, plant life, paleontological deposits, sediments, minerals, speleogens, and speleothems.

(6) SECRETARY.—The term "Secretary" means the Secretary of Agriculture or the Secretary of the Interior, as appropriate.

(7) SPELEOTHEM.—The term "speleothem" means any natural mineral formation or deposit occurring in a cave or lava tube, including but not limited to any stalactite, stalagmite, helictite, cave flower, flowstone, concretion, drapery, rimstone, or formation of clay or mud.

(8) SPELEOGEN.—The term "speleogen" means relief features on the walls, ceiling, and floor of any cave or lava tube which are part of the surrounding bedrock, including but not limited to anastomoses, scallops, meander niches, petromorphs and rock pendants in solution caves and similar features unique to volcanic caves.

16 USC 4303.

SEC. 4. MANAGEMENT ACTIONS.

(a) REGULATIONS.—Not later than nine months after the date of the enactment of this Act, the Secretary shall issue such regulations as he deems necessary to achieve the purposes of this Act. Regulations shall include, but not be limited to, criteria for the identification of significant caves. The Secretaries shall cooperate and consult with one another in preparation of the regulations. To the extent practical, regulations promulgated by the respective Secretaries should be similar.

(b) IN GENERAL.—The Secretary shall take such actions as may be necessary to further the purposes of this Act. Those actions shall include (but need not be limited to)—

(1) identification of significant caves on Federal lands:

Records.

(A) The Secretary shall prepare an initial list of significant caves for lands under his jurisdiction not later than one year after the publication of final regulations using the significance criteria defined in such regulations. Such a list shall be developed after consultation with appropriate private sector interests, including cavers.

Regulations.

(B) The initial list of significant caves shall be updated periodically, after consultation with appropriate private sector interests, including cavers. The Secretary shall prescribe by policy or regulation the requirements and process by which the initial list will be updated, including management measures to assure that caves under consideration for the list are protected during the period of consideration. Each cave recommended to the Secretary by interested groups for possible inclusion on the list of significant caves shall be considered by the Secretary according to the requirements prescribed pursuant to this paragraph, and shall be added to the list if the Secretary determines that the cave meets the criteria for significance as defined by the regulations.

(2) regulation or restriction of use of significant caves, as appropriate;

Contracts.

(3) entering into volunteer management agreements with persons of the scientific and recreational caving community; and

(4) appointment of appropriate advisory committees.

(c) PLANNING AND PUBLIC PARTICIPATION.—The Secretary shall—

(1) ensure that significant caves are considered in the preparation or implementation of any land management plan if the preparation or revision of the plan began after the enactment of this Act; and

(2) foster communication, cooperation, and exchange of information between land managers, those who utilize caves, and the public.

16 USC 4304.

SEC. 5. CONFIDENTIALITY OF INFORMATION CONCERNING NATURE AND LOCATION OF SIGNIFICANT CAVES.

(a) IN GENERAL.—Information concerning the specific location of any significant cave may not be made available to the public under section 552 of title 5, United States Code, unless the Secretary determines that disclosure of such information would further the purposes of this Act and would not create a substantial risk of harm, theft, or destruction of such cave.

State and local governments. Schools and colleges.

(b) EXCEPTIONS.—Notwithstanding subsection (a), the Secretary may make available information regarding significant caves upon the written request by Federal and State governmental agencies or bona fide educational and research institutions. Any such written request shall, at a minimum—

(1) describe the specific site or area for which information is sought;

(2) explain the purpose for which such information is sought; and

(3) include assurances satisfactory to the Secretary that adequate measures are being taken to protect the confidentiality of such information and to ensure the protection of the significant cave from destruction by vandalism and unauthorized use.

16 USC 4305.

SEC. 6. COLLECTION AND REMOVAL FROM FEDERAL CAVES.

(a) PERMIT.—The Secretary is authorized to issue permits for the collection and removal of cave resources under such terms and conditions as the Secretary may impose, including the posting of bonds to insure compliance with the provisions of any permit:

(1) Any permit issued pursuant to this section shall include information concerning the time, scope, location, and specific purpose of the proposed collection, removal or associated activity, and the manner in which such collection, removal, or associated activity is to be performed must be provided.

(2) The Secretary may issue a permit pursuant to this subsection only if he determines that the proposed collection or removal activities are consistent with the purposes of this Act, and with other applicable provisions of law.

(b) REVOCATION OF PERMIT.—Any permit issued under this section shall be revoked by the Secretary upon a determination by the Secretary that the permittee has violated any provision of this Act, or has failed to comply with any other condition upon which the permit was issued. Any such permit shall be revoked by the Secretary upon assessment of a civil penalty against the permittee

pursuant to section 8 or upon the permittee's conviction under section 7 of this Act. The Secretary may refuse to issue a permit under this section to any person who has violated any provision of this Act or who has failed to comply with any condition of a prior permit.

(c) TRANSFERABILITY OF PERMITS.—Permits issued under this Act are not transferable.

(d) CAVE RESOURCES LOCATED ON INDIAN LANDS.—(1)(A) Upon application by an Indian tribe, the Secretary is authorized to delegate to the tribe all authority of the Secretary under this section with respect to issuing and enforcing permits for the collection or removal of any cave resource, or to carrying out activities associated with such collection or removal, from any cave resource located on the affected Indian lands.

(B) In the case of any permit issued by the Secretary for the collection or removal of any cave resource, or to carry out activities associated with such collection or removal, from any cave resource located on Indian lands (other than permits issued pursuant to subparagraph (A)), the permit may be issued only after obtaining the consent of the Indian or Indian tribe owning or having jurisdiction over such lands. The permit shall include such reasonable terms and conditions as may be requested by such Indian or Indian tribe.

(2) If the Secretary determines that issuance of a permit pursuant to this section may result in harm to, or destruction of, any religious or cultural site, the Secretary, prior to issuing such permit, shall notify any Indian tribe which may consider the site as having significant religious or cultural importance. Such notice shall not be deemed a disclosure to the public for purposes of section 5. Religion.

(3) A permit shall not be required under this section for the collection or removal of any cave resource located on Indian lands or activities associated with such collection, by the Indian or Indian tribe owning or having jurisdiction over such lands.

(e) EFFECT OF PERMIT.—No action specifically authorized by a permit under this section shall be treated as a violation of section 7.

SEC. 7. PROHIBITED ACTS AND CRIMINAL PENALTIES. 16 USC 4306.

(a) PROHIBITED ACTS.—

(1) Any person who, without prior authorization from the Secretary knowingly destroys, disturbs, defaces, mars, alters, removes or harms any significant cave or alters the free movement of any animal or plant life into or out of any significant cave located on Federal lands, or enters a significant cave with the intention of committing any act described in this paragraph shall be punished in accordance with subsection (b). Animals. Plants.

(2) Any person who possesses, consumes, sells, barters or exchanges, or offers for sale, barter or exchange, any cave resource from a significant cave with knowledge or reason to know that such resource was removed from a significant cave located on Federal lands shall be punished in accordance with subsection (b).

(3) Any person who counsels, procures, solicits, or employs any other person to violate any provisions of this subsection shall be punished in accordance with section (b).

(4) Nothing in this section shall be deemed applicable to any person who was in lawful possession of a cave resource from a significant cave prior to the date of enactment of this Act.

(b) PUNISHMENT.—The punishment for violating any provision of subsection (a) shall be imprisonment of not more than one year or a fine in accordance with the applicable provisions of title 18 of the United States Code, or both. In the case of a second or subsequent violation, the punishment shall be imprisonment of not more than 3 years or a fine in accordance with the applicable provisions of title 18 of the United States Code, or both.

16 USC 4307.

SEC. 8. CIVIL PENALTIES.

(a) ASSESSMENT.—(1) The Secretary may issue an order assessing a civil penalty against any person who violates any prohibition contained in this Act, any regulation promulgated pursuant to this act, or any permit issued under this Act. Before issuing such an order, the Secretary shall provide such person written notice and the opportunity to request a hearing on the record within 30 days. Each violation shall be a separate offense, even if such violations occurred at the same time.

(2) The amount of such civil penalty shall be determined by the Secretary taking into account appropriate factors, including (A) the seriousness of the violation; (B) the economic benefit (if any) resulting from the violation; (C) any history of such violations; and (D) such other matters as the Secretary deems appropriate. The maximum fine permissible under this section is $10,000.

District of Columbia.

(b) JUDICIAL REVIEW.—Any person aggrieved by an assessment of a civil penalty under this section may file a petition for judicial review of such assessment with the United States District Court for the District of Columbia or for the district in which the violation occurred. Such a petition shall be filed within the 30-day period beginning on the date the order assessing the civil penalty was issued.

(c) COLLECTION.—If any person fails to pay an assessment of a civil penalty—

(1) within 30 days after the order was issued under subsection (a), or

(2) if the order is appealed within such 30-day period, within 10 days after court has entered a final judgment in favor of the Secretary under subsection (b),

the Secretary shall notify the Attorney General and the Attorney General shall bring a civil action in an appropriate United States district court to recover the amount of penalty assessed (plus costs, attorney's fees, and interest at currently prevailing rates from the date the order was issued or the date of such final judgment, as the case may be). In such an action, the validity, amount, and appropriateness of such penalty shall not be subject to review.

(d) SUBPOENAS.—The Secretary may issue subpoenas in connection with proceedings under this subsection compelling the attendance and testimony of witnesses and subpoenas duces tecum, and may request the Attorney General to bring an action to enforce any

Courts, U.S.

subpoena under this section. The district courts shall have jurisdiction to enforce such subpoenas and impose sanctions.

16 USC 4308.

SEC. 9. MISCELLANEOUS PROVISIONS.

(a) AUTHORIZATION.—There are authorized to be appropriated $100,000 to carry out the purposes of this Act.

(b) EFFECT ON LAND MANAGEMENT PLANS.—Nothing in this Act shall require the amendment or revision of any land management

plan the preparation of which began prior to the enactment of this Act.

(c) FUND.—Any money collected by the United States as permit fees for collection and removal of cave resources; received by the United States as a result of the forfeiture of a bond or other security by a permittee who does not comply with the requirements of such permit issued under section 7; or collected by the United States by way of civil penalties or criminal fines for violations of this Act shall be placed in a special fund in the Treasury. Such moneys shall be available for obligation or expenditure (to the extent provided for in advance in appropriation Acts) as determined by the Secretary for the improved management, benefit, repair, or restoration of significant caves located on Federal lands.

(d) Nothing in this Act shall be deemed to affect the full operation of the mining and mineral leasing laws of the United States, or otherwise affect valid existing rights. Minerals and mining.

SEC. 10. SAVINGS PROVISIONS. 16 USC 4309.

(a) WATER.—Nothing in this Act shall be construed as authorizing the appropriation of water by any Federal, State, or local agency, Indian tribe, or any other entity or individual. Nor shall any provision of this Act—

(1) affect the rights or jurisdiction of the United States, the States, Indian tribes, or other entities over waters of any river or stream or over any ground water resource;

(2) alter, amend, repeal, interpret, modify, or be in conflict with any interstate compact made by the States; or

(3) alter or establish the respective rights of States, the United States, Indian tribes, or any person with respect to any water or water-related right.

(b) FISH AND WILDLIFE.—Nothing in this Act shall be construed as affecting the jurisdiction or responsibilities of the States with respect to fish and wildlife.

Approved November 18, 1988.

LEGISLATIVE HISTORY—H.R. 1975:

HOUSE REPORTS: No. 100-534 (Comm. on Interior and Insular Affairs).
SENATE REPORTS: No. 100-559 (Comm. on Energy and Natural Resources).
CONGRESSIONAL RECORD, Vol. 134 (1988):
Mar. 28, considered and passed House.
Oct. 21, considered and passed Senate, amended. House concurred in Senate amendment.

O

ABSOLUTE DATING OF PHREATIC SPELEOTHEMS FROM COASTAL CAVES OF MALLORCA (SPAIN)

GINES, Angel - GINES, Joaquin

Abstract

Coastal caves in Mallorca (Spain) offer a great variety of phreatic speleothems that have recorded Mediterranean sea paleolevels. An extensive absolute dating program, including U-Series and ESR measurements, had been carried out on many majorcan phreatic speleothems located between present-day sea level and +40 meters above.

Ages obtained were ranging from 3.9 ka (postglacial phreatic speleothems situated near the present sea level) to over 300 ka corresponding to high sea levels, related to stages 9 or even 11 of marine oxygen isotope record. These results agree well with a chronological model previously proposed on the basis of altimetrical correlation between phreatic speleothems and beach deposits of Majorcan coast.

These investigations demonstrate the relevance of chronological studies of phreatic speleothems, in order to establish Mediterranean sea level history during the Middle and Upper Pleistocene.

Resumen

Las cuevas costeras de Mallorca (España) presentan una notable variedad de espeleotemas freáticos relacionados con paleoniveles pleistocénicos del mar Mediterráneo. Muestras de espeleotemas freáticos, que abarcan desde el actual nivel marino hasta la cota +40 metros s.n.m., han sido objeto de un amplio programa de dataciones absolutas mediante la técnica de las series de Uranio complementada con mediciones de ESR.

Las edades obtenidas se extienden desde 3.9 ka (espeleotemas cercanos al presente nivel del mar) hasta edades superiores a los 300 ka, que corresponden a paleoniveles altos atribuibles a los estadios 9 ó 11 del registro marino de isótopos de oxígeno. Estos resultados confirman a grandes rasgos el modelo cronológico propuesto previamente, en el que se establecían correlaciones altimétricas entre los espeleotemas freáticos de las cavernas costeras y los depósitos de playa fósil presentes en el litoral mallorquín.

Al mismo tiempo, se evidencia la utilidad de los estudios cronológicos emprendidos sobre este tipo de espeleotemas, en lo que se refiere a precisar con mayor detalle las vicisitudes experimentadas por el nivel marino durante el Pleistoceno Medio y Superior.

INTRODUCTION

Littoral karst areas in Mallorca island (Spain) have numerous caves that show phreatic pools originated in correspondance with present-day marine level; these subterranean brackish pools are clearly affected by periodic oscillations of sea level, like tides.

In this sea-level controlled phreatic environment, today conspicuous carbonate deposition phenomena occur at the current ±0 meters level. However, the main speleo-chronological interest of these processes of carbonate precipitation is related to the fact that ancient positive fluctuations of the Mediterranean sea (corresponding to interglacial events) are recorded inside coastal caves by means of phreatic speleothems alignments (GINÉS et al., 1981 a). This type of crystallizations are linked to paleolevels reached by the ground water-table, simultaneously with the glacial-eustatic fluctuations of the Mediterranean sea. Obviously, the history of sea level fluctuations implies a chronological component, that must be taken into account. From a morphological and mineralogical point of view, a wide approach to these carbonate deposition phenomena can be found in POMAR et al. (1976, 1979) and GINÉS et al. (1981 b).

Several caves of Mallorca allow to establish altimetric correlations between paleolevels of phreatic speleothems and ancient beach deposits from the Middle and Upper Pleistocene. In such a manner, geomorphologic attempts to date these cave deposits were made in the past: 15 years ago we had reported (GINÉS & GINÉS, 1974) about phreatic speleothem paleolevels that were correlated to interglacial Tyrrhenian stages. The proposed chronology ranges from post-Wurmian times to ages older than Paleotyrrhenian (Mindel-Riss warm period).

In 1981 it was possible to start an isotopical dating program on majorcan phreatic speleothems, in order to check previously established geomorphic chronological model. Speleothems ranging in heighth from the present-day sea level (probably post-glacial in age) to +40 meters a.s.l. were investigated; the latter samples belong to high marine levels presumably ascribed to the Middle Pleistocene. The results of this dating program are set out in this paper. However, some of the present results of these investigations have been published already a few years ago (HENNIG et al., 1981; GRÜN, 1985; GRÜN, 1986).

SAMPLED SPELEOTHEMS

Eleven speleothems were collected from six coastal caves of Mallorca island. All the caves are well characterized by the presence of conspicuous calcium carbonate overgrowths deposited around dripstone speleothems like stalactites, stalagmites or wall-coating flowstones.

Geomorphological explanation of these sampled speleothems is always related to subaqueous precipitation of calcite or aragonite in the uppermost phreatic zone near the water-table, at an elevation determined by pleistocene high sea-level standings. Previous speleo-chronological studies have claimed for several interglacial events regarding the development of this kind of coastal-cave deposits (GINÉS & GINÉS, 1974; GINÉS et al., 1981 a).

In order to obtain more accurate data on the interglacial paleolevels attained by the Mediterranean sea in the coastal karst areas of Mallorca, nineteen samples were selectively taken from the collected speleothems. They were dated by means of Uranium-series and ESR techniques. Moreover, it was expected that speleothem dating should provide additional information to the chronological model suggested for some of the complex cave stratigraphies investigated (GINÉS & GINÉS, 1986).

Only some brief informations on the samples dated and their location in the caves can be given here:

- Drowned in a brackish pool in **Cova de Cala Varques** (Manacor), a fragment of broken column whose top presents a thick calcite overgrowth placed approximately at the current level of the water-table was taken (see description in POMAR et al., 1979; page 13).
  - *Sample Varia*: outer part of the subaqueous overgrowth.
  - *Sample Varib*: inner part of the subaqueous overgrowth.
  - *Sample Varic*: estalagmitic core built from dripstone water during a negative shift of the water-table.
- From the roof of a chamber in **Cova des Pont** (Manacor), 2 meters above a pond named Llac Victòria (TRIAS, 1977), a group of small stalactites and helictites covered with subaqueous calcite were collected.
  - *Sample Pont9* corresponds to a coated stalactite of this level.
- In **Cova de Na Mitjana** (Capdepera), at an elevation near 6 meters

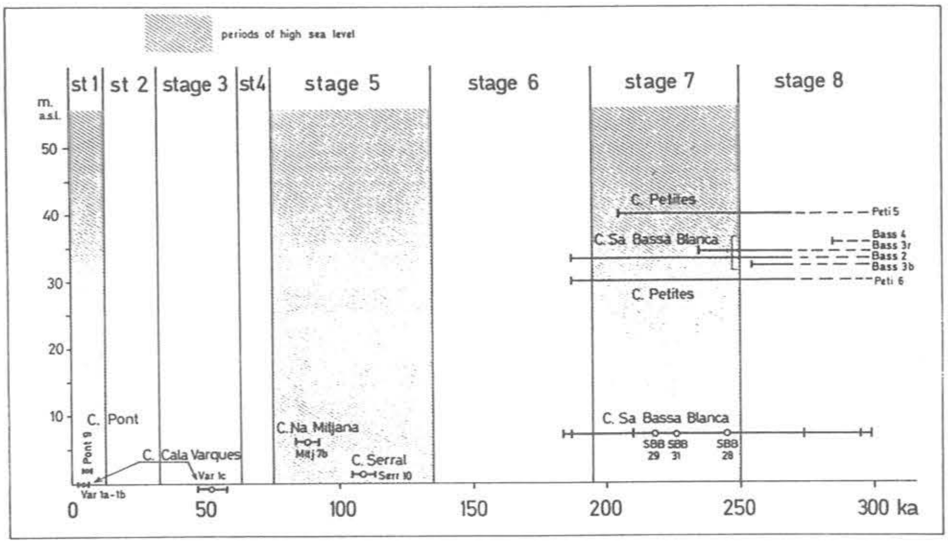

Figure 1: Results of the dating program plotted on the SHACKELTON & OPDYKE (1973) marine oxygen isotope record.

a.s.l., a group of large bulbous stalactites was reported (GINÉS et al., 1975). One of these bulbous speleothems was sectioned to find the stalactitic core, and then the subaqueous cover was dated.

Sample Mitj7a: outer part of the subaqueous coating.

Sample Mitj7b: inner part of the subaqueous coating.

From the eastern wall of **Cova des Serral** (Manacor) a fragment of bulky subaqueous belt was taken at 1.4 meters above the water-table pool.

This speleothem has provided the *Sample Serr10*.

Several phreatic paleolevels appear in **Coves Petites** (Capdepera) as bulbous stalactites and mainly as wide speleothem-linings at different levels higher than 30 meters a.s.l. (GINÉS, 1973). One of each type of speleothems were taken.

Sample Peti5: subaqueous coating around the tip of a stalactite.

Sample Peti6: subaqueous belt on the walls of the lower cave-chamber.

A great amount of phreatic speleothems cover most of the floor, the walls and even the ceiling of **Cova de Sa Bassa Blanca** (Alcúdia); the most striking feature of this cave being the up to thirteen speleothem-linings (i.e. water levels) easy to recognize around the walls of its chambers. These paleolevels are distributed between +35 meters and the current water-table, as has been described and explained in GINÉS & GINÉS (1974), GINÉS et al., (1981 a) and POMAR et al., (1987). Searching to test their geological interpretation that correlates speleothem-linings to interglacial sea paleolevels, a group of five speleothems was collected at different elevations: a very thick wall-coating placed near 7 meters a.s.l. that has been drilled horizontally as much as two meters deep; three stalactites with calcite overgrowths appartaining to the first chamber, higher than 30 meters a.s.l.; and finally, a stalactite with aragonitic overgrowth obtained from the lower passages of the cave.

This five speleothems were sectioned to obtain the following ten samples.

Sample SBB28: piece of wall coating, from drill-core (3-6 cm. inward).

Sample SBB29: piece of wall coating, from drill-core (21-25 cm. inward).

Sample SBB30: piece of wall coating, from drill-core (41-47 cm. inward).

Sample SBB31: piece of wall coating, from drill core (155-158 cm. inward).

Sample Bass2: subaqueous calcite overgrowth on stalactite.

Sample Bass3a: outer part of a calcite overgrowth on stalactite.

Sample Bass3b: stalactite core of the same speleothem than 3.

Sample Bass3r: repeated dating on the same stalactitic core than 3b.

Sample Bass4: subaqueous calcite overgrowth on stalactite.

Sample Bass8a: aragonite subaqueous overgrowth on stalactite tip.

RESULTS OF SPELEOTHEM DATING

Table I summarizes the results of the dating program, as have been reported to us by HENNIG (pers. comm. 1981-1988). Technical comments on each sample-analysis should be the object of another paper in the near future by Dr. Hennig. Our intention in this study is only to provide a geomorphological background regarding the correlation postulated between phreatic speleothems and interglacial sea-paleolevels.

ESR datings obtained by GRÜN (1985,1986) as well as by HENNIG (pers. comm. 1982, 1984) suggest an age substantially older than 350 ka for several speleothems collected in Cova de Sa Bassa Blanca. Additional work on this complex cave-stratigraphy could yield promising and interesting data in this respect.

CONCLUSIONS

Nineteen samples of speleothems from coastal caves of Mallorca island, associated with phreatic sea-controlled paleolevels, were dated by means of Uranium-series techniques. Ages obtained were ranging from 3.9 ka (post-glacial phreatic speleothems situated near the current sea level) to over than 300 ka corresponding to higher sea levels (Figure 1).

The dated speleothems younger than 250 ka are in good agreement with the ages expected from the SHACKELTON & OPDYKE (1973) oxygen-isotope record of core V28-238, being clearly related to stages 1, 5 and 7 (i.e. periods of high sea level).

The ancient phreatic speleothems, being found high above the current water-table, have not yielded controversial data regarding the proposed geomorphological model of subaqueous growth during interglacial stages, previous to the Riss glaciation.

ESR-measurements and Uranium-series dating of the ancient speleothems from Cova de Sa Bassa Blanca, as well as the results and altimetric location of the samples from Coves Petites, seem to suggest ages of phreatic speleothem formation older than 350 ka, some of them appartaining maybe to stage 9 or even stages 11 or 13.

Acknowledgements

This report would not has been possible without the data provided by Dr. Gerd J. Hennig, of the Niedersächsisches Landesamt für Bodenforschung. We appreciate his kind permission for the publication of their personal communications, and we wait with interest for a more detailed paper on the technical discussion of the datings. Our grateful acknowledgement must be emphasized.

Many thanks are also due to Dr. Ruth Hausmann, Geologisches Institut der Universität zu Köln, who carried out some of the U-series analysis, and to Dr. Rainer Grün, Cambridge University, for the ESR measurements of Cova de Sa Bassa Blanca samples.

Locality	Sample number	Heighth above sea level (m)	U [ppm]	Th [ppm]	$^{234}U/^{238}U$	$^{230}Th/^{234}U$	$^{230}Th/^{232}Th$	Calculated age and standard error (ka)
Cv. Cala Varques	Var1a	0	0.38±0.01	-	1.503±0.049	0.035±0.004	-	3.4-4.3
Cv. Cala Varques	Var1b	0	0.46±0.01	-	1.689±0.051	0.048±0.004	-	4.9-5.8
Cv. Cala Varques	Var1c*	-1	0.26±0.01	-	1.292±0.044	0.388±0.029	-	47.3-57.4
Cv. des Pont	Pont9	2	0.278±0.006	0.005±0.000	1.456±0.029	0.064±0.002	13.7±2.1	6.3-6.9
Cv. Na Mitjana	Mitj7a	6	0.048±0.001	0.017±0.003	1.065±0.026	0.946±0.057	8.54±1.89	275?
Cv. Na Mitjana	Mitj7b	6	0.189±0.003	0.001±0.001	1.022±0.015	0.563±0.014	41.42±5.04	84-92
Cv. des Serral	Serr10	1.4	0.233±0.005	0.001±0.001	1.487±0.025	0.663±0.015	733.3±733.3	105-113
Cvs. Petites	Peti5	40	0.046±0.003	0.038±0.005	1.206±0.107	0.993±0.083	4.45±0.60	>205
Cvs. Petites	Peti6	30	0.130±0.008	0.031±0.008	1.118±0.081	1.039±0.090	14.88±4.00	>187
Cv. Sa Bassa Blanca	SBB28	7	4.46	0.06	1.08±0.03	0.91±0.04	-	210-299
Cv. Sa Bassa Blanca	SBB29	7	0.41	0.02	1.08±0.06	0.88±0.05	-	184-274
Cv. Sa Bassa Blanca	SBB30	7	0.25	0.01	1.17±0.07	1.08±0.07	-	>326?
Cv. Sa Bassa Blanca	SBB31	7	0.30	0.01	1.07±0.06	0.89±0.05	-	187-295
Cv. Sa Bassa Blanca	Bass2	30-35	0.20±0.01	-	1.060±0.060	0.895±0.054	-	>187
Cv. Sa Bassa Blanca	Bass3a	30-35	0.17±0.01	-	1.081±0.045	1.630±0.093	-	>350?
Cv. Sa Bassa Blanca	Bass3b*	30-35	0.21±0.01	-	1.097±0.049	0.982±0.045	-	>255
Cv. Sa Bassa Blanca	Bass3r*	30-35	0.244±0.007	0.168±0.011	1.011±0.029	1.205±0.052	5.39±0.32	>235
Cv. Sa Bassa Blanca	Bass4	30-35	0.22±0.01	-	1.059±0.024	1.000±0.052	-	>285
Cv. Sa Bassa Blanca	Bass8a	<30	0.886±0.019	0.032±0.004	1.064±0.017	1.072±0.029	96.3±12.6	>310

* dripstone speleothems

TABLE I

Finally, we wish to thank Dr. Mebus A. Geyh (Niedersächsisches Landesamt für Bodenforschung, Hannover) and the members of the Laboratori de Geologia (Universitat de les Illes Balears, Palma de Mallorca) for their encouragements.

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THE LIMESTONE CAVE RESOURCES OF GREAT BRITAIN

HARDWICK, Paul - GUNN, John

The majority of caves in Great Britain are formed in the Carboniferous Limestone which crops out mainly in the Mendip Hills, Derbyshire, North and South Wales and The Yorkshire Dales. A smaller number of caves are formed in older limestones, principally the Devonian Limestone (Devon) and the Durness (Cambrian) Limestones of Scotland. Extensive areas of karst have formed on younger limestones (Cretaceous Chalk, Jurassic Limestone and Permian Magnesian Limestone) but there are few caves of any extent. Although descriptions and surveys exist for most caves, no detailed inventory of cave resources has been undertaken. Such an inventory is an essential pre-requisite to conservation and effective management. This paper provides summary statistical and tabular information from a computerised national cave database, compiled from existing published information.

La plupart des grottes en Grande Bretagne se sont formées dans le calcaire carbonifère qui se trouvent principalement aux collines de Mendip; en Derbyshire; au Pays de Galles, nord et sud; et dans des vallons de Yorkshire (Yorkshire Dales). Un nombre plus petit de grottes se sont formé dans des calcaires plus formees vieux, principalement le calcaire devonian (en Devon) et les calcaires durness (Cambrian) de l'Ecosse. De grandes étendues de karst se sont formées dans des calcaires plus jeunes (les craies crétaces, le calcaire jurassique, et le calcaire magnésian permian) mais peu de grottes d'une longeur signifiante. Quoiqu'il existe des levés et des descriptions pour la plupart des grottes, il n'existe pas d'inventaire detaillé de resources spéléologiques. Un tel inventaire est une nécessité préalable à la conservation et à la gestion effective de ces grottes. Ce papier provient des renseignements statistiques en sommaire et tabulaires d'une base de données spéléologiques nationales gardée à l'ordinateur, et compilée de renseignments déjà publiées.

The majority of caves in Britain and all of those of significant length and depth are developed in the Carboniferous Limestone which outcrops in five main regions (Figure 1). The older Devonian Limestone of South Devon and the Durness Limestone (Cambrian) of northern Scotland (Figure 1) also contain a scattering of caves with lengths of up to 3000m and 2000m respectively. Extensive karst areas have formed on the younger limestones (Cretaceous Chalk, Jurassic Limestone, Permian Magnesian Limestone) but there are few caves of any extent and although these are often of scientific interest they are not considered further in this paper. Similarly sea caves and those caves formed in mass movement deposits are outside the scope of this discussion.

In the first major report on caves and conservation in England and Wales, Wilmut (1972a), 1735 caves were recorded of which 58 were classified as being of national importance, 114 of regional importance, 209 of local importance, 293 as being seldom visited or only of interest from a scientific viewpoint, 20 as show caves and 1041 (60%) as being very small or of no particular interest and very seldom visited for any purpose. However, no indication of passage length was given and to the authors' knowledge the total length of cave passage in Britain is unknown as no detailed inventory of cave resources has been undertaken. However, guide books are available for all the main caving regions and data on the caves contained within these has been transferred on to a computer database. The resulting NATIONAL CAVE DATABASE has been used to compile the summary statistics in Table 1. These should be regarded as a preliminary assessment, as problems such as whether or not to include natural cavities in mines and how to assess multiple entrance systems have still to be resolved.

The Northern Pennines contains more known caves than any other cave region, with 67% of the national resource. The region's caves also contain the greatest amount of known passage, almost 55%. In contrast, South Wales region contains 26% of all known cave passage but only 7.1% of cave entrances giving a mean passage length per cave of 0.949 km against only 0.19 km for the Northern Pennines and similarly low figures for the other regions (Table 2.)

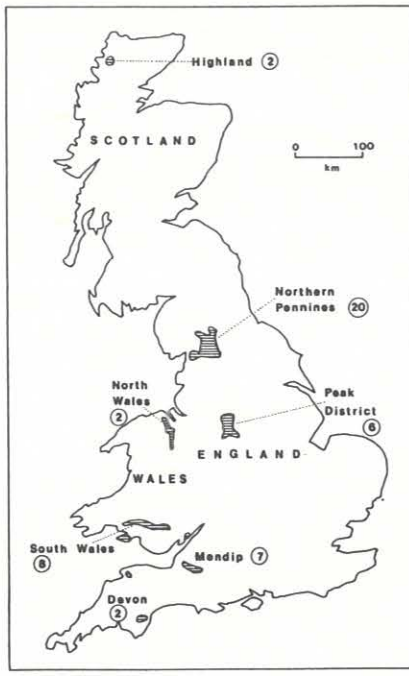

Figure 1. The Seven Main Cave Regions in Great Britain (Numbers of Cave SSSI Encircled)

TABLE 1 LIMESTONE CAVE RESOURCES OF GREAT BRITAIN

REGION	Number of caves	Per Cent of Total caves (%)	Number of caves in SSSI	Per Cent region's caves in SSSI (%)	Total length (km)	Total length in SSSI (km)	(%)
Scotland	185	6.8	28	15.1	10.378	5.322	51.3
N. Pennines	1818	67.1	637	35.0	345.472	248.262	71.9
Peak District	204	7.5	78	38.2	43.018	36.624	85.1
Mendip	192	7.1	62	32.3	52.324	41.915	80.1
N. Wales	44	1.6	6	13.6	9.876	3.484	35.3
S. Wales	168	6.2	30	17.9	159.486	138.804	87.0
Devon	99	3.7	19	19.1	11.803	5.705	48.3
G.B. TOTAL	2710	100.0	860	31.7	632.357	480.116	75.9

TABLE 2. MEAN LENGTHS OF CAVE PASSAGE : BY REGION

	Mean Passage Length (km)	Mean Passage Length in cave SSSI (km)
Scotland	0.056	0.190
N. Pennines	0.190	0.389
Peak District	0.210	0.469
Mendip	0.273	0.676
N. Wales	0.224	0.581
S. Wales	0.949	4.627
Devon	0.119	0.300
Great Britain	0.233	0.558

TABLE 3. CAVE SYSTEMS <100 m LONG IN GREAT BRITAIN

LENGTH CLASS (M)		NUMBERS OF CAVES
<10		646
10- 20		338
20- 30		147
30- 40		102
40- 50		85
50- 60		40
60- 70		69
70- 80		46
80- 90		18
90- 100		37
	TOTAL	1528

48 cave Sites of Special Scientific Interest (SSSI) have been designated by the Nature Conservancy Council (NCC) and receive some measure of protection from the external impacts of agriculture and other human activities (Hardwick & Gunn 1989). As can be seen in Table 1, cave SSSI boundaries encompass 13.6-38.2 % of cave entrances within the cave regions and 35.3-87.0 % of known cave passage. Thus it is apparent that, in most regions, official cave conservation measures may apply to the majority of accessible caves. In South Wales, the mean length of cave passage both per cave and within cave SSSI (Table 2) emphasises the small number but large size of their cave systems, and the greater degree of official protection in the region. The aggregate data presented in tables 1 and 2 hides a wide variation in the length of cave systems. A more detailed study is in preparation by the authors. However, length data on caves of less than 100 m are shown in Table 3. The 1528 entrances represent 56% and thus the majority of known caves. In addition, the 646 caves of up to 10 m in length represent 23.8% of all cave resources. This may present problems for the definition of cave systems in Britain, since many of these small caves may not possess a dark zone. Nevertheless, whilst of little interest to recreational caving, these sites may be of scientific interest and therefore should be included in cave resource assessments.

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CAVE MANAGEMENT AND CONSERVATION IN BRITAIN: AN HISTORICAL OVERVIEW

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The conservation and management of caves in Great Britain has recently been the focus of much debate within the speleological literature. This paper provides an historical overview of management of caves in Great Britain from the establishment of early tourist caves to the designation of Cave Sites of Special Scientific Interest (Cave SSSI) by the Wildlife and Access to the Countryside Act of 1981. The Act strengthened the powers of the Nature Conservancy Council (NCC) in the conservation of these sites, particularly against external threats such as the agricultural and mineral extraction industries. However, the problem of internal damage by the recreational use of cave resources has yet to be effectively tackled.

La conservation et le gestion des grottes en Grande Bretagne à été récemment le sujet de beaucoup de discussion dans la littérature spéléologique. Ce papier donne un sommaire historique du gestion de grottes en Grande Bretagne des l'établissememt des premières grottes touristiques jusqu'à la désignation des endroits spéléologiques d'interêt scientifique spécial (grotte designée SSSI) ce qui s'est passé dans la loi de 1981 concernant l'accès au pays vis-à-vis ses animaux et oiseaux natifs. Cette loi a augmenté le pouvoir du Conseil pour la conservation de la nature (le NCC) dans sa lutte de conserver ces endroits-ci contre, en particulier, des menaces telles les industries d'extraction agricole et minérale. D'ailleurs, le problème des dommages intérieures des resources spéléologique par l'usage sportif attend toujours être effectivement abordé.

1. INTRODUCTION

Human use of British caves for accomodation and water supply has a long history, and serious (scientific) exploration of caves commenced over one hundred years ago. Nevertheless, the number of known caves and the length of surveyed passage continues to grow annually as a result of vigorous exploration activity. One particularly good example is Ogof-Y-Daren Cilau in South Wales which has been extended from about 1km in 1982 to over 21km in 1989 (this cave also contains the largest cave passage in Britain, the Time Machine). However, during the 1960s and early 1970s it became obvious that the number of caves and length of accessible passage (the resource base) was growing much less rapidly than the number of people wishing to explore them. This resulted in an increasing pressure on the resource and particularly on certain easily accessible systems. Considerable concern was expressed over the impact of this activity and general conservation issues were addressed by Black (1964, 1969), Warwick (1965, 1975) and Wilmut (1972b). Individual concern over specific sites continued through the 1970s (e.g. Barrington & Stanton, 1977) but there was a marked absence of any overall cave management and conservation review until that by a series of authors in a theme issue of 'Studies in Speleology' (volume 6, 1985). This paper reviews current cave management and conservation practice in Britain.

The management of Britains cave resources is undertaken for a number of reasons. Water from cave streams is important in some localities, particularly on the Mendip Hills, but on the whole the Carboniferous Limestone is not considered to be a major aquifer rock. The minerals contained in natural caves, particularly lead and associated ores, have been exploited in the past but this is no longer the case. However, fluorspar continues to be mined in the Peak District and natural cavities are sometimes encountered in these workings (Butcher & Hedges, 1987). Consequently, in the British context the conservation and management of caves as a resource may best be considered under two headings: recreation and tourism, and science.

2. THE MANAGEMENT OF CAVES FOR TOURISM, RECREATION, AND SCIENCE

Until relatively recently, a division could be made between those individuals interested in the exploration of caves for sport and recreation or for science, and those content to make an occasional visit to a commercially operated, artificially lit 'tourist cave'. However, since the 1970s, the division has become somewhat blurred with the development of a third category, 'adventure caving' in which groups, usually of young people, are taken underground by paid instructors. The number of caves visited is inversely proportional to the number of visitors in each category and the pressures and need for protection vary accordingly.

2.1 Commercially operated tourist caves

The British Association of Show Caves (BAS) list 12 'true' limestone caves which are open to the public for all or part of the year, and there are also a number of mines containing natural cave passage which are open to the public (e.g. Blue John Cavern and Speedwell Cavern in the Derbyshire Peak District). Although no published numbers are available it is estimated that they are visited by over 2 million people each year (BAS, pers. comm.). Many of these show caves have suffered damage from visitors in the past, particularly those which have been visited for over a century. Principal impacts have been removal of or damage to speleothems, graffiti, soot from early forms of lighting, and the modification or destruction of some passages and sedimentary deposits in order to improve access for visitors. However, most operators now recognise the need for protection and there are elaborate efforts to prevent further vandalism and to minimise the impact on the cave environment. Nevertheless, the growth of lampenflora and changes to cave microclimate continue to present problems in most show caves, and recent proposals to extend White Scar Cave in Yorkshire proved to be controversial because of the potential for damage. The attitude of show cave owners to cavers wishing to visit those parts not open to the general public varies, but in most cases there are at least some restrictions which result in better preservation of the cave and its deposits than would be the case if open access was allowed.

2.2 Wild caves

Those caves not operated commercially can only be visited by cavers with, as an absolute minimum, an independent source of light. The number of visitors depends on the popularity of the system which is itself a function of factors such as location with respect to centres of population, accessibility (distance from road and nature of terrain), degree of difficulty and features of interest. No figures on visitor numbers are available but the number of 'active' cavers is thought to be in excess of 20,000 and it is well known that many of the popular systems are overcrowded, particularly at weekends, with substantial queues developing around vertical drops. Those caves used for adventure caving are particularly heavily visited; for example it has been estimated on the basis of a sample visitor survey that some 20,000 people visit the wild caves of the Derbyshire Peak District every year.

Each human visitor to a cave causes some change to the cave environment, however minor. The amount of change will vary with the type and number of visitors in a complex manner. For example, in order to enter a new cave passage it may be necessary to break speleothems or excavate sedimentary deposits. Explosives are also widely used to remove obstacles to progress, although some have questioned the ethics of this. Such actions are damaging to the cave but they are generally accepted as a necessary consequence of exploration, and are often followed by attempts to protect the newly discovered passage, for example by using tape to define a route through a particularly sensitive area. Another controversial subject in recent years has been the damage caused by the use of bolts rather than natural belays for rigging pitches.

The common factor in all these impacts is the desire to extend access and to improve safety rather than to damage the cave as such. They may therefore be distinguished from both accidental impacts such as the deposition of litter or breakage of speleothems as a result of carelessness, and also from deliberate acts of vandalism. In general it would appear that both accidental and deliberate damage increases with the accessibility of the cave (both entrance location and nature of passages) and with visitor numbers although the relationship is by no means a simple one. For example, a survey by the National Caving Association found a statistically significant relationship between cave usage and a damage index but there was no statistically significant relationship between damage and either access restrictions or the number of years that the cave had been open (Wilmut, 1972a). The rise of 'adventure caving' has placed additional pressures on certain popular caves and a recent proposal to install fixed equipment, including extensive scaffolding, steel ladder sections, platforms and safety net in Bar Pot (Northern Pennines) in order to allow easier access to novice groups has caused considerable controversy (Hall, 1987).

2.3 The scientific value of caves

Scientific interest in British caves is focussed on four main aspects : archaeology, biospeleology, hydrology/geomorphology, and mineralogy. Of these archaeology has largely been confined to the entrance zone of a limited number of small cave systems, most of which now enjoy protection as palaeontological Sites of Special Scientific Interest . Substantial lists of cave fauna have been compiled for most areas of the country, notably by the late Mary Hazleton, but there have been few studies of cave ecology because "animal life... does not feature very prominently in British caves; the animals being few in number and usually small in size, and mostly inconspicuous" (Jefferson, 1976, p.359). There have also been relatively few studies of cave flora (e.g. Cubbon, 1970), or of the mineralogy of cave deposits as such although minerals in caves have been discussed in the context of the various ore bodies within the Carboniferous Limestone (e.g. Worley & Ford, 1977). In contrast to the lack of research on the above topics, cave related hydrology and geomorphology have received considerable attention from both 'amateur' and 'professional' cave scientists. Many studies relate to the hydrology (e.g. Christopher, 1984; Gunn, 1985a) or speleogenesis (e.g. Waltham 1977; Ford, 1986) of individual cave systems. However, with the advent of Uranium series dating of calcite speleothems studies of cave sediments have achieved particular prominence because of the information which they can give on Pleistocene chronology, Quaternary climates and landform evolution (e.g. Ford et al., 1983; Gascoyne et al., 1983a, b). Hence, it can be argued that the ability of caves to act as museums preserving evidence of past events at the earths surface makes them a particularly valuable resource which is deserving of conservation (Gunn, 1985b).

Few attempts have been made to control or limit the amount of damage to wild caves resulting from visitor pressure. 31% of Britain's caves and 75.9% of cave passage lie within cave Sites of Special Scientific Interest (SSSI) conserved for their geological and geomorphological interest by the Nature Conservancy Council (NCC) (Hardwick & Gunn, 1989). However the NCC have only attempted to influence external anthropogenic activities such as mineral extraction and agricultural practices on land above or adjacent to cave SSSI. No attempt has been made to control the internal activities of recreational caving which cause the majority of damage to the caves' scientific interest. Recreational caving in Britain is represented by the National Caving Association (NCA). This is a federal organisation of 5 regional councils and 6 'specialist bodies' (e.g. the British Cave Research Association) which in turn represent member clubs and/or individuals. Nevertheless, since there is no compulsory membership scheme for individuals, neither NCA nor its constituent organisations can control the actions of individual cavers. Moreover, disciplinary procedures within the constituent organisations vary widely from no expulsion procedure to expulsion if 'found acting against the interests of speleology' (Potts, 1989). At regional level , only the Council of Northern Caving Clubs (CNCC) directly controls access (to some areas of the Northern Pennines). However, other controls on caver access exist either by cave management committees or by caving clubs acting primarily on the behalf of landowners. Therefore, mechanisms apparently exist whereby caving organisations could limit the damage caused to cave resources. Unfortunately, these mechanisms appear to have been little tested, and consequently, despite voluntary codes of practice, the attrition of cave resources continues unabated.

3. CONCLUSIONS

Britain's caves are of value as an amenity resource for tourists and cavers; they and their flora and fauna have considerable intrinsic scientific interest; and they have particular scientific value as 'museums' preserving both archaeological remains and sediments which contain valuableevidence on past environments at the earths surface. External threats to the caves come from quarrying and agriculture both of which have the capacity to totally destroy cave passage or prevent all access. However, when notification of the 48 proposed cave SSSIs is completed about 30 per cent of British caves and some 80 per cent of total passage length will receive the protection from these and other external Potentially Damaging Operations which is provided to SSSI under the Wildlife and Countryside Act (1981). The value of this protection remains to be tested but it should greatly reduce the danger of caves being lost. There remains the internal threat posed by the pressure of increasing caver numbers on a resource base which is increasing less rapidly. This is perhaps the most controversial issue in British caving at the present time with some authors advocating access restrictions while others believe that this is an infringement of individual freedom. A more practical middle ground may be a "hard-hitting programme of education, together with access control for the most vulnerable locations" advocated by Judson (1985, p.37).

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THE IMPACT OF AGRICULTURAL OPERATIONS ON BRITISH CAVES

HARDWICK, Paul - GUNN, John

ABSTRACT

British agriculture, in common with that of much of Europe, has undergone a radical transformation in the post-war period. The intensification of agricultural land use has led to a deterioration of both surface and ground water quality due to increased rates of nitrate fertiliser and pesticide applications together with increased rates of soil erosion within agricultural systems. Despite much research on ground water quality, little work has been carried out into the impacts of such practices on cave systems. The Wildlife and Access to the Countryside Act (1981) has led to greater controls on agricultural practices, notably in Sites of Special Scientific Interest (SSSI). A series of potentially damaging operations (PDOs) are set out for each SSSI, and landowners farming the SSSI are required by law to notify the Nature Conservancy Council (NCC), the government body responsible for nature conservation in Great Britain, of their intention to carry out any of these operations. The NCC may then object, in which case the farmer may be offered compensation. Fourty eight Cave SSSI have been designated for their geological and geomorphological interest. However, the impact of the PDOs and other operations on the caves' scientific interest has not been fully quantified and in 1987, the NCC commissioned research by the Limestone Research Group at Manchester Polytechnic, into the documented and potential impacts of a range of agricultural operations on cave SSSI.

L'agriculture britannique, en commun avec celle de la plupart d'Europe, a été radicalement transformée depuis l'après-guerre. L'usage du terrain a été intensifié, ce qui menait à une détérioration du qualité et de l'eau du surface et de l'eau souterraine, dû aux niveaux augmentés de L'engrais NO_3, à l'usage de pesticides et aux niveaux augmentés d'érosion de la terre dans des systemes agricoles. En dépit des recherches nombreuses sur la qualité de l'eau souterraine, peu de travail ont été fait sur l'impact de telles habitudes sur des systemes de grottes. En Grande Bretagne la loi de 1981 qui concerne l'accès au pays vis-à-vis ses animaux et oiseaux natifs a mené à une contrôle gouvernmentale plus grande sur les habitudes agricoles de la nation, notamment sur des endroits d'interêt scientifique spécial (des 'SSSI'). Une série d'opérations ayant le potentiel de faire des dommages (un 'PDO') a été redigée pour chaque SSSI et des propriétaires qui cultivent des SSSI doivent, sous la loi, notifier le Conseil pour la Conservation de la Nature (le NCC), la corporation gouvernmentale responsable pour la conservation de la nature en Grande Bretagne, s'ils proposent faire aucune de ces opérations. Le NCC a le droit de loger des objections, en quel cas le cultivateur a le droit de recevoir une idemnité. Quarante huit grottes nommes SSSI sont designés pour leur interêt géologique et géomorphique. D'ailleurs, l'impact des PDO sur l'interêt scientifique a été le sujet de beaucoup de discussions et en 1987 le NCC a commandé le 'Limestone Research Group' (groupe qui fait des recherches sur le calcaire) au Polytechnique de Manchester, Angleterre de faire des recherches sur les impacts documentes et poténtial d'un assortiment d'opérations agricoles sur des grottes designées SSSI.

1. THE LEGISLATIVE FRAMEWORK FOR CAVE CONSERVATION IN BRITAIN

Conservation is frequently seen as being in conflict with other 'more productive' uses of land and there is no question that the range and quality of Britain's natural ecological and physiographical resources has diminished during this century as a result of pressure from agriculture, forestry, water supply and mineral extraction, defence, recreation, housing and industrial development. Many of these activities are now subject to planning control but the only general controls on agriculture and forestry are those imposed on agricultural building and certain engineering works by the application of General Development Orders under the Town & Country Planning General Development Order 1977 for England and Wales, or the Town & Country Planning General Development (Scotland) Order 1981. However, additional controls on development apply within Britain's 10 National Parks, and to sites conserved for their wildlife or physiographical interest by the Nature Conservancy Council (NCC), the official body responsible for nature conservation in Britain. The highest level of protection is accorded to National Nature Reserves (NNR) within which any development is prevented. Sites of Special Scientific Interest (SSSI) are important areas where existing land use continues as a primary concern, but is subject to a degree of influence designed to safeguard the nature interest (Department of the Environment 1982; Nature Conservancy Council 1983).

In an attempt to control development and to facilitate conservation, the Wildlife and Access to the Countryside Act (1949) and the Countryside Act (1968) were passed. Unfortunately they did not provide adequate protection for SSSI in the face of the rapid intensification of agriculture. Moreover, since there was no requirement to register SSSI designation as a land charge, many landowners and developers purchasing land remained unaware of any SSSI interest, and consequently the scientific interest of many sites was inadvertently destroyed. The loss of important sites, together with an emerging public concern for the environment, led to the strengthening of legislation to resist further depletion, through the Wildlife and Countryside Act (1981). The Act has required the NCC to notify or renotify about 6000 SSSI, covering around 8% of Britain (Nature Conservancy Council, 1986). The NCC now has a statutory obligation to notify the landowner of the existence of a SSSI and then to issue a list of Potentially Damaging Operations (PDOs) which might affect the interest of the site . In addition, any SSSI boundaries must be notified to a prospective purchaser as a land registration requirement. The NCC influence development in SSSI by the legal requirement of the land manager to give four month's notice of intention to carry out any PDO. If the NCC agree, the operation may proceed. However, if the scientific interest of the site is threatened they may object, and either a management agreement will be negotiated and compensation paid, or the case will become the subject of a Public Inquiry under a Planning Inspector with the final decision resting with the Minister for the Environment.

Land underlain by cavernous limestones is generally subject to a number of land uses which may conflict with each other and which may also have adverse <u>external</u> impacts on the recreational and scientific value of the cave geoecosystems. In addition, recreational activities can result in <u>internal</u> impacts on the same geoecosystems. This paper is concerned with the external impacts of agriculture on British caves, since agriculture (including forestry) is the predominant use of land overlying or adjacent to British caves.

The geological and geomorphological importance of limestone caves was recognised by the designation of 48 Cave SSSI (Waltham, 1983), and over 32% of known caves and 80% of accessible cave passage is contained within them (Hardwick and Gunn 1989). The designation of Cave SSSI has created a range of unique problems for the management of their scientific interest. Firstly, in contrast to the majority of SSSI which are conserved for their surface features, the land overlying the cave system is designated yet may have no intrinsic wildlife or physiological value. Secondly, agricultural activities on non- limestone terrain, which form part of the cave's hydrological catchment will impact on cave systems via allogenic stream inputs. Thirdly, there is a lack of scientifically verifiable evidence for damage to caves caused by agricultural practices. Consequently, the NCC commissioned the authors to investigate the documented and potential impacts of agricultural operations on cave systems, and thus inform the management of land overlying and adjacent to cave SSSI.

Table 1. Recorded Agricultural and other Anthropogenic Impacts on British Cave Resources

Outcrop	Agricultural Impacts	Other Anthropogenic Impacts	Total Impacts
Northern Pennines	25	4	29
Derbyshire Peak District	4	4	8
Wales (North & South)	6	9	15
Mendip Hills	18	2	20
Devon		5	5
Scotland	1	1	2
	54	25	79

2. AGRICULTURAL OPERATIONS AND THEIR IMPACT ON BRITISH CAVES

The primary data on the caves of Great Britain are contained in a series of area guidebooks. These cover the Northern Pennines, the Derbyshire Peak District, Wales, Scotland, the Mendip Hills, and Devon . However, the majority of the guidebooks are aimed at the recreational user of caves rather than the cave scientist and therefore include caves formed in non-limestone lithologies (e.g. sandstones), and by a variety of geomorphological processes (e.g. mass- movement and by littoral processes). In addition, many anthropogenic sites such as surface 'digs' (sites dug by cavers in search of new caves) and karst features such as dolines which do not 'window' into cave passage, stream risings and stream sinks with no known or accessible cave, artificial caves, rock shelters, and 'hard rock' (e.g. limestone, sandstone) mines are included. This paper is concerned solely with limestone caves which are defined as accessible conduits developed by solutional and mechanical erosion processes. Natural cavities accessed via mineral workings fall within this definition and 47 of the 48 cave SSSI meet this criteria, the exception being Beachy Head Cave in Sussex which formed in Cretaceous Chalk. The inclusion of related features such as dolines (the term 'sinkhole' is ambiguous and should not be used) as caves is unjustified although these features may be significant as sources of rapid recharge to underlying cave systems.

Published site descriptions were searched for evidence of external anthropogenic impacts. An additional constraint was applied by excluding all caves which have been directly impacted upon by mineral extraction activities. The impact of mineral extraction (quarrying) is dichotomous, since whilst caves may have been damaged or totally removed, caves have also become accessible after quarrying has ceased. The relative impact of quarrying on caves is the subject of an ongoing investigation by the authors. Evidence of an external anthropogenic impact is explicit or implicit in the descriptions of seventy nine sites (2.9% of the British cave resource)(Table 1). It is possible to classify impacts as either agricultural (54 sites) or non- agricultural (25 sites) since many site descriptions include words that have an explicit agricultural meaning (e.g. 'rusting farm machinery' or 'farm tipping'). However, in several cases an agricultural impact has either been implied, for example by the term 'dumped animal carcasses', or assumed given the remoteness of a site from public highways or footpaths.

Table 2. Recorded Agricultural Impacts on British Cave Resources.

AREA	Number of caves	Impact type
Northern Pennines	2	Entrance Infilled
	5	Closed (water supply)
	7	Farm Tipping
	3	Carcass Disposal
	4	Scrap metal/Cars
	1	Oil Waste
	2	Land Drainage
	1	Farm Sewage
Derbyshire Peak District	4	Farm Tipping
Wales (North & South)	2	Entrance Infilled
	3	Farm Tipping
	1	used as Byre
Scotland	1	Farm Tipping
Mendip Hills	3	Entrance Infilled
	11	Farm Tipping
	4	Farm Sewage
Devon	0	

The agricultural impacts were grouped into 9 categories and the numbers of sites in each category for each of the seven main cavernous limestone outcrops are shown in Table 2. Similarly, non- agricultural impacts were grouped into 7 categories (Table 3).

The main agricultural and non-agricultural impact on impacted caves is the tipping of materials within cave entrances (83% and 84% respectively). Farmers tip materials into cave entrances for a variety of reasons, not least because they form a convenient hole in the ground. Similarly, several local authorities have located tips in disused quarries which contain cave entrances. A second major impact is the effective loss of access to cave entrances due to the use of the cave as a water supply . Several cave systems are impacted upon by a variety of pollutants including runoff from farmyards and dungsteads (farm sewage), oil waste from farms and active quarry operations, and chemicals which may be input from chemical waste tips, again often located in disused quarries.

The major problem in using guide book descriptions is their subjectivity, which creates a number of problems. Firstly, the main aim of the cave guidebooks is to provide a description of the cave site for recreational users. Only one cave guidebook (Barrington & Stanton, 1977) has explicitely considered the internal and external impacts of anthropogenic activities on caves; the other guidebooks only include evidence where the contributor was sufficiently impressed by the impact. Secondly, given the temporal distribution of guidebook publication (1975-1988) it is not possible in a desk study to determine whether impacts are of acute or chronic nature. For example Greenbridge Cave in West Wales was described as having a large but otherwise unremarkable entrance by Stratford (1982) (and in the later (1986) edition), but three years' earlier the entrance was described by Oldham (1979, p30) as: "a fine 5 foot high by 30 foot wide entrance, practically blocked with tipped rubbish, old car bodies etc" . Whether the cave entrance had been restored to its natural condition in the intervening 3 years, or an adequate description was omitted from the later guide for the sake of brevity is a matter for conjecture. Similarly, Kail Pot in the Northern Pennines is: " now one of the largest rubbish dumps in the 'Dales" (Thorp, 1985 p.86) yet this is not mentioned in the guidebook description (Brook et al., 1983). The status of this site has been confirmed during site visits for this study, yet in contrast, some agricultural impacts (eg. 'one-off' animal carcass dumping) are of transient nature, and recent site visits have failed to find any evidence of the impact.

Table 3. Recorded Anthropogenic Impacts on the British Cave Resource Excluding Agriculture and Mineral Extraction .

AREA	Number of caves	Impact type
Northern Pennines	4	Fly Tipping
Derbyshire Peak District	1	Road Construction
	1	'Landscaping'
	2	Fly Tipping
Wales (North & South)	6	Fly Tipping
	1	Sewerage
	2	Oil from quarrying
Scotland	1	Fly Tipping
Mendip Hills	2	Fly Tipping
Devon	2	Fly Tipping
	2	Official Tipping
	1	Chemical Dumping

3. CONCLUSION

This preliminary study using published data sources has suggested that anthropogenic impacts on British caves may affect a small percentage of known cave entrances. Anthropogenic activities which are of agricultural origin affect 68% of the 79 caves identified. However these 79 caves should be considered as the minimum number impacted upon since only the most obvious problems are likely to have been documented. This inherent subjectivity means that the real scale of external impacts on cave systems is impossible to determined without visiting each cave. Moreover, ongoing research by the authors suggests that there have been very few studies of the impact of external anthropogenic activities on cave geoecosystems either in Britain or overseas. Due to the dearth of scientific research it is difficult to determine the impact on the geological and geomorphological interest of caves of materials dumped in cave entrances or input as pollutants.. Indeed the major impacts of such operations are likely to affect cave ecosystems and the human ecology of caves, particularly access to caves and the health and safety of cave scientists.

The authors are currently modelling the impact of agricultural operations on cave geoecosystems using potential impacts based upon considerations of hydrogeochemical processes operating on both karstified limestones and other lithologies. In addition, the impact of agricultural operations on the quantity and quality of autogenic and allogenic recharge are under investigation using the catchment of the Castleton karst aquifer, Derbyshire, England.

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CAVES OF THE KOPRUCAY RIVER BASIN AND VICINITY, SOUTHERN TURKEY

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The Koprucay river basin is situated about 40km east of Antalya in the western Taurus Mountains of southern Turkey. Above the site of the proposed Beskonak dam the basin has an area of some $1950 km^2$ and the mean annual flow is about $85 m^3 s^{-1}$. Limestones outcrop widely in the basin, the two main units being a conglomeratic limestone of Miocene age with a maximum thickness of 700m and a slightly metamorphosed and highly contorted Cretaceous limestone sequence. The Karst Water Resources Research Centre of Hacettepe University is engaged in a study of the area's hydrogeology and as part of this study a team under the direction of the authors explored and surveyed 15 caves during the summer of 1987. The longest caves in the conglomerate are Kurukopru Magarasi (530m) and Honaz Deligi Magarasi (>650m), the latter being particularly interesting because of upwards stoping into overlying non-carbonate facies. The longest cave surveyed by the expedition was Zindan Magarasi (740m) but the spectacular resurgence cave Pinargozu Magarasi which lies close to the topographic watershed has over 5000m of passage and an elevation of 250m.

Le bassin fluviale de Koprucay se situe environs de 40 km à l'est d'Antalya aux montagnes occidentales de Taures au sud de la Turquie. Au-dessus du lieu proposé pour le barrage de Beskonak, le bassin a une superficie de $1950 km^2$ et l'écoulement annuelle moyen est à peu pres $85 m^3 s^{-1}$. On trouve le calcaire dans tout le bassin, le deux blocs principaux etant d'une part un calcaire conglomératique de l'âge Miocène et d'une epaisseur maximum de 700 m et d'autre part une serie de calcaire crétace fortement tordue et faiblement metamorphosée. Le Centre des Recherches sur des resources d'eaux karstique de l'Université d'Hacettepe est engagé dans une étude de l'hydrogéologie de cette region. Comme partie de cette étude, une équipe sous la direction des auteurs a exploré et fait des plans de 15 grottes pendant l'été de 1987. Les grottes les plus longues de ce conglomerat sont celle de Kurukopru Magarasi (530 m), et celle de Honaz Deligi Magarasi (>650 m), dont la dernière est particulièrement intéressante à cause des gradins qui montent le roc superposé et non-carbonaté. La grotte la plus longue qui etait explorée par l'expédition était celle de Zindan Magarasi (740 m) tandis que la grotte de Pinargozu Magarasi, une résurgence spectaculaire, qui se trouve pres de la ligne topographique de partage des eaux contient plus de 5000m de corridors et vante une élévation de 250m.

1. INTRODUCTION

About one third of Turkey is underlain by carbonate rocks and a substantial proportion of the countries hydro-electric potential is located in or adjacent to karstified limestones. The Taurus Mountains karst north east of Antalya is drained by three large rivers, the Manavgat, Koprucay and Aksu (Figure 1).

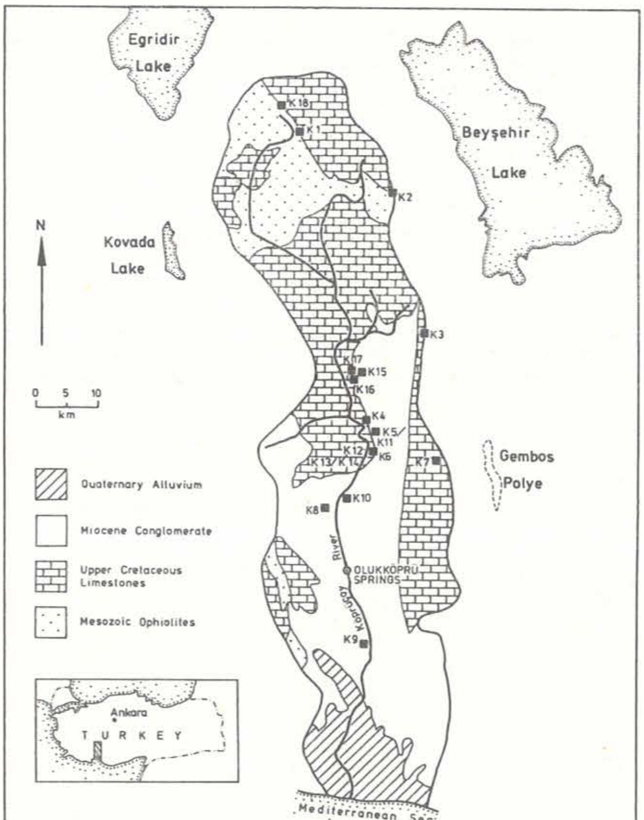

FIGURE 1 LOCATION OF STUDY AREA

The mean annual discharge of each river is inversely proportional to its surface catchment (Manavgat River 156.3 $m^3 s^{-1}$ from 928 km^2 ; Koprucay River 85.4 $m^3 s^{-1}$ from 1942 km^2; Aksu River 39.9 $m^3 s^{-1}$ from 6472 km^2). Since each basin has approximately the same net precipitation these differences must indicate a substantial amount of inter-basin underground water transfer. The hydro-electric potential of the Manavgat River has been realised by the construction of the 185 m high Oymapinar Dam downstream of Dumanli Spring and hydrogeological investigations have been underway since 1965 with a view to establishing a similar dam on the Koprucay River at Beskonak. The Karst Water Resources Research Centre of Hacettepe University is participating in these investigations and as part of their studies a team under the direction of the senior author explored and surveyed fifteen caves in the Koprucay River Basin (Table 1).

TABLE 1 CAVES OF THE KOPRUCAY KARST

	Name	Grid reference	Altitude (m)	Length (m)	Depth (m)
K1	Zindan Magarasi	3145 8691	1300	740	+21
K2	Pinargozu Magarasi	5095 7350	1570	Not surveyed	
K3	Dudenyayla Dudeni	5210 5070	1580	>60	>70
K4	Yesilbag Bati Dudeni	432 424	890	Not explored	
K5	Yesilbag Dudeni	445 416	915	95	62
K6	Degirmenozu Magarasi	4325 3960	500	60	13 (6, +7)
K7	Gurlevik Magarasi	5307 3592	1350	35	5
K8	Keteriz Cukuru (doline)	3711 2278	1750	Not explored	
K9	Kurukopru Magarasi	4090 0920	130	530	30
K10	Honaz Deligi Magarasi	3825 2760	520	670	+24
K11	Yesilbag Magarasi	4435 4155	910	150	15 (10, +5)
K12	Karain Magarasi	4188 3848	530	60	7
K13	Kayaarasi Magarasi	4192 3840	540	Not surveyed	
K14	Inkusagi Magarasi	4178 3814	490	10	
K15	Onbasidusen Magarasi	4208 4420	790	50	16
K16	Baridini Magarasi	4090 4439	700	35	
K17	Yemislioglu Magarasi	4087 4480	680	75	
K18	Sorgun Magarasi	3220 9060	1415	303	13

One of the caves (K1, Zindan Magarasi) has been previously described by Aygen (1984) but not (to the authors knowledge) surveyed. The remaining fourteen caves are not thought to have been visited previously except by local villagers. A deep shaft near Yesilbag village (K4, Table 1) was visited but not descended and a very large doline (K8, Table 1) which was said by villagers to contain caves was noted. The famous resurgence cave Pinargozu Magarasi (K2, c. 5300m long, +250m elevation) which lies within the Koprucay Basin was also briefly visited. Access to most of the caves is by rough tracks and route finding is difficult in the absence of detailed maps which are unfortunately still classified as secret.

2. GEOLOGY

The four main stratigraphic units in the Koprucay basin are : (1) the impermeable Mesozoic Ophiolitic Series, (2) a 1000 - 2000 m thick, homogenous Upper Cretaceous limestone sequence which contains some igneous intrusions, (3) some 2000 m of Miocene deposits subdivided into the impermeable shale/sandstone alternation of the Beskonak Formation and the Koprucay Conglomerate which is made up of limestone gravels and cobbles in a carbonate matrix and (4) Quaternary alluvial deposits (Figure 1). Both the Cretaceous limestones and the Koprucay Conglomerate are folded and faulted and have well developed joints which are a focus for underground water movement and cave development.

3. CAVES IN THE KOPRUCAY CONGLOMERATE

Seven caves were explored in the Koprucay Conglomerate, the longest being K9 and K10 (Figures 2 and 3, Table 1) both of which are resurgence caves. K9 (Kurukopru Magarasi) is associated with the only major spring downstream of the Olukkopru Springs (Figure 1). It was dry during our visit (July, 1987) but has a flow of 4-5 $m^3\ s^{-1}$ during the wet season. The cave is developed along a prominent NW - SE joint and consists of an entrance chamber in which there has been some breakdown followed by a steep slope down loose sediment to a high rift passage which terminates in an unstable boulder choke. A second passage leads back to the surface from half way down the slope. The sediments diminish in size upslope from pebbles to coarse sand and it is clear that water flows upslope out of the cave during the wet season. K10 (Honaz Deligi Magarasi) is also developed along a NW - SE joint but is essentially horizontal (Figure 3). A small stream flows through the cave and sinks just inside the entrance which probably functions as an overflow in times of flood. The cave is developed just below the junction between the Koprucay Conglomerate and the overlying Beskonak Formation and terminates in a breakdown chamber in which sandstones and shales have been exposed by upwards stoping. Yesilbag (K5) and Onbasidusen (K15) Dudeni are essentially vertical shafts with tight, immature passage leading of from their bases. Yesilbag Magarasi (K11), which is situated in a somewhat larger depression descends, less steeply but also ends in tight, immature passage. K5, K11 and K15 probably drain to Degirmenozu Spring (K6). The two remaining cave, K16 and K17 are short lengths of relict resurgence cave.

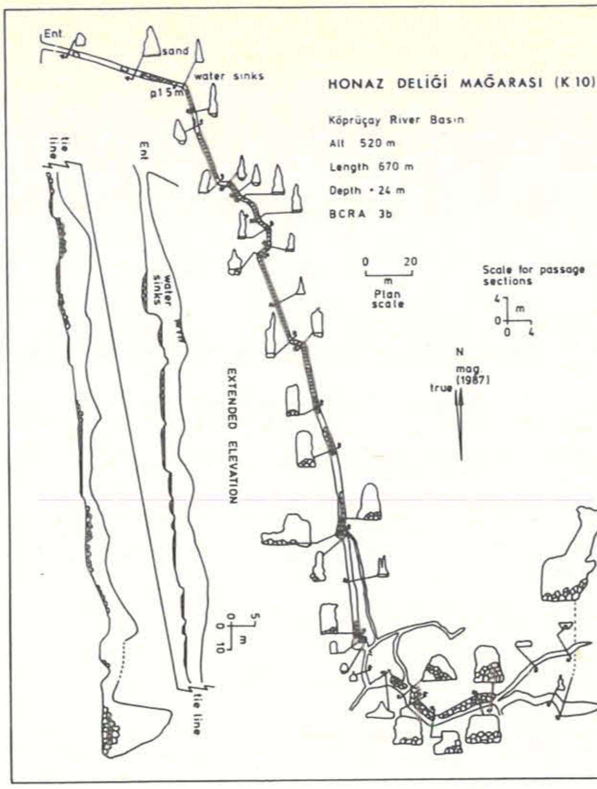

FIGURE 3 HONAZ DELIGI MAGARASI (K10)

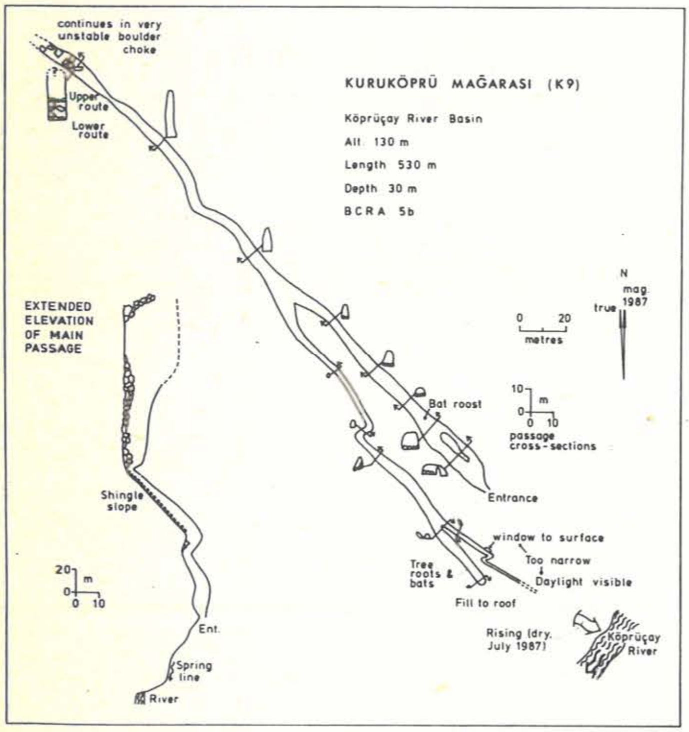

FIGURE 2 KURUKOPRU MAGARASI (K9)

4. CAVES IN THE CRETACEOUS LIMESTONE

Zindan Magarasi (K1) has a large entrance close to a road which has probably been a place of refuge for several thousand years. Aygen (1984, p.77) records "remnants of gates from the Byzantic ages, ornamented with embossed relief marbles" but these were not seen on our visit. The cave is essentially a single, joint controlled conduit which is initially up to 15m high and 3 m wide but grows progressively smaller into the hill and finally terminates in a low, wet bedding plane. The only other cave of any significant size which was explored was Sorgun Magarasi (K18, Figure 4), which has developed a few metres above the junction between the limestone and the underlying Triassic sandstones and shales. The entrance is a relict outlet point, the present outlet being phreatic. Upstream the passage is initially 2 - 4 m wide and up to 5 m high but like Zindan it gradually diminishes in size and eventually becomes too tight for further exploration. Dudenyayla Dudeni (K3, Figure 5) is an impressive fault/joint guided shaft system at the end of a dry valley which was incompletely

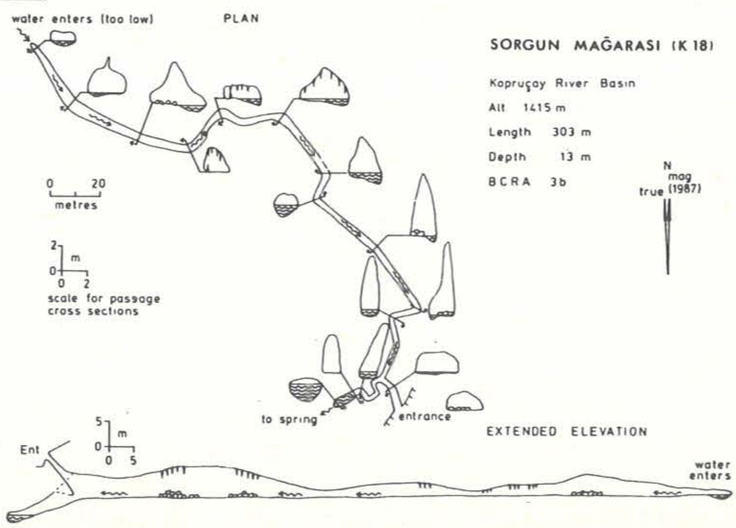

FIGURE 4 SORGUN MAGARASI (K18)

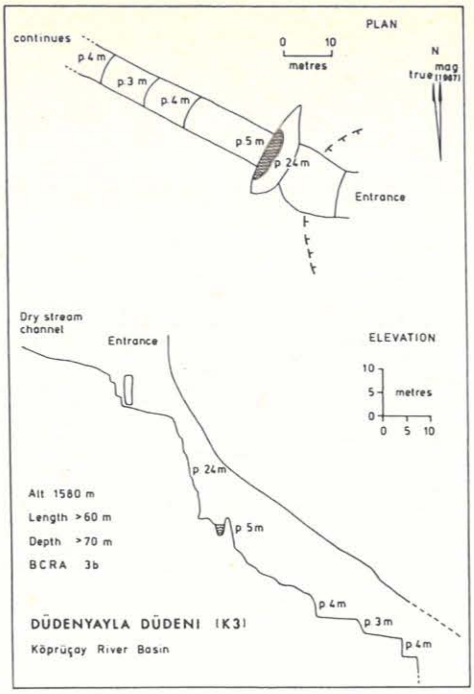

FIGURE 5 DUDENYAYLA DUDENI (K3)

explored owing to lack of rope. It may drain to Cukurca which would give a depth potential of almost 1000 m. Degirmenozu Magarasi (K6) is a large resurgence cave which is flooded after only 60 m and Gurlevik Magarasi (K7) is an immature resurgence cave which like Sorgun Magarasi has developed above the limestone/sandstone contact. K12, K13 and K14 are relict resurgence caves.

4. SUMMARY

Limestones crop out over a substantial area in the Koprucay basin and although the caves described in this report are relatively small there is considerable potential for both long and deep systems as shown by Pinargozu. At least two sites, K3 and K4 await further exploration and there is also scope for further work in the north western part of the basin.

REFFRENCE

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CAVES ON THE TONGAN ISLANDS OF TONGATAPU AND 'EUA

GUNN, John - LOWE, David

ABSTRACT

During the summer of 1986 a team of British speleologists visited the islands of Tongatapu and 'Eua in the Kingdom of Tonga where little previous cave exploration had taken place. The island of Tongatapu is entirely composed of Plio-Pleistocene limestones with a maximum relief of 65 m in the south-east where all the known caves are located. The caves were probably formed close to the freshwater - saltwater interface and have been exposed by subsequent uplift. They are generally short (10 - 400 m) and horizontal with relatively few active speleothems but with considerable accumulations of guano. The adjacent island of 'Eua is smaller but has older rocks, a much greater relief (max. 312 m) and, in consequence, substantially more caves. As a result it was the focus for a second expedition in 1987. The 'Euan caves include primarily vertical systems in limestones of Eocene to Oligocene age and longer, more horizontal systems which had their origins in Pliocene limestones and subsequently cut down into Miocene arenaceous rocks.

Pendant l'été de 1986 une équipe de spéléologues britanniques ont fait la visite aux îles de Tongatapu et 'Eua au royaume de Tonga, endroit où préalablement peu d'exploration de grottes s'était passé. L'île de Tongatapu se compose entièrement de calcaires plio-pleistocènes d'un relief maximum de 65 m au partie sud-est de l'île où se trouve des grottes connues. Il est probable que la formation des grottes s'était passé près de la jonction entre l'eau douce et l'eau de mer et que ces grottes auraient été exposées conséquent à un soulèvement subséquent. D'habitude elles se montrent courtes (10 - 400 m) et horizontales, sans grand nombre de spéléothèmes actifs, mais avec des accumulations considérables de guano. 'Eua, l'île adjacente est plus petite, formée des roches plus vieilles, d'un relief beaucoup plus accentué (312 m maximum) et, par conséquent vante beaucoup plus de grottes. À cause de cela elle s'est trouvée l'objet d'une seconde expédition en 1987. Les grottes d'Eua comprennent d'une part des systèmes qui sont principalement verticaux dans des calcaires datant de l'âge Éocène à l'âge Oligocène et d'autre part des systèmes plus horizontaux qui dérivent des calcaires Pliocènes qui plus tard ont creusé des roches Miocènes arénaces.

1. INTRODUCTION

The Kingdom of Tonga (also known as the Friendly Islands) is located some 3200 km NE of Sydney and 1760 km NNE of Auckland (Fig. 1). It consists of at least 170 islands varying in size from small sand cays up to 700 km². Only 36 of them are inhabited (total population 96,000) and only a few have limestones of sufficient age and elevation to give a reasonable expectation of cave development. Geologically, there are three main island chains : the Nomuka Group and 'Eua Island where relatively ancient volcanic basement rocks are overlain by post-Eocene deposits, mainly limestones which are still being formed; a belt of younger islands (including Vava'u and Tongatapu) which lie to the west where massive lagoonal and reefal limestones have been deposited on a submerged volcanic basement since Pliocene times; and a chain of young active or potentially active volcanic islands (the Tofua Arc) which lie still farther to the west and are surrounded by fringing reefs which are forming concurrently with volcanic deposition.

Caves have been known to exist on islands in the Tongatapu Group since the time of Polynesian colonisation but serious cave exploration did not commence until 1981 under the direction of Cunningham and Anscombe (1985). Their work was built upon by a British Expedition ("Tonga '86"; Lowe & Gunn, 1987) which explored a small number of caves on Tongatapu and a larger number on 'Eua. Such was the success of this expedition that a second ("Tonga '87"; Lowe, 1989) was mounted to continue exploration on 'Eua. The present paper briefly outlines the nature of the discoveries, full details and surveys being published in the combined expedition reports (Lowe, 1989).

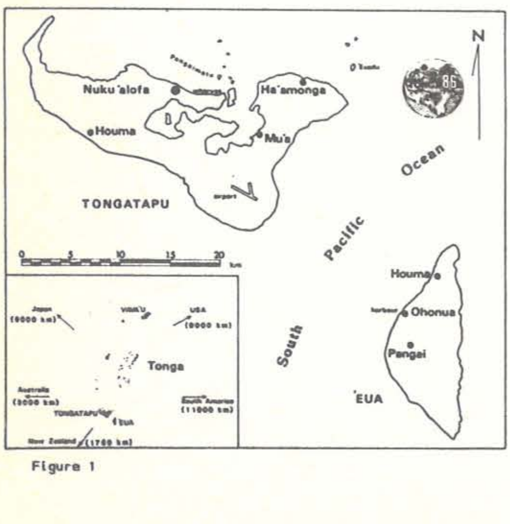


Figure 1

2. TONGATAPU

Five caves were explored by Cunningham and Hood (unpublished report) and a further three during the Tonga '86 expedition these being Pila's Cave, Fatumu Cave, and Oholei Cave (Table 1, Fig 2). All the caves on

TABLE 1 CAVES OF TONGATAPU

Name	Grid reference	Altitude (m)	Length (m)	Depth (m)
Ana Hulu	970 356	2	420	+9
Ana Nakolo	954 472	35	180	10
Fatumu Cave	962 526	25	132	17
Fua'amotu	937 464	3	>400	+6
Havaluliku Incline	971 537	17	52	16
Matt Dean's Cave	828 546	12	50	6
Oholei Cave	967 503	25	300	20
Pila's Cave	835 545	15	64	9

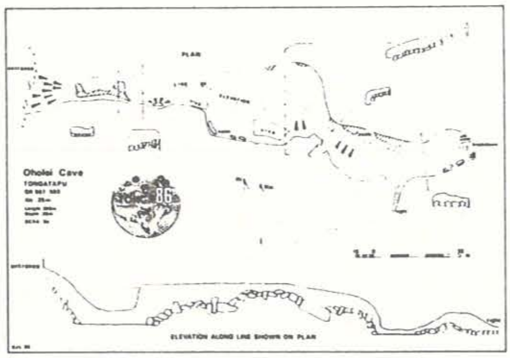


Figure 2

Tongatapu are sub-horizontal and each consists essentially of a single large passage (up to 50 m wide in Oholei) terminating in a boulder choke and with considerable breakdown on the floor. They are the homes of large numbers of cave swifts and probably of some bats although none were positively identified. It is suggested that these caves formed close to the freshwater - saltwater interface under conditions analogous to those which currently prevail on fringing reefs around islands in the Tofua Arc.

3. 'EUA

The island of 'Eua is the second largest in the Tongatapu Group being almost 20 km long (north-south) with a maximum width of 7.5 km near the middle. By Tongan standards it has high relief, reaching 312 m above sea level and it is also geologically more complex than other Tongan islands. Speleological investigations in a 6 km² area east of Petani and Kolomaile settlements near the centre of the island have identified four distinct types of cave: doline drains, stream-sink caves in Eocene Limestone, stream-sink caves in Pliocene limestone, and recent caves. In addition a solitary cave in the side of a spectacular sea cliff was entered after an interesting abseil but terminated after only 10 m.

TABLE 2 CAVES OF 'EUA

Name	Type	Grid reference	Altitude (m)	Length (m)	Depth (m)
Ana Ahu	2	1484 3276	191	170	95
Ana Kaka	1	1581 3238	207	324	135
Ana Loloto	1	1630 3160	220	537	137
Ana Maui	1	1599 3169	188	1024	111
Ana Moa	1	1618 3230	222	314	113
Ana Moko	1	1562 3250	227	189	103
Ana Mu Uli'uli	1	1599 3252	211	83	52
Ana Niu	1	1555 3248	224	251	109
Ana Paka	1	1588 3503	265	142	50
Ana Peka Beka -	3	1940 3302	125	390	+38
Martins Cave system		1425 3299	163		
Ana Salato	1	1540 3272	220	62	>38
Ana Sikota	1	1629 3117	238	137	102
Ana Tapatolu	1	1568 3200	211	187	118
Ana Toputapu	1	1631 3204	213	280	125
Captured Fish Cave	3	1426 3335	165	40	5
Collapse Cave -	3	1431 3341	165	353	43
Shower Cave system		1416 3340	125		
Danger Cave	1	1578 3369	220	90	35
Dry Cave	1	1599 3482	270	150	61
First Cave	1	1586 3435	260	350	65
Fish Cave	3	1429 3332	170	510	45
Fish Head Cave	3	143 333	175	87	8
Fish Tail Cave	3	1388 3306	125	30	1
Parkers Hill Cave	1	159 358	300	130	55
Rift Cave	1	1640 3266	220	180	120
Second Cave	1	1587 3403	260	130	55
Third Cave	1	1585 3418	260	300	75
Tokua Ana Ahu	2	1482 3271	192	110	72

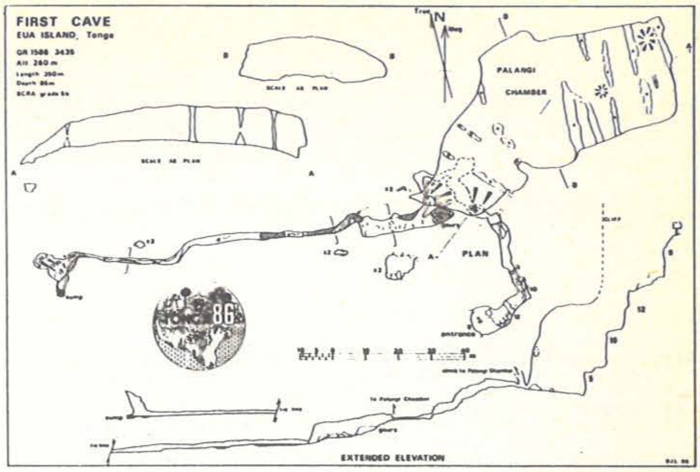
3.1 Doline drains

These are primarily vertical caves up to 140 m deep entered at the base of solution dolines in the Eocene Limestone which crops out between about 200 m and 300 m above sea level in the area studied. The dolines contain well developed centripetal drainage channels which converge on the cave entrances and although no surface flow was observed during the visit it is clear that the caves function as doline drains. Nineteen caves were explored (Table 2), each consisting of a series of dry 5-25 m pitches with clear evidence of structural guidance. Most become too tight with depth but in some small streams emerge from tight sump-pools and flow through sub-horizontal passages into restricted sumps. These constricted, immature passages are either incised into or a short distance above the volcanic basement and have probably been formed relatively recently. However, in some of the caves there is evidence for larger abandoned passages at higher level which appear to bear no relationship to the present cave. For example, Palangi Chamber in First Cave which was entered by an upward climb from the 1 - 2 m diameter main passage is 100m long, 40m wide and up to 20m high (Fig. 3). It contains numerous large and fine, though largely dead, speleothems and a prolific population of cave swifts and bats. Similarly, Ana Maui contains a long section of phreatic tube with a diameter of over 5 m which is largely filled with clastic sediment overlain by a profusion of speleothems. It is suggested that these passages are remnants from an earlier (pre-Miocene) phase of speleogenesis and that their formation took place close to the freshwater - saltwater interface under conditions analogous to those which prevailed on south-east Tongatapu prior to recent uplift and which prevail on islands in the Tofua Arc at present. More recent passage development has taken place by vadose incision during or following uplift and there is clear evidence of joint/fault guidance.

3.2 Stream-sink caves in Eocene Limestone

Two caves were entered via vertical shafts which have developed where surface streams flowing on late Middle Miocene / early Pliocene calcareous volcanic arenite have cut down to the underlying Eocene Limestone . One (Ana Ahu) is active and the other (Tokua Ana Ahu) abandoned. Both are essentially vertical vadose slots with clear joint/fault guidance.

Figure 3



3.3 Stream-sink caves in Pliocene Limestone

These are predominantly horizontal caves which originated under phreatic conditions at the base of the Pliocene Limestone and which have subsequently cut canyons down into the underlying calcareous volcanic arenite by a combination of mechanical and solutional erosion. Six cave systems 50 - 500 m in length and up to 45m deep were explored. All are multiple entrance linear streamways which form part of integrated underground drainage networks feeding to three springs. Water from these springs forms the local domestic water supply, being partially captured by a complex arrangement of pipes which extend some distance into one of the caves (Ana Peca Beca).

3.4 Recent caves

Several short, relatively recent caves were noted where streams which rise at the edge of the arenite outcrop sink into altitudinally lower limestones of uncertain age.

4. CONCLUSIONS

The Tongan islands in general and 'Eua in particular are speleologically extremely rich and it is certain that many more caves await discovery. There are considerable opportunities for the study of speleogenesis in that the three island chains are at different stages in their development enabling analogies to be made between presently forming, recently formed and ancient passages.

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RADON DAUGHTER CONCENTRATIONS IN BRITISH CAVES: IMPLICATIONS FOR CAVERS AND TOURIST CAVE OPERATORS

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Since June 1987 we have measured natural radiation levels on a sporadic basis in several British caves using a "Radon Sniffer" (Working Level Meter) and the Kusnetz Method. Radon daughter concentrations vary spatially (both across the country and within individual cave systems) and temporally (both seasonally and diurnally). The highest concentrations (>24 WL) occur in the Castleton area of the Peak District where regular cavers may receive a radiation dose well in excess of that received by classified workers in the nuclear industry. Concentrations in tourist caves are lower and the dose received by a member of the public on a guided tour would be negligible. However, guides may receive a significant dose and, as a result, several operators are considering changing to self-guided tours which may in turn produce a greater incidence of speleothem damage.

Depuis Juin 1987 on a mesuré le niveau de radiation naturelle. On l'a mesuré d'une base sporadique dans plusieurs grottes britanniques par moyen d'un "Radon Sniffer" (compteur du niveau de travail) et la méthode Kuznetz. Des concentrations filiales de radon varient spatialement (et à travers le pays et en dedans des systèmes de grottes individuelles). Les concentrations les plus élevées (> 80 000 Bq m⁻³) se trouvent dans la région du Peak District près du village de Castleton ou des hommes qui font regulièrement de la spéléologie peuvent recevoir une dose de la radiation bien en excès de celle dont recevoir les travailleurs classifiés dans l'industrie nucléaire. Des concentrations dans des grottes touristiques, sont plus bas et la dose reçu par un membre du public faisant un tour guide serait négligeable. Cependant, il est possible que les guides de ces tours peuvent recevoir une dose significative, et à la suite de cela, plusieurs opérateurs de grottes sont en train de considérer la possibilité des systèmes auto-guidés, malgré les dommages possibles aux speleothèmes aux mains des visiteurs.

1. INTRODUCTION

Radon is a gas formed from the decay of radium which itself arises from natural uranium, an element which is widely distributed in the earths crust, though generally in low concentrations. The radon gas decays to give short lived isotopes of lead, polonium and bismuth ("radon daughters") which emit alpha-particles. The radon daughters tend to attach themselves to dust or water particles and can thus be inhaled. The alpha-particles from the radon daughters which lodge in the lungs irritate the lungs and can initiate lung cancer.

Radon daughter concentrations may be determined in several ways, the most practical for caves being (1) the "Kusnetz" method which is relatively quick but requires access to a scintillation counter to process the samples within 90 minutes of collection, (2) a battery operated 'Radon Sniffer' which will give an initial estimate in 15-20 minutes but takes 30-60 minutes to produce a reliable reading or (3) an Instant Working Level Meter which gives results within a few minutes using the "Rolle" method but is very expensive.

Unfortunately there are several units of measurement for radon daughter concentrations, the commonest being the "working level" (WL). In assessing the risk to health it is necessary to compute dose which is concentration multiplied by exposure-time. Dose may be expressed as millisieverts per unit time (e.g. $mSv\ y^{-1}$) or as working level hours where 1 WLH equals one hours exposure to 1 WL. Dosemeters which measure cumulative exposure to radon gas and which may be left underground or worn on an individual are available but there is some controversy over the interpretation of dosemeter results owing to problems in determining the equilibrium concentration.

In Britain, Government legislation (The Ionising Radiations Regulations 1985 and the Approved Code of Practice Part 3 "Exposure to Radon", 1988) control the annual dose which may be received by an employee at a place of work. Normally a worker should receive no more than 15 $mSv\ y^{-1}$ (about 204 WLH) but a classified radiation worker may receive up to 50 $mSv\ y^{-1}$ (about 680 WLH) although such a high dose is considered undesirable. The National Radiation Protection Board (NRPB) recommend that a member of the public should not receive more than 0.5 $mSv\ y^{-1}$ (about 6.8 WLH) above the average natural background. However, at least 20,000 people in Cornwall and Devon receive over 40 times this amount from radon in their homes.

The actual health risks which result from exposure to radon daughters are not clearly defined, particularly with respect to short term exposure to relatively high doses as could happen in some caves/mines. However, recent figures (BEIR IV, 1988) suggest that exposure to about 204 WLH per year for life doubles ones risk of dying from lung cancer whereas lifetime smoking increases the risk of dying from lung cancer tenfold. It is very important to note that exposure to radon and cigarette smoke has a multiplicative effect which in simplistic terms might be expressed as a 2 x 10 = 20 rather than a 2 + 10 = 12 risk. It has also been suggested that exposure to radon may (1) increase the risk of developing leukaemia and (2) be linked to several chest complaints.

2. RESULTS

Since June 1987 we have been collecting data on radon daughter concentrations somewhat sporadically from commercial show caves and from wild caves, principally in the Derbyshire Peak District. A Radon Sniffer has been used to obtain most of the wild cave measurements and the Kusnetz method in tourist caves. Wherever possible observations of internal and external air pressure and temperature were recorded whilst the "Sniffer" was in operation. In addition, estimations of the direction and velocity of air currents were obtained (Middleton, 1988).

2.1 Spatial variations

To date there have been insufficient measurements to draw any firm conclusions. However, it is clear that radon daughter concentrations vary spatially at three scales : within cave, from cave to cave in the same area, and from area to area.

2.11 Within cave variation

Most caves exhibit within cave variations and in some cases these are very large. For example, on 4 November 1987 the lowest reading in Peak Cavern was 0.17 WL and the highest, at a site less than 100 m away, was 12.6 WL. Similarly, in Giants Hole on 2 July 1988 concentrations ranged from 5.5 to 24.3 WL. In Pooles Cavern the absolute values are lower but maximum concentrations on any one day are generally 3 - 6 times the minimum. For example, on 23 September 1987 the range was 0.18 - 0.98 WL and on 14 December 1988, 0.05 - 0.29.

2.12 Between cave variation

The mean radon daughter concentrations for seven caves in the Derbyshire Peak District exhibit a considerable range (Table 1). The highest readings to date come from Giants Hole over the period 20 June to 3 July 1988. Concentrations at individual sites ranged from 2.1 to 24.3 WL and the daily mean for the cave ranged from 4.5 to 17 WL. One hour in the cave was sufficient to exceed the recommended maximum annual dose of radiation for a member of the public and during the ten caving trips which were made to obtain these figures the observer received almost 500 WLH of exposure, well in excess of the annual dose received by the vast majority of workers in the nuclear industry and over 70 per cent of the maximum permitted annual dose for a classified radiation worker. Concentrations were still high on 14 October 1988 but had dropped dramatically by 17 December and were equally low on 15 January 1989 (Figure 1).

The entrance to P8 (Jackpot) cave lies approximately 1400 m west of Giants Hole and both systems are morphologically similar. However, on the basis of very limited sampling, it would seem that radon daughter concentrations in P8 are very much lower than those encountered in Giants Hole. The Peak - Speedwell system, which receives drainage from Giants Hole, P8 and a number of other stream - sinks (Gunn, 1985), also has lower concentrations. Similar low readings have been obtained from Bagshaw Cavern and Carlswark

Cavern (Table 1). Nevertheless, even in these caves the maximum desirable dose of 204 WLH y^{-1} could be achieved in about 100 hours of caving.

TABLE 1 RADON DAUGHTER CONCENTRATIONS

1. Statutory limits for places of work and dwellings

HSE limit for "supervised area"	0.03 WL
Govt. action level for houses	0.05 WL
HSE limit for a "controlled area"¹	0.10 WL

2. Measurements in Peak District caves

SITE		READINGS	MEAN WL	RANGE WL
Giants Hole²	(Castleton)	34	0.28	0.00 - 1.63
Pooles Cavern	(Buxton)	144	0.30	0.00 - 0.98
P8 Cave	(Castleton)	8	2.15	0.17 - 2.96
Carlswark Cavern	(Eyam)	8	2.15	0.04 - 5.02
Bagshaw Cavern	(Bradwell)	6	2.17	0.68 - 3.23
Peak Cavern	(Castleton)	86	2.52	0.00 - 12.60
Oxlow Cavern	(Castleton)	16	3.63	0.18 - 16.40
Giants Hole³	(Castleton)	70	9.70	2.10 - 24.30

#1 A controlled area may only be entered by classified radiation workers or by unclassified workers as part of a written scheme of work under the guidance of a radiation protection adviser.

#2 Measurements made in winter (December - January)

#3 Measurements made during summer & autumn (May - October)

2.13 Between area variation

The results of our very limited sampling of caves beyond the Peak District indicate that in the Penwyllt area of South Wales concentrations range from negligible (less than 0.01) to 3 WL; in the Yorkshire Dales from negligible to 1.5 WL and in Devon are generally less than 0.5 WL.

2.2 Temporal variations

Sufficient measurements have been made in Giants Hole, Peak Cavern and Pooles Cavern to demonstrate a clear seasonal trend with higher values in summer than in winter . The seasonal trend in Giant's Hole is particularly pronounced (Figure 1). More detailed measurements in Giants Hole have also shown diurnal variations (Figure 2).

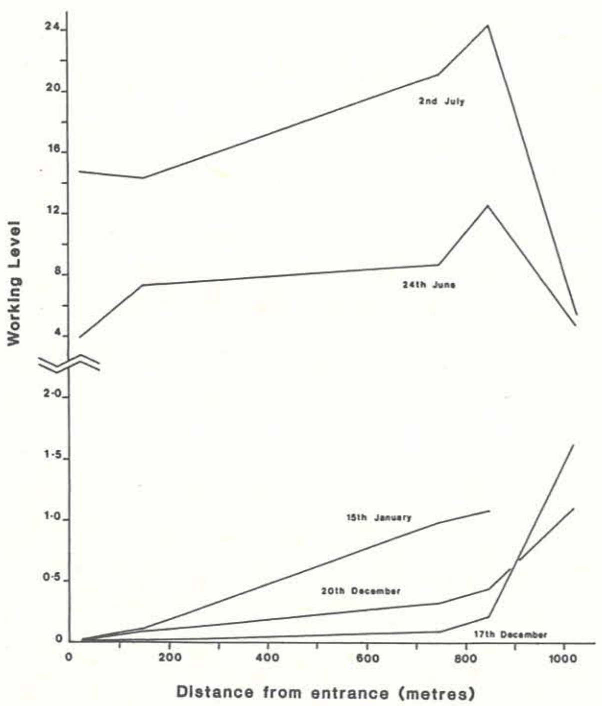

FIGURE 1. Radon daughter concentrations at sites in Giants Hole

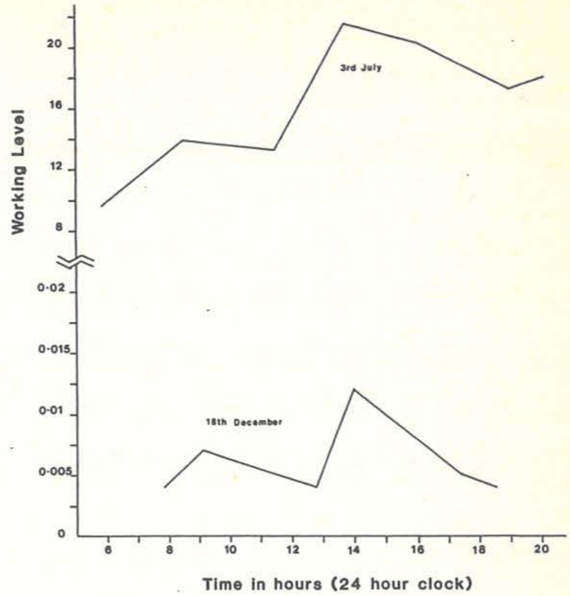

FIGURE 2. Temporal variations in radon daughter concentrations at site G3 Giants Hole

3. IMPLICATIONS

On the basis of our limited results we would suggest that active recreational cavers in the Peak District probably receive a greater radiation dose than that received at work by the majority of British coal, fluorspar or tin miners or by workers in the nuclear industry. Current legislation does not apply to recreational caving and we would suggest that provided the individuals are aware that they are placing themselves at risk then nothing more can or should be done. Further measurements are necessary to establish which caves have the highest concentrations and at which particular time of day or season so that cavers may choose to plan their trips accordingly. No element of compulsion is necessary as the presence of radon would be accepted as one of the risks of caving. However, the risk is long term and not readily observable.

The current legislation does cover cavers who are employed as instructors at Outdoor Pursuits Centres. As a result many Outdoor Centres have temporarily suspended caving activities in the Peak District until further data become available on the magnitude of the problem. Although this is to the detriment of the sport of caving it could have positive impacts in terms of cave conservation. On the other hand, it would seem likely that those caves and caving areas which are identified as having low radon daughter concentrations will receive greater traffic in the future than those with high concentrations and this will consequently lead to increased pressure. The implications of this for cave conservation will need to be considered as more information becomes available.

Members of the public visiting show caves do not spend sufficient time underground to receive anything approaching their permitted dose but, in some caves, guides may be exposed to an unacceptably high dose. As ventilation is generally not a practicable solution, the working hours of certain guides will need to be reduced. In some show caves the management is considering the possibility of self-guided tours. Such potential developments pose other implications, particularly with respect to general visitor safety and cave conservation and these have yet to be fully explored.

4. CONCLUSIONS

An initial survey of radon daughter concentrations in some British caves has shown:

(1) that there are wide spatial variations at all scales (within cave; cave to cave; area to area).

(2) there are substantial diurnal and seasonal variations.

(3) some caves, principally those in the Castleton area of the Derbyshire Peak District, have very high concentrations for at least part of the year.

The first two observations are substantially in accord with overseas experience (Yarborough et al 1976, Ahlstrand and Fry 1976, Ahlstrand 1980) and reflect the fact that radon levels vary with proximity to source (uranium), ventilation, atmospheric pressure and, less clearly, water levels. However, our initial literature review suggests that the radon daughter concentrations in some of the Castleton caves are substantially higher than anywhere else in the world although greater concentrations have been recorded in mines and natural cavities intersected by mine workings. Potential sources of radon in the Castleton caves include: (1) uranium rich shales in close proximity to the limestone (e.g. the basal Namurian shales which are stratigraphically above the Carboniferous Limestone in the Peak District); (2) vein minerals intruded into the limestones (e.g. lead ores) which usually contain uranium; (3) volcanic horizons within the limestones as these usually contain uranium; and (4) collophane, a uraniferous phosphatic deposit which occurs in some Peak District and Yorkshire limestones. As radon is soluble in water it may be transported by solution into caves and then released.

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STORM WATER MANAGEMENT IN KARST AREAS

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Stormwater management is an increasingly important problem as areas underlain by carbonate rocks become more urbanized and more populated. Sinkholes and wide, shallow swale areas when subjected to increased runoff, are prone to develop piping-failure (suffosional) sinkholes. Suffosional sinkholes occur naturally but are enhanced by runoff modifications that accompany urbanization. Suffosional sinkholes in the karst valleys of central Pennsylvania are typically 1.5 to 2.5 meters in diameter depending on soil thickness and soil type. The vertical transport of soil to form the void space and soil arch that are the precursors to sinkhole collapse is through solutionally widened fractures and cross-joints and less often through large vertical openings in the predominantly dolomite bedrock. All aspects of suffosional sinkhole development are shallow processes: transport, piping, void and arch formation, and subsequent collapse take place usually less than 10 meters below the land surface. Factors exacerbating sinkhole development include pavement, street, and roof runoff, as well as seepage pressure from stormwater management ponds. Such seemingly minor activities as replacing high grass and brush with mowed grass is observed to accelerate sinkhole development. De-watering of aquifers by pumping or during periods of drought has also caused sinkholes to form although this is less of a factor than storm water runoff in most regions of the Appalachians.

ZÁPORVÍZ ELVEZETÉSE KARSZTOS TERÜLETEKEN

A záporvíz-elvezetés egyre fontosabb probléma,ahogy a karbonát-kőzetek feletti területek benépesülnek és városiasodnak.Süllyedékes és széles,lapos,vizenyős területeken valószínű a vízelvezetés elégtelensége /telítődés/ és telítődési süllyedések kialakulása.Telítődési süllyedések előfordulnak a természetben is,de a lefolyás városiasodást követő módosulása megnöveli keletkezésük esélyét.Közép-Pennsylvaniában a telítődési süllyedések átmérője a talaj tipusától és vastagságától függően 1,5-2,5 m.A függőleges talajszállítás, mely kialakítja az üreget és a talaj-áthidalást,melyek a berogyás előjátékai,oldás által kiszélesedett hasadékokon át történik inkább mint nagy,függőleges nyílásokon át a főleg dolomitos kőzetben.A telítődési süllyedések keletkezési folyamatai sekély mélységűek.Vízszállítás,befolyás,üreg és talajáthidalás képződése és az ezekből eredő berogyás a felszín alatti 10 méteren belül történik.A süllyedések képződését elősegítő faktorok közé tartozik a burkolati,utcai, tető-lefolyás és a zápor-medencékből elszivárgó víz.Olyan látszólagosan apró tevékenység,mely a magas füvet nyírt pázsittá változtatja,felgyorsíthatja a süllyedések kialakulását.Víztartó rétegek kiürülése szivattyúzás által,vagy aszályos időszakban természetes úton szintén okoz süllyedéseket, de az Apalache-hegységben ez kisebb tényező,mint a záporvíz lefolyása.

1. INTRODUCTION

Stormwater management is a process to evaluate both the short and the long-term impacts of accelerated surface water runoff caused by land development or disturbances and to control the duration, volume, and velocity of stormwater runoff. The engineering device of choice in many suburban areas is the detention basin, a small pond designed to catch excess stormwater runoff and then reduce the outflow peak rate to the level of pre-development by flattening the hydrograph as shown in Figure 1. In karst areas, detention basins become, in effect, artificial dolines; likewise the natural dolines (sinkholes) also act as stormwater detention basins. Together, these constitute a new aspect of the environmental engineering of karst terrains. There is nothing new in these observations, of course. What is new is the level of regulation and the degree of expected engineering control. The nature of stormwater management both from an engineering and regulatory point of view, as it pertains to karst terrains, is the subject of the present paper.

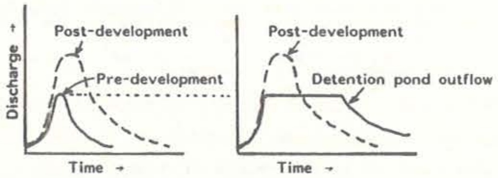

Fig. 1. Schematic diagram comparing a typical hydrograph before development with a hydrograph after development with no detention (left sketch). The right sketch shows the post-development excess outflow being monitored by a detention pond.

A major portion of all damages caused by devastating floods in non-carbonate areas are attributable to construction of buildings in floodplains subject to the natural flooding of streams. In carbonate areas the closed depressions fill with water either (1) because surface runoff exceeds the rate of infiltration or the capacity of the drain or (2) because the regional water table rises - thus the drain reverses and groundwater backs up onto the surface. Dolines flooded by stormwater runoff usually drain quickly; dolines flooded by raising the regional water table often remain flooded for long periods of time. Often when the dolines contain water for extended periods of time, the natural drainageways open to form additional sinks within the dolines.

2. STORM WATER MANAGEMENT

2.1 Stormwater Runoff

Urbanization many times results in a three-fold increase in discharge volume of storm water runoff as shown in Figure 1a. Additional stormwater runoff is created by activities such as land development, land disturbance and alteration, construction of impervious surfaces, new structures and additions to existing structures, changes or alterations to watercourses or drainageways, diversion or piping of natural or man-made stream channels, and installation of storm water systems or appurtenances.

Urban and suburban areas are generally under the management of planning commissions and town boards. These and other government agencies attempt to control stormwater problems through a regulatory process. The purpose of the stormwater management ordinances are:

(1) to control accelerated runoff and erosion and sedimentation problems at their source by regulating activities which cause such problems, to utilize and preserve desirable existing natural drainage systems, to encourage recharge of groundwaters, to prevent deterioration of groundwater quality, to maintain existing stream flow watercourses, quantity, and quality, and to preserve and restore the flood carrying capacity of streams;
(2) to provide for the design, installation, and proper maintenance of all permanent storm water management structures;
(3) to assure the peak rate of storm water runoff is not greater after development than prior to development activities.

The engineering approach to storm water management involves:

(1) the design of storm sewers, detention ponds, and related structures, such as weirs, spillways, culverts, and end walls with various sized orifice openings.
(2) the design of bridges or culverts within the flood plain of a river or stream.

2.2 Typical Codes, Ordinances, and Regulations

Each state within United States has a different amount of authority for enforcing storm water runoff regulations. Partly this is due to the major differences between water laws in the eastern vs. western states. The discussion that follows deals mainly with codes and ordinances applicable to Pennsylvania with some references to southcentral Kentucky where extensive stormwater investigations have been made by Crawford and his group (Crawford, 1984).

Both the state government and the Department of Environmental Resources in Pennsylvania have transferred the responsibility fo. enforcing the laws with respect to storm water management to the county and municipality governments. The county and municipality governments in Pennsylvania were given authority under a grant of power by the General Assembly of Pennsylvania via the "Storm Water Management Act" of October 4, 1978. A number of communities have tested a broad spectrum of legal, administrative, and technical approaches to the problem of controlling stormwater runoff from land development.

Most municipalities, usually at the local levels, in Pennsylvania (also some areas of Kentucky), have explicitly incorporated stormwater management requirements into their zoning ordinances. Typically, regulations specify the volume of runoff that must be detained on site. The volume of runoff specified is based on a total precipitation which would occur within a period from 3 to 24 hours with a return period anywhere from 5 to 100 years. Some municipalities specify the design base as the quantity of precipitation which would occur within a 3-hour period and would occur on the average every 5 years - other municipalities use the other extreme - the 24-hour, 100-year return period precipitation event.

Some municipalities, usually at the county level, have developed zoning standards which implicitly seek to regulate stormwater runoff from land development as a part of an overall environmental planning approach. In general, the explicit schemes requires that no greater rate of runoff from the site is permitted than occurred prior to development so all post-development excess runoff must stay on the property site. On the other hand, the implicit scheme has been interpreted so that stormwater is managed on a larger area basis. This usually means that properties in the upper reaches of the local drainage basin have no on-site detention facilities, however, in the lower reaches of the stream, property owners may lose all their property to retain the excess stormwater runoff.

Stormwater poses several threats to karst groundwater: (1) when concentrated and swiftly moving, it can remove the soil plugs in the doline drains and underlying cave passages, causing sinkhole collapse; (2) detaining stormwater in detention ponds can result in frequent raising and lowering of the water table, thereby, increasing underground erosion and the potential for collapse; (3) if there is an insufficient topsoil layer, polluted stormwater can be recharged directly to the aquifer and can spread over great distances. Within those areas in Pennsylvania underlaid with carbonate rocks and where sinkholes are present, the municipalities have begun writing specific ordinances which pertain to carbonate stormwater management.

In comparison, in Bowling Green, Warren County, Kentucky, sinkholes created stormwater management problems of such a magnitude that a stormwater management program was established in 1976 under the direction of the City-County Planning Commission (Matheney, 1984). The Bowling Green-Warren County Stormwater Management Program requires flood easements in sinkholes below the flood level of a three-hour, 100-year storm. Developers are required to build retention basins which will retain on site any increase in runoff during the 100-year storm resulting from a change in landuse. [A retention basin is designed to retain water after the storm; a detention basin is designed to be dry after the storm - the outflow is monitored as shown in Figure 1.] The Management Program in Kentucky has been very successful in reducing sinkhole flooding. However, the numerous retention basins have been expensive for developers, difficult to maintain, and the majority have experienced sinkhole collapse. The United States Department of Housing and Urban Development defines the 100-year flood elevation along streams as the flood plain for flood insurance purposes. For Bowling Green, the Department has accepted the sinkhole flood plain as the three-hour, 100-year flood elevation assuming no drainage from the sinkhole (Booker, 1978)

Some typical Pennsylvania ordinances which pertain to sinkholes exclusively include the following:

(1) Storm water from roadways, parking lots, storm sewers, roof drains, or other concentrated runoff paths shall not be discharged directly into sinkholes.
(2) Sinkholes capable of absorbing substantial amounts of storm water shall be protected by diverting such runoff around the sinkhole or, upon recommended approval of the Municipal Engineer, by use of other methods. These include planting and maintaining a dense filter path at least 10 meters in length of suitable vegetative material (e.g. tall grasses), in such manner and location to disperse and slow the runoff and to promote the maximum possible filtration of impurities.
(3) Sinkholes with a capacity sufficient to receive appreciable rates of storm water, as determined by the Municipal Engineer, shall be designated as such by posting on-site notices clearly visible at the sinkhole prohibiting any disposal of refuse, rubbish, hazardous wastes, organic matter, or soil into the sinkhole. Rock fill may be permitted in the sinkhole for the purpose of preventing dumping of said materials.
(4) If increased runoff is to be discharged into a sinkhole, even in a filtered condition, a geologic assessment of the effects of such runoff on increased land subsidence shall be made and submitted with the storm water management plan. Such discharge shall be prohibited if the Municipal Engineer determines that such poses a hazard to life, property, or groundwater resources.

2.3 Typical Design Schemes for Stormwater Basins:

Soil characteristics are important factors in sinkhole development by soil piping mechanisms. There are extensive mapping efforts by the Soil Conservation Service, the Department of Environmental Resources' Division of Geologic Mapping, the U.S. Geological Survey, and private watershed groups. However, it appears that few communities or state agencies in limestone areas make use of such maps to establish design restrictions or to consistently review proposals. Design of detention or retention facilities and stormwater conveyance systems in limestone areas rarely have the special problems of karst incorporated into most regulations. The municipality's specification of how much runoff to control and how to calculate it are usually one part of an ordinance. Commonly the design criteria are determined by negotiations between the municipal engineer and the applicant's engineer.

Typical stormwater detention basins, usually earthen, are located at points where stormwater runoff has been concentrated by storm sewers, drainage swales, or ditches. Although three municipal engineers from southeastern Pennsylvania were encouraging the design of facilities which would always contain water (retention basins), detention basins have been more common. It is somewhat rare for storm sewers to be specified by ordinance as the only means of conveyance, since the cost of storm sewers to accommodate a 100-year storm would be prohibitive. Throughout Pennsylvania, a 25 or 50-year design is often the maximum criterion for storm sewers (Brandywine Conservancy, 1980). This means that high runoff must be carried by the natural watercourses, drainage swales, or concrete drainage ditches. This can be a serious problem in areas of steep slopes, limestone bedrock, landslide-prone soils, or other easily eroded soils or rock. Most municipalities require inside slopes of 2:1 or 3:1 for all detention or retention basins to insure that a child could safely walk out of a full basin. The outside slopes are usually 3:1.

A second design factor with both detention and retention basins involves the outlet structures. Within the Centre Region of Pennsylvania, the outlet structure must detain the post-development 2, 10, 25, and 100-year runoff to the pre-development level for each of the corresponding return periods. Generally an orifice or culvert drain is constructed at or near the bottom of the pond to monitor the outflow for the low flow (2-year) return period flow; a drain is constructed at or near the top of the pond to monitor the outflow for the high flow (100-year) return period flow. The detention ponds are usually designed to drain completely within 2 to 36 hours, allowing some infiltration through the soil.

Outlining the subarea (property) boundaries for development onto topographic maps and soil survey maps is the first step in stormwater design. On the topographic map, the watershed boundaries must include all drainage which would drain both onto and from within the subarea. Generally, for pre-development conditions, the watershed is assumed to be meadow therefore it does not need to be subdivided. However, if the watershed area is wooded or urbanized or if it overlies carbonate bedrock, then the area must be subdivided according to the relative percentage of each.

There are two major methods of calculating runoff which have been used by many municipalities in the United States; (1) the Rational Method, an early simplified engineering procedure developed for storm sewer design (Chow, 1962); and (2) the Soil Cover Complex Method (SCCM), also called TR-55 (Soil Conservation Service, 1986), developed specifically to assist in the development of runoff control measures for agriculture, but since adapted to urban watersheds . For those basins with carbonate rock in the subsurface, the Pennsylvania Department of Transportation recommends PSU-IV (Aron et al., 1981). The PSU-IV method incorporates both the Rational Method with an analysis for the limestone based on the area and the relative position of the limestone within the basin. Other modeling techniques in use in United States include the Hydraulic Engineering Center, Davis California, HEC series; the Penn State Runoff Model, PSRM (Aron, 1987); and the San Francisco Model, SWMM (Huber et al., 1987). HYMO, (Williams and Hann, 1972) the storm water model

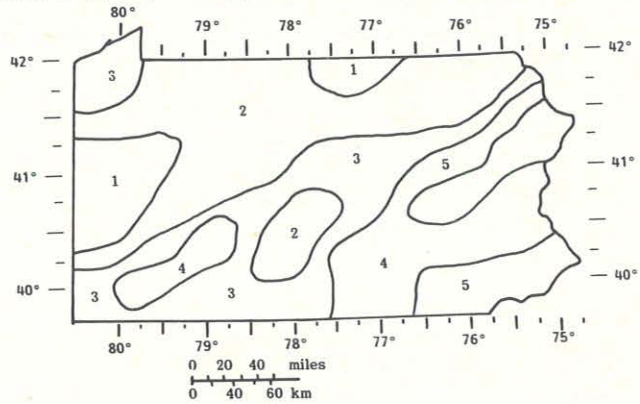

Fig. 2. Regional rainfall distribution for Pennsylvania. Distribution was based on 35 years of hourly precipitation data from 253 stations throughout Pennsylvania.

generally used in Canada, is a hydrograph modeling technique which has the flexibility to allow the design hydrograph to have the standard narrow peak or to have a more flattened shape (more typical of surface stream hydrographs in carbonate areas (White and Reich, 1970). Any of these may be used. Using the Rational Method, the peak runoff rate, Q_p (cfs or cms), at any point in the watershed may be computed by any number of methods. The Rational Formula, Q = CIA, can be used for these relatively small watersheds (less than 400 hectares) with relatively good success. In the Rational Formula, Q is the design discharge, C is the runoff coefficient based on the land use, and I is the uniform rainfall intensity for a duration equal to the time of concentration. Some typical runoff coefficient values are found in Table 1.

The rainfall intensity, I, is a function of return period, duration, and the geographic location of the design project. Technical Paper 40 contains rainfall intensity maps for the entire United States at intensities greater than 1 hour duration (Hershfield, 1961). For precipitation frequencies from 5 to 60 minutes the National Oceanographic and Atmospheric Administration published HYDRO-35 for eastern United States (Frederick, Myers, Auciello, 1977). More detailed maps are available for some states. An example, shown in Figure 2 (Aron et al., 1986), has Pennsylvania divided into five homogeneous rainfall regions based on 35 years of hourly precipitation records from 253 stations. For each region a set of rainfall and rainfall intensity curves were developed as shown in Figure 3 for Region 2. Using the Rational Formula, if rainfall intensity is given in millimeters/hour and the watershed area is given in hectares then the resulting discharge, Q, is in cubic meters per second (cms) using the formula: Q = 0.00276 CIA. [For Q in cfs, use Q = CIA with I in inches/hour, and A in acres].

3. DETENTION BASINS AS SINKHOLES AND SINKHOLES AS DETENTION BASINS

3.1 Piping Failures in Sinkholes and Detention Basins

Soil piping is the well known mechanism for sinkhole collapse in natural karst areas and in karst areas that have been developed. Soils from the base of the soil column are flushed by infiltrating water into solutionally widened fractures and sinkhole drains. A cavity develops, roofed by a soil arch which migrates upward and laterally. Depending on the shear strength of the soil, a size of cavity will be reached when the arch will no longer support its own weight. Circular shear cracks appear, usually followed quickly by catastrophic collapse of the soil roof (and whatever it is supporting) into the void. The size and depth of soil piping sinkholes depends on soil thickness and cohesive strength. The piping process, although it occurs naturally in undisturbed karst areas, is exacerbated by increased infiltration and by any mechanism that concentrates the infiltration into a limited area.

If, during the course of development, existing natural sinkholes are allowed to serve as detention ponds, the ponded water saturates the soil filling the sinkhole and increasing the seepage pressure at the base of the soil. Conditions are optimum for soil piping and sinkhole failure may occur in the modified situation of a development project that would not have

Table 1. Typical C Coefficients for 5- to 10-year Frequency Design

Description of Area	C	Description of Area	C	
Business - Downtown	0.70-0.95	Unimproved areas	0.10-0.30	
" - Neighborhood	0.50-0.70	Streets - asphalt	0.70-0.95	
Residential(suburban)	0.25-0.40	" - concrete	0.80-0.95	
" - Single-family	0.30-0.50	" - brick	0.70-0.85	
" - Multi, detached	0.40-0.60	Drives and walks	0.75-0.85	
" - Multi, attached	0.60-0.75	Roofs	0.75-0.85	
Industrial - Light	0.50-0.80	Lawns;	sandy soil	heavy soil
" - Heavy	0.60-0.90	Flat, 2%	0.05-0.10	0.13-0.17
Parks, cemeteries	0.10-0.25	Average, 2-7%	0.10-0.15	0.18-0.22
Playgrounds	0.20-0.35	Steep, 7%	0.15-0.20	0.25-0.35
Railroad yard areas	0.20-0.40			

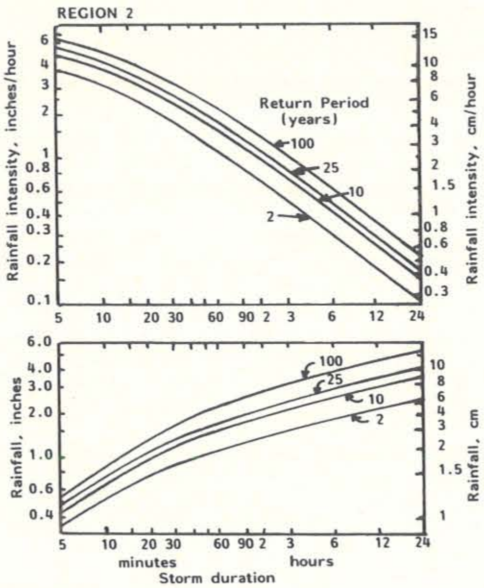

Fig. 3. An example of rainfall intensity and rainfall duration for Region 2 in Pennsylvania.

occurred under natural circumstances. Detention and retention ponds built in karst areas have the same hydrologic characteristics as natural sinkholes. Fracture swarms and solutionally-widened joints large enough for soil transport occur at many locations beneath the soil cover. It is not necessary that a sinkhole previously exist at the site. The collection of water in the artificial detention pond causes the same seepage pressures, rapid vertical infiltration, and soil piping from the soil column that occurs in natural sinkholes. Piping failures and cover collapse sinkholes are endemic to stormwater management structures built in karst regions.

3.2 Some Examples from Central Pennsylvania

Numerous karst related problems have been identified in the course of reviewing municipal practices and regulations for stormwater management in Pennsylvania (The Brandywine Conservancy, 1980). As one example, a detention basin built on the grounds of the Hershey Medical Center, Dauphin County, Pennsylvania, continually overflowed and ponded in a low area outside the facility. Seepage pressure and soil piping caused a major collapse including a large section of road surface. The repair costs for bridging the sinkhole area approached $100,000 at the time of the report and were not yet complete.

Following a recent 6-month drought in the Centre Region, Pennsylvania, three new detention ponds developed cover collapse sinkholes within a few days after construction. The first of the piping failures occurred when a nearby well was pumped for a capacity test. Sinkholes formed within the pond, the weir outlet structure tipped into another sinkhole, and cracks developed across an adjacent roadway. The other two detention ponds in the area also developed sinkholes just after construction. The causes are complex in this case but certainly the lowering by pumpage of a water table already low because of the drought played a role. The contractor's solution for all three ponds was to bring in extra soil and smooth over the sinkholes. The weir structures were repositioned and the roadway cracks were filled.

Near the western edge of the Borough of State College, Centre County, Pennsylvania is a region of low swales and shallow sinkholes overlying a dolomite aquifer. There is no surface drainage; all runoff from the rapidly developing area is to the subsurface through the sinkholes. One sinkhole, in particular, takes the storm runoff from a large paved area. No precautions are taken to maintain the quality of storm water draining into the subsurface. On the paved area is the parking garage for the Region's buses. A drainage channel about 30-cm wide and about 5-cm deep takes the runoff into the sinkhole. The vegetation is completely blackened by organic material. A sample of the runoff water had a very high total concentration of organic carbon (TOC=740 mg/liter) with a very high oil content (Gert Aron and Brian Dempsey, personal communication, Feb 20, 1989).

The Borough of State College has made deliberate use of sinkholes in its stormwater management plan. Within the Borough, stormwater is diverted into storm drains. In much of the town, storm drains flow into master drains which discharge the stormwater runoff into the headwaters of a surface stream that heads in a spring (and in the sewage treatment plant) at the east edge of town. However, the town is built over a sequence of low hills and the storm drains from many parts of town are blocked from the master drain system by the hills. Various segments of the storm drain system are simply diverted into sinkholes. The natural underground drainage system is used as an integral part of the stormwater management system.

5. CONCLUSIONS

It has long been known that karst processes and urban development come often into conflict. As the density of development increases, officials attempt to maintain environmental quality through ordinances and regulations concerning acceptable management of such problems as stormwater runoff. Much better understanding is needed of karst processes under conditions of urban stress. Using stormwater management as an example, we have shown that the engineered structures of the detention and retention basins, which are a solution in some terrains, can easily become part of the problem in karst terrain.

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LUMINESCENCE OF SPELEOTHEMS DUE TO FULVIC ACID AND OTHER ACTIVATORS

WHITE, William B. - BRENNAN, Edward S.

Calcite speleothems from nearly all caves exhibits a uniform blue-green phosphorescence when excited by an ultraviolet lamp or by a photographer's strobe lamp. Spectroscopic measurements show a broad emission band in the wavelength range of 400 to 550 nm. The exact position of the band depends on the wavelength of excitation. The luminescence arises from electronic transitions within molecules of fulvic acids which are shown to be present in white to tan colored speleothems. Some longer wavelength emission is associated with the humic acid component which is also responsible for the brown colors seen in many calcite speleothems. The luminescence spectrum is shown to be a characterization of the mix of humic substances present in the calcite.

Other luminescence colors occur: A crimson red is seen in most calcites if they are electron beam rather than UV excited. Traces of divalent manganese are the activator. Bright green emission due to the uranyl ion is sometimes observed under UV excitation.

Gypsum, which is usually non-luminescent under UV and electron beam excitation, can be excited by a hydrogen flame (candoluminescence). A green emission appears at lower temperatures and a bright yellow-orange emission occurs as the sample is heated. Both are associated with divalent manganese in the gypsum and partially dehydrated bassanite structures respectively.

BARLANGI KÉPZŐDMÉNYEK FULVINSAVBÓL ÉS MÁS AKTIVÁTOROKBÓL EREDŐ LUMINESZCENCIÁJA

Csaknem bármely barlangból való kalcit-képződmény egységes kéke s-zöldes foszforenciát mutat UV lámpával,vagy vakuval gerjesztve.A spektroszkópiai mérések széles kibocsátási sávot mutatnak 400 és 500 nm közötti hullámhosszakon.A sáv pontos helyzete a gerjesztés hullámhosszától függ.A lumineszcencia a fehértől a barna képződményekig kimutatott fulvinsav-molekulákban történő elektron-áthelyeződések során keletkezik.Bizonyos hosszabb hullámú fénykibocsájtás a huminsav-összetevővel hozható kapcsolatba,mely sok kalcit képződmény barna színéért felelős.A lumineszcencia spektruma bizonyítottan jellemző a kalcitban lévő huminanyagok keverékére.

Fgyéb lumineszcencia színek is előfordulnak:bíborvörös észlelhető a legtöbb kalciton,ha UV helyett elektorsugárral gerjesztjük.Itt kétértékű mangánnyomok az aktivátorok. Élénkzöld fénykibocsájtást okozhat az uranil ion,melyet néha UV gerjesztésnél figyelhetünk meg.

A gipsz,mely általában nem lumineszkál UV fényben,vagy elektron-sugárban,gerjeszthető hidrogén-lánggal /candolumineszcencia/.Zöld fény jelenik meg alacsonyabb hőmérsékleten és élénk sárga-narancs fénykibocsájtás jelenik meg,ha a mintát hevítjük.Mindkettő a gipszben lévő kétértékű mangánnal,illetve a részben dehidrált bassanit-szerkezettel hozható kapcsolatba

1. INTRODUCTION

The secondary calcite deposits and other minerals that occur commonly in caves are frequently luminescent. This phenomenon has been widely observed. It can be observed by examining the cave itself with hand-held mineral prospecting UV lamps. It can be observed by examining cave specimens under ultraviolet light in the laboratory. Likewise, the phenomenon is well known to cave photographers who observe a distinct afterglow with a decay time on the order of a second after a calcite deposit has been illuminated by a flashbulb or strobe.

The formal literature on luminescent cave minerals is sparse. There are some early observations on flashbulb excited phosphorescence (O'Brien, 1956). Slacik (1976) examined the speleothems some Bohemian caves with a portable ultraviolet lamp. Cigna (1958) measured the luminescence emission spectra of some stalactites by a spectrographic method and found two broad emission bands at 460 and 540 nm. There is a commentary on luminescence in the cave mineral books of Hill (1976) and Hill and Forti (1986).

The object of the present paper is to lay out in broad brush terms the types and origins of luminescence observed in caves.

2. EXPERIMENTAL MEASUREMENTS

The data reported in this paper have been obtained by the following methods.

A large collection of cave related material was examined visually under the long wave (365 nm) and short wave (253.7 nm) excitation of a mercury vapor lamp.

Quantitative measurements of photoluminescence spectra of cave minerals were made using a Hitachi spectrofluorometer. This instrument allows both excitation and emission wavelengths to be varied independently. Other quantitative measurements of emission spectra used the 457 and 488 nm lines of an argon ion laser for excitation in the visible region of the spectrum with the emission spectrum observed with an ISA Model U-1000 Ramanor Raman spectrometer as a high resolution, high sensitivity measurement device.

Qualitative observations of the cathodoluminescence of cave minerals were obtained by placing specimens in a glass test tube, partially evacuating the test tube, and then exciting the residual gas with the high voltage, high frequency spark discharge of a Tesla coil vacuum leak detector. Electron and ion bombardment of the mineral chips in the test tubes were very efficient at exciting luminescence, often of a different color from that observed in photoluminescence experiments.

A few specimens were examined qualitatively for candoluminescence emission by brushing powdered speleothems with a hydrogen diffusion flame. Candoluminescent emission spectra were measured by painting the powdered specimen onto a resistance heater so that temperature could be controlled independently, brushing the heater with a hydrogen flame, and then focusing the luminescent radiation onto the entrance slit of a spectrophotometer.

3. LUMINESCENCE IN INSULATOR MATERIALS

We here review briefly the principles of luminescent emission. For further information see reviews of mineral luminescence by Blasse and Bril (1970), White (1975), Geake and Walker (1975), Marfunin, (1979), Waychunas (1988).

Luminescent materials are broadly classified first by the electronic characteristics of the emission and second by the mode of excitation. From the viewpoint of their electronic structure, luminescent materials are divided into molecular phosphors, insulator phosphors, and semiconductor phosphors.

Molecular phosphors are those in which the absorption of energy from the excitation sources, its internal rearrangement through the energy level structure of the activator, and its re-emission as luminescent radiation takes place entirely within a single molecule. Of major interest to cave materials is the emission associated with fulvic and humic acids to be described later in this paper.

Insulator phosphors are those in which the luminescence center has localized energy levels falling within the forbidden energy gap of the host crystal. For calcite, aragonite, and gypsum, the bands gaps are greater than 6 eV. Certain transition metal ions, particularly Mn^{2+} can substitute for Ca^{2+} in the calcite structure and the luminescence is associated with transitions between the partly filled orbitals of the Mn^{2+} ion. Other transition metals and metal complexes such as the uranyl ion also give rise to luminescence.

Semiconductor phosphors are those in which the excitation energy is sufficient to excite electrons from the valence band into the conduction band within the mineral structure. This allows the excitation energy to spread throughout the crystal rather than interact only with localized centers. Any center: an impurity ion, a crystal defect, or energy levels associated with the crystal band structure itself, can be excited by this process and leads to a rich assembly of luminescent phenomena. The band gaps of the cave minerals are sufficiently large that, with few exceptions, they do not behave as semiconductor materials.

Discussion of luminescent phenomena in terms of mode of excitation is the historical classification. Photoluminescence is luminescence excited by ultraviolet or visible light, cathodoluminescence is excitation by electrons, and ionoluminescence and x-ray luminescence are excited by ion and x-ray beams. Candoluminescence and radical recombination luminescence refer to the excitation of energy levels within the crystal with energy released by recombination of active species in flames or plasmas (Ivey, 1974). Electroluminescence is a semiconductor phenomenon in which inter-band emission is driven by strong electric fields. It is not pertinent to the discussion here. Finally, the phenomena of thermoluminescence and triboluminescence are somewhat different from the others. Thermoluminescence refers to the thermally activated decay of trapped charges within defects in the crystal structures. Triboluminescence, a complicated phenomenon, refers to light that appears when crystals are ground or fractured. The calcite crystal structure often contains defect centers and thermoluminescence is frequently observed. Thermoluminescence was an early method of dating carbonate sediments (Zeller et al., 1957) and has been reconsidered as a technique in parallel with ESR methods for the dating of calcite speleothems (Debenham, 1983).

4. OBSERVATIONS ON THE LUMINESCENCE OF SPELEOTHEMS

4.1 Photoluminescence of Speleothems

Several hundred speleothems, mostly calcite, with some aragonite and gypsum were examined in both 365 and 253.7 nm ultraviolet light. Nearly all speleothems were luminescent to some degree. Many were phosphorescent. There was a persistent afterglow when the UV light was removed. By far, the most common phenomenon is a blue-green phosphorescence observed in essentially every calcite specimen examined. The blue-green fluorescence was much brighter under 365 nm UV than under 253.7 nm UV and lighter colored speleothems fluoresced more strongly than the darker colored ones. Darker colored calcites also tended to have a deeper more yellow or yellow orange luminescence. We will argue that most of the blue-green and yellow luminescence is due to organic constituents, humic and fulvic acids, and will be discussed later. Of the remaining observations some appear to be due inorganic causes or cannot be explained at the present time.

A characteristic bright green luminescence was seen as streaky patches on specimens from Cueva del Guacharo (Venezuela), in the "frostwork" aragonite crystals in Wind Cave (South Dakota), and in a few other specimens such as a nodular speleothem from Cumberland Caverns, Tennessee. The green emission was fluorescence, not phosphorescence, and it was excited only by the 253.7 nm short wave UV. It was, therefore, easy to distinguish from the background blue-green emission which also appeared in the same specimens. The emission spectrum (Fig. 1) shows several sharp peaks. These match closely the spectrum of the uranyl, UO_2^{2+}, ion. Uranium is easily mobilized in karst by carbonate complexation. In the oxidizing environment of karst groundwaters uranium occurs in its six-valent state and is occasionally sufficiently concentrated to be spotted by its fluorescent emission spectrum.

A few specimens of acicular aragonite crystals gave a bright orange luminescence. The emission was brightest under 365 nm UV and the color was distinctly more orange than the emission observed from calcite speleothems. On some specimens of clear white aragonite crystals, the luminescence appeared to be patchy with some bright orange regions and some regions that were not luminescent at all. No spectra were obtained from the aragonite and the origin of the luminescence was not determined.

Somewhat surprisingly, most of the gypsum specimens examined gave a deep yellow luminescence under 365 nm UV. The luminescence of gypsum is surprising in that hydrated minerals are not generally luminescent. In fine-grained gypsum crusts, the luminescence took on more of an orange or pink tinge. In one sample of gypsum crust bright orange specks of luminescence appeared against the yellow background. Specimens of limestone that contained veinlets of gypsum or had particles of gypsum on their surfaces also had a weak yellow luminescence, probably showing the distribution of gypsum in the rock. No spectra were obtained of the photoluminescence of gypsum and the origin of the luminescence remains unknown.

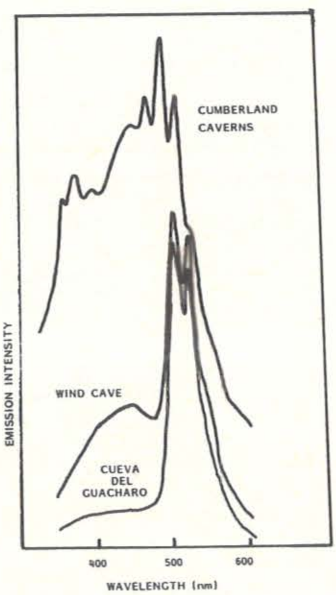

Figure 1. Emission spectra of three bright green fluorescing specimens excited by 253.7 nm UV light.

4.2 Cathodoluminescence of Speleothems

Most of the calcites examined gave a scarlet pink color under electron and ion bombardment in the qualitative cathodoluminescence experiment. No spectra were obtained from these measurements. The visible appearance of the emission is very similar to that of the fluorescent calcites found in such famous mineral localities as the Franklin, New Jersey occurrences and very different from the luminescence of the same specimens under ultraviolet light. The cathodoluminescence was assigned to Mn^{2+} substituting for Ca^{2+} in the calcite crystal structure. The unfilled d-orbitals of the Mn^{2+} ion provide the energy levels for luminescent emission. The energy levels, and thus the wavelength of the luminescence, are very sensitive to the structure of the host crystal in which the Mn^{2+} ion is located (White, 1975).

4.3 Candoluminescence of Speleothems

Powdered samples of speleothems were screened for candoluminescence by brushing the powder with a hydrogen flame. The calcite specimens tested were not candoluminescent. Most gypsum samples, however, gave a strong candoluminescence.

The gypsum specimens showed a strong green emission upon brief exposure to the flame although the intensity varied markedly from sample to sample. Upon extended heating, the green luminescence gave way to a bright lemon yellow emission rather different in visual appearance from the photoluminescence. When a gypsum sample was heated in the flame just sufficiently to develop a uniform green emission, its x-ray diffraction pattern indicated a mixture of bassanite ($CaSO_4 \cdot 1/2H_2O$) and anhydrite ($CaSO_4$) with only traces of the original gypsum remaining. The green emission rose quickly and persisted for some minutes under continuing excitation indicating that the gypsum lost water of hydration rather readily but that the resulting hemihydrate was at least somewhat stable in the atmosphere of the flame. When the same sample was further heated to achieve a uniform yellow emission the resulting x-ray pattern indicated a pure anhydrite phase. After cooling, the green emission did not immediately recur, but did recur after the sample had been allowed to stand in the laboratory overnight.

The emission spectra of the green and yellow emission both consist of broad bands with no additional fine structure (Fig. 2). By preparing

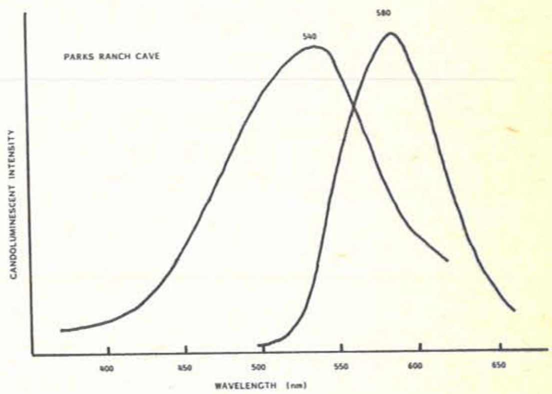

Figure 2. Candoluminescent emission spectra of gypsum from Parks Ranch Cave, New Mexico excited by a hydrogen diffusion flame.

synthetic bassanite and anhydrite phases deliberately doped with manganese and examining the cathodoluminescence of the synthetic materials, it was established that the green emission was due to Mn^{2+} substituting for Ca^{2+} in the $CaSO_4$ structure. The cathodoluminescence of Mn-doped anhydrite is also green so that the origin of the lemon yellow emission remains uncertain.

A characteristic of candoluminescence is that the brightness exhibits a pronounced maximum at some temperature in the range of a few hundred degrees Celsius. The green emission faded rapidly with rising temperature indicating that it's temperature maximum is near room temperature. The yellow emission reaches a sharp maximum at temperatures in the range of 150 to 360 C with the position of the maximum depending on the sample.

4.4 Thermoluminescence of Cave Calcites

Only a few samples were examined for thermoluminescence and these at low temperatures. The powdered calcite speleothem was chilled to liquid nitrogen temperature (78 K), the trap centers were charged by illuminating the cold specimen with ultraviolet light, and then the sample was permitted to warm back to room temperature. There was a consistent thermoluminescent glow-peak at 105 K and hints of several weaker features. High temperature thermoluminescence, of interest for speleothem age dating, was not examined.

5. LUMINESCENCE DUE TO FULVIC AND HUMIC ACIDS

Measurements with 365 nm UV excitation as well as excitation by 458 and 488 nm laser radiation showed the ubiquitous blue-green-white phosphorescence to be a broad band emission that varied in detailed band shape from specimen to specimen. Detailed measurements of both emission and excitation spectra were obtained from more than 20 calcite speleothems from various localities. The details of this work will be published elsewhere (Brennan and White, work in progress) but the main conclusions are given here.

Figure 3 shows a typical set of spectra. The emission consists of a single band in the range of 400 to 450 nm, its exact position varying from specimen to specimen. The brightest luminescence was observed from the lighter colored speleothems. Luminescence from orange to brown speleothems tended to be more yellow than the blue-green luminescence of the light colored materials. Similar but not identical spectra were observed when the solid calcite was compared with a solution obtained by dissolving the speleothem in hydrochloric acid. There are usually two excitation bands; the band near 240 nm coupling most strongly to the blue emission band near 400 nm. Excitation into the 316 nm band and at longer wavelengths often causes the emission to shift toward the yellow. Many of the darker colored speleothem give broader emission bands at longer wavelengths. There appears to be a continuum of emission so that broad band excitation such as occurs with mineral prospecting UV lamps or with photographic strobe lamps excites all centers simultaneously and produces an almost white phosphorescence.

The visible and near-infrared reflectance spectra of calcite speleothems (White, 1981) combined with the absence of a correlation between depth of color and iron content (Gascoyne, 1977) suggest that the pigmenting matter in most dripstone and flowstone is organic material. It is now known to be a mixture of humic and fulvic acids (Lauritzen, 1986). Fulvic acid is more weakly colored and has a characteristic luminescence emission band in the blue region of the spectrum. Humic acid has a yellow to brown color

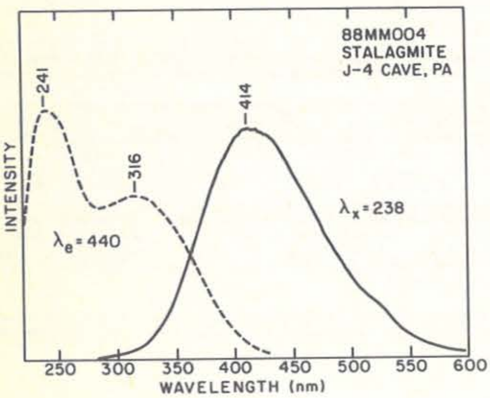

Figure 3. Emission spectrum (solid line) and excitation spectrum (dashed line) for a light brown colored stalagmite.

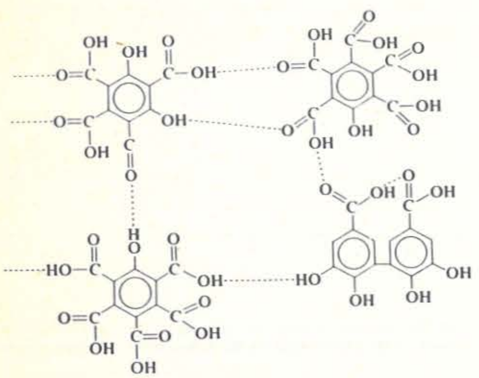

Figure 4. Molecular structure of fulvic acid as reported by Schnitzer and Khan (1972).

depending on molecular weight, and has a luminescence emission in the green-yellow region of the spectrum (Hayase and Tsubota, 1985). Comparison of the luminescence spectra of speleothems with reference samples of humic and fulvic acids and with literature data shows excellent agreement.

Fulvic acid appears to produce the brightest luminescence. It is a complex compound (Fig. 4) based on cross-linked phenolic and benzoic acid rings. The aromatic ring structure provides the energy levels for the luminescence excitation and emission. There is a continuum of structures of varying molecular weight between fulvic acid and humic acid. The variations in luminescence are thought to indicate the varying mix of molecular weights found in speleothems from different localities. The luminescence spectrum, therefore, tells something about the mix or humic material that has been captured by growing speleothems in different caves at different times.

6. CONCLUSIONS

Most speleothems are luminescent including many features not yet explained in detail. The universal blue-green phosphorescence of calcite speleothems arises from mixtures of fulvic and humic acid. The spectra are complex and vary in detail from specimen to specimen. Luminescence due to inorganic activators, notably Mn^{2+} and UO_2^{2+} is occasionally observed. Other modes of excitation such as cathodoluminescence and candoluminescence offer promise and further investigation is needed.

Acknowledgments

J.R. Sweet and J.W. Hess are thanked for collecting some of the spectra reported in this paper.

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QUANTITATIVE SPECTROFLUOROMETRIC DETERMINATION OF FLUORESCEIN DYE USED IN TRACING OF UNDERGROUND WATER

RÓNAKI, Laszlo

Several methods are used to investigate moving underground water / chemical,radiolabelled or other compounds / depending on our aim. We've used the fluorescein dye,well known in the karst-hydrological research, to investigate the underground water stream conditions. In Hungary the experiences of the practical use of fluorescein dye was elaborated first at 1966. by Rónaki. The semiquantitative colorimetric determination in the field studies was suitable to detect o,25 - o,5 µg/l dye concentration.

A great dilution and a longtime experiment was expacted in the case of underground water. For this reason we've worked out a more sensitive method, we've measured the fluorescein dye concentration in collected water samples by spectrofluorometry, using a Perkin-Elmer Mod 3ooo instrument. The measurement of optically clear samples can be carryed out immediately, the other samples only after adequate preparing /centrifuging,filtration/. The changing of fluorescency of dye was studied depending on time.

The concentration of marking compounds in the samples were determined after a soitable calibration. With this method we can detect the fluorescein dye to o,o2 µg/l concentration in underground water samples.

Felszínalatti vizek nyomjelzésére alkalmazott fluoreszcein festék kvantitatív meghatározása

A felszínalatti vizek nyomjelzéses vizsgálatához a körülmények és a cél figyelembevételével számos ismert vegyi-, radioaktív-, vagy egyéb jelzőanyag közül lehet választani. Munkánk során a karszthidrológiai kutatásokban széleskörűen alkalmazott fluorescein-festéket használtuk. Hazánkban Rónaki / 1966 / írta le ennek alkalmazásával szerzett tapasztalatokat. A terepi vizsgálatokra kidolgozott félmennyiségi kolorimetriás meghatározás alkalmasnak bizonyult 0,25 - 0,5 µg/l festékkoncentráció kimutatására is.

A nagyarányú higulásra számítva és a mennyiségi meghatározás fokozott igénye miatt kidolgoztunk egy sokkal érzékenyebb detektálási módszert. Ehhez a Perkin-Elmer spektrofluorimétert használtunk. Az optikailag tiszta minták mérése azonnal elvégezhető volt, más esetben csak a minta megfelelő előkészítése / centrifugálás, szűrés / után.

Megfelelő kalibráció figyelembevételével kielégítő pontossággal sikerült meghatározni a jelzőanyag koncentrációját. Vizsgálatainkban ezzel a módszerrel 0,02 µg/l mennyiségben is egyértelműen ki tudtuk mutatni a fluoresceint a felszínalatti vizek nyomjelzése után.

In Hungary, up to now all the publications concerning this tipe of dye were dealing with scmiquantitive colorimetric methods. / L.Rónaki 1966 / That was so because we had only the Pulfrich fotometer, by wich the limit concentracion of measurements was $5 \times 1o^{-6}$, i.e. $5 \times 1o^{-9}$ dilution. / 5 gamma = 5 mikrogramm dye in 1 liter water / For field use we advised a more sensitive system than the fotometric one

From many a possibilities here we are publishing our results with colometrics. That one was strictly controlled and proofed to be very effectiv in field works. about 4oo ml test tubes / 32-35 mm dia.,height 5oo mm / were used both for etalon series and for the samples. Comparison was made simply visu ally, from the top of the tubes, having a black background.

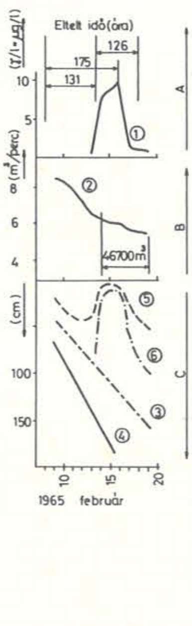
By this very simple instrumentation and method in clear water the concentratıcn of fluorescein dye could be determined up to o,5-o,25 microgramm/litre

When fluorescein appears in spring cater, that favours the sensing, as qualyand quantitative measurements are depending positively by depth of the Water, even in natural circumstanes. Such a case is represented in our figure, where both disturbing effects and important components for evaluation were observed.

As it is commonly known, fluorescein fluorescates only above 4,5 pH. Concerning that fact, proper precantions are needed not only by electing the dye, but by preparing the comparing etalon series, i.e. it must be taken from the same water of the would be examined one, and has to be stored with care.

In an ear lier publication we mentioned a data that abroad with instrument a dye concentration of $1o^{-8}$ g/litre could be revealed. / J. Zötl 1965 / Here we give information of similar results, wich is going to help to account the dilution and detection of the appearance of die.

Observation of dye in the Vizfő Spring /Mecsek Mountains/ and the examined parameters before and during the experiment.



A./ Measured dye conc., $1o^{-6}$ µg/lit.

B./ Water flow m^3/min

C./ Observation at different depth

1./ Fluorescein proofed by Pulfrich photometer
2./ Variation of water flow from the spring
3./ Limit of the clear seethrough
4./ Limit of the see-through in cloudy water
5./ Depth of the change of colour
6./ Depth of the fluorescentic observation

By our recent experiments with Perkin-Elmer spectrofotometer o,o2 microgram/litre concentration was detected in clear water. Inducation of the photometer succeeded between 49o - 51o nm with an amplification of 5x and sensibility varied from 5o to 5oo mV. With of inward edge was 15 nm, and the output one 2o nm. /By courtesy of Mrs Cz.M.Vér/

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CAVE DEPOSITS DURING GLACIATIONS AND INTERGLACIALS – AN EXAMPLE FROM THE KORALLGROTTAN IN MIDDLE SWEDEN

ISACSSON, Gunnar

Korallgrottan (The Coral Cave), the largest cave of Sweden, is situated in the Caledonian mountains at 540-600m (14°9'30"E. 64°53'16"N.). This almost 4 km long cave contains four different types of sediments, creating a deposition-sequence from A to D:

A: Coarse non-carbonate sand to gravel, calcified in a way that indicates deposition during warm climatic conditions B: Laminated silt - clay, deposited in almost stagnant water, probably under the ice during a glacial period. C: Non-calcified silt, mostly slightly wet. D: Organic matter, deposited during extreme (spring-?) flooding.

The sediments indicate that the cave remained intact during the Weichsel glacial, though it was covered with a 2-3 km thick inlandice. U/Th-datings of flowstone in sediment A will be presented at the congress.

HÖHLEN-ABLAGERUNGEN WÄHREND EIS UND WARMZEITEN -AM BEISPIEL DER KORALLGROTTAN IN MITTEL-SCHWEDEN

Die fast 4km lange Korallgrottan (die Korallenhöhle), die grösste Höhle Schwedens, liegt in die kaledonische Gebirge auf 540-600-ü NN (14°9'30"E. 64°53'16"N.). Die Höhle weist vier verschiedene Arten von Ablagerungen, die von A zu D abgelagert sind, auf:

A: Sand und Kies mit auf warme Klimaverhältnisse deutenden Verkalkungen. B: Gebänderten Lehm, wahrscheinlich während einer Eiszeit unter dem Binneneis in sehr langsam fliessendem Wasser abgelagert. C: Nicht verkalkter, oft leicht feuchten Silt. D: Organisches Material, abgelagert während extremen Hochwassern.

Die sedimente zeigen an, dass die Höhle während der Weichsel-Vereisung intakt geblieben ist, obwohl sie von den 2-3 km starken Binneneis bedeckt war. U/Th-datierung von Kalksinter im Sediment A werden auf dem Kongress vorgestellt.

1. BRIEF DESCRIPTION OF THE CAVE KORALLGROTTAN

Korallgrottan (the Coral Cave) is situated in the Caledonian mountain range at 540-600m a.s.l., Long.14°9'30"E Lat.64°53'16"N. The cave is considered to be the largest cave in Sweden with its almost four kilometer long passages. It was not discovered until 1985 though its entrance is just 4.5 km from the karst area of Bjurälven, which was described by the Swedish geologist Fredrik Svenonius in 1880 (1).

The entrance is in the side of a collapse-doline, approx. 10m deep and 20m wide, where a small creek forms a scenic waterfall. The passages close to the entrance are rather narrow and uncomfortable, but after just 20m a large tunnel, 2-4m wide and 3-6m high, brings you through both phreatic (downstream) and vadose (upstream) parts of the cave.

2. THE CAVE DEPOSITS

The cave contains four different types of sediments:

2.1 A: Calcified sand and gravel

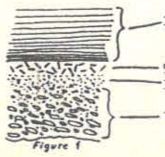
Coarse-grained sediments once probably filled more than 3/4 of the cave's volume. The remains of these sediments can be seen on many localities in the cave, most commonly as a "watermark", where the calcified sediment surface has been cemented to the wall. One of the most interesting sites with sediment A is in the so called "Active System", where travertine and small alluvial fans with finegrained sand have been deposited upon each other in 10-50 layers. The travertine layers are about 0.4-1.5 cm thick, thus indicating deposition under rather warm climatic conditions. A piece of a 10 cm thick flowstone close to this site has been sent to dr. Stein-Erik Lauritzen at the University of Bergen, Norway, for U/Th-dating. The author hopes to be able to present the result at the congress.

Although these coarse-grained, flowstone-covered sediments must have had a very great resistance against erosion, they have been almost completely washed out. The alluvial fans and travertine layers mentioned above are today hanging out from the wall. Some two meters away a vadose canyon, 1.5m deep and 45 cm wide, opens out into the chamber. In the canyon a 10 cm thick flowstone layer is hanging half way to the floor. The sediments which once underlaid the flowstone are totally washed out! What source gave the water such a tremendous power? Can it be anything but a melting inland ice?

2.2 B: Laminated clay and silt

A few localities in the upper parts of the cave contain remains of laminated clay and silt. Also these sediments show signs of large waterflows. Near one of the most beautiful stalactite galleries a 1m thick sediment has been cut by flowing water, thus revealing a sequence of about 400 layers of laminated clay and silt. The thickness of the layers rises more or less continuously from less than 1 mm at the bottom to approx. 1 cm at the top.

A second locality close to the first shows a very interesting 80 cm thick sequence of deposits, cut by flowing water (figure 1)



35cm laminated clay, layers continuously thicker towards the top
5cm unlaminated silt
3cm fine sand
37cm gravel and sand coarser at the bottom

Figure 1

Is it possible that this sequence shows the beginning and the end of a glaciation?

A third locality at the same altitude as the flowstone (above), but 80m "upstream" in the main tunnel is a small streamformed rest of hard, dry laminated clay deposited directly upon a stone fallen from the roof or deposited by violently flowing water.

2.21 The deposition of sediment B

Clay needs stagnant or very slowly flowing water to be able to deposit. In the case of the Korallgrottan that demands the existence of a lake with its surface at least 100m above the present valley floor, or the existence of water under the inland ice.

There are three possibilities which allow a lake to exist:
1. The lake was dammed by a mountain threshold, which later was eroded away during a glaciation.
2. The lake was dammed by an esker or a moraine ridge, which later was eroded away by running water.
3. The lake was dammed by ice at the end of a glaciation.

The possibility no. 1 can be excluded at once because the sediment B at the two upper sites have been deposited in a passage with vadose forms.
No. 2 is unlikely but still possible, but since there are no signs of such a ridge, this cannot have happened in the Holocene.
No. 3 is very unlikely because it demands the existence of an icebarrier for at least 400 years without permafrost in the ground. Studies of laminated clay further down in the drainage area of Angermanälven (to which the Korallgrottan belongs) indicates a melting speed of 200-300 m/year at the end of the Weichsel-glaciation at about 9000 years ago (2). A second argument against no. 3 is that even a catastrophic bursting of an icebarrier downstream the cave doesn't provide a hydrostatic gradient in the cave large enough to wash away the sediments.
The only possibility left is that the laminated sediments were deposited in free, stagnant water under the inland ice, probably at the beginning of its melting. At the end of the melting phase, vast quantities of water under enormous hydrostatic pressure rushed through the cave, thus washing the old sediments away.

2.3 C: Non-calcified, mostly slightly wet silt

These probably late Weichselian or Holocene sediments are everywhere to be found in the lower parts of the cave.

2.4 D: Organic matter deposited during flooding

Leaves, needles, branches and roots can be seen at some higher, "fossil" localities in the cave. These plant fragments have probably been deposited during extreme (spring-) flooding, i.e. years with very warm weather in the snow-melting season and/or years with extremely large amounts of snow.

Some stalactites contains parts of plants which have got stuck on them during flooding. Now they are calcified and incorporated with the stalactites, giving them a very peculiar appearance.

Some animals have also ended their days in the cave. Near the two upper sediment B-localities the bones of some ten small rodents (the lemming, Lemmus lemmus) are laying on the floor. They have probably died of starvation because some of the skeletons are still intact.

The most peculiar animal-finding is however not the lemmings, but a winter-gnat (Diptera, Trichoceridae) which has died on a stalagmite and is now being calcified and incorporated with it.

3. CONCLUSIONS AND RECORDS FROM THE LITERATURE

Many evidence indicates that the Korallgrottan existed during and before the Weichsel-glaciation and survived its enormous weight and erosive forces.

The thought that a Scandinavian cave might be older than Weichsel is not new. Dr. Leif Engh summarized 1980 (3) the works of 15 authors who had discussed that question. Most of the authors were of the opinion that the at that time known caves were of late Weichselian or Holocene age. Engh, on the other hand, shows in his article evidence from some in the late 1970-s found caves in the Vadve valley (Lat. 68,5°N, 600-1000m a.s.l.), that those caves must be at least pre-Weichselian. Five years later his theories were confirmed by the U/Th-dating of a stalagmite from one of the caves. It was dated by S-E Lauritzen to have an age of 140 000 years (4).

Another interesting dating is a C-14 dating of a travertine layer from the Labyrint cave (Lat. 66°N, 700m a.s.l.) which turned out to be 18 480 +- 220 years old (3), i.e. from a late interstadial in the Weichsel glaciation.

The deposition of laminated clay under an inland ice is also mentioned in the literature from Scandinavia. In 1983 Dr. Eiliv Larsen et.al. excavated the cave Skjonghelleren near Alesund in western Norway (5) and found that layers with bones from an arctic fauna alternated with laminated clay and silt deposited under the ice during the Weichsel glaciation.

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KARST FEATURES IN TRIASSIC LIMESTONES AND DOLOMITES OF OLKUSZ AREA (SOUTHWEST POLAND)

MOTYKA, Jacek

Studies of the geometry and distribution regularities of karst caverns were based on drill-core examinations and field observation in outcrops and mine galleries. Caverns traced by bore--holes were 0,1 - 18 m high but nearly 50% did not exceed 1 m. Cross-sections areas of karst caverns mesured in outcrops and mine galleries change from 0,0013 to 8,4 m^2 with over 57% measurements below 0,1 m^2. Dominating type of filled karst caverns in Triassic carbonate rocks are various types of breccias. In their initial stage the breccia structure are usually 1 m high and several hundreds of meters long. The mature karst forms are about 20 m high and to several hundreds of meters long. The favourable conditions for developpement of karst features in Triassic carbonate rocks prevailing along the dolomites/limestones interbedding plane.

PHÉNOMÈNES KARSTIQUES DANS DES CALCAIRES ET DOLOMIES DU TRIAS DE LA RÉGION D'OLKUSZ (SUD-OUEST POLOGNE)

Des recherches des éléments géométriques et certaines régularités de la distribution des formes karstiques on a fait à la base des résultats des forages et observations de terrain en affleurments et galleries de mines. Les cavernes rencontrées par les forages avaient le diamètre vertical 0,1 - 18 m mais vers 50% ne depassaient pas 1 m. Les surfaces des coupes des caverns trouvées dans des galleries et affleurements se changeaient de 0,0013 à 8,4 m^2 mais plus que 57% mesuraient moins que 0,1 m^2. Le genre dominant de formes karstiques remplie ce sont des divers types de brèches. Dans un stade initial les brèches ont épaisseur vers 1 m et quelques centaines de metres de la longuer. L'épaisseur de brèches dans un stade développé est 20 m aux environs et plus que quelques centaines de metre de la longuer. Les phénomènes karstiques se trouvent le plus fréquent dans une zone lelong le contact entre les dolomies et calcaires.

1. INTRODUCTION

Karst processes affecting the Triassic carbonate sequence of the Olkusz Zn-Pb District are geological factors of significant practical importance. Karst-collapse breccias host the high-grade Zn-Pb mineralization which has been mined in this area since hundreds of years. Karst features control the water level within the Triassic aquifer and, thus, affect the mining activity. Since the ore mining has expanded beneath the water table, the problem of high influxes from the karst caves and caverns to the mine workings became crucial for this industry (Wilk et al., 1977). Therefore, both the morphology of karst forms and regularities in their distribution appear to be important for prospection and development of orebodies and determination of water hazard for the existing mines and future projects.

Author presents the result of studies of karst features based on observations from drillings, surficial outcrops and underground workings. Types of filled karst forms are shown as well as some regularities of the spatial distribution of karst cavities within the Triassic carbonate aquifer.

2. PALAEORELIEF OF THE TOP SURFACE OF MUSCHELKALK CARBONATES

Deposition of the Upper Muschelkalk marine carbonates in Olkusz area has been interrupted by uplift and regression followed by the substantial break in sedimentation and erosion. Carbonate sequence has been affected by dissolution, ion exchange and other processes causing the mas removal. Its surface has been subsequently covered by Upper Triassic (Keuper), Jurassic and Quaternary successions.

In the Olkusz area the palaeorelief of the Upper Muschelkalk erosional surface reveals the features typical of matured karst (Fig. 1). An example of the first-order morphological forms of this type can be observed in the eastern part of the investigated area. It is a huge, NWW-SEE-elongated depression 1.5 - 2.0 kilometers wide, with a flat bottom cut by numerous hollows lacking a surface drainage which are presumably karst sink-holes. The largest sink-hole found in the SE part of this depression is about 1 kilometer across and 30 meters deep. It is suggested that the depression is a palaeo-polje formed during the Upper Muschelkalk which evidences the intense karstification during that period.

3. KARST CAVES AND CAVERNS

These forms were encountered in both the drillings an outcrops (surficial and underground). Their occurrence covers the full sequence of Triassic carbonates. Heights of caverns estimated from the drillings vary from 0.1 to 18 meters but over 36% of the observed caverns is from 0.5 to 1.0 meter high. Distribution of the measured heights of caverns is shown on Fig. 2.

Caverns found in the outcrops were, in most cases, unaccessible for direct measurements. Only three of them could be explored: horizontal cave developed along the boundary between Middle

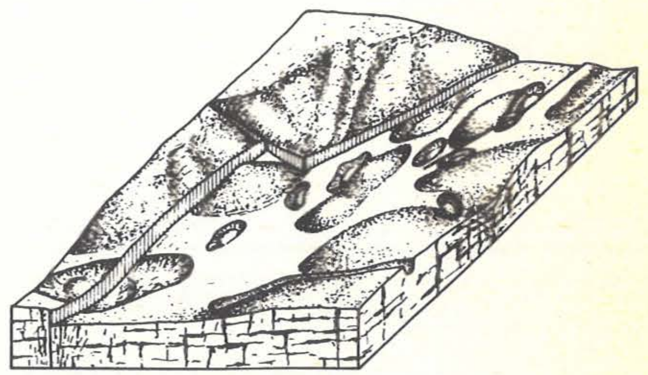

Fig. 1. Palaeomorphology of the Middle Muschelkalk in the eastern part of Olkusz Zn-Pb District.

Triassic limestones and dolomites and the two small, vertical caverns with well-developed tension domes (Fig. 3). These forms were hosted within the thin-layered limestones and presumably resulted from the progressive roof collapse of the cavern up to the formation of natural pressure arc.

Cross-section areas of the caverns outcropped at the surface or in the mine workings vary from 0.0013 to 8.4 sq. meters. More than 57% of measured surfaces had the areas below 0.1 sq. meter. The distribution of measured values is shown on Fig. 4.

Karst caverns are in most cases located along or close to the limestone/dolomite interface. Large caverns develop along the interbedding planes and within the collapse breccias. The latter are accompanied by pressure domes sometimes composed of large blocks (Motyka, Pulido-Bosch, 1985). Small caverns generally belong to the initial karst forms and are produced along the interbedding planes, at the crossing of multi-directional joints and/or at the crossing of joints with interbedding planes. It is suggested that in Triassic carbonates of Olkusz area the karst caverns were produced mostly by dissolution and mechanic destruction of brittle rocks if their mechanical strength has been exceeded.

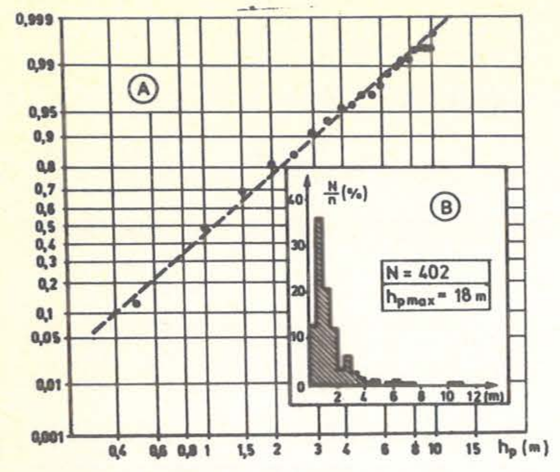

Fig. 2. Distribution of caverns heights (h_p), traced by bore-holes. A - Cumulative relative frequencies. B - Frequency of cavern heights.

4. FILLED KARST CAVERNS

In almost all outcrops of the Triassic carbonates the filled karst cavities can be observed. These are chiefly sink-holes up to several tens of meters across and few to more than ten meters deep. Some of them pass downward into the initial joints along which the dissolution has proceeded. Filled karst cavities are also located along the interbedding planes and in breccia bodies. In the latter forms laminated, clay-sandy internal sediments were observed with fragments of carbonate rocks (Motyka, 1988).

In the mine workings of the Olkusz Zn-Pb District all the types of cavity fillings were noted: detrital, chemical, organic

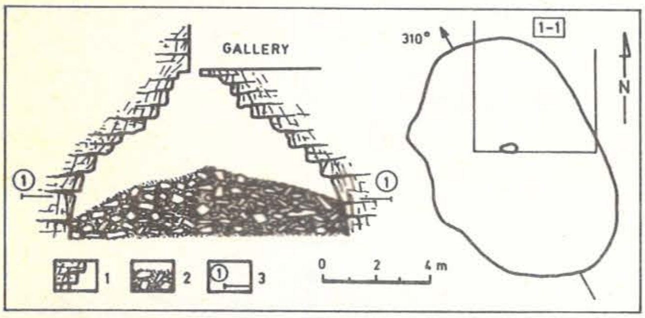

Fig. 3. Large, vertically extended karst cavern in the bottom of a gallery in Pomorzany mine (after A. Kozik, modified by author). 1 - limestones; 2 - blocks mixed with fine-grained matrix; 3 - cross-section line.

and complex (see Paloc, 1977). However, various types of breccias seem to predominate: metasomatic and/or karstic (Sass-Gustkiewicz, 1974). Despite the chemical processes affecting the host-rocks under the influence of waters, breccia structures can be produced in that parts of the Triassic sequence in which the mechanical strength of the rocks has been destroyed as a result of mass removal. Various stages of the rock destruction can be observed corresponding to the various stages of breccia formation (Fig. 5).

In their initial stage of development, the breccia bodies are up to 1 meter thick and several hundreds of meters long. Advanced brecciation corresponding to the matured karst stage produces bodies up to 20 meters high and several hundreds of meters (Sass-Gustkiewicz, 1985). The type of filling material depends on the stage of karstification and on the degree of cementation. During the initial brecciation joint density increases which leads to the formation of cracle breccia (see classification after Norton, fide Dżułyński, 1976). Further dissolution and collapse of the carbonate layers cause the displacement and rotation of the fragments. Simultaneously, the percentage of small fragments and residual material increases which results in the formation of mosaic and rubble breccias (Norton, fide Dżułyński, op. cit.). The final brecciation produces conglomerates composed of large blocks of the karstified rocks embedded within the fine-grained matrix of mostly residual clay, silt and sand (pudding breccia according to Norton). Such breccias are commonly encountered in the mine workings.

Dissolution of carbonate rocks has been accompanied by precipitation of Zn, Pb and Fe sulphides as well as calcite and, occasionally, barite. These minerals form cements in, especially, mosaic and rubble breccias. Moreover, organic matter and brunckite may also be present as fillings of the cavities. Karst caverns in limestones may be filled with redeposited, primarily residual clays whereas in some small, initial caverns laminated internal sediments are commonly observed. The internal sediments consist of clay, silt and sandy fractions and typically occur within the caverns developed in the thin-bedded limestones of Lower Muschelkalk, at the boundary between limestones and dolomites or within the brecia bodies (Fig. 6).

Mining activity and resulting intense drainage of the mining fields caused the rejuvenation and/or intensification of karst processes (in the meaning of Gèze, 1973). Removal of the unconsolidated material composing the pudding breccias resulted in

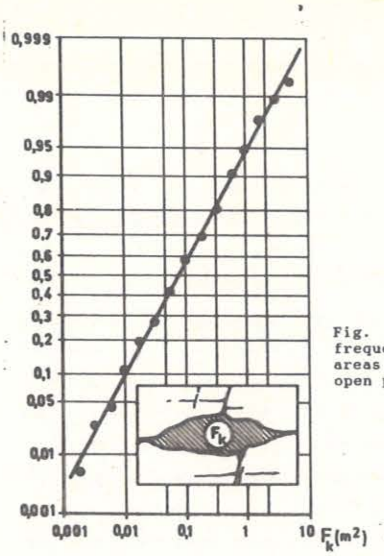

Fig. 4. Cumulative relative frequency of the cross-section areas of caverns (F_k) cut by open pit or mine gallery.

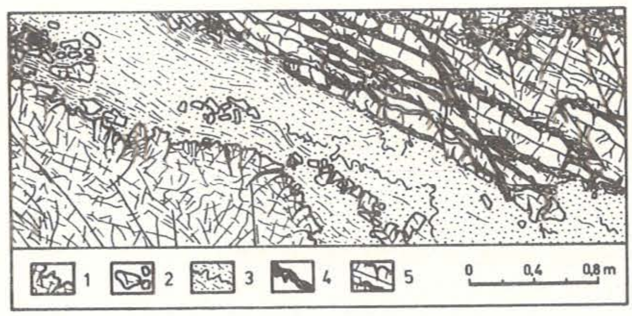

Fig. 5. Various types of breccias. 1 - cracle breccia; 2 - fragments of limestones and dolomites; 3 - pudding breccia (sand, sandy clay and clay with fragments of carbonate rocks); 4 - laminated internal sediments; 5 - mosaic and rubble breccia in limestones.

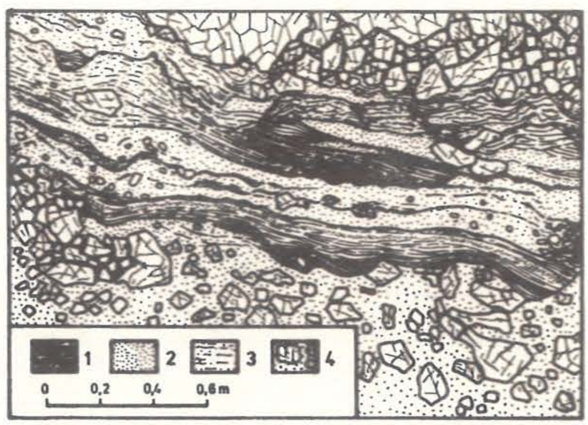

Fig. 6. Internal sediments within breccia structure (Olkusz mine). 1 - clay; 2 - sand; 3 - sandy clay; 4 - dolomite fragments.

their subsidence and opening of the interbedding planes with the displacement of larger blocks (Fig. 7). Increasing flow rate caused by the hydraulic gradient produced around the mines, gave rise to the removal of fine-grained internal sediments and, consequently, to the formation of sink-holes at the surface.

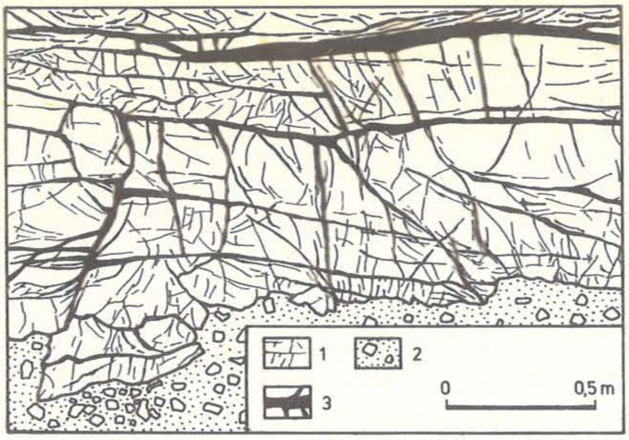

Fig. 7. Rejuvenation of karst processes within the fragment of a breccia body as a result of drainage and compaction of pudding breccias. 1 - limestones; 2 - pudding breccia; 3 - crevices (fissures and opened interbedding planes).

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INFOLGE DER DENUDATION DER BASALTPLATEAUS ENTSTANDENE PSEUDOKARST-ERSCHEINUNGEN UND HÖHLEN

ESZTERHAS, István

Basaltvulkanism has created mostly overlying rocks in Hungary. From the environment thereof destroyed was the less resistive basic stratum, hence mostly typical mountains of truncated cone shape were formed. According to our measurements the stratum carbon contents were high (20 to 40 p.c.).
On the plateaus formed by basalt covers the water infiltrating through gaps becomes heavily carbonic, thus agressive water against carbon will solve the stratum containing much carbon. The same applies to the linear erosion of underground waters. Such caves will settle in the basalt cover. Dependent on the direction of inclination of fracture causing falling in basalt dolinas (occasionally basalt ponds), basalt sumps or splitting caves will be formed. Under the verge of basalt covers lack of material will occur by sqeezing out and/or deflation. Tearing of verges are formed along the breakings vertical to and parallel with verges, forming tectonic caves in several cases.

INFOLGE DER DENUDATION DER BASALTPLATEAUS ENTSTANDENEN PSEUDOKARST-ERSCHEINUNGEN UND HÖHLEN

Der Basaltvulkanismus des Ungarns hat vor allem Decken zustande gebracht. Aus der Umgebung dieser Basaltdecken wurde das weniger widerstandsfähige Grundgestein abgetragen: auf diese Weise sind in der Mehrzahl der Fälle Berge entstanden, die Form eines Stumpfkegels besitzen. Nach unseren Analysen ist der Kalkgehalt des Grundgesteines verhältnismässig hoch /20-40 %/. Durch die Spalten, die im Gesteinsmaterien der Basaltdecken entstanden sind, sickert das Wasser in den Boden hinein, wo es besonders reich an Kohlensäure wird. In dem Grundgestein, das besonders reich an Kalk ist, verursacht dieses gegenüber dem Kalkstein agressive Wasser den Kalkstein lösend einen grossen Stoffmangel. Stoffmangel kann auch als Ergebnis der linearen Erosion des Grundwassers entstehen. Solche Hohlräume des Grundgesteines "vererben sich weiter" auch in die Basaltdecke hinein. Der Richtung der Störungslinien entsprechend, die Einsturze zu ihren Folgen hatten, entstehen Basaltdolinen /unter Umständen Dolinenseen/, Wasserschlinger sowie Risshöhlen. Unter dem Rande der Basaltdecken entstehen durch Herauspressung, bzw. Deflation Hohlräume, in welche der harte Basalt einstürzt. Die Einstürze am Rande entstehen entlag von Risslinien, die vertikal auf den Rand, bzw. mit ihm parallel laufen, und in vielen Fällen tektonische Höhlen bilden.

BAZALTFENNSÍKOK LEPUSZTULÁSA KÖVETKEZTÉBEN KELETKEZETT PSZEUDOKARSZT-JELENSÉGEK ÉS BARLANGOK

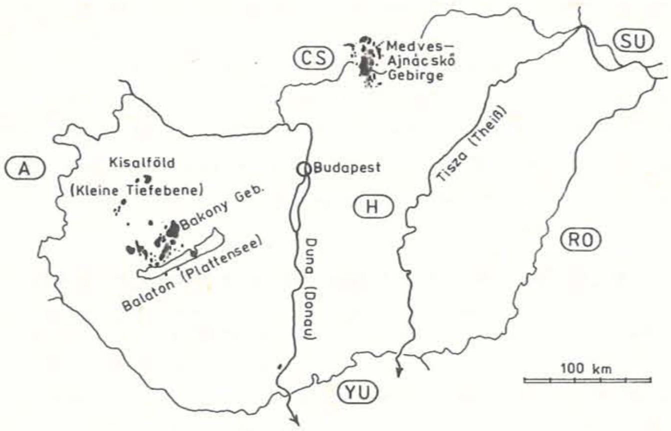
A magyarországi bazaltvulkanizmus nagyobbrészt takarókat alkotott. E takarók környezetéből lepusztult a kevésbé ellenálló alapkőzet, így az esetek többségében jellegzetes csonkakúp formájú hegyek alakultak. Méréseink szerint az alapkőzet mésztartalma magas /20-40 %/. A bazalttakarók alkotta fennsíkokon a repedéseken át beszivárgó víz a talajon áthaladva erősen szénsavassá válik. E mésszel szemben agresszív víz karsztos oldódással tetemes anyaghiányt produkál a mészben gazdag alapkőzetben. Anyaghiányt eredményez ; még a víz földalatti lineáris eróziója is. Az alapkőzet ilyen üregei "öröklődnek" át a bazalttakaróba. A beszakadásokat előidéző törések dőlésének irányától függően bazaltdolinák /alkalmasint dolinatavak/, bazaltvíznyelők, vagy felszakadásos barlangok alakulnak. A bazalttakarók pereme alatt kisajtolódással, deflációval anyaghiány keletkezik. A peremleszakadások a peremre merőleges és azzal párhuzamos törések mentén alakulnak, sok esetben tektonikus barlangokat alkotva.

In der Mehrheit des Basaltvulkanismus Ungarns ist vor 2-5 Millionen Jahren in zwei grö3eren Gruppen hervorgekommen. In der Umgebung der Kisalföld und vom Bakony und in dem Medves – Ajnácskő Gebirge sind ungefähr 100-100 basaltvulkanische Berge bekannt. Die meisten sind aus reinem basaltischen Gestein oder mit wenig Tuff geschichtet entstanden, allein aus Tuff bestehende Berge findet man kaum. Die meisten Lavaergie3ung haben sich in der Form von Decken gefestigt. Unter den Decken sind in den meisten Fällen lockere Schichten, die um die Decken abgeödet wurden, so sind charakteristische Stumpfkegel förmige Zeugenberge entstanden, auf ihren Gipfel mit der flachen Reste der Decken, mit den Basaltmezas. Bei der Abödung der Decken ist eine besondere Pseudokarst-Ladschaft entstanden mit vielen postgenetischen Höhlen. Mit den zahlreichen syngenetischen Basalthöhlen möchte ich mich in diesem Studium nicht beschäftigen. Unser Kollektiv hat versucht, die bestimmenden Faktoren, Gesetzlichkeiten des Entstehens der Pseudokarst-Erscheinungen zu erleuchten, dessen Wesentliche ich in diesem Studium erläutern möchte.

1. DIE GESTEINE UNTER DEM BASALT

1.1. Die territoriale Teilung der Grundgesteine

Auf dem zwei untersuchten basaltvulkanischen Gebiet /Kisalföld - Bakony und Medves - Ajnácskő Gebirge/ kommen unter dem Basalt global dreierlei Sedimentgesteine vor, beziehungweise kommt auch der Basalttuff oft vor.



Basaltgebiete Ungarns

1.11. Kalksteine nach Meeresherkunft Der gro3er Teil des Basaltdeckens der Kab Berg, Agár Plateau, Dobos Plateau sind auf den abgeödeten Trias, Jura, Eozän Kalkstein- und Dolomitoberflächen gesiedelt.

1.12. Oligozän und Miozän Zeitaltrige hauptsächlich Sandsedimente Die Basalten des Medves - Ajnácskő Gebirges sind auf abgekahltem Oligozän und Miozän zeitaltrige Terrain gesiedelt. Auf dem nördlichen /tschechoslowakischen/ Teil war die Abödung gewaltsamer vor der Basaltgie3ung, so kommen hier meistens die aus der Oligozän-Zeit stammenden Schichten vor, die glaukonitischen und apokischen Sandsteine kommen unter dem Basalt vor. Auf dem südlichen /ungarischen/ Gebiet war die Abödung mä3iger, so auf den vorher erwähnten Oligozän-Sandsteinen findet man sogar auch die ganze Miozän-Schichtreihe mit den charakteristischen Sandstein, mit Konglomeraten, mit lehmigen und steinkohlegischen Zwischenbesiedlungen.

1.13. Pontus /Pannon/ Zeitaltrige sandlig-lehmige Sedimente Unter den Basalten von Kisalföld - Bakony sind die meist verbreiteten Grundsteine die Oberpontuser sehr dickige sandig-lehmige Schichten. Ihre Entwicklung ist territorial und horisontal veränderlich. Meist die verschiedenen dickigen, sandigen, schotterigen Schichten wechseln sich mit den lehmigen, kalkmergeligen Schichten. In der Umgebung von Nagyvássony ist der Basalt auf oberpontuser, levanter seitaltrigen sü3wasserigen /innenseeischen/ Kalkstein gesiedelt.

1.14. Basalttuff und -tuffit Bei den stratocharakteristischen Basaltvulkanen /Kab Berg, Somló Berg, Medves Plateau usw./ ist die unterste vulkanherkömliche Schicht hauptsächlich der Basalttuff oder Basalttuffit. Darauf siedelte sich als Basalt erstarrte Lava.

1.2. Das Gleichcharakteristikum der Grundgesteine

1.21. Der wichtige Kalkgehalt

Aus der Sicht der Entstehung der basaltischen Pseudokarsten ist ein wichtiger Betsandteil die Zusammensetzung des Grundgesteins, besser gesagt mit der zusammenhängenden Abödung. Auf diesen Zusammenhang ist zuerst Győrffy Dezső daraufgekommen, später haben Verfasser und sein Team die Untersuchung der Zusammensetzung der Gesteine unter dem Basalt fortgesetzt. Bei den Analysen kam hervor, da3 der Kalkgehalt der meisten Grundgesteine von den Erwartungen viel höher ist /siehe in der Tabelle/. Die Abödung durch karstischen Auflösung der hochkalkhaltigen Schichten ist unter der Basaltdecke auch bedeutend. Die so entstandene Hohlraumbildung durcherbt sich in die Überbasaltschichten /ausführlicher in den 2.3. und 4. Absatz/.

Ort	Gesteine unter dem Basalt	Epochen	$CaCO_3$-Gehalt
BAKONY GEBIRGE			
Kab Berg	Sü3wasserkalk	Pliozän	92 %
	Nummuliten-kalkstein	Eozän	87,5 %
Szebike	Sandstein	Pliozän	46,7 %
Bondoró	Gesteinmehlig Sand	Pliozän	40,2 %
Sarvaly	Sandstein	Pliozän	26,9 %
Szentgyörgy Berg	Sand	Pliozän	18 %
Badacsony	Sand	Pliozän	24,5 %
Fekete Berg	Basalttuff	Pliozän	16,5 %
MEDVES - AJNÁCSKŐ GEBIRGE			
Kis-kő	Glaukonitischen Sandstein	Oligozän	45,1 %
Ragyolc	Glaukonitischen Sandstein	Oligozän	38 %
Szilvás-kő	Aquitanischen Sand	Miozän	20,5 %
	Glaukonitischen Sandstein	Oligozän	15,4 %
Pogányvár	Glaukonitischen Sandstein	Oligozän	13 %

Einige Angaben von dem Kalkgehalt der Gesteine unter dem Basalt /Analyse von István Eszterhás/

1.22. Das Wechseln der verschiedenen Granulärschichten

Die Abrei3ung der Kanten der Basaltdecken verursachen hauptsächlich die verschiedenen Denudationsvorgänge der Granulärgrö3e der Grundgesteine. Nach den Beobachtungen ist die Mächtigkeit der sandigen, lehmigen, mergelichen Schichten verschieden. Die undichte wasserdurchlassende Schichten wechseln sich mit den lehmingen wassersperrenden Schichten. Diese Schichtung ist territorial sehr diskrepant, darum beeinflu3t die Abödung der Basaltkannten nach Form und Modus nach besonderer Art.

2. DIE PSEUDOKARST-ERSCHEINUNGEN VORBEREITENDE ABÖDUNGSVORGÄNGE IN DEM GRUNDGESTEIN

Die Denudation des Grundgesteins ist eine poligenetische Erscheinung, ist Resultat der Erscheinungen der gemeinsamen und nacheinander Einflü3e. Die Abödung von dem Basalt nicht gedeckte, undichtstrukturelle Teile sind viel schneller als bei den bedeckten Teile.

Aus der Sicht der Pseudokarst-Erscheinungen der Basalten sind abödende Vorgänge unter den Basaltdecken viel wichtiger. Die Priorvoraussetzung der Abödung des Grundgesteins vom Basalt ist bedeckt, daȝ das Wasser durch die deckenden Basaltschichten su diesen Schichten hinunterkommt. Dies hat ja kein Hindernis, weil die Basaltdecke nach der Festigung spröd wird und wegen endogene tektonische Einflüȝe, wegen die Resultate der Postbasaltbewegungen Brüche erleidet.

2.1. Die Kelterung ist eine solche abödende Form, als einige Schichten der Grundgesteine plastisch werden und sich wegen den wuchteten Druck aus den Zwischenschichten auspreȝt. Dessen Möglichkeit liegt hauptsächlich in der Nähe der Basaltkanten, wo die Aufdeckung der Erosion der Berghänge freie Basis für die Kelterung sichert. Für die Kelterung sind hauptsächlich der von der Wasseraufnahme plastisch gewordener Lehm und Süȝwasserkalkstein fähig.

2.2. Die lineare unterirdische Erosion greift die Grundgesteine unter den gröȝeren Basaltdecken, mit Stöȝe begleitete Brüche an. Wegen der Brüche sichert meist die kippte Basaltdecke ausreichend viele Wasserspeicher für den Bruch, wo das Wasser fast ohne Behinderung zum Grundgestein hinunterkommt, wo an Ort und Stelle gefundene und mit sich genommene Schutt bewegend erodierende Wirkung ausübt. Eine solche Denudationstätigkeit kann abhängig von den Niederschlägen sein, ob sie stärker oder geschwächt ist oder sogar pausiert.

2.3. Die karstische Löslichkeit ist die gröȝte Materiemangel produzierende abödende Form der Gesteine unter der Basaltdecke. Worüber schon vorher die Rede war, ist der Kalkgehalt dieser Schichten nach den Messungen bedeutend. Die Spaltung des Basalts, obwohl bescheidend als der Kalkstein ist, aber in diesem hinunterläufenden Wasser viel agressiver. Der CO_2-Gehalt der Böden, die den Basalt bedecken, ist nach den vergleichenden Messungen gröȝer /3-6 %/, als die Böden die Kalksteine bedecken /2-4 %/. Anderseits übt das durch den Basaltschichten hinuntertropfende sehr agressive Wasser /Solution/ den kalkhaltigen Grundgestein erreichend übt konzentriert Wirkung aus. So die weniger kalkgehaltenden Gesteine können auch bedeutender karstidieren. Mann kann auch die korrosiven und erosiven Formen der Karstidierung unter den Basaltoberflächen finden. Die Karstidierung knüpft sich in den meisten Fällen su der aushölende Arbeit der linearen unterirdischen Erosion, damit zusammen erhöhende Denudation ausübend. In dem Quellwasser erscheinende gelöste Kalkgehalt liefern Durchschnitt gerechnet von 1 km^2 Territorium in 1 Jahr die Quellen 40 Tonnen, besser gesagt 20 m^3 Kalk weg.

2.4. Die Rolle der Deflation bei der Abödung der Schichten unter der Basaltoberfläche ist kleiner, aber auf die vom Wind geschlagene Seite der Mesakanten, wo der Sand der Grundgestein ist, kommt vor.

3. DIE ÖDUNG DER KANTEN DER BASALTDECKEN UND DIE SO ENTSTEHENDE SPELÄOERSCHEINUNGEN

Auf den Kanten der Basaltdecken entstehen auf die Kante vertikale und mit der Kante paralelle Brüche, und mit denen genetisch verwandte Abreiȝungen, Muren. Diese Erscheinungen verursacht hauptsächlich die Kelterung der Grundgesteine, weniger die Deflation und korrodierende-erodierende Tätigkeit des Wassers. In einigen Fällen bröckelt sich die Kante Steinsäcke gestaltend.

3.1. Bröckelung Einige Sorten des Basalts sind auf die Zerstückelung auf klimatische Einflüȝe fähig /strukturelle Sedimente und bei der Härtung gespaltete/. Aus solchen Basalten stehende Kanten zeigen bei der Bröckelung steinsäckige /orgellige/ abödende Formen. Zwischen den nebeneinander stehenden Türmen sind manchmal tiefe, höhlengroȝe Höhlungen ausgebröckelt /z.B. Sziklakonyha auf dem Somló Berg, Rodostó-Höhle im Badacsony/.

3.2. Auf der Kante vertikale Brüche entstehen bei solchen Basaltdecken, bei denen sich dickere Basaltschicht auf die undichte Sediment siedelte. Aus der Sicht der Masse der Basaltschicht keltert die plastisch gewordenen, von dem Berghang ohne Stützung geliebene Schichten und deswegen geht es auch unter, inzwischen in sich Spannung anhäuft. Wenn auf der Kante die Dickheit der Basaltdecke unterschiedlich ist, löst sich die angehäufte Spannung wegen diesen Unterschied, dem auf die Kante vertikalen Bruch. Längs der Brüchen lösen nach solcher Art frei abgebröckelte Stücke weitere Kelterung aus. Wenn die abbröckelnden Stücke in nach unten ausbreitenden Blöcken brechen, so verbreitet sich der Bruch, manchmal in höhlengroȝe Höhlungen ausgebildet /z.B. Tátika-Schluchthöhle/.

3.3. Mit der Kante paralelle Brüche sind auch wegen der Kelterung entstanden Materiemangel dort, wo an den Kanten die Dickigkeit der Basaltschichten gleich war. Allgemein sind sie öfters, als auf die Kante vertikale Brüche, weil ja die Kelterung an der Kante auf eine lange Strecke geschieht. Darum häuft sich die Spannung in der kalten Basaltdecke mit der Kante paralall, dann brechen die großen Scheiben von der Kante wegen der Auflösung der labilen Gleichgewicht paralell ab. Von der Basaltkante abgebrochene, aber susammengebliebene Gesteinmenge sind zu den an Ort und Stelle gebliebenen Teilen gesunken und denen sind sie ein wenig entfernter gegangen. Die Fortbewegungsgröȝe ist territorial unterschiedlich, manchmal bringt es mehr Meter breite Schluchthöhlen zum Stande /z.B. Remete-Höhle auf dem Tátika oder Pokol-lik auf dem Bonderó/.

3.4. Die Kanteabreiȝende Steinstraȝe ist mit den Höhlen von den paralellen Brüchen hervorgebracht sind genetisch verwandte Erscheinungen, aber in der Maȝe ist es gröȝere und morphologisch zeigt sie auch ein anderes Bild. Die abgerissene Gesteinscheiben ist nicht in einem geblieben, sondern die hausgroȝe Stücke haben während der Ausbreitung paralelle Graben, sogenannte "Steinstraȝen" geformt. An dem Hang gerutscht sind in ausgebreiteten Gesteinmaȝen offene und bedeckte Spalten entstanden - diese letztere sind die atektonische Höhlen /z.B. die Steinstraȝen des Kovácsi Bergs und der Pogányvár mit vielen Höhlen/.

3.5. Die Steinflüȝe sind die charakteristischen Formen der Ödung der Basaltkanten. Bei den Füȝen der Basaltkanten findet man immer groȝe Menge Gesteinschutt. Dieser Schutt stammt einerseits aus dem Zusammenbrechen der Basaltscheiben, anderseits aus den Stücken, die vom Kantenmauer wegen der Wärmeschwankung abgebrochen sind. Von den groȝen Götzen zusammengehäufter Schutt beinhaltet manchmal ausgebreitete labyrintcharakteristische Scheinhöhlen /z.B. Höhlen des Steinmeeres der Pogányvár/.

4. DIE PSEUDOKARST-ERSCHEINUNGEN DER BASALTPLATEAU

Die Zweitkarstformen der Basaltplateaus hat die Unterkarstidierung nach der Lavafestigung hervorgebracht. Diese Karstschluchtung wurde in die Basaltschicht übererbt. Daȝ durch die übererbte Schlichtung wasfür Pseudokarst-Erscheinungen hervorgebracht werden, sind darin die zueinander proportionierende Richtung in dem Basalt enstandenen Brüche bestimmend. Diese Bestimmung durch den Brüchen hat der Verfasser gezeigt.

4.1. Die Basaltdolinen Wenn über der Schluchtung der Grundgesteine die vertikalen Brüche des Basalts paralell sind, entstehen auf der Oberfläche eingerissene oder eingestürzte Dolinen. Nach unseren Beobachtungen sind diese Dolinen in der Reihe geordnet, wahrscheinlich leuchten sie das karstische Wasserleitungssystem in dem Grundgestein auf die Oberfläche /z.B. Kab Berg, Dobos Plateau/.

4.2. Die pseudokarstischen Dolinenseen sind mit der Weiterentwicklung der größeren Basaltdolinen entstanden. In den durch Einsturz entstandenen Dolinen ist zuerst das Wasser periodisch aufgehäuft, später, als das angesiedelte Flora genügend Wasserschließende Schicht produziert hat sind sie zu ständigen Seen geworden. Die Älteren sind sümpfig geworden, wurden aufgestopft /z.B. Basaltdolinenseen sind auf dem Kab Berg, Fekete Berg, Dobos Plateau/.

4.3. Basaltwasserschlinger entstehen, wenn die vertikalen Brüche der Basaltschicht über dem schluchtenden Grundgestein nach unter größer wurden /Lampenschirm-Form/. In solchem Falle entfernen sich die abbrechenden Basaltblöcke in den immer größeren Spaltungsräumen immer besser voneinander große wasserleitende Spalten hinter sich zu lassen /z.B. Kab Berg, Fekete Berg/.

4.4. Aufreißende Höhlen entstehen, wenn die Brüche der Basaltdecke nach unten zusammenhaltende Richtung haben /Blumentopfform/, weil die unteren Schichten des Basalts in dieser Falle fähig zum abreißen sind, aber die oberen verengern sich - daswischen entsteht ein Schluchtsystem. Aus dem Wesen der Sache entstehen diese Höhlen durch den Menschen belaufbare natürliche Eingänge solcher Höhlen selten /z.B. Basalthöhle in Pula/, aber ihre Zahl kann ähnlich, wie der Basaltwasserschlinger sein. Innerhalb des Basalts können sich durch syngenetischen Weg Höhlengänge aufreißen /z.B. Halász Árpád-Höhle/.

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THE CONNECTION BETWEEN THE DIFFERENT SOIL-TYPES AND THE SEEPING WATER SYSTEM IN THE CAVE HAJNÓCZY

MUCSI, Laszlo

Our further observations showed that long-lasting staying in the cave can improve significantly and permanently the pulmonary function in healthy people. This improvement gives rise to several factors. One of the most effective therapeutical component is the speleoaerosol deriving from the dropping water in the cave.

The aim of this study was to investigate the changes of the chemical compounds in the speleoaerosol and in the dropping water depending on the soil-type above the different parts of the Hajnóczy-cave.

The comparative analysis of the soil-types on the catchment area of the cave, the seepage waters as well as the dropping waters shows that the soil plays an important role in the forming the chemical compound of the dropping waters. We found dropping waters of various features /mainly in the ion concentrations/ in the different parts of the cave under various soil-types.

Our present observations show that the quality of the soils can exercise significant influence on the therapeutical efficiency of different cavities in the caves.

BEZIEHUNG UNTER VERSCHIEDENEN ERDBODENTYPEN UND DEM TROPFWASSER-SYSTEM DER HAJNÓCZY-HÖHLE

Unsere frühere Beobachtungen haben bezeigt, daß ein längerer Aufenthalt in einer Höhle die Atmungsfunktionen der gesunden Menschen wesentlich und standhaft verbessern können. Diese Verbesserung ist ein Ergebnis mehreren Faktoren. Einer der wirksamsten Therapiekomponenten ist der Speleoaerosol, der aus den Höhlen-Tropfwässern stammt.

Unsere Forschung hatte das Ziel um die Veränderungen der im Speleoaerosol und den Tropfwässern anwesenden chemischen Verbindungen — über den verschiedenen Erdbodenteilen der Hajnóczy-Höhle — in der Funktion des Erdbodentyps zu untersuchen.

Die Vergleichs-Analyse der Bodenarten, der Sickerwäller, sowie der Tropfwäller beweisen, daß der Erdboden eine wichtige Rolle in der Entstehung der chemischen Zusammensetzung von Tropfwässern spielt.

Wir haben Tropfwässer mit verschiedenen Eigenschaften gefunden /besonders in Ionkonzentrationnen/ unter verschiedenen Bodenarten, auf unterschiedlichen Teilen der Höhle.

Unsere Beobachtungen weisen, daß die Qualität /Zusammensetzung/ der Erdboden die therapeutische Wirkung der verschiedenen Räume der Höhle wesentlich beeinflussen können.

1. INTRODUCTION

In former observations we analysed the microclimate of the cave - Hajnóczy and registered changes in the respiratory function of the cave caused by the stay and speleologic activity.

We reported /2/ that a treatment-like stay in the cave could significantly improve the respiratory function of the healthy individuals. This improvement is the result of several correlated factors. Among spirometric parameters, PEF /relevant for obstructive disorders/ most precisely followed these changes. Our later observations argued in favour of the hypotetic existence of positiv bronchomotor tone in healthy individuals.

The aim of this study was to investigate the connection between the surface-soils and the microclimate of the cave.

2. RESULT

There are different soil-types on catchment-area of the cave. This variety is the result of the geologic structure /Fig.1./. The cave-Hajnoczy was formed in cherty grey limestone /Upper Ladinian/. The elder /Lower Ladinian/ sequence of dark grey shales was thrust on to the cherty grey limestone. There is shale above the cave on a big area and what is more, the overthrust was more significant earlier.

The soil-types were arranged in the following groups:

1. gritty soil is full of rubble,
2. black rendzina,
3. brown rendzina,
4. acidic brown forest soil.

On Fig. 2. you can see where the different soil-types are above the cave.

The first soil-type is in the top area of the hill Odorvar, in a little rock garden. The thickness of the soil is very little - 5-10 cm - in the rock garden. The karren-phenomena and the soil-development show that the gritty soil is the remain of the black rendzina. The thinning down of the soil can be caused by the former treefelling and by the following erosion.

The black rendzina developed closely to the cherty grey limestone. The dark colour soil, which is rich in humus, covers the surface uniformly. The rubble of dark grey shale accumulated in the sand-fraction of the black rendzina and in the cave-parts under that area. The geologic overthrust is proved by this fact.

The brown rendzina is paler and less abundant in humus. It shows the geologic boundery line between the cherty grey limestone and the dark grey shale. The brown rendzina occupies an intermediate position between the black rendzina and the acidic brown forest soil. The hidden-opened karst changes continously into the covered karst.

The acidic brown forest soil developed on the dark grey shale. The rubble of the shale occuring in the soil increases the speed of the soil-erosion.

The analysis of the water soluble ions of the soil shows that the greatest number of ions are in the black rendzina /Fig. 3./. The brown rendzina and acidic brown forest soil contain almost the same quantity of ions. This is the result of the humus as well as of the replaceable ions in larger quantity in the black rendzina /Fig. 4./.

The water dropping into the cave have different chemichal compounds. The dropping waters can be compared with each other because the sample plots are found near to each other in every place in the cave. The sample plots arranged in groups based on the ionconcentrations of dropping water /Fig. 5./. A high level of Calcium and Magnesium characterizises the first group. The sample plots were always under the surface with black rendzina. The minimum quantity of the Calcium and Magnesium is in the second group. These places are under the surface covered by brown rendzina. The values of the third group are between the previous groups. Their sample plots in the cave are always under the acidic brown forest soil.

You can see that the dropping waters kept their character in ionconcentrations, which were shown by the investigation of the water soluble ions of the soils.

The soil-layer is thick in the karst covered by forest. The rainfall seeps down slowly there, it becomes more aggressive and richer in humus. The development of the dripstone is slower in the cave-parts under barren-opened karstfield, because the ionconcentration is smaller and the rainfall flows away quickly on the rocks.

3. DISCUSSION

The characteristic microclimate of the cave, for example, the high relative but small absolute humidity, the high carbondioxide concentration of the air, the chemichal compounds of the speleoaerosol have a significant influence on the therapeutical efficiency in the cave. These factors are result of the quantity and quality components of the seeping waters.

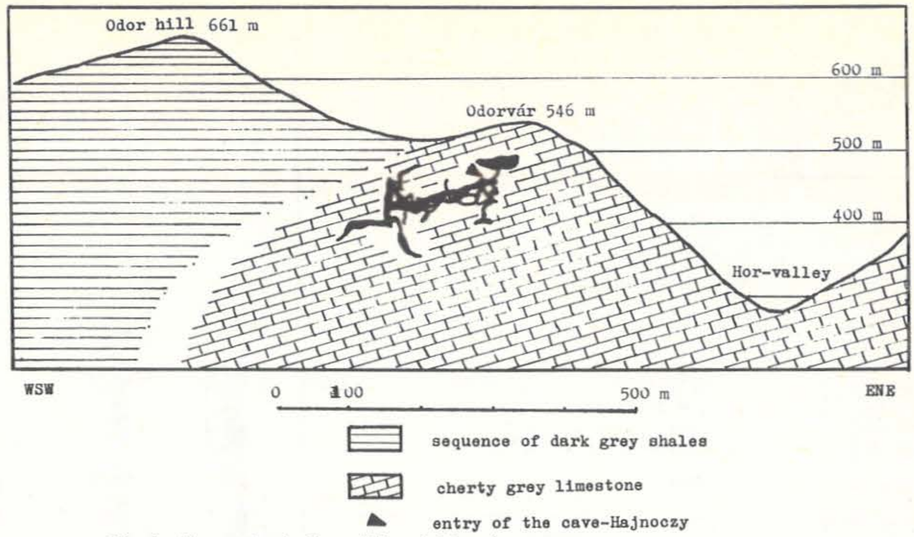

Fig.1. The geological profile of Odorvár.

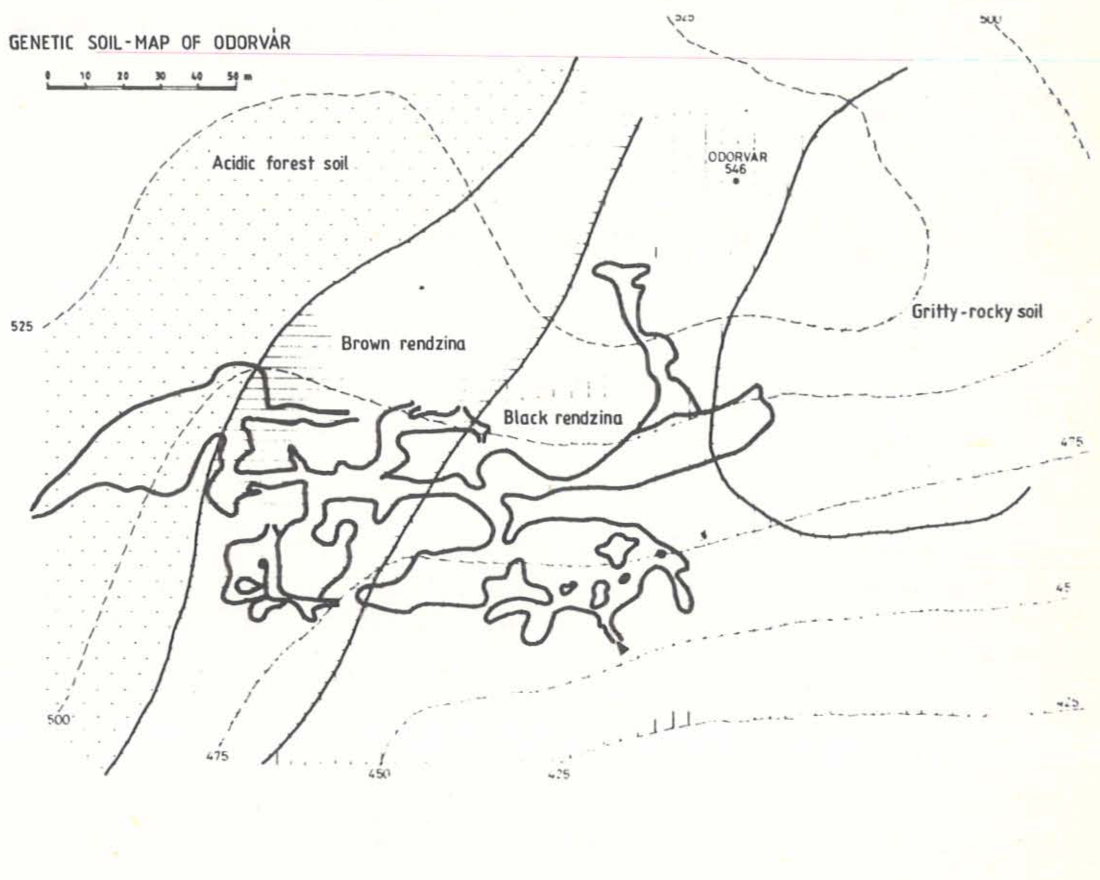

Figure 2. Genetic soil-map of Odorvar

cave-Hajnoczy

entry of the cave

level-line

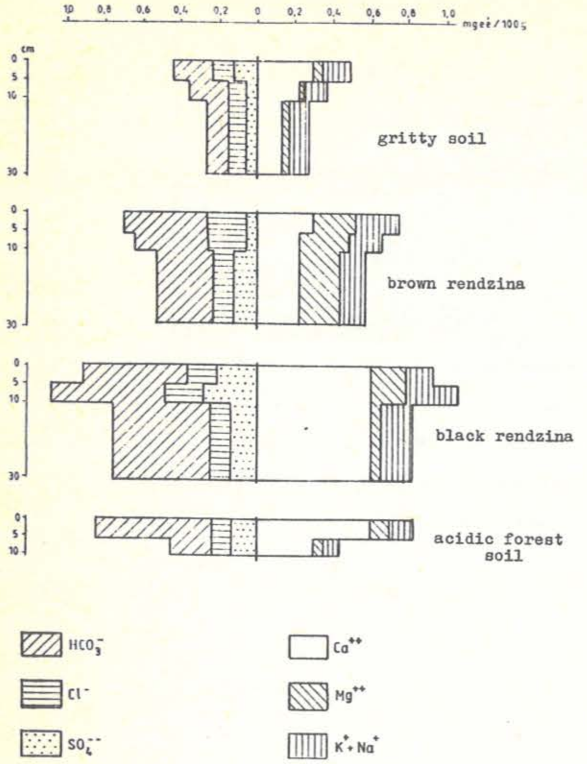

Figure 3. Replaceable ions of the different soil-types

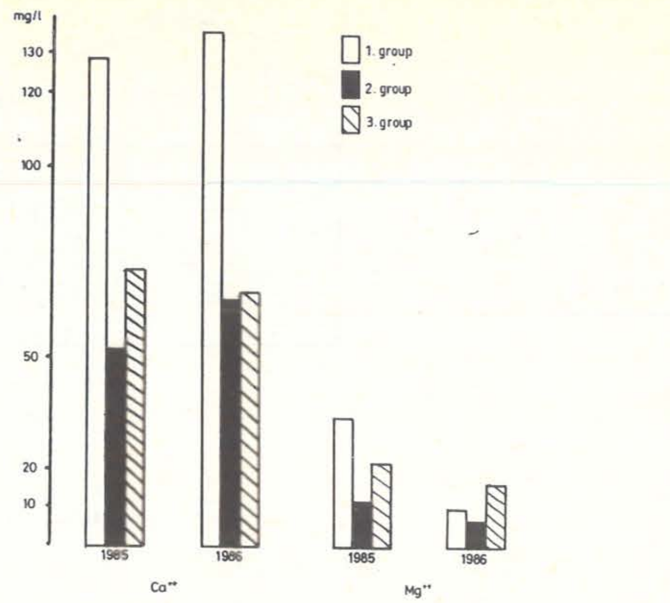

Figure 5.
The Ca- and Mg-ion-content of the water-samples collected in Hajnoczy-cave in July 1985.1986., in terms of milligram/litre.

Soil-type	G.s.	G.s.	B.r.	B.r.	B.r.	Br.r.	Br.r.	Br.r.	A.f.	A.f.	A.f.
deepness	5 cm	10 cm	5 cm	10 cm	30 cm	5 cm	10 cm	30 cm	5 cm	10 cm	30 cm
pH KCl	6,63	6,75	6,58	6,91	6,91	5,97	5,96	5,94	5,55	4,4	4,04
pH H_2O	7,05	7,18	6,55	6,76	7,13	6,38	6,41	6,55	6,24	5,54	5,34
$CaCO_3$ %	5,2	7,2	0,1	0,1	0,7	0	0	0	0	0	0
NO_3+NO_2 ppm	2,9	6,6	12,3	6,8	9,4	43,3	16,5	5,0	8,3	2,3	1,5
Fe ppm	82,4	59,8	832	487	442	512	451	471	437	555	509
Mg ppm	126	106	87	51	57	278	248	192	181	148	208
Na ppm	61	71	11	18	14	19	15	20	51	61	77
Zn ppm	14,6	9,5	15,6	13,6	16,8	20,9	12,5	4,6	6,5	4,2	2,9
Cu ppm	4,7	4,1	8,1	9,8	12,4	5,4	4,7	4,2	3,4	3,8	4,1
SO_4 ppm	11	1	2,5	0,1	1,3	9,2	2,8	0,2	10,8	1110	25,4
humus %	5,5	5,2	5,15	4,93	5,29	5,46	5,32	2,5	4,3	3,2	2,7
0,00-0,002 mm %	13	16	19	20	23	11	13	15	6	8	9
0,002-0,02 mm %	15	16	15	18	21	19	18	15	8	10	11
0,02-0,1 mm %	19	20	17	22	23	21	20	16	17	18	27
0,1-2 mm %	46	43	32	26	26	22	43	21	44	44	48
2-20 mm %	7	4	27	14	7	27	5	33	25	20	15

Figure 4.
G.s. = Gritty soil B.r. =Black rendzina
Bl.r.= Brown rendzina A.f. =Acidic forest soil

The soil-types can be found on the catchment-area of the cave, and the oozing in water, just as the analyse of the dropping-water of the cave shows that the soils are important from the point of view of chemical composition of the dropping--water. It is provable that the dropping-water, which have got various characteristics, first of all they have got various ion-compositon, appear in the parts of the cave being under the different soil-types. The characteristics of the disolved-ion-content of these dropping-waters are coming into being next to the infiltration through the soil.

In consequence the surface-soils are very important in the forming of the therapeutical effect in the cave. This connection is the reason why the soil-erosion can decreases and on the other hand the forest-plantation and the soil--strengthening can improve the therapeutical effectivity.

Our present observation shows that the quality of the soils has a significant influence on the therapeutical efficiency of different cavities in the cave.

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RESULTS OF ELECTROENKEPHALOGRAPHIC (EEG) AND PSYCHOLOGICAL EXAMINATIONS OF CAVE EXPLORERS

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During the regular medical examination of healthy male civil flying-equipage /pilots and navigators/ lo-12 per cent showed a special EEG sign which did not correlate with any of their parameters /age, flying hours, type of aircraftm weather sensitivity etc./. This sign was found by the same individual at repeated examinations over years. It was assumed that the EEG sign is somehow related to their vocation and personality type. To check this hypothesis a group of volunteers /n=54/ with no medical history and -according to the public opinion- with dangerous jobs /cave explorers,etc./ were examined. /Their distribution by age, sex and 'occupation' see Table 1./

In this pouplation investigated, the EEG sign was observed in near 13 per cent of all cases /Figs.1.-3./. The characteristic EEG signs are indicated by an arrow: they are generalized, symmetric, slow-wawe crescendo-decrescendo transients, emerging from the background activity, uninfluenced by hyperventilation and apnoe. These EEG signs /which are not pathological deviations!/ point to dienkephalic structures, which play a well-known role in the regulation of behaviour.

In order to reveal the background of this phenomenon in more detail, psychological examinations /exploration, Rorschach,Lüscher, SSS tests/ were performed by the persons who showed the EEG sign and by their counterparts. Following common features were found: high level of education; accentuated demand for physical activity, free movement, informality; need for autonomy; hunger for stimuli. Their achievements serve to compensate their lability of self esteem; in their human relations they are left alone.

It is to be underlined, that in none of the cases did the psychological examinations indicate any organic neurological disease.

1. EEG INVESTIGATIONS

It is a well known fact that the civil flying equipage /pilots and navigators/ are from medical point of wiew a stricly selected population and regularly controlled. lo-12 % of this "very healthy" population whowed a special EEG sign. It was found by the same individuals at repeated examination over years and in different situations consistently and without any clinical complaints or signs. This EEG sign is an approximately synchronous, generalized, symmetrical slow-wawe crescendo-decrescendo /theta/ transient, emerging from the beckground activity. with a duration of half to several seconds. As we could not find any correlation between EEG sign and other parameters /age, flying hours, type of aircraft, weather sensitivity, etc/ it was assumed that it is somehow related to their vocation or - with other words - to their personality-, and vegetative type.

To prove the hypothesis above we choosed another group of volunteers with no medical history whose job, "hobby" is - according to the public opinion - also very dangerous, to see whether they produce the same EEG sign. We choosed the speleo-alpinists /cave explorers/ and light divers, tho make this "job" from enthusiasm, as sportsmen, voluntarily. Our cascadeurs did not submit themselves to medical and psychological examinations.

The examined papulation consisted of 54 young volunteers /females and males/ completed with 4 glider pilots /females and males/ and 1 already pensionated bomb disposal squad member. Meningitis or meningo-enkephalitis in the previous history and commotio cerebri with residual EEG signs were the reason as 3 and 2 persons resp. were dropped out /table I./. The examined volunteers make this "job" for 5 to 37 /mean 16,2/ years i.e. they are reliable members of the staff and do it as a serious hobby. At the time of the investigation they had no complaints and any symptoms.

SPELEO-ALPINISTÁK EEG ÉS PSZIHOLOGIAI VIZSGÁLATÁNAK EREDMÉNYEI

A polgári légiforgalom egészséges férfi hajózó állományánál rendszeres vizsgálatok során lo-12%-ban különleges EEG jeleket lehetett észlelni,ami egyetlenpparaméterükkel sem correlált /életkor,repült idő,géptipus,időjárási érzékenység,stb./, ugyanannál az egyénnél éveken át, megismételt vizsgálatok alkalmával kimutatható volt.Ezért föltételeztük, hogy az EEG jel választott hivatásukkal, személyiség tipusukkal függ össze.Ennek ellnőrzésére egy másik, a közfelfogás szerint szintén veszélyes munkakörben önkétn.dolgzó csoportot /n=54/ vizsgáltunk /megoszlásukat az l.tábl. mutatja/.

Az EEG görbéken /1.-3.ábra/ nyil mutatja a jellegzetes jelet: generalizált, szimmetrikus, a háttértevékenységből kiemelkedő, lassu hullámokból álló, crescendo-decrescendo jellegü sorozatok, melyeket hyperventilatio és apnoe nem befolyásol.Ezek az EEG jelek a dienkephalikus strukturákra utalnak, közismert ezek szerepe a magatartás szabályozásában. A vizsgált populációban 13 %-ban észleltük.

Ez utóbbiaknál és választott párjaiknál psycholgiai vizsgálatot is végeztünk /exploratio,Rorschach,Lüscher,SSS test/.Ezek eredményei: magoas átlagos iskolai végzettségy fokozott fizikai aktivitás, szabad mozgás-igény; fokozott inger-, élmény-éhség; önértékelési labilitásukat teljesitményükkel kompenzálják. Emberi kapcsolataikban magukra maradnak. Ötödrészük introvertált, egy ötödük kifelé forduló, aktiv szerepre törekvő.

A psychologiai vizsgálatok sem utaltak organikus idegrendszeri eltérésre.

Table I.

a., Examined volunteers	59
dropped out:	
st.p. meningoenkephalitidem	-3
st.p. comm.cer. residual EEG-sign	-2
	n= 54

Distribution according to

b., age: 16 - 5o /57⁺/ years /mean: 33,6/

c., sex:

female	6
male	48

d., "job":

speleo-alpinists, light divers	49
glider pilots	4
bomb disposal squad member	1

+Only the single bomb disposal squad member had 57 years.

Table II.

EEG sign present:

total number n = 54

EEG sign	case	per cent
+	4	7,4
±	3	5,55
	7	12,95

sign uninfluenced by hyperventilation and apnoe /Table II., figs 1-3./

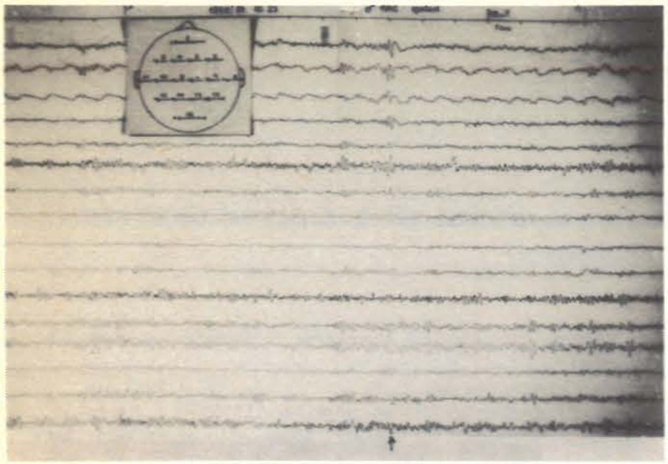

Fig. 1. Male cave-explorer, 42 years. Resting EEG. EEG-sign at the arrow.

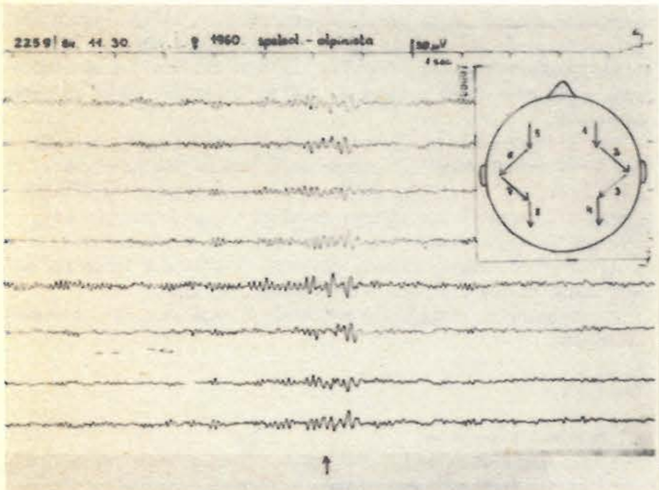

Fig. 2. Female cave-explorer, 24 years. Resting EEG. EEG-sign at the arrow.

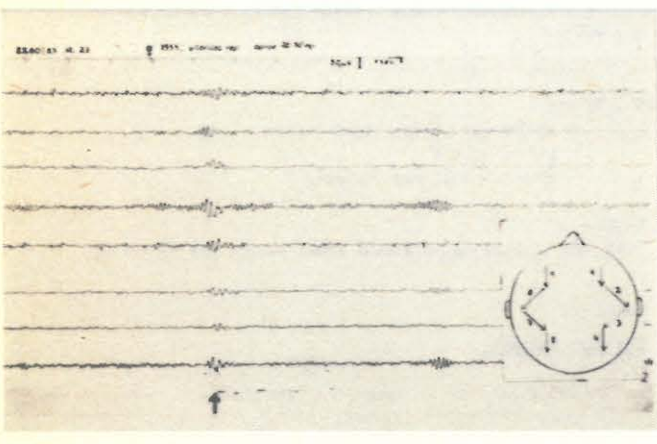

Fig. 3. Female glider-pilot, 28 years. Apnoe EEG. EEG-sign at the arrow.

These synchronous, generalized, symmetrical EEG signs -by no means pathological alterations! - point to dienkephalic structures which are the first collector of sensorial stimuli coming from internal or external milieu and whose role as in maintaining hormonal and vegetative equilibrium as in regulating of behaviour is well known.

The Curry weather-sensitivity test, the ergotrop/trophotrop quotient /E/T/ and the vegetative index /VI= $1 - \frac{D}{P} \cdot 100$; D = diastolic blood pressure, P = pulse rate /of lo persons with no EEG sign and those of lo matched pairs /sex and age/ who had + or $\pm$ EEGswere compared. One, two or all three tests gave an opposite result /the EEGs were already different!/. This proves that the presence or absence of EEG signs is to be observed at persons with different vegetative reactibility, in almost all cases the personality types were different too.

Our EEG observations have a practical benefit, namely in the case of /sport/ medicinal examination on the basis of the above mentioned EEG-sign could not be reject a candidate, moreover it may be, that from them resruite the best speleo-alpinists, divers and gliders.

2. PSYCHOLOGICAL INVESTIGATIONS

Our next question was whether the presence of absence of the EEG-sign shows any correlation to the personality type or is there any special difference from the general population. 24 cave-explorers with great expertise were examined autumn,1985. /mean age females: 26,o; males: 35,2 years/ by means of Rorschach, Lüscher test and sensation seeking scale /Zuckerman 1978. SSS/ and of clinical exploration.

7o,8 % educated at university and high scool. Nearly in all cases their education and special training /e.g. ingeneers of hydrogeology, of chemistry and of metallurgy, etc/ are closely related to cave-exploring and are directly profitable in field and theoretical work. They have a great claim to physical activity: 33 % have had formerly good results in different sports. Many of them choosed a working-place where they may work independently and is guaranteed their free movement /e.g. in economical teams, civil cooperatives/. According to one's opinion the fact, that they have not to work in a hierarchic organisation is already a great reward. According to this, the psychological tests revealed their great need for independency and autonomy.

The red preference in the Lüscher test showed their need for activity and for autonomy /summarized value: 238/, the yellow preference is also greater /2o8/ as by the average population. Red and yellow is chosen in first and second range by 17 persons. Most common negative choice are the violet and black: most of them refused the blue /symbole of quiet and peace/. All these show their restlessness, awareness for stimuli and experiences /TAS 8,7/.

The explorations revealed their motivations, why do they claim to cave-exploring and why did they choose it. So many of them mentioned the desire of adventures and of risking their life. Others enjoy the underground silence or quietness. One of them explained his feeling "as he would became a child again" in the cave. /It needs further investigations, what kind of conscious or unconscious needs are satisfied by the cave-exploring/. Many of them said unanimously that they want to prove - for themselves and for others - their capacities, their achievements, force, skill and courage. One of them said very properly that they compensate their own weakness with their activity. The great majority of the interwiewed did not agree that the cave-exploring would be dangerous, ded not find any difference between walking at the street or cave-exploring. These seemingly rational statements are however a kind of averting strategies: some interwiews reveal the experience and solution of a dangerous situation.

The Rorschach associative material of cave explorers is very typical. E.G. "this is a section of a sacht/aven map ...abyss, trees and water on the bottom of it", "this is a circus-performance somebody is precipitating two others try to catch him", "at the edge of a split/abyss human figures strech their hands". "Climbing men stretch their arms down, aiding the others". That is: besides the motive of danger also the helping-effort, the clearing-away the danger is to be seen.

Human relations: as a result of the great need of autonomy and of independence on one hand, the indifferentiated sentiments on the other, 5o % could not build up true mature interpersonal relations, given a weak need of habitual social contact, they remain alone. Of he interwiewed only

29 % lives in normal well regulated familial relation or partnership;

5o % divorced, widow, lone or lives in occasional partnerships;

25 % has a bleak emotional life with a narrowed outward interest;

33 % strives to enhanced objectivity and is of materialinterest;

2o % is introverted: passive observer of the events around him; by

33 % we have found signs of dysharmonic personality, with vegetative sign of anxious tension /gastris complaints, sleep disorders/.

16 % found we extroverted personalities with active role seeking.

In the examined population we found a variety of personality and conflict-elaboration types:

hystero-impulsive	29 %
anxious-neurotic	29 %
Immature-infantile	17 %
psychopathic aggressive	21 %
mature, integrated	4 %

The percentage of pathological attitudes and dissocial tendencies is sufficiently high. It is probable that cave-exploring is a possibility for tension-mindering and in their special experiences one may see a kind of autotherapeutic tendency /Dumfarth/.

All cases examined show no sign of organic neurological disease!

Summarizing:

The mean motivations of cave-explorers are the seeking of adventures and sensations. The self-confident facade however disguises a deep disturbance of self esteem resulting an intense need to prove themselves. The experiences and the successes of their activity for years is an important evidence too.

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THE LATEST RESEARCH OF SPELEOLOGICAL OBJECTS IN DINARIC KARST AREA (YUGOSLAVIA) FROM THE GEOLOGICAL POINT OF VIEW

GARAŠIĆ, Mladen

The author describe some new caves which have been founded a few years ago. Some of them are the deepest, and the longest in Yugoslavia and Croatia. For example:

Jame na Vjetrenim brdima in Durmitor mountain - depth 897,5 m is the deepst vertical shaft in Yugoslavia. Special geology position (in flysh beds) are described.

Đulin Ponor - Medvedica cave system are the longest cave in Croatia, and the second in Yugoslavia - lenght 15860 m. Special and rare erosion forms are present in this cave.

Muškinja - Panjkova - Crno Vrelo cave system are the third long cave in Yugoslavia with length of 12920 m. Many cave diving are made in this system. More the 20 syphons are dived there.

In this moment more the 17000 caves are know in Yugoslavia (more then 15000 caves are in Dinaric Karst) and prognosis is that it is only 1/4 of the present caves in Yugoslavia.

1. INTRODUCTION

In the last few years Yugoslav speleologists have found and researched some of the very deep and very long caves and pits in Dinaric-karst-belt.

In our days, over 17.000 speleological objects are known in Yugoslavia (and more than 15.000 in Dinaric karst system) but we assume that it is only about 25 percent of all speleological objects in Yugoslavia.

In this material are presented the short descriptions of three very interesting and big speleological objects: **Vjetrena brda pit, Đulin ponor-Medvedica cave system,** and **Muškinja Panjkova - Crno vrelo cave system.**

2. VJETRENA BRDA PIT

This pit is found on Durmitor mountain in SR Montenegro, and the entrence is situated on the 2196 m above sea level.

The researches were done in 1984., 1985 and 1986. (topographic surveying, diving, photographing, geological mapping).

Vjetrena brda pit is interesting because of its significant deep (897,5 m) and because of the surrounding (rocks) in which it is developed there it is a Upper Cretaceous Senonian flysch, so called "Durmitor flisch" (known in literature). It is a rock complex, about 1000 m wide. Caracteristic of that complex is rashress in changing of fatness and position of its beds. This complex starts with beds of breccias and conglomerates about 50 m wide., and then follows very intensively wrinkled structure of clay, marle, sand and limestone parts of beds. That part of flysch is several hundreds metres wide. After that there are the limestones which probably transform in Paleogene limestones. In Vjetrena brda pit the cherts are seen, which, with its layerish appearance, obviously show the intensive wrinkling of layers. Generally it is a matter of the part of synclinorium which anticlines and synclines follow the north-east fall (fig 1.). Very close to this object there is a contact of so called "Durmitor nappe" which "covered" Jurassic carbonate beds on Cretaceous flysch. Neotectonic moving of this area is very intensive and during Neogene and Quarternary that part rose over 1.500 metres. Recent vertical movements of the earth surface in that area are about 6 mm/year.

Vjetrena brda pit potential (fig 2.) is over 1500 metres, while the today's deep of 897,5 m is the greatest deep in speleological objects in Yugoslavia (G a r a š i ć, M. 1989.).

3. CAVE SYSTEM ĐULIN PONOR-MEDVEDNICA

Althrough Đulin ponor and Medvednica are konwn from the speleological literature or over 60 years, only in recent few years these two caves are connected in one, so their length is extented from 1000 metres to over 15.860 metres. (Č e p e l a k, M. 1986.). The largest Yugoslav cave is still Postojna cave. The entrances in these cave are situated in the very town of Ogulin in SR Croatia.

Cave system was formed in Lower Cretaceous limestones, rarely in dolomites under which there are dolomites of the upper Malm (Upper Jurassic). The object was mostly formed by that contact and potential lenght is over 30.000 metres. Since it is a matter of active abyss the researches are very difficult, and also because of the very complicated morphology of the objects (dendritic and multifloored cave system).

Particular part of this system are the most different corrosive forms (whirlpoolpots, fasettes) and particular small-forms (G a r a š i ć, 1986.) which can't be formed in that form in no other cave of Dinaric system.

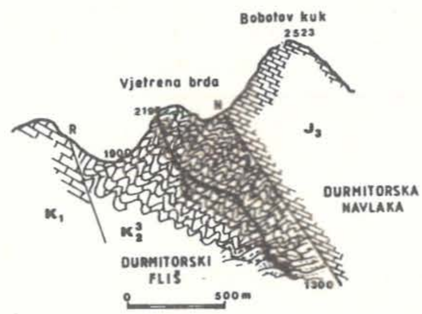


fig 1. - Geologicas cross section (Durmitor mountain and Vjetrena Brda pit) K_1 - Lower Cretaceous limestones, K_2^3- Senoman flysch called "Durmitor flysch", J_3 - Upper Malm limestones, R-fault, N-nappa called "Durmitor nappa"

4. CAVE SYSTEM MUŠKINJA-PANJKOVA-CRNO VRELO

This cave system also has been one special success of the speleologists, because since 1983. up today over 12.920 metres of cave channels have been researched, and of that number over 11.000 metres was with water in (fig.3.). This object is situated near the Plitvice lakes in SR Croatia (G a r a š i ć,M. 1988.). In the system formed in under and upper cretaceous limestones there are 24 syphons and the potential of the object is about 30.000 metres. The great quantity of water is found in this system, up to now the most in Dinaric karst.

Neotectonic researches (G a r a š i ć,M.1984.) show the the area in which this system was foremed rises relatively fast and that the system is morphogeneticaly young in the speleological meaning.

5. CONCLUSION

In the last few years the speleologists from Zagreb have researched several very interesting object in geological and hydrogeological meaning.

Vjetrena brda pit (the deepest pit in Yugoslavia and in Balkan), cave system Đulin ponor-Medvednica (the largest cave in Croatia, the second largest in Yugoslavia, with special corrosive formes) and the cave system Muškinja-Panjkova-Crno vrelo (the third largest cave in Yugoslavia, the greatest quantity of water in Dinaric system, the greatest number of siphons).

In future in these objects the speleological researches will be held, which will contribute with the new geological date, important not only fot the object area, but regionaly and wider.

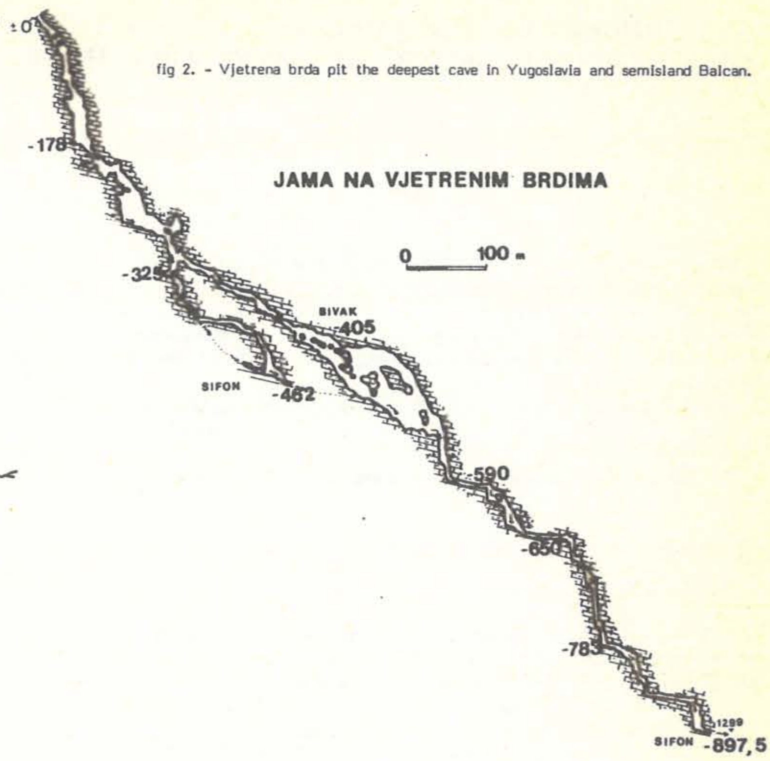
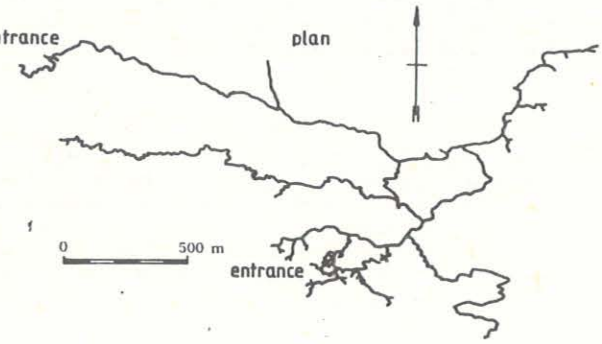


fig 2. - Vjetrena brda pit the deepest cave in Yugoslavia and semisland Balcan.

fig 3. - Topographic plan of the Muškinja-Panjkova-Crno Vrelo Cave System



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NEW CONCEPT OF THE MORPHOGENESIS AND HYDROGEOLOGY OF THE SPELEOLOGICAL OBJECTS IN KARST AREA IN CROATIA (YUGOSLAVIA)

GARAŠIĆ, Mladen

In this work author uses the data for more than 5500 caves in the karst in Croatia, which be managed to collect in his speleological work for many years duration.
The number of objects is different in different lithostratigraphic areas. In the permian limestones only few objects, in triassic limestones 6%, in jurassic sedimentary rocks more then 14%, in cretaceus limestones 65%, in paleogene breccias 13%, and neogene lithotamnium limestones 1,5%.
About 66% of sp.ob. are oriented in the direction NW-SE, called "Dinaric direction", while 16% are almost vertical on that direction, and 18% objec ts are oriented in different directions.
In this karst area 29% of caves are horizontal and 69% are vertical shaft. In the internal and in the midle karst belt were there 2% of objects that are combined or complex, it is difficult to determine wheather they are pits or caves. According to the form and distrubution of the chanels in the objects there are:
simple pits and caves 20%. branched out objects 30%, level objects 9%, knee-formed objects 40% and cave system 1%.
From the hydrogeological stand point, objects are divided according to the functions- dry objects 65%, and with water 35%. Water are always present in the 20% of caves. Following hydrogeological function are present, occasional springs 3,5%, permanent springs 0,7%, occasional ponors 5%, permanent ponors 1%, estavelas 7,5%, vruljas (undersea springs), 0,3%, and pouring spel.obj. 17%.

1. INTRODUCTION

In this work there are used the data (location,dimensions,stretching out, hydrogeological data, etc.) for 5647 speleological objects in the karst of Croatia, which I managed to collect in my speleological work of many years duration.

In the openning part he describes the purpose and goal of his researches, the description of the methods I used (speleological and geological) and the sketches of the areas of researches. Follows the review of researches in the speleological sense that have been done up to now, and the categorisation of the present speleological degree of the exploration of the karst in Croatia (30% methodically researched, 40% partly researched, 30% purely or not at all researched).

Hydrogeological distribution has been used and the karst of Croatia was divided into external, middle and internal karst belt. In the external karst belt 37% (or 2089) speleological objects has been registrated, 34% (or 1920) has been registrated in the middle part, and 29% (or 1638) were found in the internal karst belt.

The influence of today rainfalls,temperature,and above sea level, on the appearance of the speleological objects must be overviewed trought the paleoclimatic and paleogeographic conditions in the time of the origin of these objects. Most of them are situated on the levels between 450 and 850 metres. The deepest speleological objects are situated of the levels above 1100 metres, and the longest on the levels about 300 to 350 metres.

2. LYTHOSTRATIGRAPHICAL ASPECTS

The number of the objects is different in different lithostratigraphic areas. In the permian limestones (Velebit) only a few objects were found. In triassic dolomites,dolomite limestones,limestoned dolomites and limestones 6% (or 339) of the objects were registered, in jurassic limestones 14% (791) of the objects were found, in cretaceous limestones and dolomite limestones 65% (or 3671) objects were registered. In paleogen breccias and limestones 13% (734), in neogen (miocene) lithothamnium limestones 1,9% (107) of the objects were found, while in the quaternarius breccias were found only a few objects in the Croatia karst.

3. TECTONICAL ASPECTS

Frequently, the objects are formed in the interstice fissures, so they follow the direction and the incline of the stratum. Than they appear and follow the curving of the stratum. At the top of the anticlines the vertical speleological objects are mostly developed, and at the bottom of synclines many horizontal objects were found. Fissures and ruptures have an important role in the genesis of Croatian karst speleological objects. The appearances of the faults (mountain mirrors) and strias are more often in underground than on the surface above the object. The objects follow the direction of the rift. Also the nappes (overturened foulds) can influence the appearance of the objects. In that case, objects follow the contact line of the covering which determines the incline and the direction of the main channels.

About 66% (3727) speleological objects are oriented in the direction NW-SE, so called "Dinaric direction", while 16% (903) objects are almost vertical on that direction, and 18% (1016) objects are oriented in different directions.

Looking at the dominant role in the genesis of the objects, that role is connected with abrasion, in the external (adriatic) karst belt near the sea. On the islands and in the mountaines of the external karst belt, the role of erosion and corrosion, inculiding the strong tectonic, is most intensive. The most interesting corosive forms are found in the jurassic limestones (Gorski kotar). In the middle and in the internal karst belt, the influence of tectonic, erosion and corrosion on the appearance of the speleological objects is about equal.

In the Croatian karst 29% (1638) of the caves are registred, which are mostly in the internal and middle karst belt. Also were found 69% (3896) of the pits (shafts) vertical speleological objects, and they are mostly in the external and middle karst belt. In the internal and in the midle karst belt were there 2% (113) of the objects that are combined or complex, it is difficult to determine wheather they are pits or cave.

4. MORPHOLOGICAL ASPECTS

According to the form and distribution of the channels in the objects, Croatian speleological objects are dividet on simple pits and caves 20% (1129), branched out objects 30% (1694), level objects 9% (508), knee-formed objects 40% (2259) and cave systems 1% (56). Simple pits and caves are frequently found in the external karst belt, branched out objects are found in the areas where several fissure sxstems meet (especially in the internal karst belt), level speleological oblects are formed in the areas of the neotectonic raisings and lowerings, knee formed pits are found in the the area where dolomites and limestones take turns, in other works,where the lithological, and sometimes even the stratigraphical links, change. Cave and pits systems are formed on the very activated tectonic zones, where hydrogeological conditions bring together several objects in only one (Gorski kotar) (fig.1, fig 2., fig 3., fig 4., fig 5.).

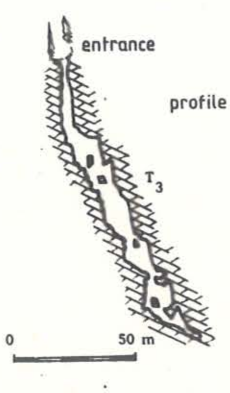

Fig 1. - **Step like (knee formed)** - Ponor on Grgin brijeg (Jadovno, Velebit Mountain)

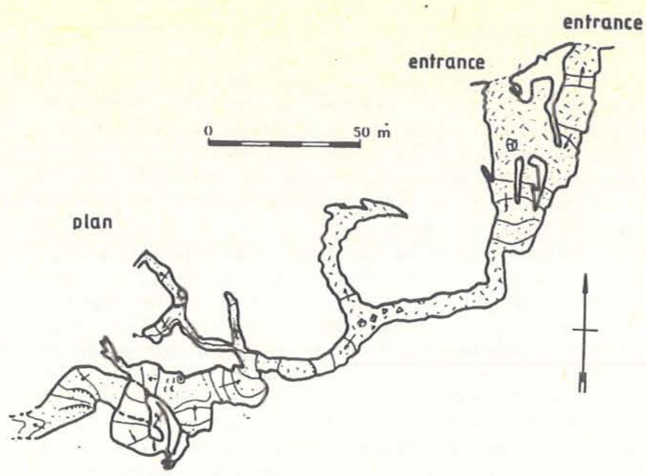

Fig.2. -**Branching (dendritic) cave** - Baračeva cave (Ličko Petrovo selo, Lika)

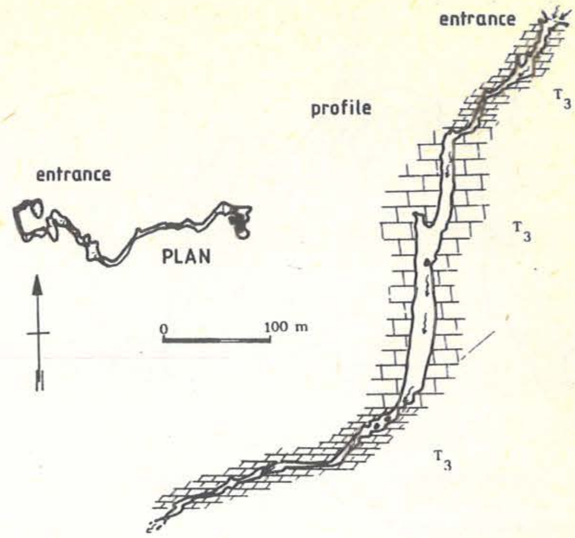

Fig 5. - **Permanent sink hole** - Ponor on BUNOVAC (Bunovac, Velebit Mountain)

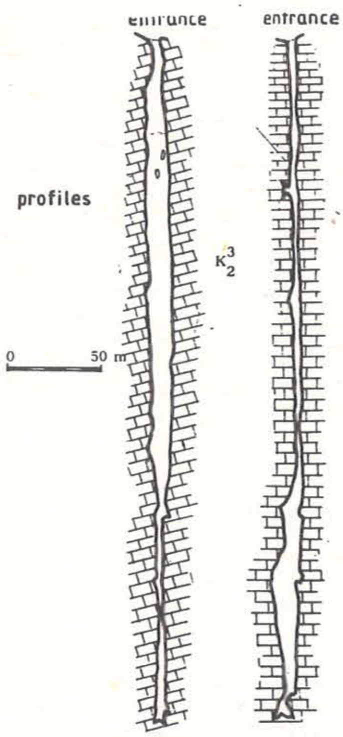

Fig 3. - **Simple pit (Shaft)** - Podgračišće II (Pražnice, insle Brač)

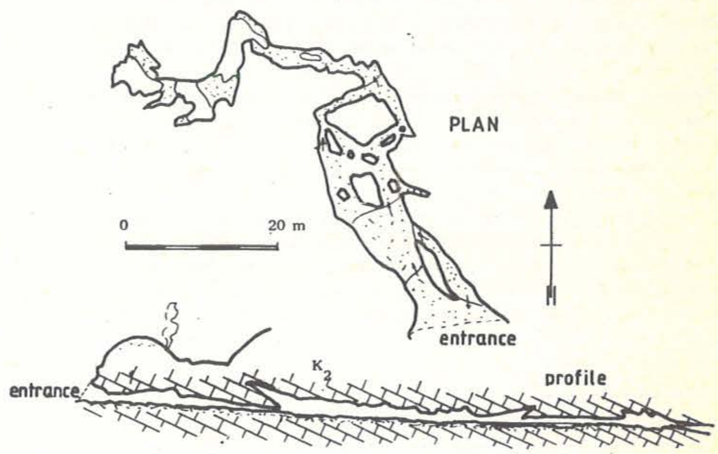

Fig 6. - **Periodical sink hole** - Tumarna ponor (Potok, Kordun)

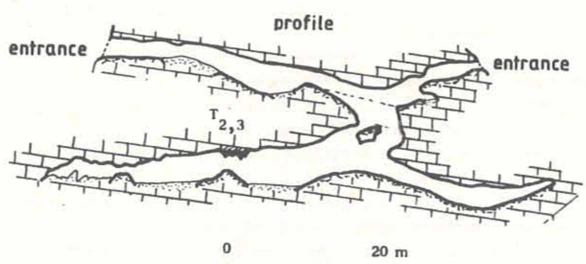

Fig 4. - **Level cave** - Little Hajdova hiža cave (Kuželj, Gorski Kotar)

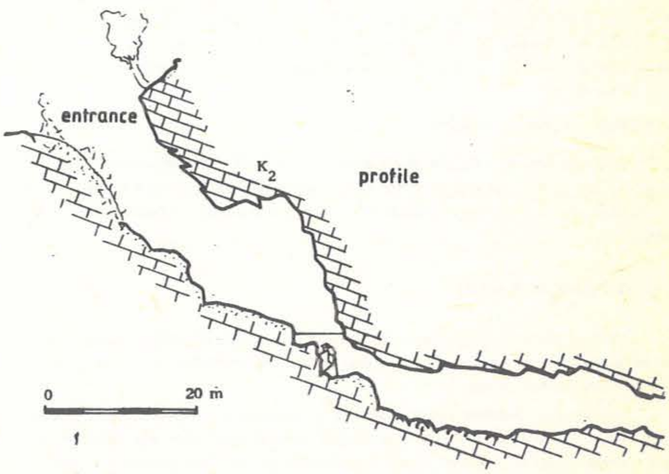

Fig 7. - **Estavela** - Markova Cave (Stajnica, Lika)

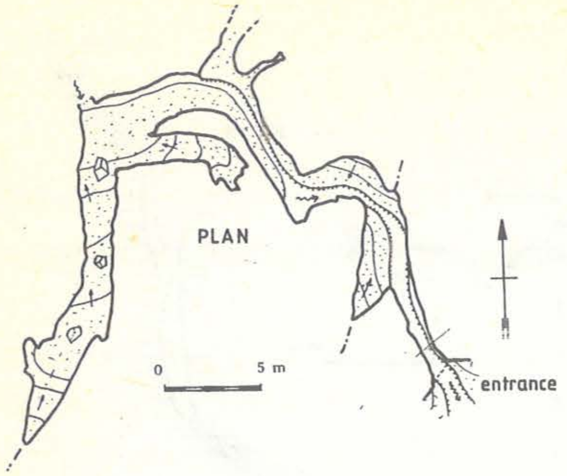

Fig 8. - **Permanent spring cave** - Jastrebinja cave (Frketić selo, Kordun)

5. HYDROGEOLOGICAL ASPECTS

From the hydrogeological stand point, speleological objects are dividet according to the functions - dry objects 65% (3671) and objects with water 35% (1976). Water is always (continually) present in about 19% (1073) of the speleological objects, and in 16% (904) of the objects it depends of the seasons (for example,occasional springs and occasional ponors, estavels). In the Croatian karst, water appears in the objects with following hydrogeological functions: occasional springs 3,5% (198), Permanent springs 0,7% (40), occasional ponors 5% (282), permanent ponors 1% (56),estavelas,7,5% (424), vrulja (undersea springs) 0,3% (17) and pouring speleological objects 17% (960).(fig.6., fig 7., fig 8.).

Seperately is described water in objects that appears like the instil water, in the form of the lakes of the underground streams (rivers), permanently sinked objects and siphons. Waterfalls, sand ponors and intermitent springs in speleological objects are also given with examples. Description of the sepearate little waterfall fro the stalgmite is given, which has not been found anywhere else in the world.

From the geological aspect, the secondary sediments, are also important, because they sometimes give answers about possible underground connections, which can be proved by some fragments in the sediments. This fragments are known only in ponor zones, while in the objects they are secondarily deposited. Size and form of the grain tell us about speed duration of transportation. Such connection is proved among the ponors Ričica and Opsenica rivers (in Lika) and with spring cave Čude and Čavle in the valley of Zrmanja.

6. SECONDARY SEDIMENTS

Speleothems, corrosive and erosive forms, sharpenings and smoothing down, fassetes,cave scallops,whirl-pots,hierogliphs and recesses of inverse melting (karstification) are described with examples, because they are some of the characteristics of the speleological objects in Croatia. In this work are given examples fo very rare (in the world) and not yet explained phenomena like, so called, snail like forms, louts, and "dishes and plates", that have been found in the Croatian karst speleological objects.

7. METEOROGICAL ASPECTS

Temperature of the underground water is on the average lower for 1 to 2°C from the temperature of the air in the objects, and that means that in the internal karst belt it is between 8-9°C, in the middle karst belt is about 7°C, and along the sea shore is about 11°C. The coldest underground water has been measured in Ponor na Bunovac (Velebit), 4,2°C, on the depth of 534 metres, and the warmest cave water (15,3°C) was measured in the system of Muškinja and Panjkova pećina (Kršlja, Kordun), about 3400 metres away from the entrence in the cave. Probably it is hypothermal spring

8. HYDRO LOGICAL ASPECTS

Some quantitative data are given, about pouring waters and accumulations in the caves, for examples - quantity of water in the system of Muškinja and Panjkova pećina (Kršlja,Kordun) and is as far as 100000 m^3 (about 9 kilometres of channels filled with water).

9. NEOTECTONICAL ASPECTS

The morphometric and neotectonic maps of the system of Jopičeva spilja (Kordun) and Muškinja (Kordun) are given,because they helped the researches of the new and unknown parts of the objects.

Seperately is described direct measuring of neotectonic movements in 9 speleological objects of the Croatian karst - the biggest vertical movements was registered on Južni Velebit (about 60 mm/100 years), and the smallest one was registered on the north Velebit (about 4,8 mm/100 years). Horizontal movements are mostly ones of the dinaric direction of stretching, in the external and middle karst belt. According to the intensity they are several times smaler that the vertical neotectonic movements.

10. QUANTITIVE ASPECTS

The list of the longest (Djulin ponor-Medvedica,near Ogulin,15860 metres long)and the deepest objects (Pit Stara škola on Biokovo, 576 metres deep) in Croatian karst is given. Averige, length of the speleological objects is between 50 and 100 meters, and the averige depth is between 30 and 70 metres. For example, for the 25 longest objects in Croatia, total length is about 70 kilometres, that means about 2800 metres for on objects, and the total depth for the 35 deepest objects is about 9,5 kilometres, that is averige of 270 metres for one objects.

The averige width of the channels is between 1 and 3 metres, averige hight is 2 to 3 metres, and the cahmbers are high and wide about 10 to 15 metres. The averige incline is 52°, but in reality the objects are vertical or slightly inclined.

The area of the Kordun (Potok,G.Dubrave,Rudnica etc.) has 15 to 20 objects/km^2 and on Samarske and Bijele stijene (Gorski kotar) there are up to 25 obj./km^2. Those are the richest regions of the Croatian karst. In averige there is 2 to 3 obj/km^2 (on the whole area of the karst).

On the contrary in some places (parts of Gorski kotar and Velebit) where tectonic,lithological,hydrogeological and other geological conditions are suitable for the genesis of the speleological objects, these objects are not found and seen on the surface. That doesn't mean that they can't be found in the underground (cavernas,cavity).

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GENAUIGKEIT VON HÖHLENPLÄNEN

SCHONE, Tilo

Precision of cave-maps

For the peparation and execution of research-programs precise cave-maps are often necessary. Many of usual maps have the disadvantage, that no data about the measurement-methods and the resulting point precision are obtained. Thereby the value is reduced. In special cases a second measurement is necessary.
These paper tries to show possibilitys, to estimate the precision of measurement taking into account the methods and devices, which are used in the GDR.
The most of the caves on the territory of GDR belong to the typ of small and middle caves. The result is the surveying of caves with "Freiberger Hangezeug" (compas and clinometer). Transit-measurements are reserved only to some special measurements.
The representation of caves is given almost exclusively in an analogous form (as a map), the accumulation in digital form is unusual.

Für die Ausarbeitung und Durhcführung von Forschungsprogrammen werden oft sehr genaue Höhlenpläne benötigt. Viele der herkömmlichen Pläne haben den Nachteil, daβ sie keine Angaben zu verwendeten Meβverfahren und den sich daraus ergebenden Punktgenauigkeiten enthalten. Dadurch werden sie erheblich in ihrem Wert gemindert. In einzelnen Fällen kann sich sogar eine Neuvermessung notwendig machen.
Dieser Beitrag versucht Möglichkeiten der Einschätzung von Meβgenauigkeiten, unter Berücksichtigung der in der DDR üblichen Verfahren und benutzten Geräte, aufzuzeigen.
Bei den Höhlen auf dem Territorium der DDR handelt es sich in der überwiegenden Anzahl um Klein- und Mittelhöhlen. Daraus resultiert die Vermessung von Höhlen mit dem Freiberger Hängezeug (Hangebussole und Gradbogen). Theodolitvermessungen sind nur wenigen Spezialvermessungen vorbehalten.
Die Darstellung von Höhlen erfolgt fast ausschlieβlich in analoger Form (als Karte), Abspeicherung in digitaler Form ist nicht üblich.

0. EINLEITUNG

Für die Ausarbeitung und Durchführung von Forschungsprogrammen werden oft sehr genaue Höhlenpläne benötigt. Viele der herkömmlichen Pläne haben den Nachteil, daß sie keine Angaben zu verwendeten Meßverfahren und den sich daraus ergebenden Punktgenauigkeiten enthalten. Dadurch werden sie erheblich in ihrem Wert gemindert. In einzelnen Fällen kann sich sogar eine Neuvermessung notwendig machen.
Dieser Beitrag versucht Möglichkeiten der Einschätzung von Meßgenauigkeiten, unter Berücksichtigung der in der DDR üblichen Verfahren und der benutzten Geräte, aufzuzeigen. Dazu werden Gebrauchsformeln angegeben, mit deren Hilfe schnell und einfach zulässige Fehler berechnet werden können. Bei den damit errechneten Genauigkeiten handelt es sich um innere Genauigkeiten eines Zuges.
Bei den Höhlen auf dem Territorium der DDR handelt es sich in der überwiegenden Anzahl um Klein- und Mittelhöhlen. Daraus resultiert die Vermessung von Höhlen mit dem Freiberger Hängezeug (Hängebussole und Gradbogen). Theodolitvermessungen sind nur wenigen Spezialvermessungen vorbehalten.

1. GENAUIGKEITEN DER VERWENDETEN GERÄTE

1.1. Bussolen

1.11 Aufsatzbussole

Die Aufsatzbussolen ermöglichen durch die Verbindung mit einem Fernrohr genaue Anzielungen. Der Teilkreisdurchmesser beträgt je nach Gerätetyp ca. 10cm, der Skalenwert 1 Grad. Untersuchungen zeigten, daß damit magnetische Azimute mit einem mittleren Fehler m(a) von +/- 0.3 Grad gemessen werden können.
Aufsatzbussolen finden jedoch nur selten Anwendung, da sich der beachtliche Aufwand an Meßvorbereitung und Durchführung nicht immer lohnt.

1.12 Hängebussole

Die am häufigsten angewandte Methode in der Höhlenvermessung der DDR ist die Anlage von Bussolenzügen mit dem Freiberger Hängezeug. Die darin enthaltene Hängebussole hat einen Teilkreisdurchmesser von 8 cm und einen Skalenwert von 2 Grad. Eigene Untersuchungen zur Genauigkeit zeigten, daß die gemessenen magnetischen Azimute einen mittleren Fehler m(a) von +/- 0.4 Grad aufweisen. Es lassen sich damit bei entsprechend sorgfältigen Messungen gute Ergebnisse erzielen.

1.13 Geologenkompaß

Bei einigen speziellen Vermessungen wird auch auf die Verwendung eines Geologenkompasses zurückgegriffen. Solche Fälle sind z.B. schwierig befahrbare Räume, untergeordnete Gänge, aber auch die Vermessung von Höhlenteilen, deren Befahrung ein Sicherheitsrisiko darstellt.
Der Durchmesser des Teilkreises beträgt 5.2 cm (F.W. Breithaupt & Sohn, Kassel). Er hat eine 1 Grad Teilung. Damit lassen sich Azimutmeßgenauigkeiten von +/-0.2 Grad erzielen. Der größte Fehleranteil kommt hier aber von der Visur des Zieles während der Messung, da die Zielachse nicht fest ist. Versuche ergaben dabei einen mittleren Fehler einer Messung m(a) von +/- 1.1 Grad. Dem Rückgriff auf dieses Gerät sollte ein Genauigkeitsvoranschlag vorausgehen.

1.2. Neigungsmesser

1.21 Vertikalkreis eines Theodolits

Bei der Verwendung von Aufsatzbussolen oder Bussolentheodoliten wird die Vertikalwinkelmessung mit dem Theodolit durchgeführt. Damit lassen sich Genauigkeiten erzielen, die weit über der der Messung des magnetischen Azimutes liegen. Die Ablesung auf 0.01 Grad ist daher ausreichend genau.

1.22 Gradbogen

Das wichtigste verwendete Gerät zur Bestimmung von Neigungswinkeln ist der Gradbogen (Klinometer). Er ist Bestandteil des Freiberger Hängezeuges. Der Gradbogen besitzt eine Teilung von +/- 90 Grad und ist auf 0.5 Grad geteilt. Bei diesem Meßverfahren wird das Klinometer in eine, zwischen zwei Punkten straff eingespannte, Schnur eingehangen. Der dabei auftretende Durchhang hat einen großen Einfluß auf das Meßergebnis. Untersuchungen zeigten, daß bei Beachtung des vom Hersteller vorgeschriebenen Einhängepunktes der mittlere Fehler bei m(ß)= +/- 0.2 Grad liegt.

1.23 Geologenkompaß

Auch der Geologenkompaß besitzt eine Einrichtung zum Messen von Vertikalwinkeln. Sie hat einen Skalenwert von 1 Grad. Hier wird die Neigung durch Anlegen des Kompasses an die Meßschnur ermittelt. Somit kommt es zu großen Anlegefehlern. Bei verschiedenen Messungen lagen die mittleren Fehler m(ß) bei +/- 0.3 Grad. Die Messung wird aber subjektiv durch den Beobachter beeinflußt, so daß die Fehler auch beachtlich größer sein können.

2. FEHLERFORMELN

2.1. Lage-Genauigkeiten

2.11 Einseitig angeschlossener Bussolenzug

Bei der Herleitung geht man von den einfachen Berechnungsformeln

$$\Delta x(i)=s(i).\cos a(i).\cos \beta(i) \qquad /1/$$

und

$$\Delta y(i)=s(i).\sin a(i).\cos \beta(i) \qquad /2/$$

aus.

Unter Anwendung der Beziehungen

$$m(p)^2 = m(\Delta x)^2 \,.\, m(\Delta y)^2 \qquad /3/$$

$$m(w)^2 = m(a)^2 + m(\beta)^2 \qquad /3a/$$

und Näherungen folgt :

$$m(p(i))= +/-(\ m(s) + m(w)/rad \ .\ s(i)\ ) \qquad /4/.$$

wobei m(s) der mittlere Streckenmeßfehler ist.
Der Bussolenzug hat n- Punkte mit (n-1) Strecken. Damit kannder mittlere Punktfehler vorabgeschätzt werden :

$$m(p) = +/- (\sqrt{(n-1)} \,.\, m(s) + m(w)/rad \,.\, \sqrt{\Sigma\, s(i)^2}\,)\ (i=1,n-1) \qquad /5/.$$

Für die weiteren Betrachtungen genügt es, wenn angenommen wird, daß die Strecken (z.B. innerhalb eines Gebietes) etwa gleichlang sind. Damit ist S= (n-1).s und

$$m(p) = +/- (\sqrt{(n-1)} \,.\, m(s) + m(w)/rad \,.\, S / \sqrt{(n-1)}\ ) \qquad /6/.$$

2.12 Beiderseitig angeschlossener Bussolenzug

Die mittleren Fehler verhalten sich hier so, als ob der halbe Zug jeweils von beiden Endpunkten aus gemessen wird. Der maximale Fehler tritt deshalb in der Mitte auf. Bei analogem Vorgehen wie unter 2.11 folgt

$$m(p) = +/-(\sqrt{0.5(n-1)} \,.\, m(s) + m(w)/rad.\ S/\sqrt{2(n-1)}\ ) \qquad /7/.$$

2.2 Höhen-Genauigkeiten

2.21 Einseitig angeschlossener Bussolenzug

Ausgehend von der Berechnungsformel $\Delta h(i) = s(i) \cdot \sin \beta(i)$ /8/ und ähnlichen Überlegungen wie in den vorangegangenen Kapiteln kann der mittlere Höhenfehler nach folgender Formel abgeschätzt werden :

$$m(\Delta h) = +/-(\sqrt{(n-1)} \cdot m(s) + m(\beta)/rad \cdot S/\sqrt{(n-1)}) \qquad /9/.$$

2.22 Beiderseitig angeschlossener Bussolenzug

Für einen beiderseitig angeschlossenen Bussolenzug wird dann

$$m(\Delta h) = +/-(\sqrt{0.5(n-1)} \cdot m(s) + m(\beta)/rad \cdot S/\sqrt{2(n-1)}) \qquad /10/.$$

2.23 Barometrische Höhenmessung

Die barometrische Höhenmessung ist eine wirkungsvolle Ergänzung der anderen Meßmethoden. Gerade in sehr tiefen Höhlen, in denen es keinen Höhenabschluß gibt, hat diese Methode zur Kontrolle Bedeutung. In kleineren Höhlen macht sich der große konstante Fehleranteil negativ bemerkbar.

Ausgehend von der barometrischen Höhenformel

$$\Delta h = k \cdot (1 + a.t) \cdot (\lg B - \lg b) \qquad /11/$$

(mit k = 18464 für 50° Breite und mittleren Höhen von 500 m,
a = 0.00037 Konstante der Temperaturkorrektion -2- , B,b = Luftdruck) ergibt sich ein Fehlereinfluß von

$$m(\Delta h)^2 = M^2 \cdot k^2 \cdot (1+a.t)^2 \cdot (m(B)^2/B^2 + m(b)^2/b^2) + h^2 \cdot a^2 \cdot m(t)^2 \qquad /12/$$

(M=logaritmisches Modul, m(t)= Fehler in der Temperaturbestimmung, m(B),m(b)=mittlerer Fehler der Luftdruckbestimmung).

Diese Formel kann als Gebrauchsformel verwendet werden, wenn $m(t) = 1°C$, $m(b)=m(B)= 1$ mbar :

$$m(\Delta h) = +/- \sqrt{2.42\ m + (a \cdot \Delta h)^2} \qquad /13/.$$

3.0. GENAUIGKEITEN DER HÖHLENPLÄNE

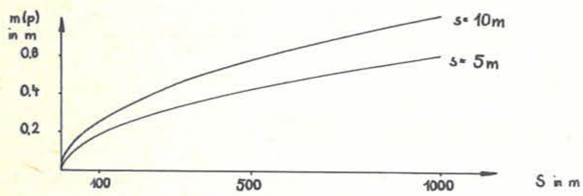
Das Ziel einer Höhlenvermessung ist in erster Linie die graphische Darstellung eines Hohlraumes, davon ausgehend Angaben für Ausdehnung, Fläche und Volumen.

Für die Aufmessung der Hohlräume spielt die Morphologie der Höhle eine wesentliche Rolle, so daß die eigentliche Messung regional sehr unterschiedlich gehandhabt wird. Die Betrachtungen zur Genauigkeit werden deshalb nur auf die Genauigkeit des Bussolenzuges beschränkt. Dieser wird in der DDR nach einheitlichen Gesichtspunkten gemessen.

Die oben angeführten Formeln gelten nur für annähernd gestreckte Züge. Die eingeführten Näherungen erlauben die Anwendung der Formeln für Bussolenzüge beliebiger Konfiguration.

3.1. Lage-Genauigkeiten

Aus den in 2.1 angeführten Formeln ist sofort die Abhängigkeit des mittleren Fehlers von der Länge der Teilstrecken ersichtlich.



In den Höhlen der DDR kommen in der Mehrzahl Seitenlängen von 5 - 10 m vor. Die sich daraus ergebenden Punktgenauigkeiten (Messung mit Freiberger Hängezeug) zeigt Abbildung 1 ,(m(s)=+/- 0.004 m).
Die überwiegende Anzahl der Höhlen haben eine Ausdehnung von 10 - 1000 m.
Die mittleren Lagefehler am entferntesten Punktliegen bei ± 0.8 m.

3.2. Höhen-Genauigkeiten

Die Längenverhältnisse von Teilstrecken und Gesamtlänge bleiben wie bei 3.2.. Die daraus abgeleiteten mittleren Höhenfehler zeigt Abbildung 2 ,(m(s)=+/- 0.004 m).

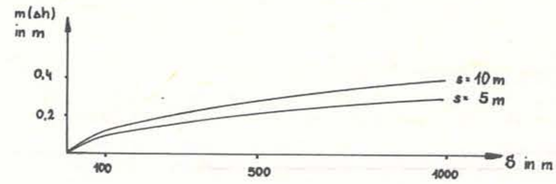


Abbildung 2

Die mittleren Höhenfehler überschreiten +/-0.40 m nicht.

3.3. Wertung der erreichbaren Genauigkeiten

Die Auswertung von einzelnen Ringbussolenzügen aus Höhlen unterschiedlicher Größe zeigt die Richtigkeit der hergeleiteten Formeln. Punktfehler die über den berechneten lagen, waren immer Folge von Messungsfehlern. Allerdings kam es bei späteren Kontrollmessungen teilweise zu größeren Abweichungen von den Ursprungswerten. Unter den spezifischen Bedingungen "Höhle" sollte der Grenzfehler von (3 . m) aber nicht überschritten werden.
Für die wichtigsten Nutzungsarten eines Höhlenplanes, wie z.B. Orientierung und Geologie, sind diese Genauigkeiten ausreichend. Sind für andere Nutzer die Genauigkeiten zu gering, wie sie sich aus den oben genannten Formeln berechnen lassen, müssen andere Meßverfahren angewendet werden.

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THE PALEOLITHIC OF MIDDLE BOSNIA (YUGOSLAVIA)

MULAOMEROVIĆ, Jasminko

Couple of last years some sonde digings were done in the caves near Sarajevo and in middle Bosnia (the central part of Yugoslavia). Besides the remainds of plaistocen phaune some signs of paleolitic hunters roeve found. This paper gives not only the list of findings but the main characteristics of culture conserning geografic position between Adriati Adriatic Sea an Panonian Valley.

1. INTRODUCTION

The Paleolithic findings in Bosnia and Herzegovina are mainly divided into two gruops. One group consists of the numerous open sites within the lower course of the Rivers Bosna, Usora, Ukrina and Vrbas. According to their cultural classification these sites belong to the Pannonian Region. The Badanj site, near Stolac, for the time being is a sole site in Herzegovina, but unique in the Balkans with regard to the number of quartz and body artifacts, ornaments and engravings on the bones and rocks. This site belongs to the Mediterranean cultural region (1).

Fig. 1: 1-Gigića cave, 2-Varvara, 3-Gornja Bijambarska cave

2. EARLIER INVESTIGATIONS

The next three Paleolithic sites, which have been investigated (Gigića cave, Varvara and Gornja Bijambara cave) are located between these two groups of findings.

The Gigića cave is a simple speleological site. It has a form of channel covering the total lenght of approximately 170 m. It is located on the Eastern slope of the mountain Ilica, above the village of Resanovci. During the speleological investigations approximately 15 m below the entrance, in red-brown cave loam, only one Mousterian artifact is discovered (2).

The second site is known as Velika Gradina in the village of Varvara near Prozor. During the archeological investigations, carried out in 1899 (3), the handaxe of the Musterian age was discovered. The circumstances under which this tool is discovered are unknown, but in 1960 and 1067 the revisal excavations were made and the flakes, culturally and periodically not defined, were discovered at the cross-section of the Bronze Age layer and layer of compact red clay. Therefore, it was not possible to define a closer stratigraphical determination of the location of handaxe.

The Gornja Bijambara cave is a third site. The complex of Bijambara caves is located approximately North-West of the village of Krivajevići on the road to Srednje-Olovo. During the complex investigations of the caves in 1967 for the purpose of the protection of the sites, which are naturally rare, the Gornja Bijambara cave was investigated, as well (4). At the beginning of the North section, a probing was excavated and seven layers were separated. The layers C and D (depth 0.08 - 0.25 cm), the later was defined as Wurm III - Glacial, in yellow-brown and grey-brown loam, together with sharp-edged rocks, animal bones and coal pieces, the quartz artifacts were discovered and defined as Epigravettiene.

Therefore, in the Middle Bosnia the residence of the Paleolithic hunters is defined in the Gornja Bijambara cave.

A notion Middle Bosnia here means area of Sarajevo and Zenica. This area is closed by high mountains, in the South by Jahorina (1913), Treskavica (2088) and Bjelašnica (2086), in the West by Romanija (1649), in the East Bitovnja (1744) and Vranica (2112), in the North by Vlašić (1943) with few mountains which are less then 1500 m a.s.l. Therefore, this is area of a upper course a river Bosna and their tributaryes Miljacka, Željeznica, river Fojnica and Lašva where are many river valeys and fields.

3. RECENTLY INVESTIGATIONS

The intensive activities for the purpose of recognition and treatment of the speleological sites in the surounding area of Sarajevo have been observed during last few years. Ten sites have been registered and according to their position, relief, general appearances, exposition of the entrance part, presence of the respective sediments etc. they are very important for the archeological investigations and trail probings should be made, at least (5).

The reliable evidences of the presence of the Paleolithic man have been found out at several locations.

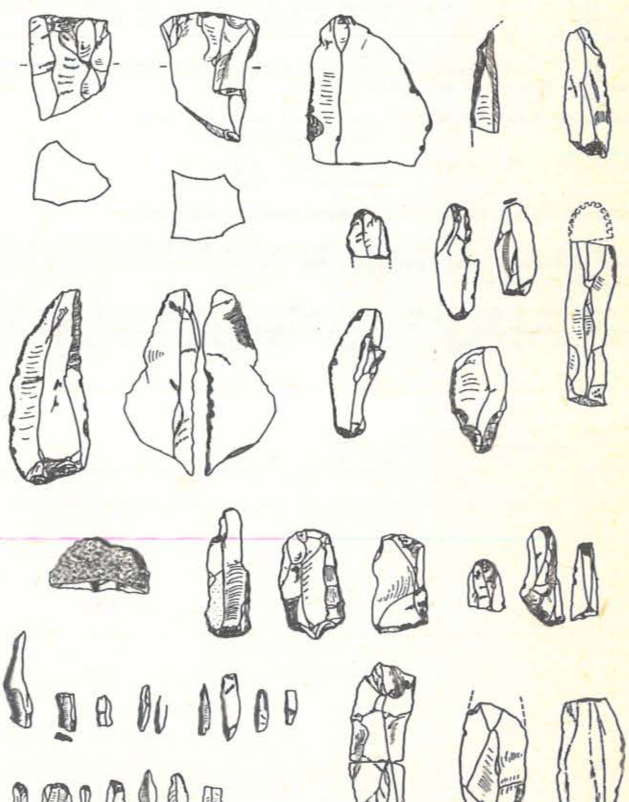

Fig. 2: Artifacts from the Ruda Glavica cave

Not far from here, there is a rock shelter Duga Peć, approximately 7 km to the East of Trnovo in the direction of village Delijaš in the gorge of the river Crna Rijeka. It is located approximately 30 m above the riverbed and approximately 20 m below the wide plateau along which edge the Crna Rijeka cut its bed. The rock shelter facing the South is protected against the cold winds from the North and West by high rocks.

In front of the rock shelter there is a talus approximately 30 m high and it possibly indicates one covered little cave. At the bottom of talus, on the surface, one artifact is found. It is a large river round pebble primitively cut on both sides. Such tools are known as chopping tools. According to the type and shape of the tool it may be dated very early but the appearance in Bosnia is not rare during the period of Lower Paleolithic (6).

Not far from Duga Peć is Dankova Jama cave near willage Delijaš. Cave is located on teh right side of river Crna Rijeka 5 or 6 meters above water-level. Morphology appearance of cave is very simple. The entrance is almost rectengular, two meters high and six meters wide. It is oriented exactly to the North.

In the layer reddish-brown loam, just below surface, two flint artifacts and some bones of tinny animals. The determination of bones is held in Institute for Quartar Geology in Zagreb. The preliminary results shows that part of this remains belongs to Marmota Marmota, which point out of pleistocene origin of this layer. This confirme paleolithic origin of the find artifacts. The artifacts are only two catters without retouches.

The third site is a small village of Sarajevo not far from Sumbulovac near Mokro. A large rocky massif Orlovača is located immediately behind the last houses. On the South and East side of this massif there are several speleological sites in line.

One defined artifact has been found in landslide under the cave at this location. It is a grattoir sur eclat of Lower Paleilithic type. The bonely axe is found too. It's stratigraphic position is not remarked.

Proves the presence of the Paleolithic hunters in the surroundings of Sarajevo, have been found at the left bank of the river Mokranjska Miljacka, under the hill of Zmijina Glava, opposite to the village of Bulozi. A several dozen smaller speleological sites, mostly facing the North, but some of them are facing the West and East, are located within the lower part of the Northern slope of the hill of Zmijina Glava, sharply inclined to the river canyon.

The artifacts have been found at a place which is the sole natural passage from the cave area to the large area of the village Bulozi because the inaccessible stone sides of canyon raised on the upstream and downstream side. Therefore, the artifacts which have been found are doubtlessly in connection with the caves.

Two uncharacteristic artifacts have been found at this location. One can be defined as a piece a encoche of the Lower Paleolithic age.

The last site is a cave on the Southern rim of the Trnovo setlement, towards the village of Tošići, on the Eastern slopes of the limestone hill Ruda Glavica (7). The entrance is arched facing the East. It consists of one small trapezium room. The room is four meters long and it is high one meter in entrance and 1,5 m in the middle.

The four sond dimension of 1 x 1 meter weer diged in cave. The cross-section makes following layers:

Layer 1: 0.00 - 0.08	dark brown soil with tiny sharp-edged rocks
Layer 2: 0.08 - 0.40	red-brown sandy loam with many sharp-edged rocks
Layer 3: 0.40 - 0.95	compact sharp-edged rocks.

In the first and second layer bones of tiny and large animals and some scattered coal particle was found. The third layer was completly sterile.

In the area of four square meters 239 flints were diged from which defined shape or 27 %. In the comparison with other finds of paleolithic residence in Bosnia and Herzegovina, we can assert that Ruda Glavica cave falls into the group of relative wealthy finds.

Here we need to emphasize lage number of microlites. One example produced by colorless mountain crystal stands out among them. A few artifacts made by this material were found in Badanj near Stolac.

4. CONCLUSION

Although, it is not possible to carry out the detailed analyses with regard to the cultural origin and dating of the findings and sites, due to their quality and degree of site investigation, they, however, allow some conclusions to be made. Although, few in number, they will be useful, in any way, for future investigations.

First of all, these artifacts are characteristics of the Lower Paleolithic. The copping tool from Duga Peć Cave makes and exception because the layers of the older cultures may be excepted due to the thickness of talus.

The size of the structures and estimeted thickness of deposits indicate the permanent settlement at such locations. But, in fact, they were the temporary places of settlement during the hunting periods. The large constant settlements and residences should have to be serached.

Although find Ruda Glavica cave by Trnovo abound in define artifacts, on this level of investigations, there are no serious arguments to put together with Mediterranean or Pannonian region. Because of this we have a tendency to put paleolitic find Ruda Glavica cave , at least now, in one separate, perhaps "middle-bosnia cultural region", surely because of regional belonging of the place, more then resons which are point out former.

The findings and sites of the surroundings of Trnovo are of the particular interest because it is a part separated from Herzegovina, with two saddles, Rogoj and Sarajevska Vrata, on Treskavica mountain. Therefore, it is necessary to provide more detailed recognition of the caves near Dobro Polje and Kalinovik as transit zone between two different region in terms of geographical conditions. The Hajdučka cave in Piligrad hill above Dobro Polje may be considered, for the time being, as an interesting structure with regard to archeology. The possible discovery of paleolithic findings and sites within this zone and their cultural definition and dating will provide better understanding of the problems with regard to the human settlements of sapiens kind over the areas not included in the Paleolithic or Mediterranean region.

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CAVE IN SIDERITE

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ПЕЩЕРА В СИДЕРИТАХ

Во время ознакомления с уникальным железорудным (сидеритовым) месторождением в районе г.Бакал (Урал, СССР) в борту одного из действующих карьеров летом 1988 г. была обнаружена полость. Она заложена по крупной трещине, имеет протяженность 26 м, площадь - 90 м^2, объем около 500 м^3. Ширина хода изменяется от I.0 м до 4.3 м. Высота полости колеблется от 2.5 м до 6.0-7.0 м. Предполагается следующий механизм формирования полости (этапы):

I. Окисление сидеритов в приповерхностной зоне месторождения под действием атмосферных и грунтовых вод. Растворение - важная составляющая процесса окисления сидеритов. Окисление происходит по трещинам, однако, свободные полости не образуются, поскольку трещины одновременно заполняются продуктами окисления - охрой, лимонитом.
2. Вскрытие толщи карьером, искусственное понижение уровня подземных вод. Вследствие этого - суффозионный вынос рыхлого материала (охры) из полости.
3. Осушение полости в результате доальнейшего понижения уровня подземных вод, её вскрытие уступом карьера, развитие обвалов и формирование глыбовых отложений

In the course of the first-hand acquaintance with unique iron ore (siderite) deposit in the surroundings of Bakal city (Ural, USSR) cavity developed in the slope of one of the operating quarries was discovered in summer, 1986. The cavity 26 m long (total square - 90 m^2; volume - 500 m^3) is found to be associated with large joint. The height of the cavity varies from 2.5 m up to 6.0-7.0 m; the width of its corridors - from 1.0 m up to 4.3 m. The following mechanism of cavity formation (stages) is proposed:

1. Oxidation of siderite by atmospheric and underground water in the near surface zone of deposit. Solution is known to be an important constituent of the process of siderite oxidation. Oxidation is through the joints, but cavities free of filling material have not been observed there since joints are simultaneously filled with oxidation products (ochre and limonite).
2. Stripping of rock thickness by quarries, man-made lowering of subsurface water table result in suffosional removal of loose material (ochre) out of the cavity.
3. Drying out of cavity caused by subsequent lowering of subsurface water table, its reroofing by quarry, formation of failures and block deposits.

As is known, the opening of large subsurface cavities in the course of exploitation of iron ore deposits is a familiar but infrequent phenomenon. General data on the problem can be found in G.A. Maximovich's work (1975) dedicated to caves and cavities formed in ferruginous quartzites of Gabon, Venezuela and Brasil. The volume of one of the caves developed in Belinga and Batusla massifs (Gabon) is 30000 m^3. Ramified cave systems with grottoes, galleries and subsurface water circulation have been discovered there. At Sierro-Bolivar deposit (Venezuela) collapses, indicating subsurface caves and cavities, and springs have been revealed at the top of and around the ore bed hill. Having used the data obtained by some investigators, G.A. Maximovich cited a long list of Brasil and Venezuela iron ore deposits where extensive cave systems more than 1 km long with failures, springs and even limonite flowstone were encountered.

After G. Marescaux (1973) G.A. Maximovich explained the formation of large cavities in ferruginous quartzite by retard solution of silicate components through joints. Solution of ferrugineous quartzites results in removal of silica and concentration of iron. So, weathered (subjected to solution) ferrugineous quartzites enclosing cavities are considered to be the ores high in iron content. According to G.A. Maximovich, ore rich in iron is a result and manifestation of s i l i c a t e   k a r s t   called by him "b r a d y   k a r s t" (from Greek word "bradis" - slow or weak). It is believed that formation of silicate caves takes millions of years (Marescaux, 1973, Maximovich, 1975). In the USSR there are some deposits (Kursk Magnetic Anomaly, Krivoj Rog) famous for silicate karst manifestation (Klekel, 1966; Odoky, 1966; Odoky, Semkin, 1966; Petrun, Pirogov, 1962). In Kursk Magnetic Anomaly area brady karst features are performed by closed basins and small poljes 1.5-2.0 km long, 0.1-0.4 km wide and 90 m deep. In Krivoj Rog area small, chiefly slit-like cavities, about 10 m^3 in volume filled with water and, here and there, with limonite flowstone, developed at intersection points of tectonic joints were discovered by boring. These cavities were called "k a r s t - s u f f o s i o n al (V.F. Petrun, B.I. Pirogov, 1962).

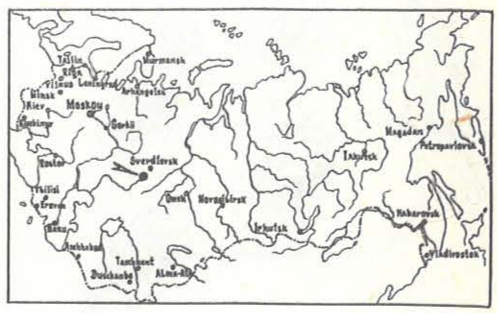

Fig. 1. Geographical position of Bakal siderite deposit.

Thus in ferruginous quartzites and oxidized iron ores, cavities due to solution and retard removal of silica are to develop. All the above examples of iron ore deposits fall under the same wide-spread type associate with ferruginous quartzites.

A large cavity, discovered in one of the benches of south highwall of Vostochno-Bulandikhinsky quarry (Bakal siderite deposit) in 1985, was carefully investigated by joint field team of Mining and Geology and Geochemistry Institutes of Ural Department of the USSR Academy of Sciences in June, 1988 (Fig.2).

The cavity entrance, located in the middle of a working bench 6 m thick, is an oval inlet in vertical wall cutting (> 50°)

steeply dipping siderite beds (Fig.3). Dimensions of hollow are 1.0x2.0 m. The cavity is sited along a large bedding joint (joints) spreading deeply into rock thickness in SSW direction at an acute angle (about 40°) to the bench plane. The oval entrance slit leads to a long corridor with pronounced faces of fissure, collapses and accumulations of block material. The corridor is 19 m long, 1.0 m (near entrance) - 4.0 m wide and 2.5 (near

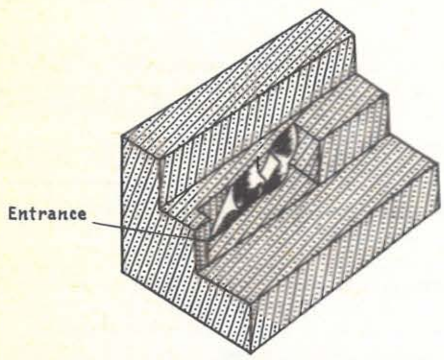

Fig.3. Location of Siderite Cave in relation to rock bedding in highwall benches of the quarry.

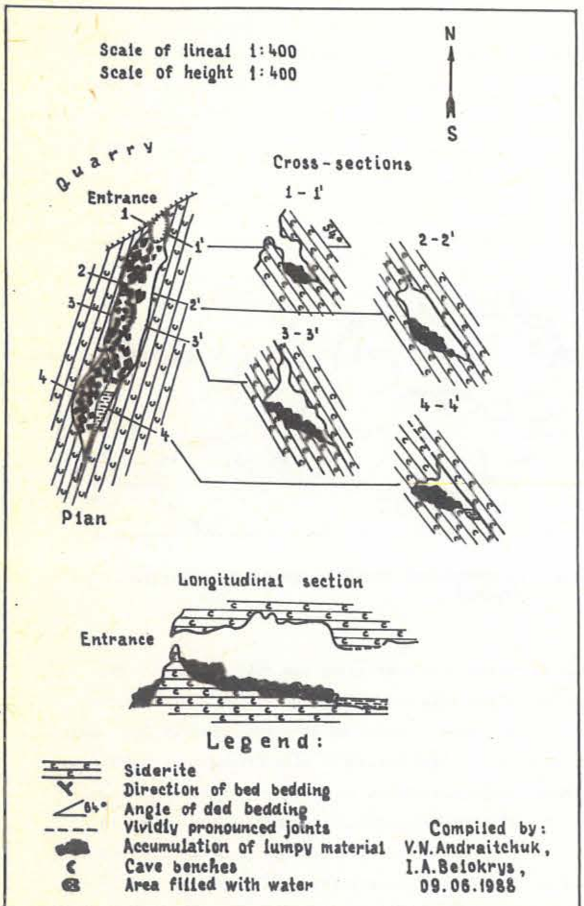

Fig.2. Cave in siderite.

entrance) - 7.0 m high. It terminates in a complex narrowed joint filled with water and one face "swallen" (Fig.2). Water mineralization is 0.935 mg/l, pH - 6.8, free CO_2 - 32.5, so Kurlov's formula can be written as:

$$0.9\ \frac{SO^4_{61}\ HCO^3_{37}}{Mg_{51}Ca_{45}(Na+K)}$$

The total length of the cavity is 26.0 m, square - 90 m^2, volume - 500 m^3. Cavity bottom is covered with fallen blocks of various dimensions; its ceiling, pitted with niches, pockets and cracks, is rather rough.

Walls of the joint are formed by siderite transformed, to a certain extent, by through joint oxidation. A pronounced block-like structure of the rock is easily observed (Fig.4): siderite blocks, preserved to some extent their former composition and structure, are divided by interblock jointed zones, filled with loose limonite. Dimensions of siderite blocks are 15x20 cm, while those of dividing limonite zones - 5x10 cm. Monolithic blocks are of light-grey and yellowish colour; material of oxidized zones is brown. Small limonite stalactites (1 cm) are encountered in loose, divided by strong partitions limonite mass.

Close to the described cavity there are some small ones (0.2 m in diameter) free of or filled with loose ferruginous formations.

The problems in question are: what is the mechanism of cavity formation and how solutional processes, usually identified with karst ones, relate to the cavity formation? To answer the questions synonymously, much further research is needed. The principal task of the authors is to explain the fact under consideration bearing on available data and experience gained.

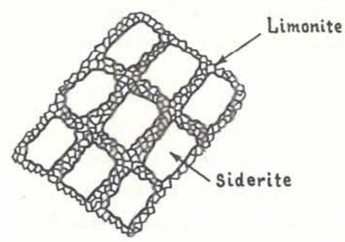

Fig.4. Characteristic structure of Siderite Cave walls.

The process of hypergene transformation of ores in near surface zone (zone of oxidation) has taken and is taking place at many mines and deposits, Bakal siderite deposit included. Oxidation of siderite and its subsequent transformation into limonite are due to the activity of the agents of landscape media, of which fresh water, free oxigen and temperature fluctuations are of primary importance. High jointing of siderite in near surface zone contributes to and is conditioned at the same time by hypergene process and the effects induced by unloading.

Solution plays an important role in siderite oxidation. It is a key process in a chain of geochemical reactions developed in stages, which can be schematically written as:

1. $\underset{\text{siderite}}{FeCO_3} + H_2O \rightleftharpoons Fe(OH)_2 + CO_2$
2. $Fe(OH)_2 + O_2 + H_2O \longrightarrow Fe(OH)_3$
3. $Fe(OH)_3 + H_2O \longrightarrow \underset{\text{limonite}}{Fe_2O_3 \cdot nH_2O}$

Solution and transformation of siderite take place in water permeable zones, i.e. through joints. So, limonite fills joints, of various genesis and dimensions, developed in siderite. Depending on the stage of oxidation and diagenesis, limonite formations have different states (gel, flowstone, crusts and partitions, ochre and loose concretions) and colour (from light-yellow to brown and red). Physical properties of limonite filling material vary greatly: equally with dense crystalline and flowstone formations there are loose (ochre) and lumpy easily subjected to suffosional removal.

A characteristic feature of siderite dissolution as compared with the other carbonate rocks is that dissolved matter is not removed away from solution completely in the form of ions (due to lesser density than that of the former material), but being transformed, fills potential voids. This is a reaction of substitution similar to that of metasomatic type, taking place under hypergen conditions. In the course of further transformations (crystallization) limonite becomes more consolidated and turns into highly cemented ferruginous rock with secondary voids and heterogenous structure.

In the case under consideration, oxidation process, in all probability, spreads into jointed zone easy of ground water access (Fig.5). Preliminary estimations show that the zone is 15-20 m below the surface. Due to transformations, a large inclined vertical limonite lens has been formed in the zone. Ochre traces on the surface of blocks, probably, prove the fact that interstratal oxidized zone is to form by loose limonite components - ochre and lumpy material.

Stripping operations in siderite result in water level lowering, changing of hydrodynamical and hydrogeochemical zonation and active ground and subsurface water circulation. At a definite stage of subsurface water level lowering, due to fluctuations of one of the intermediate levels cutting horizontally the oxidized zone, loose material can be easily removed (contact suffosion). Getting free of the filling material, the oxidized zone turns into a cavity which bottom has traces of ferruginous material and walls have no indication of leaching (because of a short period of interaction with circulating water).

Deepening of the quarry and lowering of subsurface water level make the cavity absolutely dry and bring it into a zone of active weathering. It results in failures of the rock and accumulation of lumpy material (Fig.5). Not long ago the cavity was opened up by the quarry and turned to a cave accessible for investigation.

G.A. Maximovich (1975) attributed siderite, a carbonate of iron, to karstified rock. He pointed out that the solubility of $FeCO_3$ is lower than that of calcite. At 18°C and pCO_2=1 atm, its solubility makes 720 mg/l, while that of calcite - 1100 mg/l. Under pCO_2 being increased, solubility of siderite is also increased and under pCO_2 =86 atm it achieves 770 mg/l.

Having used the data by A.L. Jasnitsky and O.P. Sergeev, 1962; L.A. Pentegova, 1965; Y.A. Davidenko, 1973, G.A. Maximovich stated that filled up ancient karst sinkholes were characteristic of the roof of Bakal siderite deposit, while caverns and cave-like cavities (1-2 cm - o.5-1.0 m in diameter) were typical of siderite rock thickness. After D.S. Korzhinsky the above authors believed that the cavities were due to solutional activity of hydrothermal solutions of carbonate deposits and removal of matter through joints. This fact proves G.A. Maximovich's supposition. At the same time one should be aware of evident distinctions between karstification of siderite and that of the other carbonate rocks (dolomite, limestone, marble etc.) In the first case the main result of solution is an oxidized rock - limonite - which "blocades" the development of potential void or, under a definite condition, can be moved away by suffosion. In the second case the processes of solution followed by synchronous removal of their products are active enough to form voids which initiate other new processes and phenomena (failures, landscape transformations etc.)

Under active subsurface water circulation direct formation of large cavities in siderite is highly probable since reaction of

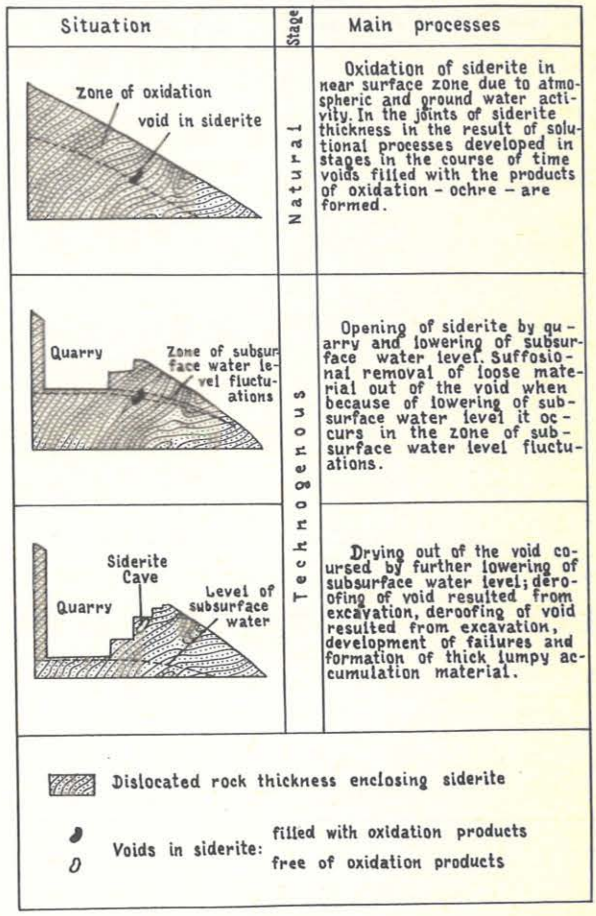

Fig. 5. Scheme of Siderite Cave formation

oxidation can be broken at a stage of iron hydroxide, when limonite has not been formed yet. However, an active water exchange in siderite is hardly possible because of very low permeability of the rock for concentrated water flows. Film, condensation, pore and infiltration water possesses no sufficient energy to transport and wash away the products of solution, so the process is completed with formation of limonite.

Having put forward the mechanism of formation of large cavities in siderite, the authors do not except the other ways. The most attractive is a hypothesis that claims the formation of cavities due to leaching of "residual" dolomite, i.e. a dolomite lens avoiding "sideritization". However, this supposion meets considerable difficulties which authors failed to overcome.

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CONSIDERACIONES EN TORNO A LA CUEVA DE PENCHES (BURGOS) Y SUS REPRESENTACIONES PARIETALES

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RESUMEN

La Cueva de Penches, ubicada en la Provincia de Burgos, representa una de las escasas manifestaciones con arte rupestre de cronología paleolítica, existentes en la Meseta Norte de la Península Ibérica.

El presente trabajo constituye un estudio del citado conjunto artístico. Partiendo del análisis del soporte de la obra parietal, es decir, del propio fenómeno cárstico con sus características geológicas, morfogénesis y desarrollo topográfico, pasamos al estudio de las representaciones parietales desde una óptica fundamentalmente tecnoestilística, que nos permitirá formular, en términos relativos, una posible adscripción cronológico-cultural para el yacimiento que nos ocupa, definido por una particular problemática, derivada de su situación a caballo entre los "ricos" conjuntos cantábricos y las estaciones parietales de características mediterráneas.

SUMMARY

Cueva de Penches, located in Burgos Province, represents one of the few examples of Paleolitic Chronology rupestrian art existing in the Spanish Meseta Norte.

This report is a study of the aforesaid artistic unit, beginning by the analisis of the parietal work base, that is to say, of the cave itself with its geological features, morphogenesis and surveyed lenght.

Afterwards, a study of the parietal representations is made from a techno-stylistic wiewpoint which will allow us, in relative terms, to express a possible chronological-cultural classification for the studied site, defined by a particular problematic due to its situation between the "rich" Cantabrian sites and the Mediterranean featured stations.

1. CONTEXTO GEOGRAFICO Y ENCLAVE GEOLOGICO

1.1. Contexto Geográfico

La Cueva de Penches se ubica dentro del término municipal de Barcina de los Montes, al N.E. de la Provincia de Burgos, en el sector nor-central de la Península Ibérica (ver fig. 1).

Desde un punto de vista geográfico la cavidad se halla enclavada en el apéndice oriental de las estribaciones meridionales de la Cordillera Cantábrica. La orografía que caracteriza a esta zona, aparece definida por un conjunto de relieves plegados de dirección predominante N.O.-S.E. Concretamente por dos alineaciones montañosas de cronología mesozoica y altitudes próximas a los 1.000 metros, integradas por los montes de Cillaperlata al Norte y la Sierra de Oña al sur. Ambas alineaciones se encuentran separadas por un estrecho valle longitudinal de dirección E-W, por el que discurre actualmente el denominado Arroyo de Penches.

La cavidad abre su estrecha boca en la vertiente derecha del citado valle, 8 metros por encima del nivel del arroyo, en un término conocido por los lugareños como Valdelacueva, situado a 2,5 kilómetros de Barcina de los Montes, practicamente en la línea divisoria con el término municipal de Penches y a escasos metros por encima de la actual carretera que desde Barcina se dirige a Oña.

Sus coordenadas cartográficas son (1):

Longitud:	627.170
Latitud:	902.250
Altitud:	829 m.s.n.m.

1.2. Enclave Geológico

Atendiendo a un criterio estructural, la cueva se enmarca dentro de la alineación mesozoica de Oña, flanqueada por el sinclinal terciario de Villarcayo al Norte y por la depresión terciaria del Ebro al Sur (2).

Dicha unidad de relieve aparece constituída por un conjunto de anticlinales y sinclinales de dirección N.O.-S.E. que afectan a materiales comprendidos entre el Jurásico y el Terciario, viéndose las estructuras más meridionales interrumpidas por el terciario de la depresión del Ebro, discordante sobre ellas.

Desde un punto de vista geológico, la alineación mesozoica que nos ocupa aparece definida por una litología típica del Cretácico Superior, constituída fundamentalmente por materiales carbonatados. En concreto la boca de la cavidad se abre en un estrecho paquete de calizas del Cenomanense (facies marina), poco potente y dolomitizada, integrado por calizas arcillosas y algunas intercalaciones de areniscas calcáreas, desarrollandose su única galería a favor de terrenos del Turonense Inferior, constituídos por calizas y margas calcáreas (3).

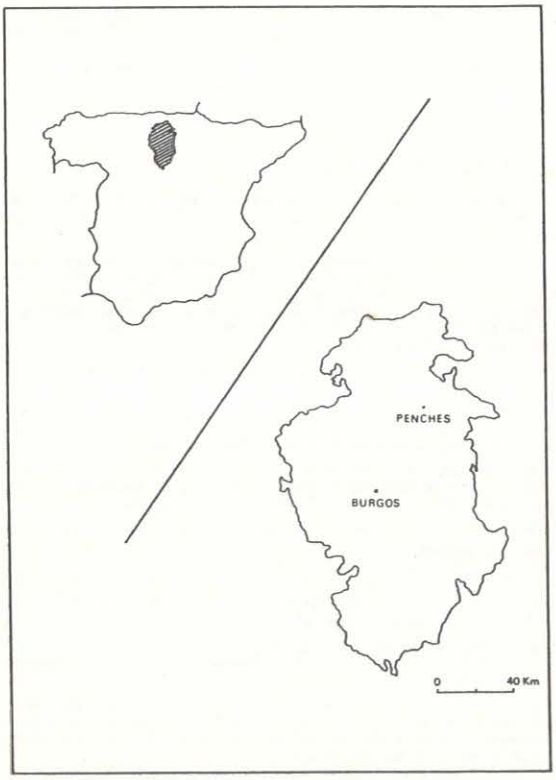


Fig. 1 Ubicación de la Cueva de Penches

2. MORFOGENESIS Y ANALISIS TOPOGRAFICO

2.1. Morfogénesis

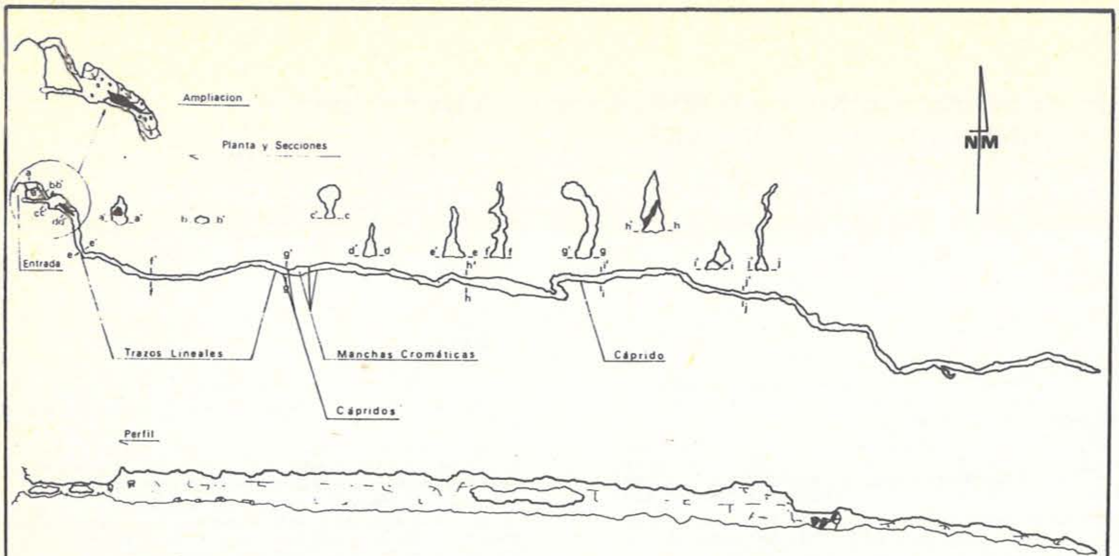
La Cueva de Penches es un fenómeno cárstico de desarrollo longitudinal, con una única galería de dirección O-E, que traduce en el subsuelo el panorama estructural del exterior.

Su espeleogénesis se explica en términos generales por la acción erosiva de un reducido acuífero hipogeo a favor de una diaclasa orientada conforme a la estructura. Ello determina el aspecto de grieta que caracteriza a todo el recorrido de la galería. La actuación erosiva de la corriente subterránea se efectuó en diversas fases, en relación con la variabilidad climática exterior, factor determinante de un mayor o menor aporte de agua. Este fenómeno dió lugar a la formación de incipientes líneas de cornisa, correspondientes a sucesivos niveles de encajamiento erosivo.

En la actualidad la cueva se encuentra en estado fósil, hallándose interrumpida la circulación hídrica, excepto esporádicas ocasiones en la que la intensa pluviosidad origina pequeños aportes ocasionales, nunca importantes.

2.2. Análisis Topográfico

En el presente análisis he utilizado como marco de referencia el levantamiento topográfico efectuado por el G.E. Niphargus de Burgos (4), en el que podemos observar además de la planta y el perfil longitudinal proyectado, las secciones y ampliaciones de los sectores más representativos de la cavidad, lo que nos permite hacernos una idea más completa del aspecto y morfología de la misma (ver fig. 2).



CUEVA DE PENCHES

Barcina de los Montes-Burgos

G.E.Niphargus 17-9-1977

Fig. 2

La caverna de Penches cuenta con un desarrollo espeleométrico global de 175 metros topográficos. El acceso a la misma en la actualidad se efectúa a través de una angosta galería de 0,7 metros de diámetro y desnivel ligeramente descendente que a los 6 metros desemboca en la galería principal; aunque seguramente éste no fue el aspecto de la entrada original, a juzgar por el hundimiento y posterior concrecionamiento de este sector. La galería principal presenta una sección diaclasiforme y dimensiones relativamente homogéneas en todo su recorrido, con una anchura que oscila entre 0,5 y 2 metros y una altura comprendida entre 2 y 5 metros. Esta tónica general se ve interrumpida en el tramo central, en el que la galería aparece subdividida en dos pisos por una cornisa intermedia.

Por lo que se refiere a la ubicación de las representaciones parietales en el citado marco topográfico hay que señalar en primer lugar, la abundante presencia de diversos trazos lineales de carácter no figurativo en las zonas elevadas del tramo 10-35 metros de la galería principal.

Centrándonos en los conjuntos figurativos (de cronología y técnica diferente a los anteriores), el núcleo principal se compone de cápridos y se sitúa a 37,5 metros respecto a la boca de entrada y a 3 metros de altura sobre el nivel del suelo. En sus proximidades, entre 41-42 metros se disponen una serie de manchas de color ocre y morfología indefinida. Finalmente, a los 78 metros respecto a la boca se ubicaba un nuevo cáprido, en la actualidad desaparecido bajo los grafitis contemporáneos (ver fig. 2).

En suma, los sectores más próximos a la entrada han sido los más utilizados, mientras los tramos más alejados se hallan practicamente desprovistos de cualquier indicio de representación, hecho que tal vez haya que poner en relación con las condiciones de impenetrabilidad de los últimos tramos.

3. ANALISIS TECNICO Y ESTILISTICO DE LAS REPRESENTACIONES

Dentro del conjunto de representaciones localizadas en la cueva de Penches, en el presente trabajo sólo haremos referencia a las de carácter figurativo, integradas casi exclusivamente por cápridos, excepción hecha de algunos trazos lineales de difícil lectura interpretados por algunos autores como presuntos antropomorfos (5).

Por lo que se refiere a las primeras, el núcleo central, situado a 37,5 metros de la entrada, se halla integrado por 4 cabras asociadas por "parejas", dos en el muro de la izquierda y otras dos en el de la derecha.

- La pareja de la izquierda es la menos detallada . Se compone de dos cápridos parcialmente figurados. El inferior es acéfalo y apenas tiene insinuadas las extremidades posteriores, mientras el superior carece de la parte anterior de su cuerpo, así como de sus patas. Hay que destacar en este grupo, la utilización de un convencionalismo frecuente en el arte paleolítico como es el representar al animal de perfil y la cornamenta frontalmente en un claro ejemplo de perspectiva torcida.

Tecnicamente ambas figuras han sido ejecutadas por grabado. El trazo simple y la incisión profunda producen un marcado contorneado de la figura.

Desde un punto de vista compositivo las dos figuras se hallan yuxtapuestas dentro de un mismo radio de acción manual, observandose como particularidad representativa un incipiente atisbo de simetría oblicua paralela.

- La pareja de la derecha contrasta con la anterior por su mayor detallismo. No obstante esta afirmación sólo es válida para el cáprido inferior , ya que es situado sobre éste se halla tambien incompleto al carecer de sus cuatro extremidades. Hecho que tal vez responda a un recurso representativo del artista prehistórico, a la denominada perspectiva por ocultación parcial, empleada para conseguir sensación de perspectiva cuando se representan dos figuras parcialmente superpuestas.

Desde un punto de vista técnico se utiliza el mismo procedimiento que en el conjunto anterior, el grabado profundo, cuyo efecto volumétrico se va acentuando por la descalcificación superficial del soporte.

También hay que apuntar en contraste con la pareja anterior, el empleo de una perspectiva "correcta" en la representación de los cuernos.

- Finalmente hay que hacer referencia al cáprido situado a 78 metros de la entrada, desaparecido hace ya algunos años por la acción incontrolada de desaprensivos. Para su análisis seguiremos los testimonios gráficos publicados por Hernández Pacheco. (6)

Sin duda, se trataba de la figura más interesante desde el punto de vista técnico pues combinaba grabado y pintura. El contorno general de la figura aparecía grabado por finas incisiones y revelaba un perfecto conocimiento anatómico. Además el efecto de modelado volumétrico se había señalado con finos haces de trazos incisos en el cuello, dorso y cuarto trasero, así como por la extensión de un difuminado en negro a determinadas partes del animal (cuello, dorso, etc.). De esta forma la pintura complementaba al grabado confiriéndole al animal una expresión de volumen de la que carecen el resto de las representaciones.

4. CONSIDERACIONES CRONOLOGICAS

La adscripción cronológica de las representaciones de la Cueva de Penches ha sido tratada por diversos autores en función de criterios generalmente estilísticos.

Ya en 1917 Hernández Pacheco (7), siguiendo esta línea estilística aunque cargada de un marcado subjetivismo, sitúa el conjunto central de cápridos en el Magdaleniense Inferior, apoyándose en el detallismo con el que se ha representado al cáprido inferior del muro de la derecha, frente a la mayor sencillez figurativa de las otras tres cabras a las que llega a equiparar con representaciones amiñacienses.

Por otra parte, adscribe el último cáprido grabado y pintado al Magdaleniense Medio, amparándose en el "elegante" estilo que caracteriza al animal y en el empleo de técnicas más "evolucionadas".

Algo después Brevil (8), situará todo el conjunto de Penches en el Magdaleniense Medio, apoyándose también en analogías estilísticas.

Leroi Gourhan (9), cita Penches entre su repertorio de cuevas con arte paleolítico, pero se abstiene de emitir ningún juicio cronológico más preciso, ni tampoco los argumentos que le llevan a tal adscripción.

Ripoll Perello (10), revisa la cueva en 1957, pero no aporta nada nuevo en materia cronológica.

Casado López (11), visita la cueva en la década de los "70", descubriendo algunos trazos de escasa especificación que le hacen basar su cronología en la dada para las representaciones animalísticas.

Posteriormente, Jordá (12), en función de criterios tecno-estilísticos situa el conjunto dentro de sus denominados "estilos de transición del Magdaleniense Cantábrico".

Por su parte García Soto (13), sitúa los cuatro cápridos del conjunto central dentro de un estilo IV antiguo de Leroi Gourhan, mientras adscribe sin argumentos convincentes, el último cáprido y los presuntos antropomorfos al estilo IV reciente del citado autor.

Corchón Rodríguez (14), relaciona el conjunto de Penches con los santuarios empobrecidos en temas con tendencia al esquematismo, situados en una fase avanzada del complejo magdaleniense con arpones, es decir, hacia el Magdaleniense Final.

Para Moure Romanillo (15), tanto la técnica, de trazo simple y único como la existencia de líneas de despiece y la propia composición avalan una cronología paleolítica. Pero la ausencia de pruebas concluyentes le impiden apuntar una dotación más precisa.

Personalmente considero fuera de lugar el establecimiento de una cronología absoluta para el presente conjunto, ante la inexistencia en la cavidad de materiales arqueológicos que hicieran posible la correlación entre arte rupestre y estratigrafía prehistórica. No obstante, ello no es óbice para apuntar una cronología en términos relativos. En este sentido, la utilización de convencionalismos de representación del arte cuaternario como la perspectiva torcida, las superposiciones o la perspectiva derivada de la ocultación parcial, respaldan plenamente una cronología paleolítica.

Por otra parte, y a pesar de que las técnicas no siempre conllevan un valor cronológico seguro, hay que argumentar que el empleo en la representación del último cáprido, de un fino rayado interior, que modela la figura y el difuminado en negro que completa la acción del grabado, constituyen técnicas específicas de expresión del volumen que podrían muy bien encuadrarse en una fase magdaleniense.

Estas afirmaciones no son del todo gratuitas y podrían ser apoyadas de forma indirecta por una argumentación de tipo arqueológico, derivada de la existencia en las proximidades de la estación que nos ocupa, de algunos yacimientos con cronología del Paleolítico Superior (16).

Desde un punto estilístico el empobrecimiento temático y la tendencia al esquematismo de algunas representaciones, tal vez nos lleguen a conclusiones similares a las ya apuntadas. No obstante, hay que valorar adecuadamente el alcance de estas ideas, ya que el contexto eco-ambiental que enmarca a la Cueva de Penches (abierto a influjos atlánticos y mediterráneos), le aleja bastante de los conjuntos clásicos de la Cornisa Cantábrica. Ello hace arriesgado extrapolar los sistemas estilísticos elaborados en otras zonas, al arte meseteño, definido por una problemática específica en la que será preciso profundizar si se quiere superar la mera comparación formal y el analogismo estilístico, para llegar a alcanzar conclusiones más sólidas y objetivas, que no sólo contemplen estos aspectos referenciales sino también los caracteres intraespecíficos que definen a las manifestaciones artísticas de esta zona geográfica.

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PRINCIPALES ETAPES DE L'ETUDE SPELEOLOGIQUE DE LA GEORGIE

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PRINCIPAL STAGES OF SPELEOLOGICAL STUDY IN GEORGIA

The following division into periods of speleological study in Georgia are offered by the authors. I. Presoviet period is divided into two stages. During the first stage covering the period from the antique till the second half of XIX century, the general information on karst landscapes was collected. The second period - from the fifties of the XIX century till the establishment of the Soviet Power in Georgia is specified by the accumulation of the actual material on the easily accessible small caves. The speleological features of mountain massifs remained unexplored yet. On the whole the presoviet investigation of the caves was occasional. II. Soviet period - from 1921 up to date) is characterized by the comprehensive and systematic study of Georgian karst and is divided into 4 stages: I. 1921-1940; 2.1941-1945; 3.1946-1957; 4. from 1958 up to date. The essential achievements are observed in the study of karst and speleology on the territory of Georgia during the last stage. New scientific trends as are: geomorphology of karst, physical speleology, hydrology and hydrogeology of karst, underground landscapes have been succesfully developed. Special consideration is given to the development of theoretical points of karstology and speleology of mountain regions as well as to its scientific background for the purpose of utilization of karst caves in the national economy.

ОСНОВНЫЕ ЭТАПЫ СПЕЛЕОЛОГИЧЕСКОЙ ИЗУЧЕННОСТИ ГРУЗИИ

Авторы предлагают следующую периодизацию спелеологической изученности Грузии: I. Досоветский период нами делится на два этапа. На первом этапе, длившемся от античных времен до второй половины XIX столетия, накопливались некоторые общие сведения о карстовых ландшафтах. На втором этапе, охватывающем время от второй половины XIX в. до установления Советской власти в Грузии, продолжается накопление фактического материала о легкодоступных небольших пещерах. Оставались неизученными спелеологические черты горных массивов. В целом, досоветский период исследования пещер носил случайный характер; II. Советский период исследования (с 1921 г. по настоящее время), ознаменовавшийся планомерным и всесторонним изучением карста Грузии, нами делится на 4 этапа: I. 1921-1940; 2. 1941-1945; 3. 1946-1957; 4. с 1958 г. по настоящее время. На последнем этапе исследования наблюдаются существенные сдвиги в карстолого-спелеологическом изучении территории Грузии. Созданы и успешно развиваются новые научные направления - геоморфология карста, физическая спелеология, гидрология и гидрогеология карста, подземное ландшафтоведение; особое внимание уделяется разработке теоретических вопросов карстоведения и спелеологии горных регионов, а также научных основ для использования карстовых пещер в народном хозяйстве.

L'abondance des phénomènes karstiques sur le territoire de la Géorgie fait de cette dernière une contrée classique du Karst. Ce relief karstique a joué, depuis les temps les plus réculés, un rôle important dans la vie du peuple géorgien. Son étude géographique date de l'antiquité et a pris une grande extension dans la période contemporaine.

De l'antiquité a nos jours, cette étude n'a, bien entendu, pas suivi un rythme régulier tant en ce qui conserne l'intensité des recherches que extension géographique sur laquelle elle portait, ceci étant dû, d'une part aux changements sociaux et politiques survenus dans la vie du peuple géorgien au cours des siècles et à l'évolution de l'état économique agricole du pays, d'autre part à l'évolution même du Karstologie. Aussi, peut-on délimiter très nettement cette étude spéléologique du karst de la Géorgie en deux periodes bien distinctes, la première allant depuis ses débuts jusqu'à l'instauration du Pouvoir Soviétique en Géorgie (1921), la seconde de 1921 à nos jours.

Jusqu'en 1921, l'on peut dire que l'étude du karst de la Géorgie se limitait à l'enregistrement des faits concrets intéressant le karst (extension territoriale des phénomènes karstiques, description de certaines phénomènes karstiques, en particulier description morphographique-morphometrique des cavernes et gouffres) mais l'aspect génétique des phénomènes en question était quelque peu négligé. Il faut également préciser que dans cette première période de l'étude spéléologique de la Géorgie, les phénomènes karstiques étaient rarement étudies pour eux-mêmes, leur étude accompagnait le plus souvent, et au second plan, des recherches entreprises pour l'étude d'autres problèmes géographiques. L'étude du karst était limitée, ne possédant d'ailleurs pas son propre organisme central pour diriger les travaux. Elle n'avait pas encore suscité l'interêt de l'Etat et les recherches dans ce domaine étaient fortuites, dépendant seulement de la curiosité scientifique qu'elles pouvaient éveiller chez tel ou tel chercheur.

Depuis l'instauration du pouvoir soviétique, l'étude spéléologique a pris un tout nouvel essor, suivant en cela le développement intense qui prenait l'étude de tous les phénomènes de la nature; l'étude des phénomènes karstiques se fait sous un angle plus vaste; on ne se limite plus à la description de la répartition des phénomènes karstiques sur le territoire et à leurs descriptions particulières, la recherches porte aussi sur leur génèse; souvent l'étude du monde souterrain est liée a la recherche de solutions pratiques dans le domaine d l'économie du pays. Non seulement les chercheurs scientifiques et le corps enseignant dans cette branche participent à l'étude du karst, mais à eux se joignent également des organismes d'Etat les plus divers; entre autres ceux groupant des ingéniers. La nécessité d'un centre de coordination des recherches karstiques s'est fait sentir davantage chaque jour et, effectivement, l'on a procédé à la création d'un tel centre.

L'étude spéléologique de la Géorgie dans sa première période n'a pas été uniforme en ampleur et en intensité. L'on y distingue plusieurs étapes.

La première étape (dite antique et féodale) s'étend depuis les temps les plus reculés jusqu'au milieu du XIX[e] siècle. Dans cette première étape, l'étude du karst consiste en une description d'ensemble des phénomènes karstiques, particulièrement des cavernes et grottes, à l'occasion de l'étude de la nature du pays ou d'événements historiques dont ils sont le cadre. C'est ainsi que l'on trouve nombre de renseignements dans ce domaine dans les écrits d'auteurs et de savants de l'Antiquité et de l'époque féodale (par exemple: dans "Les Argonautiques" d'Apollonies de Rhodes, II-III s. av.J.-C.- "La Géographie" de Strabon, 1-e s.av. J.-C.-les oeuvres de Pseudo Plutarque, II-e s. de notre ère, - dans "La vie de la Géorgie", "Le Chevalier à la peau de Tigre" de Chota Roustavéli, XII-e s.-"Relation de la Colchide hoggi detta Mengrellia" d'Archangelo Lamberti, 1654,- "Description géographique de la Géorgie" de Vakhouchti Bagrationi 1745 -"Peregrinatis Georgica" d'I.A.Güldenstädt, 1787-1789- "Voyage autour du Caucase", de Dubois de Montpéreux, 1839-1843, etc).

La deuxième étape (dite étape capitaliste) commence au milieu du siècle dernier. Elle coïncide avec les progrès étonnants qu'enregistrent vers cette époque les sciences de la nature en Europe et en Russie; c'est également vers cette période que la Russie impériale se préoccupe des territoires situés dans la région du Caucase, et particulièrement de la Géorgie en raison de sa position stratégique. C'est pour cette raison que l'on procède au relevé topographique du territoire de la Géorgie et à l'étude des conditions naturelles du pays.
Nous citons ci- dessous les ouvrages parus pendant cette période et qui ont plus ou moins trait aux phénomènes qui nous intéressent: Ouvrages de géographie générale: El.Reclus.1881, et autres; Ouvrages de géologie: Abrioutski 1852,-H.Abich, 1868 - G.Chtcheurovski, 1862 -L.Batsevitch et S.Simonovitch, 1873 -S. Simonovitch, A.Sorokine et D.Batsevitch, 1874-1875 -E.FAVRE, 1875 -E.Fournier, 1896.et autres; Ouvrages de biogéographie: G.I.Radde, 1866, 1873 et 1901 V.I. Tcherniavski, 1877, 1879, 1882-1883 et 1887- N.M.Albov 1883-1894, 1896 et 1899 - Iv. Akiniev, 1894 -M.P. Kalinine, 1895, 1899 et 1902 -A.V. Lomakine, 1902 et autres; Ouvrages d'archéologie: F.Baiern 1871 - V.I. Tcherniavski, 1879 et 1882- V^e Congrès archéologique de Tbilissi, 1881- A.I.Vvedenski, 1882 -E. Weidenbaum, 1882- A.Bernatski, 1884- Ouvarova 1887, 1891 et 1904 - V.Sizhov, 1899, et autres; Ouvrages d'art militaire et de statistique militaire et autres: Kraévitch, 1870 -V.T.Maévski, 1896-M.Serguéev, 1898 -I.I.Pantioukhov, 1896 et autres; En outre, on trouve des descriptions de phénomènes karstiques dans des ouvrages concernant l'étude de la nature de la Géorgie ou des monuments historiques du pays, le phénomène karstique étant consideré sous tel ou tel angle. Ce sont ceux de : K.B. Pfaff, -A.Steianov, 1876, et autres; C'est au cours de cette deuxième étape que l'on voit apparaître les premiers ouvrages consacrés proprement au Karst de la Géorgie, plus particulièrement aux cavernes et gouffres karstiques: Gr.K.Krenhelm, 1873- 1.Zikhatchev, 1887 - N. Sakharov, 1892 -A.P.Ivanov, 1898, et d'autres. Au cours de cette même étape, surtout vers les vingt dernières années, s'affirme l'étude des phénomènes karstiques sous l'angle génétique: H.Abich, 1852 - S. Simonovitch. L. Batsevitch et A.Sorokine, 1873-1875 -E. Fabre, 1875- N.M. Albov, 1893-1899 -E. Fournier, 1896-M.V.Sergueév, 1898, et d'autres.

La troisième étape (dite 2-ème étape capitaliste) de l'étude spéléologique de la Géorgie, s'étend sur le premier quart du XX-e siècle (jusqu'en 1921). Au cours de cette période s'intensifie la description géographique des phénomènes karstiques, notamment du point de vue du nombre des chercheurs et de l'extension des objectifs.

L'aspect génétique du Karst de la Géorgie a été particulièrement étudié chez les auteurs suivants: V.N.Leonov, 1902 et 1910- M.V. Sergueév, 1904- A.M.Margolius, 1905-Ed.A.Martel, 1910-V.Babet, 1915- A.A.Krüber, 1911-1912 et 1915, et d'autres.

Au cours de l'etude du Karst géorgien, les auteurs ci-après cités ont porté une attention toute particulière aux aspects pratiques des problèmes envisagés: K.A.Satounine, 1911 - L.A.Koniouchevski, 1913- XIII-e Congrès des Médecins et Naturalistes russes, à Tbilissi, 1913, etc.... Les auteurs suivants s'attachent à l'étude de la flore des roches calcaires: A.N. Krasnov, 1901 - I.N.Voronov, 1905-1906 et 1908- A.B.Chelkovnikov, 1913, etc. et à celle de la faune cavernicole: A. Semenov, 1901 -A.M. Chougourov, 1907-1908 -K.A. Satounine, 1911-1913- B.P.Ouvarow, 1912 -N.Smirnov, 1918, et d'autres.

Dans des ouvrages parus au cours de cette même période, on trouve nombre de renseignements intéressants dans le domaine de la géographie et notamment dans celui de la géomorphologie; parmi les ouvrages de géologie, citons ceux des A.M.Margolius, 1902 - E.Weber, 1901-1902 - G.M. Smirnov, 1909 - L.K.Koniuchevski, 1913 - V.V.Doubianski, 1915 et d'autres. Parmi les ouvrages d'archéologie, ceux de: St.Kroukovski, 1914 - T. Margvelachvili, K.Tchirakadzé et T.Djaparidzé, 1914 - R.Schmidt et L.Koslovski, 1919 et d'autres. Parmi les rapports concernant les relevés topographiques, ceux de: K.I.Podozerski, 1902, et d'autres. Parmi les descriptions de la nature et les récits de voyages, ceux de: K.K.Matchavariani 1900 et 1914 - A.V.Zelenine, 1902 - N.A.Choustak, 1903 - A.N.Diatchkov-Tarassov, 1903-1904 - A.G.Peredelski, 1908 - K.A.Satounine, 1911 et d'autres.

Une telle masse de renseignements ont été rassemblés au cours de cette période qu'il a été possible d'établir une carte où était délimitée la première région karstique: l'auteur en était A.L.Reinhard, 1917.

Abordons maintenant la période soviétique de l'étude du karst géorgien. Ici encore, cette étude a suivi une courbe variée quant a l'intensité et à l'extension des recherches et, de ce fait, l'on peut y distinguer quatre étapes.

La première étape va de 1921 à 1941. Au cours de cette période l'étude des cavernes karstique n'est pas encore organisée sous l'égide d'un organisme spécialisé et les travaux enregistres dans ce domaine sont dus à l'initiative personnelle des chercheurs, relevant parfois d'organismes qui ne sont pas directement intéressés à la branche de la géographie. Cependant, on publie, surtout dans les dernières années de cette première étape, des rapports de travaux scientifiques très importants et des ouvrages de vulgarisation scientifique, concernant la géographie et qui fournissent des renseignements précieux sur le karst Géorgien; certaine de ces ouvrages concernent la géomorphologie, ce sont ceux de: A.J.Djanelidzé, P.S.Panioutine, N.A.Kandelaki et G.S.Dzotsenidzé, N.A.Gvozdevski, L.I.Marouachvili, Ch.I.Kipiani, et d'autres; certains, les climats spéléologiques et l'hydrologie, ce sont ceux de: A.G.Balabouev, P.S.Panioutine et B.I.Kavrichvili, - certains, la géographie des sols et la biogéographie, ce sont ceux de: S.A.Zakharov, A.A.Kolakovski, A.A.Sadovski, I.A.Birstein, V.G.Lopachov, F.A.Zaitsev, D.G.Kharitonov, et d'autres.

La deuxième étape de l'étude spéléologique en Géorgie dans la période soviétique, comprend les années de la Grande Guerre nationale de 1941-1945. Au cours de ces années, l'étude du karst fut subordonnée aux problèmes posés par la défense nationale. C'est ainsi que des travaux de recherches très importants ont été accomplis concernant les grottes et cavernes d'Imérétie, de Ratcha et de Mingrélie, en vue de leur utilisation éventuelle; citons les auteurs de ces travaux: G.Devdariani, G.Kokotchachvili, L.I.Marouachvili, A.A.Sadovski, et d'autres. La publication de ces travaux n'a eu lieu que dans la période ultérieure.

La troisième étape s'étend sur la décade qui suit la fin de la guerre (1946-1957-. On assiste alors à une intensification de l'étude spéléologique, laquelle se manifeste, entre autres, par la publication d'un grand nombre de rapports scientifiques et d'ouvrages de vulgarisation scientifique. Citons parmi les noms des auteurs, ceux de: N.A.Gvozdetski, L.I. Marouachvili, Ch.I.Kipiani; mais il faut cependant signaler que la recherche des cavernes karstiques a encore un caractère épisodique.

La quatrième étape (ou étape actuelle) de l'étude spéléologique en Géorgie dans période sovetique, débute en 1958 et se prolonge de nos jours. C'est alors que l'étude du karst s'organise véritablement en Géorgie; elle s'organise sous l'égide des chaires de géographie des hautes écoles de la RSS de Géorgie (Université d'Etat de Tbilissi, Instituts pédagogiques d'Etat - Institut pédagogique d'Etat A.Tsouloukidzé de Koutaissi, Institut pédagogique d'Etat M.Gorki de Soukhoumi - etc...); un laboratoire de karstologie-spéléologie à l'Institut Géographique Vakhouchti Bagrationi de Tbilissi; de même qu'un centre de coordination, appelé conseil de spéléologie, rattache à l'Academie des Sciences de la RSS de Géorgie; toujours pour l'etude du karst, des services sont fondés auprès d'organismes divers, tels que: la section de karstologie-speleologie dépendant des services scintifiques de la Sociéte de Géographie; le Comité du sport spéléologique rattaché a la Societé Sportive de la RSS de Géorgie et aux Syndicats; la section de sport spéléologique auprès de l'Union du Tourisme de RSS Géorgie. Tous cas organismes ont contribue aux progrés de l'étude du karst, a son developpement et à la création de nouvelles branches scientifiques, telles que la géomorphologie du karst, spéléologie physique, hydrologie et hydrogéologie du karst, étude du paysage southerain; on a attaché beaucoup d'importance aux études des questions théoriques de la karstologie etde la spéléologie des régions de montagne, ainsi qu'aux études des fondements scientifiques de l'utilisation des cavernes et des grotte dans les buts de l'économie nationale.

Rapports scientfiques et ouvrages de vulgarisation scientifique se multiplient à la suite de l'extension des recherches; citons ceux de: N.A.Gvozdetski, L.I. Maruachvili, Z.K. Tintilozov, G.N.Gigineichvili, T.Z.Kiknadzé, L.A.Vladimirov, C.D.Tsikarichvili, K.Ch.Rakviachvili, K.G.Mgeladzé, L.N. Soloviov, E.V.Sokhadzé, B.A.Guerguedava, A.A.Okrodjanachvili, D.D.Tabidzé , E.M.Abachidzé, D.Ch.Gabetchava, S.N.Nemanichvili, V.M.Djichkariani, K.V. Kavrichvili, Ch.I.Kipiani, et d' autres. Signalons la parution de recueils specialisés , entre autres en spéléologie.

L'on voit donc que l'étude du karst de la Géorgie a pris un grand essor mais il reste encore bien des problèmes de spéléologie à étudier et à élucider. Il ne faut pas s'en étonner, car chaque nouvelle étude d'un phénomène karstique entraine l'apparition de nouveaux problèmes à résoudre pour le chercheur.

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PARAMETER DER HÖHLENGROSSE UND RAUMGROSSE

KRIEG, Walter

Some parameters responsible to development of long cavesystems and/or hugh rooms are discussed: Most important for both seem to be a low density of fissures, a long time of development and a big hydrological area. Less important are the existence of vegetation (with high variation), a great amount of precipitation and a well stratified limestone or rocks with strong tectonic history. Very important for long caves (but not for big cave-rooms) is a small altitude-difference between surface and karst-spring.
These parameters should work combined, either in addition or in contrary. Therefore are the regional typic hugh domes in small cave-systems only the rest of former bigger systems. Long systems with small rooms should be early phases in development, and the altitude should be small.

In diesem Referat wird ausschließlich über die Verhältnisse an und in Karsthöhlen im Kalkgestein diskutiert. Es fällt auf, daß je nach den regionalen Karstverhältnissen sowohl die Höhlengrößen als auch die Raumgrößen sehr stark differieren und daß man gegenüber solchen an sich auffälligen Verhältnissen eher "betriebsblind" wird. Trimmel nennt die Entwicklung der Höhlengröße mit Recht einen "komplexen, im einzelnen schwer faßbaren Vorgang" und die frustrierenden Vergleiche zwischen einem Arbeitsgebiet mit einer Vielzahl enger Kleinhöhlen zu einem anderen mit Riesensystemen und gewaltigen Höhlenräumen (bis zu 5 Mio m3) werden verständlicherweise selten angestellt.

Allgemein darf davon ausgegangen werden, daß sowohl Höhlengrößen als auch Raumgrößen vom Wirkungsgrad der korrosiven, erosiven und inkasiven Prozesse abhängen. Auch die Parameter dieser Prozesse sind bekannt und sollen im folgenden vorgestellt werden, eher unsicher sind aber ihre qualitativen Richtungen und schon gar ihre quantitativen Wirksamkeiten.

1. Die tektonischen Bedingungen sind sicherlich von besonderer Bedeutung: Ausmaß und Intensität von Faltung kann das Einzugsgebiet des Karstobjekts determinieren und die Vorbedingungen für die Höhlengenese (und wohl auch die Raumgenese) bestimmen. - Weitaus wichtiger ist nach allgemeiner Erkenntnis die Kluftdichte. So zeigt sich nur an den Riesenhöhlen von Tennessee, sondern wohl in allen Karstgebieten der Welt, daß geringe tektonische Beanspruchung und deshalb in der Folge ein weitmaschiges Kluftnetz mit sehr wenigen und nur engen Klüften zur karsthydrologischen Bevorzugung dieser wenigen Klüfte und zur lang anhaltenden Wasserbenutzung gerade dieser Klüfte, schließlich somit zur Ausbildung großer Höhlensysteme und Höhlenräume führt. Umgekehrt bewirkt ein besonders enges Kluftnetz eine geradezu flächenhafte Durchfließung des Gesteinskörpers durch Karstwasser, sodaß Korrosion und Erosion an Einzelklüften so klein bleiben kann, daß sich überhaupt keine befahrbaren Höhlen entwickeln, obwohl das Areal extrem verkarstet ist. Dies gilt etwa für die Dolomitkarstvorkommen der Alpen.

Bereits Bögli hat festgestellt, daß kapillare Fugen, also alle Schichtfugen und viele Klüfte, nur unter Druck durchflossen werden können, sodaß sich an ihnen ausschließlich in phreatischen Verhältnissen Höhlen bilden können. Für vadose Entwicklungen sind demnach nur (offene) Zerrklüfte und auch die schon phreatisch aufgeweiteten Klüfte und Schichtfugen geeignet.

Eine geringe Kluftdichte erweist sich somit als wahrscheinlich wichtigste tektonische Voraussetzung für die Entwicklung großer Höhlensysteme und dementsprechend auch großer Höhlenräume.

2. Der Entwicklungszeitraum sollte auf Höhlen- und Raumgrößen nicht nur linear wirken. Denn die Durchlässigkeit steigt mit dem Grad der Entwicklung und die Initialphase der Höhlengenese dauert wegen der beschränkten hydrologischen Fähigkeiten in vielen Fällen sehr lang. Dabei kann die Durchlässigkeit (Bögli folgend) im phreatischen Raum vorwiegend an Schichtfugen und im vadosen Raum vorwiegend an Klüften erwartet werden.

Mit Recht wird immer wieder betont, daß Höhlengenese mit irgendwelchen theoretischen geographischen Reifezyklen schlecht korreliert werden werden kann und daß solche Korrelierungen zu sehr unscharfen schematischen Vorstellungen führen müßten. Trimmel erinnert daran, daß zumindest bei der Raumentwicklung Phasen vorwiegender Raumerweiterung und Phasen vorwiegender Raumerfüllung eintreten können. Dies sollte nicht in dem Sinn verstanden sein, daß dies eine notwendige Aufeinanderfolge von Phasen ist, sondern durch Sedimentation kann die Evakuation ganz oder teilweise gefüllt werden. Von "fossilen Höhlen" sollte deshalb erst dann gesprochen werden, wenn der Konvakuationsraum tatsächlich null wird. Bloße Inkasion vergrößert die Oberfläche des Gesteins gegenüber dem lösenden Medium und kann daher die Raumgrößenentwicklung noch beschleunigen.

Höhlensysteme und Höhlenräume müssen demnach wachsen, solange ihre Entwicklung andauert. Nur durch Erreichen des Stadiums einer fossilen Höhle oder durch gänzliches Trockenfallen - beides hat eine Änderung der geologischen und/oder geomorphologischen Parameter zur Voraussetzung - ist der Entwicklungszeitraum tatsächlich beendet.

3. Die Größe des Einzugsgebietes dürfte eine mindest ebenso wichtige Größe wie die Länge der Höhlenentwicklung sein. Von ihr hängt die Durchflußgröße ab, und je nach der Reliefgröße, den stratigraphischen, lithologischen und tektonischen Verhältnissen sollte das summierte absolute Maß der Kalklösung vorwiegend auf die Entwicklung der Höhlengröße oder der Größe einzelner Höhlenräume wirken.

4. Die Niederschlagshöhe und der Durchflußcharakter ergeben sich vorwiegend aus den Klimawerten des Areals. Während Höhlen- und Raumgrößen mit den Niederschlagshöhen linear steigen sollten, ist der jährliche Abflußgang im Karstsystem weitaus schwieriger einzuschätzen: Jährlich wiederholte Hochwässer führen nämlich in der vadosen Hochwasserzone über dem Karstwasserkörper zu verstärkten Erosionsleistungen, reduzieren aber die chemische Lösungsfähigkeit drastisch, sodaß die an sich so bedeutsame Korrosionsleistung wesentlich geringer ist als bei gleichem, aber relativ gleichmäßigem Wasserdurchsatz.

Daher wird insgesamt abgeschätzt, daß der Durchflußcharakter als Parameter der Höhlengröße und Raumgröße von geringerer Bedeutung ist als die absolute jährliche Abflußmenge, die neben verschiedenen anderen klimatischen Bedingungen vor allem von der absoluten Niederschlagshöhe abhängt.

5. Andere wichtige Klimawerte sind für das Ausmaß der Wirkung der Mischungskorrosion verantwortlich. Aus dem Temperaturgang an der Erdoberfläche und aus der Niederschlagsverteilung resultieren die Dichte und die biologische Aktivität der Vegetationsdecke, aus ihr ergibt sich Bodenbildung, der Gehalt an Humussäuren und an CO_2, die mit dem versinkenden Karstwasser in das Höhlensystem eingebracht werden. Weil der Chemismus des Karstwassers umso mehr variiert, je vielfältiger diese Voraussetzungen an der Erdoberfläche sind, stellt nicht die gleichmäßig geschlossene, einheitliche Vegetationsdecke das Optimum für die Entwicklung im Karst dar, sondern eine möglicherweise lückige, im Bodenaufbau und unter den Pflanzengesellschaften vielfältige Vegetation. Dazu kann auch das Relief der Erdoberfläche beitragen: Ein eng gekammertes Hügelland ist der Höhlen- und Raumentwicklung eher förderlich als eine einheitliche Fläche. Umgekehrt bietet völliger Vegetationsmangel ein Minimum für die Höhlenentwicklung.

6. Die Wirkungen der stratigraphischen und lithologischen Verhältnisse lassen sich im generellen weniger gut abschätzen, obwohl sie im Einzelfall oft eine dominierende Rolle spielen. So haben reine oder unreine Kalke sehr verschiedene Lösungswerte und wird auch die Frage der Sedimentation von Lösungsrückständen oft wichtig, doch sind gerade unreine Kalke (eventuell in Wechsellagerung mit dünnen Mergelbänken) in vielen Fällen für den Mechanismus der Wasserwege bedeutsam: Schichtgrenzhöhlen weisen auch nach Trimmel eine deutliche Tendenz zur Großraumbildung auf.

Weiters wurde bereits darauf hingewiesen, daß Verbruchvorgänge durchaus nicht zum "Höhlenverfall" führen müssen, sondern im Bereich des Verbruchs eine Erhöhung der Lösungsvorgänge durch Vergrößerung der Gesteinsoberflächen - und damit eine Vergrößerung des Höhlenraumes, in dem ein inkasiver Vorgang stattfand, bewirken.

Gegen die naheliegende Vorstellung, daß standfester, reiner Kalk die Bildung von Großhöhlen und Großräumen fördert, spricht auch die berechtigte Vorstellung Böglis, wonach für die Höhlenentwicklung eine Kombination von Schicht- und Kluftfugen (wie gerade in unreinen mergeligen oder sandigen Bankkalken häufig) optimal ist, da hierdurch nicht nur günstige Abflußbedingungen entstehen, sondern auch die Mischungskorrosion gefördert wird.

Angesichts der Unklarheiten in der Bewertung dieser Parameter wird in die Auflistung lediglich aufgenommen, daß eine generelle Auswirkung der stratigraphischen und lithologischen Verhältnisse auf Höhlengrößen nicht behauptet werden darf. Höhlen sind auch in unreinen Kalken häufig. Für die Entwicklung von Großräumen kann aber generell eine geringe Standfestigkeit des Gesteins als günstig bezeichnet werden.

7. Die Größe des Reliefs zwischen Erdoberfläche und Karstquelle muß für die Entwicklung der Höhlengröße als eminent wichtiger Parameter angesehen werden: Herrschen doch bei kleinem Relief weitaus eher phreatische (und bei großem eher vadose) Verhältnisse im Gebirgskörper. Die Größe des Höhlensystems wächst gerade unter phreatischen Bedingungen, Bögli formuliert sogar, daß bei lang konstanter Karstwasserfläche die Gangquerschnitte bis zur Bruchgrenze des Gesteins anwachsen können, was im Evolutionsniveau an der Piezometerfläche geschieht. Kleines Relief ist also auf die Entwicklung von Großhöhlen programmiert, wobei zwar auch die Raumgrößen anwachsen, doch ohne daß dies eine ähnliche Bedeutung erlangte. Für Raumgrößen sind hohe Reliefbeträge sogar eher zuständig, indem innerhalb der vadosen Zone bei steilen Gangsystemen oder Schächten zusätzlich zur Korrosion auch die Erosion in beträchtlichem Ausmaß wirksam werden kann.

So scheint die These richtig zu sein, daß - anders wie bei den vorher besprochenen Parametern - die Reliefgröße zwar für die Größe des Höhlensystems sehr bedeutsam ist, für die Größe von Höhlenräumen jedoch nur eine untergeordnete und schwer abschätzbare Rolle spielt.

Die Ergebnisse der Diskussion der vorgestellten Parameter werden in der Abbildung dargestellt. Nicht darstellbar ist die hohe Bedeutung der phreatischen oder vadosen Genese von Höhlen und Höhlenräumen. Sie ist schon das Resultat einer Verknüpfung von dargestellten Parametern.

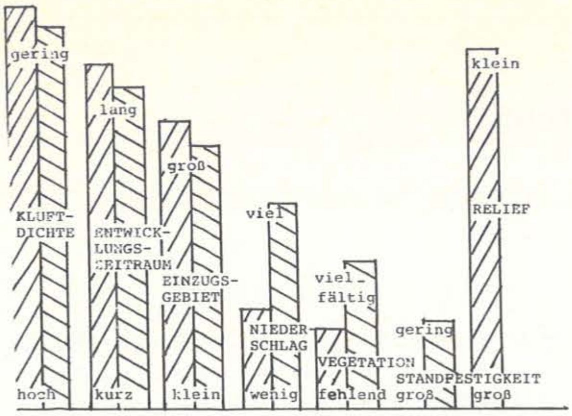

Abb.: Einschätzung der Wirkungen (nur tendenziell) der Parameter

Höhlengröße   Raumgröße

So ist in der Praxis vor allem an Kombinationswirkungen der Parameter zu denken, die derzeit nicht wirklich überblickbar sind. Es lassen sich jedenfalls sowohl bloße Summationswirkungen als auch Aufschaukelung und Auslöschung durch Wirkungen mehrerer Parameter erwarten.

Mit aller Vorsicht lassen sich aus dieser Diskussion folgende Schlüsse ziehen:

a) Höhlen- und Raumgrößen sollten tendentiell korrespondieren
b) Die für manche Regionen typischen großen Höhlenräume in kleinen Höhlensystemen stellen wahrscheinlich Reste ehemals größerer Systeme dar
c) Lange Höhlensysteme mit kleiner Raumentwicklung sind relativ frühe Entwicklungsstadien, die sich bei kleinem Relief gebildet haben.

In diesem Papier wird versucht, von sehr eingeschränkten genetischen Deutungsversuchen, wonach nicht Entwicklungsstufen eines Höhlensystems, sondern lediglich einiger Höhlenräume gedeutet werden, in allgemeiner Weise hinwegzukommen.

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PROSPECTS OF SPELEOTHERAPY IN POTASH MINE ENTRIES

KRASNOSTEIN, Arkadiy E.

Results of long-term (11 years) investigations carried out by the stuff of unique speleohospital organized in Berezniki town (Perm area) are summarized in the report. Physical and chemical peculiarities of kalium mine microclimate and mechanism of its curing effect proposed by the authors are analized. Current and remote results of speleotreatment, dynamics of different functional and laboratory tests in the process of speleotherapeutics are considered. Attention is paid to the perspectives of speleotherapeutics on the basis of kalium mines of Verhnjaja Kama region.

The Soviet Union possesses the world's largest potash deposits. One of unique for its area dimensions and mineral composition the Upper Kama deposit is situated on the western slope of the Urals and came to be developed in the 30s of our century. Since early 60s there started developing the second in amount the Starobin deposit of Bielorussia. At present there are 10 potash mines in Western Urals and Bielorussia whose annual private mean output makes up about 7 million tons.

The total worked-out volume in these mines equals about 800 million cubic metres.

The productive strata of the Upper Kama deposit occurs at the depth of 200 to 600 m from the surface and is represented with 5 commercial seams, of which 3 seams are workable - Кр II (6 to 8 m thick), АБ (2.5 to 3 m) and B (6 to 18 m).

The bedding is regular, complicated with shoaly folding, having a small inclination from east to west.

Under the commercial strata there occurs an old rock-salt series.

The Starobin deposit also has a regular seam bedding with an inclination angle of 2 to 6°. The potash occurs inside thick rock-salt seams and forms three persistent enough potash levels. The upper seam having an average thickness of 3.5 m occurs at depth of 250-300 m, the median seam lies 60 to 70 m below the upper one and is 2.6 m thick. The lower seam lies at the depth of 500 to 900 m from the surface and is divided in three benches. The lower bench only of the total workable thickness of 2 to 8.5 m is of commercial importance.

Since late 50s Perm Polytechnical Institute and then Leningrad Mining Institute and the Mining Institute of the Urals Department of the USSR Academy of Sciences have carried out a detailed research into formation regularities of gas, aerosol and ion composition and microclimate atmospheric parameters of potash mines.

The results of these investigations obtained already by late 60s convincingly testified to the fact that the qualitative atmospheric composition even in working potash mine entries deposits a considerable exhalation of passive and active gasous and suspended admixtures of natural and technological origin creates very favourable prerequisites for highly active speleotherapeutics of respiration diseases.

Based on these investigations, the world's first allergological nursing home built in the potash mass received patients in 1977 at the First Mine in Berezniki of Perm Region. Within 12 working years this nursing home has treated about 5,000 patients suffering from respiration diseases of various ethyology and degree.

The main therapeutic effect made up 70 to 80% with remote results of 1 to 3 years which practically conform with those of other speleohospitals.

Without concentrating on the analysis of strange to us purely medico-physiological aspects of speleotherapy in potash mines, we proceed to consider physico-technical problems of purposeful formation of an optimum set of atmospheric sanitary and psychogeneric conditions determining the patient treatment efficiency and capable, when observed, of considerable extention of the therapeutic effect spectrum of human organism.

To the number of such undoubtedly interdependent factors requiring optimization, there should, in our opinion, belong:

- gas, aerosol and ion composition of the atmosphere;
- microclimate parameters;
- bacterial semenness;
- psychogeneric factors.

The principal difference of our approach to speleotherapy from the conventional one in this aspect consists in the fact that we propose no limit to the use of the existing natural facilities arising in a natural way in the vicinity of the speleohospital, but on the basis of mine aerology and thermal physics achievements to purposefully form optimum atmospheric and sanitary environmental factors with a maximum use of the entire potential of natural and techogeneric agents.

The report framework does not permit to cover in necessary details all the formation aspects of the above mentioned factors, the more so because the scope of our immediate interest includes only the first two groups of parameters for the third and the forth ones we can lay down our general considerations only.

The atmospheric gas composition formation in working potash mines occurs under the effect both of natural and technogeneric factors. The composition of natural gases differs from the common one in an increased hydrogen content (from decimal fractions to 20 and more volume percent), sulphur containing gases (hydrogen sulphide, sulphur dioxide, mercaptans), heavy hydrocarbons. Among technogeneric gases the greatest place is taken by carbon and nitrogen oxides. In much smaller amounts hydrogen sulphides, sulphur dioxide and aldehydes are formed.

Three main formation features of the gas condition in potash mine entries can be brought out opening up real ways to optimize this factor. The first one consists in the fact that the presence of gas in potash and containing rock (except carnallite) is extremely low (not exceeding 0.5 m^3/m^3), and the capped-porous salt structure determines insignificant gas permeability of rock. Therefore the solid draining zone does not exceed 0.1-0.5 m from the exposed surface. Complete draining time ranges depending on the degree of the outline block disturbance from a few days to a few months. Exhalation of natural gases, in a majority of cases, in 30 or 40 days already since the surface exposure becomes infinitely small and does not effect the gas condition formation.

The second feature consists in a high chemosorbtion activity of potash which determines the process of neutralizing the main poisonous components of technogeneric origin. Having no opportunity to go into further details describing these processes, sacrifice it to note that their foundation is, on the one hand, the natural radioactivity of the solid, being a complimentary activation source (tens and hundreds of times) both of gas molecules and surface molecular layers, and, on the other, condensation process.

Both these phenomena exercise a considerable catalytic effect leading to a gradual neutralization of nitrogen oxides and carbon oxide with a formation of chemically bonded finite products.

The third feature of the gas condition formation is the presence of great volumes of worked out space counted by tens of millions of cubic meters and filled with air which went through an extended and highly effective gas cleaning.

The presence of these volumes creates in essence an inexhaustibl and renewable stock of highly conditional air masses which can be used for a required hospital air treatment.

The gas condition formation features mentioned contain the key to understanding the directions to optimize not only the gas composition proper but the rest of all the atmospheric factors determining the effect of speleotreatment. We shall therefore make use of the key mentioned only after considering the formation dynamic of all other components of the air environment.

Unlike the gas condition the atmosphere aerosolic composition is determined by the action of technogeneric factors alone.

The essential here feature of the aerosols is their real and dispersive composition as well as dynamics of these factors in various points of the ventilation network. The real composition of potash aerosols is generally determined by the composition of the seams under development. However, the quantitative ratio of the separate components of the initial dust as far as it is in a suspended condition and moves along entries and changes greatly. In relative proximity to dust formation sources and at a small distance from air supplying shafts the Upper Kama mine aerosols include $CaCl_2$ (20-24%), NaCl (60-70%), $MgCl_2$(0.4-0.6%), $CaSO_4$(2.1-2.4%), organic matter (1.2-3.5%). The microelemental composition of potash aerosols is also rich. They contain ferrum, nickel, cobalt, copper, zinc, rubedium, iridium, yttrium, barium, chrome, vanadium, titanium and a number of others.

With remoteness from dust formation sources the organic matter and water soluble salts content decreases. Stabilization of the concentrational and real composition in entries with constant relative air humidity takes place at a distance of 1.5 to 2 km from the dust formation source, the aerosol concentration by weight being 1 to 5 mg/m^3.

A similar dynamics is observed for the aerosol dispersive isotopes and their elements: potassium-40, radium, thorium, uranium and others. The natural radioactivity initiates exhalation of microquantities of rodonium, thoronium and actionium radioactive amanations and a faint ionizing radiation leading to a considerable correction of ion composition of the atmosphere.

Aeroionic prospecting of potash mines have shown that whereas the surface content of light aeroions does not exceed 250 to 300 per cm^3 with the unipolarity factor of 1.2 to 1.3, yet in pit-bottoms the total amount of light aeroions increases up to 700 to 1,000 per cm^3 and the unipolarity factor becomes lower than 1 (0.8 to 0.9). To say the truth, near shafts there remains a very high concentration of heavy aeroions (10,000 to 15,000 per cm^3). With remoteness from air supplying shafts the aeroionic air composition continuously changes towards a content increase of light aeroions and unipolarity factor reduction. The most favourable aeroionic condition arises in worked-out chambers and on the general mine outcoming stream where the light aeroions content in 1 cm^3 reaches 2,000 and more with the unipolarity factor of 0.7 to 0.8, and the heavy ions concentration reduces to 5,000 to 6,000 per cm^3.

One of the most important factors most likely determining the efficiency of any speleotherapy, is microclimate. Numerous data on speleotreatment testify to the absence at present of somewhat convincing evidence of optimum microclimate parameters being present. Most striking is that an approximately same therapeutic effect is gained in diametrically opposite microclimate conditions: at low (5 to 7°C) temperature and high (up to 90%) relative humidity and relatively high (over 20°C) temperatures and low (below 40%) relative air humidity. With this, a growing number of investigators come to the conclusion that a decisive importance does not belong to the composition. With remoteness from dust formation sources the large size particles content decreases steadily. In stabilized aerosolic composition zones in working entries with outcoming ventilation flows 97-98% of aerosol particles have dimensions up to 3 to 5 μm, the size of more than 50% of the particles not exceeding 1 to 2 μm.

The most stable aerosolic composition is observed in the atmosphere of worked-out spaces, especially in large volume chambers developed by blast hole drilling and having cross-section dimensions of 80 to 100 m^2 and more and length of no less than 150 to 200 m. In these conditions aerosol concentration by weight does not exceed 0.5 to 1 mg/m^3 and the dimensions of a greater majority of particles (80-90%) are within the limits of sub-microscopic (0.5 μm) values.

A characteristic feature of the aerosolic composition formation of potash mine atmosphere is its direct dependence of relative mine air humidity.

As is known, hygroscopic material particles when in a suspended condition in the air of humidity close to critical begin to increase rapidly in size passing therein two stages: condensational and coagulational growth with an intensive progress of sedimentary processes to follow.

The potash salts critical humidity makes up 65 to 70%, for sodium chloride 78 to 80%. For this, even small humidity variations lead to a sharp content increase of NaCl particles in aerosol at the expense of KCl particles decrease. For the same reason, there is an increase of relative content of insoluble residue.

A specific feature of potash magnium ores is their natural radioactivity created by the present therein radioactive microclimate atmosphere parameters proper but to their time stability. Therefore the subject of optimization should likely be considered to be not the atmosphere relative humidity temperature value (the air movement velocity and the barometric pressure have private values) but rather their variation level within the curing period.

On this sense the USSR's potash mines are no exception, in whose entries a wide spectrum of microclimate parameters combinations can be maintained in natural way. Together with this, should their time stability be accepted as a foundation, then likewise in relation to the gas, aerosolic and ionic atmosphere composition, quite definite requirements should be put forward to the selection of the hospital installation zone within the rock mass and its ventilation scheme.

In formulating these requirements one should proceed from the fact that in the vicinity of air supplying shafts it is impossible to provide in natural way even a relative stabilization of microclimate parameters. A minimum remoteness from the shaft along the ventilation duct where constant temperature and relative air humidity are achieved, makes up 2 to 2.5 km.

At this distance the air temperature practically becomes equal to that of the rock, and the relative air humidity becomes equal to the critical one for the given salt composition forming up the containing massif. In this sense the most stable conditions are observed in worked-out chambers situated remotely enough from the air supplying shafts.

Placing hospitals in outcoming flow areas or in worked-out zones of potash mines completely meets the minimization requirements for the atmosphere bacterial semenness. Observations have shown that with the air advancing along potash mine entries its bacterial semenness reduces abruptly and in worked-out areas it practically disappears at all. With this, even in stagnant zones ventilated via diffusion only, there occurs a rapid air regeneration via the introduced microflora which fact is extremely important for exercising restoration functions of the hospital's atmosphere after staying of patients there.

To the forth group of factors concerning the hospital condition effect on the human psychogeneric sphere, belong: hospital's aesthetic merits or faults; sound background, presence of technogeneric noise, especially sporadic, of elivated level and unpleasant frequency spectrum; the patient's confidence degree in guaranteed safety of staying in the hospital; psychological unloading (music, reading, watching TV, games etc.); the comfort level (enough room for the required ward equipment, mutual rooms, room for physical and preventive treatment, etc.)

The possibility analysis of the factor optimization of this group in potash mines brings us once more to the conclusion about expediency of arranging hospitals in working potash mines away from the working zones in sites worked out long ago and having stabilized geodynamic and rock formation processes.

Drawing a line to the factorial analysis of the ways of optimization of placing speleohospitals it is rightful to conclude that the USSR's potash mines (and first of all in the Western Urals) are one of the most perspective concentration areas for underground health establishments capable of treating no less than two or three thousand patients at the same time. Therefore it seems expedient to create in the Weatern Urals one of the world speleotherapeutic centres.

A high level scientific assistence to such a centre is ensured by the presence in Perm of the Mining Institute and the Institute of Ecology and Microorganism Genetics of the Urals Department ofthe USSR Academy of Sciences as well as by a concentration of great scientific power of the mining, geological and medical types of Perm's high schools.

(Perm, USSR)

PREDICTING THE RESPONSE TO RECHARGE OF PARTIALLY INSTRUMENTED KARST AQUIFER: TOWARD AN ADAPTIVE HEURISTIC MODEL

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Abstract: Given the output of any karst system there are several possible models which would explain the observed response to recharge. The solution of this problem can be viewed as a search through "karst space", i.e. all possible karst systems, for which several heuristic search algorithms are available. This study has investigated the so-called genetic algorithms.

The Castleton karst system, Derbyshire, UK has a very unusual response to recharge involving both major and minor fluctuations with periods ranging from hours to minutes. An integrated computer support environment containing three years of measurements has been set up. This has proved a comfortable and efficient environment within which to apply genetic algorithms to the data. Starting with a completely incorrect initial configuration, an iterative process of evolution has produced a model which will adapt more fully as the body of data increases.

LA PREDICTION DE LA RÉPONSE À RECHARGE
POUR LES AQUIFERS INSTRUMENTÉS PARTIELS:
UN MODÈLE AVEC ADAPTATION HEURISTIQUE

Résumé: Présupposé l'effusion d'un système karstique il y a plusieurs modèles possibles pour l'explication de la réponse à recharge observée. On peut regarder la solution de ce problème comme une recherche d'un bout a l'autre "d'espace karstique", c'est-à-dire tous les systèmes karstiques. Il y a plusieurs algorithmes heuristiques pour chercher: cette étude a examiné les algorithmes dits génétiques.

Le système karstique à Castleton, Derbyshire, Royaume Uni contient une reponse à recharge un peu extraordinaire avec fluctuation tant majeure que moindre et périodicité qui se range d'heures en minutes. Un environnement supportant intégral a l'ordinateur avec mesurages pour trois années s'établit. Voici un environnement confortable et suffisant pour l'application des algorithmes génétiques. Pour commencer avec une configuration complètement incorrecte, un cours itératif d'évolution a produit un modèle qui se développera de plus en plus quand les données augmenteront.

1. Introduction

Most karstified limestone aquifers are complex hydrological systems which pose many problems to would be modellers. Due to the lack of information on the internal structure of the aquifer, black box models have to be used. Recent advances in machine learning suggest a method whereby all available input/output data is used to train an adaptive model to sucessfully mimic the black box behaviour of the aquifer. Once trained, it is hoped the model may then reveal hitherto hidden details of the aquifer.

These ideas are being tested in the Castleton karst, Derbyshire, England.

2. Adaptive Modelling

If we disregard Divine Creation, then by definition Nature is full of self-adapting systems. By this we mean an entity which gradually alters itself in order to better fit its environment. The mechanism is at once extremely simple, yet produces subtle and spectacular effects.

It is the 'automatic' nature of this adjustment which is interesting, and suitable for implementation on a computer. There are two complementary approaches, each borrowing ideas from nature:

- Genetic algorithms
- Neural nets

2.1. Genetic Algorithms

The process of cumulative selection is based upon replication. Once an entity (a molecule, say) is able to replicate itself, many copies will appear. Inevitably, errors will occur in this replication. If the resulting mutant is also able to replicate, then we have two types of individual. The individual that most fits the environment will be more likely to survive and replicate. Note that in this instance the 'entity' does not adapt. It either survives or fails. It is the population of entities which gradually changes.

Cumulative selection may be viewed as a great sieve, weeding out those individuals unable to survive. It is a general optimisation process, searching 'entity space' to find the most successful type of entity. ('Success' is synonomous here with survival.) The search is a highly parallel one. A rather crude analogy is that of searching a maze with people. They are fed in one at a time at the entrance. Once inside they move about at random, but with one proviso: they do not follow another person. With enough people to saturate the maze, the exit is found quickly (by the population, if not by the individual). Darwin first proposed the mechanism of natural selection [5] (a more suitable term than cumulative selection when applied to the natural world) in 1859. An interesting note is that although not implied, sexual reproduction is widespread in nature, showing perhaps that two parents gives a greater convergence rate in the search entity space than simple asexual replication [12].

2.2. Neural Nets

The idea of neural nets as an information processing paradigm has been well known since the 1940s [11]. It is only recently that computer hardware has become powerful enough to enable simulations of such nets in software. Neural nets are similar yet complementary to genetic algorithms. The basic information processing node in such a net is the neurone; it should be noted that neurones in animals are not well understood, 'neurone' being used here in its synthetic sense. Neural nets are built by connecting many neurones together [14]. Many nets have a layered structure. A neurone has many input wires, each coming from neurones in the previous layer, its single output connected to neurones in further layers. Each of these wires has an associated weight. Once the topology of the net has been decided, it is the weights which define its behaviour. The total input to a neurone, then, is the sum of the weighted outputs of previous neurones. If this is larger than some predetermined threshold, then it 'fires', passing a 1 on to other neurones. This signal is of course adjusted by the appropriate weights before arriving at the destination neurone. Such nets have been shown to possess a self-adaptive behaviour [2], an important part of which can be attributed to the weight adjusting algorithm [13,8]. There is an analogy between neural nets and digital signal processing which is appropriate to this study due to the time series nature of the data [15]. It seems plausible that such a net can be built to mimic the behaviour of the aquifer, the intention being to extrapolate such a model to reveal interior detail of the aquifer.

Two major problems must be addressed when applying such adaptive approaches:

(1) They do not map well to conventional von Neumann computers, although efficiency is not an issue in this project.

(2) The environment in which the model grows is difficult to specify. Real world data on the cave system is required if the model is to mimic the cave system; synthetic data will not do.

The first problem is addressed by the use of transputers [10]. A transputer is a 32 bit VLSI computing element consisting of a 10 MIPS, 2 MFLOPS* processor, 4 kbytes of static RAM and 4 high speed inter-transputer serial communication links. The links are the important part of the architecture, allowing a large concurrent network of transputers to work on a single problem at once. The massively parallel nature of this approach lends itself to implementation on such a parallel architecture machine. Some workers suggest that a super-linear speedup may be obtainable [12].

For this modelling study, the environment will be actual recordings of system input (rainfall and point recharge) and output (stage at the three resurgences). This will allow both the building of a the model and its testing.

3. The Study Area

Located in north central England, the limestone area of Derbyshire has a moist climate with a moderate annual rainfall of 800 - 1200mm. The Carboniferous Limestone area consists of an elevated block of exposed limestone with marginal reef complexes, approximately 450 km^2 in area. It is sporadically covered with a thin layer of superficial deposits of Tertiary and Pleistocene age, consisting of sand, gravel, wind-blown loess and boulder clay, together with extensive deposits of scree. The limestone is bordered by shales and sandstones of Upper Carboniferous (Namurian) age on its west, north and east sides, and by Triassic sandstones to the south. The generalised structure is an anticlinal dome, which was extensively dissected in Tertiary and Quaternary times to give a complex pattern of valleys, most of which are now dry. Interbedded with the limestone are intrusive and extrusive basic igneous rocks of olivine basalt composition.

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* Millions of Instructions Per Second, Millions of Floating Point Operations per Second

The area has been subject to lead mining since at least Roman times and the mined cavities and drainage levels (locally called soughs) have extensively affected the drainage patterns. The above features, together with the local structure (e.g. the dip of the beds, the trend of the folds and the presence of faults and mineral veins) control the local hydrology [6,7].

Castleton lies at the northern end of the Carboniferous limestone massif of Derbyshire. The Peakshole Water flows through Castleton to feed the river Noe. It is fed by both Peak Cavern (SK 149825) and Speedwell Cavern (SK 139828). These two systems are believed to be hydrologically independent, except in times of flood when the water in Speedwell backs up and flows through Peak Cavern. Under normal conditions the water which discharges from Peak Cavern is entirely autogenic, whilst that from the Speedwell Cavern risings (Slop Moll and Russet Well) is mainly derived from allogenic streams, which sink in the Perryfoot area (SK 0981, 1081, 1182, 1282) to the north west of Castleton, but does also include some autogenic recharge. The allogenic stream inputs are from the sandstones and shales of the Upper Carboniferous (Namurian) period on the north-western border of the Derbyshire Dome (Figure 1). The catchment of the system is about 17 km^2 in area. Slop Moll and Russet Well are connected probably by some sort of U-tube configuration, as lowering the level of discharge at Slop Moll causes Russet Well to cease flowing.

The hydrology of the area is complex, since it is influenced by numerous mineral veins, locally called rakes. Cavers have entered only a small part of the system; further exploration requires diving of the numerous sumps. Several hydrological studies have attempted to advance exploration by deducing the nature of the presently inaccessible conduits [1,3,4,9].

4. The Logging Programme

The Limestone Research Group at Manchester Polytechnic has (among other workers), been interested in the hydrology of the area for a number of years, and the system is instrumented as follows:

(a) Inputs

(1) A Didcot Automatic Weather Station, installed in October 1984 at Oxlow House. Seven out of eight channels record the following every five minutes:

- Precipitation
- Solar Radiation
- Net Radiation
- Wind Speed
- Wind Direction
- Ambient air temperature
- Wet bulb/dry bulb temperature

(2) Ott R16 Autographic water level recorder on a compound broad crested weir at P1.

(3) Two Ott type X autographic water level recorders on FRBP flumes at P6 and P9.

(4) Obsermet data logging rain gauge (tipping bucket) at P1.

(5) Casella tilting siphon rain gauge at P6.

(b) Outputs

(1) Obsermet data logging water level recorder on a compound weir at Buxton Water.

(2) Ott type X autographic water level recorder on a compound weir in the gorge outside Peak Cavern, but before the influx of water from Russet Well and Slop Moll.

(3) Obsermet data logging water level recorder on a simple broad crested weir, at the bridge in Castleton. This water includes that from the Gorge, and from Russet Well and Slop Moll.

Other data includes water quality information and the result of many dye tracing experiments. This will probably not be used in the present study. A set of electronic data logging equipment has been developed in order to provide complementary data.

4.1. Electronic data-logging

The 'home-brew' logging kit is based around Grant Squirrel battery powered data loggers. These are capable of sampling 4 voltage sources at set intervals of between 1 second and 99 minutes. The input voltage range is 0 - 2V. A signal conditioning card has been designed to interface transducers with a logger. The major requirement for the signal conditioning is that it should be battery powered. The board as designed takes a continuous current of less than 1 mA. It is unfortunate that our pressure transducer requires 10 mA! To date, the loggers have performed well, anomalies being corrected as they occurred:

(1) Stage is measured by a Bell & Howell BHL-4104-00 pressure transducer with a range of 150 mbar (which translates into a depth range of approximately 1.5m). This is supplied with 5 volts rather than its recommended 10 V in order to reduce its current consumption. Due to the long term immersion of this part, it was felt necessary to seal the cable assembly by potting the probe in a polyurethane potting compound.

(2) Conductivity is measured by a flow through electrolytic conductivity cell. This too has been potted. Excitation is by a 50 Hz triangle wave form to avoid polarisation problems. The cell is mounted vertically to avoid sediment falling on the electrodes. The electrodes remain clean, and are brushed when the logger is serviced.

(3) Water temperature is recorded by a thermistor glued to the conductivity cell housing. The water temperature has remained (perhaps unsurprisingly) very constant. The epoxy resin does not appear to be holding up well after 3 months immersion.

(4) Originally, It was intended to measure the pH of the water. This has not been implemented due to perceived problems with the long term drift properties of pH probes. This conveniently allows the 4th logger input to monitor the battery voltage.

(5) The cheapest source of non-rechargeable power available is alkaline D-cells. 10 of these are used in series to generate 15 V when new, and 8 V when flat. The signal conditioning card operates within this limit. Problems have been experienced with the variation in the battery capacities, however. One of the 10 batteries has tended to go flat before the others. It then rapidly becomes reverse charged, to the same voltage being supplied by the other nine batteries. The circuit then receives very little voltage! An investment in sealed 'maintenance-free' rechargeable lead acid batteries is likely because of this problem.

The electronic data loggers take their readings at a fixed interval (currently set at 10 minutes), each reading being 1 byte. 2 loggers are available, each with 8 kbyte of memory, which is sufficient for 2 weeks' worth of data. At the end of the period, the logger in the field has to be exchanged with a fresh logger, and taken back to the laboratory. This is fairly inconvenient, especially as the second logger is also required in the field for recording data.

Two recent developments will much improve the situation:

(1) A rugged hand-held computer with a large semiconductor memory has recently been provided by Microscribe Ltd. of Cwmbrân. This will allow the loggers to be left in situ, while the data is down-loaded into the Microscribe. The sophistication of the Microscribe will allow checking of the data for errors to provide on-site warning of hardware failure.

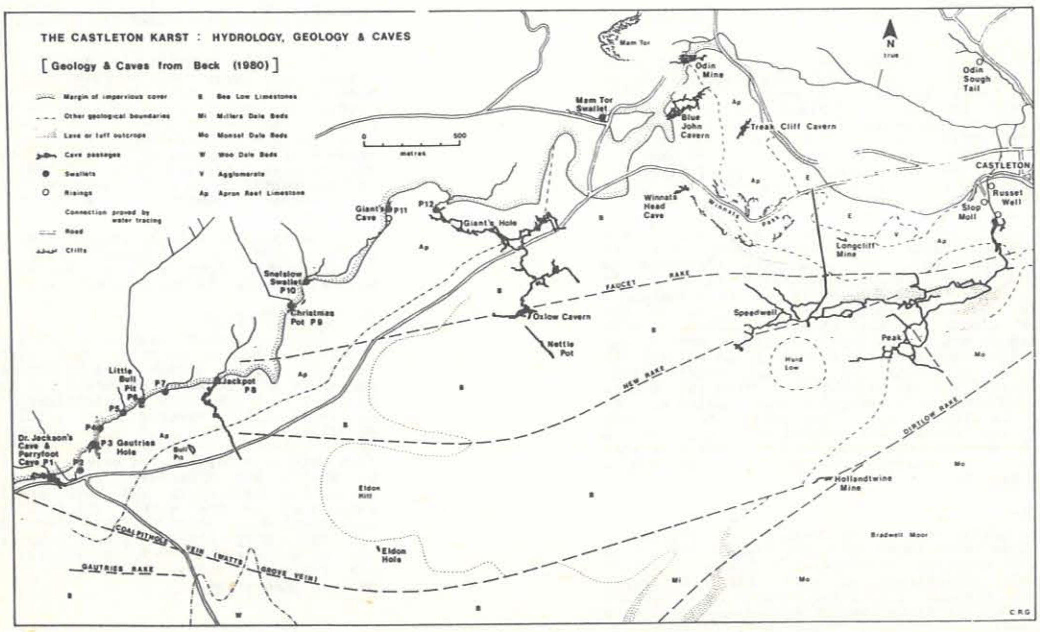

Figure 1 - The Study Area

(2) New Squirrel data loggers are now available with 32 kbytes of memory. Perhaps more importantly, they provide a signal 5 seconds before they sample. This will allow the signal conditioning cards to be switched off for most of the sampling period, thereby alleviating power supply problems and extending battery life to over a year.

4.2. Preparing an archive

The raw data comes from many sources and is stored in many formats. An important part of this study is the setting up and maintenance of a general data bank. All relevant data will be collated and stored on computer in a common file format. This creates many advantages - not the least being a uniform interface. A toolset is being developed for use with a Sun workstation. This machine was chosen for its graphical display. One of the first tools is a simple 'chart viewer', replacing the myriad of paper charts the hydrologist presently has to contend with.

4.2.1. Processing the raw data

With a sample period of ten minutes and a sample consisting of 4 bytes, then each logger provides some 12 kbytes of raw data per month. Being already digital in nature, this data requires only a little post-processing, for example that of converting stage to flow rate.

The charts from the autographic stage recorders are a different matter, however. There are many of them, each recording approximately a fortnight's data. They are digitised by following the curve by hand with a stylus on a digitising pad. As much information as possible is recorded during this process, including obvious errors. For example, the rise in stage when stepping stones were placed across the weir one afternoon will be kept.

Thankfully, data from the automatic weather station and the digital rain gauges/stage recorders also requires little re-work.

5. Summary

The purpose of this study is to model this complex cave/hydrological system on the computer, using various statistical modelling techniques. Hydrographs and other data from over three years' observations are currently being loaded onto the computer workstation, with the hope that the model may throw some light on the configuration of the passages between the sinks and risings. This progress is for the future, but already some encouraging developments have been made in deciding what the most suitable statistical modelling technique is going to be.

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AWAY WITH THE WIRES

HOLLAND, Ernst

Abstract : Wire has been placed in caves either as a protective device and method of defining pathways or to conduct electricity. The first known placement of wire fencing in the Jenolan Caves was in the early 1870s. Many other cave systems in Australia were to follow this example but there is little evidence to suggest that the rest of the world used wire netting for cave protection. Breakdown of wires by chemical changes causes pollution and staining which compromises the aesthetic appearance of the caves and interfers with the mineral and carbonate processes. Electrical wires are removed for replacement or realignment and wire netting for improving aesthetics. Today the development of new materials such as carbon glass, electronic devices (beams), fibre optics, etc. has opened up complete new areas of cave protection and lighting without the use of wire.

Resume: Les fils metalliques dans les grottes sont placés lã soit comme moyen protecteur en delimitant les voies de visite ou encore sont ceux qu'emprunte l'electricitié. C'est au début des annés 1870 qu'en remonte leur première utilisation connue. Bien que d'autres centres similaires en Australie suivirent cette example rein ne laisse á penser que cette utilisation á des fils de protection fut adoptée par le reste du monde. La deterioration de ces fils par changements chimiques est non seulment la cause de pollution et de souillure qui compromet l'aspect esthetique des grottes mais aussie agit pernicieusement avec les mineraux et processe carbonique. Les fils electriques sont enlevés soit pour être remplacés ou encore realignés et pour ce qui est du grillage d'amelior a'des esthetiques. De nous jours l'introduction de materiaux nouveaux, tel que verres au carbone, moyens electroniques (rayons), fibres optiques, etc. announce une era nuovelle quant ã la protection des grottes ainsi qu'ã leur eclairage.

INTRODUCTION

Tourist cave development in the 1990's will avoid the use of wire. Where wire must be used, its type will be selected as to minimise harmful effects on the cave environment and its location chosen so that it is effectively invisible. In fragile parts of the caves alternative lighting and protection will be devised so that even the 'invisible' wires are obselete. This paper presents the past, present and future use of wire in caves from an Australian perspective.

Many of the caves discovered in the nineteenth century in Australia and New Zealand and subsequently developed as tourist attractions were narrow with many fine and delicate decorations. It was soon realised that damage to these caves would easily result due to careless actions of visitors. The desire to show these caves to the general public meant that they had to be protected in new ways and developed differently from the larger European Caves. The Jersey Cave at Jenolan, for example, contains a 100 m section of passage less than a metre wide and two metres high decorated with many eratic speleothems.

"The formations of walls are extremely delicate, some of it is white and some like yellow coral, The roof has been slightly defaced by certain nineteenth century cads. In various places the 'mark of the beast' in lampblack has been produced by holding candles near to the ceiling and moving them about gradually. The sooty Heiroglyphics remain unto this day as an evidence of vanity and folly. The floor which was once like alabaster, is now soiled by the tramping of feet" (Cook, 1889).

To answer to this need for protection, wire netting was introduced to distance people from cave decorations and minimise further damage.

WIRE NETTING

The premier tourist caves in Australia are Jenolan Caves in the state of New South Wales. Until the 1980's wire netting was regarded as the only protective device for masses of delicate speleothems in small passages and those that are close to the edge of pathways.

The first reference to any wire netting being placed in the caves at Jenolan comes from a letter written by Jeremiah Wilson, the first caretaker of Jenolan Caves, on the 18th of March, 1879 to the Minister for Lands:

"will you be so kind as to have some money voted so that I can have wire screening and other protection made to keepe it from being destroyed by people walking on it. It is not my entention to take other visitors to this cave for some time to the necessary improvements is done I believe this cave is one of the prettiest sights in the Colony." (Harvard 1934)

Jeremiah was acting purely in the cause of conservation and was so concerned that the caves should be protected immediately that he hand wove the first netting used (A. Wilson pers. comm.)

As with many other innovations in developing tourist caves, Jenolan Caves pioneered the use of wire and the rest of Australia followed. Buchan Caves in Victoria apparently received this information from Jeremiah Wilson's brother Fred Wilson on his move there from Jenolan. Oliver Trickett the superintendant of caves for the Department of Mines travelled extensively around Australia, visiting caves and spreading the technology widely. The consequence of all of this was that hideous corridors of wire netting appeared throughout Australian caves whether they were needed or not and even spread across the Tasman Sea to New Zealand.

The support for the wire netting was a rough form of round or square steel uprights. The principle method of fixing steel posts and steel supports in caves was to drill a hole slightly larger diameter than the base of the steel post. A cement-water mixture was then made, placed in the hole and the steel post inserted. Bolts placed in stalagmite or bed rock were also used to fix the wires. No.8 fencing wire (a steel wire 3 mm diameter) was strung between the posts and the netting fixed to this by smaller diameter wire.

There is little evidence to suggest that the rest of the world used netting to protect speleothems. However, it would appear that other places were aware of its application and considered using it, for example Cango Caves, South Africa.

"On the 31st of August 1903 the Chief Inspector of Public Works forwarded this report to his Secretary, with a handbook describing Jenolan Caves in Australia to illustrate how the caves had been protected by wire netting." (Craven, 1986)

The rest of the world fortunately did not accept netting but another Jenolan innovation was universally accepted - electrical wires.

ELECTRICAL WIRE

In 1886, electric lighting replaced the far more damaging magnesium wire and candles as a means of lighting Jenolan Caves.

The use of candles and magnesium wire for lighting Jenolan Caves was of major concern to Jeremiah Wilson because of the resultant combustion products and he reported on the matter to his superiors at the Department of Mines. Others noted the contamination:

"The principal features of the night caves are illuminated by magnesium light, which is rich in chemical rays and burns with great brilliancy. There

should not be allowed in the caves any colorific or other light which would cause smoke by imperfect combustion, or emit volatile substances likely to change the interior hues. If their pristine beauty...or as much of it as remains... is to be preserved. The caves ought to be illuminated by electricity, which will neither affect the temperature nor soil the most delicate of nature's handiwork." (Cook, 1889).

On July 22, 1880, E.C. Cracknell temporarily illuminated the Margherita Cave with electric light. This was the first recorded use of electricity for lighting any cave in the world and came only two years after the electric lighting of the Thames Embankment, London (Harvard 1934).

In those early days there was no attempt to hide the electrical wires; mains wires were strung from insulators attached to the cave walls and light bulbs were suspended in a similar manner. Later, electrical wires were pinned to walls and speleothems and special groves or trenches were cut to take the wire cables. Poorly planned cave lighting inherited from earlier times is still in place today and can be observed throughout Australian and New Zealand caves.

THE NEED FOR IMPROVEMENT

In the late 1970's it became clear that at Jenolan Caves some of the most beautiful caves in the world were being displayed in an archaic manner; the protective wire netting and the electrical wires were detracting from the enjoyment of informed cave visitors. On aesthetic grounds alone wire should be removed from the caves but there are many other reasons to remove it.

* Deterioration of the netting results in foreign iron and zinc compounds being formed causing unpleasant staining of speleothems, contamination of pools and slippery areas on the pathways. The breakdown of electrical wires that are sheathed in lead produce lead carbonate (cerussite) an unpleasant white compound and copper wires react to form the blue and green basic copper carbonate minerals, azurite and malachite.

* Wire netting collects massive accumulations of lint from the air and from visitors clothing as they brush past. It has been suggested that the netting collects the lint and prevents it accumulating on the cave decorations. This is not what has been observed at Jenolan; the accumulated lint on the netting can be knocked onto the tracks and if it gets wet it forms a pulpy slime, whether wet or dry it will spread around the cave.

* Defective netting and wire rope handrails can splinter when held or brushed against. In the past wire splinters have been removed from several hands. The sharp pieces of wire also tear clothing.

* Little is known about the impact of wires and their decomposition products on the micro-fauna in the caves. It is suspected that the lead andopper compounds are toxic to cave fauna.

Clearly a case could be made for the removal of all wire but this is not practical. Present cave management practices require that any wire is not intrusive in the cave scenes being viewed by the visitors. At Jenolan Caves this philosophy has meant that many of the eyesores of the past have been removed and replaced less obivous forms of protection and lighting.

REMOVAL OF WIRES

The removal of wire fixtures is not easy. If they have deteriorated, the wires and their casings break up into small pieces requiring the surrounding cave area to be cleaned. A use for these old wires has been found at Jenolan by encasing them in a plastic material believed not to decompose and setting them as reinforcing in concrete pathways.

The steel post bases are more difficult to remove because they have expanded on rusting to become tightly fixed in their cement beds. A variety of methods have been tried. When removal was attempted by the use of gas torches it was found to be very damaging because heat causes exfoliation of both the limestone and calcite. Use of steel saws to remove the post to ground level covers the surroundings with a very fine dust and a significant amount of the fitting left in the rock to decay. The removal of these steel fixtures is now accomplished by periodically tapping them with hammers and after a while they become loose and can be removed with little damage to the rock or speleothem. Even though there is now a satisfactory method for their removal, steel supports can still be seen protruding from the speleothems in several Australian caves.

The removal of electrical wiring is somewhat easier, although where the fixtures have been set in cement, problems are similar to wire netting removal. The more attractive antique electric light fittings have been left in place and are used to illustrate past technology during historical cave tours.

REPLACEMENT

Wire netting is being replaced with controlled lighting which creates a dark zone between track and decorations, that is lighting is being used for protection. An alternative method being tried are electronic beams which when broken activate a siren. This method is being used extensively in the tourist development of Cutta Cutta Cave, in the Northern Territory. Some caves are small and fragile, one such cave is the Ribbon Cave at Jenolan. In this cave unattractive metal wire netting has been removed and yet a screen is the only practical way of protecting the multitudes of helictites in its narrow, low passages. Carbon glass has been trialed but it has two major problems, one is abrasion of the surface the other is collecting condensation. Both limit the clarity with which the speleothems can be viewed. For this cave, three other methods of protection are now being considered they are clear plastic netting, widely spaced plastic covered wire and heated glass. Heated glass especially, must be studied with care so as to avoid any problems with changes to the microclimate of the cave.

At Jenolan Caves, the replacement of obselete electric wiring has been a long term project. When this takes place the wires can be realigned and the type of cables selected so that they do not decay. On rewiring it is found that the length of cable laid can be reduced by the use of more powerful bulbs, concentrating the available light on a restricted area using focussed beams and reflectors. Features of the cave that require individual illumination can now be lit from a distance.

Despite the fact that there have been significant reductions in the length of cables laid in order to illuminate the caves, at Jenolan Caves more concealed cable than ever is being laid in the interests of public safety. In 1988 a complete telephone system was installed to allow emergencies to be reported immediately. Also a complete emergency lighting system has been installed into existing switch boards - the supplies of candles located on the tops of switch boards are no longer required.

In order to do away with the wires and associated fittings in selected areas of the caves, fibre optics have been sucessfully trialed. At present the economics of this technology is competitive with mains electricity and gets cheaper by the day.

Caves are being shown commercially at Jenolan without the use of wire under the guise of "wild cave tours". The the visitors use electric torches and the numbers in the party are kept small so that the accompanying guides can educate and protect the cave. This luxury can only be for the privileged few; Jenolan Caves has over 250,000 visitors annually.

THE FUTURE

The end of netting can be forseen. Protective screens are all expected to be either dark zones or electronic beams. In contrast, it will be many years if ever before mains electrical power is superseded as the major form of lighting for caves. In these days of space travel it is conceivable that fuel cells, longlife batteries and possibly even nuclear cells can be placed in specific places in caves powering light sources.

Education and public awareness is an important way of resource protection and this approach is being considered by the management of Jenolan Caves for the future. The approach requires specifically designed educational material with emphasis on conservation and preservation. With a well educated public the need for protective devices will be considerably reduced.

Management education is also important. The Australiasian Cave Management Association has been formed and meets this need in Australia and New Zealand. The group has a newsletter and meets once a year to discuss matters associated with caves. It is important that cave managers are not isolated in their search for new methods; communication with the rest of the world is essential to keep up with the latest innovations.

CONCLUSION

There is no doubt that the over protective practice of using wire netting in the past has preserved the speleothems and enabled decisions regarding their future protection and management minus the wire. The use of electric lighting, however aesthetically unappealing its placement, has allowed many thousands of visitors to appreciate the beauty of the caves and their decorations. Jenolan Caves have been shown commercially for over 100 years and it is hoped that the caves will be displayed for thousands of years to come. Decisions made today are critical as an ill informed one could lead to the destruction of part of our heritage. So away with the wire only if the alternative is fool proof.

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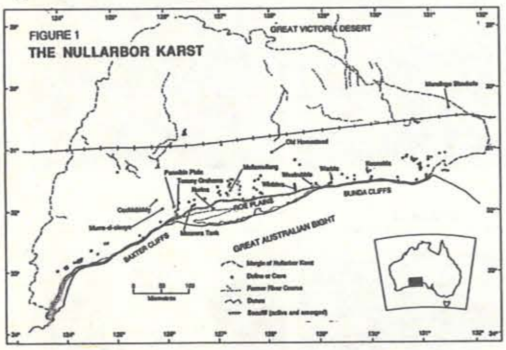
THE ROLE OF MIXING CORROSION IN THE GENESIS OF THE CAVES OF THE NULLARBOR PLAIN, AUSTRALIA

JAMES, J. M. - ROGERS, P. - SPATE, A. P.

Abstract: It is difficult to reconcile the impressive size of the caves that lie below the Nullarbor Plain in Australia with the belief that the plateau above them has been arid since uplift 10-15 million years ago. A brief introduction to the geology, geomorphology and hydrology of the Nullarbor Plain is given. Selected results of recent surveys of the water chemistry of the Nullarbor caves are presented. A review of the theories of genesis of the Nullarbor caves is given and important revisions made on the basis of new water chemical data. The conclusion reached is that the caves result from the mixing of fresh and saline waters providing enhanced chemical erosion of the limestone. This process is active during arid periods and has been continuous throughout the karst development of the Plain.

Resumen: Es diffcil acomodar el tamaño impresionante de las cuevas que se encuentra abajo del Nullarbor Plain de Australia, con la creencia que el llano arriba ha sido árido desde su levantamiento del mar hace 10-15 millon años. Se presenta una introdución breve de la geologfa, geomorfologfa y hidrologfa del Nullarbor Plain. Tambiến se presenta datos recientes de analisis quimfca de los aguas. Se da una revista de los teorfas de génesis de las cuevas con cambios importantes basado en los nuevos datos qufmicos del agua. Se logra al conclusión que las cuevas resultan de la mescla de aguas dulces y aguas saladas que causa corrosión aumentada de la caliza. Este proceso es áctivo durante los tiempos áridos y ha continuada durante el desarrollo entero del karst del Nullarbor.

Introduction: The Nullarbor Plain on the southern margin of the continent of Australia (Figure 1) is one of the largest continuous exposed karst lands in the world with an area in excess of 200,000 km^2. It has been classified as a semi-arid to arid karst (Jennings, 1983) and in proportion to its area is poor in known caves. The caves that do exist are sometimes large and extensive with the largest chamber and three of the longest caves in Australia. Some of the cave systems are almost entirely flooded with saline waters, for example, Cocklebiddy Cave contains 6.2 km of waterfilled passage; the site of a world record cave dive. The locations of the Nullarbor caves discussed are shown on Figure 1 and their descriptions found in Mathews, 1985.



The accepted theory for the genesis of these caves is that of Lowry and Jennings, 1974, who proposed that the caves had a shallow phreatic origin. The initial passages were drained when enlarging outlets improved circulation and lowered the watertable thus allowing cave enlargement to continue by salt wedging and collapse. Lowry and Jennings, 1974 addressed the question of how groundwater could obtain sufficient aggressivity to hollow out such large corridors below a desert. Their conclusion was that there must have been a past wetter period or periods when the Nullarbor Plain would have been covered in vegetation. A period of higher rainfall is supported by relict river courses on the plain and old calcite speleothems in caves. Calcite precipitation has now been replaced by crystallisation of gypsum and halite. Therein, lies a problem, as many other studies have concluded that the Nullarbor Plain has been mostly arid since its uplift in the Miocene (Benbow, pers. comm.). Grodzicki, 1985, not acknowledging other palaeo-climatic studies, simply resorted to times of much greater rainfall to create the large passages by dynamic phreatic solution. He explained the absence of correspondingly large surface karst features as due to more rapid erosion at the surface than underground.

Although the importance of salt wedging in enlarging these giant caverns had been recognised, the presence of saline waters and thus the possibility of enhanced chemical erosion of the limestone in the fresh-saline water mixing zone (Back, 1965) had been largely ignored. The hypothesis presented here is that the necessary aggressivity for limestone solution below the Nullarbor Plain is obtained by mixing corrosion. This process will occur even during extended periods of aridity. However, the greater the rainfall, the more fresh water available and thus a resultant increase in solution in wetter periods.

Geologic setting: The Nullarbor Plain lies within the Cretaceous-Tertiary Eucla Basin. A detailed discussion of the geology of the western Eucla Basin can be found in Lowry, 1970. The caves are developed in four almost horizontally bedded limestone strata (Figure 3) laid down from Late Eocene to Middle Miocene. Uplift of the limestones probably occurred at the end of the Lower Miocene. The limestones are mostly very porous and permeable. There is evidence for a number of normal faults of modest throw. Weak jointing expresses itself in both relief and in the caves. The weak jointing and absence of folding or major tilting suggests that the region has remained relatively stable since uplift.

Geomorphic setting: The Nullarbor Plain is a plateau with little relief, its depressions drop and ridges rise some 5 m. The southern edge of the Nullarbor Plain is fringed with cliffs. Set into the Plain are thousands of blowholes and a few hundred collapse dolines. The collapse dolines are more frequent in the southern part of the Nullarbor. Both the blow holes and the collapse dolines may lead to cave systems. Air photographs display linearity of depressions and collapse dolines and these can sometimes be related to the positions of caves. A typical semi-arid to arid karst, the Nullarbor Plain has limited karren features (Jennings, 1983). Solution and precipitation of calcium carbonate is occurring on the limestone surface as evidenced by case hardening of the limestone and the formation of calcretes.

Present climate: The Nullarbor Plain climate varies from warm in the extreme south-west to a hot desert in the north. The average annual rainfall over the Plain is 250 mm. The rainfall is unreliable and has little seasonal pattern, with plant growth being constrained to sporadic intervals as a result. Localised rainstorms can be very intense and cause considerable local flooding. Evaporation exceeds precipitaton tenfold.

Hydrology: There are no permanent surface streams on the Nullarbor Plain. However, there are numerous intermittent short water courses. During intense rainfall water flows into depressions or collapse dolines and rapidly disappears underground. The streams that flow into caves have only short courses before they disappear into lakes or sink in boulder piles. Ephemeral lenses of freshwater have been reported on the surfaces of the cave lakes (Jennings, 1985). The fresh water lenses do not persist as the temperature profile in the cave lakes shows that the warmest water is at the bottom. Hence the invading cold fresh waters will mix rapidly with the underlying saline waters unless the density due to salinity is higher than that due to temperature.

The water surface in all caves with lakes is 1–3 m above sea level. This uniformity of water level over hundreds of kilometres has led Lowry and Jennings, 1974 to suggest the concept of a regional karst watertable beneath the Nullarbor Plain. The surface level of this watertable is believed to be controlled by sealevel. The flow of water in the cave systems is from north to south, although there may be exceptions (R. Webb, pers. comm.). Flow in one of the cave lakes has been reported as 0.003 m s^{-1} (Jennings, 1985). Assuming this flow is through a passage of cross section 100 m^2 (a modest size for a flooded Nullarbor cave passage), 9.5 million m^3 of water will pass that point each year. An alternative approach is that for each mm of precipitation that reaches the aquifers (assuming 20 major conduits) some 10 million m^3 of seepage water will have to pass through each major system annually. Despite this, there are no known large springs issuing from the coastal cliffs and dunes and there are no known submarine springs.

Water Chemistry: The 1988 Pannikin Plain Caving Diving Expedition has collected a large suite of water samples for analysis. The methods of collection and analysis of the samples and the results and discussion of their water chemistry together with results from previous studies will be published elsewhere (James, Rogers and Spate, in prep). Figure 2 shows some of the results from this paper.

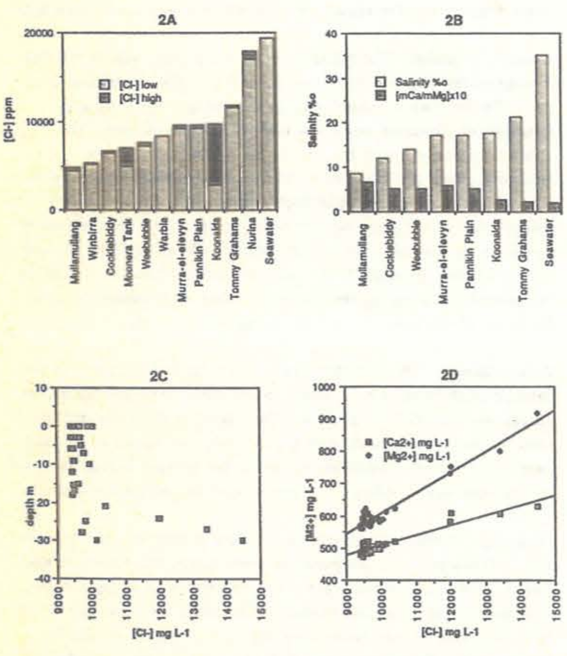
Figure 2a shows the variation of chloride concentration in the surface waters of twelve cave lakes over 40 years. Nurina Cave on Roe Plains has an analysis that is the most characteristic of seawater and Mullamullang Cave waters are the least like seawater (Figure 1). It appears from this limited sampling program that the water chemistry of the caves remains stable over long periods.

Figure 2b shows molar calcium/magnesium ratios for the caves compared with salinity. There is an inverse relationship between these parameters indicating dilution of seawater by calcium containing waters.

Figure 2c shows calcium and magnesium concentrations (mg L^{-1}) plotted against chloride concentration for samples from Pannikin Plain Cave. The line of best fit has greater slope for magnesium than for calcium, indicating the presence of seawater in the system.

Figure 2d shows chloride concentration plotted against depth in Pannikin Plain Cave. Chloride is fairly constant until −20 m, where it increases rapidly indicating a denser, more saline region. In contrast, there is insignificant variation in chloride for waters at the top of the watertable when plotted against distance (up to 850 m) into the cave.

FIGURE 2



Mixing Zones: The water chemical studies show that there are three zones within the cave conduits where the mixing of waters would increase their potential to dissolve limestone.

Zone a – is where percolation waters mix with the saline groundwater at the top of the watertable. The chemical compostion of the saline waters from this zone is such that on mixing they would have dissolved calcium carbonate (Herman *et al.*, 1983). Seepage is rarely observed in the Nullarbor Caves but there is indirect evidence that percolation waters reach the watertable.

Zone b – is where the concentrated saline waters and the dilute saline waters mix. At present, insufficient is known about this zone to assess its aggressive potential.

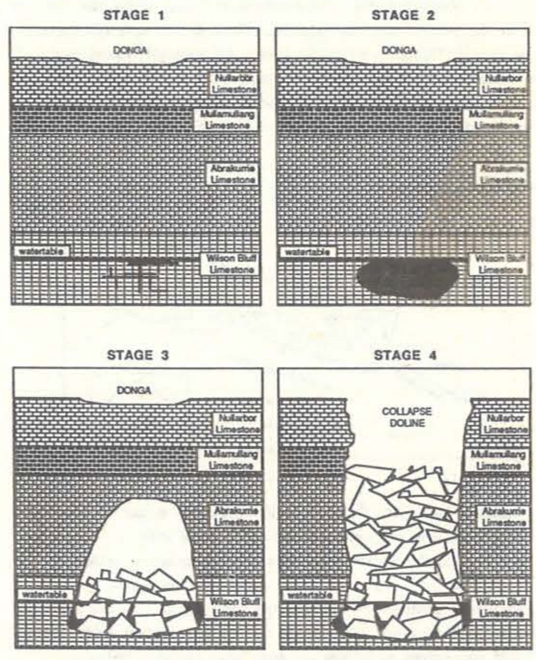
Zone c – is where runoff waters mix directly with the saline waters in the region of the cave entrances. At this time, the water chemistry will dramatically change and the mixed waters will become highly aggressive. The expected geomorhic evidence of solution incuts on lake edges has only been found in Mullamullang Cave (Hunt, 1970).

Genesis of the caves: All of the mixing zones presented have a role in cave genesis. The series of stages in Figure 3 for the genesis of the caves is the same as that proposed by Lowry and Jennings, 1974 for the "deep" caves. The major addition is that the aggression for solution is generated by mixing solutions of differing ionic compositions.

Stage 1 initiation – the caves begin through solution of limestone by the mixing of focused percolation waters and saline groundwater in Zone a. This attack can take place in any of the limestone strata and its location is governed by the position of the watertable. The thousands of blowholes on the Nullarbor are formed in this way. For example, Maralinga Blowhole formed when the saline watertable was higher than at present. There are three distinct horizontal levels of joint-widening in the cave; indicating three major rest levels as the watertable dropped. At the same time cavities can be generated much deeper in the karst in mixing Zone b.

FIGURE 3

STAGES IN THE GENESIS OF THE NULLARBOR CAVES



Cocklebiddy section (Lowry and Jennings, 1974)

Stage 2 development of conduits – the caves and cavities formed in Stage 1 may never become part of a main conduit system. For conduits to form the drainage needs to be directed by either bedding or fractures. For example, the waters that formed Old Homestead Cave moved south preferentially along more heavily jointed zones creating a maze of shallow phreatic passages. Further south the mixed waters have been channeled into a limited number of conduits. Where jointing is frequent within the caves there are shallow phreatic mazes in addition to the major conduits. The uniformity of the conduits and the uniformity of their water chemistry further endorses the theory that the necessary aggressivity for limestone solution by mixing corrosion is available throughout the system.

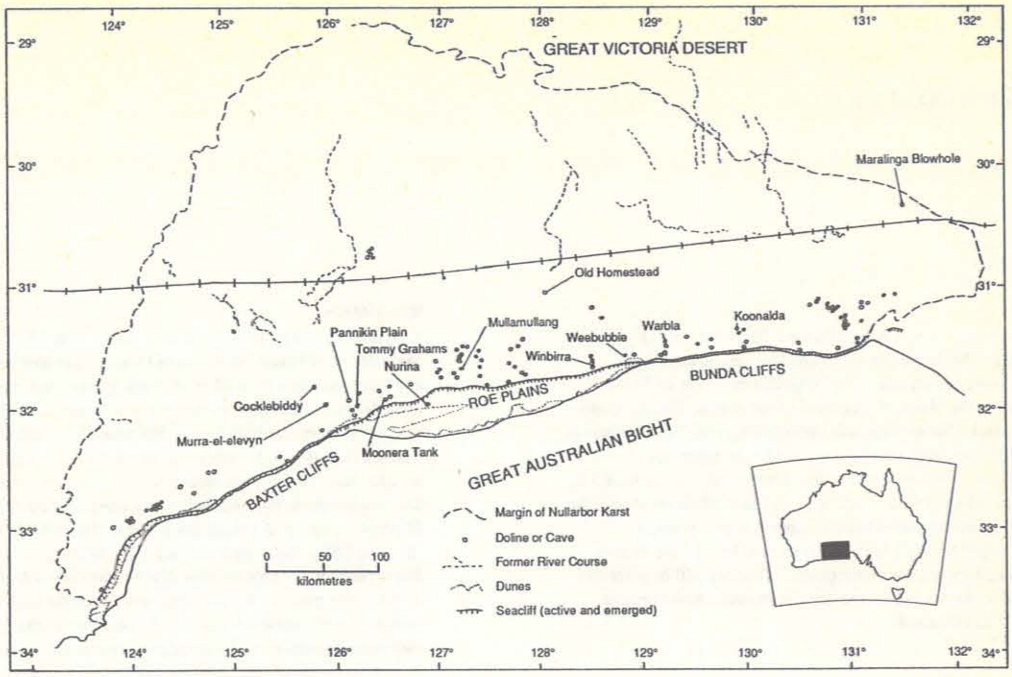


FIGURE 1 **THE NULLARBOR KARST**

Stage 3 development of chambers – the dongas concentrate runoff but the surface depressions do not develop because only a small amount of limestone is dissolved there and most of it will reprecipitate within the depression. The most continuous aggressive attack on the limestone by mixing corrosion must take place at the percolation–saline water interface, mixing Zone a, at the top of the watertable. At the present time, many of the major conduits are several metres below the watertable and solution will be taking place in the rock mass above them. If the rock is sufficiently competent and jointed, shallow phreatic mazes will develop. More frequently, blocks loosened by the solution process collapse into the passage below. The cave divers report fallen blocks throughout the flooded passages.

Any fall in the watertable assists the passage enlargement process. Loosened blocks, no longer supported by water, fall, resulting in the roof stoping upwards more rapidly. When the passage is dry this upward growth of chambers will be aided by salt wedging. Lowry and Jennings, 1974 report that breakdown is still occurring today. As breakdown will soon fill a cave because of its greater volume, solution must be occurring below. This necessary additional solution is most likely to be taking place in Zone b where diluted and concentrated saline waters mix some tens of metres below the present watertable.

Stage 4 formation of collapse dolines – finally, upward cavern excavation processes reach the surface and a collapse doline forms. The conduit now has an entrance through which runoff has direct access to the watertable. The mixing chemistry of Zone c is now operational. This mixed solution is theoretically the most aggressive to limestone but is only sporadically available and can have only been in action since the formation of the collapsed doline entrance.

In conclusion: Preliminary chemical investigations of Nullarbor Cave waters indicate that their compostion is ideal for solution by mixing corrosion. Within the caves there are three distinct zones where mixing can occur and all have a suitable chemistry for limestone solution. This process does not require an extensive wet period to generate large passages although limestone solution will proceed faster at such times. This hypothesis provides an explanation for mature karst development underground while the surface karst remains immature.

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CAVES OF ZONGOLICA

WARILD, Alan

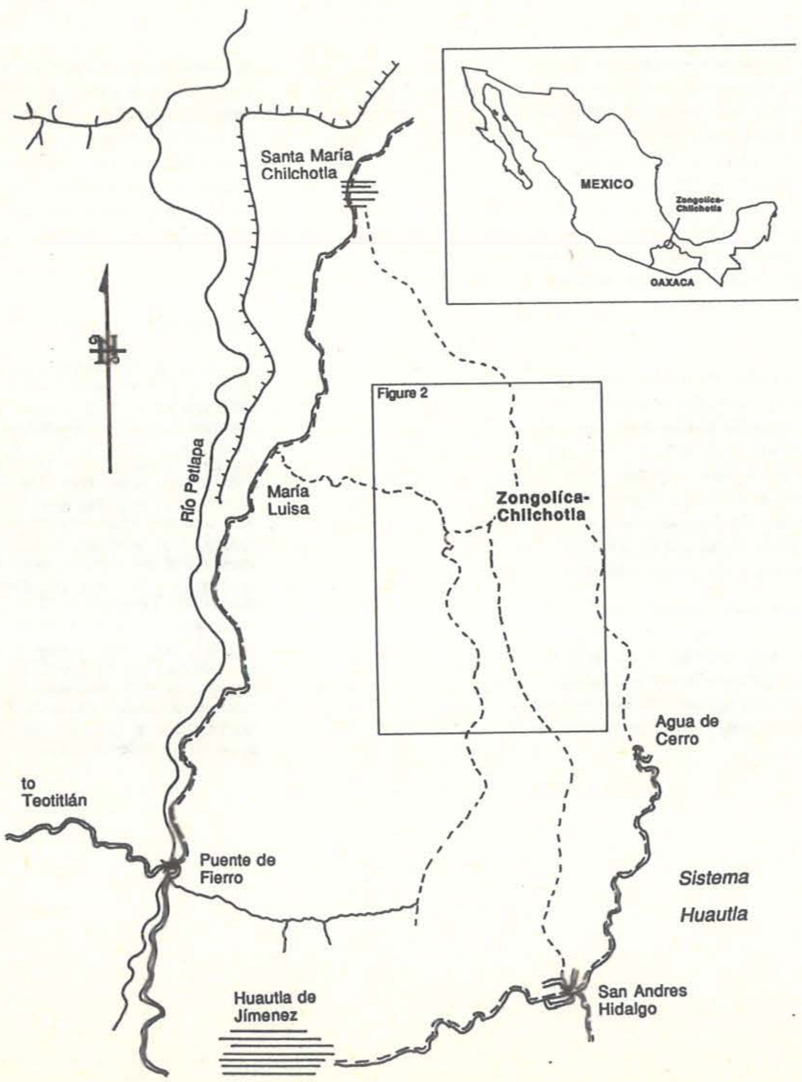
SUMMARY

Zongolíca is a small part of the much larger 150 km^2 Sierra Mazateca karst in the Mexican state of Oaxaca. The Sierra lies 17° N and has a tropical climate modified by its 1500 m average altitude. The Zongolíca caves are all found within an area of 5 km^2 in the North-West corner of the Sierra. The Zongolíca caves and those of the nearby Sistema Huautla make this area one of the richest in deep caves in the world. The caves are characterised by their extreme verticality. Most reach their ultimate depth with a depth to traverse ratio of 1:2. The Australian "Mexico '85 Expedition" was the first group of cavers to visit the area and the Zongolíca caves have since been the objective of two major expeditions. Within Zongolíca's 23.5 km and 9.6 vertical km of cave there is evidence of a complex history of cave developmen.. Theories will be presented as to how these vertical caves developed and their relationship to the present surface topography will be discussed.

RESUMEN

Zongolíca es una parte pequeña de la más grande 150 km^2 karst de la Sierra Mazateca en el estado Mexicano de Oaxaca. Las Sierra está ubicada 17° N y por eso tiene una clima tropical modificada por su altura mediana de 1500 m sobre el nivel del mar. Se encuentra las cuevas de Zongolíca dentro de un área de 5 km^2 en el limite noroeste de la Sierra. Por causa de las cuevas de Zongolíca y los del Sistema Huautla al este, esta sierra es uno de los mas ricos en cuevas verticales del mundo. Las cuevas son caracterizada por su sumo verticalidad. Casi todas logran a su ultima profundidad con un trayecto menos que doble su profundidad. El primer grupo de espeleólogos a visitar el área fue la expedición australiana "Mexico '85" y desde entonces las cuevas de Zongolíca han sido el objectivo de dos expediciones. Este informe describe las cuevas de Zongolíca. Dentro de las 23.5 km de trayecto y 9.6 km verticales de cuevas hay muestras de una historia complicada de éspeleo-evolución. Se presente teorías y argumentos sobre la evoluvión de estas cuevas verticales y como las relacionen al superficie actual.

Figure 1 **LOCATION OF ZONGOLICA-CHILCHOTLA**



INTRODUCTION

The Sierra Mazateca in the Mexican state of Oaxaca (Figure 1) has a long history of being by-passed. Even in the heyday of the Aztec civilisation the land of the Mazatecs was a cultural backwater. Like so many minority cultures in the central American sierras, the Mazatecs have clung to their language, religious beliefs and isolation to a degree which frustrates foreign cavers and Mexican authorities alike.

The first cavers to visit the region were the Canadians, who in the early 60's began the exploration of Sótano San Agustín. Throughout the 70's, Sistema Huautla, as it became known, proved to be the greatest vertical caving area outside Europe. A decade of successes by North American cavers was capped by the exploration of Li Nita, the first "New World" 1000 m cave which connected to Sótano San Agustín and rocketed the system into number three in the world.

Zongolica's history as a caving area dates back no further than April 1985 when the Australian "Mexico '85" expedition did a reconnaissance of the area. The result was several good entrances and a 430 m deep, still going cave. At the end of that year, the first of two expeditions based in the village of Zongolíca-Chilchotla explored several deep caves in the immediate vicinity of the village, the largest of which was Guixani Ndia Kijao. The second expedition in 1987-88 had similar success in the village and also explored several caves in the surrounding area. Part of the focus of the trip was even deeper caves and to this end the highest areas of the massif were prospected, although success was limited. The deepest caves seem to be located in and around Zongolíca village at an altitude of 1600 m to 1700 m.

GEOGRAPHIC SETTING

The study area on the NW flank of the Sierra Mazateca is almost completely enclosed by the municipality of Santa María Chilchotla. The local limestone relief takes the form of a plateau which drops stepwise from the 2100 m asl heights of Agua de Cerro in the south to the suspected resurgence areas along the Río Petlapa at 400 m asl in the north. The Río Petlapa forms an effective northern and western boundary. To the south is the underground watershed to the Sistema Huautla. The east is a grey zone of *terra incognita*. The 'plateau' is a large-doline/cone karst with little surface water, although Zongolíca does owe its existence to the presence of several local drainage springs. The rainfall for the region is estimated to be 3500 mm to 4500 mm annually (Lazcano 1986), most of it falling in the wet season from June to September, although deluges have surprised cavers at any time of the year. The original tropical forest of the area has long since fallen victim to heavy population pressure and the area is as intensively cultivated as hand farming methods will allow. While we may lament the destruction of such forests, it also allows us to see the karst beneath.

GEOLOGY

The Sierra Mazateca is a large thrust block of Lower Cretaceous limestone with localised areas of shale, chert and Tertiary igneous intrusions. The entire block is unconformably underlain by Upper Cretaceous shales sandstones and limestones. It is at this unconformity were the major resurgences are found.

Zongolíca is characterised by thinly bedded, dolomitic limestone, especially in the upper levels. Faults/joints play a much greater part in passage control than bedding, which is often near horizontal. Occasional beds of shale and chert are encountered although most of the chert is in nodules. Limestone colour varies from black (smelly and gritty) through to pale grey and marbled. Some caves (Na'cha Jao, Sondanga, Sonyance) have prominent dykes showing in the walls.

SURFACE KARST (Figure 2)

The area is covered in a cone/doline karst. Most high points are conical and only slightly modified by local geological structure. Almost all dolines are deeply conical. Flat bottomed dolines are rare. At times dolines form elongate glades although by far the most apparent form is of complexes of dolines within dolines within dolines. The heart of the Zongolíca area is a large (2 km^2) asymmetric doline complex which concentrates any water able to run off from the higher ground to the south. While much of the area has a good *terra rosa* soil cover (for karst), there are extensive areas of exposed limestone showing a great variety of surface features. These vary in size from the spectacular 20 m high pinnacles above the entrance to Nita Xongá down to finer features such as rillenkarren, solution pitting and rundkarren. Most often, the outcrops form fields of small pinnacles 2 m to 3 m high or crevice karst.

Cave entrances are common. Most are found in small dolines on the sides of larger ones. A few caves, notably Nita Xongá and Guixani Ndia Kijao, take surface streams. However, the majority are isolated entrances with very little apparent catchment area.

CAVES (Figures 2&3)

Ignoring all holes less than 150 m deep, a total of 9.6 km of vertical cave and 23.5 km in length has so far been surveyed.

Cave	Length	Depth
Guixani Ndia Kijao	2287 m	956 m
Sonconga	1844 m	943 m
Nita Chó	2554 m	894 m
Sonyance	1791 m	743 m
Nita Xongá	1568 m	740 m
Yuá Nita	1360 m	704 m
R'ja Man Kijao	2347 m	613 m
Nita Chaki	1060 m	493 m
Ská Kijao	1095 m	380 m
Stonindó Kijao/Nita	660 m	330 m
Thao/Thi/Tsá	1830 m	292 m
Ncá Nita	420 m	290 m
Dachiki Nita	1769 m	283 m
Sondanga	339 m	230 m
Chatsi Kijao	276 m	221 m
Na'cha Jao Nita	348 m	220 m
Cuetzo'jia Kijao	368 m	220 m
Ching'ya Nita	310 m	216 m
Na'cha Jan Nita	250 m	200 m
Nita Decho	450 m	200 m
Nia Quien Nita	312 m	160 m
Nita Chingón	150 m	150 m
Ya'chao Nita	150 m	150 m
Total Cave Length	**23.5 km**	
Total Cave Depth		**9.6 km**

The area is typified by extremely vertical caves which tend not to connect to form systems. The deeper caves have a tendency to drop to base level as a single simple passage, with very little joining or leaving along the way. All caves show a dominantly active vadose form with the occasional phreatic remnant. Some have large tracts which have been modified by wall breakdown. As may be expected from such active caves, there are few speleothems. Nevertheless, many of the drier areas do have liberal coatings of cave coral, and towards the bottom of Sonyance there is a very nice blood-red stalactite complete with a calcite

Figure 2

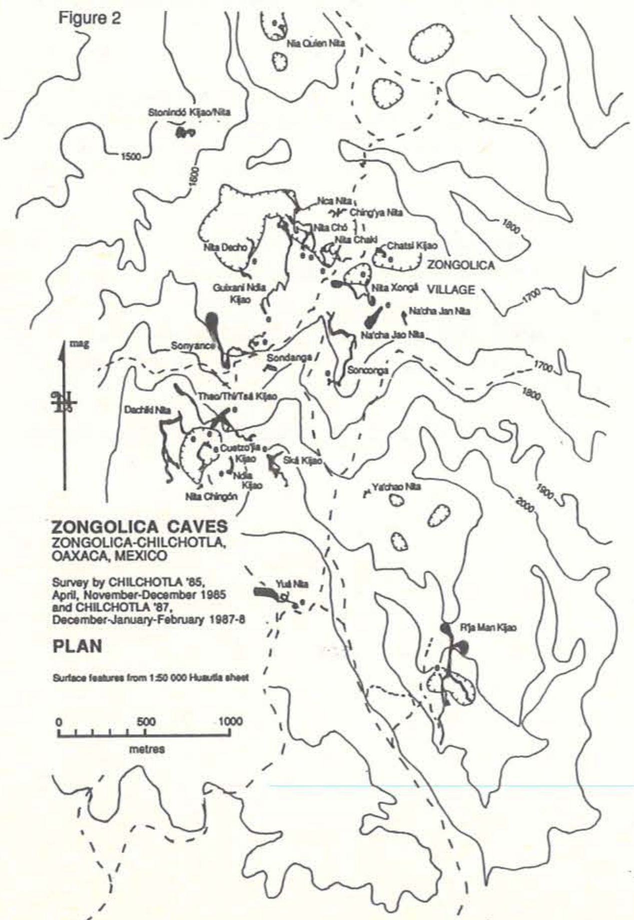
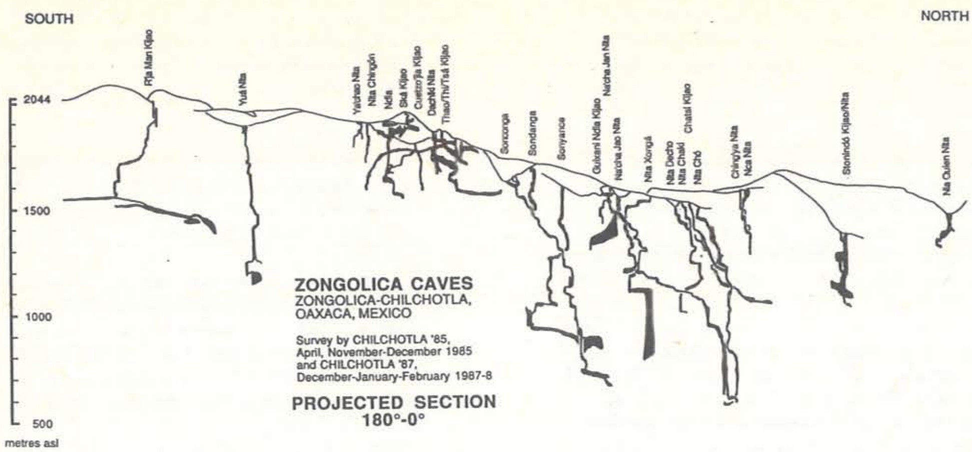


Figure 3



entombed spider. The typical Zongolíca cave has a depth far in excess of its plan length. The usual trend, apart from down, is north to northwest, a good direction for maximum depth potential. The two caves which reach the lowest altitude (Guixani Ndia Kijao and Nita Chó) both end at the same level and 100 m apart. Both also flood back easily after rain indicating a possible base level at 650 m asl which may be difficult to pass.

The classic deep cave form is that of fault controlled upper levels which switch back and forth beneath themselves. These vadose trench passages are often dry-walled due to draughts and show some degree of gypsum exsudation. Most have a small stream which picks up no major tributaries until 500 m down. Below this zone they have a short horizontal stream section and end in a impressive large chamber or shaft. The major exceptions to this are the long stream canyon in Guixani Ndia Kijao which runs from -100 m to -600 m and R'ja Man Kijao, which at -350 m strikes a large but gentle streamway which it follows to its demise in two big chambers at -550 m -600 m.

The caves in the Thao/Thi/Tsá Kijao complex, Ská Kijao, Dachiki Nita and Cuetzo'jia Nita have a different morphology. These caves have large, inactive, old degraded vadose passage which has been invaded more recently by underfit streams passing across the original system. The invading streams are generally small and diverge, forming tight young passages which cannot be followed far. All have considerable exsudation gypsum deposits in the form of sand dunes metres high and fine crystals coating the walls. Caves in this section all have extensive areas of breakdown blocks. These caves appear to be the oldest caves in the area, and are relics from a time when there was abundant drainage from overlying shales which have been long since removed. Most of the smaller caves take the form of the upper few hundred metres of a deep cave where the continuation to the rest of the cave could not be found.

GEOLOGICAL CONTROL

Looking at the rocks alone, the Zongolíca area seems like an unlikely place for deep caves. Very often the limestone is thinly bedded, contorted, dolomitised and interbedded with chert - quite simply rotten! Areas of shale and igneous intrusions weather to give vast amounts of clay to clog up the caves.

But caves there are. The isolated non-karst rocks serve to concentrate drainage as well as forming springs which flow only as far as the next limestone outcrop before sinking. This water becomes further concentrated close to the surface by impervious interbeds until they form streams capable of cutting a passable cave. Any stream which does all this at a fault produces a deep cave. The intrusions have probably contributed by causing localised ponding resulting in the larger chambers as well as metamorphosing the limestone to form the higher quality rock so characteristic of the lower reaches of the deep caves.

ARCHEOLOGY

No specific archeological studies have been done but some limited observations were made in the course of exploration. Pottery remnants were found in the entrances of several caves, including Guixani Ndia Kijao, Nita Xongá, Stonindó Kijao, Thao Kijao and Thi Kijao. Of these, Thi Kijao is the most interesting as it also contains the remnants of a stone wall, leveled areas and steps cut into the first pitch, probably in search of water. There is also a large overhang cave 200 m SW of Stonindó Kijao which has polychrome pottery remnants and a small "beehive" tomb containing human long bones and skulls with the back area deformed to produce a higher, wider head (a common pre-Columbian fashion).

CONCLUSION

After two expeditions much cave passage has been found, but the exploration of the Zongolíca-Chilchotla caves is far from finished.

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SOME PROBLEMS CONCERNING THE DATING AND STRUCTURE OF PLEISTOCENE CAVE DEPOSITS IN THE TRIANGULAR CAVE IN THE KARST SPRING REGION, WEST RHODOPE MOUNTAINS, BULGARIA

RAITCHEV, Dimiter

When investigating the cave sediments in the Triangelar cave some Pleistocene cave deposits have been found. One of them - a stalagmite - was discovered at a depth of I.80 m and was dated by the Hanover laboratory to 38 380^{+930}_{-830} years /N:H.II084/. The conclusion was that it corresponds to the increase of the chemical danudation and the deeper infiltration during the Interplain - glacial period and represents the cold phase of the freeze weathering, when the deposits and the sediments have been formed.

Some bones of Ursus Spelaeus have been dated, too, from two levels: Lower level - I7 745±465 years old

Upper layer - I5 570±3I0 years old

During the following studies of the sediments in the above mentioned layer and in some lower ones, up to 6.00 m, some other deposits have been found: calcite covers, stalactites, stalagmites,etc., which imposed new problems and they will be the subject of discussion of the section.

We should like to be provided with I m^2 of showing place during the discussion.

The report will be accompanied by slides.

ОТНОСИТЕЛЬНОЕ И АБСОЛЮТНОЕ УСТАНОВЛЕНИЕ ДАТИ ПЕЩЕРНЬIХ ДЕПОЗИТОВ

НЕКАТОРЬIЕ ПРОБЛЕМЬI ОТНОСИТЕЛЬНО УСТАНОВЛЕНИЯ ДАТЬI И СТРУКТУРЬI ПЕЩЕРНЬIХ ПЛЕИСТОЦЕНСКИХ ДЕПОЗИТОВ ИЗ ТРЕУГОЛЬНОЙ ПЕЩЕРЬ В РОДОПАХ,БЪЛГАРИИ

При изследвании пещерних седиментов в Треуголньой пещере были обнаружены пещерные депозиты плейстоцена.Один из этих депозитов-сталагмит обнаруженый в глубине - 1,80 м,датировах Хановерской лабораторий с инв.№ HV 11084 на 38 380^{+930}_{-830} с заключением:отвечает увеличению /наращению/химической денудации и более глубокому фильтрованию/проникновению/чрез интерпленигляциал и представляет собой холодную фазу морозного выветривания /холодной эрозии,когда формируются депозит и седименты.

Кроме того,были установлены даты костей Урсус спелеус с двух уровней:а/.нижнего 17 745 ± 465

б/.верхнего 15 57о ± 310 лет.

Познее в следующих изследованях седиментов в этих и в более низких уровнях до - 6,00 м были обнаружены и другие депозиты -калцитньи корь,сталактиты,сталагмиты и др.,каторы поставили новые проблемы в связи с этими тепозитами,каторы будут предметом дискусий в секции.

Нужно,чтобы во време дискусии обезпечен 1 $м^2$.

Доклад будет сопровожден диапозитивами.

The karst spring region where th Triangular cave can be found, is situated beween 24°14' and 24°16' Greenwich eastern longitude and 41°33' up to 41°44' northern latitude. It occupies the eastern part of the Velia-Viden region of the Rhodope mountains. It has all the features of a geomorphologic evolution in the Western Rhodopes. The landscape is mountainous, formed during the Quarternary, when an intensive upraising of the mountain commenced. The rivers cut in the surface and formed deep river valleys and canyons in the karst regions, with steep walls and crowns of rocks /slides 1 and 2/.

The thickness of the marble rocks, their strongly fissured nature and the highness created good conditions for karstification.

The Spring river gives the name of the karst region. The gorge it forms, is not very big, but morphologically interesting. It's lowest point is 855 m near Teshel and the highest point is 1320 m at Mount Asar Teppe. The lanscape has nearly all of the karst forms, which have been studied in the Rhodope mountains. The karst surface is 1000-1200 m above see level.

The climate, according to Subev and Stanev 1963, is mountainous, transitional and continental, under the constant influence of the southern cyclone, generating in the western areas of the Mediterranean. The average annual temperature for the highest regions of the karst landscape is 3.8° C and 8.4° C for the lowest ones.

The mould-carbonate soils are connected to the basic rocks - the marbles and are not so fertile. The holocene soils prevail, but in certain parts of the karst region and outside it there are also fragments of older soil sediments, mainly on the slopes and the terraces. Some upper and middle paleolitic findings were discovered along the terraces of the river. They included flint artefacts, the Spout, the Transformator, the Nose, Orpheus V. and some other. Some of them had been precipitated, others preserved in situ, or influenced by sulifluxional processes. During the investigation in the deeper layers some polygonal structures were found. The thickness of their fissures was 4-5 cm, and their diametres were from 20-40 cm up to 50-60 cm. Some of the fissures were filled up with whitish or yellowish and red fractions. Similar polygonal structures were discovered in the watermechanical sediments in the pre-entrance part of the Triangular cave at a depth of -4.80 - 5.20 m.

The cave is situated almost in the middle of the karst region. The two entrances can be found in the base of a crown of rocks, facing southwards, at a 2240 m absolute highness and 130 m relative highness. The entrances are almost parallel. Twelve metres inside they form a hall, developed eastwards. It is ten metres long and seven metres wide. After that the cave forms a passage with average width of 2 m, leading north-eastwards. The total length is 91 m. The floor is flat and covered with seiments and rock pieces that show up in certain places.

Before analysing the problem I wish to thank to all the young men who volunteered and carried out a great deal of the investigation work. Well-mannered, showing great interest and knowledge in studying the sediments, they wanted to work as much as they could. They quickly got into the methodology and worked on their own,without any any assistance. I wish to thank them once again, for they made real this report, too. They were wonderful.

I was supported also by a lot of organizations and fellow speleologists. The paleotic group of the Institute for Archeology helped us in finding out the traces of the

ancient dwellers. I wish to thank to prof.Lisak Starkel from the Institute for Geography in Poland.

The investigations were included together with some other caves in the SUBPROJECT 158-B programme, created by the International Quaternary Association /INQUA/.

We determined four zones of investigation of the sediments along the axis and horizontally.

1. Pre-entrance part, including the space in front of the entrances up to the rock walls.

2. The Entrance part - the lit-up and the dark zones of the cave.

In this paper we shall analyse some peculiarities and findings in the Pre-entrance zone. It represents a slope in front of the two entrances to the cave,facing southwards, 30-35o steep. The highest level of the cave sediments could be found in the western entrance.

We had three main tasks:

1. We had to find the oldest pleistocene sediments in this part of the mountain.

2.We had to enlarge our information about pre-entrance parts of the caves and their development. We lacked that information when studying the pleistocene sediments of the Sorickov's cave.

3. We had to make clear morphologic evolution of the entrance parts of the caves.

The foloowing genetic types of sediments were discovered: - Thermogravitational, built up by rocky marble pieces with different sizes and pointed on the edges, and variously coloured clays. Under the holocen layer there were an upper Wurm sterile layer and an upper Wurm fossil layer with remnants of Ursus spelaeus, herbivorous and predatory animals. The thickness in the weatern part is - 2.15 m and in the eastern part - 2.40 m.

- watermechanical types, built up in the lowest levels by gravels and sands, clay fractions with different colouring - green, yellow, up to yellowreddish. At a depth of - 2.30 - 3.05 m some bones of Ursus spelaeus were discovered together with a lower jaw of a herbivorous pleistocen animal.

Unexpectivly three parts of stalagmites were found in the pre-entrance part in situ - in front of the entrance.

- The first piece was a stalagmite with a calcite cover and sintric pockets. It was found in the western part of the area, lying over a fine frection of sands and clays from watermechanical sediments at a depth of - 1.81 m. It was 28 cm long and had a diametre of 17 cm.

- A fragment of stalagmite at a depth of 1.90 m in thermogravitational sedimants in the eastern part of the area. A piece of the stalagmite, together with two pieces of bones of Ursus spelaeus, lying in upper stratigraphic layers, were sent to prof. Starkel for dating.

The following paleoclimatic characteristics were received:

Stalagmite sample N HV II084 dates 38380-930
830

and corresponds to the increased chemical denudation and deeper filtration of waters during the Interglacial period. The lying over sediments correspond to the cold phase of the cold erosion. The two bones of Ursus spelaeus from the fossil layer date 17 740-465 and 15 570-310.

- A stalagmite formed right over a basic rock in the eastern part of the zone - 3 m in front of the eastern entrance.

Those findings made possible the dating of the time when Ursus spelaeus and the other pleistocen animals dwelled the cave, and we also received information about the denudation of the entrances - they had become 5-6 m more narrow during Wurm II and Wurm III periods. Huving in mind the dating of the deposits and theire position insitu in the sediments, we can state that the cave was in a water regime of flowing of the underground river during the Upper Ris Wurm and Lower Wurm. The sediments under the layer of the stalagmite had been formed at that time as well. The Triangular cave's sediments are the oldesr investigated sedimants in the Rhodope mountains.

During the autumnal excavations of the watermechanical sediments in 1988 in the pre-entrance zone, some new samples were found - pleistocen deposits - stalactites on different levels from 3.50 up to 6.80 m. They had different lenghts and diameters. The cross section of the samples impressed us most with their structure, which can be analysed in several aspects.

1. Strongly expressed radial fisseres. Some of them are secondarily cracked by the flowing water /pictures 50b*, 3.2. 13 and partly in picture 10 and 5/.

2. All of the cross sectioned samples show concentical fissures, too. The flowing water had cracked secondarily some of them, too /pictures 5b* and 13/.

3. In the more strongly radially concentrically fissured samples we could notice certain secondary crystallization.

4. When splitting out some of the deposits along the radial fissures, we could notice well defined sinters and secondary crystallization /pictures 6 and 5/.

DISCUSSION OF THE PROBLEMS

The first group of prblems is connected with the fissures of the deposits and some mineralogists define three ways of origin:

- singenetic way - the fissures were formed tigether with the thickening of the deposits.

- epigenetic way - the deposits had been formed and fissures appeared as a secondary process as a result of deformation in the deposits.

- diagenetic way - the process of hardening and drying led to the cracking of the deposits.

The origin of the fissures could be attributes als to a combination of these three ways.

The second group of problems is connected with the dating of the deposits. We aimed to receive information about the climate and to define the paleoclimatic and paleohydrologic conditions in the karst region.

The structure of the deposits brought up some other problems, too, connected with the morphoclimatic conditions in the evolution of the underground network. The investigation of the structure and the crystal formations of the deposits would giveus the chance to receive information about the underground climate if the karst hollows.

Before receiving the laboratory results from the excavations I would like to give my theoretical opinion on the matter, using the achievements of speleoclimatology and relying on my experience.

1. The deposits were formed under the layer of the dated stalagmite - 1.90 m during the Upper Pleistocene, the end of Ris Wurm Interglacial, Wurm I and the first half of Wurm II. The climate was not stable and the Triangular cave could be defined as a ventilation cave. During the time of the formation of the deposits the two entrances were under a rocky opening - an entrance with two galleries, that were 6-7 m longer at least. The two galleries were situated on different levels. The cave was in a water regime and, probably, it had an open pot-hole, but it lacked a constant water siphon. Those three pleistocene openings of the cave provided the conditions for the unstable climate of the ventolation type of caves.

2. During their formation the deposits had a very unstable hydrometry. They were not flooded entirely and the percolating water was with a inconstant character. The vertical fissures created conditions for a secondary dissolution. The deposits were in a "stalagtite - spouts" stage with an inconstant flow of water.

The conditions of ventilation cave, the unstable climate and the inconstant hydrometry caused concentrical and radial fissuring of the deposits.

The unstable climate and the cold processes led to the breaking up of the ceiling and dislodging of the stalactites, which fell in the underground stream and moved in its direction. Therefore, the pre-entrance zone represented the spring part of the cave during the upper pleistocene. As a result of the cold processes the thermogravitational sediments - marble rocky pieces and clays - filled and closed some of the pot-holes and openings of the cave and created living conditions for Ursus spelaeus and other pleistocene animals. During the holocene the entrances, together with the cave of the Arrows, were used as inconstant dwelling places by the inhabitants of the region.

I think you are not very much surprised by these findings in the Triangular cave, but it is siyuated in the most southern parts of the European continent and it will arous interest mainly for the revealing of its paleoclimatic processes during the Upper pleistocene. Our fellow speleologists will have the chance to compare their work with the investigations in the cave. I believe in their benevolence and let's hope for our future mutual assistance in solving these problems and acquire new information about the pleistocene development of the deposits of different caves.

HINWEISE AUF AUFSTEIGENDE KARSTWASSER IN ALPINEN KARSTQUELLEN

PAVUZA, Rudolf - TRAINDL, Helmut

1. Zusammenfassung

An vielen alpinen Quellen kann das Phänomen des gleichzeitigen Schüttungs- und Mineralisationsmaximums beobachtet werden. Dieser Effekt wird in der Literatur oft als Folge des "Piston-Effektes" verstanden, kann aber, entsprechend den hydrogeologischen und hydrodynamischen Gesetzmäßigkeiten, auch als Potentialeffekt in der phreatischen Zone des Karstwasserkörpers gedeutet werden. Durch die im zentralen Gebirgsbereich bzw. im Bereich der maximalen Kulmination des Karstwasserspiegels höchste potentielle Energie des versickernden und auf den Karstwasserspiegel auftreffenden Niederschlagswassers in Relation zu der der marginalen, tieferliegenden Aquiferbereiche werden die tieferen, auf größeren Umwegen zur Quelle führenden Wasserbahnen kurzzeitig verstärkt aktiviert. In diesen Bereichen ist durch den erhöhten Druck das Kalk-Kohlensäuregleichgewicht infolge einer erhöhten CO_2-Löslichkeit in Richtung zu höheren Gesamtionengehalten verschoben. Diese relativ älteren Wässer werden nun durch den beschriebenen Effekt für kurze Zeit - bis der Energieüberhang abgebaut ist - zur Quelle emporgedrückt.

Dies bedeutet aber, daß in den tieferen Aquiferbereichen zusätzlich zur Mischungskorrosion eine weitere, immer wieder erneute Lösungskapazität für Karbonate vorhanden ist und der Tiefgang der karsttypischen Kalklösung wohl noch größer ist als bisher angenommen. Hinweise auf das Phänomen der CCD (Calcite Compensation Depth) und die Ergebnisse der Tiefbohrungen für die Kohlenwasserstoffexploration im kalkalpinen Raume mögen dies verdeutlichen. Auf der anderen Seite sieht man indessen, daß gerade zur Zeit der höchsten Schüttung und wohl auch des höchsten Erosionspotentiales die tiefen, aufsteigenden Quelläste in vielen Fällen am stärksten aktiviert werden. In der Tat zeigen nun auch auffallend viele alpine Riesenquellen eindrucksvolleaufsteigende Quelläste, die zum Teil in beträchtliche Tiefen führen.

Summary

With many alpine springs the phenomenon of simultaneous maxima in discharge and mineralization can be observed. In literature this effect is often regarded as a consequence of the "Piston effect"; it may, however, be interpreted as a potential effect in the phreatic zone of the karstwater in accordance with hydrological and hydrodynamic laws. In the central mountain area respectively area of maximum culmination of the karst water level the potential energy of the precipitation draining away and reaching the karst water level is higher compared to that of the marginal lower aquifer zone. Due to this fact the deeper waterways reaching the spring after detours are being activated enormously for a short period of time. In these areas the $CaCO_3$-CO_2-equilibrum is shifted in direction of a higher total concentration of ions, caused by an increased solubility of CO_2 and increased dissociation as a consequence of high pressure. These comparatively old waters are pressed up to the spring by the effect mentioned above for a short time until the surplus of energy has disappeared. This means, however, that in the deeper aquifer zone there exists a further continously renewing capacity of carbonate corrosion in addition to the mixing corrosion, and that the area of carbonate-solution (which is typical for karst) reaches more deeply than assumed so far. For illustration see references to the phenomenon of CCD as well as the results of deep drillings for the exploration of hydrocarbons in the Calcareous Alpine Zone.

On the other hand it can be seen that the deep and rising branches of many springs have their highest activity just at the time of maximum discharge and erosion capacity. Indeed strikingly many alpine giant springs show rising branches partly leading to considerable depths.

2. Beobachtungen an alpinen Karstquellen

In der einschlägigen Literatur wird häufig ein Zusammenfallen von Schüttungs- und Mineralisationsmaximum bei Quellen im Karbonatkarst erwähnt. So etwa bei MÜLLER et al.(1980), KOLLMANN, W.(1975), CSER et al. (1986), um nur einige wenige zu nennen. Auch bei den eigenen Arbeiten (PAVUZA 1982, TRAINDL, 1982, PAVUZA & TRAINDL 1985) wurde der Effekt beobachtet. Im folgenden werden nun einige alpine Beispiele erörtert, wobei der Zusammenhang zwischen Schüttung und Mineralisation verwendet wird, der die "Hystereseeffekte" (siehe auch WALLING & FOSTER, 1975, EDWARDS, 1985) besser zeigt. Die beiden modellmäßigen Extremfälle - Schüttungsmaximum bei gleichzeitigem Mineralisationsminimum (wohl vor allem bei frei fließenden

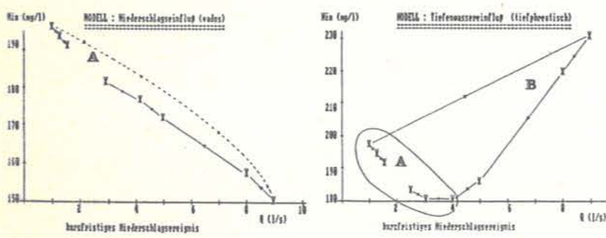


Abb. 1+2: Zwei Modellfälle für das Q/Min-Verhalten alpiner Karstquellen

vadosen Wässern gegeben), sowie der oben beschriebene mit gleichzeitigen Maxima (siehe dazu die Abbildungen 1 und 2) - zeigen deutliche Unterschiede in der Kurvencharakteristik. Doch sind bei den meisten Quellen infolge der Heterogenität im Aquifer sicherlich weit weniger eindeutige Ergebnisse zu erwarten. In den Abbildungen 1 und 2 stellt der Bereich A den überwiegenden direkten Einfluß des noch nieder mineralisierten Niederschlagswassers, B hingegen den Bereich höhermineralisierten offensichtlich hochgedrückten Tiefenwassers dar.

Das erste praktische Beispiel stammt vom Nordwestfuß des hydrologisch bereits mehrfach untersuchten Dachsteinmassives (Oberösterreich). Die "Brunnbachquelle" der Wasserversorgung der Ortschaft Gosau (siehe dazu auch PAVUZA & TRAINDL 1985 sowie TRIMMEL & PAVUZA 1988; die Traceruntersuchungen von F.Bauer & G.Völkl (Wien) wurden noch nicht publiziert), die ihr Einzugsgebiet im ausgedehnten obertriassischen Dachsteinkalk hat, der den überwiegenden Teil des Gebirgsstockes aufbaut, wurde während und nach einem heftigen Niederschlagsereignis kurzfristig beobachtet (Abb.3).

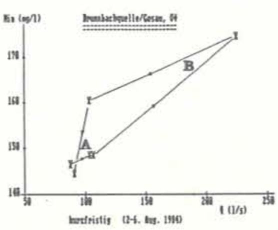


Abb.3 : Schüttungs- und Mineralisationsverhalten der Brunnbachquelle

Es tritt deutlich der erwähnte Effekt zutage, wobei die "Drehrichtung" interessanterweise umgekehrt ist (Gegenuhrzeigersinn) im Vergleich mit dem Modellfall (Abb.2). Dies mag ein erster Hinweis auf die Uneinheitlichkeit des Karstaquifers sein (siehe auch Abschnitt 3).

Im östlichen Voralpenbereich in der Gegend von Weyer (Oberösterreich) konnte an vielen Quellen ein ähnlicher Effekt beobachtet werden (PAVUZA 1982, TRAINDL 1982). Als Beispiel wird die Quelle Oberland angeführt (Abb.4), die ihr Einzugsgebiet in den obertriassischen "Opponitzer Schichten" hat, die hier unter einem meist bewaldeten Grünkarstgebiet anstehen. Wie bei der Quelle am Dachstein ist auch hier ein längeres Anhalten der hohen Mineralisation in Relation zur Schüttung zu konstatieren. Beide Quellen liegen im Talbereich, der relative Karstwasserstauer jedoch weit darunter.

Es fragt sich nun, wie gut langfristige Bebachtungsreihen, etwa im Monatsrhythmus, die ja viel eher vorliegen als kurzfristige (u.U. im Stundenintervall !) für derartige Untersuchungen verwendbar sind. Bei der Quelle Oberland (Abb.4) sind solche Punkte eingetragen, wobei aus Gründen der Vergleichbarkeit der Zeitraum der Schneeschmelze nicht verwendet wurde. Im vorliegenden Falle scheint eine gewisse Aussage hinsichtlich des Tiefenwasseranteiles bei genügend langem Beobachtungszeitraum möglich zu sein, obschon bei derartigen längerfristigen Beobachtungen schon rein statistisch gesehen die Schüttungsspitzen eher selten erfaßt werden.

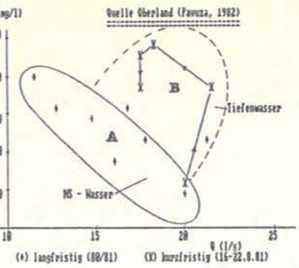


Abb.4 Schüttungs- und Mineralisationsverhalten der Quelle Oberland

Bei der Alpeilquelle an der Heiterwand in Tirol, die etwa 2 Jahre lang ungefähr im Zweimonatsrhythmus besucht wurde, zeigt sich offenbar ein markanterer Einfluß von Tiefenwasser (Abb.5), wobei durch das gänzlich vegetationslose Einzugsgebiet eher durchschaubarere Verhältnisse zu erwarten sind, d.h. Variationen in der Hydrochemie sind von externen Faktoren (Boden, Vegetation) praktisch nicht abhängig.

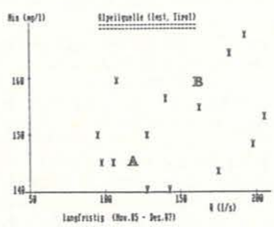


Abb.5: Schüttungs- und Mineralisationsverhalten der Alpeilquelle an der Heiterwand (Imst, Tirol)

Die hydrogeologische Situation ist recht interessant: Es handelt sich um ein hochalpines Karstgebiet von ausgesprochenem Kettengebirgscharakter mit extrem steilen Flanken, wobei die Quelle an der Grenze vom sehr gut verkarstungsfähigen Wettersteinkalk zu den relativ stauenden Raibler Schichten (Sand- und Tonsteine) austritt. Diese allerdings - und dies ist recht selten der Fall - fallen gegen das Tal ein, wodurch die Basis des Karstwasserleiters im Bereich der Quelle erst in beträchtlichen Tiefen zu erwarten ist (Abb.6).

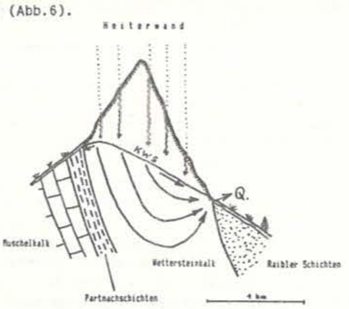


Abb.6: Hydrogeologische Situation der Alpeilquelle

3. Zur Hydrodynamik des tiefphreatischen Bereiches

Die phreatische Zone alpiner Karstaquifere, die infolge verschiedener lokaler Effekte zweifelsohne nur in größerem Maßstabe betrachtet eine dem klassischem Grundwasserspiegel vergleichbare, meist gewölbte Fläche im Raum darstellt, weist in vielen Fällen einen Kulminationspunkt irgendwo im Bergesinneren auf, der - je nach den geologischen Randbedingungen - stark azentrisch in Bezug zur Gebirgsgeometrie sein kann. Trifft nun versickerendes Niederschlagswasser - im Idealfall im gesamten Aquiferbereich gleichzeitig und in gleicher Menge - auf diese Fläche, so ergeben sich nach der Theorie von HUBBERT (1940) für freie, tiefreichende Aquifere Abflußbahnen in Richtung zur Resurgenz, die zum Teil sehr tiefreichend sind. Nach der Potentialtheorie ergeben sich für das in Abbildung 7 dargestellte Modell die tiefreichendsten Wasserbahnen vom Kulminationspunkt des Karstwasserspiegels zur Quelle.

Der Verlauf der Äquipotentiallinien bedeutet ferner auch, daß bei zwei hypothetischen Klüften (in Abbildung 7 als A und B bezeichnet), die unterschiedlich tief reichen, jedoch an ihrer Basis die gleiche Äquipotentiallinie antreffen, die Wasserstände gleich sein müssen - ein hydrodynamischer Effekt, der bei rein statischer Betrachung der Konfiguration des Karstwasserspiegels scheinbar widerspricht. Dies ist nun zweifelsohne eine der Erklärungsmöglichkeiten für manche zunächst befremdliche Beobachtungen an ganz offensichtlich phreatischen Höhlensiphonen.

Bei Annahme, daß gegen die Teufe zu die hydraulische Durchlässigkeit - aus welchen Gründen auch immer - abnimmt, sind abgeflachere Fließbahnen anzunehmen (Abb.8), was jedoch am Konzept an sich nichts ändert. Von größerer Bedeutung indessen ist das Relief des Karstwasserspiegels: je größer dies ist, desto tiefreichender ist der oben erwähnte Effekt (FETTER, 1980).

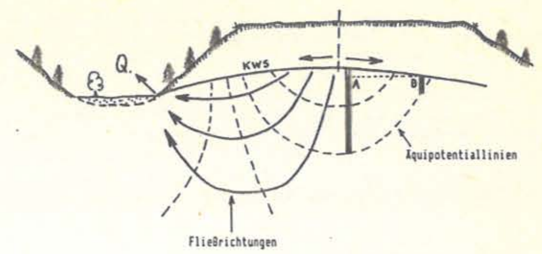


Abb. 7: Hydrodynamik des phreatischen Bereiches (nach FETTER 1980)

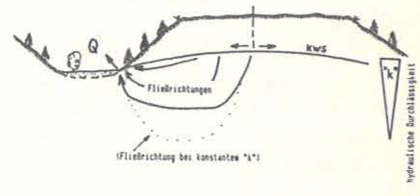


Abb.8: Fließverhältnisse in der phreatischen Zone bei Abnahme der hydraulischen Durchlässigkeit gegen die Teufe

Es ist aber nun so, daß die auf dem Kulminationspunkt auftreffenden versickerndern Niederschlagswässer eine deutlich höhere potentielle Energie aufweisen als die der marginalen Aquiferbereiche. Bei annähernd gleichzeitigem Auftreffen müssen daher die tieferen Wasserbahnen nach dem Modell in Abbildung 7 solange verstärkt aktiviert werden, bis dieser Energieüberhang abgebaut ist. Limitierender Faktor ist zweifelsohne der größere Reibungsverlust der tieferen und längeren Wasserbahnen sowie lokale Störeffekte, wie plötzliche Querschnittsveränderungen (PREISSLER & BOLLRICH, 1985). Wenn der Niveauunterschied zwischen höchstem und tiefstem Punkt des Karstwasserspiegels ein bestimmtes Maß unterschreitet, wird der Tiefenwassereinfluß ausgeschaltet und vorwiegend hochphreatische Wässer, die zumindest in der ersten Phase nach dem Niederschlag häufig noch nieder mineralisiert sind, erreichen die Quelle. Im weiteren Verlauf treffen dann aber auch wieder CO_2-reichere und damit subsequent höher mineralisierte Wässer bei der Quelle ein.

Für den Modellfall und die Beispiele (Abb. 1 - 6) tritt also zum Zeitpunkt der höchsten Schüttung (höchstes Potentialgefälle im Einzugsgebiet) offensichtlich zeitlich begrenzt Wasser des tiefphreatischen Bereiches zutage.

Zweifellos ist aber auch zum Zeitpunkt der höchsten Schüttung ein gewisser Anteil an hochphreatischem Wasser in der Quelle anzutreffen, wie ja durch Markierungsversuche im alpinen Raum mehrfach gezeigt wurde. Auch sind beim vorliegenden Modell die vadosen Quelläste nicht berücksichtigt. Diese Restriktionen sollten vor Augen führen, daß eine kritiklose Verallgemeinerung von Thesen gerade im Karst sehr problematisch ist.

4. Hydrochemische Aspekte

Die im 3. Abschnitt entwickelte These aus der Beobachtung der hohen Mineralisationen beim Schüttungsmaxixmum weist offensichtlich auf eine höhere Mineralisation der tiefphreatischen Wässer hin. Dies kann nun thermodynamisch auf eine Verschiebung des Kalk - Kohlensäuregleichgewichtes unter erhöhtem Druck in Richtung zu verstärkter Bildung von H_2CO_3 und verstärkter Dissoziation derselben auf Kosten des aggressiven und des Gleichgewichts - CO_2 zurückgeführt werden, was letztendlich eine verstärkte Kalklösung in tieferen Aquiferbereichen zur Folge hat. Zudem steigt die physikalische Löslichkeit des CO_2 in Wasser im Teufenbereich von wenigen hundert Metern um rund 0.2 % pro Meter.

Ohne auf die umfassende Literatur zur Kalklösung hier näher eingehen zu können, sei lediglich auf das Phänomen der CCD, der "Calcite Compensation Depth" in den Ozeanen verwiesen. Es ist bekannt (siehe dazu etwa MRAZEK, 1988), daß unter einer bestimmten, örtlich verschiedenen Teufe (4000 - 6000 m) in den Meeren keine Kalkausfällung bzw. eine Kalklösung stattfindet. Grund dafür ist eine erhöhte Lösungskapazität, die biogen, aber auch chemisch - durch druckbedingt erhöhte Dissoziation der Kohlensäure - begründet ist. Es gibt indessen nur wenige Möglichkeiten, diese vertikalen Variationen (siehe auch PAVUZA & TRAINDL, 1985) im Karstwasser direkt zu erfassen. Hinweise auf erhöhte Kalklösung kommen von den Tiefbohrungen im Rahmen der Prospektion auf Kohlenwasserstoffe im kalkalpinen Raume (WESSELY 1983), die einerseits starke Karstwasserbewegungen in großen Tiefen (bis über 5000 m) bei erhöhten Gehalten an Erdalkaliionen ohne Einfluß von Salinarwässern, andererseits das Aufdringen von ebenfalls hydrogenkarbonatreichen Karstwässern an den Thermen des Kalkalpenostrandes nach langem Wege im kalkalpinen Untergrund des Wiener Beckens erbrachten.

Durch diese Überlegungen wird das Modell des gleichzeitigen Schüttungs- und Mineralisationsmaximums auch aus hydrochemischer Sicht verständlich.

Für Karstgebiete mit einer starken Vegetation bietet sich freilich zunächst auch eine andere Hypothese an: Durch das versickernde Niederschlagswasser wird zunächst das extrem CO_2-reiche Bodenwasser in den Aquifer gedrückt, dann erst folgt das eigentliche Niederschlagswasser, das zwar allgemein die CO_2-Produktion im Boden erhöht, durch die große Menge in Summe aber doch eine Verdünnung dieses hohen CO_2-Potentials bewirkt, sodaß letztlich niedrigere Mineralisationen zu konstatieren sind. Das heißt, daß auch hier dem niederschlagsbedingten Mineralisationsabfall ein mehr oder minder ausgeprägter Mineralisationsanstieg vorausgehen müßte. Doch ist damit aus hydrodynamischer Sicht das oft beobachtete vollkommen gleichzeitige Auftreten der beiden Maxima auch in Grünkarstgebieten nur schwer erklärbar. Für Kahlkarstgebiete scheidet das Modell jedenfalls aus.

Das Phänomen, daß die erhöhten Mineralisationen länger andauern als die Schüttungen (umgekehrte Drehrichtung im Q/Min - Diagramm im Vergleich mit dem Modell in Abb.2) könnte gegebenenfalls in einem großräumigeren Aufdringen tiefphreatischer Wasser, die die Quelle zum Teil erst mit Verzögerung erreichen, erklärt werden (Abb. 9)

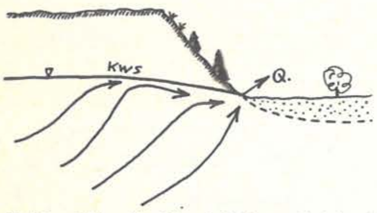
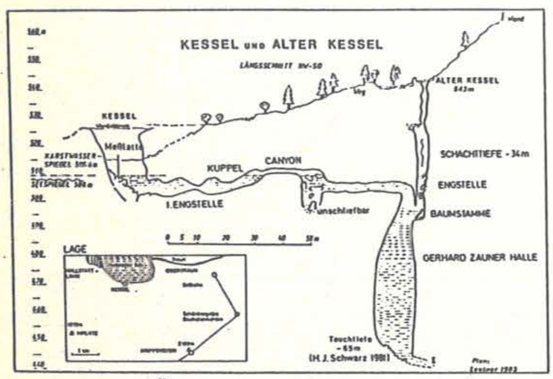


Abb. 9: Modell für nichtpunktuelles Aufdringen tiefphreatischer Wässer

5. Speläologische Konsequenzen

Die vorliegenden Überlegungen weisen einerseits auf einen großen Tiefgang der Wasserbewegungen im phreatischen Bereich bei bestimmten hydrologischen Zuständen hin, andererseits ist auch in diesen Tiefen eine signifikante Erhöhung der Kluftporosität durch druckbedingt erhöhte Kalklösung zu postulieren. Diese guten Wegigkeiten zeigten sich wiederholt bei den kalkalpinen Bohrungen der Erdölindustrie, oft auch bei Markierungsversuchen, bei denen Täler unterfahren wurden. Dies führt wieder einmal vor Augen, daß die Hohlraum- bzw. Höhlenbildung extrem tief reichen kann, was ja ansatzweise auch bereits durch spektakuläre, freilich oft auch tragisch endende Tauchgänge in situ festgestellt werden konnte. Es ist dabei bezeichnend, daß bei Vorliegen bestimmter, oben genannter Voraussetzungen gerade die aufsteigenden Wasserbahnen zur Quelle zum Zeitpunkt der höchsten Schüttung am aktivsten sind. Infolge der maximalen Strömungsgeschwindigkeit ist aber gerade hier das Erosionspotential am höchsten. In der Tat finden sich bei vielen alpinen Riesenquellen gewaltige aufsteigende Quelläste; interessanterweise auch oft deutlich über dem heutigen Talniveau, was paläohydrologisch von entscheidender Relevanz ist. Drei alpine Beispiele sollen das Phänomen abschließend anschaulich vor Augen bringen:



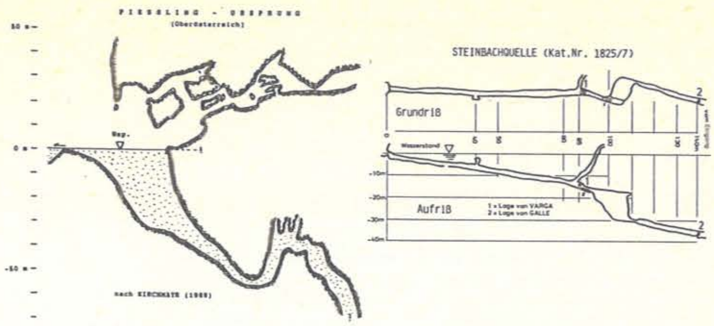


Abb.: 10-12 : Beispiele alpiner Riesenquellen mit aufsteigenden Quellästen nach KIRCHMAYER (1984,1988) und Leutner (1983)

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SUBCUTANEOUS DRAINAGE AND CAVE DEVELOPMENT IN THE INTERLAKE AREA, MANITOBA, CANADA

SWEET, Geraldine

The Interlake area is made up of several thousand square kilometers of carbonate bedrock. Predominantly dolomites of the Ordovician and Silurian, these beds form the eastern lip of the Williston Basin, a large synclinal system extending into the Northwestern States. In the north the surface has been exposed to aerial weathering for about 8,000 years, since the glaciers retreated from the region and represents a tremendous potential for Karst development. There are thousands of hectares of pavement and sinkholes, poljes and caves litter the area. Over forty caves have been found in the last three years. They are small, up to 160 meters long, and they are all within 25 metres of the surface. There is some controversy with respect to the processes of formation and age of these cavities. Presently the mean annual precipitation is less than 500mm., much of which accumulates as snow between November and April. Spring melt is a very important source of water for solution and cavities that are totally dry for most of the year, fill with water for a period of three weeks to two months at that time. During heavy summer storms water streams down the walls of several caves, although they are dry at other times. These two sources of water may play an important part in the modern development of the caves.

<u>CONDUIT D'ECOULEMENT SOUS SOL ET DEVELOPMENT DES CAVES ENTRELACS DU NORD, MANITOBA, CANADA.</u>

La region Entre-lacs est faite de plusieurs de milles kilometres carre de lits de rocher carbonate. Predominent dolomites de l'epoque Ordovician et Silurian, ces lits forme la leve des basin Williston, un grand systeme syndaical extendu dans les Etats Unis du Nord-ouest. Dans le nord la surface a etais exposer par les temps aerieus pour au pres de 8,000 annees, depuis que les glaciers sont retraitee de la region et represente un potentiel formidable de development du Karst. Il y a des milles d'hectares de pavee et de dolines, poljes et caves qui dessordre la region. Plus de quarante ont etaient trouvees dans les derniers trois ans. Ils sont petit, jusqu'a 160 metres de longueur, et ils sont tous entre 25 metres de la surface. Il y a quelque controverses par respect des procs de la formation et l'age de ces cavites. En ce moment la precipitation moyenne annuelle est moin de 500mm., le plus en accumulation de neige entre Novembre et Avril. La fondue du printemps est une tres importante source d'eau pour solution et cavites qui sont totalment sec pour la plus grande partie de l'annee, se remplisse d'eau pour une periode de trois semaines a deux mois a ce temps. Pendant les fortes orages d'ete l'eau coule en flot en bas des murs de plusieurs des caves, quoique ils sont sec d'autretemps. Ces deux sources d'eau peuvent jouer un part important dans le development moderne des caves.

An ongoing study of the area to the west of Lake Winnipeg (Fig. 1), has resulted in some interesting reclassification of pavements and has added significantly to this author's knowledge about hydrologic regimes in carbonate terrain. The greatest addition to the information on Karst development has come in the last three years, and is the result of a systematic search for caves in the region. In the last three years at least forty caves have been located in two distinct areas of the Interlake. In the north, close to Grand Rapids and in the south, around Hodgson. There are several other locations in the Interlake, but these have not yet been fully investigated. Of those that have been explored more than twenty have been accurately surveyed (Fig. 2).

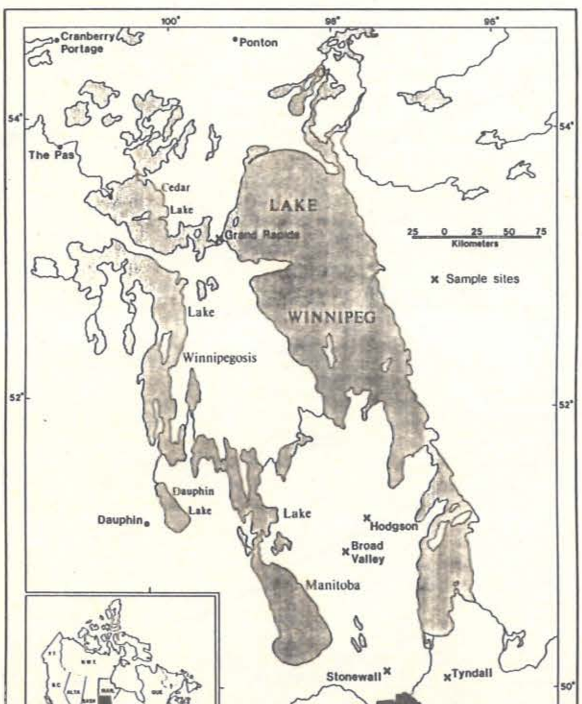


Figure 1

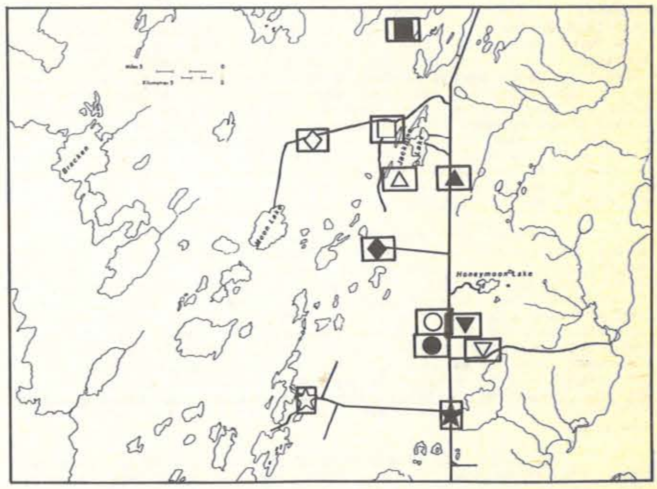


Figure 2

The karst landscape has developed in rocks of the Devonian, Silurian and Ordovician periods. These are predominantly dolomites, but there are significant beds of limestone, calcareous sandstone and some concentrations of gypsum. The area is large stretching for about 10,000 square kilometres. So far study has been concentrated in the two areas mentioned above. The caves at Hodgson are in Ordovician limestone and cherty dolomite. Those of the Grand Rapids Uplands are in Silurian dolomites.

This paper considers only the development in the Grand Rapids area. The stratigraphy includes a mixture of reefal deposits, algal mats and stromatolites, over draped with finely bedded dolomites, all of which are found at the surface. The area was glaciated as recently as 10,000 b.p., the ice removing any surficial material and the result is a massive area of pavement in which the cave entrances are found.

With continued exploration and study of each of the caves a more competent picture of their development emerges. There is apparently some correlation with respect to the processes of formation and the probable age of these cavities and they fall into two general categories of physical shape. They are all quite small with a maximum length of 150 metres and they are all located within fifty metres of the surface. There are small vertical pits, generally between 5 and 10 metres in depth, tapering off to nothing at the base. Secondly there are steeply sloping shafts, which bell out into horizontal chambers or passages at the bottom. The maximum depth of any of the features found so far is less than 20 metres below the surface. This is well below the frost line in the ground, but not necessarily deep enough to avoid fracturing in the past as a result of glacial compression and release, nor to prevent frost action today, in the shaft.

From the exploration and surveying of the last two years a distinct pattern of cave type is emerging and the development within those caves is clearly defined.

1) None of the cavities is very large, the maximum length measured is about 45 metres and the passages are not more than 3-4 metres wide, or 6-7 metres high.

2) They are all primarily joint controlled and there is little development of side passages, loops etc.

3) All the caves show evidence of breakdown, especially in the entrance zone.

4) Not all the caves have major evidence of solution and re-precipitation is sporadic. The development of speleothem is non existent, in the very early stages of formation, or takes a very long time to form.

5) Entrances are generally small, often with a vertical or near vertical drop, with the development of a main chamber below or slightly to the side of that entrance.

6) Many of the smaller cavities are simply enlarged grykes in which the top of the gryke is partially or fully blocked with breakdown and local detritus.

7) The caves are all apparently independent of each other and seem to have individual hydrologic systems.

8) Caves have been found in several stratigraphic units.

9) None of the cavities have permanent water in them or passing through them, but both flowing and standing water has been seen in many of them during the spring melt period.

10) Cavities are found in the exposed bedrock and below overburden and there does not appear to be a significant difference in form between the two environments.

11) It is apparent that the rock type and the local water table combine to create an hydrologic environment which is conducive to small isolated cave development.

Initial research in the province suggested that the caves were relatively old. In some places drill cores show cavities filled with Jurassic sediments, but these are at depth. Nevertheless it does mean that cave development has occurred in earlier geological times. It has been suggested by some authors [1] that the exposed cavities are the remains of much larger cave systems, which were erased by glaciation. This author would dispute this. There is nothing in the area, which shows any remnants of a larger system. One would expect to see at least a few examples of truncated passages in the present caves or in the walls of the overlying scarps for this to be a possibility. The only openings in scarp walls or cliffs is along the shores of several lakes and I think these can be attributed to wave/ice action.

Early analysis by this author proposed that the caves were the result of warmer temperatures and wetter conditions, probably in the last interglacial period. There were several reasons for this direction of thought. Most of the caves do have elements of breakdown and solution in them and there is some incipient speleothem in some of the caves. Postglacial conditions have been generally dry. The area gets less than 400 mm of precipitation per annum. Study of the caves during the summer shows them to be almost perfectly dry. Water sampling in one cave in particular takes about three weeks to catch a 500 mm bottle set under the most active drip. During the late fall or possibly early spring there appears to have been a little more activity. This is evidenced by the formation of an ice stalactite all the way down one wall of the sampled cave. This is often still in place as late as July. In any event the total water flow in the caves was apparently very small and hardly conducive to the development of even these small cavities.

However the conditions in the Sangamon interglacial period were warmer and wetter. Research in the area of bio-geography indicate considerably more variety and lushness of vegetation, for example. This would be a much more appropriate environment for the formation of caves. The secondary precipitation takes the form of a very thin veneer of flowstone, including mini gours and popcorn/cauliflower. There are a few very small stalactites actively, but slowly developing. The amount of breakdown could be explained by the increased pressure exerted on the bedrock during glacial advance and the subsequent release as the ice retreated. Everything then pointed to inter-glacial development, with some minor modification in the postglacial environment.

Further study of a number of the caves, over the last two years has encouraged me to reconsider. There are several conditions within the system that point to postglacial development. Although there is not much glacial till in the areas a whole, there are significant amounts in many of the bedrock hollows, throughout the region. Despite this there is no evidence of glacial till in any of the caves, which might be expected if the cavities had been there when ice moved over the area. The only deposits are fine clayey materials, probably a residue from the cave solution. In those caves with a sloping entrance passage and main chamber beyond there is little or no evidence of breakdown in that main chamber, despite the fact that these chambers are close to the surface. The entrance passages on the other hand are largely breakdown. They are exposed to the outside atmosphere much more than the inner chambers, indeed mid-winter temperature differences are as much as 15 degrees. In rock outcrops in the area, the breakdown is in evidence to a depth of 15 to 20 metres. (What is not known is the internal extent of that breakdown, although spot drilling in the area has shown crushed rock to a depth of 20 metres in some holes.) If the caves existed before the last ice advances one might expect to find some collapse this close to the surface. It is possible of course that the ice was not thick enough to cause compression and release, but all indications are that even the last major advances extended into the U.S. so the ice thickness would have been considerable. (The local quaternary geologists suggest >1,000 metres.)

Perhaps the most persuasive argument for postglacial development is the recent discovery that the caves are subjected to a great deal more water than was previously thought. During the summer time the caves are almost totally dry. It is possible to rub a fine film of dust off the walls. In the winter moisture cannot enter the caves because the surface is frozen, as is the ground to some depth. Notwithstanding there are two situations when the caves have a great deal of water flowing through or standing in them, on a regular basis, sometimes for several days or weeks at a time.

All the caves are within several metres of the surface. The bedrock is generally well jointed and in some cases fractured as well, the surficial debris is almost nonexistent. Vegetation is comprised of Jack Pines, Juniper bushes and a variety of lichens. In the winter the total accumulation of snow amounts to at least two metres. When this melts in the spring the melting begins from the top down, the meltwater passing through the decomposing snow into the ground. Apparently the ground does freeze, for this meltwater ponds on the surface. In April and May it is not unusual to have significant ponding in depressions and the bush as a whole is saturated with water. Melting of the snow is usually complete before the ground unfreezes, allowing the maximum amount of water to be available to pass into the cavities, when that occurs.

The result is water streaming down the walls of the caves and concentrating to form mini spouts in the main joint systems. This water is cold (snow meltwater is known to be enhanced with respect to CO_2), so it is highly aggressive, it passes directly from the surface to the subcutaneous zone, as there is no calcareous overburden. It then passes into the caves, quite rapidly, over a period of several days and it may have been slightly enhanced by its prolonged association with the vegetation. So solution should be a major process during these periods of flooding. Certainly the physical appearance of the caves, enlargement along major joint orientation, smoothly sculpted walls, and vertical solution pockets in the roof, attests to this. Because the caves are so close to the surface outside air circulates freely and toward the end of the melt the amount of water sliding down the walls lessens and evaporation could be expected to take place. Thus the mechanism for the flowstone veneer is also established.

Eventually the water passes through the caves into whatever spaces there are below. So far two different systems of drainage have been noted. Generally the outlet from the cave is such that some ponding occurs, either because the input is greater than the output, or because the floor of the cave is still frozen. Although the ground would not be frozen to this depth, the fact that some outside air does lower the cave temperature, below zero, means that the floor would also be below zero. As a result the water entering the cave ponds to various levels. In May 1988 the water in Moose Arm Pit (Fig. 3), was about a metre deep, preventing access to the second chamber of the cave. This water was slightly above freezing point, despite the fact that the outside temperatures were in the upper 20's. Less than 48 hours later the water had completely drained, which implies that once the floor of the cave becomes unfrozen the drains are relatively large, possibly incipient caves. In Bat Cave water was entering the cave at a rate of more than one litre per second, down the fracture zone at one end of the cave. Despite some ponding on the floor, most of the water drains away as fast as it enters, again indicating relatively large drains below the clay floor.

Evidence of the ponding is apparent in several forms. In at least one of the caves, Moose Arm Pit (Fig. 3), there is a notch around the wall marking the level of ponding. In Bat Cave the walls bell out close to the floor, suggesting more solution in that zone (Fig. 4). In yet another cave the rock surface in the lower level shows a form of fretwork suggesting differential solution. This may be another result of the ponding, or at least evidence of water streaming down the walls some of the time, and dry at others.

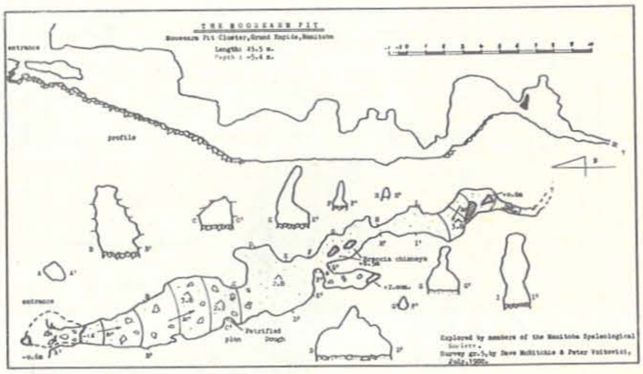


Figure 3

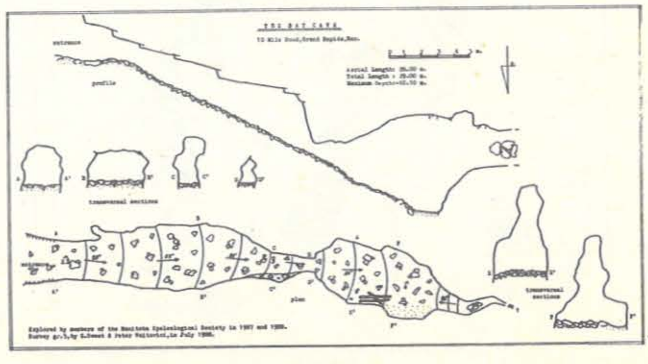


Figure 4

[1] Lockery, A. personal communication.

It seems entirely possible that annual repetitions of this meltwater flooding could be a mechanism capable of creating solutional cavities of the size found in this region. Despite the fact that dolomite is slow to dissolve, the caves could have been formed by this process since the last ice advances, 9,000 years ago. Certainly solution is occurring to day and these caves are part of an active system.

During the summer precipitation in this area is sporadic, it takes the form of thunder storms, the result of intense convectional heating. These storm events produce heavy rainfall, some of which is absorbed immediately by the crackling dry lichens. and later evaporated. Again some ponding occurs in the depressions and this water will pass quickly along the joints into the subcutaneous zone, and thus into the caves. For example less than 24 hours after such a rain storm, water was encountered pouring down the walls of one cave. This water too will be available for solution. The lack of overburden means that this water is still fully aggressive when it reaches the bedrock. This water will be more limited in its effectiveness than that available earlier in the year. It will not have as high a CO_2 content as the spring melt. There is not nearly as much water available at any one time, so the length of time for potential solution will be less, but any aggressive water will cause some solution, all of which adds to the overall process.

I am almost convinced that the processes mentioned above are sufficient to produce some of the cavities found in the Grand Rapids area, over a period of ten thousand years. I am quite convinced that they do not explain all the caves for some are obviously breakdown formations. I also think this transient subcutaneous water is responsible for secondary development in the caves.

When there are large quantities of water flowing through the subcutaneous zone into the caves that water is always aggressive. These large amounts of water should react with the bedrock causing solution. However in this particular environment the water does not provide a permanent or even long lasting condition. Instead most of the time the cave walls are dry. So the cave walls are saturated, for a short time they are awash. Then evaporation occurs first drying the actual wetness from the walls, then drawing the moisture from the surface layers of those walls. There appear to be three distinct surfaces developing as a result and each is found in a different physical environment.

Some of the caves have a very thin veneer of flowstone on the walls, generally not more than 2 mm thick, although mini gours have formed where there is a change of angle on the wall. This may be so thin because of the inconsistency of flow, and the very small amount of solution that will have occurred in the waters passage from the surface. It makes sense that the flow at non flood times, which will be very slight, is more likely to have some carbonate in solution, than the flood waters which reach the caves so quickly. In some of the caves there are excellent if small masses of what appears to be cave popcorn, but which was apparently not formed under water. It closely resembles cauliflower in form, although it is much smaller and occurs in clusters on rock ledges and corners, particularly in enlarged joint systems, which are partially closed at the surface. Lastly, many of the caves, regardless of size or stratigraphy, have a covering of fretwork or trellis on the lower walls, formed presumably by the rapid alternation of very wet and ultra dry conditions in the caves.

There is obviously a great deal of work to be done in this area, before any definitive answers are forthcoming. In the meantime exploration of the region and the discovery of more cavities adds to a gradually expanding bank of knowledge on the genesis of these features. At time of writing we have just been told of a cave, two miles long, with side passages. Even as I write excavation of the entrance grows apace, and by the time this paper is presented the story may have changed again. One thing is clear, despite the simplicity of the rock structure, the Interlake area is as complex as any found in this country.

A csapadék gyakorlatilag csak hó formájában érkezik és tavasszal 1 hónap alatt olvad el. Ilyenkor a bg-ok 1-2 hétig tele vannak vízzel, majd kiszáradnak. Lényegében tehát korróziós bg-ok. A base-level nagyon messze van, ott sok apró és néhány nagyobb forrás csapolja meg az aquifert, a water-table kb 100 m-rel van a felszín alatt.

KARST PAVEMENTS, DEPRESSIONS AND CAVE DEVELOPMENT IN THE INTERLAKE AREA OF MANITOBA; A RANDOM RELATIONSHIP?

SWEET, Geraldine

In the Northern Interlake area there are large areas of dolomite pavement, exposed by the last glacial advances about 8,000 years ago. On this surface there are innumerable shallow bedrock depressions, varying considerably in size. In the last three years over forty small caves have been located in the area. These are roughly clustered in groups. With very few exceptions the caves entrances are horizontal openings, in pavements, with steep vertical drops into the cave. There are at least five different morphologies in the pavements, these generally correspond with the differences in stratigraphy. The caves are apparently found in several of the stratigraphic units, and entrances are found in different environments. The depressions may be gently sloping inwards or have vertical sides. The initial finding of this author and her colleagues is that the cavities are found randomly throughout the area and neither the morphology of the pavements, nor the location of the depressions is necessarily linked to the caves. A possible explanation is that the caves were formed before the surface was exposed and thus the surface has developed independently. A second theory would be simultaneous development. Lastly the system may in fact be directly correlated although this does not appear so at first glance.

PAVES KARST,DEPRESSIONS ET DEVELOPMENT DE CAVE DANS LES REGIONS ENTRELACS DE MANITOBA: UNE PARENTE AU HASARD.

Dans la region Entre-lacs du Nord il y a des grandes superficies de pave dolomite, exposee par le dernier progres glacial d'a peu pret 8,000 annees passe. Sur cette surface il y a d'innombrable depressions superficiel de lits de rochers, d'une variete de grandeur. Dans les derniers trois ans plus de quarante petites caves ont etaient trouver dans cette region, ceux-ci sont rudement grouper ensemble. Avec peu d'exceptions les entrees des caves sont d'ouvertures horizontal, en paves, en chutes rapide vertical dans la cave. Il y a au moins cinq differentes morphologies dans les paves, ceux-ci correspondes generalment avec les differences de stratigraphie. Apparenment les caves sont trouver dans plusieurs des groupes stratigraphic, et les entrees sont trouver dans des environments different. Les depressions peuvent etre doucement en pente interieur ou en cotes vertical. La decouverte initial de cette auteur et de ces collegues est que les cavitees sont trouver par hasard entre toute la region et ni la morphologie des paves, ni la location des depressions sont necessairment lier aux caves. Une explanation possible c'est que les caves ont etaient formee avant que la surface fut exposer et de cette maniere la surface a developer independantment. Une seconde theorie serait un development simultane. Enfin le system peut en fait etre directment correlatif quoique ce-ci n'apparait pas au premier coup d'oeil.

Twelve thousand years ago the whole of Manitoba was covered by ice. The last major advance of the Quaternary ice reached as far south as The Pas and Long Point, where an end moraine was created from the calcareous debris collected from the bedrock immediately to the north (Fig.1). That debris was collected from an undulating surface, where thin beds of finely grained dolomites are draped over algal mats and stromatolites, primarily of the Silurian period. The whole area sits above an escarpment 85 metres high. Lake Winnipeg, immediately below this escarpment creates the ultimate base level for both overland and underground flow. On top of the escarpment there are several glacially scoured lakes of various sizes, which add local complications to the hydrology of the region. The rest of the surface is made up of exposed bedrock with pockets of till in the hollows. This then is the environment which is home to a number of karst features. Vast areas of pavement are littered with sinkholes, caves, massively enlarged joints, shallow depressions, and scars. There are several distinct types of pavement, the physical properties of which are related to the stratigraphic units, which are exposed on the surface. Otherwise initial observation leads to the conclusion that there is apparently no set pattern to the development of the landscape.

Pavements in the area north of the The Pas Moraine cover an area of several thousand square kilometres. In many places these are sparsely covered by boreal forest, made up largely of Jack Pine, Tamarack and Spruce and its accompanying undergrowth of Juniper bushes, mosses and lichens. There are also large areas that have been cleared of this vegetation, either by man, or more frequently by natural fires. That they are generally naturally cleared may be one of the peculiarities of these pavements. There are distinct physical characteristics and in some cases chemical differences, which help to divide the pavements in this area into at least five distinct categories. Obviously there is some lithological control, but a second important factor in determining the characteristics of the pavements is the climate of the region.

The following is a visual, physical classification of those pavements, with an attempt to link them to the various internal structures of the bed rock. In some cases this means particular stratigraphic units, but not necessarily. The different pavement types are found exposed in a number of places, throughout the area, but it is proving very difficult to link them positively and particularly to stratigraphic members. In most cases the areas of exposure are large enough to see both the micro structure and the overall morphology.

The very thin-bedded fine grained dolomites break up easily under solution and frost action. These mechanisms have been enhanced by the compression and release produced by glaciation. The result is a pavement surface made of a shillow/felsenmeer like rubble, which extends to a depth of 20 centimetres or more. The clasts range in size from three to thirty centimetres and are very brittle, breaking easily from any pressure. This particular form is confined to one stratigraphic unit. This platey rubble, includes large numbers of bi-valve fossils. Initially frost action appears to be the dominant weathering process, but closer investigation shows that the edges of each clast are smoothed and rounded by solution. The clast surfaces are rough from solution weathering. Where this material is found in vertical exposure the solution is very obvious and is probably the first weathering to occur.

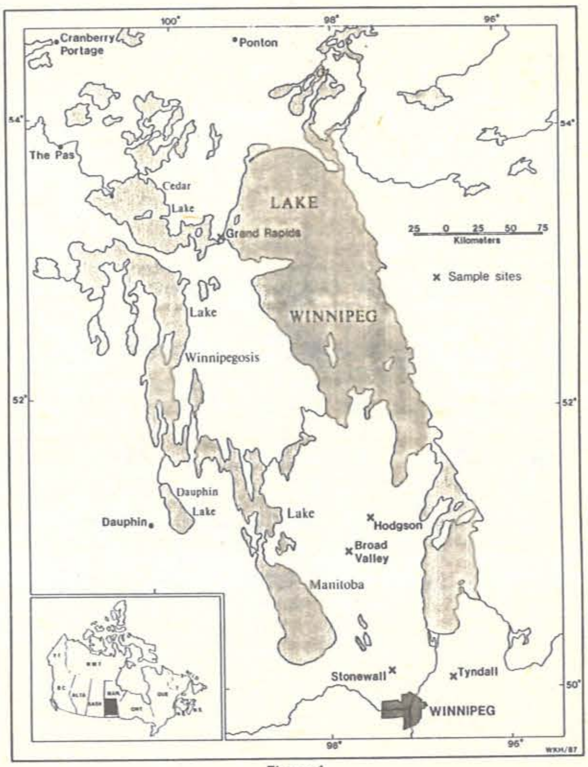


Figure 1

A second major pavement type, found throughout the region, is much more traditional in form. Some of the rock is more thickly bedded, and often includes some packstone, with fossils. Where this is exposed it breaks down slowly and is apparently more affected by solution, than by frost action. As a result the pavement is in large well defined clints, with long straight grykes. In this case the edges of the clints are rounded and there is occasionally a hint of runnelling. Solution pitting is in evidence on the surface of the clints, often fossil oriented. In areas which have only recently been exposed the surfaces are smooth and the grykes very narrow. In other locations, where the rock has apparently been exposed to the atmosphere for some time, the grykes may be as much as half a metre wide and extend through more than

Figure 2

one stratum. In several cases it is possible to climb into these enlarged joints to a depth of several metres.

The stromatolites forming a large proportion of the bed rock in the area range in areal size from several centimetres to several metres in diameter. This has a very distinct influence on the type of pavement that develops where these strome have been exposed by the glaciers. The very large strome have retained their morphology and the result is an undulating surface of smoothed gently rounded hummocks, indispersed by large star shaped hollows. In several areas these surfaces have been cleared of vegetation by a succession of fires in the last forty years. As a result the form is easily seen. Little weathering, chemical or mechanical has altered these. The smoothly rounded surfaces are apparently the tops of strome, the rock thus formed is relatively resistant and frost action is minimal. Water would run into the hollows, so little moisture would be available for solution. The hollows are sometimes lined with a sediment layer up to half a metre thick, and appear to be sink points, frequently filled with aspen and sometimes containing a pit of some type.

Where they are exposed, the very small stromatolites form a cobblestone effect. Particularly good exposures are the result of fluvial erosion and can be seen in a now dry river bed. A cross section of these strome reveal them to be very thinly laminated, as a result the individual cobbles may be partially eroded, from the centre out. Frost apparently causes a form of spalling and sometimes the exfoliated shells are seen on the surface. Here the typical clints and grykes are seen again, the fractures cutting across the whole, enclosing large diamond shaped clints. The edges of which have been rounded by solution. The individual beds of stromatolites are only 5 to 10 centimetres thick and in several places blocks of pavement have been lifted by the action of the river and it is possible to see the grykes to a depth of several tens of centimetres, generally cutting through more than one strata. Since the diversion of the river, twenty-three years ago, frost has become an important agent and in some patches the laminations are splitting, to form thin platelets on the clint surfaces.

By far the most interesting of the pavements is that found in the areas of mid sized strome, ranging from thirty centimetres to about two metres in diameter. Here distinct differences occur, depending on where in the vertical mass of the stromatolite, the glacial shearing has occurred. If the slicing is close to the top of the stromatolite, the feature retains its domed form and a pavement of large cobbles results, similar to that described above. However if the stromatolite is cut off closer to its base, the resulting pavement is different indeed. There is an initial dissection into large clints, two to five metres wide. The grykes are straight overall, but locally bend to accommodate the rounded edges of the strome. These fractures, with well rounded vertical edges, extend well over a metre down, often into a different stratigraphic unit. The surfaces of the clints have definitely been affected by solution in two distinct ways. All of the surfaces are liberally speckled with solution pitting, and minute depressions with very sharp undulating edges, are common. In addition the surface is littered with large holes, where the centres of the stromatolites used to be. This part of the strome was apparently less resistant to erosion, and has been removed. These holes are quiet deep and usually spread laterally below the surface, often coalescing. The first half metre or so of such a pavement is very rotten, and highly susceptible to both solution and frost action.

It is interesting to note that similar areas which have had a shallow calcareous overburden, until recently(Twenty Years) present a completely smooth pavement with the internal structure of the strome clearly outlined. There has been little or no weathering, probably because water reaching the rock was already saturated. Now that the surface is exposed it will be interesting to study these over the next few years and see if any changes develop.

Where the vuggy, units are exposed the pavement has little or no form. The rock breaks down very easily, especially under the influence of frost action. The result is a rubbly shillow, which is found in individual pockets, sometimes over a metre deep. This rubble is very crumbly and disintegrates almost upon touch, thus forming small patches of sediment, which could be removed by water. These pockets occur between the more traditional pavement found in the breccias surrounding them.

It is quite obvious that the pavements are lithologically controlled, and as such do not have a random distribution. However the different lithologies are not peculiar to specific stratigraphic units. Stromatolites are found in at least three of the six identified stratigraphic units in the immediate area. The thinly bedded dolomite is found at several depths. This does not create a random pattern, but it is certainly chaotic.

This chaotic situation apparently continues into other aspects of the karst development in this landscape. There are for example significantly enlarged joints scattered throughout the whole of the Interlake region. These features measure anywhere from five to fifty metres in length, they at least three metres deep, sometimes cutting through more that one lithology and they range from less than one to five metres in width. Physically they develop a wide variety of shapes, but are all a continuum of the grykes developing in the various types of pavement.

In this northern region the majority of these features are long and narrow, often with slabs of the local pavement lodged in the top. Many of them are just wide enough and plenty deep enough to explore. Some have evidence of secondary precipitation in them. These enlarged joints develop in a variety of stratigraphic units and are apparently not affected by such factors as distance from the edge of the escarpment, or the location of surface depressions in the bedrock. After careful analysis they can be classified into two types according to physical shape.

The first of these is the long narrow slit. In this case the ratio of length to width is always more than 5:1 and the depth in all surveyed cases is greater than three metres. The enlargement is always joint oriented, but may follow more than one joint, so the features sometimes have a dog-leg appearance. In almost every case such features show evidence of differential weathering and are therefore seldom uniform in width (Fig. 2). These have been found almost exclusively in open pavement, they probably exist in the till covered areas too, but would be buried and infilled. Photographs taken during the excavation of the forebay for the local dam uncovered such joints tens of metres long. Examples have been found isolated on the pavements, in clusters and in direct relation to some of the explorable cavities. There are some within 100 metres of the scarp edge, others are several kilometres inland. They are found in more than one stratigraphic unit, the only pattern to their development is that they are joint controlled and they all therefore fall within a thirty degree orientation.

The second class is a wider feature, with a length, width ratio of 2:1. In this case there are generally two or three such features in a line all oriented on the same joint. Such features are at least as deep as they are wide and there is always much breakdown in the form of big blocks, in the floor. Other characteristics of these trenches include well developed undercutting at various levels in the walls, short explorable tunnels in the end walls and various amounts of surficial debris. There is a greater variety of shapes in this category and greater variation in the ratio of solution and breakdown in their formation.

Both types exhibit predominantly solutional weathering. The edges of the blocks forming the lip of each trench are rounded and covered with micro pitting. In most the moss growing well within the crack is moist at any time, suggesting that these are local sinking points. Most of the wide trenches are in fact in slight depressions, but the long narrow ones rarely are. This probably means that the depression is the result of the enlargement, rather than the other way round. Indeed the breakdown in the wider ones and the fact that many of the smaller ones are narrower at the top than lower down, suggests that these features opened up from below. In which case solution has to be the mechanism. There is also evidence of breakdown in most, if not all the trenches, and it is particularly significant in the wider ones.

In none of the features found to this date has there been any evidence of erratics, or till in such features, which leads to the assumption that they were not opened up onto the surface until the post glacial period. Their initial formation may have been earlier. The last inter-glacial was wetter and warmer than the present so they may have been developed from that time. In addition it is probable that the ice in this area was warm based for at least part of its history, so solution could have been a vital mechanism below the ice.

The discussion of the location of such features leads naturally into an analysis of the location of cavities in general. The two are obviously connected, in fact, in many cases, it is difficult to quantify the point at which the enlarged joints become caves. There is undoubtedly a continuum, the end points of which are easy to define. For the purposes of this paper caves are considered as features big enough to move about in and which have at least a portion of their length cut off from direct access to the surface. They can be classified into different physical types. Those divided into an entrance tunnel of sorts and at least one chamber, those extending as a passage or series of passages and those that open out into a chamber-like cavity immediately below the small surface entrance. Ranging in size from 5 metres to 40 metres in length all the caves discovered have been within 30 metres of the surface. In all cases there is a distinct orientation to the cavities that is the same as the main jointing.

Caves have been found clustered and singly. They have been found in at least three of the stratigraphic units. They have been found close to the escarpment and at a distance from it. There appears to be no correlation between cave type and distance from the escarpment edge, nor is a particular type of cave found in particular units. Moose Arm Pit has a large chamber like room which is primarily solutional. While Microwave cave (Fig. 3) is almost exclusively formed by breakdown and the two are in the same stratigraphic unit. They are both about the same distance from the escarpment edge. At the same time Bat cave is almost identical in physical form as Moose Arm Pit, but is about 20 kilometres farther from the escarpment, in a different unit.

Within one area, about 4 kilometres square, some twenty caves have been located (Fig. 4). Included are several long passages, a fine example of a solutional chamber and a breakdown passage descending to more than 20 metres. There is a natural Bridge, a large collapsed sink and several sets of enlarged joints.

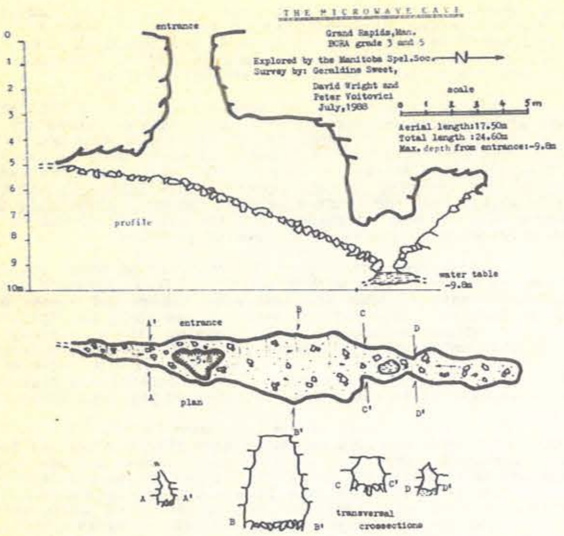
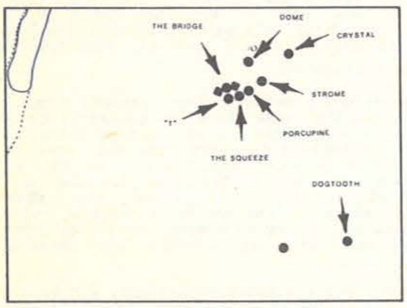


Figure 3



PORCUPINE CLUSTER

Figure 4

Inside the caves the characteristics are equally diverse. There are incipient speleothem in some, one has fine samples of Dogtooth Spar and another is totally bare of any secondary precipitation. There are solution pockets in the roofs of several of these caves, and scallops on the walls of others. Most of the cavities are very simple in shape, but one or two have apparent stages of development and separate sections. All but one of the caves in this area are entered vertically. Even where they are comparatively close together the caves are not necessarily the same type and there is no evidence that they might link up.

Sinkholes are an important component of any Karst environment and have been variously described by a number of authors. In this particular area the sinkholes are generally of two types. The most obvious are shallow, saucer shaped, features formed in bedrock. Secondly vertical joint junctions are well developed throughout the area and serve as drains. Both types are clearly discernable on many of the pavements and are indicated by changes in vegetation where they cannot be readily seen. Over 2,000 were identified within 10 kilometres of the local dam site, during the surveying for that site. Relationship to the escarpment edge is complex.

Commonly the saucer like sinks are stepped inward and in many cases the floor of the sink is covered in forest litter. The largest of these depressions are over three hundred metres in diameter, two or three metres deep and have one or more actual sink points in them. These sink points are characteristically small openings belling out below the surface to a depth of three metres, where they are plugged with fine sediments. While such features have been found in several areas they always seem to be associated with a local step of the escarpment. The depressions developing in the lows between the big stromatolites, may also have a steplike edge, but it is correspondingly smaller. In a number of cases these depressions also have a definite sink point, but many do not. In all of the cases observed so far the sink point has had bedrock exposed in it. Smaller depressions of this type are also found, in some cases they appear to be the centres of stromatolites, which have eroded preferentially, but others are found in places where the strome are not exposed on the surface.

The vertical sinks are typically in small sharply defined depressions, deeper than they are wide. They are found everywhere, but it is difficult when to define them as sinks as opposed to simple enlargement of the joint. Once again the idea of a continuum comes into play. The other problem is that these can only be inferred if there is any kind of overburden. Water sinks relatively rapidly in this environment, so the drainage points must be many, however the total amount of water available is small, so they would develop slowly. In many of the observed cases the drains are filled with sediment, but this does not appear to retard the sinking significantly. Sinks of any kind are not significantly larger or more abundant close to the escarpment.

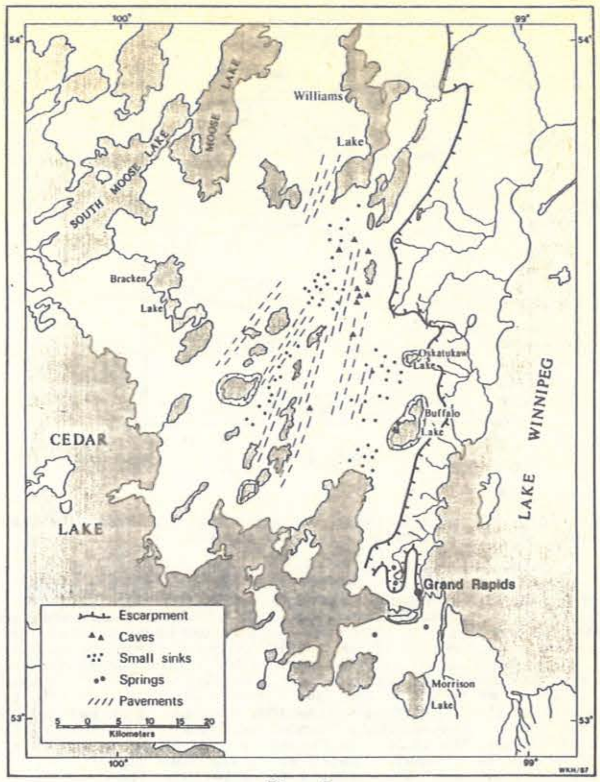


Figure 5

The main front of the escarpment is about 85 metres high. It follows a somewhat curved pattern northward, parallel to Lake Winnipeg. There are a number of embayments, the most pronounced of which contains Buffalo Lake (Fig. 5). Above the main front there are a series of steps at intervals, ranging in height from 2 to 10 metres. These stretching back from the edge for several kilometres, forming distinctive scars, most of which are oriented semi-parallel to the main escarpment. This orientation becomes less obvious the greater the distance from the main scarp and there are a few scars that do not seem to follow any particular alignment at all.

The steps are eroded in several different stratigraphic units, but the edges are best defined in the bedded dolomites. The leading edge is generally concave and is very weathered both chemically and mechanically. There are exceptions. The scars which are not aligned are generally straight or convex and show less solution. Clints and grikes are well defined, short small passages have developed at right angles to the edge, and although small cavities have been found, no major caves have been discovered in these leading edges. In a number of places there is evidence of water sinking at the base of the step.

The steps themselves may be stepped or have a steep front. In each case there is a scree component to the edge and often there is a slight depression behind the leading edge. The height of the steps changes radically from step to step and sometimes within the length of one step. That ice enhanced these scars is probable. That postglacial solution has occurred is possible. Lake Agassiz is supposed to have covered this area for several thousand years.

Does all this add up to a random distribution? Quite simply no. There is an order or pattern in the distribution of many of the types of features. Quite obviously the caves, like the joints are not randomly distributed. There is a definite relationship between these features and the tectonic effects. That the caves and the enlarged joints are part of a continuum is also apparent, although the two do not specifically follow each other. In some locations there are enlarged joints, then caves in the same line, but this does not occur regularly.

There is however a chaotic distribution of one set of features and the next, cave entrances are found in different types of pavements and in different lithologies, sinks may not be associated with caves and so on. The reason for this may not only be attributable to the methods of formation, but also to the time of formation, both length and chronology.

The dominance of solution in the development of one set of features and not in another paves the way for some interesting hypotheses on the age of development. This may also be a key to the apparent lack of order that appears in the location of different features. Some of these features could well have developed prior to the most recent phase of glaciation, the solution of joints for example. Possibly some of the caves were developed much earlier. The scars were probably cut as the ice sheets moved over the area, from more than one direction. The pavements as they are now are almost certainly postglacial. Thus very different climatological, hydrological and physical conditions have contributes to the development of this landscape and therefore correlation between existing features would be unlikely.

SUMMER SYNUSIE AND DISTRIBUTION OF THE FAMILY HELEOMYZIDAE (INSECTA, DIPTERA) IN A CAVE OF THE WESTERN CARPATIANS

KOSEL, Vladimir - MARTINEK, Vladislav

1. INTRODUCTION

Diptera of the family Heleomyzidae regularly penetrate into some caves and are parts of parietal associations on walls and roofs of cave thresholds /Motas et coll., 1967, Negra S., Negrea A. 1972, Jefferson 1986/. Though the species composition of cave heleomyzids being well known, there is little information about their synusiae /taxocoenoses/, space distribution and dynamics. /Collart 1940, Decu-Burghele 1963, Martinek 1987, 1982, 1984/. The present paper deals with the summer synusiae and space distribution of Heleomyzidae in a cave of the Western Carpathians in Slovakia. The material was collected from the same cave in the course of two summer periods in 1986 and 1987.

2. DESCRIPTION OF THE LOCALITY

Vlčie diery Cave /Wolf Holes/ lies in a karst mountain of the Slovenský raj /Slovak Paradise/ National Park. The cave is developed in triassic limestone in south part of the territory south of a village of Stratená. The entrance of the cave situated on forested slope with the exposition to north reaches an altitude of 990 m above sea level. The cave has approximatelly horizontal passages without underground streams and pools. The length of the main passage reaches about 60m and a total length of the cave attains about 100m. Due to a debris rampart, the cave entrance being diminished with a hight of 1.4m and width of 0.8m but the main passage maintains a width mostly about 3m and a hight up to 5-7m. Between polygonal points 7 and 11 there is a narrow rock fissure that separates the main passage from the terminal hall /Fig.1/. Substrate in the first 40m is clay, in the fissure and the hall rock with sinter debris.

3. MICROCLIMATIC CONDITIONS

Temperature and relative air moisture inside the cave were measured at 5m sections 1m above the floor. Table 1 shows the values of the temperature within the main passage where the flies occured. The temperature is relative low and besides the entrance does not exceed 5.5°C. It falls down from the entrance up to the fissure /about 40m/ due to the descending character the main passage. Higher and stable temperature /about 4.6°C/ is only in the hall. Very low summer temperature is caused by -high altitude, -north exposition of the entrance, -small dimension of the entrance, -forested surrounding and by accumulation of cold air in the desdending passage.

In the whole threshold, relative air humidity had values of 100%. In the periods of studies, the floor and walls were wet because of great amount of water which dropped from the roof.

The passage with direct daylight /euphotic zone/ is very short /13 m long/because the next part of that being rectangular. Diffuse light is noticeable up to 29 m and all other parts of the cave lie in dark /aphotic/ zone. Illumination was measured by a luxmeter /PU 150, Metra Blansko, CSSR/ and the data are in Table 1. The last measurable data were obtained at a distance of 10-13 m from the entrance /0-3 lx/.

Air movements within the cave are negligible and therefore it may be considered as relative static.

4. METHODS

The cave passage including sidebranch with polygonal points 3-5-6 were divided into longitudinal sections each with a length of 5 m. Flies were collected from walls within each section separately up to 2 m above the floor /Košel 1976/. As a sampling technic, exhaustor was used.

5. RESULTS

A total 545 specimens were sampled in August 8, 1986 and 335 ones in July 28, 1987. In both summer samples, 12 species of Heleomyzidae were represented. Seven species of them occured in both years. In 1986, ECC OBS and SCO VEN were absent, in 1987, HEL SER, SCO BRA and SCO prope SCU /Table 2/.

ECC PAL was the most numerous species in both years /422 and 255 spec./ with the highest dominancy /72.4 and 76.1 % respectively/. All other species were conspicuously less abundant with the highest dominance of 9.5 - 10.6 % /Table 2/. It is interesting, that in spite of a large difference in total number of the flies between both seasons, dominances in the same species were similar in both samples.

In the case that a species occured in low quantity /1-3 specimens/, it was represented mostly by one sex - male or female. In the most abundant species ECC PAL the sex ratio can be considered 1:1, though females inconspicuous prevailed /52.8 and 53.3%/. The females prevailed distinctly only in HEL MOD /2:1 and 3.7:1/. The males prevailed mor or less in SCO CAE /1.1:1 and 2.2:1/ and SCO SPE /1.8:1 and 4:1/.

The highest number of flies /51.0 and 51.2%/ occured on the walls within the sections 0-5 and 5-10 m with direct daylight /Table 3 and 4/. Relatively high number of flies was collected also within the sections with diffuse light regime: 10-15, 20-25, 25-30, but on the other hand they were in low quantity in the sections 15-20, 15-20 and 20-25. In dark zone, behind the section 25-30, the flies occured only sporadically.

The most abundant species in the cave ECC PAL has been distributed almost within all sections where heleomyzids occured. The same distribution has also most other species though they may absent at some sections. Only near the entrance within sections 0-5 and 5-10, ECC EMA, ECC OBS and SCO prope SCU occured. In deeper part of the threshold only SCO BRA was found /one pieces/.

As regards the distribution of the flies according to sex, there has not been found out any distinct and regular rule. It seems, that the males of SCO SPE tend to prevail at the near-entrance zone, on the other hand, the females tends to prevail in deeper parts /20-30 m/ in ECC PAL. /Table 5/. The similar situation appears to be in males of SCO CAE.

To obtain the chracter of synusie /taxocoenoses/ within particular sections, dominances of the species represented were calculated. In both years and within almost all sections, ECC PAL was high dominant species with a minimal dominance of 50.0%. Of the other species, only SCO SPE and SCO CAE /only 1986/ have sometimes dominances above 10% mainly in the sections 0-5, 15-20, 15'-25', 25-30 and 20-25 /in 1987/. Table 3 and 4.

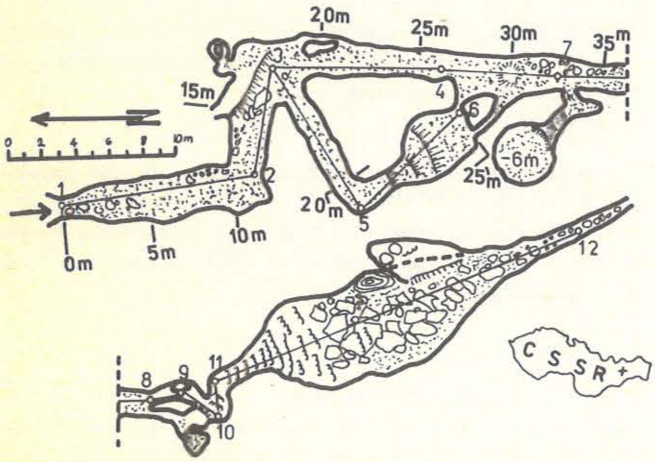


Figure 1. The plan of Vlčie diery Cave /Wolf Holes/ with marked sections /after Hochmuth, 1970/.

Station	Temperature		Humidity %	Light regime	Lux
	8.8.1986	28.7.1987			
Outside	16.7	11.4			
0 m		6.2			550
5 m	5.1	5.1	100	euphot.	1-10
10 m	5.1	4.9	100	euphot.	0-3
15 m	5.0	4.7	100	diffuse	
20 m	4.9	4.6	100	diffuse	
25 m	4.4	4.4	100	diffuse	
30 m	4.4	4.1	100	diffuse	
35 m	4.2	4.0	100	aphotic	
Hall	4.6	4.6	100	aphotic	

Table 1. Microclimatic parameters of Vlčie diery Cave.

6. SUMMARY

Diptera of the family Heleomyzidae as a part of parietal association in the threshold of a cave /the Western Caspathians/ were studied. Twelve species were found during two summer seasons 1986 and 1987. A total 545 and 335 specimens respectively were collected from the walls from the entrance up to 35 m. In both years, Eccoptomera pallescens was the most numerous species with dom nance of 72.4 % and 76.1 %. Other species had the dominance mostly less than 10 %. Most species were represented by both sexes. Males prevailed in Scoliocentra caesia /1.1:2 end 2.2:1/ and Scoliocentra spectabilis /1.8:1 and 4:1/. Females prevailed distinctly only in Heleomyza modesta /2:1 and 3.7:1/. In Eccoptomera pallescens, sex ratio was approximatelly 1:1. Space distribution of flies was studied within sections 5 m long. The highest number of flies /51.0 and 51.2%/ occured from the entrance up to 10 m in euphotic zone. Most species were spread within the whole threshold and only Scoliocentra prope scutellata, Eccoptomera emarginata E. obscura occured near the entrance. There was no distinct and regular distribution of the flies according to sex in particular sections. The main species of synusie in most section was E. pallescens with minimal dominance of 50.0 %.

Species	Sign	1986		1987	
		n	D%	n	D%
Eccoptomera					
-emarginata Loew, 1862	ECC EMA	2	0,4	2	0,6
-obscura /Meigen, 1830/	ECC OBS			2	0,6
-pallescens /Meigen, 1830/	ECC PAL	422	77,4	255	76,1
Heleomyza					
-captiosa /Gorodkov, 1962/	HEL CAP	2	0,4	10	3,0
-modesta /Meigen, 1838/	HEL MOD	6	1,1	14	4,2
-serrata /Linné, 1758/	HEL SER	5	0,9		
Scoliocentra					
-brachypterna /Loew, 1873/	SCO BRA	1	0,2		
-caesia /Meigen, 1830/	SCO CAE	46	8,4	32	9,[illegible]
-sabroskyi /Gill, 1962/	SCO SAB	1	0,2	3	0,9
prope					
-scutellata /Garrett, 1921/	SCO SCU	2	0,4		
-spectabilis /Loew, 1862/	SCO SPE	58	10,6	15	4,5
-ventricosa /Becker, 1907/	SCO VEN			2	0,6
Total	12	545	100,0	335	100,0

Table 2. Number and dominance of Heleomyzidae found for two summer seasons /1986, 1987/.

Section	00-05	05-10	10-15	15-20	15'-20'
Species	n D%	n D%	n D%	n D%	n D%
ECC EMA	2 4.8				
ECC PAL	24 57.1	192 79.7	79 90.8	11 57.9	9 60.0
HEL MOD		2 0.8		1 5.3	
HEL SER		2 0.8	1 1.2		
SCO CAE	4 9.5	20 8.3	3 3.4	3 15.7	2 13.3
SCO SCU	1 2.4	1 0.4			
SCO SPE	11 26.2	24 1.0	4 4.6	4 21.1	4 26.7
Total	42	241	87	19	15

To Be Continued

Section	20'-25'	20-25	25-30	30-35	Total
Species	n D%	n D%	n D%	n D%	oo OO
ECC PAL	4 57.1	70 81.4	32 74.4	1 20.0	199 223
HEL CAP		2 2.3			2
HEL MOD			3 7.0		2 4
HEL SER				2 40.0	3 2
SCO BRA			1 2.3		1
SCO CAE	2 28.6	5 5.8	5 11.6	2 40.0	24 22
SCO SAB		1 1.2			1
SCO SPE	1 14.3	8 9.3	2 4.7		37 21
Total	7	86	43	5	

Table 3. Quantity and dominance of Heleomyzidae in particular sections on 8 August, 1986.

Section	00-05		05-10		10-15		15-20		15'-20'	
Species	n	D%	n	D%	n	D%	n	D%	n	D%
ECC EMA	1	1.7	1	0.9						
ECC OBS	2	3.4								
ECC PAL	48	81.3	99	88.3	45	76.2	7	70.0		
HEl CAP			1	0.9	3	5.1				
HEL MOD	1	1.7	3	2.7	3	5.1			1	16.7
SCO CAE	6	10.2	1	0.9	4	6.8	3	30.0	3	50.0
SCO SAB			2	1.8						
SCO SPE	1	1.7	5	4.5	3	5.1			2	33.3
SCO VEN					1	1.7				
Total	59		112		59		10		6	

To Be Continued

Section	20'-25'		20-25		25-30		30-35		Total	
Species	n	D%	n	D%	n	D%	n	D%	oo	OO
ECC EMA									1	1
ECC OBS										2
ECC PAL			40	74.1	16	50.0			119	136
HEl CAP			3	5.6	2	6.3	1	33.3	3	7
HEL MOD			2	3.7	3	9.4	1	33.3	3	11
SCO CAE			8	14.7	7	21.8			22	10
SCO SAB					1	3.1				3
SCO SPE			1	1.9	2	6.3	1	33.3	12	3
SCO VEN					1	3.1			2	
Total			54		32		3			

Table 4. Quantity and dominance of Heleomyzidae in particular sections on 28 July, 1987.

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Section /m/	ECC PAL		SCO CAE		SCO SPE	
	1986 oo:OO	1987 oo:OO	1986 oo:OO	1987 oo:OO	1986 oo:OO	1987 oo:OO
00-05	2 :1	1 :1,3	1 :1	2 :1	1.8:1	1:0
05-10	1 :1	1.1:1	1 :1	1 :0	2.4:1	5:0
10-15	1 :1,5	1 :1	1 :2	1 :1	3 :1	2:1
15-20	10 :1	7 :0	3 :0	0 :3	1 :1	
15-20	1.3:1		1 :1	3 :0	1 :1	1:1
20-25	1 :1.3	1 :3	2 :0	8 :0	0 :1	
25-30	1 :1.7	1 :1.3	1.5:1	1.3:1	2 :0	1:1
30-35	0 :1		0 :2			1:0
Total	199:223	119:136	24:22	22:10	37:21	12:3

Table 5. Sex ratios in three dominant species within particular sections.

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THE REMARKABLY CONSTANT LONGITUDINAL PROFILE OF TOOTHPICK STREAM, FRIARS HOLE CAVE SYSTEM, WEST VIRGINIA, U.S.A.

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1. OVERVIEW

An investigation of surface and subsurface longitudinal stream profiles in the Appalachian karst belt (Sasowsky, 1988) revealed a 4.5 km reach of cave stream with a nearly constant gradient, within the Friars Hole Cave System. What is remarkable is that the stream, along its reach of constant gradient, does not follow a straight, down-dip path, but rather follows a complex, sigmoidal path, whose overall plan-view trend is at 90 degrees to the major trend of the Friars Hole Cave System and valley. The current paper addresses possible causes for the observed phenomena within the context of the regional setting.

1.1 Study Site Description

The karst of Friars Hole is probably the second most studied in the United States, with Mammoth Cave, Kentucky, being the first. Beneath these hills and hollows of Pocohantas and Greenbrier Counties, West Virginia, lie 68.9 kilometers (42.8 miles) of cave passages, making the Friars Hole Cave System one of the longest known in the world.

The area (figure 1) is on the eastern edge of the Appalachian Plateaus province. It is separated from the Valley-and-Ridge province by Droop Mountain to the southwest. Dissection of the plateau has been complicated in this area by the presence of karstifiable lithologies, and a broad flexure known as the Brown's Mountain Anticline, upon whose western flank the study site lies. The strike within the study area averages 030 degrees (N30E), with a maximum dip of 5 degrees to the northwest (Worthington, 1984). Thrust faults observed and tallied by Worthington (1984) have an approximate strike of 025 degrees (N25E) and dip to the West. These thrusts have been interpreted as backthrusts of relatively minor displacement associated with an eastward dipping thrust beneath Droop Mountain. The oldest rocks exposed within the study area are the Greenbrier Group of Mississippian age. The valley floor elevation is near 720 meters (2400 feet), with nearby mountains, known locally as "knobs", rising steeply to elevations of 1200 meters (4000 feet) or so.

In ascending stratigraphic order the formations which outcrop in this study area are: Hillsdale Limestone, Sinks Grove Limestone, Patton Limestone, Taggard Formation, Pickaway Limestone, Union Limestone (all entrances to Friars Hole Cave System are in this formation), Greenville Shale, and Alderson Limestone. Lying above these, forming the mountains, are the clastic Mauch Chunk and Pottsville (Pennsylvanian) Groups.

The valley of Friars Hole is dry. Streams which rise on the clastic flanks of Droop and Brushy Mountains, and Jacox Knob, flow for a short distance into the valley on streambeds armored with clastic detritus and are then absorbed into the groundwater flow system, primarily via swallets. Dye tracing has revealed that water draining into this valley travels several kilometers to the south and then resurges in an estavelle on the east bank of Spring Creek (Baker, 1982; Medville, 1981). White and Schmidt (1966) noted that free surface conduit flow occurs at a depth of up to 300 meters (1000 feet) below the surface locally, and that the water table does not mimic the surface topography in this area. The Greenbrier River, which controls local base level, flows southwest from here, paralleling regional strike.

Figure 1: Location of the study area, on the eastern edge of North America. Dashed lines are political (state) boundaries.

1.2 Friars Hole Cave System

The cave (see figure 2, upper half) represents a response to a very long and varied hydrologic history. The oldest passages in the cave are approximately four million years old (Worthington, 1984). Worthington has established a detailed history of the speleogenesis, which shows migration of inputs and drainage routes throughout the basin.

All entrances to the cave are developed in the Union Limestone, though the majority of the passage development is in the Pickaway Limestone. Jameson (1985) conducted a structural segment analysis on a portion of the North Canyon Passage in the Friars Hole Cave System. Using this very detailed method he was able to trace the growth (speleogenesis) of the cave. He found that the inception of conduit flow was controlled by bedding plane partings 37 percent of the time, joints 29 percent of the time, and bed-joint intercepts 20 percent of the time. Thrust faults and fault-joint intercepts also acted as high permeability zones.

The cave currently consists of three separate drainage systems each of which contains a master drainage and numerous feeder tributaries. The Toothpick Stream is a part of the central drainage.

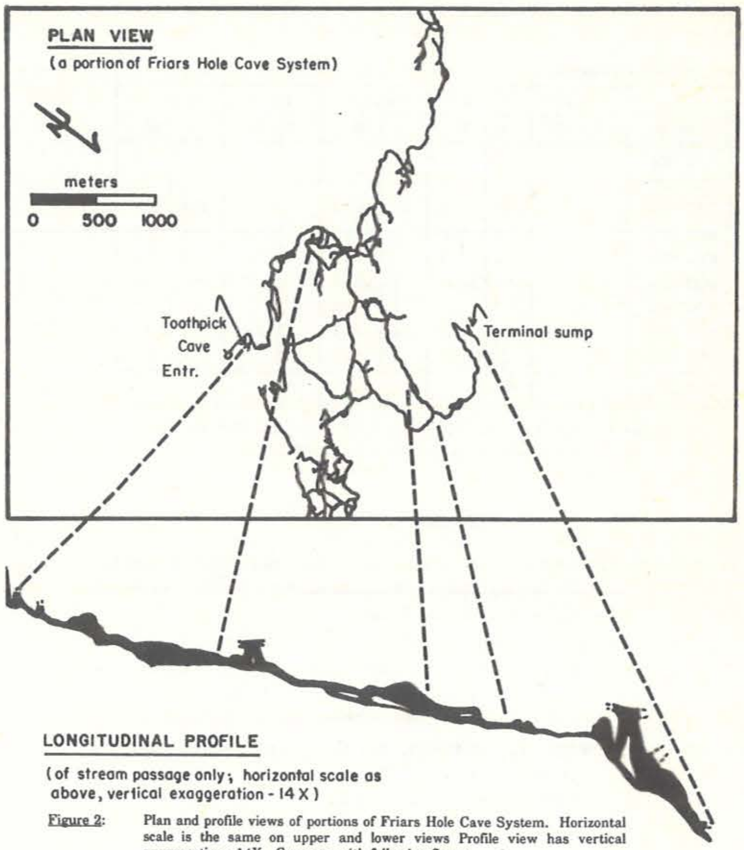

Figure 2: Plan and profile views of portions of Friars Hole Cave System. Horizontal scale is the same on upper and lower views Profile view has vertical exaggeration - 14X. Compare with following figure.

2. THE TOOTHPICK STREAM

2.1 Construction of the Profile

The longitudinal profile was constructed using surface data at 20 foot contour intervals from the U.S.G.S. 1:24,000 scale topographic map, and subsurface data from cave surveys conducted with hand-held compass and inclinometer. The profile, with all data points indicated, is presented in figure 3. The reader should note that this is a true longitudinal profile, a plot of elevation versus distance along the stream channel, not a standard (projected) cave profile.

2.2 Detailed Description of the Toothpick Stream Passage

A small stream in Ravens Nest Hollow drains a surface basin 3.4 square kilometers in area, and sinks in its bed at the top of the 50 meter thick Union Limestone. The stream is seen in a bedding plane crawl within 20 meters of the sink point and a few meters below it. The stream flows west for 200 meters at the base of a multi-level joint in the upper Union. It then drops 20 meters via two 10 meter vadose shafts. This is the largest single stratigraphic drop along the entire route of this stream in the cave.

The beginning of the 4.5 Km, constant-gradient passage is at the base of these shafts. The stream flows at the base of a 10 to 15 meter solutionally enlarged joint trending west and then north for a total of 120 meters. At this point, the base of a 20 meter shaft, ultimately connecting to the surface and the Toothpick Cave entrance, is reached. The passage turns to the north for 180 meters as a very low and wet solutionally enlarged bedding plane, two to three meters wide and less than a meter high. The stream flows to the northwest and then southwest for 220 meters in a one meter high and 6 to 10 meter wide bedding plane.

The stream then follows joints trending at S60W, subparallel to the strike (N20E), for over 800 meters. The ceiling height gradually increases to 10 and then up to 20 meters. The passage width is between two and three meters. Along this section of passage are found several short (1 to 3 meter) drops in the largely bedrock floor. A gradual stratigraphic drop results in the the passage reaching the basal Union Limestone.

The stream passage then gradually turns to the west-southwest in 10 to 15 meter high joints and then trends to the west for another 700 meters, descending into the upper Pickaway Limestone. The passage configuration changes from development along joints, characteristic of the Union, to development along solutionally enlarged beds, more characteristic of the Pickaway. Passage ceiling heights along this segment drop to three and then less than two meters while the width remains at three to four meters. The stream flows on limestone bedrock with shale and silt partings visible in the walls. Vertical stylolites, also a characteristic of the Pickaway, are visible as well.

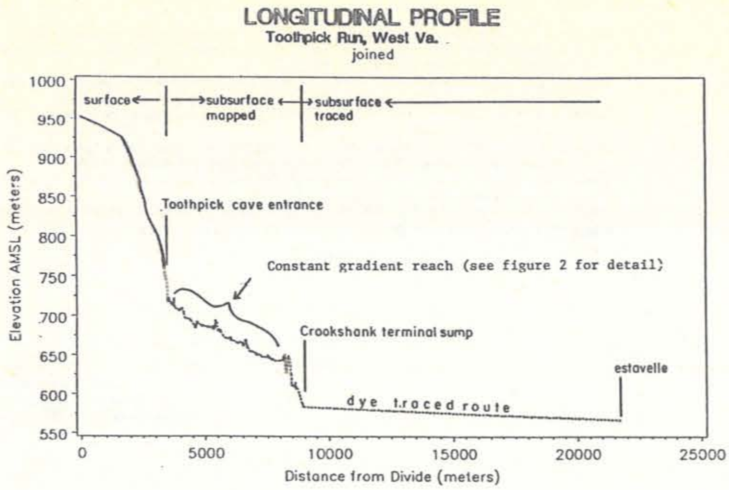

Figure 3: Longitudinal profile of the entire Toothpick stream. Vertical scale is exaggerated. For detail of the constant gradient reach see preceding figure.

The passage gradually turns to the north-northwest, then to the north, and finally to the north-northeast, paralleling the local strike (about N20E). Passing beneath converging surface valleys containing sinking streams, several infeeders enter from the east via high joints in the Union Limestone. Consequently, the volume of water in the cave stream about doubles although the stream gradient does not increase.

As the passage trends to the NNE, the stream flows in a semi-flooded solutionally-enlarged bed, two to three meters wide and 50 cm to one meter high. Larger (ten meter wide and 5 meter high) passages are found above and serve as overflow routes. Occasional faulting is also seen along and above the stream passage. The strike of these faults varies between N40E and N50E and the dip is to the southeast at 10 to 15 degrees. While the faults affect the passage cross-section, they do not appear to affect either the passage directional alignment or the stream gradient.

After about 200 meters, the various levels merge and the stream flows at the base of a single conduit, rectangular in cross section, six to eight meters wide and and up to four meters high. The passage trends N45E for 800 meters with the streambed alternating between sand, small cobbles and limestone bedrock. This entire passage lies in the upper 12 meters of the Pickaway limestone.

The stream then drops three meters through a small (one meter diameter) hole in the bedrock floor and flows in a tubular passage up to one meter in diameter for another 80 meters to the west; terminating at a sump. The passage in which the stream had been flowing continues to the north and northeast; finally rejoining the stream and serving as an overflow route.

Beyond the sump, the stream is seen again a few meters to the west and resumes its flow to the north-northeast along strike for 400 meters in relatively small passage in the upper Pickaway. This passage, three meters wide and two to three meters high, is paralleled by several other higher-level parallel passages which serve as overflow routes. The upper passages, the floors of which are about three meters above the stream, become larger to the northeast, reaching 20 meters in width and up to 10 meters in height. Several interruptions exist in the continuous traverse of the stream; these are caused by rockfall and short sumps.

The stream is then seen again, still flowing in a solutionally enlarged bed less than a meter high and up to three meters wide. This bed is 10 meters below a continuation of the larger upper level passages noted above. Slickensides seen in the ceiling of this upper passage follow a fault plane dipping 15 to 20 degrees to the east-southeast (strike of the fault parallels the strike of the limestone; about N20E). After 250 meters, the upper passage descends to the stream.

The continuation of the stream passage, three meters wide and up to 10 meters high, trends NNE for another 500 meters, remaining in the upper Pickaway limestone. The ceiling then lowers to within a few cm. of the water surface and after 50 meters, a confluence with a higher gradient stream, entering from the east, is reached. Just beyond this junction is a 50 meter long near-sump caused by rockfall and subsequent ponding of the stream.

Just downstream of this pool, the passage turns abruptly to the west, finally leaving the 2.2 Km long strike-oriented passage complex in which it had been flowing. The passage then trends to the west, sub-parallel to the dip. Passage dimensions enlarge somewhat; becoming up to three meters in height and five meters in width. The stream gradient continues to be about one degree. The passage continues to the west and then southwest for 600 meters, maintaining a constant gradient.

Finally, after a 4.5 Km subsurface flow path in which the stream drops 80 vertical meters and thus, has a relatively constant gradient of 1 degree, the gradient abruptly increases. For the last 900 meters of traversible cave, the stream follows the strike of the limestone, flowing first to the SSW, then to the NNE, and finally again to the SSW. Over this distance, the stream drops 60 vertical meters (gradient is 3.8 degrees) prior to terminating at a deep sump.

This last section of cave is fairly voluminous; 10 meters wide and up to 15 meters high. Over its length, the stream drops through the 30 meter thick Pickaway Limestone and reaches the upper Taggard Shales, an 8 to 10 meter thick local aquitard.

The terminal sump is only 16 meters higher than the spring where the cave stream rises, but is also 12.6 Km. to the NNE of the spring. Indeed, the direction from the spring to the sump, N23E, parallels the regional strike. Also, the spring is itself just above the Taggard Shales and it is possible that the entire flow path between sump and spring is perched on this unit.

2.3 Observations on the Constant-Slope Section of the Profile

The constant gradient reach begins in the sub-surface, 3500 plan-view meters from the surface water divide. The reach begins at an elevation of 720 meters, traverses 4500 meters of stream length, and begins to drop sharply at an elevation of 640 meters. This yields a gradient of 0.018 (one degree) for the reach (note correction from value published in abstract). Below this reach the cave stream has a gradient of 0.06 (3.4 degrees) for 1 kilometer to the terminal sump. Between the sump and the resurgence (12.6 kilometers straight line distance) the elevation difference is only 16 meters. This is an average gradient of 0.0013 (0.07 degree), although it is possible the water follows a deeper phreatic loop.

As a test for control by a planar feature, an attempt was made to fit a plane to several of the data points along the constant gradient reach. 22 points were selected, and it was found that a plane dipping in the direction 303 degrees (true) with magnitude 2.25 degrees could account for the position of the points with a very high degree of significance. This plane, and a representative plane of bedding, are shown in figure 4. While this information further constrains the geometry (and the genesis) of the passage, it is rather confusing at first: How can a cave passage wander in many different directions, have a constant gradient, and exist within a plane all at the same time? The answer is two-fold. First, these conditions can be satisfied geometrically only if, in plan view, the passage always has the same angular rotation (either clockwise or counter-clockwise) from the dip direction of the plane in question. The constant gradient of the passage, then, would in effect, be provided by two different "apparent dips" of equal magnitude within the plane. Second, while the former condition is not rigidly met in this instance, it is approximated by the general orientations of the passage, and the low dip of the plane serves to obscure portions where it is not met. The overall trend of the passage is "down" the dip of the plane, although the passage wanders to either side of the dip line, much as a sailboat would "tack" into the wind.

2.4 Possible Causes of the Constant-Gradient Reach

Two structural causes are presented, followed by two hydraulic causes.

2.4.1 Bedding-Plane Control

Bedding plane control of the passage gradient (e.g. a stream running directly down dip on a bedding plane) was first considered after the constant gradient reach was noted (see Palmer, 1987). The sigmoidal plan view of the passage, precludes this as a direct cause, as do the results of planar regression on bedding and passage presented in figure 4. An argument for inception of the passage along bedding, followed by downcutting might be made, but the problems of passage orientation and gradual lowering from the bedding plane require explaination. In addition, although upper levels are noted on the profile, (see figure 2) their presence over the reach is minimal. It is possible that local variations in structure might have provided deviation from the regressed plane during passage inception. The orientations of the passage are not inconsistent with expected conjugate joint-set directions given the regional tectonic setting, but field observation does not support the presence of these joints.

2.4.2 Thrust Plane Control

The regional structural trend has produced minor backthrusts in the area, of a general orientation that might provide a plane of weakness for speleogenesis. The hypothesis that the passage is formed along a single thrust plane is rejected because observations in the cave show minor thrusts along the passage, but not a continuous surface. In addition, stratigraphic observations in the cave show that there is insignificant shortening of section. It seems that the passage truly cuts down stratigraphically, and does not do so by structural shortening.

2.4.3 Water Table Control

Preferential solution along a piezometric surface which mounded beneath Droop Mountain is considered unlikely due to the high slope of the plane the passage lies in (2.25 degrees).

2.4.4 Graded Erodable Bed

In classical geomorphology, a surface stream with this sigmoidal pattern, and this nice, constant gradient, would bring to mind the term "grade". This term given to rivers with alluviated beds and smooth profiles is usually applied to high order streams with low gradients, and erodable/aggradable channels. The floor of the Toothpick Stream is bedrock in general, which, along with its steep gradient, precludes this mechanism as a cause for constancy of profile.

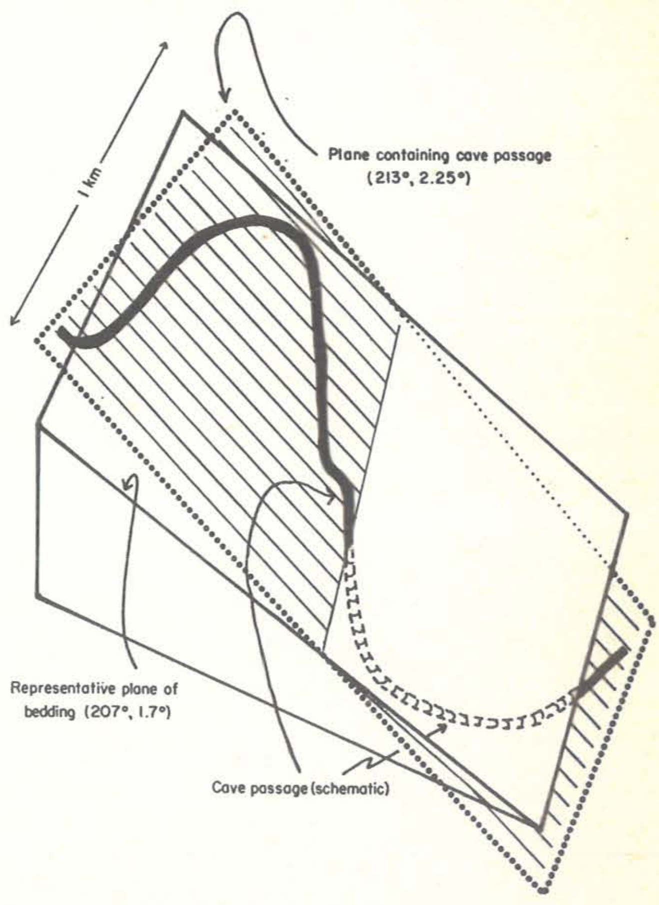

Figure 4: Geometric relations between the cave passage and planar elements.. See text for discussion.

3.0 SUMMARY

The reach of constant gradient is doubly remarkable in that it displays a sinuous pattern in plan view, and resides distinctly within a plane. The observed morphology, when considered with the local and regional geology appears to be best explained by a variation on the cause discussed in section 2.4.1, bedding plane control. The constant slope of the reach has been observed to consist or minor upward and downward segments, probably locally controlled, which either served as points of inception, or local perching layers.

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EVIDENCE OF QUATERNARY ENVIRONMENTAL CHANGES IN EASTERN AND SOUTHERN AFRICA FROM CAVE AND ROCK SHELTER SEDIMENTS

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1. INTRODUCTION

Despite clear evidence of former wetter or more arid conditions, there are two basic shortcomings in the present state of knowledge about eastern and southern African paleoclimates. These are that well-dated environmental histories are available for only a few sites and that there is little accurately-dated evidence beyond c. 40,000 B.P. -- the range of the ^{14}C dating method. One reason for the lack of spatial data is that much of the surface area is either arid or semiarid and pollen preservation is usually poor in the highly oxidizing conditions (Fig. 1).

Sediments in caves, which are numerous in some African countries and present in almost all, could provide the spatially detailed data needed for paleovegetation and paleoclimate modelling. Furthermore, as cave sepeleothems can be dated to c. 350,000 B.P. by the $^{230}Th/^{234}U$ method, and potentially to one million B.P. by the TL and ESR methods, cave sediments could extend our knowledge of African paleoenvironments well beyond c. 40,000 B.P.

In 1982 a study was begun to assess the potential of cave sediments to provide paleoenvironmental data for eastern and southern Africa within the range of the $^{230}Th/^{234}U$ dating method and if possible to develop long environmental histories for selected cave sites within these regions. Three months were spent in Somalia in 1982 and nine months in Zaire, Kenya, Zambia, Zimbabwe, South Africa, and Botswana in 1987. Ten caves were studied in environments ranging from hyperarid to humid tropical (Fig. 1). An important part of the work was to employ a specially-designed electric drilling rig to obtain cores from large speleothems that might contain a long record of environmental conditions at the site. During the fieldwork, 190 speleothem samples were collected, in addition to 73 samples of clastic sediments, and 8 samples of bone. Also, eight cores, 4.5 cm in diameter, were drilled from eight stalagmites or wall flowstones in five caves. These cores ranged in length from 0.25 to 1.5 m.

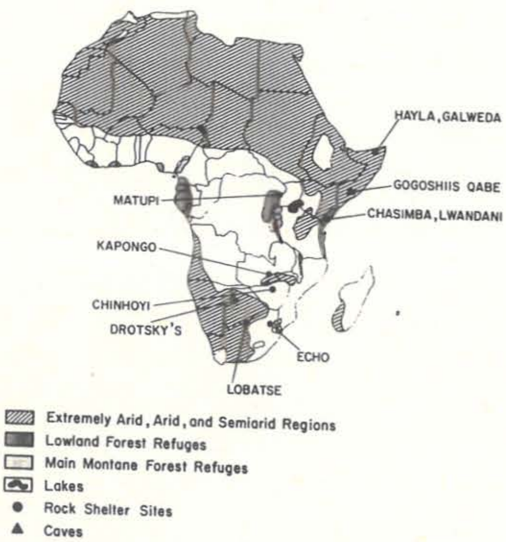

Figure 1. Locations of cave research sites in eastern and southern Africa. Arid and semiarid regions are after Meigs (1953) and hypothetical montane and lowland forest refuges follow Hamilton (1976).

2. PRELIMINARY RESEARCH RESULTS

Our preliminary analyses of only a few samples have already demonstrated the great antiquity of many of the cave sediments and have shown that speleothems may contain rich pollen assemblages. Results of our studies at five of the ten caves examined will now be presented.

2.1 Drotsky's Cave, Botswana

To date, our studies of Drotsky's Cave in the Kalahari Desert have focused on two cores 1.0 and 0.5 m long that were drilled from a wall flowstone and a column, respectively. The 1.0 m long core consists of layers of massive, unrecrystallised calcite separated by broad zones of porous carbonate showing extensive recrystallisation of aragonite to calcite. The layer of unrecrystallised calcite at the surface has been $^{230}Th/^{234}U$ dated to 197,400 ± 41,300 B.P., the oldest age yet reported from the cave. Precipitation at the site today is c. 450 mm. Deposition of the 3 m high flowstone, from which the core was drilled, implies wetter conditions than exist at the cave today. As the outer surface of the flowstone was clearly submerged and re-dissolved by standing waters in the cave after its deposition, it is evident that a major wet phase followed 197,000 B.P.

Two uranium-series ages for the 0.5 m long core (14,520 ± 650 and 5,360 ± 1,390 B.P.) indicate that it was probably deposited in the period c. 15,000 to 2-3,000 B.P. The core preserves evidence of two periods of increased aeolian activity when sand was blown into the southwest entrance of the cave and incorporated into the growing column. The earlier of these events occurred between 14,520 and 5,360 B.P. and the later shortly after 5,360 B.P. Importantly, based on processing of two samples, pollen is preserved in the carbonate of this core and promises the first record of late Glacial and Holocene vegetation changes in the northern Kalahari Desert.

2.2 Echo Cave, South Africa

At Echo Cave annual precipitation is 550 mm coming mainly in the summer months. Active speleothems are few and small. Sediments in the cave indicate major phases of speleothem deposition, and therefore more available moisture, at 227,000, 200-197,000, and > 43-29,000 B.P. Heavily re-dissolved speleothems deposited 227,890 ± 36,067 and 198,764 ± 21,428 B.P., and a wall flowstone dated to 197,102 ± 17,558 B.P., and later buried by clastic sediments, suggest a major phase of surface instability above the cave after c. 197,000 B.P., possibly during isotope stage 6. At lower elevations in the cave there is evidence of a more recent period of clastic sediment deposition that was also accompanied by flooding of passages and re-solution of speleothems. For example, in Ladder Chamber, a wall flowstone that stopped growing c. 31,000 B.P. was later buried by 3 m of laminated sediments, clearly laid down in standing water after being washed into the cave by particularly intense rains (Brook 1982).

2.3 Galweda and Hayla Cave, Somalia

Fifteen speleothems, six from Galweda Cave (rainfall < 50 mm/yr) and nine from Hayla Cave (rainfall 435 mm/yr) have been uranium-series dated along with three relict spring tufas. Ages indicate that deposition of these sediments occurred only during interglacials and interstadials of the last c. 270,000 years, implying that these were times of increased humidity. The absence of speleothems and spring tufas during northern hemisphere glacial maxima implies that these were periods of aridity in the Horn of Africa (Brandt and Brook 1984).

Eight small subsamples from seven Hayla Cave speleothems, ranging in age from 176,500 B.P. to modern, contained a sufficient number of pollen grains for counts of 400-600 grains to be possible. Three of the samples contained extremely large numbers of pollen grains and other microfossils such as cuticles and phytoliths. A most significant preliminary finding is that the pollen in an early Holocene stalagmite dated to 9,995 ± 1,500 B.P. indicates a mesic wooded savanna vegetation at this time similar to vegetation in regions of East Africa today with a precipitation of about 1,000 mm/yr. This implies that early Holocene precipitation at Hayla Cave may have been more than twice the present 435 mm/yr.

In 1985, a 2.5 m deep excavation at the Gogoshiis Qabe granite rock shelter near Bur Hakaba in southern Somalia (Fig. 1) uncovered thirteen individual burials and exposed sediments laid down during the last 30,000 years (Brandt 1988). Textural variations in the sediments at the site reflect the intensity of the chemical weathering environment and the density of the vegetation cover at the time of deposition. Finer sediments were deposited at times of more abundant moisture, more effective chemical weathering, and a denser vegetation cover. It is significant that the evidence for wetter conditions at Gogoshiis Qabe (finer sediments) is supported by the evidence from northern Somalia. Phases of speleothem growth at 11,800, 10,713-9,500, 7,600-6,300, and 5,590-4,020 B.P. at Galweda and Hayla Cave correspond with deposition of finer-grained sediments at Gogoshiis Qabe (Fig. 2). The lack of speleothem deposition at Galweda and Hayla Cave, and the presence of much coarser sediments at Gogoshiis Qabe before c. 12,000 B.P., imply much drier conditions in both northern and southern Somalia in the period c. 30,000-12,000 B.P. although finer sediments at Gogoshiis Qabe c. 21,000 B.P. suggest a brief wet phase during this interval.

2.4 Matupi Cave, Zaire

Matupi Cave is at 1,100 m, on the western shoulder of the Western Rift Valley in northeastern Zaire. Vegetation is species-rich equatorial rain forest, the mean annual temperature is 23°C and annual precipitation is 1,687 mm. Perhaps the most significant finding of our preliminary study of sediments from Matupi Cave is that speleothems in this cave frequently contain abundant microfossils including pollen grains, spores, phytoliths, grass cuticles, and charcoal. Of seven speleothems examined, four of them (MAT 11, 14, 16 and 23) contained sufficient numbers of pollen grains in small subsamples for counts of 400-600 grains to be possible.

Pollen and spores identified in MAT-23, deposited in the time range 14,820 ± 790 to 13,260 ± 520 B.P., and in MAT-16, a modern active stalactite, are presented in Table 1. The presence of Pinus pollen, a twentieth-century introduction to sub-Saharan Africa, confirms that the MAT-16 spectrum is indeed derived from a modern environment.

The late-Pleistocene and modern spectra show remarkable differences. The former is dominated by pollen of grassland plants, whereas these pollen types are relatively scarce in the modern spectrum (e.g., Gramineae, 67.9 vs. 11.9%; Cyperaceae, 10.3 vs. 4.5%). Significant traces of pollen types associated with high-elevation montane environments in eastern Africa are also better-represented in the Pleistocene spectrum: Ericaceae, 3 vs. 0.4%; Lycopodium, 1.1 vs. 0%; Podocarpus, 1.1 vs. 0%. On the other hand, the Pleistocene spectrum is virtually devoid of pollen types associated with the mid-elevation mesic forest characteristic of the site today, including Ficus, (0 vs. 2.2%), Urticaceae-Moraceae-type (0.8 vs. 19.4%), Meliaceae (0 vs. 4.5%), Olea (0.8 vs. 3.7%), and monolete psilate fern spores (0.8 vs. 11.9%). Preliminary examination of pollen and spores in MAT-11, dated to 40,100 ± 3,500 B.P., has revealed Protea, Gramineae, Lycopodium, and Olea as well as graminoid charcoal.

The data for MAT-23 indicate that during the Last Glacial Maximum the vegetation near Matupi Cave was a savanna grassland and that high montane

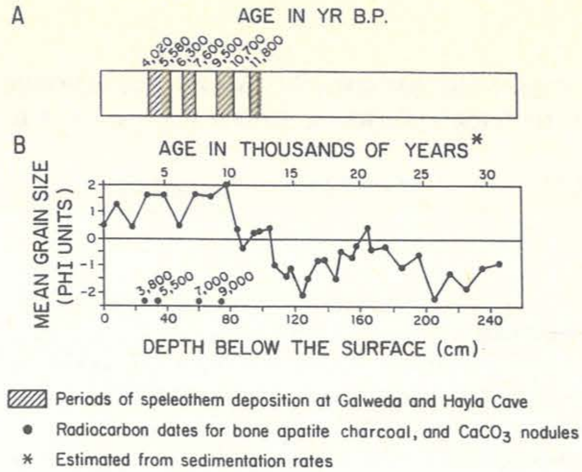

Figure 2. Phases of speleothem deposition at Galweda and Hayla Cave in northern Somalia (A) compared with the mean grain size of sediments at Gogoshiis Qabe rock shelter in southern Somalia (B).

Table 1. Fossil pollen spectra from Matupi speleothems MAT-16 and 23. Taxon frequency expressed as % of all grains counted, excluding crumpled indeterminate category.

TAXON	LATE PLEISTOCENE STALAGMITE	MODERN ACTIVE STALACTITE	CHARACTERISTIC HABITAT G	E	F	M	U	I
Acalypha	0	9.7	X	X	X	X		
Acanthaceae diporate	0	0.4					X	
Acanthaceae prolate	0.8	0					X	
Airoaceae	0	0.4	X	X		X		
Alchornea	0	1.9		X	X			
Ambrosiinae	0.4	0	X					
Antidesma	0	1.1		X	X			
Artemisia	0.4	0	X			X		
Bauhinia	0	0.4		X				
Brachylaena comp.	0.8	0	X	X				
Cadaba	0	0.4	X	X				
Caesalpinoideae comp.	0	0.8					X	
Capparis	0.8	0	X	X				
Celtis	0	5.6		X	X			
Combretaceae-Melastomataceae	1.9	1.9	X	X	X			
Cyperaceae	10.3	4.5	X					
Dorstenia sim.	0	0.4		X	X			
Elaeis guineensis	0	0.4			X			X
Equisetum	0	0.4	X	X				
Ericaceae	3.0	0.4				X		
Euphorbia	0.8	0	X	X				
Fagara	0	0.4		X	X			
Faurea comp.	0.8	0				X		
Ficus	0	2.2		X	X	X		
Gramineae	67.9	11.9	X	X		X		
Helichrysum comp.	0.4	0	X			X		
Hippocratea	0	0.4			X			
Holoptelea	0.8	1.1		X	X			
Hymenocardia comp.	0	0.4	X	X	X			
Julbernardia	0	0.4		X	X			
Liliaceae	0	0.4	X	X	X	X		
Lycopodium	1.1	0	X			X		
Maesa comp.	0.8	1.9		X				
Malvaceae	0.4	0.8	X	X	X			
Meliaceae	0	4.5			X	X		
monolete psilate fern	0.8	11.9		X	X	X		
Myrica	0.4	0				X		
Olea	0.8	3.7	X	X	X	X		
Palmae large monolete	0	0.8					X	
Pandanus	0	0.4		X	X			
Phyllanthus	0.8	0.8		X	X			
Pinus	0	0.8						X
Podocarpus	1.1	0				X		
Polypodiaceae	0	1.1			X	X		
Pteridium sim.	0.8	0	X	X		X		
Salix sim.	0	0.4		X		X		
Salvadoraceae	0	0.4	X	X				
Selaginella	0	2.6			X	X		
Syzygium	0.8	0	X	X	X			
Tapinanthus	0	0.4			X			
Taxodiaceae sim.	0	0.4					X	
trilete echinate	0.4	0					X	
trilete psilate	0.4	0					X	
trilete regulate	0	0.4					X	
trilete verrucate	0.4	0.4					X	
Typha	0.4	0	X					
Urticaceae-Moraceae	0.8	19.4		X	X	X		
unknown	1.5	3.0						
crumpled indeterminate	28.4	32.8						
total number of grains counted	366	399						

G = grassland and open marsh
F = closed-canopy forest
U = affinities uncertain
E = forest edge and riparian woodland
M = montane communities, > 2000 m
I = exotic introductions and indigeneous cultivated plants

vegetation may have existed closer to the site than at present. Moderately warm, dry conditions are indicated for this period. Pollen in MAT-11 suggest a high-elevation montane vegetation near the site c. 40,000 B.P. with temperatures lower than now and at c. 14,000 B.P.; and drier conditions than today (Brook et al. 1989).

3. SUMMARY

Fieldwork at ten caves in Africa in 1982 and 1987 has established that the sediments at these sites preserve evidence of changing environmental conditions. Preliminary studies of selected sediments have demonstrated the antiquity of the sedimentary records preserved indicating that these sediments will provide paleoenvironmental information well beyond the range of the ^{14}C dating method. Most significantly, we have shown that many ancient speleothems contain large numbers of pollen grains and other microfossils, that appear to provide reliable information on vegetation characteristics near the cave at the time of speleothem deposition. We are particularly hopeful that dated speleothems from Matupi Cave in Zaire, and from Lwandani and Chasimba caves in coastal Kenya, will provide evidence about the hypothesized tropical rain forest refugia that may have existed at or close to these sites during late Pleistocene glaciations (Fig. 1). Pollen preserved in cave speleothems may also provide paleovegetation data for arid and semiarid regions where lake, spring, and bog sites with good pollen preservation are rare.

ACKNOWLEDGEMENTS

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WEATHERING STUDIES ON PSEUDOKARST-CAVES ALONG THE NORTHERN SWEDISH COAST

SJOBERG, Rabbe

1. INTRODUCTION.

The Schmidt Test-hammer, also known as an impact hammer or sclerometer, measures the distance of rebound of a controlled impact on a rock-surface. The distance of rebound (R) gives a relative measure of surface hardness or strength. The Schmidt hammer is light and portable and allows *in situ* tests to be made in the field. It is also relatively cheap and has proved to be robust during extensive trials in vaiable conditions. With a test hammer large numbers of samples can be tested in a small area in a short period of time (Day & Goudie, 1977). McCarroll (1987) has studied the instrument error, explained the sources of the error and made suggestions to minimize their effects. The most important of which is a regular calibration of the instrument.

The Schmidt Test-hammer has been used by geomorphologists for more than 20 years. The first published paper seems to be by Monroe (1966), who used the test-hammer to study case-hardening in Puerto Rico and in Indonesia. Yaalon & Singer (1974) used the hammer to study calcrete-crusts (Nari) in Israel. However, the most extensive field-studies with the instrument has been done by Matthews & Shakesby (1984), who used the instrument in conjunction with lichenometry to examine the relative age of the outermost Neoglacial moraines in front of glaciers in the Jotunheimen mountains in southern Norway (Matthews & Shakesby, 1984). They concluded that "This first application of the Schmidt hammer to glacial chronological problems suggest considerable potential for the instrument in the differentiation of the ages of Holocene deposits,particularly when applied in conjunction with other relative-age dating techniques, such as lichenometry".

In 1985 the Center for Arctic Cultural Reseach initiated a broadbased study of prehistoric and historic seal hunting cultures in the Bothnian region. One of the main goal of the project has been to date sites and features from the Late Iron Age and the Medieval period, about 1500 to 500 BP. Unfortunately many coastal sites from this period are found on rocky islands and shores and consist solely of boulder and cobble constructions. For this reason the potential of lichenometry in archaeology was investigated (Broadbent & Bergqvist,1986; Broadbent, 1987). As the growth of the lichens also is dependent on the weathering of rock, attempts have been made to measure the weathering through quantifiable methods. The Schmidt Test-hammer was used for this pupose (Sjöberg, 1987;1988;1989). Parallell to this project the present author also tested the hammer to try to solve different problems in pseudokarst research. This paper presents some of the results of this research.

1. Around the Swedish rocky shores, up to the highest post-glacial shore-level, there are a number of secondary round-abraded isostatically raised crevice caves which have been studied by the author (Sjöberg, 1981; 1986; 1987). Even those caves which are now situated high above the present sea-level have as perfectly polished surfaces as those caves situated at, or around, the present sea-level. Is this seemingly non-existent weathering a fact or just ilusionary?

2. It has been suggested that several of the boulder-caves in Sweden, Bodagrottorna, Gillberga gryt, and Rövarklippan at Nordingrå, etc., were formed by earthquakes during the melting of the Weichselian glaciation about 10.000 years B.P., when the caves were situated more than 100 m below the surface of the Baltic sea (Sjöberg, 1987a). Could this neotectonical formation be confirmed by using the Schmidt hammer technique? What about caves of similar type situated above the highest post-glacial shore-lines?

1.2. Method.

The research-method is built on statistical calculations. On each site, tested by the Schmidt hammer, a minimum of seven inpacts are done. The statistical mean and the standard deviation are calculated. These values are compared to a weathering regression-line from a nearby rocky shore, with the same type of bedrock. This regression line is constructed as follows: the weathering is tested, with the Schmidt hammer, level by level, and the means for these levels are correlated with the elevation above sea-level. On a isostatically raised coast each level above the present sea-level represents a specific time B.P.(Mörner, 1979; e.a.). By correlating the weathering value (R) with elevation (m.a.s.l.) the correlation-equation, and the correlation coefficient for the equation, are calculated.

2. RESULTS.

2.1. Tunnelcaves at Lidberget, Nordmaling, N. Sweden.

Three small raised tunnelcaves, Stora Lidbergsgrottan, cave nr. 9, and cave nr. 10, at the Nature Reserve "Lidbergsgrottorna" in Nordmaling, N. Sweden, were investigated by testing the walls of the horizontal caves from the entrance to the inner parts (Sjöberg, 1987). The caves are situated at an elevation of around 100 m a.s.l. This investigation showed that the R-values increased toward the inner parts of the caves, fig. 1. This might be due to the fact, that even in caves as small as these, a local climate is formed which protects the caves against chemical weathering.

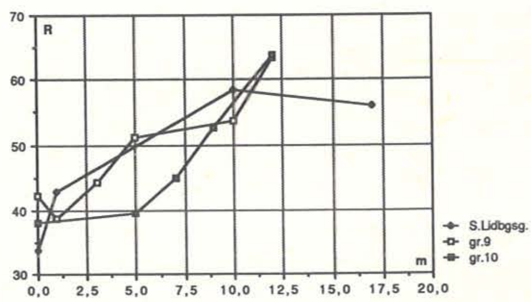

Fig. 1. Diagram showing the R-values inside three caves at Lidberget, N Sweden. It can clearly be seen that the R-values increase toward the interior of the caves, which indicates a lower rate of weathering .

In the inner parts of the caves the R-values are above 60. What does that mean? To answer this question the weathering of a nearby rocky shore, formed by the same bedrock, was tested from sea-level up to 41 m a.s.l., which, with an isostacy of 0.9 cm per year, covers weathering of the bedrock during the last 4.000 years. This weathering is described by a regression-equation, with a correlation-coefficient of R_{xy}= 0.92, fig. 2. Figure 2 shows that R-values around 60 >

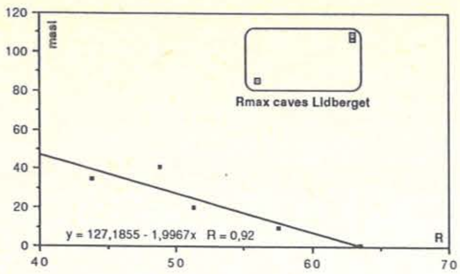

Fig. 2. The highest (inner) R-value in three caves at Lidberget, compared to a weathering regression line on bedrock at Stavarehalla, 5 km S of the caves.

correspond to values on bedrock from around 10 m a.s.l. and downword on the weathering-curve. This shows that the caves, even though they are situated at 100 m a.s.l., have been protected against weathering. During the last 7 000 years, which is the time that has elapsed since the caves were elevated above sea-level, the inner parts of the caves have not weathered more than the sea-cliff, of similar bedrock, which have weathered no more than a 1000 years.

How generally applicable are these results? To answer this question another 10 caves in different parts of the Bothnian coast were tested. The data for elevation, length and R-values in the outer(Rmin) and inner parts of the caves (Rmax) are given in table 1.

Table 1. Tunnelcaves in the county of Ångermanland.

Cave	m.a.s.l.	length	Rmin	Rmax
S Lidbergsgrottan	85	23	42.9	58.4
Lidberget c.9	107	8	38.0	63.4
Lidberget c.10	107	10	43.0	63.8
Tjuvantes grotta	90	25	34.6	62.1
Räckebergskyrkan	180	34	41.7	46.3[1]
L. Räckebergskyrkan	180	22	43.8	64.8
Södra grottan, Ulvön	5	8	55.3	63.7
Norra grottan, Ulvön	2	14	59.0	65.0
Härnöklubb 10	11	20	50.6	58.2
Härnöklubb 11	10	15	48.9	62.7
Härnöklubb 11a	10	5	48.9	60.0
Härnöklubb 14	0	10	59.1	60.4
Härnöklubb 15	1	14	50.9	52.3

[1] the roof within the inner parts of the cave is open.

On fig. 3 the big difference between Rmax and Rmin is seen. This difference is also independant of elevation. As most of the caves are formed in gneissic granites/sediment gneisses the values from table 1 has also been compared with a weathering regression line. This is the one from Stavarhalla, described above.

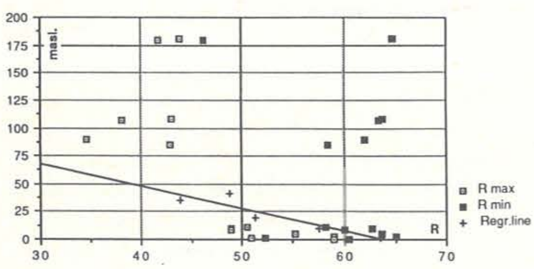

Fig. 3. Diagram showing the lowest (external) and highest (internal) R-values from 12 elevated sea-caves in the province of Ångermanland, compared to the weathering-regression line from Stavarhalla in the northern part of the province.

The diagram, fig. 3, indicates in accordence with the variables, m.a.s.l., Rmax and Rmin, that local climatological conditions in the inner parts of the caves protected these parts against weathering and that they are independent of the elevation above sea-level. Rmax values from the higher elevated caves do not differ much from those in the lower elevated caves. It can also be seen that the Rmin values in the lower elevated caves have values similar to Rmax values in the higher elevated caves. To further test the connection a three-dimensional graph was constructed from the values of table 1, were X= depth of the cave, Y= elevation, and Z= R-value, fig. 4.

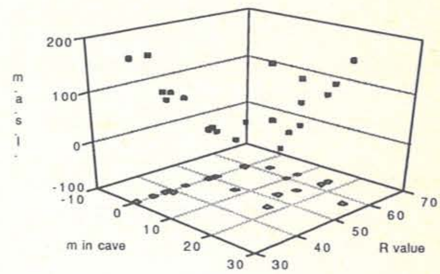

Fig. 4. Three-dimensional graph showing the altitude, the lenghts and the R-values from the external and internal parts of the caves in table 1.

From the graph it can be seen that elevation is an independent factor in reference to the R-values inside the caves. The dependent factor seems to be the depth of the cave. As the reseached caves are formed in different bedrocks, such as sediment-gneiss and dolerite, the connection also seems to be independent to the type of bedrock. To further develop this problem speleoclimatological research has to be done. However, a previous study (Sjöberg, 1975) has shown, that immediately inside the entrances of small caves, there exists a different climatological situation, than which exists outside the caves.

2.2. The cave Bodagrottorna, Iggesund, N. Sweden.

The cave Bodagrottorna is a neotectonically formed cave-system in a small hill of gneiss-granite, reaching up to 35 m. a.s.l. The cave-system, which is the longest pseudokarst cave in Sweden, with a length of more than 2600 m, is situated at the coast near the village of Iggesund in N. Sweden.

In this case neotectonics means fairly huge earth-quakes, caused by a very fast isostatic uplift, which appeared below the margins of the ice at the end of the Weichselian glaciation. During that stage, the *roches moutonnées* in which the cave was formed were still situated far below the surface of the sea. The formation of the cave is described by Sjöberg (1987a).

If the hypothesis of the subglacial formation is correct, all sides of the huge cave forming boulders released by the earth-quake ought to show similar weathering values corresponding to the weathering which has taken place since the hill was elevated above sea-level. To investigate this five boulders on the 30 m level were tested on the striated upper side and on the lateral sides. Only boulders with a clear striated upper side were chosen. As the lateral sides of the boulders were exposed to different quarters, a certain difference in the R-values was expected, depending on local-climatological situations. The results of this study is shown in table 2.

Table 2. Bodagrottorna.
R-values on upper-, and lateral sides of five tested boulders.

Boulder	upper side	N side	S side
1	43.1	48.8	-
2	42.6	50.2	-
3	45.6	47.1	51.0
4	44.8	42.1	47.3
5	41.4	44.0	42.1
Rect. mean	46.2	46.3	46.5

The results show that the expected variance between the R-values of the lateral-sides of the boulders did not occure. Instead a clear similarity between the upper- and lateral sides is shown, after that the values are rectified to the angle of impact. The values in table 2 have been plotted in fig. 5, where a romboid symbol shows the values of the upper sides of the boulders, and a black square symbol shows the values of the lateral sides.

To test the hypothesis that the weathering on the upper and lateral sides of the boulders should corresponded to the expected R-value of the 30 m level, a couple of weathering regression lines from adjacent localities were used. These were taken from a bedrock cliff and a raised boulder beach, both at Hornslandet, 15 kms E of the cave. Hypothetically, the values from Bodagrottorna should correspond to a value for the 30 m level at the bedrock locality, or with the 30 m value at the boulderfield. The results of this investigation are shown in fig. 5. Here it is shown that the values from the Bodagrottorna do not correspond to the 30 m level on the weathering regression lines, but rather to a level of 7 - 12 m.a.s.l. The reason for this might be that the bedrock at Bodagrottorna differ more from the one at Hornslandet than a visual examination of the bedrock indicates. Another explanation could be that the localities at Hornslandet are situated in a more exposed position, whilst the cave Bodagrottorna has for a long time been situated in the inner part of a protected bay. The difference in exposion can be the cause of the different weathering conditions.

Another minor study was done on a well rounded erratic, situated on the crevice-rich upper part of the hill. The situation of the boulder speaks against its deposition by a melting glacier, but for its dropping from the bottom of an iceberg, after that the hill had been split by an earthquake. The following R-values were noted from the erratic: upper-side R= 32.3, northern side R= 34.0, and southern side R= 37.4. These values show that the boulder, in spite of its roundness, and like the cave-boulders, has higher values on its upper side, compared to the value on its lateral sides. The values are more in accordance with the values from the similar level at Hornslandet, fig. 5. However, it is possible that the proportionately low R-values on the erratic show that the R-values on the boulder do not only depend on postglacial terrestric weathering. The well rounded form of the erratic indicates that the boulder might have been a core-stone, removed in its existing scape by the glacier.

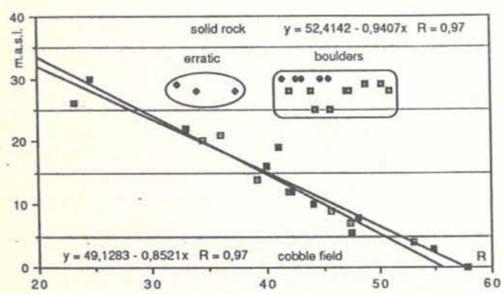

Fig 5. Graph showing the R-values from upper-, and lateral sides of surface boulders at the Bodagrottorna, and R-values from an adjacent erratic. These values are compared to the w eathering regression lines from a bedrock and a cobble-field at Hornslandet.

2.3. The cave Rövarklippan, Nordingrå, N. Sweden.

This cave is also formed by neotectonics. It is situated on the southern side of a steep hill, formed as a *roches moutonnées*. The hill is 68 m high, and the base-level for the cave is 47 m.a.s.l. The cave, which consists of several big rooms and passages between gigantic boulders, was formed when the southern escarpment of the hill collapsed do to a severe earthquake. Did this earthquake occur at the same period of time as the one described above, when the hill was situated deep below the present level of the sea? If this was the case, hypothetically the R-values from the outer part of the cleft, which divides the cave forming boulders from the mother-cliff, ought to be equivalent to the ones on bedrock outside the cave (with minor differences dependent on local climatic conditions).

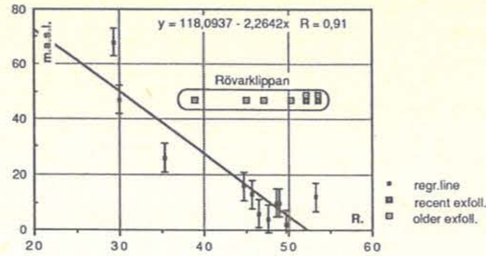

Fig. 6. R-values from the inner crevice at the cave Rövarklippan, compared to a weathering regression line for the area. Two R-values for a recent exfolliation are marked with a black square-symbol.

Harness-surfaces on recently, by frost-wedging, exfolliated boulders would also be able to differentiate from those contemporaneous with the cave, by higher R-values than normal for the level.

Firstly, a weathering regression line was constructed from sea-level up to the top of the hill, fig. 6. This line has a very high correlation coefficient R_{xy}= 0.91. Secondly, the R-values from the big cleft which divides the boulders from the mother-cliff was tested. In the outer, western part of this cleft, the surface of a seemingly recent rockfall gave very high values (R= 52.1). Correspondent harness-surface on the mother-rock had the value R=53.5. These values corresponds to R-values for levels below 2 m.a.s.l., showing that these boulders were released about 200 years ago, calculated on an isostatic uplift of 0.85 cm per year. In the outer part of the big cleft a value of R=47.1 was measured on the bedrock, and R=50.4 on the boulder. Further into the crevice the R-values went down to R=38.9 on boulder and R= 44.9 on bedrock. Considering local climatological conditions these values are somewhat higher than expected for the level, fig. 6. R-values around 40 correpond to a level around 30 m.a.s.l.; this could indicate that the earthquake which formed the cave appeared some 3-4000 years ago according to the shore displacement curve for the area (Miller, 1982).

This shows that the cave could not have been formed during the period when neotectonic activity normally was to be expected, namely 10.000 years ago, when these parts of Sweden presumely had an isostatic uplift reaching rates of 20-50 cm per year (Sjöberg, 1987a). Instead, the cave seems to have been formed by an eartquake when the hill already had been raised to a terrester environment. This earthquake ought to have had a magnitude of around 7 on the Richter scale, which is considerably higher than those of contemporaneous earthquakes in the area.

5.4. The cave Vitterhuset, Åsele, N. Sweden.

This cave is formed by gigantic rocks on the southern side of a *roches moutonnée* like hill in Revsund-granite, around 305 m above sea-level, in the inner parts of northern. The elevation is clearly above the local highest post-glacial shore-line. With an ice-movement from NW, during the Weichselian glaciation, the cave is situated on the lea-side of the hill. The cave forming rocks have one, or several, smooth harness-surfaces, showing that the rocks have been broken from the mother-rock, and that this breaking-up has occured along former joints in the bedrock. The question is wither the breaking-up of the rocks was formed by glacigen forces or by neotectonics.

On the horisontal crest of the hill a R-value of 28.3 was measured. This is so far the lowest R-value measured on bedrock. The very fast weathering of the Revsund-granite was also shown by recent grus-weathering close to the tested surface. In the cave two opposite vertical surfaces were tested. One on a bedrock surface exposed to the south (R=44.2), the other on a smooth, vertical rock-surface exposed to the north (R=52.7).

The situation of the cave, on the lea-side of a glacigene *roches moutonnée*, would indicate a glacigen formation of the cave. The high R-values in the cave, especially the one on the exposed northern wall, compared to the low R-value on the crest indicates, that the cave was formed after the deglaciation of the area. Thus, the cave was most likely formed by neotectonics.

3. Conclusion.

The Schmidt test-hammer, originally constructed to measure the quality of concrete, has been used and proved to be useful for applied speleological reseach. The method is shown to be very useful as a relative dating technique, when comparable *before* and/or *after* data are available. The Bothnian Sea region, with its thoroughly studied postglacial isostatic uplift, has given almost laboratory-like circumstanses for this study.

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SEVERAL REMARKS ON THE PROTECTION OF KARST BASED ON EXPERIENCE GAINED BY THE SLOVAK SPELEOLOGICAL SOCIETY

GAÁL, Ludovit

In the last years the extraordinary importance of caves, and the crucial importante of preserving them, was referred to by many authors in the framework of UIS congresses and also in the many speleological bulletines. At the same time an emphasis was laid on the intricacy and uniqueness of the subject. Karst regions constitute a very unstable geosystem exceptionally sensitive to external influences. In this highly organized geosystem a very important role is played by caves which are to a considerable degree dependent on the processes taking place on the surface /e.g. changes in vegetation, in the chemical composition of earth and air, water circulation etc./. Due to natural or manmade changes on the surface the shape of underground routes can be altered as well as the general outline of the cave decoration and kinds of contents: microclimate, biosphere, etc. Caves help a rapid flow of karst water with a minimum of filtration but the karst region, the microclimate and low level of fauna found there allow for a slow rate of decay of organic substances. From this it follows that there is a firm link between the processes going on on the surface and those under the earth with which it can prove very dangerous to interfere. We should consider carefully ways of protection and conservation when deciding for which purpose the cave is to be used /e.g. scientific, instructional, aesthetic, recreational, economic and others/. As a majority of visitors to caves are speleologists it is of crucial importance to get a wide strata of the speleologic public involved in the protection of karst, and especially of the caves themselves. It is necessary not only to conserve the value of caves by speleologists, but as a start it is necessary to obtain and process in an appropriate way the information provided by them concerning the conditions found in the caves. A lot of valuable information on pollution found in caves and abysses is being lost. Because of this the Committee of the Slovak Speleological Society for the protection of karst produced forms which are to be used by speleologists to report on negative conditions found in karst regions. These completed forms are collected, processed and if need be passed on to the authorities, bodies conserved with nature conservation or water supplies administration. The most frequently reported sources of pollution is by agricultural waste /fertilizers or other similar activities dealing with agriculture/. Less frequently is that waste produced by industrial and the human population. Also the damage inflicted upon the decoration of caves is caused by tourism, followed by that due to the excavation of raw materials and to an insensitive approach when opening up the caves to public view. A few cases of increased corrosion to stalagmite and stalactite decoration due to the pollution of karst waters or air /especially by sulphates/ pose a very difficult problem to solve. A variation of approaches to the protection of caves according to their value is also needed. In order to recognize the natural, cultural and the historical value of caves a thorough course of reserach is required with the required protective action given according to the results. Specialists in many scientific fields are to be involved. In order to process the data on the values of caves the Committee of the Slovak Speleological Society for the protection of karst produced in 1986 a questionaire in which regional groups of the Society recorded all important caves. Their value was judged by the occurence of decoration, geological or geomorphological shapes, paleonthological and archeological findings along with those rare animals. Once the value of the conditions found in the caves had been assesed the best method of protection could then be followed, e.g. by closing the entrance. The list of important caves is being updated each year. As a result out of 2678 caves now investigated in Slovakia, 200 caves /7,4 %/ with natural and cultural value were registered by the 31st December 1988. From this number 27 caves were chosen to become known as a protected natural creation. In their selection not only was the existence /and other values caves/ taken into account but also the threat posed to the caves and their representation of a particular geographical region were considered. A special regime for the protection for caves with exceptional scientific and cultural value is being produced.

Cosing the entrance to caves is still the most widespread and simplest way of protection. Out of 200 registered caves of importante in Slovakia 90 are at present closed. Sadly in the most touristic areas there are frequent cases of the breaking down of the closing barrier.

Irrespective of these cases of vandalism the greatest amount of interference to the internal conditions of caves is due to ignorance and the lack of information. Because of this we consider it to be of crucial importance to support education through information, along with the supervision aimed specially at the managers of enterprises /who deal with the karst regions/ along with the public. Speleologists must also be included in this. In the area of speleological research we are firstly concerned with conservation of sediments valuable for their stratigraphic and archaeological information /the services of specialists are often needed for this/. The Committee of SSS for the karst protection gave guide-lines for the carrying out of the speleological research in the important caves, the use of which the speleologists are guided when precious findings occur.

From the above one realizes that the problems of cave conservation is still with us. It is necessary to make use of all worldwide and national speleological activities to promote the idea of karst protection, especially for the need to preserve the scientific and cultural values of karst regions and caves as well as the halting of the contamination of underground spaces by all polluting substances.

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SNOW AND ICE FORMATIONS IN CAVES AND THER REGIME

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1. SNOW AND ICE FORMATIONS (SIF) IN CAVES

1.1. Position of cave SIF in natural ice system

Cave ice - specific class of natural ice, that have different origin but common place of existece - caverns, connected with surface and atmosphere. Cave ice is intermediate class of ice arranged between the surface and grownd ice. Cave environments can be favourable for forming of Hydrospheric, surface and grownd ice.

1.2. Classification of cave SIF

Hierarchic classification of cave SIF (modified from V.E. Dmitriev, 1980) and specific classifications of different groopes of cave SIF is proposed (Fig. 1, 2). We will not describe different forms of cave SIF since they are occur in many publications beginning from R.G. Brown (1865) and others. But one point has to be mentioned is that congelation ice advantage formed in horizontal and inclined caves, sedimental ice - in inclined and vertical caves, metamorphic ice - in vertical caves, sublimation ice (in meteorological meaning) can be formed in all kinds of caverns.

1.3. Chemical composition of cave SIF

Chemical composition of cave SIF depends from chemistry of water and reflects environment conditions, where this water forms. Cave SIF can be divided into: fresh (to 1.0 g/l), soline (1.0 - 5.0 g/l) and salty (more 5.0 g/l). Congelation ice can be belong to every of these types. Sediment-metamorphic ice can be fresh and soline; sublimation ice can be only fresh.

1.4. Age of cave SIF

We will concern with perennial cave SIF only. Usually cave SIF is not older than some tens years, but there are caves, in which ice more older (outside the zone of permafrost). In Dobshinska Cave (ČSSR) age of lowest layes of ice was estimated in 5000 years (Droppa, 1964); in horizontal Kungurskaja Cave (The Urals) there is ice older then 100 years (Lukin, 1965); in abyss Snezhnaja (The Caucasus) age of SIF is not less then 500 years (Mav-

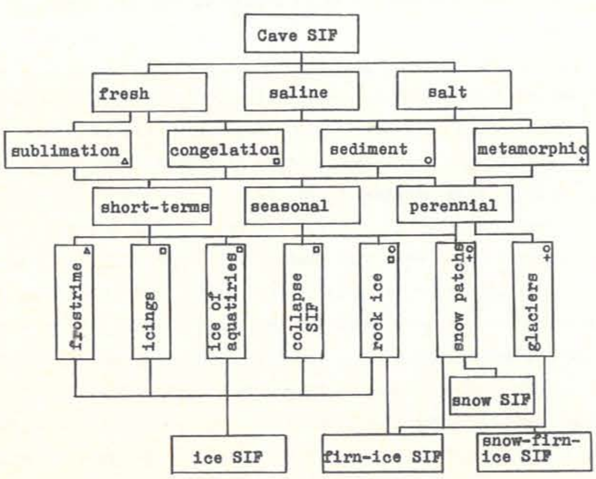

Figure 1. Classification of cave SIF

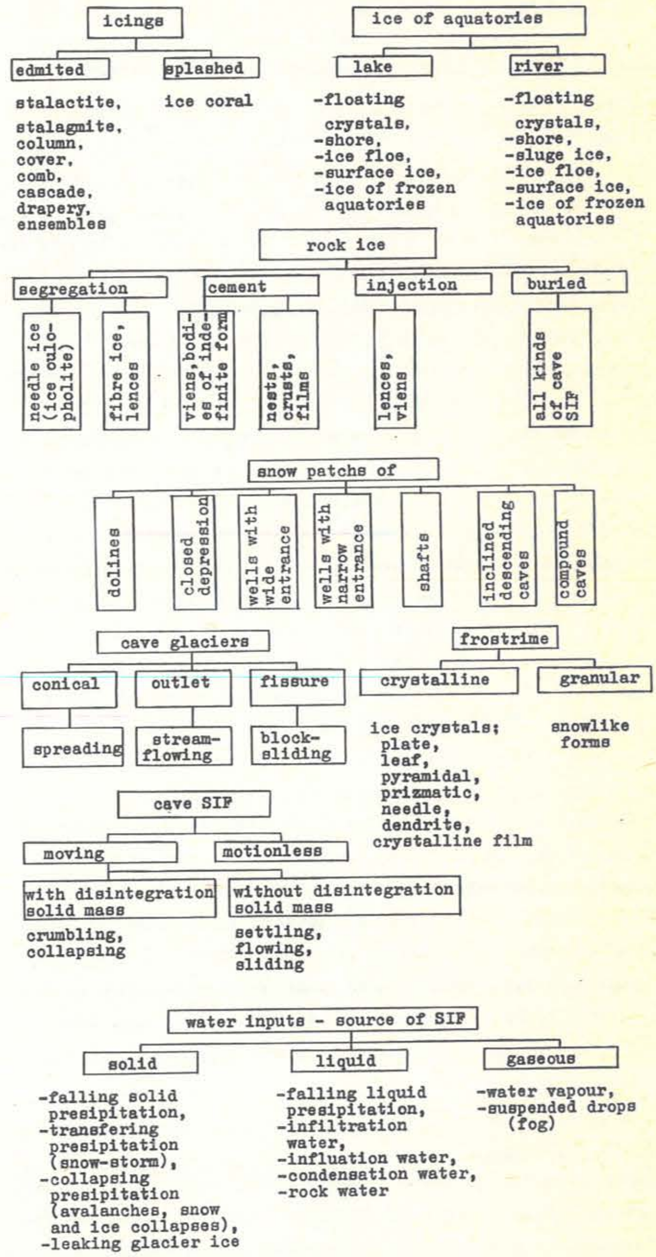

Figure 2. Specific classifications of cave SIF and their sources

lyudov, 1980). On base of pollen-spores analisis relict stratum of ice in Cave Nachodka (Kuznetskiy Alatau) was dated as holocen-late plejstocen (Dmitriev, 1979). P.W. Marshall (1981) suggests, that nature of ice in caves can be determined, if one finds caves with ice formed in our time. For example, Kichmenskaja Cave (The Urals) was exposed by collapsing of cavern roof in 1950 (Ginin, 1963), so age of the cave glaciation is not more then 40 years. Generally SIF age in caves depends both from position of cave and of ice in cave, and from conditions of ice accumulation and preservation. Best conditions of ice preservation exists in caves in permafrost.

2. REGIME OF CAVE SIF

Regime of cave SIF is studied very poorly. It depends from climate variations in caverns and can be described as a complex of processes mainly on the surface of SIF. The most importent processes are accumulation and ablation of SIF.

2.1. Accumulation of cave SIF

Accumulation of cave SIF dependes from the shape of cavern, which determined: 1)size and charecter of water inflows; 2)value of cold content. If solid water get into caverns sedimental ice forms, if liqid water flow into caverns congelation ice forms, and water vapour is a source of sublimation ice. Ice accumulation in caverns in permafrost depends only from volume of water input in caves. If water input in caves is too large it leed to filling in them by ice completely.

2.1.1. Accumulation of congelation ice in caves

Regularities of congelate ice accumulation in caves is not studied yet. Thus we will use the data on freezing of ice outside caves. Average intencity of ice freezing is about 1.0 g/cm^2 on one degree of negative average day air temperature (Hodakov,1978). From this data we can estimate possible potential quantity of freezing ice in caves. In reality quantuty of freezing ice in caves will be smaller and will depend mainly from water input. For example, in Kungurskaja Cave only about 1 per cent from potential possible quantity of ice forms taking into account cold content (Lukin, 1965). In horizontal caves maximum of water input connect with fissure on ceiling of galleries, and there are maximum of accumulation of congelation ice. In inclined caves main water input connect to cave entrance, therefore quantity of accumulated ice in them decreace from entrance to the end of cavern.

2.1.2. Accumulation of sedimetal ice in caves

Sedimental ice formed mainly in vertical caverns. Quantity of these SIF depends from snow concentration in caverns (normal and snow-storm). Normal snow concentration dependes from shape and size of wells entrances and determined by engle of natural slope of snow at the edge of wells entrances (Mavlyudov, Vturin, 1988). Normal snow concentration coefficient can be more then 4 in fissure well, when snow depth is about 2 m on the surface. Snow-storm cncentration in wells can be on the forestless areas and depends from direction and velocity of wind and from position of cave in relief. For Bzibskiy mountain ridge (The Caucasus) at altitude about 2000 m snow-storm concentration coefficient is estimated about 1.4 (Mavlyudov, Vturin, 1988), but for caves of Kuznetskiy Alatau it reachs 16 (Dmitriev, Chuikov, 1982). For The Caucasus low boundary of snow accumulation in wells be considered near level of local forest limit and below it snow-storm concentration is absent. Upper boundary of snow accumulation in wells connected with local snow line, higher than that level snow will fill in all vertical caverns.

2.1.3. Accumulation of sublimation ice in caves

Accumulation of sublimation ice in caves depends on degree of supersaturation of air by moisture, quantity and velocity of moisture inflow into freezing caverns. Sublimation ice in caves is frostrime. The main forms of ice are: gexagonal-pyramidal and rectanglar-prizmatic skeleton crystals. Because of lack of observations ice sublimatin in caves, we have to use data on growth of atmospheric ice. It's maximum growth intensity was recorded at air temperature about -5°C (Harris-Hobbs, 1987), this air temperature is usually observed in caves with ice in temperate climate regions in winter time. There are next to nothing measurments of ice sublimation intensity in caves, but from available data maximum intensity is 0,17 mm/day (in water layer) in Kungurskaja Cave (The Urals) in Febriary 1985.

2.2. Ablation of cave SIF

Ablation of cave SIF consists from melting and ice evaporation It is determined by heat balance of surface of SIF, which is sum of heat flow from air, from ice and from phase changes of water.

2.2.1. Melting of cave SIF

Intensity of SIF melting in caves does not depend from: 1)altitude and latitude of region, where cavern is situated; 2)shape of caves, but depended from temperature and less from moisture of cave air. Compatible influence of cave air temperature and moisture on melting of SIF is calculated from air equivalent temperature: $T_e = T + 1.5(e - 6,11)$, (Puzanov, 1956), where T - cave air temperature, e - water vapour pressure. Study of SIF melting in caves of the Urals, the Caucasus, the Pamirs shows that melting rate is equal: $A = 0.15 + 0.64\ T_e$ or $A = 0.24 + 0.81\ T$ in mm/day (Mavlyudov, 1988). For inclined and vertical caverns we can estimate year melting of SIF: $\Sigma A = (0.15 + 0.64\ T_e)(1 - K)365$ or $\Sigma A = (0.24 + 0.81\ T)(1 - K)365$ im mm in water layer, where K - temperature index of cave glaciation (look at B.R. Mavlyudov "Cave glaciation" in this book). It is observed that low wind velocity (up to 2 m in second) weakly influence on SIF melting in caves.

2.2.2. Evaporation of cave SIF

Evaporation of cave SIF depends from air moisture deficit and wind velocity in caverns. Investigations in caves of the Urals, the Pamirs, the Caucasus and north of Russian Plain shows that evaporation intensity in caves without wind can be calculated from: $E = 0.02d$ in mm/day in water layer, where d - air moisture deficit in millibars. Evaporation intensity of SIF in caves was studied for wind velosity not more 1.0 m in second.

2.2.3. Mass balance of cave SIF

Mass balance of cave SIF can be: 1)negative; 2)zero; 3)positive. If total mass balance of cave SIF is zero , SIF are seasonal or perennial constant. If SIF mass balance is negative, SIF are perennial decrease, if it is positive, SIF are perennial increase. In areas outside permafrost in cav3s with perennial SIF there are 3 zones: near entrance zone and distant zone with zero SIF mass balance and middle zone with positive balance. In inclined and vertical caverns distant zones can be absent because they have little length. In some caves we have opportunity estimate SIF specific mass balance: in horizontal: in Kungurskaja Cave - $-1.5\ g/cm^2$; in inclined: in Schvava Cave (The Caucasus) - $+16\ g/cm^2$; in Askinskaja Cave (The Urals) - $+2.0\ g/cm^2$; in vertical: in abyss Snezhnaja (The Caucasus) - $+0.8\ g/cm^2$. Difference between SIF specific mass balance in two inclined caves we can explain by different moisture conditions of the Urals and Caucasus. Negative SIF specific mass balance in Kungurskaja Cave is reflecting anthropogenic changing of cavern ventilation regime and is showing that cave glaciation decreases. Analisis of SIF strata thickness structure shows that SIF mass balance in caves can markedly oscillate from year to year and sometimes it change a sign. But general trends of oscillations of SIF mass balance as in caves and in group of caves of one country will be probably common. SIF ablation in caves is stable enough and wearly depends from oscillation of external conditions comparing with SIF accumulation. Thus SIF mass balance in caves mainly depends from accumulation. SIF accumulation mainly indicates the variation of moisture conditions outside the caves and in less degree change of temperature. In general SIF mass balance will depend from regional moisture conditions (if the shape of cave is constant). SIF mass balance in some zone of caves (for example, in Kungurskaja Cave) is found to be negative for many years. Therefore SIF mass balance of these zones in caves must be calculated not for one year but for longer time period.

3. CONCLUSION

Unlike other groups of cave sediments, SIF are climatic dependent, therefore they change their shape and structure very rapidly (as regards to other groups of cave sediments) during the time and in space. SIF forms abundance in caves depends on difference of natural situation existing in caves and by quantity of water that feeds caverns. Conditions of cave SIF existing definitly distinguish from conditions of surface and grownd ice existing that allow to take new speleological and glaciological information by investigation of cave SIF.

Knowledge of regularities of SIF accumulation and ablation in caves allows in very near future to investigate the question about precipitation outside caves during long period.

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CAVE GLACIATION

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1. INTRODUCTION

Cave glaciation is complex of interacting processes and phenomenons resulted in existing of snow and ice in caverns. Cave glaciation is pourly known, in spite of abundant publications dealing with ice in caves and cave with ice (Listov, 1885; Balch, 1900; Kruber, 1915 and many other). In these publications authors examine causes and conditions of cold accumulation in caves, ice accumulation forms, in some publications - structure and texture of ice, and more rarely - evolution and age of ice. Few publications concerned with regime of ice in caves and distribution of these caverns.

2. CAUSES AND CONDITIONS OF CAVE GLACIATION

Main features of cave glaciation are cave walls freezing and solid water existing in caves. Existing of caverns is necessary for cave glaciatin. These caverns can be artificial and natural. Natural caverns can have karstic, pseudokarstic, tectonic and eolic origin. Glaciation occur in caverns of vadoze stage of development characterised by mature state, i.e. without lardge water inflows.

2.1. General prerequisites of cave glaciation

These prerequisites are: 1)climatic (external air temperature must be negative during some period of year); 2)microclimatic (cave air temperature must be negative during some period of year); 3)hydrological (water must inflow in caverns).

2.2. Conditions of cave glaciation

Two groups of conditions are distinguished: general and second order. General conditions are: 1)favourable combination of air and rock massif temperature; 2)spesific cavern form; 3)presence of cold content; 4)presence of water inflows.

2.2.1. Combination of air and rock massif temperatures

Cave glaciation can developed in all kind of caverns in frozen rocks. If temperature of rock massif is positive cave glaciation can be only in definite external conditions, which can characterized by temperature index (K), which connected with average January air temperature (T_j) and rock massif temperature (T_m): $K = -T_j/(T_m - T_j)$, (Mavlyudov, 1988). T_m can be expressed by average year temperature of surrounded area (T_o): $T_m = T_o + a$, where a - additional member. For many caves of West Europe a = 0; for weak watered caves of the USSR a is usually from 2 to 6°C (Frolov, 1976). Index K shows degree of possible cooling of rock massifs by cold winter air penetrating through caverns. The greater is K the higher is caverns cooling. Cave glaciations can existes only where K 0, and if K 0,25 glaciation can be perennial.

2.2.2. Favourable cave form

Possibility of cave glaciatin in permafrost areas does not depend from forms of caverns. Perennial glaciatin in non permafrost areas can be developed in caverns of following forms: 1)horizontal, with entrences at different levels; 2)inclined descending (cold bag); 3)vertical (fig. 1) and compound. In all these caves negative anomaly of temperature can be formed (fig. 2), in which average annual air temperature is below of rock massif temperature.

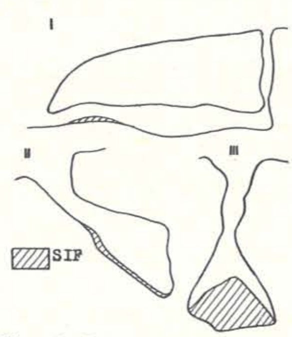

Fig. 1. Caverns with glaciation

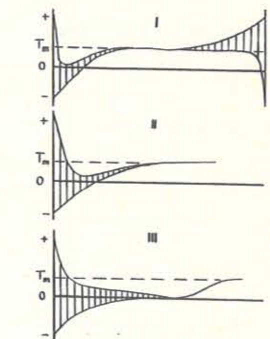

Fig. 2. Amplitude of temperature oscillations in caves with SIF: I - horizontal; II - inclined; III - vertical

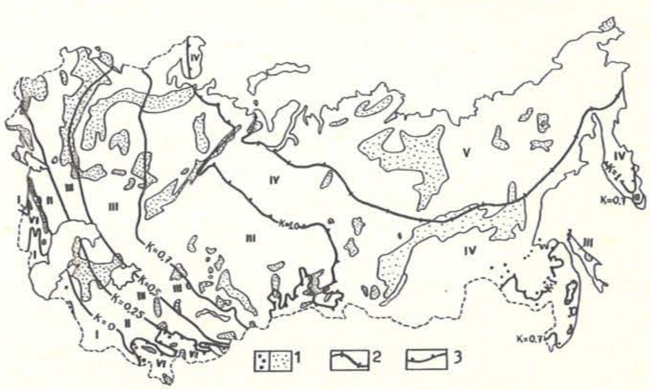

Figure 3. Map "The USSR cave glaciation". Cave glaciation: I-absent; II-seasonal; VI-seasonal and perennial of separate mountain caves. Perennial glaciation of caves: III-separate; IV-majority; V-all; 1 - karst rocks. Permafrost boundaries: 2 - continuous; 3 - discontinuous and sporadic. Boundaries of cave glaciation: K = 0.7 - perennial glaciation of horizontal caves; K = 0.25 - perennial glaciation of inclined caves.

2.2.3. Accumulation of cold content

Cold content in caverns is equivalent to the amount of heat, which is necessary to return the thermal conditions of cave in initial state before cooling, when air and rock massif temperatures are equal. For origin of cave glaciation is necessary the air and rock temperatures in caverns fall below zero. Cold content in caves accumulates as cold of frozen walls and snow-ice formations (SIF). In northen areas cold content accumulates mainly as cold of cavern walls and in southen areas mainly as cold of SIF. Ratio of cold content of SIF and total cold content in caves can be used as index of glaciation extent of specific caverns; this index can varies from 0 to 1. Cold content in caves can be preserved during short-term, seasonal and perennual period, that can be a cause of formation of corresponding glaciations. Cold content changes during the year: it minimum is before winter, it maximum is at the end of winter. Cold content decreas from entrance to end of caves. Cold content of SIF dependes on size and position of water inflows in caverns. Cold content is difficult to calculate, but it manifestation can be estimated by average annual air temperature in caves. If this temperature is below +0.2°C perennial glaciation can exists in caves; if it changes from 0.2 to 1.0°C and more cave glaciatinn can be only seasonal (or it decreas). Since average annual air temperature in caves mostly unknown we can characterise cold content in caves by index K°, which calculated also as index K, but from average January air temperature in specific points of caves. Maximum of cavern cooling can be reached when index K° approachs to 1.0 and minimum when K° is near to zero. Perennual glaciation can occure in caves with K° from 0.05 to 1.0.

2.2.4. Water inflows in caves

Water inflows in caves are one of general input of heat in caverns. If annual and seasonal heat input which water bring in caverns does not compensated all cold content in it, perennial cave glaciation is formed (at positive SIF mass balance). If heat input by seasonal water inflows is not compensated by cold content in cave but annual heat input is compencated, then seasonal cave glaciation is formed. Volume of water inflows in caves determines morphology, distribution, volumes and mass balance of SIF. Quantity of water inflowing in caverns depends from: 1)quantity of solid and liquid precipitations that get into caverns directly or through grownd water; 2)conditions of condensation and sublimation (in meteorological meaning) of water vapour in caverns.

2.2.5. Second order factors of cave glaciation

Cave glaciation can also depends from: atmospheric phenomenons (wind direction and velocity, variations of atmospheric pressure which influences on air movement in caves); cavern position in relief (northen slopes and lardge altitudes are favourable); morphology of caverns (size of galleries, lenght, depth,heigth difference between entrances); vegetation (which promots to preservation of cold, but prevents from snow concentration). Influence of sun radiation and rock composition for cave glaciation is not essential.

2.3. Cave glaciation stability

Cave glaciation stability is determined by ratio of cold content and heat input in cavern. If they are equal (on absolute value) cave glaciation is unstable; if cold content is higher (on absolute value) cave glaciation is stable and can increase; if cold content is smaller (on absolute value) of heat input cave glaciation can be seasonal or decreases.

2.4. Causes of cave glaciation variation

Scale of cave glaciation can variate following changes: external climate, water inflows, morphology of caves. Influence of external temperature and water inflow variations is shown in table 1. Change of cave morphology can result as in increase or decrease of cold content in cavern.

2.5. Distribution of cave glaciation

Perennial glaciation occurs in nearly 10 per cent of all caverns in temperate areas. The southen and lowest (in mountains) limits of distribution of caves with ice coincide with isoline K=0, the northen limits of caves with seasonal ice can be drawn along zero isoterm of warmest month temperature. The territory of the USSR can be divided into zones: 1)glaciation of all caverns (T_m<0); 2)glaciation of majority of caves (K>1.0); 3)perennial glaciation of selected caves: a)inclined and vertical (K from 0.25 to 1.0); b)horizontal (K from 0.7 to 1.0), if difference of height between entrances is not more than 70 m ; 4)seasonal glaciation of caves: a)inclined and vertical (K from 0 to 0.25); b)horizontal (K from 0.5 to 0.7). The map on figure 3 shows that glaciation distribution limits by isoterms of average annual air temperature outside caves: for horizontal - +4.0°C; for inclined descending -+10.0 - 12.0°C; for vertical -+6.0°C. In maritime climate (near the Baltic sea) limits of zone perennial cave glaciation follows along latitude 48°N, but at continental climate regions of Kazakhstan this boundary shifts southward to 62°N. Cave glaciation zones in mountains are established the same manner. Cave glaciation includes two interacting comple : SIF and permafrost. Cave SIF are the lower part of nival-glacial belt of the Earth, but permafrost is sporadical. Some scientists (Haeberli, 1978; Harris, 1979) suggest that permafrost boundary have to be established by southen boundary of distribution of caves with permanent ice. Thus cave glaciation boundaries are equivalent to boundaies of permafrost.

Table 1. Variation of cave glaciation in dependence from changing of water inputs and cave air temperatures

water input	cave air temperature	cold content	ice content
C	-	+	+
+	-	+	+
-	-	+	-
+	C	C	+
-	C	C	-
C	+	-	C
+	+	-	+
-	+	-	-

where C - constant, + - increase, - - decrease.

Table 2. Combination of ice formation zones in caves and outside them.

ice formation zones outside caves	ice formation zones in caves		
	horizontal	inclined	vertical
seasonal congelation (sc)	sc c sf	sc c	sc c wf
congelation (c)	sc c	sc c	sc c cf
warm firn (wf)	sc c		sc c wf cf *
cold firn (cf)	c		cf sf *
snow firn (sf)			sf s *
snow			s *

* only in glacier caves and crevasses

2.6. Iceformation zones in caves

Since cave SIF are highly protected from external influence the iceformation zones (Shumskiy, 1955) in them often accord with higher zones of criosphere, then zones in which caves are situated (table 2).

2.7. Interaction between cave glaciation and environment

From geografical point of view cave glaciation is highly azonal phenomenon of nature, which creates local climatic anomalies as rule more rigorous comparing with surface conditions; environment impact is local but strong and influences on litosphere, hydrosphere, atmosphere and biosphere components.

3. CONCLUSION

In this report author try to show that existence of snow and ice in different caves in various conditions produces integrated natural phenomenon of cave glaciation, which has its own origin, specific and regularities. Understanding of this phenomenon give us a possibility to approach to examination of cave SIF and their regime in all caverns from common positions.

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SOME CAVES IN SILICIOUS ROCKS IN NORWAY

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In Norway around 200 caves in non - limestone rokcs are known. The counties Al, Bjugn, Afjord and the Hardangerfjord area are remarkably rich in caves and shelters. The caves are mainly developed along tectonic structures, primarly prominent fissure zones and nappes. 5 modes of origin seem reasonable:

1. Tectonic movements and gravity sliding producing fissures. Modification of fissures by ice and meltwater.

2. Preferential Weathering of brecciated zones formed in thrust planes.

3. Dissolution of small limestone lenses within the gneises.

4. Wave abrasion of pre - existing cavities and fissures.

5. The formation of gas pockets in crystaline rokcs.

In many cases two or more of the processes appear to have worked together. Abundant speleothem growth suggests that calcareous zones exist in the rocks. Gas pockets with the size of caves are very rare in Norway, less than 10 are known.

In addition to numerous limestone caves, Norway has a fair amount of caves in igneous rocks. The caves described fall into the following categories:

a) Tectonic caves.

b) Limestone lentile caves.

c) Sea caves.

d) Gas - pocket caves.

a) TECTONIC CAVES.

Tectonic caves are cavities resulting from movements and dislocations in the earth's crust. Tectonic caves can be divided into two main groups :

Fissure caves.

Nappe caves.

Fissure caves.

Large, open, generally vertical, fissures are usually found in conection with steep hillsides and are thougt to be the result of gravity sliding tipping and turning of sections of hills or mountains. Very large fissures are found in areas with gneises located on layers of phyllites.

In many cases pre - existing fisures may have been enlarged by the expansion and movement of ice during the pleistocene. Formations caused by ice and/or water are found in fissure caves. The tremendous amounts of water present during the end of the ice - ages must obviously have had a great influence on the modification of these caves.

Caves are formed by "Flooring" and "Roofing" of the fissure at different levels. Floors and roofs are formed by blocks and slabs geting wedged, often in combination with irregularties such as horisontal shifting of the fissure.

Examples of fissure caves.

Probably the best example of tectonic caves in Norway is the "Ljøtehølet" (1, Schrøder 1980) Al, Hallingdal, south - eastern Norway.

"Ljøtehølet" (fig.2) is 55m deep and has a horisontal extention of about 70m. The fissure is about 2m wide on top and about a half m at the bottom. Vertical rope tecniques are necessary to explore Ljøthølet.

Ljøtehølet is located in a steep hillside with frequent minor landslides, indicating a certain instability of the ground. The Ljøtehølet fissures are probably the result of gravitational forces acting on an unstable part of the hillside. The walls of the lower part of the fissure are very smooth and slickesided , suggesting that the fracture was initiated by shear forces.

In the Hardangerfjord area a great number of very large and deep fissures are known . (Vibe 1896). One of them is about 500m long and up to 60m deep. This contains caves at 2 to 3 levels. During the snowmelting in spring and during heavy rainfalls, a large stream runs into the fissure, forming a 25m waterfall. So far no passage that might convey the water has been found. Most likely it just disappears between the rocks on the bottom.

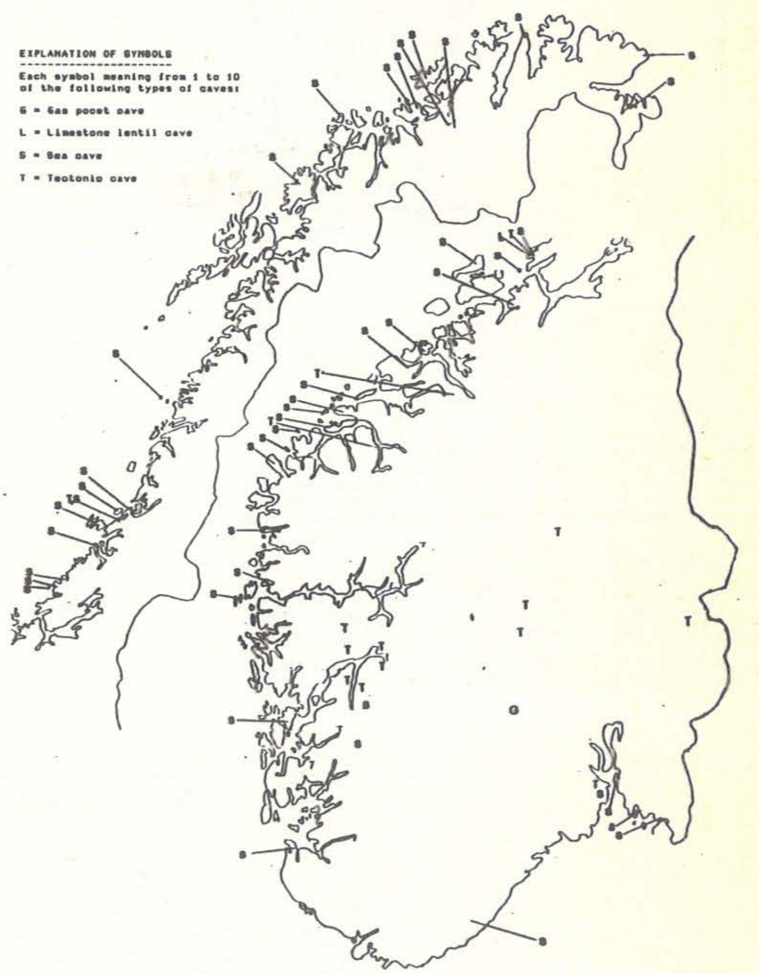


Fig.1

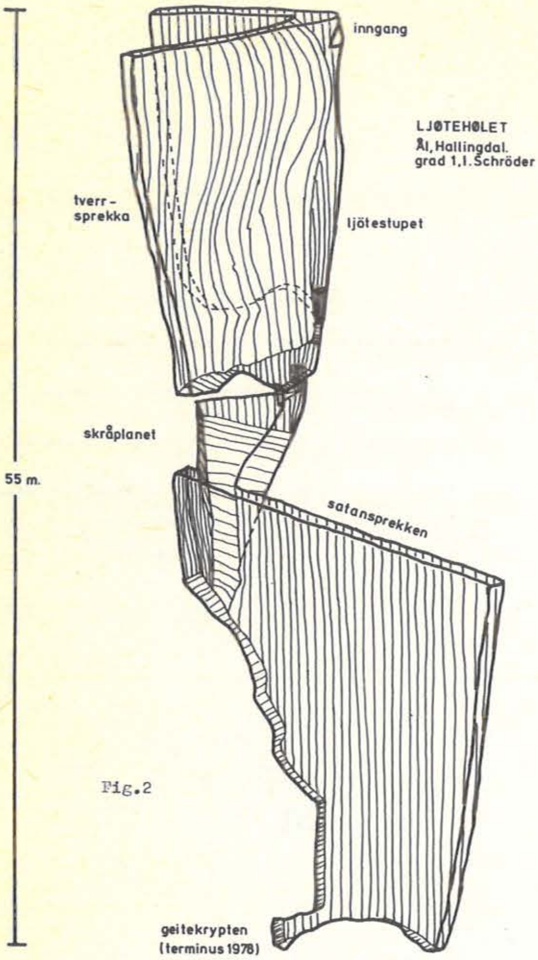


Fig.2

So far about 90 fissure caves are known from a number of sites mainly in southern Norway. Less than half of them are explored. The number of fissure caves is probably much higher than the number reported of.

Nappe caves (Thrust plane caves)

Nappe caves are hollows between two rock layers having had a relative movement. The movement is thought to have caused grinding and disintegration in the shear zone, leaving a stratum of brecciated rocks and soil, very vulnerable to flowing water, frost wedging, sea breakers and other weathering effects.

Examples of nappe caves

The best known example of Nappe caves in Norway is the "Gaupehola" (I.Schrøder 1982),(R.Sjøberg 1983) in Bjugn, Sør - Trøndelag.

From a distance, what is thought to be the remains of a Nappe having a 30 degree inclination forming allmost half of the "Rømmesfjell" , is clearly seen. The entrance to Gaupehola is situated at the bottom of the overhanging cliff at an altitude of about 170m. asl. The passages of Gaupehola are shown in outline in fig.3. The walls and ceiling of the cave are to a great extent "lined" with a crust of gypsum formations . The gypsum has been dated(using the Uranum method, by S.E.Lauritzen), to an age of app.10000 years, the end of the last ice age. This may indicate that the cave lay on the Marine border at the end of the ice age and was formed by breakers washing out the brecciated strata. The development of the gypsum crust started after the landrising had lifted the cave above sea level. Another example of what is thought to be a Nappe cave is "Pyntehula" (K.Schrøder 1985), situated just a few km from Gaupehola. Pyntehula lies at about 160m asl. and is probably formed in the same manner as Gaupehula. The innermost part of the cave is decorated by flowstone, stalactites and stalagmites , indicating that the rock is the host of Calcite lentils, or layers.

b) LIMESTONE LENTIL CAVES

Some caves found in Bjugn, Sør - Trønderlag seem to have been formed, neither by Tectonic nor "traditional" sea - breaker processes. An example of this is the "Duehellarhola" (A. Helland 1889, I. Schrøder1982). This cave contains none of the typical rounded forms created by breaker abrassion, the cave seemingly has a solid rock roof unlike fissures created by dislocation. It is therefore proposed that the cave is the result of solution of a large limestone lentil, a number of lentils or layers of calcite.Duehellarhola lies about 130m asl., both sea and meltwater might have been acting on the soluble rocks.

The discovery of a partially disolved limestone lentile (I. Schrøder 1984) about two km east of Duehellarhola, supports the "limestone lentile cave hypothesis".

c) SEA CAVES.

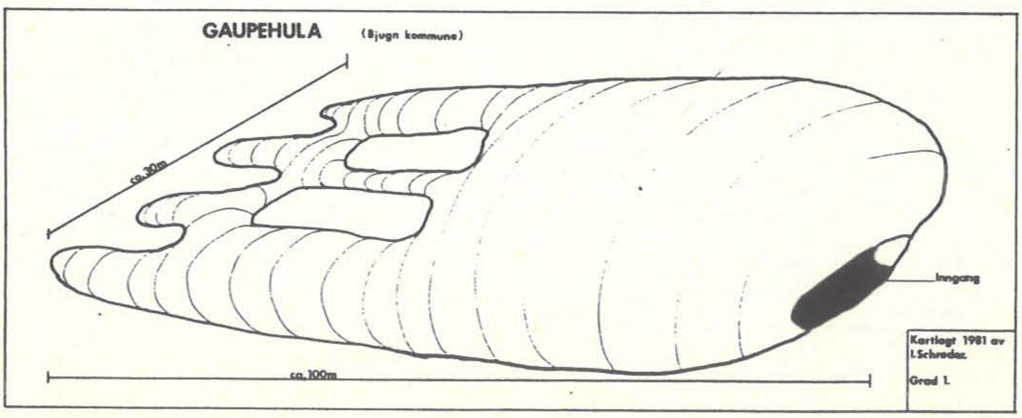
Along the entire coast of Norway, and especially the west coast, there are a great number of caves formed mainly by sea breakers. They are situated at distances from 0 - 5 km from todays coast and lie from 0 - 170m. asl.

The described caves have initialy been fissures created by Tectonic or solutional prosesses mentioned above. A sea cave usually is a combination of both a fissure and a tunnel-like cave, formed by breaker abrasion(R. Sjøberg 1986).

One of the largest and most beautiful sea caves in Norway is the well known "Harbakkhulen"in Afjord, Sør - Trønderlag (A. Helland 1898, R. Sjøberg 1983, I. Schrøder 1986). Harbakkhulen lies about 1 km from the coast at about 130m. asl. It consists of an entrance chambre 100m long, 30m high, 12m wide. At the end of the entrance chamber a steep hill leeds upp to 10m below the ceiling. From here the cave branches into two fissure shaped pasages terminating at 30 and 40m respectivly.

A close inspection of the roof and walls of Harbakhulen shows that it is smooth and unbroken with no sign of any significant crack or fissure. This might indicate that the speleogenesis of this cave started as a Limestone lentil or calcite layer dissolution prosess.

Another small, but beautifull sea cave is the "Nedre Flatheiahula" in Bjugn (I. Schrøder 1984) This lies in the midst of the forest about 4km from the coast. It lies about 120m asl and is 45m long. The walls are beatifully smoothed and rounded and the cave has the typical sea cave profile with tunnel shape in the lower part and fissure above. The floor of the first 20m consists of sharp cut rocks and mud - not as expected - rounded rocks and pebbels. The rocks probably have been shoved in by a "pasing" glacier.



About 5 km west of Nedre Flaheiahula lies "Stygg - hølet"(platell), (I. Schrøder 1982, 1984) from a distance this cave seems to be a "pure" fissure cave, but a closer look reveals a fearly large breaker - formed hall about 25m below the entrance From the innermost end of the hall a narrow fissure leads innwards and uppwards another 40m. The breaker formed part of this cave must have been formed during one or more intermediate ice age periodes, whilst the closure of the "breaker entrance" has been caused by rockfall or by glacier transported rocks since the end of the latest ice age.

d) GAS POCKET CAVES

Small pockets in crystaline rocs are not uncomom in Norway. These pockets are thougt to be the result of the expantion of gaseous water or other gases while the rock was in a magmatic state. Very few of these pockets have the size of a cave, so less than 10 such caves are reported of.

Probably the best known example of such caves are the "Dvergesteinholene" (Drammen og omland Turistforenings Årbok 1971, I. Schrøder 1983) in Numedal, south - eastern Norway, lying about 1100m asl. The Dvergesteinholene consist of 4 separate cavities within a distance of not more than a 100m. The longest one is about 15m long with a diametre of about 1m. Old sayings tell that there was an abundance of beautiful quartrite crystals in these caves a 100 years ago. Today, naturally, they are all removed.

One might of course speculate upon wether the Dvergesteinholene, all lying in a steep mountain side, once were parts of a much larger cave that has been cut of during the ice - age.

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THE MIANSHAN - TYPE KARST IN WEST CHINA

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Introduction

China is a vast country with complexities & varieties of Geology , Topography, Climate and Bioecological environment , Karst of different types are distributed widely, and developed in carbonate rocks of huge thickness of Cambrian, Ordovician , Devonian, Carboniferous, Permian and Triassic. You can observe tropical & subtropical Fenglin Karst(peak-forest plain with peak-forest depressions, or tower karst with cockpit karst) in southern China, subtropical karst hills in central China,normal erosional karst of the temperate zone in northern China,arid & semi-arid karst in west-northern China, paramous karst of pla - teau area in western China and coastal karst in eastern China , Karst of Mianshan-type we shall discuss in the paper is a sub - type of paramous karst developed under the condition of solid alpine climate.

The Mianshan mountain range is situated on the western edge of Sichuan basin, in the deeply dissected front of eastern Chinghai - Tibet plateau, on the side of the Yangtze - Yellowriver watershed belongs to the Yangtze River Basin. That is, with respect to the topographical outline of three step west-east stair case of China, it is on the western side of the second-third step dividing line at elevation varying between 2,000-5,588 metres,and it is at longitude 103.5°E and latitude 33°N(Figure 1.).Stratigraphically the study area is covered by carbonate rocks of Devonian , Carboniferous and Permian with a total thickness of 4,950 metres.

System composition and basic characteristies of Mianshan-type karst

Mianshan-Type karst is constituted by two subsystems in vertical section : The mountains paramous karst of upper part that is situated in the mountain peak , and the gorges temperate karst of lower part,and the altitude of two subsystems above is about 3,700- 4,000 metres. Figure 2. shows the basic features of this karst system .

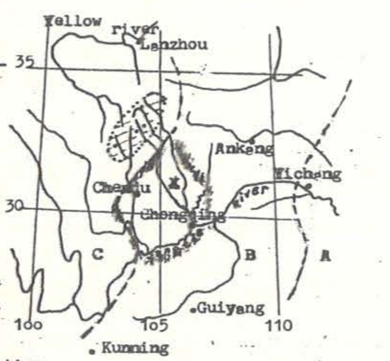


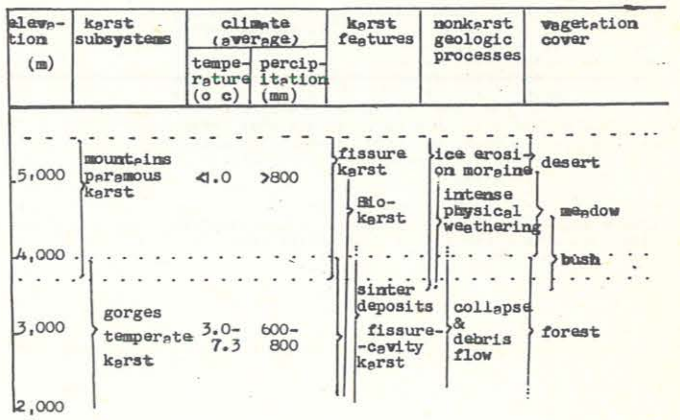
Figure 1. The situation of Mianshan-type karst in China

research area

A,B,C - the first step(1000m), second step(1000-2000m), third step(2000-5000m) of topography in China
X - Sichuan Basin

In fact, surficial karst phenomena of the mountains paramous karst zone are not very prominent, but it's geologic process is marked by the infiltration and recharge of karst water, and it actually acts as the main input source of energy and material of karstic springs and sinter deposits in the lower gorges temperate karst zone. Comparing with the temperate karst zone, relative relief of upper zone of the mountain range is relatively gentle, and because precipitation in the forms of ice and snow can lag longer and melt gradually on the surface of paramous karst zone which is of broken rocks and much debris deposits formed by intense physical weathering, so obviously all these conditions are favourable for melt water to infiltrate downward and to recharge karst aquifer. According to the determinations, the SI_c value (saturation index of calcite) and the SI_d value (saturation index of dolomite) of precipitate water of mountains area are -1.61 and -3.61 respectively, apparently it has very strong solvent power of calcium carbonate ($CaCO_3$). Although the density of

Figure 2. the basic features of Mianshan-type Karst



co_2 in air decreases with the raising of elevation, the solubility of $caco_3$ increases a little with the drop of temperature of environment around under the condition of constant p_{co_2}, and this also is in favour of $caco_3$ dissolution in the course of karst water movement in the paramous zone. Therefore , although the paramous karst zone of the study area has broken landforms with high potential & steep slopes, and most part of this karst zone is in vadose hydrodynamiczone, and thus karst water cycles severely, so the total dissolved solid, the temporary hardness & the SI_c value of karstic spring water in lower temperate karst zone are much higher than of common karst discharge area, springs of Huanglong Temple for example, are about 0.3-0.7g/1,21-36.4 Germanic hardness and -0.28-0.10 (SI_c) (mean value: 0.598 g/1 ; 31.75; -0.03).

The gorges temperate karst zone is mainly charaterized by steep topographic gradient, great daily variation of temperature, luxuriant vegetation and wide spread emergences of karst springs accompanying by vast deposits of sinter.

Springs issued from karst aquifer have different genetic types: vadose springs, shallow phreatic springs and thermal springs of deep saturated belt are four distinguishable springs based on the characteristics of water temperature, the total dissolved soilds, the hardness, the saturation index, the discharge and the environmental isotope of the spring water and their dynamic analyses, but all of them are recharged by precipitate water, and the cycle of recharge vavies from a few years to 6,000-7,000 years (Table 1. 2.).

spring types	temperature (°c)	total dissolved solids (g/l)	temporary hardness	content of uncombined co_2 (mg/l)	SI_c	SI_d	$\log p_{co_2}$
vados soring	2.5-13.8	0.16-0.30	7.76-15.98	5.5-12.5	-0.24	-1.15	-2.26
shallow phreatic spring	5.2	0.61	31.75	139.9	-0.03	-1.02	-1.03
deep phreatic spring	22.8	1.39	75.52	512.3	0.55	0.03	-0.50

Table 1. Physical & chemical features of springs of different types (means)

spring types	^{3}H (TU)	δD (SMOW)	$\delta^{18}O$ (SMOW)	^{14}C (age.a)
mountains snow water	33.7±2	-139.7	-19.67	
vados spring	91.3±7	-85.3	-12.62	
shallow pheratic spring	62.2±5	-89.2	-13.53	
deep phreatic spring	55.0±2	-101.6	-14.53	6,600±160

Table 2. Hydrogen & Oxygen Isotopes and Carbon-14 dates of diffierent springs

Each of three type springs is able to form its sinter deposits, but the deposition of tufa formed by the phreatic springs are the dominant.

There are three impotant depositional sites of sinter in the area: Huanglong & Zhangjia gorges which are the river head of Fujiang River; Monigou gorge which is a tributary of Mian - jiang River (including Erdaohai lakes, Linchangou gorge and Zhaga Waterfall etc.) and Fairy Pool & Jiuzhaigou gorges which are the upstream reach of Baishuijiang River, of which Huanglong gorge & Fairy Pool are characterized by the combination forms of flowstone dams-pools and others are marked by both waterfall -dams and tufa terraces. So it is possible to divide depositional forms of travertine into three chief types : the pool-travertine, the waterfall-travertine and shoal-travertine (Figure 3. 4. 5.).

Figure 3. The Pool- Travertine (Huanglongou& Fairy pools)deposit

a--flowstone dam pool
b--flowstone dam
c--leak circles

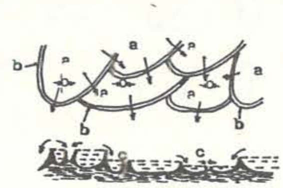
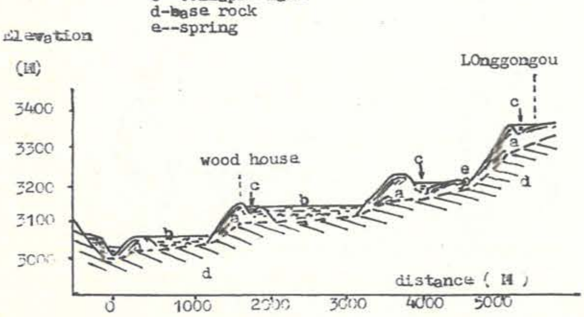


Figure 4. The waterfall-travertine (Monigou gorge)deposit

a--waterfall travertine
b--bog
c--collapse lake
d-base rock
e--spring



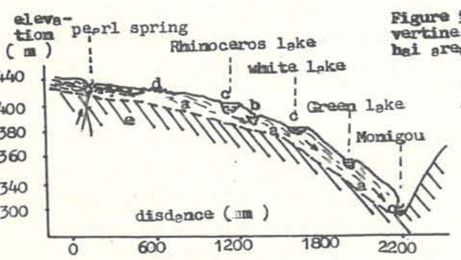


Figure 5. The shoal travertine deposit in Erdaohai area

a - shoil tufa deposit
b - secondary cave
c - collapse lakes
d - pool tufa deposit
e - base rock

Discuss and preliminary condusions

1. Mianshan-Type karst is a High mountain-gorge karst system constituted by two subsystems of mountain paramous karst and gorges temperate karst in vertical space.

Chemical corrosional action of carbonate rocks of the mountains paramous karst zone is still comparatively active, and phenomena of biokarst are also easy to be observed , but surface karst features are not remarkable, this is because the going-ahead-destruction resulting from severe physical weathering at a high speed of geomorphologic process. Today, distributed everywhere in the morphological zone of mountains area at the height of 3,500-5,000 metres, there are lots of teeth-peaks , sharp-pointed pagodas (pinnacle) , natural bridges and vast debris deposits which are formed by geomorphologic process of the fracturing & collapse of hard carbonate rocks under the condition of severely varied temperature. In view of this , we dont think it is believeable with regard to the viewpoint that relict Fenglin karst landforms of Tertiary still existed in the paramous zone of Tibet Plateau until recently.

Corresponding with the function of material input of the mountains paramous karst zone, the gorge karst zone is the material output area of karst water discharge & sinter deposition. As the whole of a system, both karst zones shows an orderly texture & a clear sequent variation in all aspects such as the vertical difference of karstification, the hydrodynamic division zones of karst water, the input & output of material and energy, the natural landscape and so on.

2. The principal feature of the karst system is the vast deposition of travertine at the most places where karstic spring flowed out.

The deposition of tufa in fact reflects a kind of material output in the course of variation & balance of co_2 component & pco_2 of karst water, it is the adverse-reaction of $caco_3$ dissolution (material input). There are many factors which affect & control this depositional process such as the temperature, the evaporation & transpiration of spring water, the biochemical process, the evironmental medium in contact with water (atmosphere, soil, surrounding rocks), the content of corrosive co_2, the atmospheric pressure & hydrostatic pressure, the charactor of surrounding rocks, the flow type and flow velocity of water .Furthermore, the time co_2 of karst water need to get the balance state and the feature of open or close system also have an important effect on the deposition of travertine. Based on the author's study, the mechanics of sinter deposition of studied area are chiefly controlled by the temperature effect, the biology effect ,the pressure effect and the hydrodynamic effect , of which the temperature effect is a widespread active factor.

Huanglonguo and Fairy Pool two places have more than thousands pool-basins surrounded by flowstone dams of travertine, and there are colourful algaeof different types grow in the pools. The photosynthesis of algae has decreased the pco_2 value of pool water and increased the PH value at the same time (a high PH value is possible to reach to 7.7-8.1 at noon), so the depositional velocity of travertine has been speeding up greatly in this way. Therefore, biologe effect holds a very important part in the deposition of pool travertine.

Pressure effect is quite important to the sinter deposits of thermal springs coming from artesian aquifer , pearl spring for instance,spring water at the spring-mouth is of boiling-water-like because a great deal of co_2 escaping from the water. Once the karstic artesian spring comes to the surface, the spring water is in a over saturated state because of a sudden drop of pressure, the SI_c=0.79~0.91.

Splashing water drops & water moisture makes co_2 component of spring water have more chance to escape , high-velocity flow might bring about the drop of inner pressure of water and thus the formation of gas cavity & gas explosion. That is to say, hydrodynamic effect is of significance in the process of deposition of water -fall-travertine & shoal-travertine under the condition of waterfalls and rapids.

We should point out that, the deposition of tufa is in an open system. In an ordinary way, the formation & development of sinter deposition in any depositional unit or deposition of different type tends to be the result of the co-action & teamwork of multi-mechanics rather than be controlled only by a dominant mechanic.

3. The preliminary study shows that, sinter deposits of the study area accumulated up in quite a high speed . Pool travertine and shoal travertine have an accumulational vate of 0.52~5.46 mm per year, but waterfall-travertine relatively has a higher speed of 7.50~33.33 m m per year. Carbon-14 dates tell us that sinter deposits of the area have been forming since 11,000 years ago.

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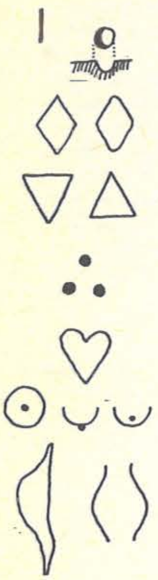
SEXUALZEICHEN IN HÖHLE UND FELS

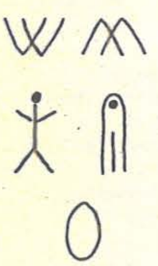
KITTEL, Erika - WOLLENIK, Franz

Symbole sind Abstraktionen, der Teil steht für das Ganze. Es ist der Körper und seine Körperteile, die als Kürzel für Sexualität verwendet werden. Sexualsymbole lassen sich daher relativ leichter bestimmen als andere, in Höhle und Fels geritzte Zeichen. In den verschiedensten Stilen und Spielarten kann man sie von der Gegenwart bis in historische Tiefen zurückverfolgen, wenn man sich die wichtigsten Grundformen vor Augen hält.



Der aufrechte Strich ist die einfachste Darstellung des männlichen Gliedes (penis)
Noch knapper das weibliche Genital : Punkt, Näpfchen, Schale, Öffnung
Die Raute entspricht den Schamlippen (vulva)
Ein Dreieck mit der Spitze nach unten steht für das weibliche Schamdreieck
Mit der Spitze nach oben ist das männliche Gegenstück.Potenz.
Drei Punkte, zu einem Dreieck geordnet, weisen auf die Fruchtbarkeitsphase der Frau in jedem Monat hin. (Zunehmender, voller und abnehmender Mond)
Herz = herzliche Gefühle. Auch Sinnbild der weiblichen Brüste.
Weibliche Brüste, Rundformen, mit Brustwarzen
Herausgestrecktes Gesäß für den Geschlechtsakt von hinten.
Gewölbter Leib = Schwangerschaft, Gefäß der Fülle

Weiblicher Körper, liegend, Oberschenkel betont
Weiblicher Körper, stehend, Brüste und Schenkel betont. Diese "Ägypterin" auf der Expeditionswand 1976" im Hagengebirge ist umstritten, weil die alte Ritzung brutal in ein modernes pin-up-girl umfunktioniert worden ist.

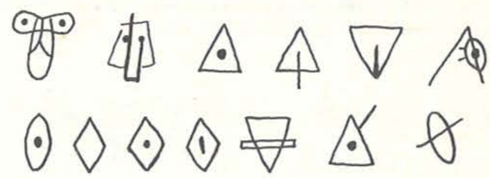


Zwei ineinander verschränkte Beinpaare. Als "W" mit verschränkten Holmen für weiblich, als "M" für männlich. Gebildet aus zwei "V" werden sie lateinisch als "VIVA" = Leben,gelesen. Umgekehrt gelten sie für "MORT" = Tod.
Gesamtkörper mit geraden Strichen
Gesamtkörper in Rundungen, beide werden jeweils mit männlichen oder weiblichen Symbolen ausgestattet
OVAL = das Ei, Keimzelle des Lebens
Tier, männlich

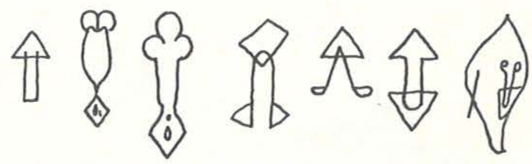
Soweit die Materie, das Stoffliche. Nun zu Gefühlen und Gedanken. Symbole haben einen "Sinn". Bei den Sexualsymbolen ist das "SINN-liche" Element ziemlich deutlich. In ihnen steckt Urkraft und Lebenstrieb. Heute sprechen wir von SEX. Er treibt die Menschen an, Symbole in Baumstämme zu schneiden, mit Kreise, Stift und Spray an Mauern zu malen.

Allen voran manifestiert sich der Wunsch nach einem Koitus und einem Partner. Es werden meist weibliche Genitalien und die Vereinigung von weiblichen und männlichen Genitalien im Geschlechtsakt dargestellt. Viele solcher Sex-Symbole fanden wir im Tennengebirge und Hagengebirge, nördlich des Tauerntunnels im Bundesland Salzburg. Sie stammen teils aus den letzten Jahrhunderten.

Sexualsymbole Tennengebirge und Hagengebirge



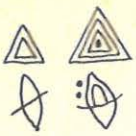
Der Raum Lofer im Saalachbecken ist vom Tal bis zur Baumgrenze voll mit Sexualsymbolen für den Geschlechtsakt. Etliche sind sehr alt



Die letzte Figur erinnert an eiszeitliche Darstellungen von Frauen ohne Kopf und Füsse. Das herausgestreckte Gesäß hat einen Penisstrich, der Leib vorne eine Art Schamdreieck mit Penis+Hoden.

Solche Sexualsymbole haben bei den Höhlenforschern des Bundeslandes Salzburg weder moralische Entrüstung noch wissenschaftlich - distanzierte Ablehnung ausgelöst. Gravierte Wände, die sie auf den Wegen zu Höhlen in alpinen Wildnissen gefunden haben, meldeten sie dem Landesverein für Höhlenkunde in Salzburg. So konnten wir in den letzten zwölf Jahren systematischer Felsbildforschung in drei Gebirgsregionen rund 110 Bildwände dokumentieren.
Nun zu den kombinierten Sinnbildern, die über Sex hinausgehen.

Man erkennt ein schreitendes Paar in Bogen und Oval. Es könnte ein Liebespaar sein, das sich unter den Schutz einer höheren Macht gestellt hat.



Die "Schwarzwand" im Tennengebirge wirkt wie eine Unterrichtswand für Einzuweihende : Dreiecke mit und ohne Punkt, mit angesetztem und eingeführtem Stiel, konzentrische Dreieck, Körper mit Penisstrich.

Auf der "Wand der schwarzen Götter" in einem Gewitter umtobten Kar im Tennengebirge sind Gestalten mit weiblichen (drei Punkte) und männlichen (Penisstriche) Symbolen. Eine dieser zweigeschlechtlichen Gestalten ist mit Lanze und kosmischen Kreis als höheres Wesen ausgewiesen.

Mit kosmischen Kreisen ausgestattet ist auch dieser "Leiternturm" in Lofer. Er ist auch Penis mit Hoden und Raute.

Der "Dreieinige" im Tennengebirge kann gesehen werden als 1.) Penis mit Hoden im Dreieck, als 2.) Gestalt mit Kopf und heiligem Dreieck und 3.) als himmlischer Spender von Regen und Fruchtbarkeit

Um die Bitte von Fruchtbarkeit geht es auch bei diesem Felsbild, hoch oben im Raucherkar (Totes Gebirge) über einem riesigen Höhlenpark. Fruchtbarkeit wird hier mit kreisförmiger Sonne, Raute und Regenstrichen beschworen.

In der "Hirschenhöhle" trägt ein starker Hirsch in seinem Geweih eine Raute mit Strich und Punkt. Die vielen Näpfchen, die das Bild umgeben, sollen wohl die Bitte an Mutter Erde verstärken, sie möge die Tiere fruchtbar machen und vermehren.

Das imposanteste Felsbild im Tennengebirge ist das der "Grossen Mutter". In der Fülle ihres Leibes birgt sie einen Embryo. Unter dem Felsbild öffnet sich ein Höhlenschacht mit geritzten Symbolen.

Höhlen sind Öffnungen in jener Mutter Erde, die Leben gewährt und in die Tote wieder eingebettet werden. Von den Symbolen der Sexualität sind wir also zu Sinnbildern der Paarung, der Fruchtbarkeit und der Schicksalskräfte gelangt. Erfahren haben wir, daß auch der Geschlechtsakt einem historischen Wandel unterworfen ist. Wissen um religiöse Vorstellungen, um Volksglauben und um kosmische Vorgänge erleichtern uns das Verständnis für alle diese Felsbilder.
Was bleibt, sind ihre Geheimnisse.

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Illustrationen der "SeXualsymbole in Höhle und Fels":Franz Wollenik, Felsbildforscher in Wien.

FLUORIT CAVES IN THE DECIN SNEZNIK (CZECHOSLOVAKIA)

LYSENKO, Vladimir

Within 1983-86 the members of ČSS ZO 1-05"Geospeleos" registrated new caves in fluorspar deposit between Děčínský Sněžník and Jílové(Fig.I A,B).This region is formed of Upper Cretaceous sandstones.On the surface the main tectonic linear structures are present a fissures NE-SW and W-E to WSW-ENE directions and seldom ESE-WNW direction. The caves I,2,3,5,7 are following the fluorit veins of the W-E directions.The caves 6 and west part of the cave 4 are following WNW joints(Fig.ID).The system of N-S direction was observed not only in the cave(Fig.I C)but also has been constructed on the basic of interpretation of aerial photographs.Some caverns are faulted along NE-SW directions(tear faults?).

The fluorit mineralization making an irregular connected crust on walls and roofs(Fig.II.).Three fundamental generations has been classified in the caves:columnar agregates, concentric-radial aggregates and laminated fluorit.

The caves has hight differance from 536 m a.s.I.to 598 m a.s.l. The spaces has been flooding with water bellow the hight 548 m a.s.l. Joint caverns predominate but somewhere they was formed in conformity with layers.In the relation to fluorit mineralization we have determinated the caves

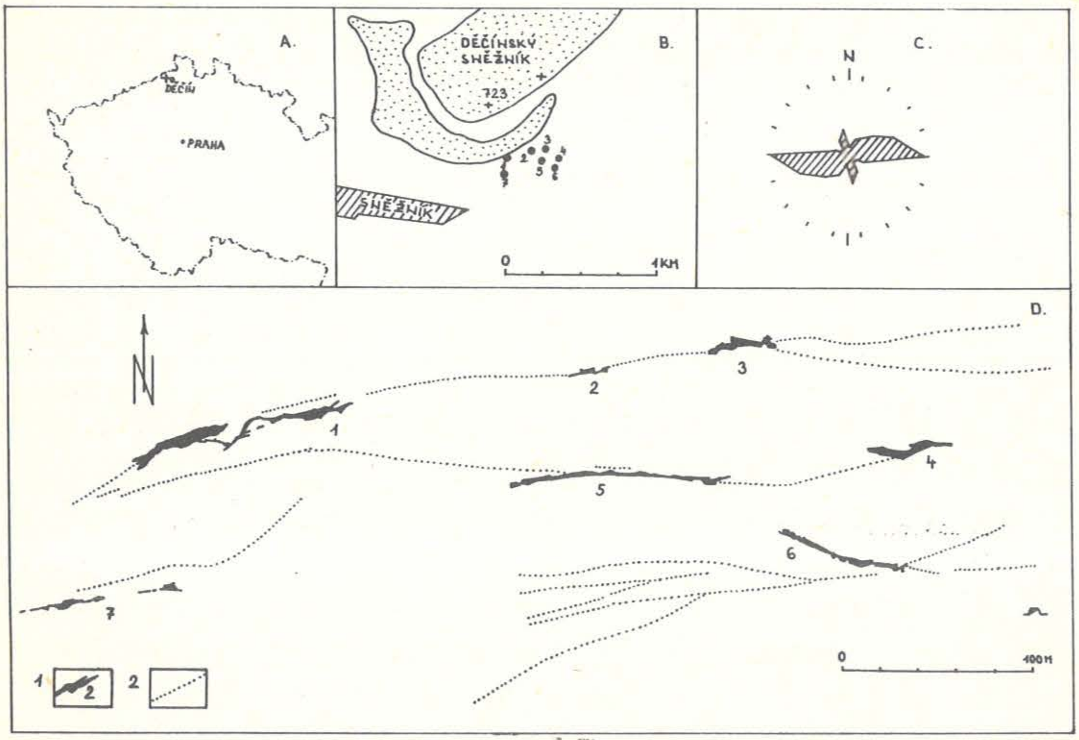

Fig.I.A,B-Situation of the fluorit caves in the Děčín Sněžník
C-Diagram of join frequency in the fluorit caves
D-Distribution of caves in the fluorspar deposit
1-caverns;2-maine tectonic line with fluorit

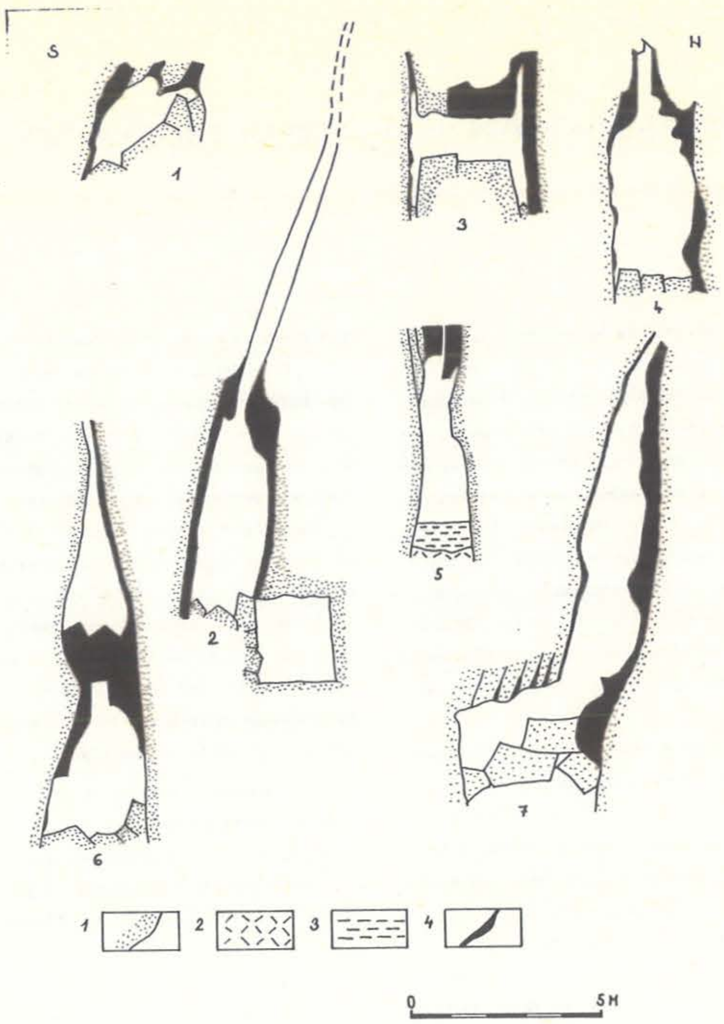

Fig II. Types of cross-sections of cave pasages with fluorit deposits. Cave 1(section 2,7), cave 3(section 1), cave 5(section 4,5,6)and cave 6(section 3). 1-sandstone;2-loam and send;3-water;4-fluorit.

of pre-mineral stage and post-mineral stage. The caves of pre-mineral stage are younger than silicification of sandstone but older than fluorit mineralization. The age of this caves is probably Upper Miocen.

Table of caves:

1)The cave got 150 m longer, 6 m wide, the denivelation is 62 m. The volume is 2512 m^3.

2)The cave is 22 m long, 3 m wide, 10 m hight. The volume is 650 m^3.

3)The cave is 37 m long, 8 m wide, 4-5 m hight. The volume is 700 m^3.

4)The cave is 45 m long, 5 m wide, 30 m hight. The volume is 708 m^3.

5)The cave is 115 m long, 2,5-3 m wide, 12 m hight. The volume is 1100 m^3.

6)The cave is 73 m long, 4 m wide, 11 m hight. The volume is 1347 m^3.

7)The cave is 40 m long, 1-3 m wide and 8 m hight. The volume is 210 m^3.

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PHYSICAL AND CHEMICAL RESEARCH OF GYPSUM IN THE STRATENSKÁ JASKYŇA

KOSIK, Miroslav - TULIS, Ján

The Cave Stratenská jaskyňa is created in Wetterstein and Steinalm limestones of Middle Trias age. They are very pure limestones (average content of CaO is 54,60 %) and this limestones very good karstingable. Fluvial allochtonous and autochtonous sediments are in abundant representation in underground spaces. They are especially clays, varied sand-clays, sands, clay-gravelsands and gravels. Minerals of heavy fraction are in plentiful representation in this sediments. They are minerals: pyrite, magnetite, hematite, chrome spinels, apatite, zircon, edisonite, ilmenite, titanite, delphinite, grenats, chlorite, tourmaline, amphiboles.

Limonite have the most plentiful representation and this reality referring to long process of weathering and oxidation Fe-minerals (magnetite, limonite, pyrite).

The secondary calcite filling - cave decoration(from chemogenic sediments) is in abundant representation also. Aragonite occurs in lower quantity only. Gypsum belongs among frequent minerals of caves and in the Cave Stratenská jaskyňa it occurs either in the form incrustations on walls of the Cave or in the form crystalline aggregates on boulders, on walls or in allochtonous sediments.

The gypsum (sample No. 1) occurs in the Aragonite Dome on aboulder, which is drowned in clay sediments (especially on its vertical wall) and it occurs on walls of the Dome in the form independent fibrous aggregates sickle-crooked. Its colour is white to transparent.

The gypsum (sample No. 2) occurs in the Jazerná Passage on walls to 2 m highly of the ground, but on boulders it occurs too.

The gypsum occurs in the form of fibrous crystalline aggregates 1,5 - 2 cm long. The fibrous aggregates are often sickle-crooked and they are achromatic and transparent. Maximum quantity of the gypsum is concentrated in a horizontal strip (0.3 - 0.5 m wide) along walls, created by dark sinter, which is stuck on walls. They are relics of old ground-sinters, which were destructed later.

The gypsum (sample No. 3) occurs in the Passage of Surprises in front of crossing with the Crystal Passage, on vertical walls of crashed boulders, which are in a hole of a fallen through bottom. The gypsum occurs here prevailingly in the form of white films (maximum 1 cm of thickness). This gypsum is comound from slight slabby crystalls. And covered plain 20 x 40 cm long. The gypsum occurs in the form independent fibrous aggregates, sickle-crooked crystalls are here in smaller quantity.

The abundant occurence of gypsum is in the Crystal Passage in fluvial sediments (sample No. 4) in clay-gravelsands on a side riverbeds. Druses of slabby crystalls (5 - 7 cm long) occur here also.

Very interesting occurence of gypsum is in Crystal Passage in the second siphon (sample No. 5). Slabby brown crystalls are situated here with particle size 3 - 5 mm. Besides this crystalls the gypsum occurs here in the form white crustes (of thickness: 5 - 7 mm) compound from tiny slabby little-crystalls. The gypsum occurs here on the east wall of the Passage only and it spreads from the bottom up to the height 2 m. The most abundant occurences are over the bottom and towards up the occurences dwindle. The browness of crystalls is on their surface only, inside they are white. The little-crystalls

Chemical Composition	standard ofgypsum (Harz)	Sample No.1		Sample No.2			Sample No.3		
		Sediment	Limestone	Gypsum	Sediment	Limestone	Gypsum	Sediment	Limeston
SiO_2	0,345	60,23	2,59	1,39	59,50	0,81	8,44	59,89	0,70
Al_2O_3	0,10	17,83	0,84	0,42	17,23	0,23	2,30	17,54	0,26
Fe_2O_3 total	0,077	7,01	0,47	0,15	7,93	0,12	1,97	7,42	0,17
TiO_2	0,0058	1,106	0,045	0,027	1,057	0,01	0,151	1,258	0,014
CaO	32,97	1,57	52,96	32,[illegible]	2,07	55,00	30,56	1,31	54,93
MgO	0,01	1,76	0,57	0,07	1,62	0,25	0,29	1,75	0,40
MnO	0,001	0,138	0,011	0,0[illegible]	0,250	0,005	0,190	0,190	0,008
SO_3 total	46,634	0,034	0,120	45,40	0,024	0,014	34,27	0,048	0,010
Na_2O	0,01	0,24	0,16	0,01	0,16	0,12	0,09	0,14	0,20
K_2O	0,02	2,80	0,10	0,07	2,44	0,001	0,38	2,28	0,04
L.O.I.	0,67	6,46	42,15	0,60	7,01	43,16	7,00	6,67	42,91
H_2O^+	0,66	-	-	0,36	-	-	1,64	-	-
H_2O^-	15,65	(2,67)	(0,35)	19,56	(2,83)	(0,19)	13,56	(2,22)	(0,21)
Cu	1	28	7	1	29	5	7	30	1
Pb	4	60	20	5	65	13	5	98	10
Zn	3	200	28	50	196	12	106	288	12
Ni	1	74	4	1	72	1	15	92	1
Co	1	17	1	1	17	1	1	19	1
Cr	4	110	5	5	135	5	85	145	5
V	4	125	5	5	125	5	20	130	5
B	10	170	5	5	100	5	5	180	5
Y	1	42	8	2	38	2	11	46	2
La	1	56	4	14	50	1	32	66	1
Zr	1	305	8	5	324	4	39	406	3
Sr	292	79	170	130	84	170	120	89	190

Chemical		Sample No.4			Sample No. 5		A	5
Composition		Sediment	Limestone	Gypsum	Sediment	Limestone	Gypsum	Gypsum
SiO_2		60,39	0,21	1,22	58,25	0,62	2,12	0,49
Al_2O_3		17,95	0,04	0,46	18,91	0,29	0,75	0,14
Fe_2O_3	total	6,75	0,04	0,38	7,98	0,14	0,31	0,06
TiO_2		0,935	0,004	0,030	0,898	0,015	0,044	0,013
CaO		1,08	54,70	33,10	0,98	54,93	32,0	32,88
MgO		2,35	0,87	0,08	2,05	0,35	0,12	0,02
MnO		0,128	0,004	0,003	0,188	0,015	0,006	0,001
SO_3	total	0,034	0,01	42,51	0,099	0,045	44,61	45,95
Na_2O		0,16	0,10	0,01	0,12	0,08	0,04	0,02
K_2O		3,72	0,01	0,08	3,30	0,01	0,11	0,02
L.O.I.		5,44	42,98	2,28	6,52	42,86	2,24	0,68
H_2O^+		-	-	1,16	-	-	1,03	1,64
H_2O^-		(1,49)	(0,23)	18,04	(1,99)	(0,12)	17,40	16,28
Cu		30	2	1	32	3	2	3
Pb		55	11	5	67	18	5	5
Zn		181	5	50	272	13	21	10
Ni		136	1	1	157	2	1	1
Co		23	1	1	23	1	1	1
Cr		225	5	5	170	5	5	5
V		105	5	5	125	5	5	5
B		230	5	5	245	5	5	5
Y		37	1	2	41	2	3	1
La		54	1	13	54	1	8	6
Zr		290	1	7	218	2	12	3
Sr		114	300	130	71	330	165	220

of the gypsum and gypsum-crustes create coherent fields only in evorsion concave crooked areas of dimension 1 m^2 maximum.

We conclude, from obtained analytical results, that all crystalls of gypsum contain an impurity of calcite, especially it shows the sample No.2 and sample No.4.

The representation, the reciprocal relation of oxides CaO and SO_3, evidences it and relative high values of L.O.I. (lost of ignition) show contents of CO_2, which is typical for carbonates.

Macroelements or their oxides have higher values in samples to opposite a standard - crystal of gypsum from Harz (GDR), especially sample No. 2. Increasid values this oxides are due to microscopic mechanic impurities mostly (macroscopic impurities were separated at sampling). The highest values of oxides were found in crystalls of gypsum, which occur in allochtonous sediments (in Crystal Passage and Passage of Lakes).

The browness of gypsum-crystalls in the second siphon of the Crystal Passage is due to raids of rigid small parts, recomanded by analysis, from the speleoaerosol on the surface of gypsum-crystalls. Crystalls-aggregates have not least impurities, as we expected to it, but gypsum in the form of white crustes (sample No. 5B). Its chemical composition is very near to the standard (Harz).

From watching trace elements, the strontium have the highest content, but mostly don't reach concentrations, which are present in parent rocks. The origin of strontium we suppose from the parent rock above all. Increased contents of another trace elements, but with a considerable dispersion, were found for elements : zinc, yttrium, lanthanum and zirconium, to opposite the standard.

Following elements (copper and nickel) present in a considerable dispersion and another elements (lead, cobalt, vanadium) have values near standard. Trace elements chromium and boron have a lower content in samples than standard. This reality is indicated by a transport of elements (zinc, yttrium, lanthanum and zirconium)from allochtonous fluvial sediments.

The research of gypsum in the Cave Stratenská jaskyňa is not extensive, but the research showed on interesting problems and questions and it sketched next ways of a research in the Cave Stratenská jaskyňa.

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TYPES OF POSTAGE-STAMPS AND PICTURE-POSTCARDS CONTAINING CAVE-MOTIVES

LENART, László

Seit der Erscheinung von Briefmarken sowie Ansichtskarten haben zahlreiche Länder die gewaltigen propagandistischen sowie wirtschaftlichen Gelegenheiten und Möglichkeiten ihre Berghöhlen und deren geologische Formationen, die dortigen geschichtlichen Ereignisse und die in den Berghöhlen lebenden Lebenswesen durch Briefmarken und/oder auf Ansichtskarten vorzuführen benützt. Im Rahmen meiner Diskussionsartikel möchte ich dieses speläo-philatelistisches Motiv begrenzen, die Einzeltype ausgestalten sowie den neuen Markensammlern in der Systematisation ihrer Briefmarkensammlung Hilfe leisten.

Since the appearance of the postage-stamps and picture-postcards a large number of countries xx have been taking the opportunity of the considerable propagandistic and economical possibilities to present on postage-stamps and/or on picture-postcards their caves, the geological formations of these caves, the historic events relating to them and living creatures living in them. In the scope of my introductory paper I should like to define this spelaeologico-philatelistic motive, to shape the individual types and to assist the new-fangled stamp-collectors to systematize their stamp-collection.

A barlangos bélyegek, képeslapok tipusai

A bélyeg és képeslap megjelenése óta igen sok ország élt azzal a hatalmas propaganda és gazdasági lehetőséggel, hogy barlangjait, annak képződményeit, az ottani történéseket, élőlényeit bélyegeken és/vagy posta képes levelezőlapokon mutassa be. Vitacikkemben ezt a szpeleofilatéliai motivumot szeretném lehatárolni, az egyes tipusokat kialakitani, valamint segitséget adni az új gyüjtőknek az anyaguk rendszerezésében .

1. SPECIFICATION OF A MOTIVE.

I have classified as postage-stamps and picture-postcards containing cave-motives all the art-publications having been related unambiguously to the caves and to the spelaeologists as well. Setting the limits of a motive would be inevitably subjective. I know the opinions written or enounced by many of my fellow-collectors in this subject. With full knowledge of these opinions I have tried to trace the limits considered to be valid by myself as well.

2. THE SHARE OF OCCURRING OF THE CAVE-MOTIVES.

The collection of the postage-stamps and picture-postcards would be parallel only in special cases therefore I will treat the relevant activities synchronously only in the case when I could accomplish some simplifications in this way.

Having taken into consideration some philatelistic evaluations it can be said that postage-stamps of about 400.000 various types have been issued all over the world so far. Within this enormous amount I could classify 771 issues as cave-motives containing ones on the basis of the Michel, Scott, Zumstein and Yvert catalogues and on the evidence of a number of private collections. It indicates a 0,2 p.c. share related to the issues and it does not signify an exceedingly high one. /However taking into consideration the share of 0,01 p.c. of the Hungarian spelaeologists having arranged the 10th Congress of Spelaeology relating to the population of their native country, the general pattern would not be so alarming at all.

Within the range of the picture-postcards the share of the cave-motives is more significant. Having taken into consideration a large amount of picture-postcards numbering a few hundred thousands reviewed by myself at the Museum of Picture Postcards settled in Szerencs and at some collectors and stamp-dealers I am of the opinion that the share of the cave-motives could be estimated to be within a range of 0,4-0,8 p.c. in any unselected stock of postage-stamps. /As an additional data could be mentioned that the Handbook of the Collectors of Picture-postcards has been publishing two hundred picture-postcards and among the units of this material one could be classified as a motive in question/.

3. THE TYPES OF THE CAVE-MOTIVES.

In the Tables 1 and 2 I will exemplify the types of the cave-motives established by myself. Having some informations more detailed relating to the postage-stamps in question, these tables could indicate exact figures /and the corresponding p.c. values too/ within the range of each types as well. However in the case of the picture-postcards I have established a sequence of comparison containing some "semi-quantitative conclusions.

The relevant types are as follows:

3.1. The ornamental elements /i.e. the stalactite/stalagmites, cave-ice and other formations/ could be demonstrated on picture-postcards above all. Their share within the range of the stalactite/stalagmite elements are representing the bulk.

3.2. The actions carried out in caves have been demonstrated rarely on postage-stamps and in addition they are relatively sporadic on picture-postcards as well /with the exception of the caves where a touring group is represented on the picture/. As a matter of curiosity scenic railways or boats could be represented within a postcard-series, however their number is generally low even taking into consideration e.g. the world-famous Blue Cave in Capri having been accessible only sitting in a boat /i.e. using a boat/.

3.3. Rock-engravings and cave-paintings could be defined and identified problematically similarly to the definition of a "cave". In many instances I could not identify quite exactly whether a human work of art were be placed in a cave or under an overhang or on a rock-surface out of the cave. I have rejected some items where I could not separate exactly the probability of a cave-environment. I have left in the bulk the cases where I could not state or identify these circumstances. /Probably in this subject would be the assistance of the stamp-collectors the most effective and useful/. This type of the motives is the most frequently recurrent one occurring on the stamps /in a share of about 25 p.c./, whereas it occurs on the picture-postcards relatively infrequently /the reason for this is that caves in question are situated in relatively remote regions and on the other hand the caves containing such works of art not developped for the frequentation to be accomplished by the general public - for the very reason of the protection of these works of art. Therefore in the case of a cave not frequented by the general public the issue of the relevant picture-postcards could not be a thriving business/.

3.4. Among the animals related to caves bats are the most significant and well-known. Unfortunately in a number of cases it is not easy to decide that a species or subspecies in question is living also in caves. In addition the zoological labelling of the bats is adherent to the notion of a cave to such an extent that I had not the intention to divide them into groups either of cave-friend or not cave-friend ones. I am taking rather the risk of getting non cave-friend bats /e.g. tropical plant-eating ones/ into my collection. A relatively large number of the postage-stamps of this type have been issued so far /their amount is approximately equivalent of the postage-stamps containing pictures of stalactites/stalagmites representing such motives/. However picture-postcards of this type are very rarely available and in addition these stamps have been issued rather for representative purposes. Cave-bear and newts, fish and birds are rarely depicted on postage-stamps and presented on picture-postcards very sporadically or not at all.

3.5. Notable spelaeologists and cave-explorers have occurred only on postage-stamps in my experience so far. Also in this case we encountered a problem of the definitive limitation. On the basis of individual opinions could be classified as persons in question Avicenna /having mentioned some caves/, A. v. Humboldt /having described a number of caves discovered and explored by himself/ or Otto Herman, the "father of the Hungarian spelaeology". However I had omitted Avicenna from the list of the above mentioned persons because mentioning him - and taking into considdration other persons having described a cave in a work written by then - would make the motive in discussion indefinite or vaguely identified.

3.6. The ruined cave-remains, natural vaults and stone-bridges have stirred up the imagination of many stamp-designers and publishers of picture-postcards. A large number of postage-stamps have been issued so far and their share has been approximately equal to the shares of the issues presenting the ornamental elements of the caves. Among the picture-postcards the littoral wave-cut stone-bridges and vaults and partly ruined caves are typical because the sea-coasts are frequented generally by greater masses of people and they are representing a greater salaried one. The national limitation of the relevant picture-postcards is generally very simple.

3.7. Cave-entrances are unambiguously recognizable having been main motives or secondary ones on picture-postcards presenting a secenery or a landscape. Their representation on picture-postcards is also wide-spread however there are serious problems of identification raised by the miniature dimensions of the postage-stamps /of course either the catalogues or the local knowledge could assist the process of identification very successfully/.

3.8. In caves and cave-entrances have been frequently built castles, strongholds, houses or other human establishments. In spite of this fact they have been presented in very numerous cases neither on postage-stamps nor on picture-postcards. I have included them into the series of churches or temples hewn in living rock situated not infrequently on various sites. Their share of occurring on picture-postcards is considerable because the religious masses of people are providing the potential customers. Their identification and classification will raise some problems because quarries, artificial cavities and quarried /or enlarged/ caves have been labelled frequently as "cave-churches" and it would be inscribed on the picture-postcards as well. Although they are not caves in literal sense, I had to class them in this group in accordance with my definition.

3.9. The art of painting preferred ever the cave-motives. On postage-stamps are occurring frequently mithological subjects having been enacted in caves or in front of cave-backgrounds /e.g. birth or departure having taken in a cave, saints living in caves etc./. On picture-postcards this subject occurs more rarely, they are occurring in larger numbers on series presenting paintings situated in museums.

3.10. Bats are depicted on coat-of-arms or on other objects as decorative elements possibly incidentally in a concealed form. Their share of occurring on postage-stamps is similar to the preceding ones, however on the other hand I did not encounter this subject on picture-postcards so far.

3.11. Gears and equipments used /also/ in the spelaeology could imply acetylene lamps, helmet-shields used for cave-exploring, electrical headlamps, various ropes and rope-knots of various types. In the identification some problems could be raised because the proper place of classification of a postage-stamp presenting mineworkers wearing well distinguishable electric headlamps. /I am of opinion that it cannot be classified in this motive-group with the exception of cases implying as a main motive helmets used in spelaeological explorations. I am considering this subject only tangentially as a significant cave-motive. It occurs on postage-stamps very rarely and in addition I has not found it on picture-postcards at all.

3.12. Exposed travertine-segregations have been recognized on postage-stamps primarily, however they are occurring on picture-postcards as well. It is one of the peripherical subject of the cave-motives because the characteristic formation implies the metastatic correspondence between these formations and the spelaeological ones.

3.13. Maps and vertical cross-sections of caves or cave-entrances have been presented on postage-stamps only sporadically and on picture-postcards also very rarely.

Table 1.

Distribution of the postage-stamps of cave-motives by types.

Types	Items	p.c.
1. Caves with ornamental elements		
1.1. Stalactites/stalagmites	68	8,8
1.2. Cave-ice	1	0,1
1.3. Formations	33	4,3
2. Actions carried out in caves	5	0,7
3. Rock-engravings and cave-paintings situated in caves	190	24,6
4. Animals related to caves		
4.1. Bat	69	0,9
4.2. Cave-bear	5	0,7
4.3. Cave-newt	1	0,1
4.4. Cave-fish	5	0,7
4.5. Cave-bird	1	0,1
5. Notable cave-explorers, spelaeologists and describers of caves	50	6,5
6. Caves partly ruined, natural stone-bridges as follows:		
6.1. Sea-shore formations	47	6,1
6.2. Inland formations	24	3,1
7. Cave-entrance as primary or secondary motive	98	12,7
8. Human establishments situated in caves or in cave-entrances	43	5,6
9. Paintings containing cave-motives	47	6,1
10. Bats in coat-of-arms or as other decorative elements	39	5,1
11. Gears and equipments usable /also/ in cave-exploration	9	1,2
12. Exposed travertine-segregations	32	4,2
13. Maps and vertical cross-sections of caves and cave-entrances	4	0,5
Total	771	100,1

4. POSSIBLE WAYS OF THE DEVELOPMENT OF A COLLECTION.

As every collection, this collection could be changed, modified or increased also by purchase, exchange or donation. The process of exchange carried out with a fellow-collector of similar collecting sphere of interest is very good in the beginning, however we have observed that the collector could not exchange later anything at all. In this case an opening would be necessary and useful towards the collectors collecting "other motives". In addition an extension of the international relations /or a development of ones if they are existing already/. It would be useful to introduce our acquintance in our hobby in a possible high number because we could get unexpected good materials in this way.

Table 2.

Distribution of the postage-stamps of cave-motives by types.

/The types are corresponding with the types contained in the Table 1/.

Type	In bulk	Many	Few	Sporadic	Not seen
1.					
1.1.	X				
1.2.		X			
1.3.		X			
2.			X		
3.			X		
4.					
4.1.				X	
4.2.					X
4.3.					X
4.4.				X	
4.5.					X
5.					X
6.					
6.1.		X			
6.2.			X		
7.		X			
8.			X		
9.			X		
10.					X

5. A PROPOSAL FOR THE ESTABLISHMENT OF AN INTERNATIONAL ORGANIZATION OF STAMP-COLLECTORS.

In the preceding chapter I have emphasized the importance of the international relations. I am considering an organization to be one of these relations to be established /in a form of a section or committee/ in the scope of the Union of International Spelaeology /UIS/ proposed already by other persons as well.

I am considering from this point of view the following reasons:

a/ being in want of international relations only a collection of limited extend could be established;

b/ various individuals and organizations have been trying already long ago to coordinate the relevant collectors having used systematical and regular issues as follows:
Spelaeo-Stamp Collector. 1981 - /editor: Jan Paul van der Pas, Wauwerhofweg 3, 6333 CB Schimmert, Netherlands/;
Geologie-Mineralogie-Palaeontologie-Spelaeologie 1975 /editor: J.C.V. Soeren. Steinknöck 3. D-8520, Erlangen/;
Collections Spelaeologie Alpinisme Explorations /editor: A.G. de Block, Avenue Jean de la Hoese 48, B-1080, Brussels/.

c/ an exchange of informations resp. personal relations are also indispensable in this field.

A proposed solution of this problem were as follows:

a/ to establish an official committee within the UIS, with the aim of organising the exchange of the informations, exhibitions and exchange of the relevant materials, developping the spelaeological philately /spelaeo-philately/ in the various countries, organising and maintaining the relations between the national associations of philately and picture-postcard collecting activities.

b/ publication of a systematically issued review, possibly the acceptance and maintenance of the SSC.

c/ an organized improving of the individual and personal relations.

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ON THE FLUCTUATION OF THE NUMBER OF THE BATS LIVING IN THE LETRASI-VIZES CAVE (BUKK MOUNTAINS, HUNGARY) DURING THE YEARS 1975-1989

LENART, László - BALLA, Béláné

Very far-reaching and many-sided research works and series measurements have been carried out in the cave from the year 1971. Within the scope of these research works at least once in a month has been determined the amount of the bats living in a given cave-section and and the extent of their colonies as well. Studies have been carried out to state the interrelations relating to the number of the individuals and the cave temperature, the carbon dioxyde content of the cave atmosphere and the artificial confinement of the cave space and its public frequentation. Finally the location and settling of each subspecies living in the cave have been studied as well.

A denevérek számának változása a Létrási-Vizes-barlangban /Magyarország, Bükk-hegység/ 1975-1989 között.

A barlangban 1971-től kezdődően igen szerteágazó tudományos vizsgálatok, méréssorozatok folynak. Ennek keretében havonta legalább egyszer megszámoltuk, hogy egy-egy barlangszakaszban hány denevér található és mekkora kolóniákat alkotnak. Összefüggéseket kerestünk az egyedszám és a barlang hőmérséklete, széndioxidtartalma, a barlang mesterséges lezártsága, valamint a látogatottsága között. Végezetül a fajoknak a barlangban való elhelyezkedését is megvizsgáltuk.

ÜBER DIE ZEITLICHE VERAENDERUNG DER ANZAHL DER IN DER LÉTRÁSI-VIZES BERGHÖHLE /BÜKK-GEBIRGE, UNGARN/ LEBENDEN FLEDERMAEUSE IN DEN JAHREN 1975-1989.

Sehr vielseitige und weitverzweigte wissenschaftliche Untersuchungen und messungsreihen wurden in der Berghöhle seit dem Jahre 1971 durchgeführt. Im Rahmen dieser Untersuchungen wurde die Anzahl der innerhalb einer bestimmter Höhlenstrecke lebenden Fledermäuse sowie die Grösse ihrer Kolonien mindestens monatlich einmal bestimmt. Zusammenhänge wurden hinsichtlich der Höhlentemperatur, des Kohlendioxydgehalts der Höhlenatmosphäre, der künstlichen Absperrung sowie des Besuchs der Höhle gesucht. Schliesslich wurde auch die Verteilung der Subspezies innerhalb der Höhle untersucht.

1. INTRODUCTION.

I was an undergraduate geologist-engineer when I have started the survey /i.e. the exploration/ of the Létrási-Vizes cave. It looked to me as if I have observed colonies of bats of numbers varying in time along the same route. I did not know anything about this subject however I had a presentiment that I have had to register both their number and their distribution experienced along my route of measurement travelled regularly. I have considered a series of number changing in time related to the bats having extended to several years to be interessant both for the biologists and nature conservators and in addition the acquisition of the relevant data would not require too much excess work to be done by me.

At present I can recognize and identify several species of the bats /having been instructed by my helpers and co-workers/ and I know where I have to search them within their dwelling sites. In addition I have very enthusiastic and unselfish co-workers interested in the research of the bats living both in the caves and belfries.in the similar degree /the recent paper has been also of joint character in the respect both of the research work accomplished in the caves and the methods of obtaining the data than of composing that/. My data series is rather extensive and in my opinion the experts engaged in protecting the bats could utilize it in the protection of them.

2. THE SITE OF THE RESEARCH WORK.

The Létrási-Vizes cave is situated in the northern part of Hungary in the Bükk mountains. It is a characteristic sink-hole /swaller/ containing several levels and within them there are the following elements: a main entrance /Entrance No. 1/ and an artificial entrance way opened in the year 1971 on the summit of a cave-stack /Entrance No. 4/. The entrance ways have been closed several times although they remained accessible for the bats also during these periods of closing. A number of lateral branches are joined to the main cave branch /Fig. 1/. It can be divided into 5 levels vertically /Fig. 2/. Within the fourth level numbered downwards there is a streamlet periodically active. In the other hand in the cave-sections situated above this level there are dripping streamlets only and under this section rather a system of watering rock-fissures than continuous cave-arms can be found within the cave.

We have collected the data relevant to the bats along the following exploration routes /Fig 1 and 2/:

route A: Entrance No. 1 - hall of the Earthen Head resp. the main-branch as far as the spring-well /from the year 1975 in the beginning weekly, later several data have been missing and from 1982 monthly at least/ - the entrance section of the cave in a length of

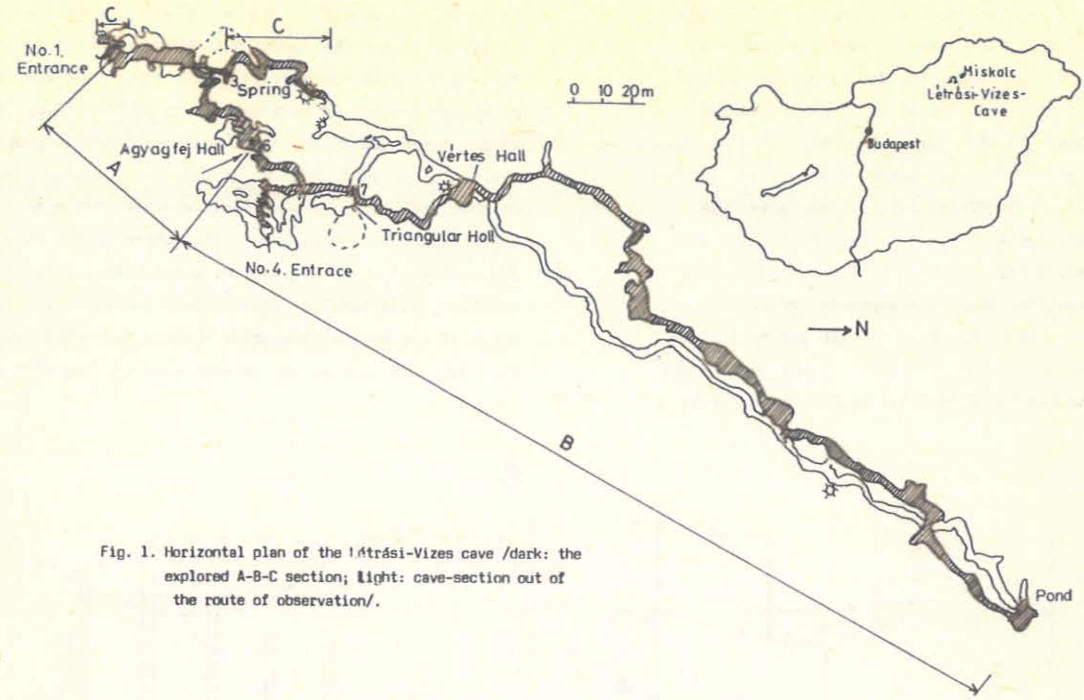

Fig. 1. Horizontal plan of the Létrási-Vizes cave /dark: the explored A-B-C section; light: cave-section out of the route of observation/.

about 150-200 m.

route B: Entrance No. 4 - Triangular Hall - Cave-Pond resp. a joint section as far as the hall of the Earthen Head /from 1982 monthly/. For the minor part the entrance section and for the greater part the proper cave-section, in all at a length of about 1000 m.

route C: the main-branch downstream from the spring-well as far as to the first siphon resp. to the Warming Room /from 1985 weekly/. The entrance section of the cave at a length of about 60 m.

route D: the remaining sections of the cave of the cave, non regularly explored.

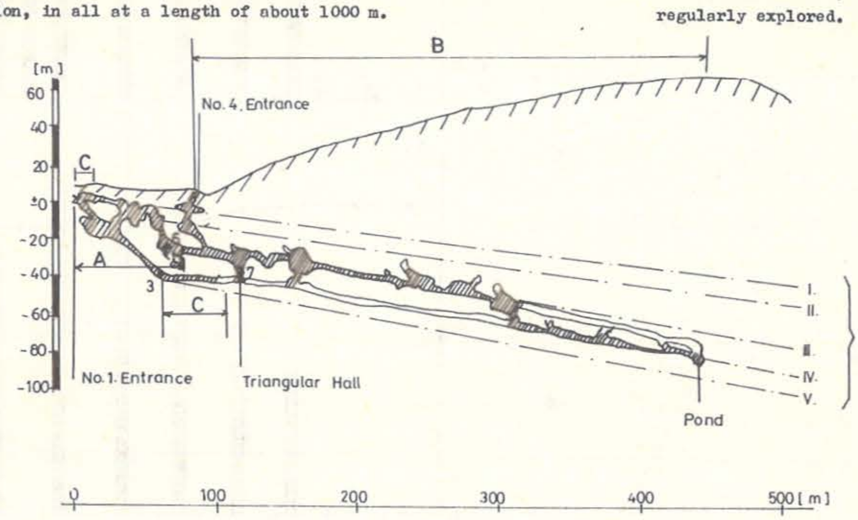

Fig.2. A simplified longitudinal section of the Létrási- Vizes cave projected upon the plane connecting the Entrance No. 1 with the Pond.

3. The method of the research work.

We have emphasize the fact that until the autumn of the year 1984 the observations have been running as "by-products" during the measuring process related to the yield and rate of the dripping water and the cave-temperature, later during the measurement of the water-level of the Pond and of the rate of the streamlet-water resp. having changed the radon-detector units. Since then we have been making regular and systematical tours of bat-observation as well, i.e. this series of research has been involved in the various scientific exploration of the cave./At present the Létrási-Vizes cave is one of the caves subject the most intensively to the scientifis research. About 50 scientific transactions, cca. 10 theses, 2 university diploma works, 2 academy diploma works and 2 theses of scientific habilitation have been written and published within the scope of the geological, tectonical, hydrogeological, climatological, radiological and biological conditions of this cave. Moreover a number of data obtained during the exploration of this cave have been published passim partly in original form in about twenty four scientific and popular books and other publications/.

Along the routes of measurement we have registered the number of the bats. We have separated the individuals hanging lonely resp. in colonies. Within the latter groups we stated the numbers of the individuals living in each colony /at least one of us having been present at the exploration works in 96-98 p.c. of the cases, our data could be compared unambiguously. We have been "tuned up" actually to the dwelling sites of the bats therefore an increase of a few p.c. could occur in the respect of the number of the bats/. We have observed in many cases bats flying about in the cave. The number of these individuals has been indicated with the above mentioned remarks. Finally we have been founding animals died off and we classified them as a separate group.

A fellow-worker having wished to deal with the bats presented oneself at the end of the year 1984. Having the intention of doing that he has identified the species observed in the cave[1-5/]. Therefore on the basis of the observations accomplished during the years 1985-1989 has been known the fact that in the cave the species Myotis oxygnathus blythi and M. myotis are living in a percentage of 65-80 p.c. /they are living mixed and promiscuously but their mutual proportions are not known yet/. Both the species Rhinolophus ferrumequinum and Rhinolophus hipposideros are living in a total percentage of 19-33 p.c. The total share of the other species /M. nattereri, M. dasyoneme, M. emarginatus, Barbastella barbatellus, Pipistrellus pipistrellus/ amount to 1-3 p.c. The share of the bats flying about and not identified amounted to 2 p.c. and that of the animals died off was also 2 p.c.

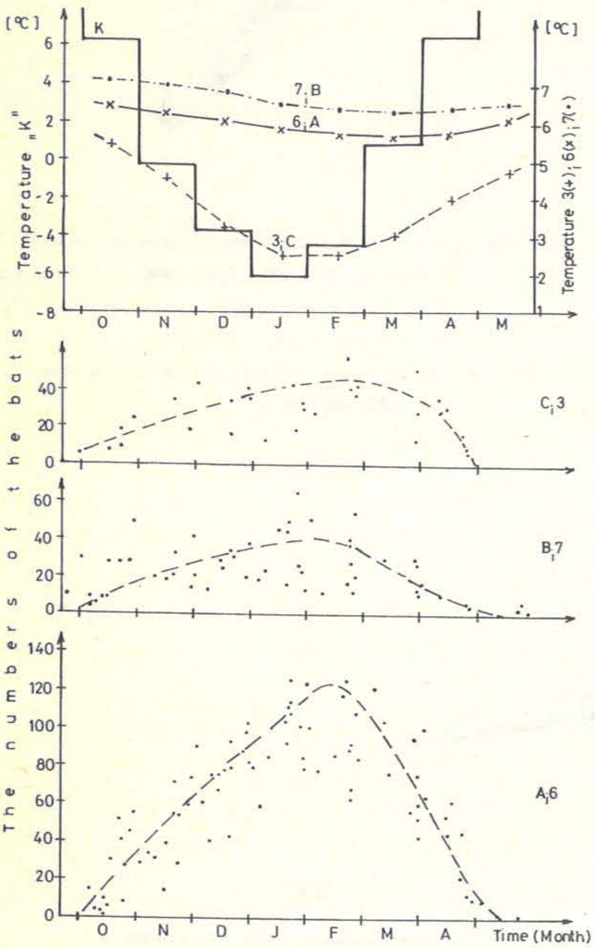

Fig.3. Distribution of the numbers of the bats observed during their hibernation period. /A: route A; Hall of the Earthen Head; 6 thermometers; B: route B; Triangular Hall: 7 thermometers; C: route C; Springwell: thermometer No. 3; K: open-air temperature corrected according to the height/.

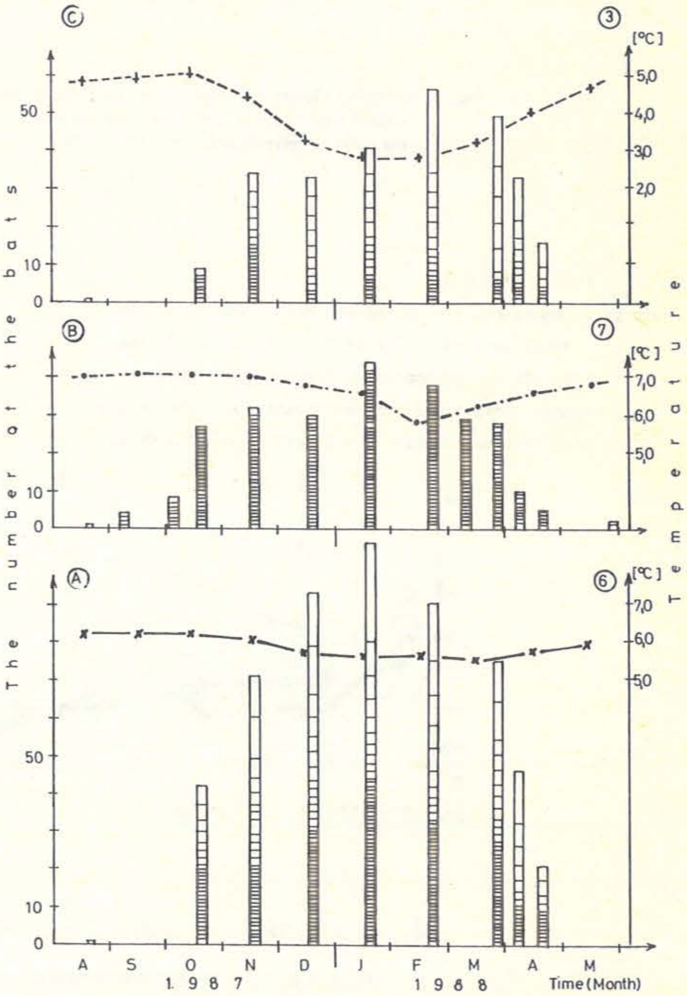

Fig. 4 - Fluctuation of the number of the individuals of the bat-colonies durintg the winterly half-year of 1987/88 according to the routes /A; B; C: routes A; B; C: 3; 6; 7; K: thermometers/.

4. Conclusions.

Taken into considdration our observations a number of unambiguous conclusions can be derived, mainly on the basis of the data obtained for the species Myotis and Rhinolophus living in the cave in the greatest number as follows /however to make the conclusion for the ambiguous cases the collaboration of a biologist would be necessary and useful/.

a/ the species Myotis is rather a significant one for the first /A and C/ sections and the species Rhinolophus is more characteristic for the inner /B/ section of the cave /taking into consideration the conditions of temperature the sections A and B are corresponding to an entrance zone. The actual cave-section is situated along the route B according to the part ranging from the Triangular Hall to the Pond/.

b/ the individuals of the species Rhinolophus have been occurring one by one almost in all cases, whereas the individuals of the species Myotis occurred either one by one or in colonies. The largest colony observed in the cave included 38 individuals and several times colonies having included 10-20 individuals occurred as well.

c/ within the section A /i.e. by far the greatest number of Myotis individuals/ the hibernation have taken a time beginning in the first days of October and ending at the end of April /Fig. 3/. The individuals are living in the greatest number at the end of January and in the middle of February i.e. the "withdrawing" period is taking a time-span of 4-4,5 months whereas the process of "evacuation" is taking a time of about 3 months /it will come out from the relevant figure on the basis of the assymmetry of the given curve/. Within the section B of the cave /i.e. in the case of the Rhinolophus species/ the peak-value will appear at the end of January. Within the section C /where Myotis individuals are appearing almost exclusively/ the maximum has been postponed to the end of February therefore the "withdrawal" includes a period of 5 months whereas the "evacuation period takes a time slightly greater than 2 months /Fig. 3/.

d/ the bats are moving also during the hibernation period and in addition the number of the colonies are fluctuating considerably. To exemplify this process the period of 1987/88 has been presented /Fig. 4/.

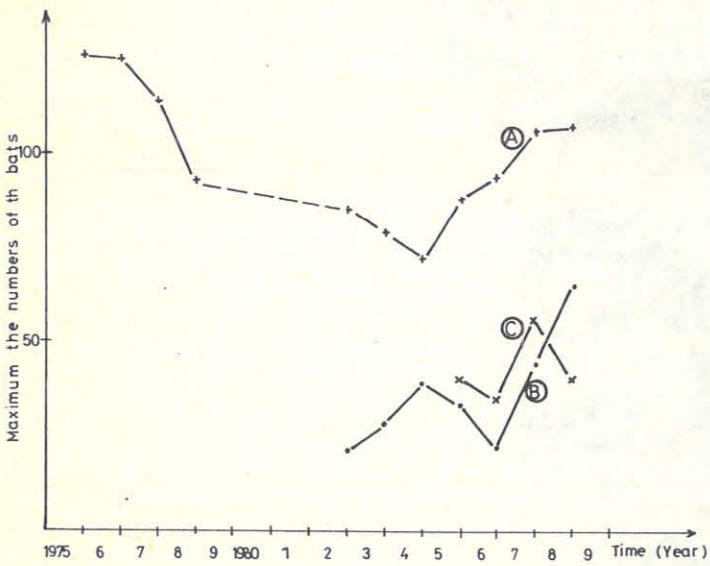

Fig. 5 - Maximum numbers of the individuals living along the various routes /A; B; C. A; B; C: routes/.

e/ within the various sections of the cave the fluctuation of the maximum number of the individuals is fairly unregular and we did not observed any relationship associated with external meteorological factors. Within the route A an expressed decrease has been found for the period 1975-1985 however after this period an unambiguous increase could be observed /Fig. 5/. We have a shorter data series related to the routes B and C and in addition the trend of the process of changing is more unstable. The curves A and B are changing synchronously whereas these curves are changing rather in an inverse trend related to the curve B /this phenomenon could be specific for a given species!/.

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