Cave and Karst Science

The Transactions of the British Cave Research Association

BCRA

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Cave and Karst Science

Authors are encouraged to submit articles for publication in the *Transactions of the British Cave Research Association* under four broad headings:

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Scientific papers, normally up to 6,000 words, on any aspect of karst/speleological science, including archaeology, biology, chemistry, conservation, geology, geomorphology, history, hydrology and physics. Manuscript papers should be of a high standard, and will be subject to peer review by two referees.

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Manuscripts may be sent to either of the Editors: Dr D J Lowe, British Geological Survey, Keyworth, Nottingham, NG12 5GG, UK, and Professor J Gunn, Limestone Research Group, Department of Geographical and Environmental Sciences, The University of Huddersfield, Queensgate, Huddersfield, HD1 3DH, UK. Intending authors are welcome to contact the Editors, who will be pleased to advise on manuscript preparation. Enquiries by E-mail are welcomed, to: djlo@bgs.ac.uk or j.gunn@hud.ac.uk.

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Cave and Karst Science

TRANSACTIONS OF THE BRITISH CAVE RESEARCH ASSOCIATION

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Cover photo: Cone karst in Laos
These cones stand on the edge of a fengcong massif between Thakkek and Mahaxai, in the heart of the Khammouan karst (see the paper in this issue). The bridge in the foreground crosses a small river draining out of a series of mature caves onto an alluviated karst plain that extends to the left. (Photo: Tony Waltham)

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EDITORIAL

John Gunn and Dave Lowe

The final part of the *Cave and Karst Science* editorial process is writing the actual Editorial. This may seem self-evident but sometimes, when we are under a great deal of pressure and have struggled to get another issue published as close to the cover date as possible, it can be the proverbial straw that comes dangerously close to breaking the backs of the editorial camels! Hence, it was with some trepidation that JG decided to mark the completion of our 7th Volume (only 4 months late at the time of typing) by looking back at the 20 previous editorials.

Certain themes have been repeated several times, including our desire to maintain the reputation of *Cave and Karst Science* as an international refereed journal, while simultaneously encouraging a wide range of papers from a wide range of authors. At the same time, in recognition of the fact that *Cave and Karst Science* is also the *Transactions of the British Cave Research Association*, we have tried repeatedly to encourage British cavers to present papers at BCRA meetings, and to offer them for publication in the *Transactions*. The present issue contains the abstracts from the excellent March 2001 meeting in Oxford, where a wide spectrum of topics was presented, both orally and as posters. The 2002 meeting will be held in Leeds, so those interested in attending should keep all Saturdays in March 2002 free, pending an announcement of which date has been chosen. Andy Baker has again volunteered to put the programme together, and a call for papers will be going out later in the year.

In addition to the 'perennial' issues, we have tackled a number of themes, sometimes provoking a rash of correspondence, sometimes a disappointing silence. The recent Editorial on water tracing was in the former category, as several people contacted us to say that they too had experienced problems with 'false positives' when using fluocapteurs, and one promised a future paper on the vexed question of 'how much dye' to use. JG was also asked to write a more general article for cavers, and this was published in *Caves and Caving*. Mention of the forthcoming *'Encyclopedia of Cave and Karst Science'* in the last issue also resulted in a greater than normal number of E-mails and offers of articles. In this issue we thought that we would raise a less practical, and almost certainly more controversial, topic - the question of the use of scientific terminology by cave and karst scientists.

We have been stimulated to do this by considering the article by Trevor Ford on 'vein cavities' in Volume 27(1) and the additional information on 'vein cavities' in the Castleton caves provided by John Cordingley in Volume 27(2). Use of that invaluable scientific tool the 'back of a fag packet calculation' suggested that if all the 'vein cavities' in the Peak-Speedwell cave system were to be stacked one above the other the total height (?depth) would be well over a kilometre, and possibly more than 1,500m. Thinking that this might be of interest to readers, we asked John if he would compile a table with some accurate dimensions, enabling total height and volume to be computed. John encountered problems trying to decide what to include or leave out, and asked for an exact definition of a 'vein cavity'. Of course, no definition as such has ever been provided and, to complicate the issue, not all of the cavities listed are actually located on a mineral vein, and some show no signs of mineralisation!

In attempting to satisfy John's request for a helpful definition, we were at once confronted by a mass of possible aspects to consider (age, size, morphology, morphological relationships, geological constraints, type of mineral occurrence, mode of genesis, etc) and an equally daunting set of potential contradictions. We were faced by the age-old dilemma that "...everyone knows, or thinks they know, what they mean when they use the term 'vein cavity'". At least that's the case until they are asked to define the term and suggest valid criteria for use in recognising such features.

The case of 'vein cavities' is by no means unique within the cave and karst sciences (nor indeed within some other sciences). All too commonly a term has been adopted by a scientist to describe a single example of a feature, or a suite of similar features in a specific context, but the term has subsequently been used to describe features that might be "not quite the same" in different contexts. Elsewhere terms that were coined as convenient shorthand to describe a feature, a regime, or a process have had their supposed meanings ruthlessly extended, with or without the addition of appropriate (or inappropriate) prefixes, suffixes or whatever.

We have in the past, for instance, supported a discussion within these pages of the meaning and range of the term 'pseudokarst', so far as we know without any widely acceptable conclusion being reached. Equally, the underlying turmoil surrounding the term 'karst' itself, and the myriad qualified offspring terms that have been spawned from it, is no closer to being calmed, whereas even the seemingly clear-cut term 'cave' means different things to different people. Beyond that, the karst stage is littered with terminology that is undefined, poorly defined or defined specifically and then used in an inappropriate, unspecific, fashion. We have only to think of everyday terms such as 'vadose' and 'phreatic', together with their supposed link, the 'water table', to see that even the simplest-seeming terms can cause confusion if taken beyond their original context without due thought and consideration.

Scientifically speaking the answer is, of course, 'up front' and simple – always define your terms before you use them, so that future readers will know if you are using an expression in the sense that it was originally coined, or whether you have imposed additional considerations upon its use. However, it would be a truly Herculean task if we had to redefine every scientific term that we used in every publication, and the whole point of introducing the verbal shorthand would be defeated. Even if we do take the trouble to do this, it may not lead to the hoped for understanding and acceptance of a term's current use.

Taking a specific and admittedly personal example, eight or nine years ago, one of us (DJL) produced a PhD thesis that attempted to introduce lateral geological thinking into aspects of karst and cave development. Realising that such views required that caves and, indeed, karst as he then understood them, be considered in an altogether wider context, the author went to the trouble of examining a selection of existing definitions and the scopes of their use. He then provided wider definitions of the terms for specific use in the context of the thesis and the hypothesis that it presented. Equally importantly, he looked at terms used previously to describe the themes under discussion, decided that they could NOT be stretched to cover some new ideas, and coined and defined new terms, with more specific meanings. Whereas this pragmatic step served its purpose in both respects, it has led to subsequent confusion, if not controversy. On the one hand some workers consider that the widening of these existing definitions takes the processes discussed in the thesis outside the realm of cave development. On the other hand others have said that the "new" and narrowly defined terms are superfluous, because the ground they cover is already catered for within terms with wider definitions.

As stated, the above is just one personal example, but it points out the very hub of the problem – well-used and well-loved terms will continue to be used, in some cases grimly and "unto death", even if their original meaning and significance are devalued. Meanwhile, specific attempts to remove confusion will commonly be ignored or overlooked. The opposite argument, if we understand it correctly, is that generation of new and more specific terminology is itself confusing and unjustified if something falls within a pre-existing but wider definition. This leads to obvious questions such as '...why call something a tiger when you could call it a "big stripey cat"?'.

We do not claim to know the answer here. However, returning to the case of John Cordingley's 'vein cavities', we have adopted the pragmatic view that provision of a definition that is meaningful in the context of John's study is a valid expedient. Adoption of this definition, for this study, is without regard for whether it ignores elements that are accepted explicitly or implicitly in current everyday use of the term, or indeed whether new constraints are introduced.

A huge mailbag of contributions is expected on this general topic, both from those who have had their own problems with the use or abuse of undefined, poorly defined or over-stretched terminology, and from those who think they know how to improve things in the future. If we receive responses and suggestions that are of interest to the readership in general, we will revisit the problem in later issues of the *Cave and Karst Science Forum*.

Our review of the past 7 volumes of *Cave and Karst Science* also reminded us that there have been only two 'theme issues'. Volume 22(2), in 1995, was the report of the Yangtze Gorges Expedition, and Volume 25(2), in 1998, contained papers on aspects of the Andros Project in the Bahamas, written as a tribute to the life of Rob Palmer. A number of people have suggested to us that it would be appropriate to have another Theme Issue dedicated to a pioneering cave diver, Graham Balcombe. We are very receptive to the idea of a Theme Issue on cave diving, highlighting in particular the scientific discoveries made by divers. However, as this is an area in which we have no specific expertise, a Guest Editor is needed, and we would welcome genuine offers from anyone who is suitable qualified and appreciates the amount of effort that the task will involve.

Moving on to a brief consideration of the contents of this Issue, we wish to comment on two aspects. First of all we have departed from our usual practice by including two reports by the same author in a single Issue. We justify this on the grounds that the two reports (one joint-authored) cover related aspects of a single topic, and they are at least partially complementary. Secondly, throughout our editorship we have attempted to use *Forum* to include information that is both of scientific interest and of more general interest to cave and karst scientists. The articles in the current issue concerning 'Histoplasmosis in Southern Africa: an epidemiological update' and 'Furuncular myiasis caused by *Dermatobia hominis* in a caver returned from Belize' are cases in point. Each provides a reminder that tropical caving has a range of hazards beyond those associated with exploration of the caves themselves.

As this is the final Issue in Volume 27, we wish to acknowledge the assistance of the following reviewers, additional to ourselves, all of whom have given generously of their time, some to referee more than one Paper or Report: John Beck, Simon Bottrell, Rain Curl, Russell Drysdale, Ian Fairchild, David Gillieson, Helen Goldie, Adrian Gregory, Stein-Erik Lauritzen, Armstrong Osborne, Martyn Pedley, Paul Wood and Chas Yonge.

In closing, as previously, we stress yet again that we could not hope to produce a publication of such a high standard without the good-will, co-operation and forbearance of Jean Reeve, who does all of our Desk Top Publishing work, and the staff at the Sherwood Press in Nottingham, who continue to provide a ready response to our sometime unpredictable publishing schedule. Our thanks to all of them.

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Contribution of airflow to the control of seasonal variations in radon concentration in Ogof Ffynnon Ddu, Penwyllt, South Wales

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Abstract: A new winter and summer investigation of radon concentrations in the Ogof Ffynnon Ddu system at Penwyllt, South Wales, was carried out using 100 standard National Radiological Protection Board track etch detectors. Fifty detectors were installed in the system in December 1998 and August 1999 for a period of 28 days. The data obtained confirm that the system has moderately high radon concentrations with mean values of 2,318 Bq m^{-3} in winter and 2,844 Bq m^{-3} in summer. Traverse means showed that OFD I to Cwm Dwr has the highest mean concentration of the system in summer at 3,094 Bq m^{-3}, and has the lowest mean in winter, 1,946 Bq m^{-3}. The extremely high concentrations reported from the system in a previous study have not been reproduced. A significant find from the data was that the airflow directions at the entrances are not what might have been predicted. In the main, air appears to be emerging continuously from the lowest entrance but, counter to predictions, air enters at the higher entrances in winter and appears to come out or be variable in summer. Inside the cave there are sites that have very low radon concentrations in winter, and this can only be explained by ingress of fresh air from the surface. This ingress is a surprising result, given that warmer cave air might be expected to exit at these points. The low readings are not matched in the summer experiment results, indicating again that ingress of fresh air to some parts of the system is very variable. The complexity of airflow within a multi-entrance system is thus illustrated.

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INTRODUCTION

Production of radon 222 as part of the decay sequence from uranium is well understood, and the geological factors behind its distribution are also relatively well known (e.g. Ball *et al.*, 1991; Ball and Talbot, 1994). However, gaining an understanding of how radon concentrations are controlled within cave systems is an extremely difficult task (e.g. Gunn, 1991; Gunn *et al.*, 1991; Hyland and Gunn, 1994). Even in single entrance systems where the main entrance/exit for the air is clear, there are usually many smaller exits that may be taken by air, through otherwise impassable cracks and fissures. In multi-entrance systems, understanding how each entrance interacts becomes a much more complex task. It is well known that factors such as air pressure and temperature, as well as wind direction, control the distribution of radon (e.g. Gunn, 1991; Gunn *et al.*, 1991). The amount of water flowing through a system, particularly that issuing from waterfalls, can generate strong air currents that will control, at least locally, the concentrations of radon. Additionally, the creation and removal of a sump by changing water levels can also play an important role in controlling airflow between different parts of a system, as can such more mundane points as whether and for how long a cave is solidly gated. Opening and closing a solid gate does change the internal airflow significantly, and this change will inevitably control the distribution of radon through parts of the system as the air moves in response to such disturbances. It is understood that whereas some generalisations may be made, each individual cave system is likely to be quite different in the way it reacts.

It is emphasised here that for professional cavers, cave (and/or abandoned mine) systems are defined as work places, and the requirements of legislation regarding the control of exposure to ionising radiation are fully implemented into this setting (Health and Safety Commission, 1988; I.R.R., 1985, 1999). Therefore, any persons entering a system for the purposes of work must be aware of their responsibilities, and discharge their obligations under the legislation correctly. However, recreational caving, where there are no financial or other contractual arrangements in place, is not so constrained. None-the-less, it has long been recognised that there are good reasons to limit, as far as is practicable, exposure to any radiation, so that only the minimum dose is acquired. The National Radiological Protection Board (NRPB) have recommended that in any one year those undertaking only recreational caving should not exceed a time-integrated exposure of 10^6 Bq m^{-3} h (Kendall, 1995), a recommendation fully endorsed by the National Caving Association (NCA, 1996). Because it is prudent to limit exposure to radiation, to be able to assess any potential radiation risk from caving requires that radon concentration data are available. This in turn requires that databases for individual cave/mine systems are acquired. This paper represents a continuation of that process and attempts to explain some of the variations that can occur in the data.

One previous radon survey of the Ogof Ffynnon Ddu system was carried out in 1991-1992. TASTRAK detectors were placed on parts of the main through route of the cave system by members of South Wales Caving Club (SWCC) for a study by R Hyland, and these data are described in an unpublished thesis (Hyland, 1995). Concentration data were obtained for the months August, November, February and May and presented as maxima, minima, means and standard deviations. The August experiment recorded very high (up to 20,000 Bq m^{-3}) radon concentrations in some parts of the system. As part of its brief for managing the Ogof Ffynnon Ddu Site of Special Scientific Interest (SSSI) and National Nature Reserve (NNR) at Penwyllt, the Countryside Council for Wales (CCW) decided to re-investigate the radon concentrations in the underground system. Part of this study would be an attempt to investigate the very high concentrations previously reported.

GEOLOGY AND RADON

In the upper Tawe valley the main rock units belong to the Devonian and Carboniferous systems and a summary of the stratigraphy and regional setting of the rocks can be found in Barclay *et al.* (1988) and Lowe (1989). Various details of the characters of the cave-bearing limestones in the vicinity of Penwyllt and the relationship of the cave to sedimentology and structure have been described previously (Charity and Christopher, 1977; Smart and Christopher, 1989; Ball and Jones, 1990). Briefly, the oldest beds are red Devonian sandstones, which underlie Lower Carboniferous strata largely comprising limestones and grey, calcareous sandstones. The limestones are commonly well-cemented, and recrystallised with much sparry calcite. They exist in a reduced state, with much finely disseminated sulphide (e.g. Ball and Jones, 1990). Straddling the Carboniferous/Devonian boundary, red and grey grits and conglomerates of Courceyan age pass upward without any apparent significant break in sedimentation. Instead a change of depositional environment led to development of the Lower Limestone Shale sequence, dominated by dark, calcareous mudstone and limestone (e.g. Barclay *et al.*, 1988; Lowe, 1989), which is locally overlain by a thin oolitic limestone (Abercriban Oolite), also of Courceyan age.

The next higher unit, the Dowlais Limestone Formation (previously the Cil-yr-Ichen Limestone) of Holkerian (S_2) age follows the Courceyan beds unconformably. Rocks representing the Chadian and Arundian stages (K and C zones) are missing, and in the east the Dowlais Limestone oversteps the Abercriban Oolite and overlies the Lower Limestone Shale (Barclay *et al.*, 1988). Most of the cave system lies within the Holkerian rocks, which are well-bedded and jointed, and vary from relatively pure bioclastic limestone with a micritic matrix through to sparry bioclastic rocks that have undergone diagenetic or later recrystallisation. Sporadic beds of oolite with a dark-coloured micritic matrix are also present and, when fresh, the limestones are black or dark-grey. The limestones show grading and in some instances there is also evidence of emergence. Thus, the limestones are interpreted as the deposits from environments varying from subtidal shelf to intertidal backswamp (Barclay *et al.*, 1988). Organic-rich units from the latter environment are in a reduced state, and potentially contain uranium minerals.

Overlying the Dowlais Limestone, the (Asbian) Penderyn Oolite largely comprises massive, pale grey oolites above a thin basal bed of mudstone or calcareous sandstone. A higher calcareous sandstone, known locally as the 'Honeycombed Sandstone' due to its carious weathering, may also be present. Overlying Brigantian rocks, known as the Penwyllt Limestone (middle D_2 Zone), contain many subaerial surfaces and beds that commonly include prominent chert layers.

Radon 222 is a product of the radioactive decay of uranium, which is usually present in very small amounts (parts per million) in most rocks. For the purposes of this study two other isotopes (Rn-219 and Rn-220) have been ignored because, with relatively limited abundance and extremely short half-lives, they do not contribute significantly to radiation exposure. It is known that Rn-222 concentration varies according to many different parameters but, initially, it is controlled largely by the amount of uranium in the surrounding rocks (Ball *et al.*, 1991; Ball and Talbot, 1994). In a reconnaissance analysis no dissolved uranium was detected in stream water flowing from the Devonian sandstones onto the Carboniferous at the Nant Byfre sink. However, in the water that emerges as the Byfre Fechan, at the Ffynnon Ddu resurgence, detectable uranium was found at c.5 ppm. This is at least a qualitative indication that soluble uranium occurs within the limestone units through which the water flows and within which the Ogof Ffynnon Ddu system has developed.

The most significant units as a potential source of uranium are horizons containing thin black shales and mudstones that are relatively rich in organic debris. Such layers, interpreted as representing palaeosols and other emergent surfaces, are well displayed, for example, in the Penwyllt Limestone, at Penwyllt Quarry. In some cases they may indicate the temporary development of emergent surfaces in an otherwise marine or near-marine sequence. Because of their highly reduced state these units, potentially contain higher amounts of uranium than the more typical bioclastic limestones. Uranium may be present in the ordinary limestones at concentrations that commonly reach 2 ppm but which may be up to 10 ppm, normally held within the organic portion of the cement (Ball *et al.*, 1991, 1996).

Various mechanisms that are used to explain the release of radon gas from U-bearing compounds, and the factors controlling its emanation, have been discussed by Ball *et al.* (1991). Whereas radioactive decay will always take place, gaseous daughter products cannot escape unless a route to the atmosphere is available, and many remain locked in the rock. Release of radon depends upon several factors, most notably the fluid transmission characteristics of the rock (Ball *et al.*, 1991). In the case of the limestones at Ogof Ffynnon Ddu, many of the passages contain water and, as radon is soluble in water, transport may be enhanced. There are many examples of water seepages along joints and fractures giving rise to calcite curtains and stalagmites, simultaneously allowing release of dissolved radon into the atmosphere.

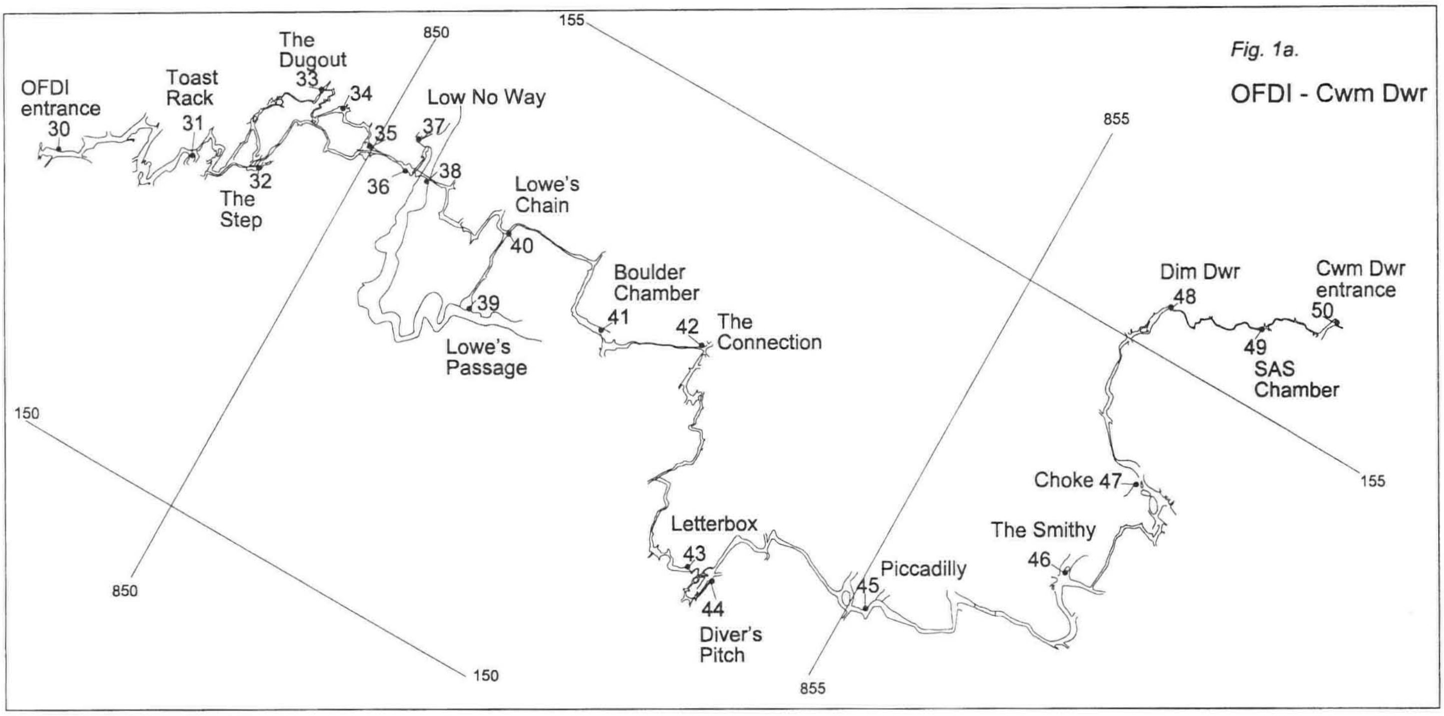
When freshly broken many of the limestones have a characteristic oily or sulphurous smell, which may relate to disseminated sulphide minerals or can be associated with hydrocarbons. At Ogof Ffynnon Ddu both may contribute because, as well as containing sulphide, some of the limestones also contain traces of bitumen (e.g. Barclay *et al.*, 1988; Ball and Jones, 1990). The rocks are, therefore, generally in a reduced state and conducive to containing uranium. However, surface waters flowing into the rocks are acidic, largely from the peat on which they collect. The aggressive water causes dissolution and oxidation, and consequently any uranium in the rock can be released into the fluid system and then removed in solution.

The uranium may also undergo decay to daughter products, including radon gas, that may migrate to join the atmosphere of the system (e.g. Ball and Talbot, 1994). Such migration from the rock into the atmosphere is facilitated by the fractures, normally joints and faults, present in the limestone. All of the limestones are regularly jointed and in many places the joints have either been widened by dissolution or expanded by ice during freeze-thaw action, thus aiding egress of radon from the rock. Fault lines are also known within the system. Most are complex features with many anastomosing fracture sets, rather than one identifiable plane. Many faults have been the site of deposition of sparry calcite that effectively seals most of the fractures. However, in some places the rocks have not been resealed, and open fractures that might provide sites for enhanced radon egress are still present.

STUDY METHOD

The Ogof Ffynnon Ddu cave system comprises at least five interconnected parts, OFD I, OFD II, OFD III, Cwm Dwr and Cwm Dwr II, which together have an overall passage length in excess of 80km (SWCC, 1992). There are several other important parts of the cave that have yet to be fully penetrated although known to be connected, such as the sink at Pwll Byfre (SN8767 1647; 492m) and the resurgence section at Ffynnon Ddu (SN8473 1505; at 182m). Additionally, there are minor segments of cave such as Twll Gwynt Oer (SN8587 1659), not included in this total, that presently are only known to connect by dye-tracing, but which contribute stream waters to the main system. There are at least five possible entrances to the system but only three, all artificial and solidly gated, are commonly utilised. These three entrances have a maximum altitude difference between the lowest and highest of some 230m. The lowest entrance is at Ogof Ffynnon Ddu at 205m (SN 84789 15198) An intermediate entrance, Cwm Dwr, lies at 340m (SN 85745 15592), and the highest entrance, Ogof y Nos Hir ('Top Entrance') is at 436m (SN 86360 15877).

Thus, there is the likelihood of very complex airflow and it is clearly an enormous, if not impossible, task to develop a detector placement plan that covers all of this large, multi-entrance system adequately. An obvious approach is to place detectors on a main route that is used frequently. Whereas this appears to be relatively practicable, any detectors located on a main route will potentially be subject to fluctuations due to ingress of air from unmonitored parts of the system. This is particularly the case in the Ogof Ffynnon Ddu system, where



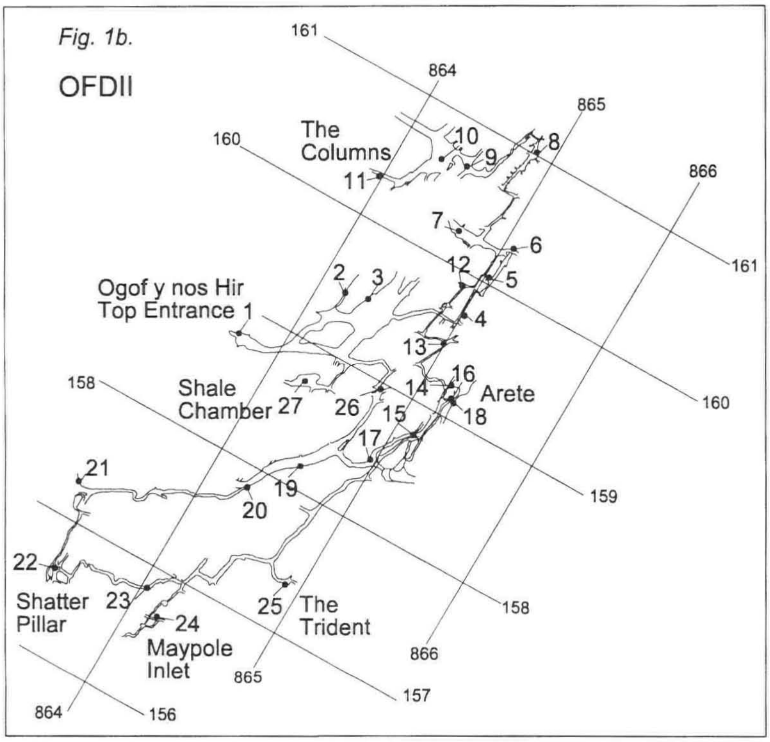


Figure 1. Summary sketch of relevant parts of the Ogof Ffynnon Ddu system, taken from SWCC (1992) showing the location of the detectors. a) Traverse from OFD I (SN 84789 15198) to Cwm Dwr (SN 85745 15592). Numbered National Grid squares are 500m apart for scale. b) Traverse in OFD II (SN 86360 15877). Numbered National grid squares are 100m apart for scale. These sketches are provided for location purposes only and ***must not*** *be used as a basis for any navigation within the system.*

there are many side branches, some parts of which involve sumps. Also, due to the technical expertise required, some of the farther reaches of the cave system, OFD III for example, are not generally visited by large numbers of cavers. Therefore, those parts of the system that are visited by relatively few cavers were given a low priority for monitoring. Despite all the possible pitfalls, a plan was eventually devised for 50 detectors to be placed in the cave (Fig.1).

The NRPB track etch detectors used were squares of PADC (polyallyl diglycol carbonate) mounted inside a domical plastic diffusion chamber as routinely supplied. Typically these have a dynamic range of 10KBq h m^{-3} to 2MBq h m^{-3} and the data have an uncertainty of 15%, inclusive of background, counting statistics and variations in etching. The detectors were supplied by the NRPB in radon-proof bags and were initially kept outside any building until they were put in place over the course of two days. At the end of the specified month they were collected during a similar time, in the same order that they were emplaced. In each experiment, therefore, each detector spent the same length of time in the cave. Return to the NRPB was accomplished within the week, and development by the NRPB took place as soon after receipt as possible.

The chosen routes for study were firstly to cover OFD I, parts of OFD II and Cwm Dwr by starting at the Ogof Ffynnon Ddu entrance and coming out at Cwm Dwr, and secondly a round trip in OFD II using only Top Entrance (Fig.1). As explained above OFD III, with relatively few visitors, presently remains unmonitored. The exercise was carried out twice, firstly under winter and secondly under summer conditions, in order to reassess the seasonally controlled concentration differences that were known to occur. Some of the detectors were to be placed as near as possible to the positions used by the SWCC in the previous study (Hyland, 1995), hopefully to provide further corroboration (or otherwise) of those data. Whereas this would not guarantee direct comparability, it might at least give a guide as to what variations might be observed over a number of years. The remaining detectors were to be placed in other parts of the system in order to provide a more complete coverage, and particular attention was paid to having detectors at different elevations within the system. This might reveal something about variations in the vertical radon profile in certain shafts, and so represent potential airflow routes.

RESULTS

Detectors numbered 1-27 were placed on a round trip in OFD II with a side trip down to The Columns area (Fig.1b; SWCC, 1992), and those numbered 30-50 were placed on a through trip from OFD I to Cwm Dwr (Fig.1a, Table 1). The two sequences were essentially separate, as the link is through an active streamway that is prone to flooding. As it was considered important that recovery of the detectors should be accomplished on time, this relatively small part of the route through the system was avoided. Two other detectors were placed above ground to monitor the free-air and background concentration internal to the SWCC headquarters. Detector number 28 was placed inside the HQ and number 29 was placed outside, initially under the overhang of the garage roof. As this detector was flooded by rain the position was moved to inside the garage for the second experiment. For each experiment a record of direction of the airflow at the entrances on the day of placement and recovery was noted. For both experiments the air was observed to be going in at Top Entrance and at Cwm Dwr, and coming out of OFD I, during placement and recovery. The data accord with most verbal reports, which are of air issuing consistently from the OFD I entrance, whereas airflow direction at the other two entrances is variable.

December 1998

Fifty detectors were put out for the period 28/11/98 to 01/01/99. The overall experiment was disappointing because, rather surprisingly, 12 of the detectors placed along the OFD II traverse were rendered ineffective due to water ingress (Table 1), such that a film of water on the plastic detector sheet inside the detector prevented alpha particles from damaging the plastic surface. It is emphasised that it is very unlikely that this was due to interference and tampering with the devices, because three of the detectors involved were placed in a locked portion of the cave (numbers 9-11). Care was taken when initially siting the detectors in the cave to ensure that they were not in direct contact with running water or placed in particularly wet positions. However, detector number 29, placed under the garage eaves, was certainly swamped by rain because the eaves gave insufficient protection. Detector 9 was placed at the Drip Towers formation in The Columns area, and this might have been subject to splashes during very wet weather conditions. All of the other ineffective detectors were located in relict or dry areas of the cave and the data could only have been lost due to the effects of condensation. This result also surprised the NRPB, and time was spent discussing why the data loss had occurred. As part of the normal preparation routine the detector housing is coated in detergent - ordinary washing-up liquid - that when dry acts as a static suppresser. As the detergent contains quantities of sodium salts it is hygroscopic and so attracts moisture. After testing to ensure no loss of sensitivity, the NRPB recommended that to prevent water ingress in the second batch of detectors, each should be wrapped in Clingfilm, which is radon-porous but waterproof, and seemingly allows the detector to equilibrate relatively quickly. This method actually followed that used in the experiments carried out for Hyland (1995), where the plastic detector sheet was laid in the bottom of a plastic cup, the mouth of which was covered with Clingfilm.

The dataset for the winter experiment (Table 1) returned some interesting results (Fig.2a, b). Data for the two traverses are plotted against approximate distance from a known entrance and they show quite different features. Some of these were as expected from the geometry of the cave, but others suggest that there was at times a complex movement of air within the system. Importantly, none of the detectors analysed recorded the extremely high concentrations, approaching 20,000 Bq m^{-3}, reported by Hyland (1995). Broadly, the concentrations recorded were about four times lower.

Various statistics for the four elements of the experiments are presented in Table 2. The calculated mean for the OFD I to Cwm Dwr traverse is 1,946 Bq m^{-3}, but this includes some significant low points (Fig.2a). That for the OFD II traverse (Fig.2b) is 2,876 Bq m^{-3}, though again this includes low values obtained near the entrance. The highest recorded radon concentration was in OFD II, in the middle level of The Arete (16, Table 1, Fig.1b), at 3,800 Bq m^{-3}, followed by 3,780 Bq m^{-3} at the top of the Diver's Pitch (44) in OFD I (Fig.1a, Table 1). Several places deep within the cave showed very low readings, for example The Letterbox, at 600 Bq m^{-3}, and Low No Way (positions 43 and 37 respectively, Fig.2a). By comparison with the entrances, such low readings are taken to indicate that there has been a dilution by an influx of fresh air. Although the possibility was considered, there was no indication from these two detectors that they had suffered from a small amount of condensation that reduced their effectiveness such that they provided a low reading.

August 1999

The repeat layout and recovery of the second batch of fifty detectors was accomplished successfully for the period 31/07/99 to 29/08/99. A surprise was that despite using Clingfilm to cover the detectors, two of them, both on the OFD I to Cwm Dwr traverse, were rendered unusable due to water ingress (Table 1). Even more puzzling is that this period was not particularly wet and the two detectors, numbers 34 and 49 (Fig.3a), were in positions not affected by water in the December experiment, when it had been rather wet. Again, the possibility of either of these detectors being tampered with was ruled out, as neither could be seen directly, and there was no reason to know that detectors had been placed at those positions. The reason for their failure, given that they were in a dry part of the system and wrapped in Clingfilm, remains unresolved.

As with the winter experiment, no extremely high values were recorded by any of the detectors. The data obtained for OFD I appear to be less variable than those recorded during the winter experiment (Fig.2a), and the minimum concentration was measured at 2,500 Bq m^{-3}. There were more sites with readings over 3,000 Bq m^{-3}, which lead to a significantly higher mean concentration at 3,094 Bq m^{-3} (Table 2). This value is higher than the winter mean, as would have been predicted (e.g. Hyland, 1995). Importantly, there are not the marked low concentration values and so the data demonstrate that fresh air penetration into the system is not so great (Fig.2a). The summer data for OFD II (Fig.2b) provide a very irregular pattern, which is difficult to compare directly with the earlier data because of the loss of detectors in the winter experiment. However, the pattern is interpreted to be rather different because several of the summer values are lower than the equivalent winter readings. A mean of 2,667 Bq m^{-3} is very similar to that recorded for the winter data, and although the maximum value is increased, the minimum, 1,370 Bq m^{-3}, is lower (Table 2). Low concentrations were recorded in the vicinity of The Columns, and a further surprise was that elevated concentrations were recorded near the entrance to Cwm Dwr (Fig.2a), rather than lower concentrations as recorded at Top Entrance.

DISCUSSION

Comparing the winter and summer data for both traverses, there are some variations that are outside the 15% uncertainty limits and thus represent specific differences in the conditions within the cave during the two periods (Fig.2, Table 2). The overall cave system means reported here, 2,318 Bq m^{-3} for winter and 2,844 Bq m^{-3} for summer (Table 2b), are not really a true reflection of the value that might be viewed as an equilibrium state for the system. Such a value should ignore the low values obtained near the known entrances, as these have been diluted by fresh air and are thus unrepresentative in relation

Number	Position	Dec-98	Aug-99
1	Top Entrance [on LHS just past first scree pile]	170	1,750
2	Passage to Upper Columns Series [on RH wall about 5m into passage]	1,120	1,370
3	Big Chamber near the Entrance [on LH wall round from the route across chamber]	2,240	1,620
4	Second turn to Bagpipe Chamber [ledge on RH wall, on way to Cairn Chamber]	2,940	2,130
5	Square Window [LH wall, on RHS of window, on way to Cairn Chamber]	*	2,660
6	Bottom of climb to Cairn Chamber [ledge on opposite wall]	3,310	3,670
7	Cairn Chamber boulder choke [centre of choke, a little way up pile on flat boulder]	3,490	3,250
8	Last chamber at turn to Columns [wall alcove on RHS]	*	2,480
9	The Drip Towers [on dry mud bank opposite]	*	1,780
10	Column Hall [on large flat boulder in taped area]	*	1,810
11	Bottom sump passage [ledge on LHS of the passage on right beyond Columns pitch]	*	2,630
12	Labyrinth Y-junction [ledge on RHS facing]	2,830	3,060
13	Labyrinth X-roads [ledge on LHS wall]	*	3,310
14	Bottom of Arete [on LHS by large boulder, c.5m towards Bagpipe]	*	3,170
15	Salubrious Passage cross-roads [wall on RHS climbing up]	3,190	2,860
16	Arete middle level [wall ledge on RHS overlooking pitch]	3,800	2,610
17	Wedding Cake [on wall ledge behind]	2,910	2,650
18	Arete top level [on mud bank on RHS opposite pitch]	3,250	3,060
19	Gnome Passage [alcove LHS halfway down to Edward's Shortcut]	*	2,760
20	Edward's Short Cut, Gnome end [in roof alcove on RHS at crawl down]	*	2,710
21	Edward's Short Cut, Frozen R. end [alcove in wall on RHS]	*	3,050
22	Shatter Pillar [in boulders low down on Lugubrious side]	3,660	2,910
23	Presidents Leap cross-roads end [ledge on RH wall, just beyond]	*	3,600
24	Top of Maypole Inlet 35' climb [small alcove RHS in passage at top of climb]	*	2,580
25	The Trident [open ledge on RHS above water]	3,190	3,160
26	Elephant Turd Passage [ledge on wall RHS at start]	2,400	3,280
27	Shale Chamber [just off main route, under flat boulder on floor]	1,930	2,100
28	SWCC key cupboard	70	170
29	The garage	*	30
30	OFD I entrance [in old entrance passage on ledge on RHS]	2,490	3,430
31	Toast Rack fixed steps [ledge on RHS wall opposite, above head]	2,210	3,290
32	The Step [ledge on RHS wall round to right towards the jump across stream]	2,130	3,040
33	The Dugout (top) [ledge on LHS wall upper side]	2,080	2,960
34	Rocky Holes Chamber [ledge on LHS wall]	2,430	*
35	Bolt Traverse (start) [under roof on RHS at the start of wire]	2,410	3,320
36	Bolt Traverse ladder [under boulder RHS at ladder end]	2,240	2,500
37	Low No Way [on boulder just away from main arch]	730	3,190
38	Rawl Passage [ledge on LHS at 2nd large hole from Pi Chamber]	1,100	3,390
39	Lowe's Passage (top) [ledge RHS top end at start of climb down]	2,440	3,500
40	Lowe's Chain [ledge on RHS wall at top]	2,380	3,510
41	Boulder Chamber [on boulder just up pile]	2,250	2,770
42	The Connection (OFD 1.5 end) [alcove on LHS wall]	2,190	3,270
43	Letterbox [by boulders/formations on LHS of wall]	600	2,660
44	Diver's Pitch (top) [on ledge at top RHS]	3,780	2,920
45	Piccadilly [LHS of passage in taped area]	2,440	3,110
46	The Smithy [on floor near bolt]	3,130	3,010
47	Cwm Dwr Choke [in boulders on LHS on Big Shacks side]	2,340	3,320
48	Dim Dwr hole in Jama [above hole down into Dim Dwr]	930	2,720
49	SAS Chamber [in roof tube just at entry to chamber]	350	*
50	Bottom of Cwm Dwr entrance shaft [ledge, LHS of chamber just before final climb up]	210	2,880

Table 1. Radon concentration data (Bq m^{-3}) for the 1998 winter and 1999 summer experiments, Ogof Ffynnon Ddu system. Left [L] and right [R] are given in the direction of progress from one station to the next, see Fig.1 for details of location. Asterisk indicates missing data, see text.

to the rest of the cave. The results obtained in these two experiments for the two parts of the system do show some systematic variations and differences and, at least superficially, the OFD I - Cwm Dwr data appear easiest to interpret. None of the sites utilised in this study replicated the very highest concentration of 19,968 Bq m^{-3} recorded earlier. Rather they conform more closely to the overall average reported (Hyland, 1995). Whereas it is accepted that the exact site of this reading was not duplicated in these experiments, there is no indication from any of the values obtained that such extremely high concentrations were present in any parts of the system sampled by the detectors. It is possible that the location used in the Hyland experiment was adjacent to a uranium-rich layer or a fracture set within the limestones, thus giving high but very localised radon concentrations. Problems presently exist in correctly identifying and monitoring any possible local transient high concentrations, largely because the dataset for the system is small. The relative contributions to the concentration at any one site due to emanation versus exhalation cannot be ascertained accurately at present.

Generally, for the OFD I – Cwm Dwr traverse, the overall summer concentrations are higher than the winter concentrations and statistically the standard error and standard deviation are lower, whereas the minimum value is higher (Table 2). This result generally accords with the understood behaviour of radon in the system (Hyland, 1995). However, the highest concentration recorded for summer conditions - 3,510 Bq m^{-3} (40) - was slightly lower than the 3,780 Bq m^{-3} (44) recorded in winter. Interestingly, the highest summer concentration was at a different location to the sites recording the highest winter concentration (Table 1). The high concentration obtained at the OFD I entrance and the similar values obtained from the detectors in the passage leading away from the entrance are interpreted as indicating that the air normally flows out of the system via this entrance in both winter and summer. This confirms the general perception of cavers, that the air comes out of this entrance when the solid gate is opened. Comparing the concentrations recorded at the OFD I entrance, 2,490 and 3,430 Bq m^3, with the seasonal traverse mean (Table 2a) and the seasonal system mean (Table 2b), it can be shown that the values are slightly higher. As a consequence, it is suggested that the detector placed at the entrance might give an approximation of the average for the rest of this part of the cave (Fig.2a). Therefore, it is possible that this feature might be utilised as a future experiment to provide a general representation of concentrations in this part of the system.

There are several anomalies superimposed on the seasonal traverse and system means. At two sites, Low No Way (37) and The Letterbox (43), very low concentrations were recorded in the winter experiment. These are interpreted as indicating that during this period there must have been regular ingress of fresh air causing a local dilution of radon. The adjacent site to Low No Way, The Rawl, also has a concentration reduced from the mean. Similarly, from The Letterbox, the sites towards The Connection and Boulder Chamber (42 - 39) show a gradual increase. In both cases this change might be taken to indicate the dominant direction of airflow. However, in summer, concentrations close to the mean were measured at both sites, interpreted to indicate that airflow was no longer entering the cave in the vicinity, allowing a build-up of radon (Fig.2). The summer concentration at Low No Way, 3,190 Bq m^3, is about the seasonal traverse mean (Table 2a), and similar values are seen from the detectors towards Lowe's Passage (38 and 39). This suggests that no fresh air entered under the atmospheric conditions that prevailed during the August experiment. In the summer experiment at The Letterbox, a concentration only slightly lower than the mean was recorded, and may also suggest that fresh air was not entering this way.

The radon concentration at the top of the Diver's Pitch (44) was higher in the winter than in the summer (Tables 1, 2). A possible interpretation might be that in this area there is a circulatory system of fresh air entering near the Letterbox and warm cave air flowing out of the system above Diver's Pitch. However, in summer, with warmer air outside the system, this flow is stopped and no significant fresh air enters, thus allowing a build up to near average concentrations. The detector at the Smithy (46) provided similar winter and summer values and so could reflect a local equilibrium that is possibly influenced by the large volume of air present within the chamber.

Several detectors were placed in sequence along some passages and it was hoped that these could give an indication of airflow direction. This appeared to be successful where there was ingress of fresh air. In summer the concentration gradient along the passages from The Letterbox towards Piccadilly gradually increases, suggesting that airflow might be in that direction. There is also an increase in concentrations for both winter and summer from a high-level part of the system at Rawl Passage, downwards through Lowe's Passage (39), and on down towards the top of Lowe's Chain (40), which is at a much lower altitude. This direction probably accords with the flow of air out towards OFD I entrance. However, Boulder Chamber (41), at the head of the old main streamway passage, records similar winter and summer values, both of which are lower than the equivalent readings at the top of Lowe's Chain. This is interpreted to indicate that Boulder Chamber is on a different air supply that issues from the choke, and it is only towards the entrance that the two become combined. This is consistent with the data from The Letterbox and the known flow of air out of that part of the system towards The Connection and Boulder Chamber.

Radon concentrations at two sites on Bolt Traverse, the beginning (35) and ladder end (36), were similar in winter, but concentration at the ladder was lower in summer. Whereas it is thought that airflow

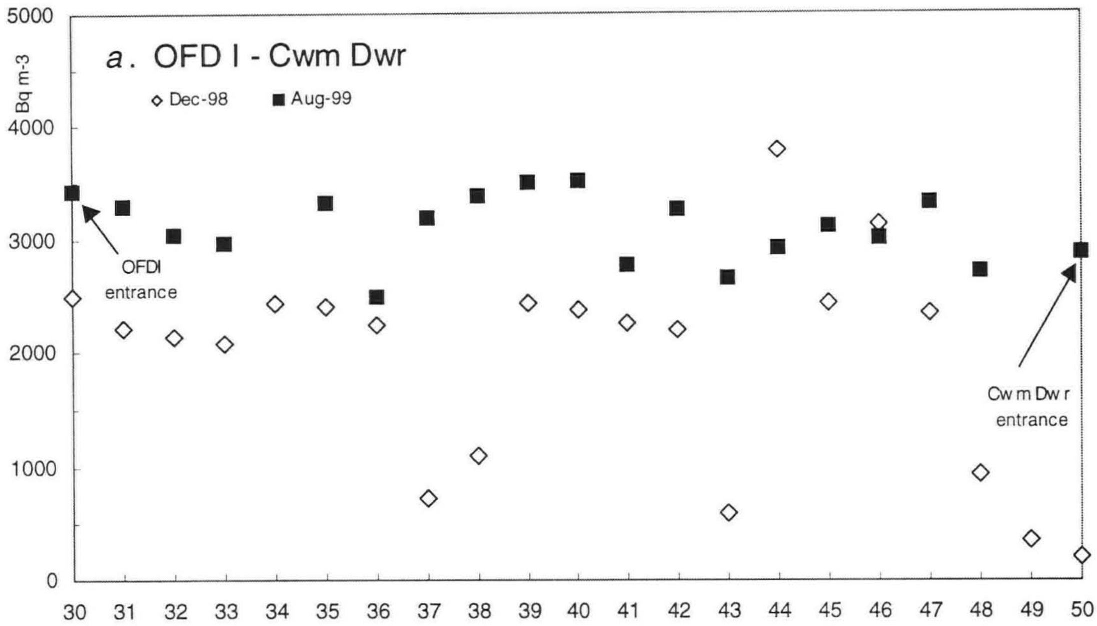
		December	August		
		OFD I – Cwm Dwr	OFD II	OFD I – Cwm Dwr	OFD II
Mean		1,946	2,876	3,094	2,667
Standard Error	203	196	69	119	
Standard Deviation	930	753	299	616	
Minimum		210	1,120	2,500	1,370
Maximum		3,780	3,800	3,510	3,670
Count		21	14	19	27

a) Data for the cave system separated into individual traverses, by season.

	Winter	Summer
Mean	2,318	2,844
Standard Error	163	81
Standard Deviation	963	548
Minimum	210	1,370
Maximum	3,800	3,670
Count	35	46

b) All data for the cave system by season.

Table 2. Statistics for the radon concentration data presented in Table 1 broken down into traverse and time of year. All cave data, including low values observed near entrances are used, the surface readings are excluded.



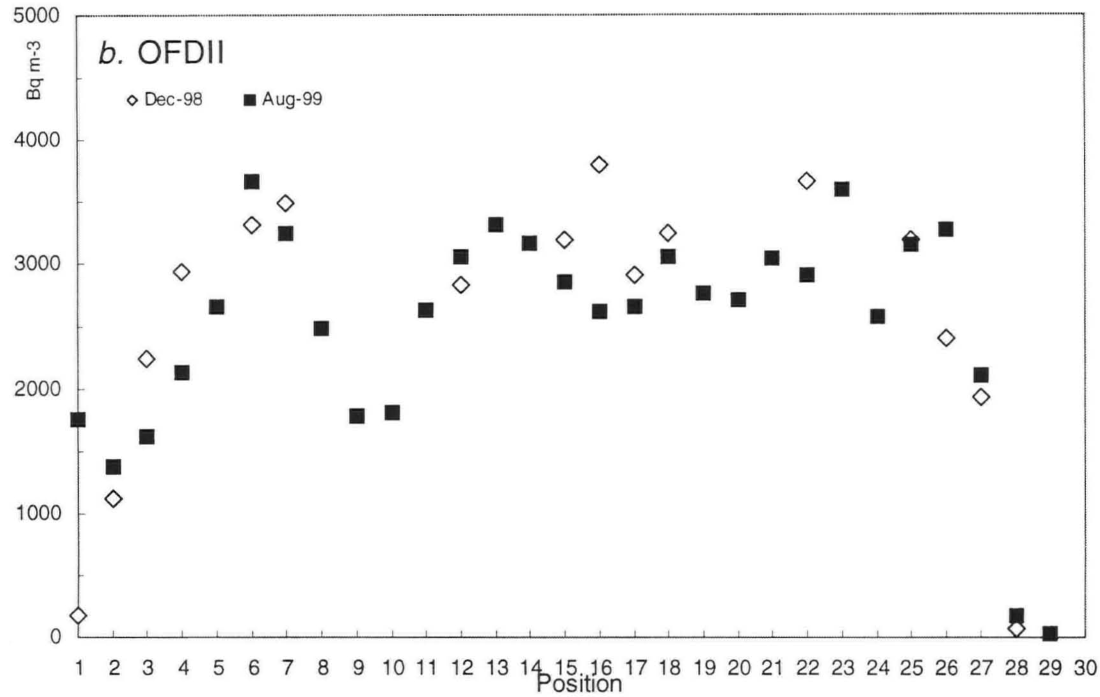


Figure 2. Plot of radon concentration (Bq m^{-3}) versus position for the Ogof Ffynnon Ddu cave system. a) data for the traverse from OFD I to Cwm Dwr. Detector 28 was used as a monitor of radon within a local building, SWCC HQ, and 29 represents the external, free-air concentration. b) data for the round traverse in OFD II.

along this high level in the passage is in part controlled by the amount of water issuing from inlets and flowing in the streamway below, this result was not expected, and such a rapid change in a relatively short distance is not easily explained.

The two other higher entrances to the system, Cwm Dwr (altitude c.340m) and Top Entrance (c.436m), show different behaviour to the lower Ogof Ffynnon Ddu entrance. Their winter behaviour is similar in that there is a gradual fall in concentrations along the routes towards Cwm Dwr and Top Entrance (detectors 46 - 50 and 5 - 1 respectively, Fig.2a,b). This dilution of radon concentration appears to be in accord with the perceived penetration limits expected from fresh air entering the cave with the diluting effect gradually being lost as penetration increases and the air becomes thoroughly mixed. This is interpreted to show that in winter, despite being the higher entrances, there must be a regular ingress of fresh air through them. In Cwm Dwr, which has very constricted passages, fresh air penetration is noticeable as far as Cwm Dwr Boulder Choke (47), before its effects are lost. In Top Entrance, because of the much larger passages, the effect is only noticeable to the end of the entrance series.

However, the summer pattern at both entrances is different. The concentrations are higher in Cwm Dwr (Fig.2a), which must indicate that air is flowing outwards for some of the time. Concentrations at Top Entrance (Fig.2b), are initially higher and then fall below the winter concentrations at the same sites. This might be interpreted to show that the airflow must be variable, both coming out, thus bringing high concentrations with it, and entering the cave system, giving a dilution. These winter and summer airflow regimes are the converse of what might be predicted. In winter, the warmer air in the cave would be expected to escape upwards, as indeed is noted at several other shakeholes in this part of the NNR (for example, The Hot Air Mine, SN87055 16225). In summer, the cooler air within the cave would not be expected to escape upwards. To be able to explain this paradoxical airflow more fully one would need to monitor more parameters, such as air temperature and pressure values together with wind speed and direction.

It is more difficult to make absolute comparisons between summer and winter concentrations in OFD II because of the number of detectors lost in the winter experiment (Fig.2). However, once inside the system specific points emerge. Higher winter concentrations occurred at Big Chamber near the Entrance (3), second turn to Bagpipe Chamber (4), The Wedding Cake (17), Arete middle level (16), Salubrious Passage cross roads (15) and Shatter Pillar (22). Other than summer ingress of fresh air, there are no obvious reasons for these reversals. There are also some sites where the concentrations are similar in summer and winter, e.g. The Trident (25) and Shale Chamber (27), and these might reflect some form of equilibrium. There are also odd values at the different altitude levels of The Arete (14, 16, 18) with no real pattern emerging. The highest value was found at the middle, in winter, but in summer a lower concentration was obtained. No systematic change in concentration with height in summer was found here. The distribution of concentrations suggests complicated airflow through this major, multi-level shaft.

Concentrations in the side branch down from Cairn Chamber to the area of The Columns were relatively low in summer, reflecting the ingress of fresh air down from the higher level passages. This is well understood from the observed airflow regimes where air enters down through the main passage roof at the Columns Pitch. The detectors at The Drip Towers and in Column Hall are essentially monitoring the same large air space and provide relatively similar values that might be taken as representative for the large passages in the area of Columns. The detector in the side passage down to the bottom sump (11) showed the highest concentration, which might be predicted because the passage is a dead end, being frequently sumped.

Although several detectors were placed along set routes, it is not obvious that there were any significant concentration gradients. For example, the detectors starting at the Trident (25) and progressing 15, 17, 19 and 26 do not show any evidence for a consistent gradient. How mixing occurs along these passages is not clear, as the detector closest to the entrance (26) gave the highest reading. Equally, the sequence 19 - 23 gives a similarly confusing picture.

CONCLUSIONS

The new data obtained for the Ogof Ffynnon Ddu system are superficially consistent with the presently understood behaviour of radon, showing higher concentrations in summer than in winter (Hyland, 1995). Whereas it is clear that there are several generalisations that can be made about the radon concentrations (Table 2), several anomalies not recognised previously are superimposed on the crude averages. These are probably system dependent and cannot readily be explained without further experiments. The recorded concentrations of radon within the system are moderately high and the mean value of c.2,600 Bq m^{-3} reported by Hyland (1995) was broadly confirmed (Table 2). The mean concentrations in the system are high when compared with surface levels, but the extremely high values reported previously have not been reproduced in the experiments in this study.

A significant discovery was that the airflow at the higher entrances appears to be very variable, particularly in summer. That there is air flowing out at these higher entrances during summer, thus elevating radon concentrations, was contrary to prediction. Equally, the apparent constancy of air leaving from the lowest entrance in both periods is contrary to what might have been predicted. The system also shows the possibility of using one detector placed strategically to act as an approximation of the overall radon concentration present within. It is also apparent from comparing the data for the two experiments that airflow within the Ogof Ffynnon Ddu cave changes seasonally. This facet, allied to surface temperature and pressure, would provide a topic for further study.

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Geomicrobiology of black sediments in Vântului Cave (Romania): preliminary results

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Abstract: Five species of bacteria and one species of fungus have been identified from the black sediments of Vântului Cave, Romania, using molecular methods. Three of the bacterial species (*Hyphomicrobium* sp., *Pedomicrobium fusiforme, Pedomicrobium manganicum*) and the fungus *Cladosporium* spp. are known to mediate the oxidation and precipitation of manganese in different environments, by enyzmatic or nonenzymatic mechanisms. *Sphingomonas mali* could possibly be another bacterium that contributes to the manganese precipitation in Vântului Cave. This biologically mediated process is likely to be controlled by the pH and/or Eh conditions existing within the subterranean stream environment. Additionally, these microorganisms are implicated in the retention of some rare earth elements within the black sediments.

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INTRODUCTION

Manganese-rich accumulations in natural systems have often been explained in terms of variations in both oxidation-reduction potential (Eh) and hydrogen ion activity (pH). Generally, geochemists have agreed that microorganisms, especially bacteria and algae, may create microenvironmental conditions (e.g. elevated pH and Eh) conducive to Fe and Mn oxidation. They also recognise that microorganisms may promote enzymatic catalysis of oxidation reactions. However, geochemists have had difficulties justifying a biological mechanism for ferromanganese-concretion formation because they have found it difficult to asses the role of bacteria for systems (iron and manganese) where a purely physicochemical mechanism applies (Ghiorse, 1984). Abiotic Mn^{2+} oxidation can be catalysed by extreme environmental conditions (high pH and high oxygen pressure) and by the adsorption of ions on mineral surfaces such as iron oxides and silicates (Davies and Morgan, 1989). However, biological catalysis is more likely to be important in natural environments below pH 9, where Mn^{2+} oxidation is favourable thermodynamically, but often proceeds at very low rates (Diem and Stumm, 1984; Nealson *et al.*, 1988).

Investigations of bacterial Mn oxidation are numerous (Ehrlich, 1981, 1996; Emerson *et al.*, 1982; Ghiorse and Chapnick, 1983; Ghiorse, 1984; Brouwers *et al.*, 2000). Many unrelated bacteria can mediate Mn oxidation via either enzymatic or nonenzymatic mechanisms (Ehrlich, 1981, 1996; Ghiorse, 1984). Compared with rates of abiotic Mn^{2+} oxidation, microorganisms can accelerate oxidation by as much as five orders of magnitude (Wehrli, 1990). Mn-depositing bacteria are ubiquitous. They have been detected in samples from almost every compartment of the geosphere where iron hydroxide and ferromanganese oxide deposits are found. The lists include the classical iron hydroxide- and ferromanganese-depositing bacteria (*Spaerotilus, Galionella, Leptothrix, Crenothrix, Pseudomonas*), the more recently described *Metallogenium* and *Siderocapsaceae*, and ferromanganese-depositing hyphal budding bacteria (*Pedomicrobium* and *Hyphomicrobium*) (Schweisfurth *et al.*, 1980; Erlich, 1981; Ghiorse, 1984). There are also some fungi known to be involved in Mn oxidation (*Cladosporium, Coniothyrium*) (Erlich, 1981).

Although manganese reduction and oxidation by bacteria was known and studied for many years only a few cases yielded insights into either the mechanism involved or the importance of such organisms in nature. Few of these studies were carried out in caves (Peck, 1986; Gradzinski *et al.*, 1995; Northup *et al.*, 1997). Therefore, the purpose of our investigations was to demonstrate the presence, in the black sediments of Vântului Cave, of bacteria that could have played an important role in manganese precipitation.

STUDY SITE AND SEDIMENT DESCRIPTION

Vântului Cave is located in Romania in the central northern part of the Padurea Craiului karst massif, 15km south of highway E60 that connects Oradea to Cluj (Fig.1). The cave is well known because of its length (over 48km of passages), morphology, and unique mineralogy (Onac, 1996). The cave is developed in Triassic limestones that are covered by a Jurassic caprock consisting of sandstones and microconglomerates. The region around the cave is moderately forested (mainly deciduous trees). Significant amounts of organic acids derived from the abundant decomposing vegetation are carried into the cave by the percolating water and by the underground stream. Coman and Craciun (1978) were the first authors briefly to mention the presence of black sediments in Vântului Cave. Later, Coman (1984) published a second paper in which he speculated on the role of microorganisms in the deposition of the black sediments. He based his speculations on similarities between the chemical composition of the black sediments in Vântului Cave and sediments investigated with respect to their microbiology from other caves worldwide.

Recently, speleothems from Vântului Cave were the subject of three papers that fully characterised the black sediments from a mineralogical and depositional point of view (Onac, 1996; Diaconu and Moraru, 1997; Onac *et al.*, 1997a). The black sediments in Vântului Cave cover both submerged limestone blocks and the cave walls up to the highest level reached by the water. The thickness of the sediment layer varies from 2.5-3cm on the boulders and cobbles (under the water table) to only few millimetres on the walls. Thicker sediments were observed towards the upper part of the water-column where the sediment-water interface and the overlying water supplies oxygen, especially in the lower part of the underground stream. The samples were collected from boulders and cobbles in the lower part of the cave stream (Fig.2).

The sediment consists of a deep black, jelly-like material that disperses easily when sampled under water. When dry, it crumbles and

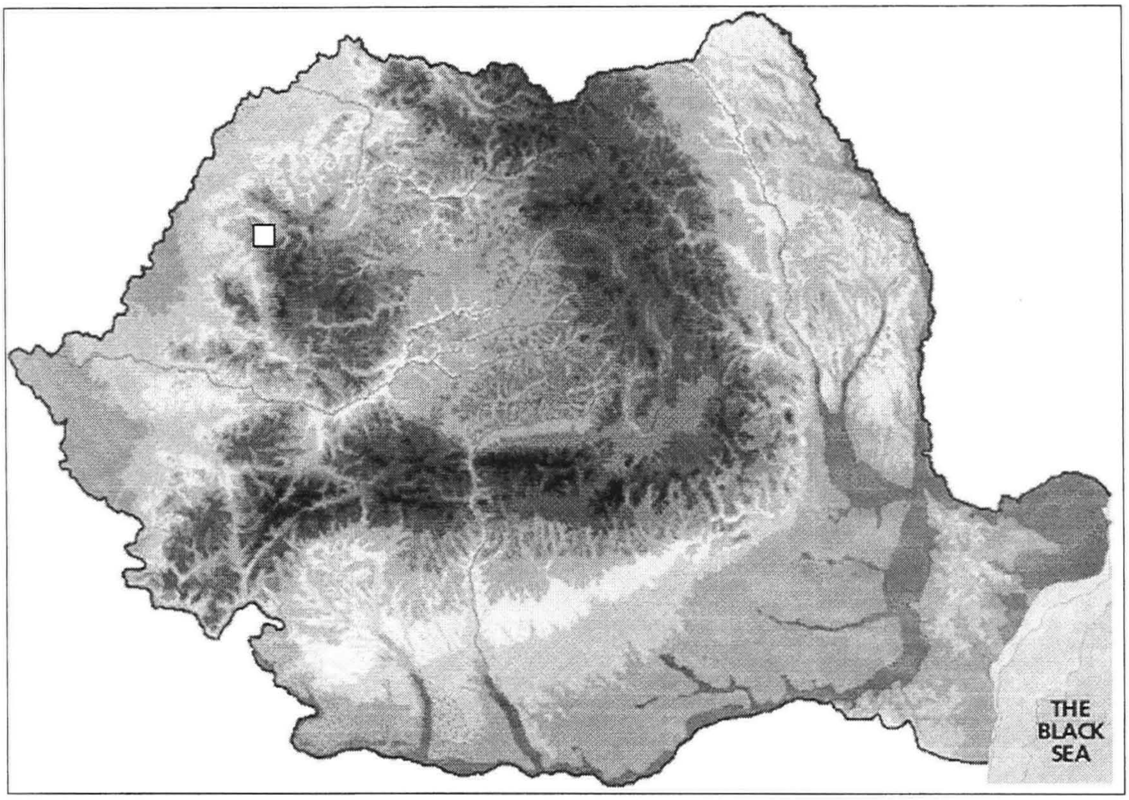

Figure 1. Map of Romania, showing the karst region (white square) where Vântului Cave is located.

stains black all materials that come into contact with it. X-ray, thermal, infrared and scanning electron microscope analyses revealed that the sediment is made up of a mixture of oxides and hydroxides of manganese and iron (Onac, 1996; Diaconu and Moraru, 1997; Onac *et al.* 1997a). Onac *et al.*, (1997b) also reported considerable amounts of rare earth elements (up to 950 ppm cerium, samarium, neodymium, lanthanum) to be concentrated in these sediments. The mechanism Onac *et al.* (1997a) suggested for the deposition of the black, manganese-rich sediments was controlled mainly by fluctuations of Eh and pH in the bacteria-bearing geochemical system of the underground stream.

MATERIAL AND METHODS

Culturing of manganese oxidizing bacteria

The samples were collected aseptically and kept refrigerated for not longer than 2 days before being cultured The basal medium used for the isolation of manganese bacteria from the black sediment sampled in Vântului Cave consisted of 0.005g KH_2PO_4, 0.002g $MgSO_4$ $7H_2O$, 0.010g $(NH_4)SO_4$, 0.010g $Ca_3(PO)_2$, 0.005 $MnSO_4$ H_2O, 2g agar, distilled water up to 100ml and pH 6.5 (B r o m f i e l d , 1974). The addition of 0.3% yeast extract and 0.3% glucose accelerate Mn oxidation on the plates. The initial inoculation was done by serial sediment dilution. The incubation temperature was 28°C. The cultures showing Mn oxidation on plates (using leuco-christal violet) (Vandenabeele *et al.*, 1992) were subsequently subcultured (streaked onto new plates).

DNA extraction and polymerase chain reaction (PCR) amplification

The extraction of DNA from mixed cultures was performed using the methods of Marmur (1961). A loop-full of colonies showing Mn oxidation was discharged into a 1ml Ependorf tube containing distilled water. The suspension was boiled for 10 minutes and 1µl aliquots were used as templates for PCR amplification.

The 16S rDNA gene was amplified using the bacterium-specific primers f27 and r1492, whereas the 18S rDNA gene was obtained with eukariota-specific primers (Giovannoni, 1991). Amplification reactions were performed using the reagents supplied with GIBCO-BRL (Paisley, Scotland) *Taq* polymerase kits, with magnesium ion concentrations of 1.5mM, 20 ng of template DNA, and 100 pmol of each primer. The reactions were carried out on a Perkin-Elmer thermocycler with 30 cycles of 92°C for 1 min, 60°C for 1 min, and 72°C for 1 min, with a final extension at 72°C for 5 min. Reaction products were checked for size and purity on 1% (wt/vol) agarose gels (Sambrook *et al.*, 1989) and then ligated into the pCR II vector supplied with a TA cloning kit (Invitrogen, San Diego, California) according to the manufacturer's instructions.

DNA sequencing of 16S and 18S rDNA clones

Small-scale preparations of plasmids containing cloned PCR products were made using the method of Saunders and Burke (1990). DNA sequencing reactions were carried out by cycle sequencing with a dye-terminator kit from Applied Biosystems. Primers used for sequencing 16S and 18S rDNA clones were complementary to conserved regions of 16S rRNA and 18S rRNA, respectively (Lane, 1991; Giovannoni, 1991). A small 16S rDNA and 18S rDNA library, containing 40 clones for each gene, was constructed. The restriction enzyme pattern of each clone (using *Eco*RI- *Rsa*I for 16S rDNA, and *Eco*RI-*Sau*3A for 18S rDNA) was compared to allow assignment into operational taxonomic units (OTUs) based on unique restriction enzyme sites caused by sequence differences within the clones. From each OTU 2 clones were sequenced.

RESULTS AND DISCUSSION

The analysis identified 5 OTUs for bacteria and 1 OTU for eukariota (Fig.3). OTU group 1 represented the largest number of library clones containing 25 out of 40 (62.5%), OTU group 2 was represented by 12 clones (30%), and the remaining OTUS (groups 3-5) were represented by only a single clone. Representatives of each OTU group were partially sequenced (approximately 460-500 bp from 370-832 *E. coli* numbering). The results were submitted to a database search (Blast Gap 2) to provide an indication of the possible identity of the clone types. The sequence results from 2 random clones chosen from OTU group 1 were identical, supporting the restriction enzyme pattern

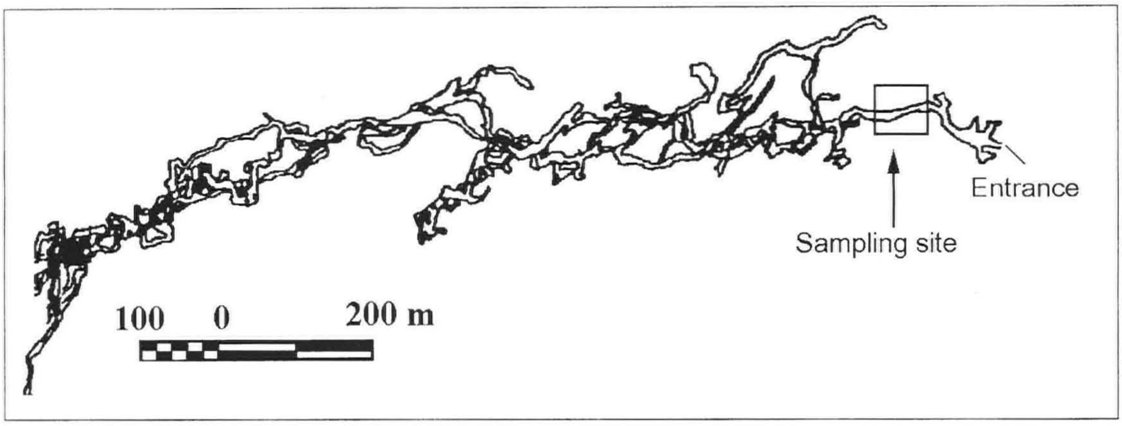

Figure 2. Plan of Vântului Cave, showing the location of sampling site.

classification. The 16S rDNA sequence from OTU group 1 clones most closely matched *Hyphomicrobium* spp., being 93% similar over 460 bp. The other OTU similarity-based matches were *Pedomicrobium fusiforme* (94%), *Pedomicrobium manganicum* (94%), *Sphingomonas mali* (93%), and *Pedomicrobium ferrugineum* (90%). For 18S rDNA clones the sequence matched *Cladosporium* sp., being 91% similar over 460 bp.

Hyphomicrobium and *Pedomicrobium* genera are known to have species involved in manganese oxidation and precipitation using both enzymatic or nonenzymatic mechanisms. The nonenzymatic mechanism is also known for *Cladosporium* spp. (Erlich 1981; Ghiorse, 1984). We have no bibliographic data for *Sphingomonas mali* as being a bacterium involved in manganese oxidation. On the other hand, there are data implicating *Pseudomonas* species in enzymatic and nonenzymatic manganese oxidation (Erlich, 1981; Ghiorse, 1984). Additionally, many species described as *Pseudomonas* were subsequently transferred to the genus *Sphingomonas* (Fredrickson *et al.*, 1995; Takeuchi *et al.*, 1993), though this genus is not recognized by the last edition of Bergey's Manual of Determinative Bacteriology (Holt *et al.*, 1994), its systematics being, as yet, uncertain.

The ability of bacteria to produce Mn oxides has been described as a protective function. Sunda and Kieber (1994) have proposed another interesting possibility for the function of microbial Mn^{2+} oxidation. In their studies they showed that Mn oxides oxidize complex humic substances, releasing low molecular mass organic compounds (e.g., pyruvate) that can serve as substrates for bacterial growth. This implies that Mn^{2+}-oxidizing bacteria may survive in nutrient-poor environments by producing a strong oxidizing agent able to degrade biologically recalcitrant carbon pools (cf. Tebo *et al.*, 1997). Fungal manganese peroxidases catalyze the formation of Mn (III) complexes, which can subsequently oxidize phenolic compounds (Brouwers *et al.*, 2000).

Direct observations and experimental studies have revealed the potential of bacterial manganese oxides in the adsorption of a large range of elements (Nealson, 1983; Ingri and Widerlund, 1994; Tessier *et al.*, 1996; Fein *et al.*, 1997; Northup *et al.*, 1997; Ferris *et al.*, 1999, 2000; Yee *et al.*, 2000). Because of the reactive surface properties and ubiquitous distribution in unconsolidated sediments, hydrous Mn and Fe oxides are considered to be among the most dominant sorbents (Stumm and Morgan, 1996). Furthermore, many studies have shown that the incorporation of organic matter into inorganic particulate solids can have a significant impact on concentrating various dissolved metals, particularly rare earth elements.

It is possible that the roles of anaerobic processes are very probably also important in controlling the geochemistry of Mn, Fe and other metals that have been concentrated in the active stream sediments of Vântului Cave, but which have yet to be assessed. The number of bacteria genera involved in these processes is probably greater than the ones we have identified.

Based on our findings as well as on previous work on this site, we believe the association of rare earth elements with the black sediment in Vântului Cave could be interpreted as an interaction between bacterial and geochemical processes. The adsorption behavior seems to be governed by the chemical speciation of the bacterial and mineral surface (Ehrlich, 1996). An exact account on how organic matter is involved in this process remains to be established. The Mn oxidation and precipitation in Vântului Cave may be due by to both abiotic and biotic mechanisms.

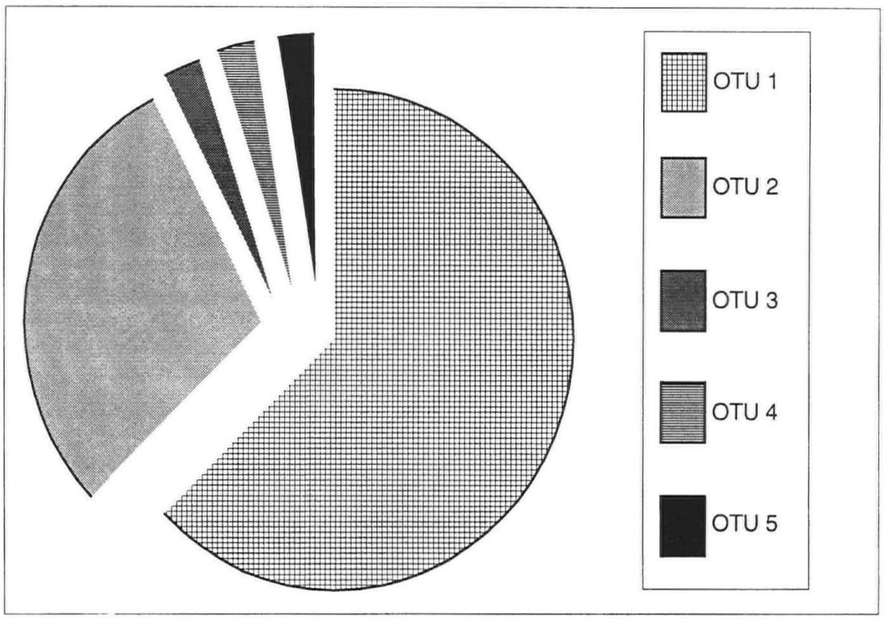

Figure 3. Proportional representation of OTUs or sequence types retrieved from a 16S rDNA gene library of a culture on Mn(II) medium from a black sediment collected in Vântului Cave. Bacterial identification of each OTU group is based on closest matching sequence identity of partial 16S rDNA sequences (approximately 460 bp) after Gene-Bank database comparison with the BLAST Gap 2 software. OTU 1: *Hyphomicrobium sp.*, OTU 2: *Pedomicrobium fusiforme*, OTU 3: *Pedomicrobium manganicum*, OTU 4: *Sphingomonas mali*, OTU 5: *Pedomicrobium ferrugineum*.

CONCLUSION

Using molecular methods we have identified 5 species of bacteria and one fungus species in the black sediments of Vântului Cave. Three of the bacteria (*Hyphomicrobium sp., Pedomicrobium fusiforme, Pedomicrobium manganicum*) and the fungus (*Cladosporium* sp.) are known to mediate the oxidation and precipitation of manganese by enyzmatic or nonenzymatic mechanisms. The presence of *Sphingomonas mali* in the investigated ferromanganese sediment could be an indication that this bacterium is also involved in the biogeochemical processes that ultimately lead to the manganese and/or iron deposition in Vântului Cave.

Although the deposition of black sediments in Vântului Cave appears to be a biologically mediated process, one should not forget that the physico-chemical characteristics of the geochemical system (i.e., pH, Eh) are essential for the behaviour of both bacteria and manganese.

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The Khammouan karst of Laos

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Abstract: The limestone hills of central Laos constitute a karst with landscapes that are notable in a worldwide context. They contain a number of large cave passages, including the Hinboun River Cave, which offers a through-trip of 6.3km entirely by powered boat.

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INTRODUCTION

Midway along the length of Laos, the province of Khammouan contains a swathe of limestone mountains that extend eastwards from the Mekong Valley across the border into Vietnam (Fig.1). A lush forest cover thrives in the warm climates and high monsoonal rainfalls, and provides the ideal environment for rapid limestone dissolution. The karst landscapes are mature and spectacular.

Laos is a sleepy country, where a succession of introverted governments has stifled development. Most of the people live in a countryside that is dominated by a higher proportion of uncleared forest than any other nation in the world, and even the alluvial plains support only small patches of rice paddy. Restrictive politics have meant that Western visitors have only been able to visit rural areas for the last few years, and numbers of tourists are still very small.

This short report has been compiled after a visit by the authors to a mere handful of the karst sites in Khammouan. There are just a few tarred roads that branch off the highway along the Mekong Valley. Away from these, travel is over very rough roads or by long river journeys in fishtail-powered canoes.

LIMESTONE GEOLOGY

The Khammouan karst forms a block over 200km long and about 30km wide (Fig.2). It is all formed in thick Permo-Carboniferous limestones that are similar in age and lithology to those in the karstlands of southern China. In Khammouan, the limestones are in a series of tight folds orientated NW-SE. Erosion of the anticlines has exposed cores of underlying sandstone that form small 'islands' of allogenic drainage sources within the karst. The northeastern boundary of the limestone is against Mesozoic sedimentary rocks that form higher ground, mostly fringed by a sandstone escarpment that overlooks the karst. Underlying Palaeozoic sandstones rise to an outcrop that forms the southwestern boundary of the karst, and faults bring Mesozoic sandstones down to floor the Mekong Valley and form low hills southeast of Thakhek. There is little allogenic drainage onto the karst from either side.

THE KARST GEOMORPHOLOGY

The dominating landscape style of Khammouan is one of karst massifs that are almost completely bordered by bare limestone walls rising up to 500m above intervening alluviated plains and sandstone-floored basins (Plate 1). Summit surfaces of the massifs are rather inaccessible beneath a mantle of thick forest on chaotic surfaces of limestone pinnacles and deep fissures. Maps compiled from air photographs indicate an egg-box terrain of steep cones and deep dolines that is a classic fengcong karst of clustered cones.

The massif margins are precipitous walls of limestone blackened by the blue-green algae in its surface crust. Many surfaces are bare rock, and these are fretted into long and spectacular karren, whose knife-edge interfluves break into successions of narrow pinnacles (Plate 2). Skeletal trees cling to parts of the cliffs. White patches of freshly exposed limestone are scars of the rockfalls by which the walls retreat. Wedges of talus, now clad in vegetation, have accumulated along the bases of most walls, but notches and foot caves can be seen where

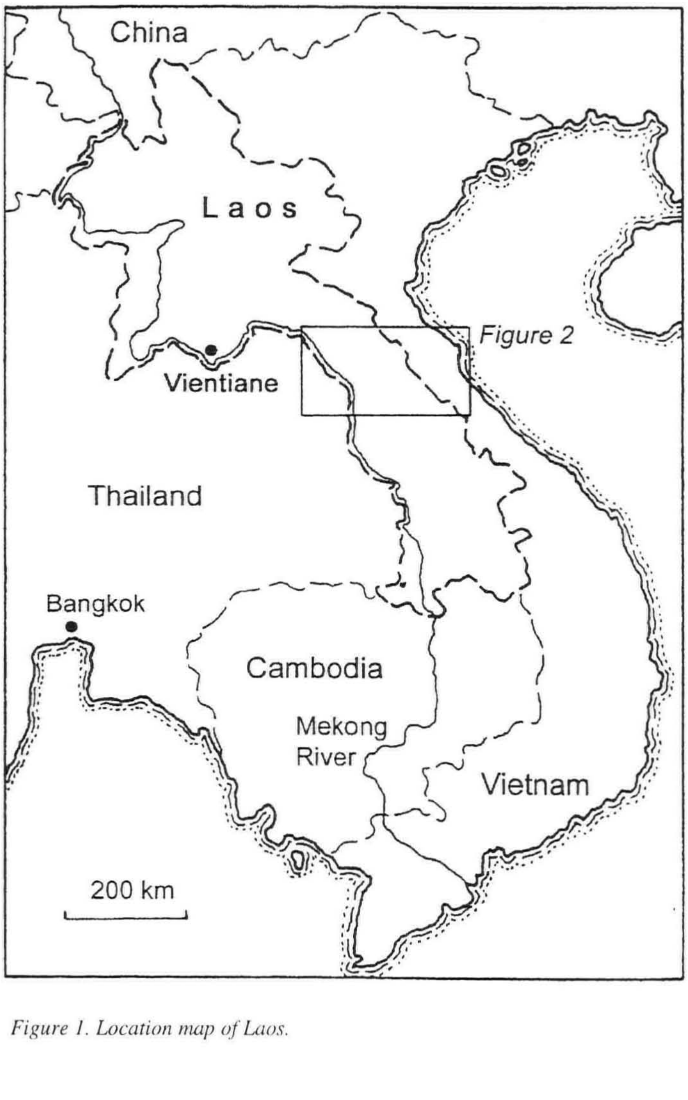


Figure 1. Location map of Laos.

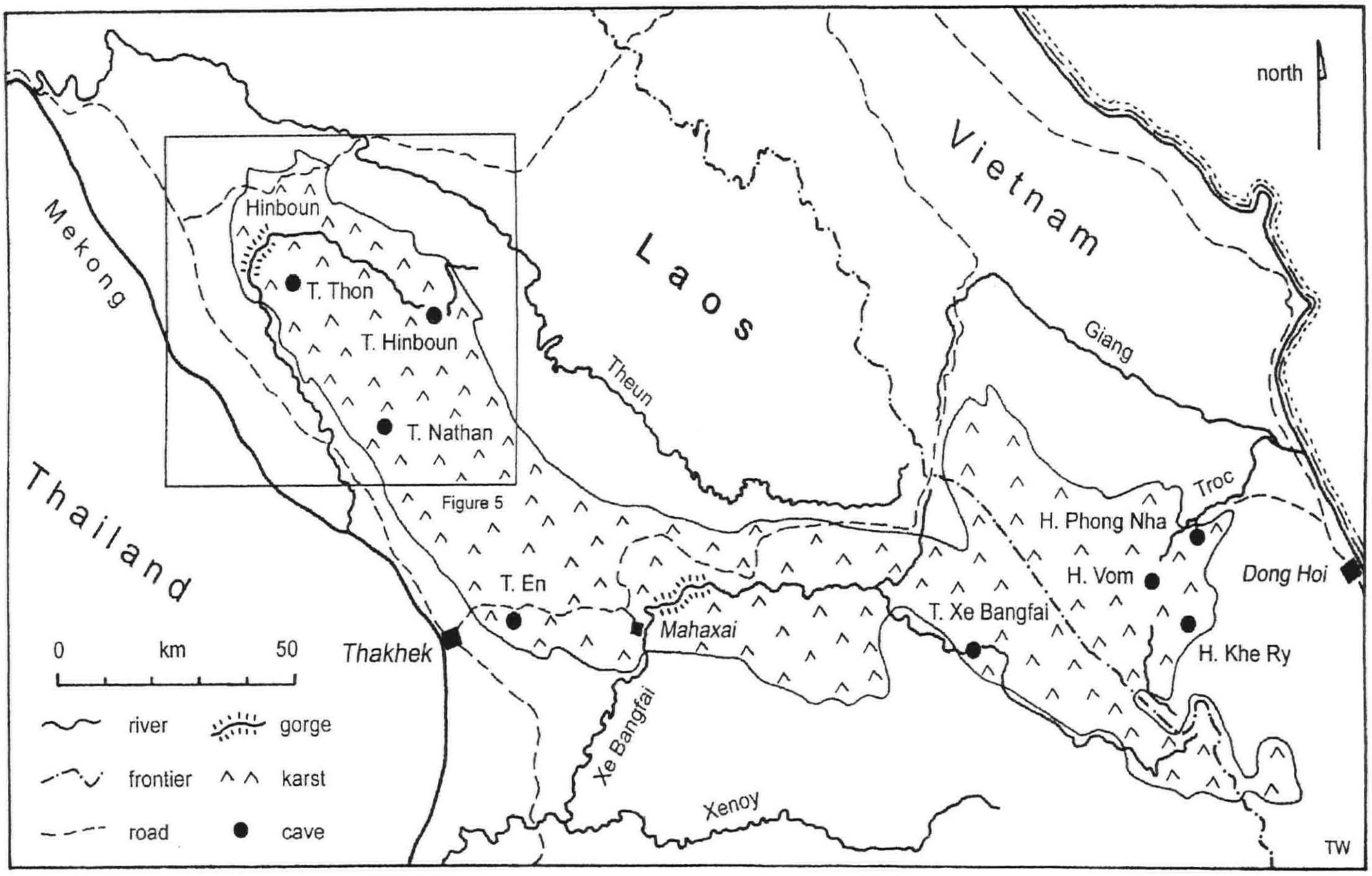


Figure 2. The Khammouan karst and its eastward extension into Vietnam.

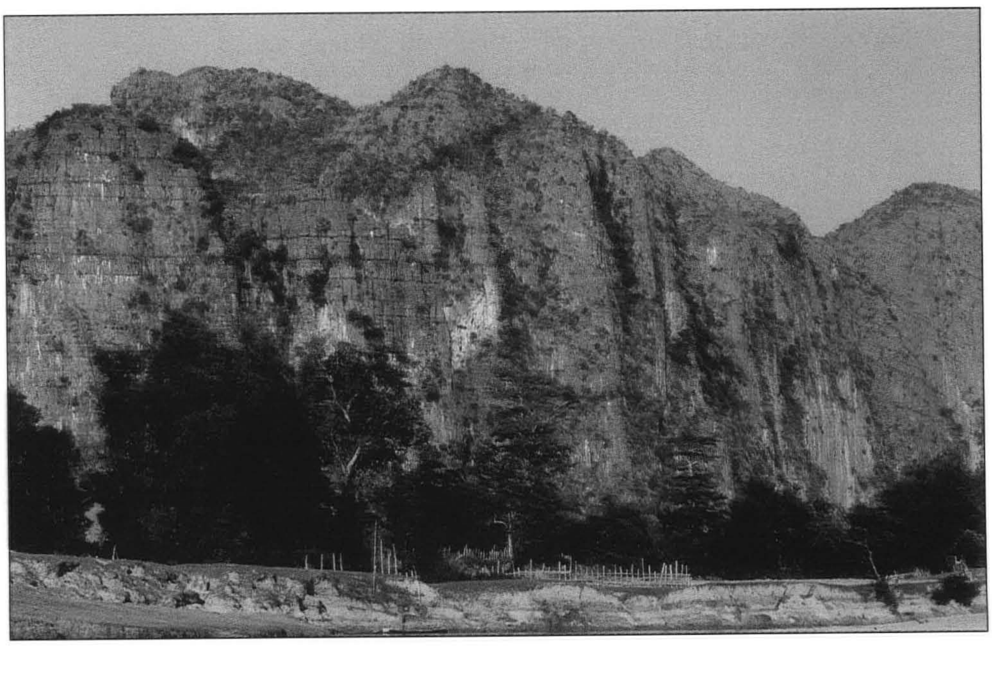
streams and rivers on the alluvium have removed the talus and now undercut the limestone.

Basins that have developed by erosion and planation, inwards from the edge of the karst, take the form of marginal poljes. Two of the largest basins are on the Hinboun River (Fig.3). The upper, eastern basin gathers drainage partly from the overlying shales beneath the fringing sandstone escarpment to the northeast. Its western and southern margins are steep limestone walls and its floor is alluviated, with no exposure of the underlying limestone. It is a true polje, as it drains out through the Hinboun River Cave (see below), into the larger basin.

The main Hinboun basin gathers more drainage from shale slopes along its northern edges, but most of its floor is an alluviated karst plain; small exposures of limestone are largely on the remains of large rockfalls from the fringing cliffs. It is not a true polje, as the Hinboun flows out to the southwest, through a gorge entrenched between limestone peaks that rise 300 to 500m above the river (Plate 3). Below the Hinboun Gorge, the river traces the axis of another marginal polje, before draining off onto the sandstones.

Extending southeast of Mahaxai, between the Xe Bangfai and Xenoy rivers (Fig.2), a broad alluviated plain is largely floored by Palaeozoic sandstones. Scattered across it are isolated limestone hills, but these are residual outliers, and are not true towers that arise from a karst

Plate 1. Limestone cliffs rise over 300m above the floor of the Hinboun basin.



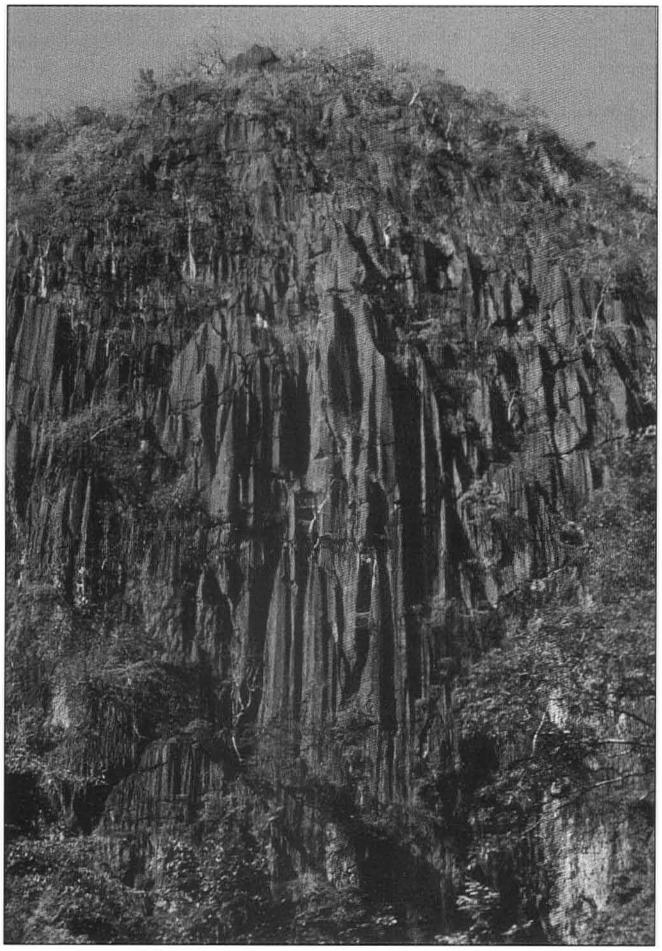


Plate 2. Giant karren, more than 100m long, fret the cliffs above the Hinboun River.

plain. The Xe Bangfai River emerges on to the plain from another fine limestone gorge upstream of Mahaxai. The isolated limestone hills, scattered across both this plain and the smaller poljes, create a fenglin style of karst, but the hill profiles are not as steep as the true towers of the Yangshuo type, and their talus aprons indicate the lack of active undercutting. Though not a classic tower karst, they do create spectacular karst panoramas that contrast with those of the adjacent fengcong massifs.

There are many interior basins, within the karst, most of which are developed on the breached cores of anticlines where the basement sandstone floors are exposed. Dissolutional planation has worked outwards to undercut the limestone and thereby create precipitous marginal cliffs. The Pathene basin is the largest (Fig.3). It lies on an anticline, with the underlying sandstone exposed as low hills within the southwestern half of the basin. Adjacent to the sandstone hills, the basin is floored by alluvium, containing cassiterite that is worked by the Phontiou tin mine. The margins of the basin are spectacular limestone cliffs (Plate 4) that have retreated as the basin floor has expanded by undercutting. Their line is unbroken except where the Pathene River drains out of the basin through a narrow valley cut between fault blocks in the limestone. The source of the Pathene water is a number of caves draining from the limestone along its northern side; these include Tham Thon with 7.9km of passage.

Just to the southeast of the Pathene basin, the Boumlou basin is a totally enclosed polje (Fig.3) that drains out through the cave of Tham Nathan (see below). Ringed by high limestone cliffs, its floor is largely covered by a pocket of untouched rain forest, whose isolation ensures the survival of its resident wild animals (reputed to include leopards and gibbons).

THE CAVES

It is clear that the mature karst limestone of Khammouan is riddled with caves. Streams and rivers flow in and out of the base of the massifs, open entrances are visible in the high cliffs, and there must be many sinkholes and shafts hidden in the forest cover of the massif-top fengcong.

Access and exploration high on the massifs is not easy, and most of the known caves are entered at or close to the foot of the cliffs. Local villagers first entered many of the open caves long ago, and still use some as the easiest route through the karst terrain. The important modern explorations, all within the last ten years, have been by French cavers. In 14 expeditions to Khammouan they have mapped over 100km of cave passage. They have another expedition in 2001, and are currently exploring a cave northeast of Thakhek, where they have already mapped over 20km of passage. Claude Moret has published various short items (1993 – 1998 among others), and is preparing a major report (intended as a Karstologie Memoire in 2002). A British team led by Adrian Gregory (1996) made some more modest discoveries, and a list of Laos caves was compiled by Brouquisse (1999).

The Khammouan caves are characterised by large passage dimensions, with large streamways and river passages at base level. Of the caves visited by the authors, three are worthy of note.

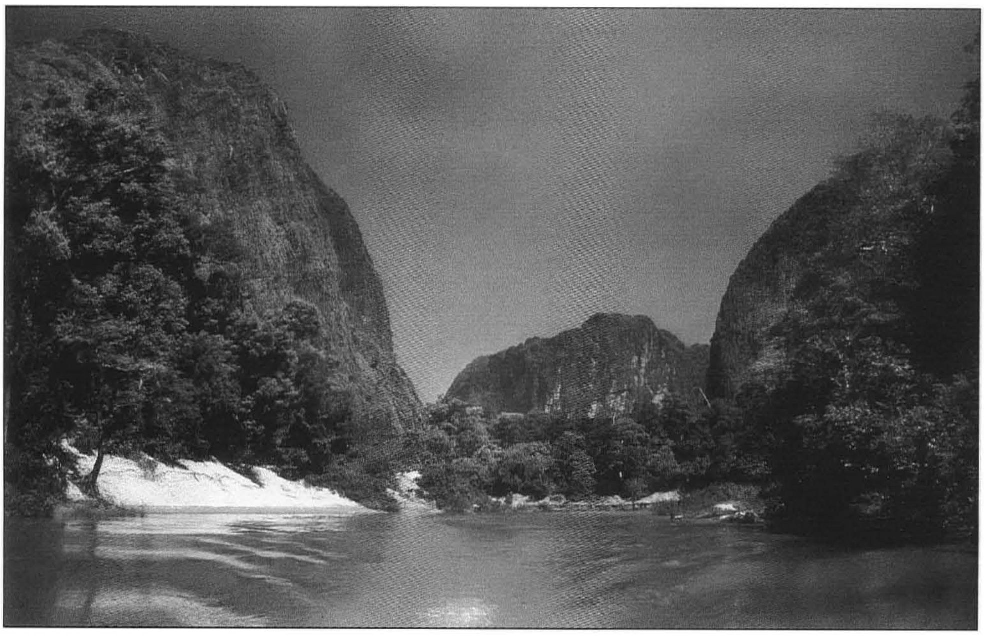


Plate 3. The gorge carrying the Hinboun River out of its main basin.

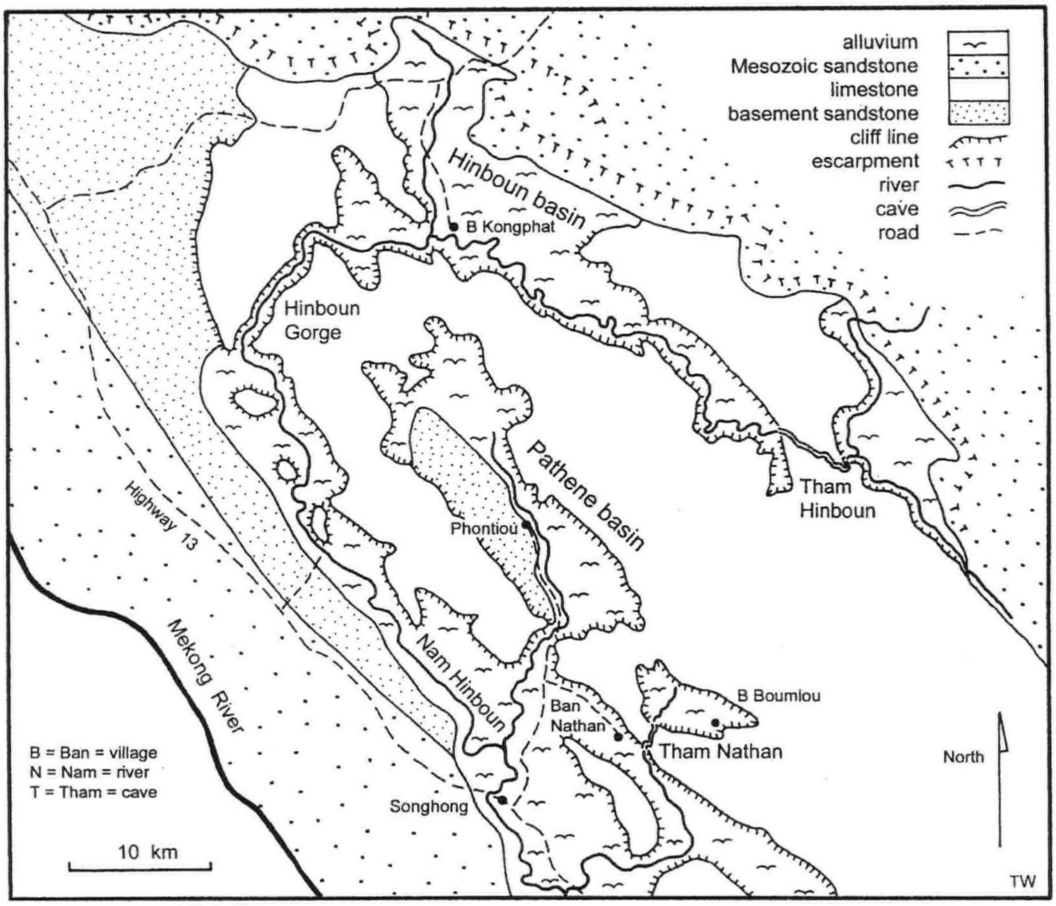


Figure 3. Main elements of the geology and geomorphology of the Hinboun River area at the northwestern tip of the Khammouan karst.

Tham Hinboun

The Hinboun River flows underground between two marginal poljes on the northern edge of the karst (Fig.4). The river passage is 6,300m long, and is navigable by fishtail-powered longboats right the way through. Village boatmen use the cave regularly as the easiest way between villages and farms in the two poljes; travellers have to get into the water at just four places to drag the boats up short sets of rapids over calcite-cemented pebble banks. The Hinboun River Cave (Tham Hinboun) offers one of the world's great underground journeys - armchair caving in its true sense.

The middle section of the cave is a passage at least 30m wide and 20m high, except where it expands into chambers containing piles of collapse that relate to large, old high-levels. Beds of cobbles indicate where the river flowed in the past, but there are few stalagmite

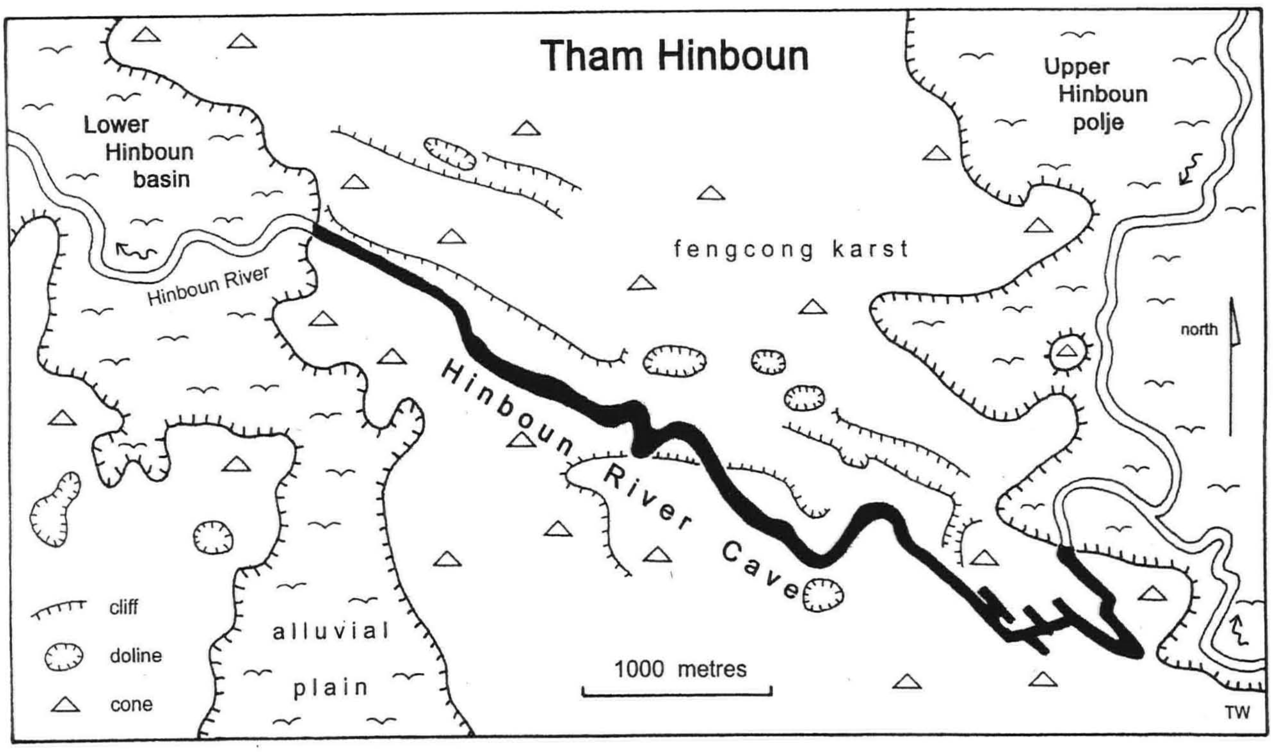


Figure 4. Outline map of the river passage in Tham Hinboun.

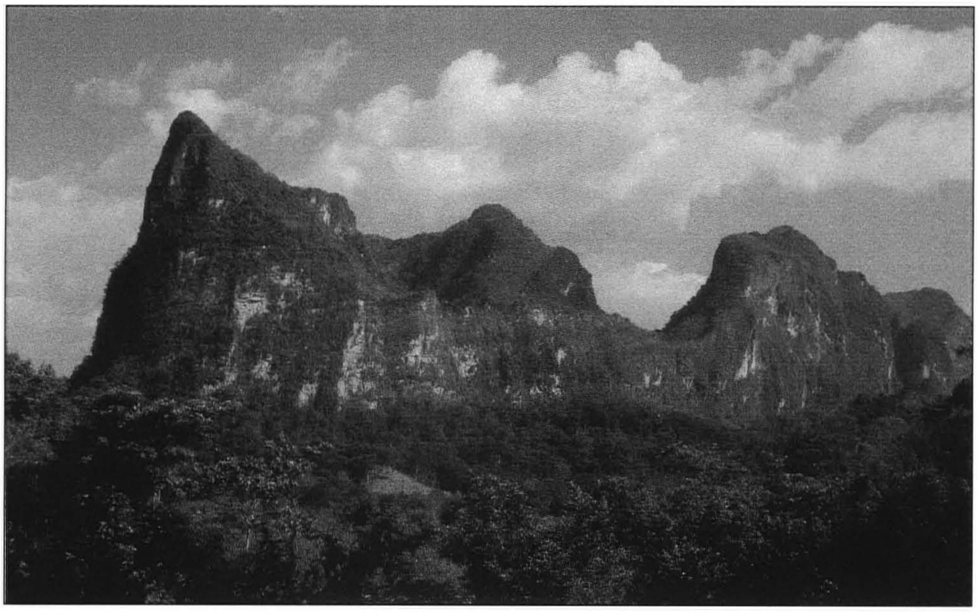


Plate 4. Limestone cliffs around the eastern end of the Pathene basin.

deposits. The modern river meanders between gravel banks (Plate 5) and has a dry-season flow of less than 1 cumec. Remnant flood debris suggests that flows are at least ten times as great during the monsoons. Much of the river's length is through wide lakes; its gradient is low, with a fall of just a few metres through the cave's length.

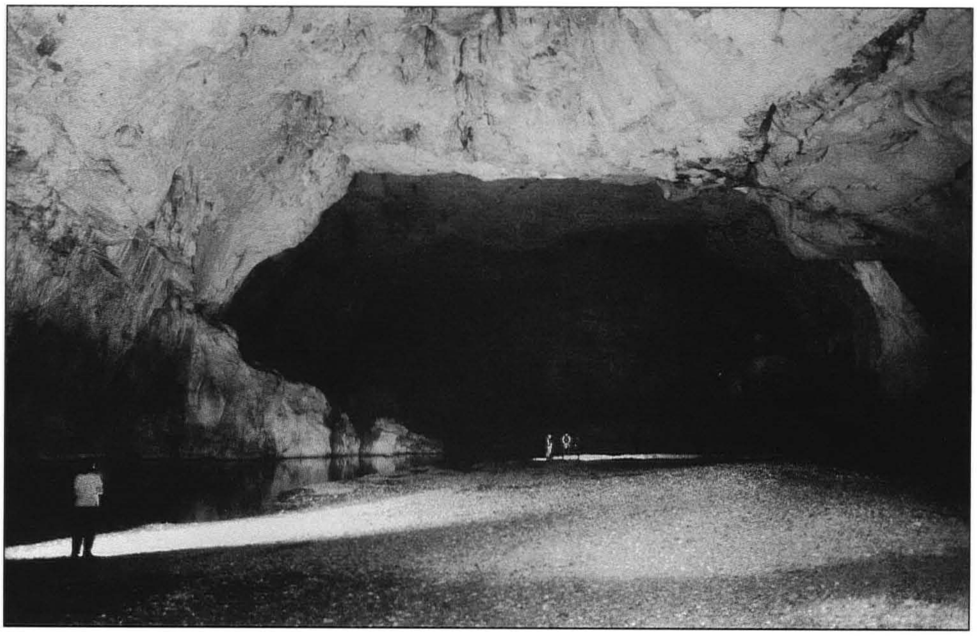
Both end sections of the river passage are smaller. The upstream kilometre includes some high joint-guided rifts less only 15m wide, and sections of half-flooded phreatic tube that cut across the joints and narrow to 15m wide between the cross rifts. High-level passages are conspicuous on many of the joint alignments. The downstream kilometre of passage, to the resurgence, is around 25m wide, but its arched roof rises only about 5m above water level (Plate 6). It appears to be just the top part of a large phreatic tube; sediment totally masks the floor and could well be many metres deep.

It appears that the cave has developed as an efficient drain between the two poljes. Where the river enters the limestone from the upper polje, dissolution has created a maze of phreatic rifts on the major joints, and throughflow subsequently expanded the most efficient route into the river passage. Further into the limestone, the system of rifts has coalesced into a single passage, and this has matured into a conduit with a profile graded close to the local base level. The lower end appears to represent a shallow phreatic loop, which may have suffered paragenetic roof enlargement over an accumulating pile of sediments. It has now been exposed as the river has entrenched into the sediment floor of the downstream polje. The cave lies beneath a ridge where the limestone cones rise to 700m above river level, with intervening doline floors not many metres above the cave roof (and almost certainly providing extra entrances).

The river cave was surveyed as part of the planning for a hydro-electric scheme. Under this the cave would have carried up to $100m^3$/sec of water diverted from the Theun River where it is perched on the sandstone plateau (Fig.2), but this part of the scheme has not come to fruition. The cave plan in Fig.4 is based largely upon the engineer's survey. French cavers have explored high-level side passages that take the cave's total length to more than 12.4km (Mouret *et al.*, 1997).

Five years ago the Hinboun was a seriously remote site. It was even difficult for foreigners to leave Vientiane, but access has since improved following publicity over the French expeditions. Local transport is still minimal, and a casual visit to Hinboun would not be easy. However, a trip through the cave (Plate 7) is on the programme of adventurous travel agents in Vientiane.

Plate 5. The river passage midway through Tham Hinboun.



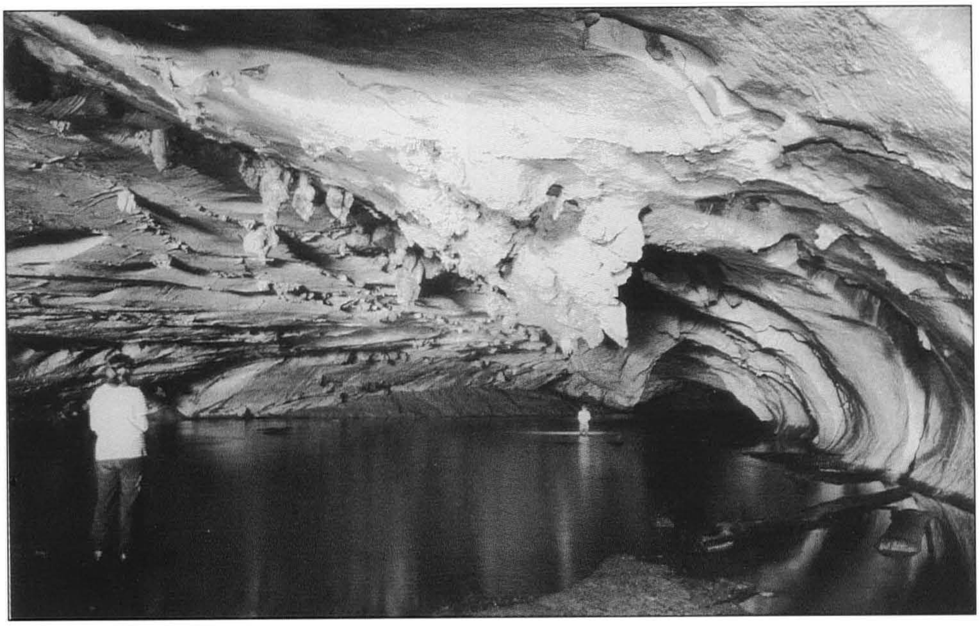


Plate 6. The partially drained phreatic tube at the lower end of Tham Hinboun.

Tham Nathan

Just 20km south of the Hinboun cave, the Boumlou polje drains out to the southwest through a cave under a high limestone ridge (Fig.3). The main passage of Tham Nathan is around 1,700m long. At its downstream end it is about 40m wide and 20m high (Plate 8). Round two bends and into darkness, the cave develops into a broad canyon below a phreatic tube that is 30m wide with its roof probably 50m high. Banks of cemented gravel 10m above stream level mark a stage in the cave's entrenchment. The upstream portal is over 50m wide, rising above a pile of blockfall (derived from the roof and the cliff above) that is towards 100m high, with the water filtering through its base. In the dry season the cave carries only a tiny stream, which is, however, ponded in three sizeable lakes. Floodwater marks suggest that monsoon flows are well over $1m^3$/sec.

The village of Ban Nathan lies close to the cave exit. Another village, Bam Boumlou, lies in a small patch of cleared forest near the eastern end of the polje, 4km from the cave entrance. Virtually the only link from Bam Boumlou to the outside world is through the cave, and the villagers have worn a path that is also marked by two short ladders and two short footbridges, all made of local hardwood. The path winds over boulder piles, round the lakes and along some fine ledges. It is easily followed - by the trail of burnt shavings from the bamboo flares that provide the locals' only light. Though the cave is clearly well-known, there is no published record or survey of it. Sadly, this was not appreciated at the time of the authors' brief visit, so no survey was then made.

Tham En

Phou Khiao is an anticlinal sandstone hill that supplies run-off streams into the base of the limestone on its north side. Tham En is one of the caves that carries an allogenic stream through the flanking limestone ridge into an interior polje (Fig.2).

The cave consists of little more than a single through-passage (Fig.5) about 1,300m long. The downstream end has been developed as a show cave, easily accessible from the tarred road between Thakhek and Mahaxai. The tourist path climbs above the stream to end on a balcony 150m in, with a branch out to a small high-level exit. Anyone continuing upstream has to swim for about 500m along a splendid flooded canyon entrenched beneath a larger phreatic tube. Beyond the canals, there is a short walk up a delightful stream passage, to where the water emerges from the toe of a pile of blockfall, with a glimmer of daylight above. The climb up the block pile is fantastic, as the walls recede until the passage is 150m wide. This huge ramp of fallen blocks rises to the cave entrance, which is spanned by a low arch, with a view out to the forested sandstone slopes of the stream catchment. The tops of many blocks on the lower

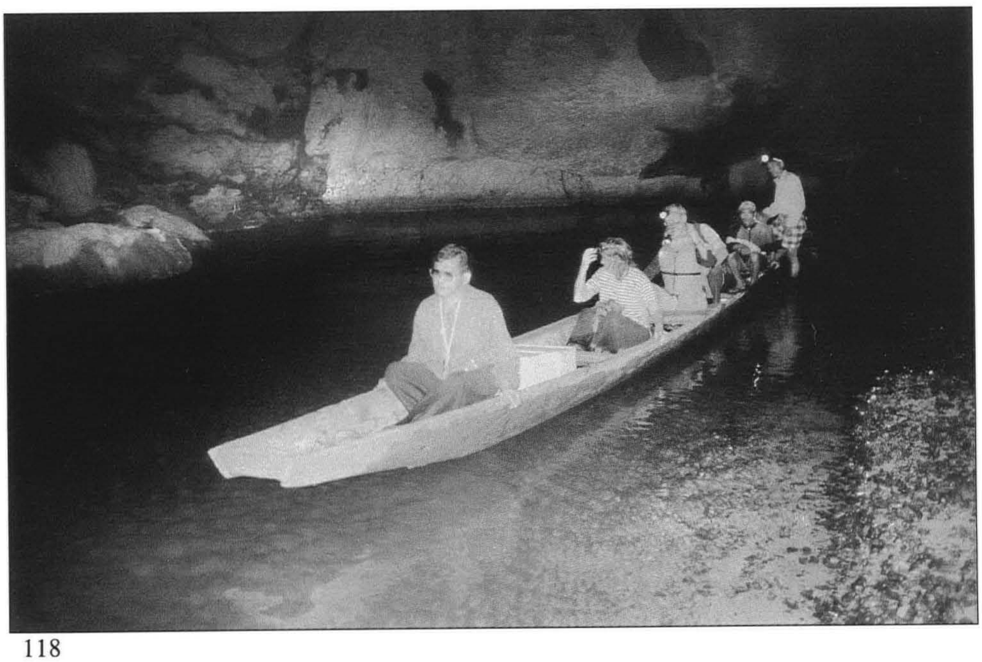


Plate 7. Three kilometres from daylight in Tham Hinboun.

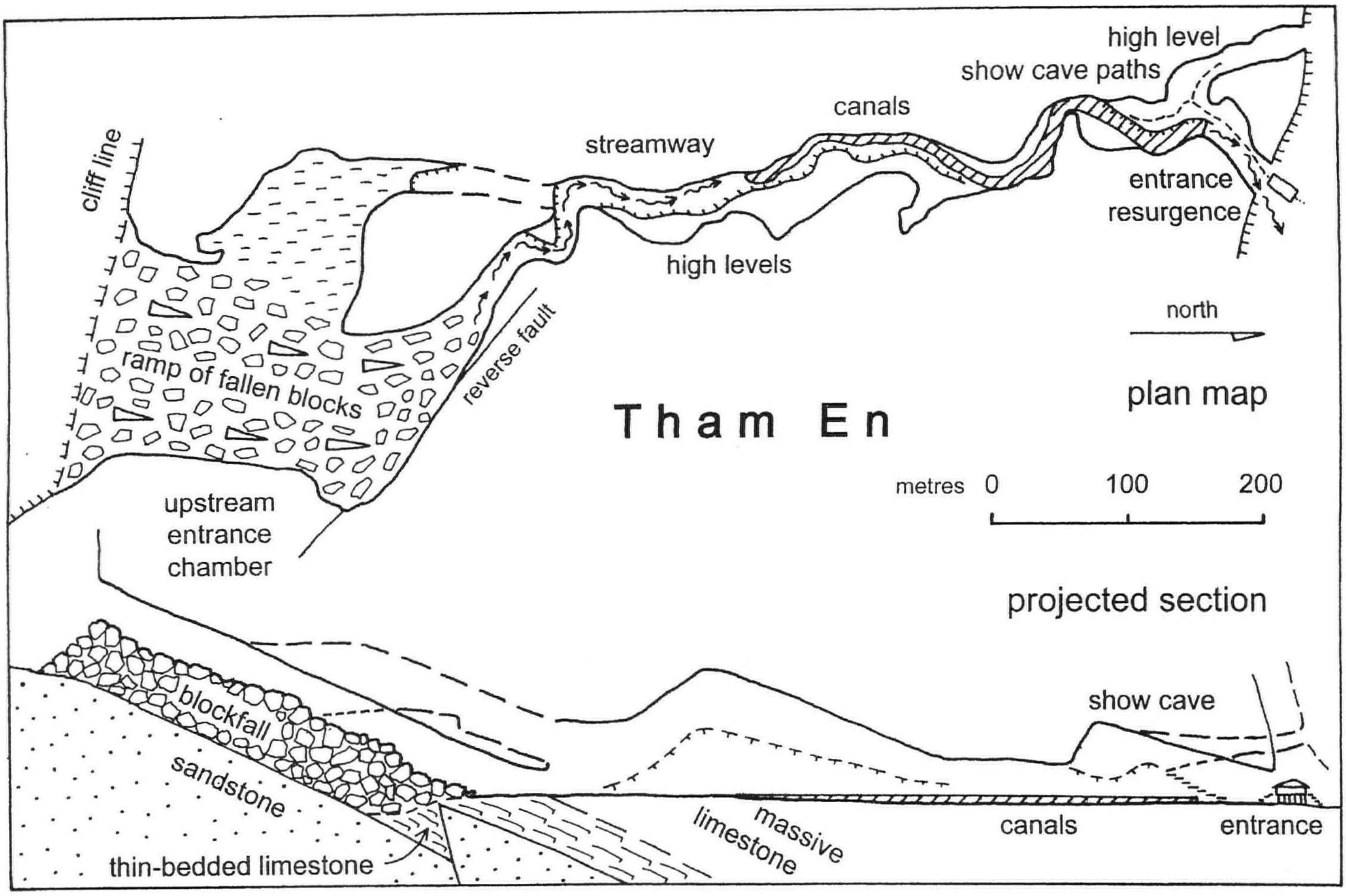


Figure 5. The main features and geology of Tham En (topography based on Mouret, 1993).

part of the ramp are fretted with phytokarst, with the pits aligned with the distant daylight. The cave has its resident swift population, and nest-collectors' poles stand against the entrance's eastern wall.

Tham En was initiated by vadose drainage down the dip at the base of the limestone. A zone of thinly bedded limestone at this position became a locus of lateral undercutting and cave widening. It is likely that multiple input routes then coalesced into a single, very wide passage, which extended as far as a phreatic lift on a small reverse fault that now defines the inner end of the chamber. Downstream, a single phreatic tube climbed stratigraphically into massive limestone. The up-loops of this tube survive in the roof of the streamway, in some high-level branches and in the high-level exit, whereas the down-loops have been modified into the canyon that gives the modern stream its graded profile.

The upstream entrance chamber is unusual because its roof structure can be seen in daylight, and there are few cave passages this wide that are so clearly visible. Its roof appears to have matured into a stable arch, where rock has fallen away along identifiable tensile stress fractures. These developed beneath the zone of compressive stress that forms naturally in the rock and now forms the stable, self-supporting

Plate 8. Looking into the resurgence end of Tham Nathan, with one of the authors standing on the rocks beyond the pool.

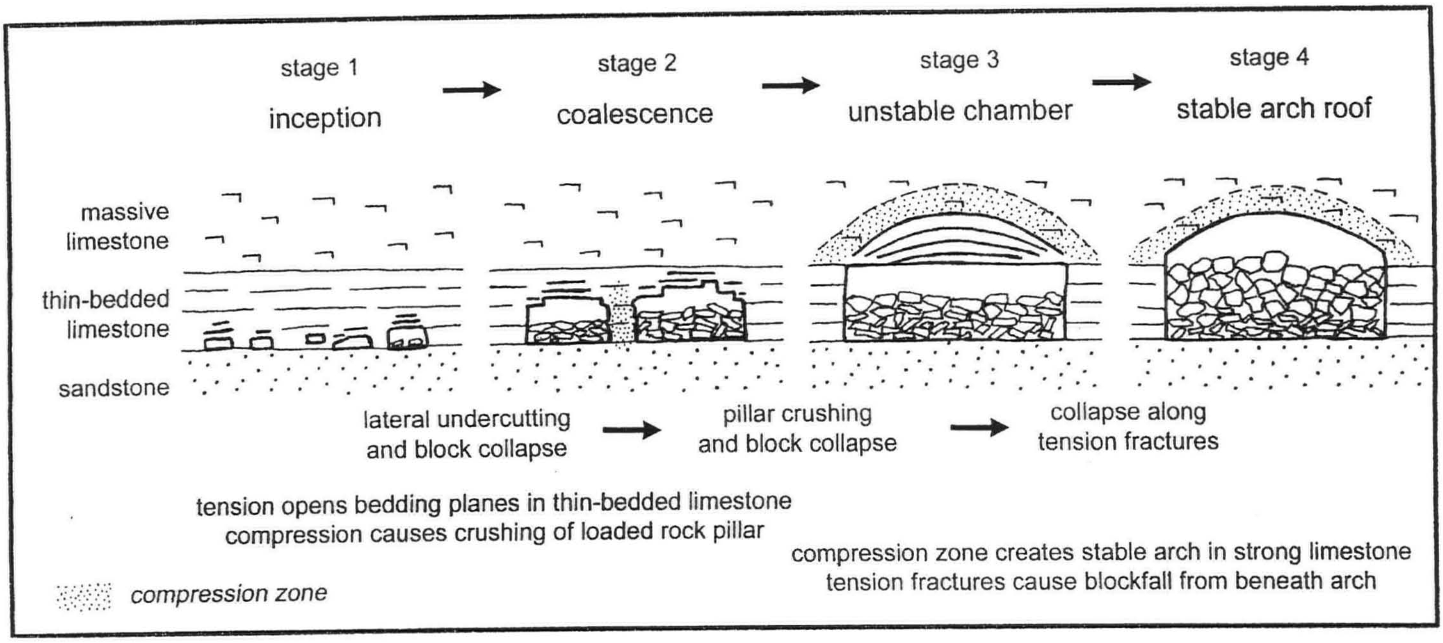


Figure 6. A sequence of sketch profiles across the upstream daylight chamber of Tham En, showing its progressive development towards a roof that is a stable arch developed on stress fractures independent of the bedding. Zones of compressive stress are marked by stippling, and zones of tensile stress are indicated by the tension fractures drawn bold. The views are looking up the dip of about 10° towards the entrance.

arch (Fig.6). The original passage roof was probably 40-50m below the present roof, and progressive upward collapse has allowed maturation from an unsupported, unstable, undercut slab into the stable, self-supporting arch. The roof fractures have formed by tensile stress, largely independent of bedding planes and tectonic joints. This is unusual, as it is only in extremely wide caves that stress patterns are large enough and bold enough to dominate over the nets of fractures that normally control blockfall and roof failure in strong, cavernous limestone. Tham En may be the best indicator of the roof structure of other very large cave chambers, including Sarawak Chamber in Lubang Nasib Bagus (Sarawak).

KHAMMOUAN IN CONTEXT

The limestone belt of Khammouan continues eastwards across the border from Laos into the Quang Binh province of Vietnam. There, the fengcong karst landscape is not quite so dramatic, rising more gently above the river valleys, with less of the high fringing cliffs that so distinguish the Lao karst. Many of the longer and larger caves lie in the eastern sector, on both sides of the border (Fig.2). In Laos the Tham Xe Bangfai is another giant river passage, 9km from sink to rising, but it is not traversable in the comfort of a boat. The mean flow on its underground river is well over 50m^3/sec, and flood flows are estimated at over 500m^3/sec (Mouret *et al.*, 1997) - which must be some form of world record. The Vietnam sector contains the splendid long river caves of Hang Phong Nha (7.7km), Hang Khe Ry (18.9km) and Hang Vom (14km), all mapped by the British teams led by Howard Limbert (1992, 1999). These extensive caves in the eastern karst appear to have developed where the regional drainage pattern provides long river routes over the wide limestone outcrop, instead of just across the narrow dimension of the more mature karst massifs in the western Khammouan.

The collection of fengcong massifs, poljes and magnificent caves in Khammouan, together with its extension into the river caves of Quang Binh, constitutes a karst region that is of geomorphological significance in a worldwide context. Though now divided between two nations, and only recently accessible for study after decades of political isolation, this great karst of what was once Indo-China deserves to be widely known and appreciated.

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Speleothem organic acid luminescence intensity ratios: a new palaeoenvironmental proxy

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Abstract: One area of recent speleothem research has been the analysis of luminescence variations. Here we present luminescence data for the dominant luminescence centre (excitation wavelength 330 to 390nm; emission wavelength 390 to 460nm). For many speleothems this peak can be resolved into two luminescence maxima. Data presented here, from a variety of speleothems and a wide range of cave locations, suggest that in many cases the ratio of luminescence intensity of these two luminescence intensity sub-centres can provide a more sensitive record of luminescence variations. Also, in some cases, it can provide a palaeoenvironmental proxy.

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INTRODUCTION

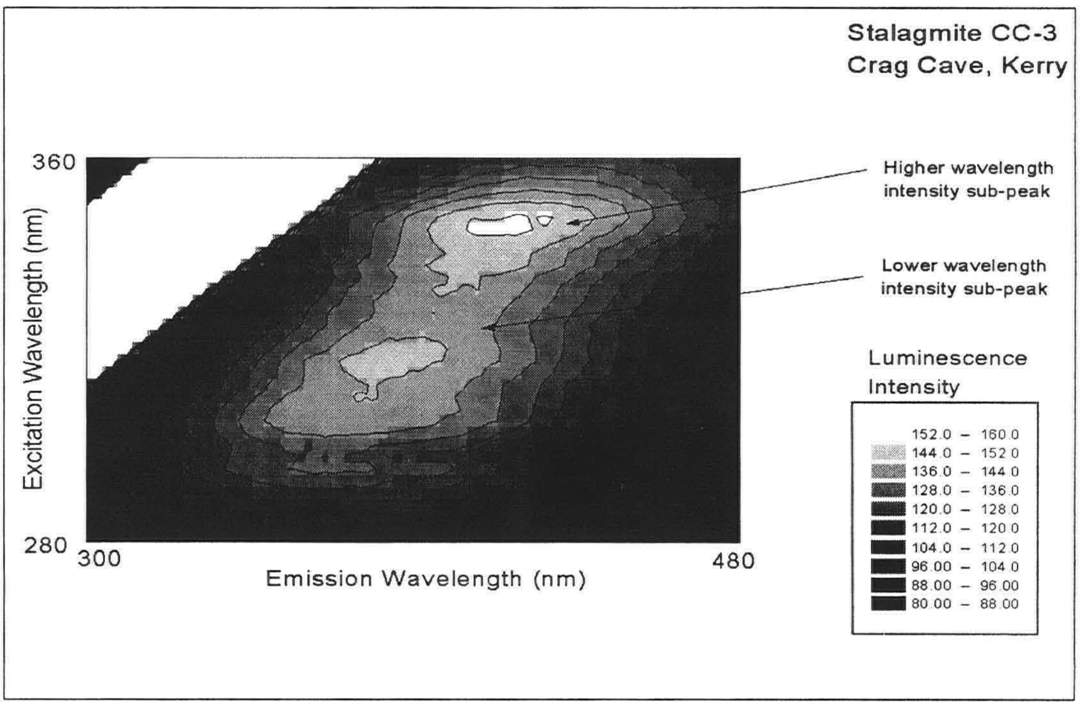
Organic acids are commonly entrapped within speleothems, and their luminescence is readily observed (O'Brien, 1956; Baker *et al.*, 1993; Shopov *et al.*, 1994). Forty to sixty per cent of all total organic carbon luminesces (Senesi *et al.*, 1993). Most of the luminescent material consists of humic and fulvic acids and protein, and this organic matter has a source in the soil overlying the cave. Recent research into speleothem luminescence has focused on two properties. Firstly, the intensity of luminescence, which for samples of constant crystallographic fabric and texture can provide a proxy of the concentration of luminescent organic material (Shopov *et al.*, 1994; Baker *et al.*, 1996). Secondly, luminescence wavelength variations, which can provide a measure of organic acid molecular weight and structure, as well as distinguish between humic/fulvic acid luminescence and that of protein (Baker *et al.*, 1998, 1999; Baker and Genty, 1999; McGarry and Baker, 2000).

Most studies of luminescence wavelength variations have focused on changes in the excitation and emission wavelength of the luminescence intensity maximum (Baker *et al.*, 1998, 1999). However, this luminescence centre is commonly observed to be a double peak (Fig.1), with two clear luminescence sub-peaks. Analysis of just the maximum luminescence therefore omits additional information that could be obtained from the luminescence centre as a whole. Recently, Proctor *et al.* (2000) demonstrated that the ratio of the two observed sub-peaks can provide a high resolution palaeoenvironmental proxy (Fig.2). By comparing the luminescence ratio against a separate climate proxy (that of mean annual rainfall/mean annual temperature, derived from growth rate variations, which is historically calibrated), a strong correlation is observed, with an increased proportion of high wavelength (high molecular weight) luminescence in wet and cold climate phases. Such a correlation agrees with our existing understanding of the effects of climate on soil humification (Christ and David, 1996; Martin-Neto *et al.*, 1998; Baker *et al.*, 1999), and suggests that further investigation is required into the sub-peaks of the organic acid luminescence centre.

METHODS

Eleven cut and polished speleothem samples were analysed for their luminescence properties, at 1mm intervals down their central axis of growth. Samples were chosen to represent a wide range of surface environments (climate, vegetation) as well as age ranges (Table 1).

Figure 1. Typical speleothem luminescence excitation-emission matrix (EEM), demonstrating the presence of two luminescence sub-centres.



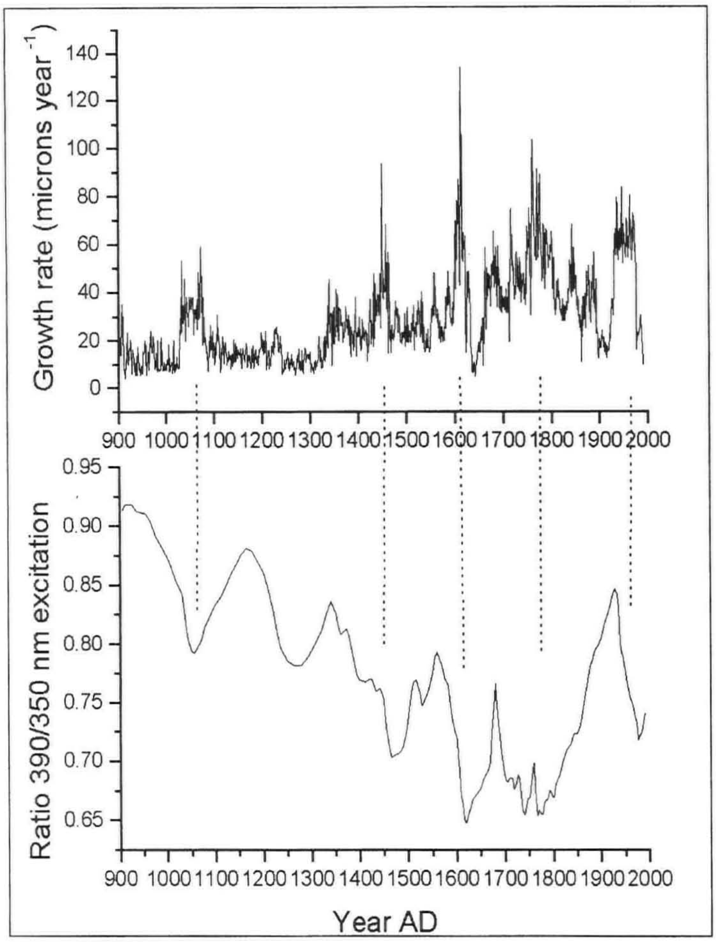


Figure 2. Growth rate (top) and ratio of luminescence intensity sub-centres (base) at excitation wavelengths of 350 and 390nm for stalagmite SU-96-7, Uamh an Tartair, Assynt. The inverse relationship demonstrates that at this site the high luminescence intensity ratio is equivalent to poorly humified soil conditions.

Luminescence data were collected using a Perkin-Elmer LS-50B luminescence spectrophotometer and Perkin Elmer fibre-optic extension. Excitation luminescence was varied from 260 to 420nm at between 3 and 5nm steps, and the emission recorded from 360 to 550nm at 0.5nm steps, in order to construct an excitation-emission matrix (EEM; Fig.1). For each EEM, the wavelength of maximum luminescence was reported (as per Baker *et al.*, 1998, 1999), as well as the ratio of the intensity of the two sub-peaks (higher wavelength peak / lower wavelength peak, as per Proctor *et al.*, 2000), if they were present.

RESULTS

Results are presented in Fig.3 and Table 1. Fig.3 demonstrates a wide range of wavelengths of maximum luminescence emission, from 380nm to 460nm. There appears to be no obvious environmental control on this parameter, with sites of similar rainfall and temperature and recently deposited speleothems having widely differing mean luminescence wavelengths (e.g. Stump Cross Caverns, Yorkshire, having some of the lowest wavelengths and Lismore Cave, County Kerry, Ireland, having some of the highest). Such results are not surprising, given the fact that luminescence wavelength variations reflect both molecular weight and aromaticity of organic acids, and that non-climatic factors such as vegetation type, soil clay content, etc. will influence the luminescence properties (Baker and Genty, 1999; McGarry and Baker, 2000). Similar results are observed for the ratio of the luminescence intensity of the two sub-peaks, with considerable inter- and intra-site variability. A statistically insignificant relationship is observed between intra-site mean luminescence wavelength and mean ratio ($r = 0.48$; $n = 11$, significant at the 80% confidence level).

Comparison of the wavelength of the maximum luminescence with the ratio data demonstrates that some samples have a strong correlation between the wavelength of maximum luminescence intensity and the ratio of the two sub-peaks (e.g. samples SU-2, Bel-1 and Vil-4). However, other samples exhibit no correlation between the two variables. Close inspection of the data suggests that these samples are those that exhibit a very small variability in the luminescence wavelength maximum (<±3nm), which is the same as the analytical error of the technique. Hence, for these samples, it appears likely that use of the luminescence intensity ratio data may provide a more precise measure. This is demonstrated by data for SU-96-7, for which the ratio data have already been demonstrated to reflect soil humification (Proctor *et al.*, 2000 and Fig.2), and yet has only a weak correlation between luminescence peak wavelength and ratio data (Table 1).

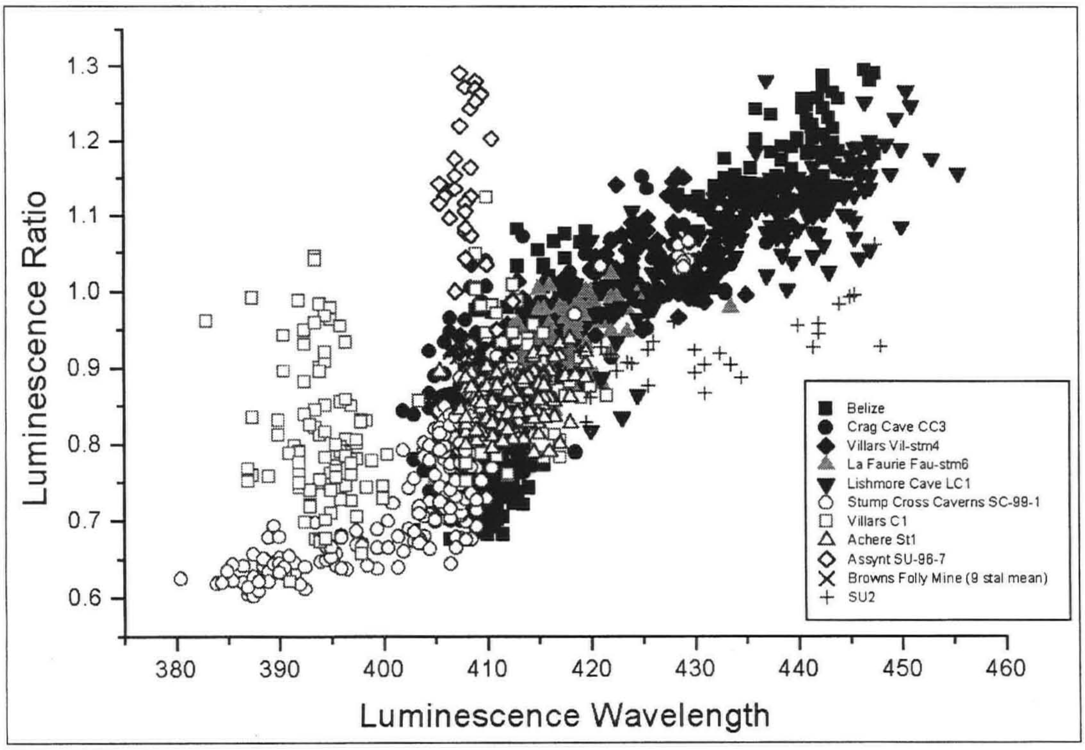


Figure 3. Mean luminescence wavelength of the lower wavelength luminescence centre vs. luminescence ratio for 11 speleothems. Sample details can be found in Table 1.

Table 1. Location, sample type, deposition period and luminescence properties of speleothems analysed in this study.

Sample ID	Location and type [a]	Deposition Period	Mean and 1σ wavelength of lower luminescence intensity sub-peak	Mean and 1σ intensity ratio	Correlation between wavelength of lower [b] luminescence peak and intensity ratio (r)
Bel-1	Belize, S	~ 180-10 ka	420.4±13.2	0.933±0.199	0.93
CC-3	Kerry, Ireland, S	10-0 ka	413.4±7.8	0.879±0.107	0.71
LC-1	Kerry, Ireland, S	10-0 ka	437.9±7.5	1.103±0.070	0.75
Vil-stm4	Dordogne, France, S	4-0 ka	419.4±6.7	0.974±0.063	0.75
Vil-C1	Dordogne, France, F	~ 100-0 ka	401.4±9.9	0.840±0.090	- [b]
Fau-6	Dordogne, France, S	last 100 yrs	417.2±3.9	0.929±0.050	0.52
SC-99-1	Yorkshire, UK, S	10-0 ka	404.2±8.7	0.763±0.098	0.86
Ach-1	Ethiopian Central Highlands, S	6-0 ka	412.8±2.9	0.856±0.033	0.31
BFM-B	Wiltshire, UK, S	last 100 yrs	408.1±1.7	0.920±0.004	-0.21
SU-96-7	Sutherland, UK, S	1.1-0 ka	408.2±1.6	1.146±0.094	-0.10
SU-2	Sutherland, UK, S	2.5-0 ka	432.1±9.7	.930±0.053	0.70

[a] S stalagmite; F flowstone;

[b] Correlation is Spearmans Product coefficient between the mean wavelength of luminescence of the lowest wavelength sub-peak, and the luminescence ratio. The bimodal distribution of the lowest wavelength centre for Vil-C1 makes correlation an inappropriate statistic, and so no coefficient is reported for this sample.

DISCUSSION AND CONCLUSION

The luminescence intensity ratio of two sub-peaks typically observed in the organic acid luminescence centre appears to provide a more precise measure of luminescence variations. This is particularly true for speleothems that exhibit little variability in the wavelength of the peak luminescence. For stalagmite SU-96-7, the use of an independent proxy has permitted the interpretation of the luminescence ratio data as a palaeoenvironmental proxy. Further work is required to investigate the palaeoenvironmental information contained within the ratio data for other sites and different soil covers.

Stalagmite SU-96-7 is overlain by thin peat, and the luminescence of the stalagmite reflects a relatively simple record of water table depth in the peat. For other sites, ratio data may reflect more complex soil processes. In addition, as the time period of study increases, so the complexity of the luminescence may increase, reflecting changes in the peak luminescence wavelength due to, for example, vegetation changes. Results presented here also suggest that considerable within-site variability may occur. Duplicate samples were analysed from the Grotte de Villars (flowstone Vil-C1 and stalagmite Vil-stm4) and Uamh an Tartair (stalagmites SU-96-7 and SU-2). At Villars, the flowstone sample exhibits a switching in wavelength of the two luminescence centres, yet for each centre there is no relationship between wavelength and the ratio due to the invariance of the former. For stalagmite Vil-stm4, a good relationship exists between the wavelength of maximum luminescence and the ratio. Both samples are from the same cave system although c. 200m apart. Given the variability of the ratio data in Vil-C1, such differences between samples are unlikely to be due to hydrological effects (mixing of waters of different ages or sources) and suggest that local variations in soil type and/or vegetation cover are important.

A similar effect can be seen between SU-2 (with strong correlation between maximum luminescence and ratio) and SU-96-7 (with a weak correlation); both samples grew over the same time period and were located less than 10m apart. Again, local soil conditions can be the most likely explanation: Uamh an Tartair is overlain by karstified dolomite with numerous small (< 2m-diameter) dolines that may affect the soil drainage and localised emplacement of glacial till affects the soil type. Despite this variability, both stalagmites exhibit variability in luminescence that has been correlated to surface environmental change (Baker *et al.*, 1999; Proctor *et al.*, 2000).

Further research is needed into the nature and cause of luminescence wavelength variability. However, preliminary results suggest that the ratio of the two luminescence sub-peaks that are typically observed commonly provides a more precise measure of luminescence properties of a given stalagmite. Partly this is due to the increased analytical precision of measuring luminescence intensity (typically <0.2% at 100 intensity units) as opposed to wavelength (±2 to 3nm). But it also appears to reflect changes in the composition of the organic acids trapped within the speleothems.

One implication of this research is the ability to obtain high precision and automated luminescence ratio data. Providing the wavelength of the two luminescence sub-centres does not change through time, then the relative luminescence intensity can be obtained through the continuous scanning of each sub-peak in turn, using a fixed excitation-emission wavelength pair and a moving stage. Using this technique as shown in Fig. 2, Proctor *et al.* (2000) presents a luminescence intensity ratio timeseries with a 1mm-wide luminescence spot and with the intensity recorded every 0.1s. This gives an effective sample resolution of 150µm (with 1mm spot size this is effectively 8 overlapping spots). With future developments in fibre-optic technology likely to reduce the fibre-optic bundle required to perform such automated analyses, this resolution can only improve and provide approximately annual to decadal scale luminescence data.

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Comparison of the luminescence intensity of speleothem feed waters from six cave systems

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Abstract: Feed waters that are associated with active stalagmite and flowstone deposition in six cave systems were sampled over individual hydrological years for their luminescence intensity. Luminescence intensity of cave waters has been demonstrated to derive from luminescent organic acids that are transported from the overlying soil. Sample sites include Sharkham Point Adit, Devon, a coastal site where luminescence may be quenched by marine derived salts; Lower Cave, Bristol; Brown's Folly Mine, Wiltshire; Grotte de Villars, Dordogne; Uamh an Tartair, Assynt and Stump Cross Caverns, Yorkshire. Comparison of the mean annual luminescence intensity within sites demonstrates that flowstone-depositing waters have higher luminescence intensity than stalagmite waters. Inter-site comparison demonstrates increasing luminescence intensity in the order Sharkham Point Adit < Lower Cave < Uamh an Tartair < Stump Cross Caverns < Brown's Folly Mine << Grotte de Villars. Villars has statistically higher luminescence intensity than all the other sites at a 95% confidence level. A higher flowstone water luminescence intensity than that of stalagmites agrees with results previously observed and may be explained by: (1) a greater transport capacity at higher mean discharge; (2) short groundwater residence time, which decreases the potential for absorption of organic acids within the karst aquifer; (3) possible wider fissures that optimise the transport of high molecular weight organic acids.
The significantly higher luminescence intensity observed at Grotte de Villars correlates with the high dissolved calcium concentration in the dripwaters at this site, and high stalagmite growth rate. It is suggested that further investigations from a range of sites with differing dripwater calcium and soil CO_2 productivity would discover if changes in luminescence intensity correlate with soil productivity, and hence can be used as a palaeoenvironmental proxy when preserved in speleothems.

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INTRODUCTION

Considerable research into the luminescence intensity of stalagmite dripwaters has taken place in recent years. Results have been published from Lower Cave, Bristol (Baker *et al.*, 1997; Baker and Barnes, 1998), Grotte de Villars, Dordogne; Uamh and Tartair, Assynt; Poole's Cavern, Derbyshire, and Brown's Folly Mine, Wiltshire (Baker *et al.*, 1999; Baker and Genty, 1999). Previous research has demonstrated significant differences in both inter-site mean annual luminescence intensity, and in intra-annual luminescence fluxes for individual drips or sites. Luminescence intensity of natural waters correlates with the total organic carbon of those waters (Senesi, 1993) and, hence, dripwater luminescence can be used as a proxy for this variable. Given the observation of variations in luminescence intensity, which is related to the drip water organic matter trapped within the speleothem sample calcite (Shopov *et al.*, 1994; Baker *et al.*, 1996), an understanding of dripwater luminescence is important in our understanding of the speleothem record.

METHODS

Dripwaters in six cave sites were sampled at regular intervals throughout the hydrological year during the period 1994 to 2000. Data and site descriptions for Brown's Folly Mine, Wiltshire, Grotte de Villars, Dordogne and Uamh an Tartair, Derbyshire, have been published in Baker and Genty (1999) and for Lower Cave, Bristol in Baker *et al.* (1997) and Baker and Barnes (1998). Here we add data from two additional sites, Stump Cross Caverns, Yorkshire and Sharkham Point Adit, Devon. Stump Cross Caverns is located on Greenhow Hill, North Yorkshire, at an elevation of 361m asl (grid reference: SE 089634). Four sites at a depth of c.12m, where speleothems is being deposited actively, were sampled between January 1999 and January 2000. Overlying vegetation is a mixture of upland grasses, heather and peat species. At Sharkham Point Adit, Devon, five drip sites (four feeding stalagmites and one feeding a flowstone) were sampled over the period August 1994 to August 1996. This abandoned mine working, at an elevation of 4m asl (grid reference: SX 737546) contains actively forming speleothems. Due to its coastal location, its dripwaters have high concentrations of marine salts (sodium ranging from 6 to 12 mmol l^{-1}; unpublished data) that may quench the organic luminescence (Buhmann and Dreybrodt, 1987). Overlying vegetation is bracken-dominated grassland.

Data for Stump Cross Caverns were analysed using a Perkin-Elmer LS-50B luminescence spectrophotometer using standard techniques (Baker and Genty, 1999); those for Sharkham Point Adit were analysed using a UV (HeCd, 325nm) laser, as per Baker *et al.* (1997). In order to compare between data collected by laser (Sharkham Point and Lower Cave) and spectrophotometric techniques (Brown's Folly Mine, Stump Cross, Grotte de Villars, Uamh an Tartair), data were standardised to a Raman peak intensity at an excitation wavelength of 350nm of 16.9 intensity units. The latter figure was the mean laboratory blank intensity during the period 1997-1998.

RESULTS

Luminescence intensity results presented in Table 1 are for just the stalagmites sampled at the six sites. Flowstone dripwater luminescence intensity has previously been demonstrated to be significantly higher than that of stalagmites at the same site at Lower Cave (Baker and Barnes, 1998). Results from the one flowstone sampled at Sharkham Point Adit demonstrate a similar relationship, having a higher mean luminescence intensity than the four stalagmites (flowstone luminescence intensity = 5.6 times mean stalagmite luminescence intensity).

The data in Table 1 demonstrate that stalagmite dripwaters in Grotte de Villars have significantly higher luminescence intensity than those at all the other sites, at a 95% confidence level. All other sites have statistically similar luminescence intensity.

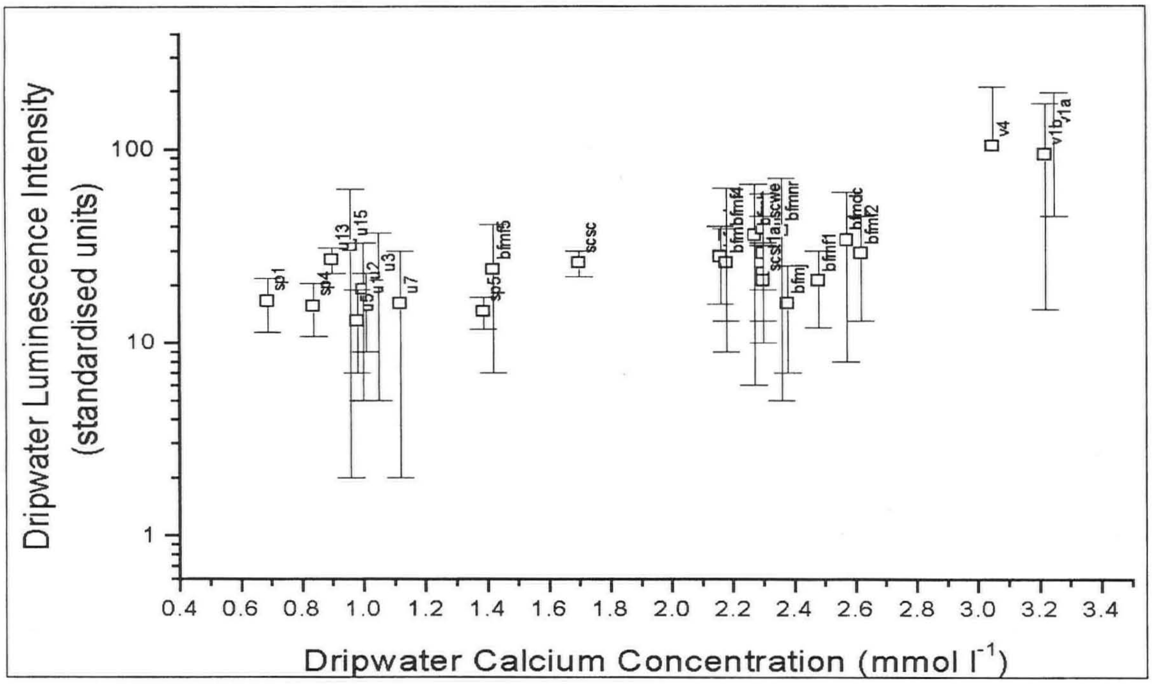

Figure 1. Mean annual calcium ion concentration vs. log mean annual luminescence intensity for dripwater sites where both parameters have been determined. Errors on the calcium concentrations are not shown for clarity, but range between 10-20% and reflect seasonal variations in this parameter.

INTERPRETATION AND CONCLUSIONS

The analysis of flowstone feed water at Sharkham Point Mine, together with the data from a flowstone at Lower Cave, Bristol (Baker and Barnes, 1998) suggest that, from this very limited dataset, flowstone waters are significantly more luminescent than stalagmite waters. This difference is as great as the inter-site variability in stalagmite luminescence intensity. It is suggested that flowstone feedwater is sourced through wider fissures, has a shorter residence time and has higher discharge than dripwaters feeding stalagmites. All three factors may affect the transport of luminescent organic carbon, given its high molecular weight and affinity to adsorb onto limestone surfaces. Stalagmite dripwater luminescence is similar between sites in the British Isles, but statistically higher at Grotte de Villars. Sharkham Point dripwaters were not significantly lower than other British Isles sites, suggesting that quenching effects of marine salts are not significant and that quenching cannot be used as a palaeoenvironmental proxy of sea-level rise in near-coast stalagmites.

A graph of mean dripwater calcium ion concentration against mean luminescence intensity is presented in Fig.1; a good correlation is observed (r = 0.74 against log intensity, significant at the 99.9% confidence level). Grotte de Villars, Dordogne, is noted for its high dripwater calcium ion concentrations and rapid growth rate (Baker *et al.*, 1998), both caused by elevated soil PCO_2. The results presented in Fig.1 suggest that further research is required for a range of cave sites with differing soil productivity and climate. Luminescence intensity could be used as a palaeoenvironmental proxy within stalagmite samples, if it can be demonstrated that it increases with soil CO_2 production.

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Sample site	Number of dripwater sample sites	Luminescence Intensity	Calcium Ion Concentration			
		mean	1σ	95% t-interval	mean	1σ
Lower Cave, Bristol	5	18.1	1.5	16.3-20.0	-	
Sharkham Point Adit, Devon	5	15.2	1.5	13.3-17.0	0.97	0.37
Brown's Folly Mine, Wiltshire	11	28.8	6.9	24.2-33.4	2.27	0.32
Grotte de Villars, Dordogne	5	82.2	33.3	40.8-123.6	3.17	0.11
Uamh an Tartair, Sutherland	7	20.6	6.8	14.3-26.8	1.00	0.07
Stump Cross Caverns, Yorkshire	4	27.3	8.1	14.4-40.1	2.15	0.30

Table 1. Stalagmite luminescence intensity data.

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Trichoniscoides saeroeensis Lohmander (Isopoda: Trichononiscidae) in the British hypogean fauna

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Abstract: The woodlouse *Trichoniscoides saeroeensis* was collected from a mine adit near the shore at Langness, Isle of Man. The record supports the contention that the species is cavernicolous in the British Isles. Field evidence points to the woodlouse being exceptionally tolerant of water, and this may partly explain its ability to survive in subterranean habitats. These observations add weight to the contention that the species is an example of a coastal invertebrate that is expanding its range by colonising the hypogean, an evolutionary route that may have been followed by some other terrestrial cave invertebrates.

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INTRODUCTION

Trichoniscoides saeroeensis Lohmander is a minute European woodlouse (under 3mm in length) with a Lusitanean distribution. It was first recorded in the British Isles from wet rotting timbers in old mine workings in the limestones near the Morecambe Bay coast at Crag Foot, Warton, Lancashire, in 1964 (Sheppard, 1968, 1971; Moseley, 1970). This population was observed there repeatedly between 1964 and 1968, suggesting it to be established. The species was found again in 1968, in limestone caves in County Clare, Ireland (Sheppard, 1968).

These records resulted in speculation that the species might be primarily cavernicolous in Britain (e.g. Chapman, 1993), but, as predicted by Jefferson (1976), it is now known that this is not the case. Further collecting has shown that there is nothing peculiar about the British distribution, which mirrors that elsewhere in its geographical range: the species is widespread here in a variety of coastal habitats. There are a few upland records (Sheppard, 1968; Cawley, 1993; Daws, 1993), whereas records from caves remain sparse.

During 1994, coastal mines and caves on the Isle of Man were searched, to help clarify the status of this species in hypogean habitats in the British Isles, and to ascertain whether it may occur more widely and predictably where suitable underground habitats exist.

RESULTS

The search on the Isle of Man was successful. Adults were collected several times between July 1994 and October 1995 on wet to waterlogged timbers in Langness Mine Day Level (British National Grid reference SC 284659), an abandoned copper mine adit in limestone close to the shore on the west side of the Langness Peninsula. This is a similar habitat to that in the Warton mines. *Androniscus dentiger* (Isopoda: Trichoniscidae) was almost always present on the same timbers. This species was also recorded at the Warton site (Moseley, 1970).

DISCUSSION

Trichoniscoides saeroeensis has been found only infrequently in caves and has not been shown to reproduce underground in Britain. Whereas we thus cannot be certain that it is a troglophile here, the weight of evidence points in that direction. It was found repeatedly and predictably during the 1964 to 1968 Warton Crag survey and throughout the 1994 to 1995 work at Langness. Therefore, the populations at both sites appear to be established.

The close association of *Androniscus dentiger* and *T. saeroeensis,* both at Warton and at Langness, is interesting. *A. dentiger* is a troglophile that is commonly found in a variety of habitats in caves in Britain. It is known to be exceptionally tolerant of water and able to withstand even total immersion with ease (Jefferson, 1976). Its close association in caves with *T. saeroeensis* suggests that the latter may likewise be a water-tolerant species. There is further evidence from the field records that *T. saeroeensis* is exceptionally tolerant of water. The site where the species was first found in England in the Warton mines was a piece of mine timber, about 0.5m in length, lying in a small alcove and bathed in a continuous trickle of water falling from the adit roof just above. The first time that the animal was collected, a dozen individuals were taken, emerging from the soaking wet wood as it slowly dried out back in the laboratory. The wood was subsequently returned to the spot where it had been found. When it was re-examined on several occasions during the next five years, it was always very wet, and one or two individuals could generally be found on it. Because no other significant organic material and thus no visible source for the population was found anywhere near the mine alcove, Moseley (1970) suggested that *"... the animals are reaching this alcove from a centre of population elsewhere ... and are carried by the water which flows from the roof here"*. The second British Isles record was in an Irish cave, where it was reported *"... in interstitial water gushing out of the right hand wall."* (Sheppard, 1968). The recent underground records from the Isle of Man were all from wet to waterlogged rotting mine timbers.

This may partly explain the ability of the species to colonise caves. Tolerance of total immersion is a typical characteristic of subterranean invertebrates, and is thought to relate to the fact that the mesocavernous voids that form the primary habitat of many species are subject to flooding during rainfall (Chapman, 1993).

T. saeroeensis is of particular interest as a cavernicole because of its primarily coastal distribution. There is now general acceptance that many aquatic cavernicoles have evolved from marine ancestors (see e.g. Coineau and Boutin, 1992, p.428). Much less attention has been paid to the possible origin of some terrestrial cave invertebrates from ancestors that inhabited littoral and sub-maritime habitats. Howarth (1981) proposed that the Hawaiian cave cricket *Caconemobius varius* (Orthoptera: Gryllidae) evolved from a marine littoral ancestor that lives in the splash zone around the coast. He suggested that the ancestral form was pre-adapted to colonise wet rock habitats that meet the coast, such as sea caves and lava tubes. This seems to be a very reasonable suggestion as, in 1996 and 2000, a population of another epigean gryllid, probably *Thetella tarnis*, was observed in Ao Nang, Krabi, Thailand (Moseley, unpublished), living in a tidal sea cave and foraging in the littoral zone at low tide.

There is also the record of a population of *Trechus fulvus* Dejean (Coleoptera: Trechidae) in a tidal sea cave on the Isle of Man (Moseley, 1997). This beetle, a coastal species living under stones near the high water mark, usually near to freshwater springs or seepages, is also found in caves near the coast in Ireland, the Isle of Man and the west of England. Such distribution implies the direct colonisation of the cave habitat by a sub-maritime species.

Chapman (1993, p.187) hypothesised that *Trichoniscoides saeroeensis* may also be an example of a coastal/sub-maritime invertebrate that is in the process of actively invading and colonising hypogean habitats. The recent Manx records and its presently known distribution support this contention.

During the past decade some evolutionary cave biologists have shifted focus from the historical emphasis on obligate cave-dwelling organisms to the use of troglophiles as more useful empirical models for studies of natural selection and adaptation in the cave environment. For example, Kane and Culver (1992) in the USA have used the freshwater amphipod *Gammarus minus*. In Britain, a rich fauna of aquatic and terrestrial troglophiles in (as pointed out by Chapman, 1993) a dynamic phase of colonisation, must offer opportunities for investigations of this type. Species such as *T. saeroeensis* may be able to provide evolutionary, ecological and physiological insights into the initial stages of the colonisation of hypogean environments by coastal terrestrial invertebrates.

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CLIMATIC AND HYDROLOGIC CONTROLS ON ANNUAL CARBONATE DEPOSITION FOR A STALAGMITE FROM BROWN'S FOLLY MINE, WILTSHIRE, ENGLAND

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A stalagmite sampled from Brown's Folly Mine, Wiltshire, southwestern England, consists of 109 layers, possibly deposited annually, that alternate between inclusion-rich calcite and clear calcite. Spectral analysis of the stalagmite layers reveals periodicities of 2.8, 4.0, 6.4, 11.6 and 16.0 years, that agree well with periodicities found within the precipitation record from the area (r^2 = 0.092, p-value = 0.014). The Saros Lunar cycle (18.7 years), ENSO (6.7 years) and the 11-year sunspot cycle may be the major climatic forcings. A dramatic increase in layer thickness 71 layers above the base may represent a reduction in surface run-off and an increase in soil pCO_2 due to the re-establishment of surface vegetation and a soil horizon after mining in the area ceased.

HYDRODYNAMICS OF THE DENSITY STRATIFIED COASTAL CARBONATE AQUIFER OF THE YUCATÁN PENINSULA, MÉXICO: A PRELIMINARY REPORT

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The Yucatan peninsula in south-east México is a large carbonate platform that hosts a density stratified aquifer where fresh meteoric water is separated by a distinct mixing zone from the underlying saline water. Extensive networks of flooded caves (more than 300km surveyed to date) have been explored in a zone extending 10km inland from the east coast, and actively discharge meteoric water at numerous coastal springs. This research investigates the time-varying controls on aquifer hydrodynamics, and on the depth and thickness of the mixing zone. The relationship between passage morphology and hydrology is also explored. Multi-seasonal records of salinity, temperature and velocity are obtained with Aanderaa oceanographic recording current meters (RCM 7s) installed using cave diving techniques at an inland fresh water site 4.3km from the coast, a coastal brackish spring, and a deeper saline passage. Additional salinity and temperature profiles have been obtained with a YSI multi-parameter probe. Time series analysis will determine the controls on fresh and saline hydrodynamics in response to ocean head and meteorological conditions.

The fresh water velocity in conduits some 4.3km inland and at the coastal spring show semi-diurnal fluctuations in response to changes in ocean head. Velocity steadily decreases as the dry season progresses until it is consistently below the instrument threshold of 1cm/s at the inland site. A number of events, including Hurricane Keith, which passed near the field area (October 1, 2000), reduce and/ or stop discharge for up to two days, and result in an influx of warm saline water at the coastal spring. Detailed salinity and temperature profiling indicates that mixing zone thickness increases with proximity to the coast. Long-term records at one site 2km inland reveal that mixing zone depth fluctuates semi-diurnally in response to ocean head by 2 to 6 centimetres around a consistent mean position. Meteorological and tidal events (including the hurricane) induce short-lived perturbations in the sharp thermocline of the mixing zone, but the mixing zone geometry is re-stabilised generally within 2 tidal cycles. The temperature of the fresh water is regionally uniform at ~25.2°C up to 10km inland. However, the saline groundwater at the coast is c.1.9°C warmer than the fresh water and thermal convergence is apparent only at >10km inland This warm saline water adjacent to the coast suggests a very active circulation of marine water from the warm shallow Caribbean Sea into the aquifer at the peninsular margin. The convergence at >10km inland may result from thermal equilibration or from reduced saline circulation at this distance threshold, which coincides with the absence of known large cave passages.

Our ongoing research has significant implications for water resource management in coastal carbonate environments, which are subject to intense tourism development pressure. This research will assist in determining the fate of effluent commonly disposed of via deep injection wells in the saline water zone.

BACTERIAL PROCESSES IN CAVE ENVIRONMENTS

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Bacteria are crucial to the development of limestone caves of any significant size. The respiration of bacteria in soils generates CO_2 that dissolves in soil water to form the carbonic acid that dissolves limestone during normal meteoric speleogenesis. In areas with no soil or in cold climates, where soil productivity and consequently soil gas CO_2 concentrations are low, cave development is restricted relative to tropical climates with warm, highly productive soils (hence all the really big caves are in tropical China, Mulu, etc.). In temperate regions, like Britain, the same phenomenon manifests itself on a seasonal basis.

Bacterial respiration of oxygen to oxidize organic material also takes place in cave sediments, and can form the basis of cave food webs. However, respiration of oxygen to produce CO_2 is not the only bacterial process of significance to cave ecology or cave formation. Bacteria can also gain energy by using oxygen to oxidize sulphur compounds to sulphate. In the absence of oxygen there are bacteria that can respire using nitrate, iron(III) and sulphate rather than oxygen to oxidize organic matter to yield energy. All these processes modify the environment in which the bacteria live in different ways. Whilst identification of species or consortia of bacteria can give clues as to what bacterial processes may go on, it does not tell us about the relative importance of different bacterial processes in cave environments. In order to do this we need to know in what ways and how much the different bacteria present have modified their environment. In particular, some chemical changes are characteristic of these processes and can be used to indicate and assess their impact. Many bacteria are also extremely fussy and prefer one stable isotope of carbon, oxygen, nitrogen or sulphur to another and thereby leave isotopic "fingerprints" of their activities.

The talk will use a number of examples of the chemical and stable isotopic approach to illustrate the importance of bacterial processes and assess their impact on cave and cave-forming environments.

THE EVOLUTION OF THE ISLAND OF IRELAND SINCE THE CARBONIFEROUS AND THE DEVELOPMENT OF ITS KARST LANDSCAPE

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Carboniferous limestone crops out over approximately 50% of the island of Ireland. However, the limestones are exposed largely in the upland areas such as the Burren (County Clare) and the Northwestern Uplands (counties Fermanagh, Cavan, Leitrim and Sligo). Elsewhere, especially across the Midlands, the limestones are buried beneath an overburden of boulder clay, sand, gravel and peat. Whereas the upland limestone areas, such as the Burren and the Northwestern Uplands, have extensive karst development, the lowland areas have widely been considered to have very few karst landforms. During the past decade, however, there has been an increase in the number of discoveries of palaeokarst, which suggest that the lowland areas have also undergone an extensive period of karstification. The fills from several of these palaeokarst landforms have been dated as being of Oligocene and early Pliocene age. Although these discoveries demonstrate that karst processes have been active in Ireland for a significant period, recent studies examining the burial and erosional history since the Carboniferous confirm that the Carboniferous limestones have been exhumed a number of times prior to the development of the modern topography.

CONDITIONS IN CAVES AND OTHER KARST FEATURES IN THE PWLL DU AREA AT THE TIME OF THE NAMURIAN TRANSGRESSION

Owen Clarke

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Plaques of sedimentary rocks similar in general appearance in hand specimen and in thin sections to the overlying basal layers of the Millstone Grit, observed on the walls of Ogof Dwy Sir, are taken as evidence that Ogof Dwy Sir was formed before the start of the Namurian Period. This study looks at the possible sedimentary infills to the cave that must have existed in some form to cause the Namurian infill to form plaques on small sections of the walls.

Siambre Ddu is an abnormal cave in that it appears to be formed entirely within basal Namurian rocks. The floor of the cave is formed of massive blocks filling a large depression. The view that this cave could have been formed by the washing out of sediment from a pre-existing surface pothole is strengthened by the evidence of a pre-Namurian valley leading towards the main chamber.

Foxhunters Rift, which is entered through the Millstone Grit, is also of interest, since some of the rocks in the cave appear to have been extruded downwards into the chamber.

GENERALLY DISREGARDED PATTERNS IN MUD FLOORS IN CAVES

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I had the good fortune to observe undamaged patterned mud and sand floors in an unexplored secret cave in Mallorca. Subsequently I have seen similar patterns in cave floors – previously crossed without really taking notice - in Wales, as well as in France and in South Africa. I have been unable to find any reference to these in the speleological literature, and those familiar with the caves have paid no attention to these formations.

The surface deposit in both types of formation is very tough mud, capable of surviving people walking across it for many years without the formations being lost. In one form, where the formation is similar to ripple marks on a beach, the underlying deposit is sand. In the other case there is competent mud for the full 50mm depth of the triangular grooves. These formations have been studied only in Ogof Fynnon Ddu II, producing evidence that here they are in a floor where there is a 3mm mud covering over sand, and that the formations are not limited to nominally flat floors.

This session is seen as an opportunity to gather views on how this phenomenon should be studied, rather than as a definitive statement on the subject.

BEDROCK AND CATIONIC CONTROLS OF THE COMPOSITION OF KARST WATERS AND SPELEOTHEMS

Ian J Fairchild [1], Anna F Tooth [1,2], Yiming Huang [1], Andrea Borsato [3], Silvia Frisia [3], Andy Baker [4], Frank Mcdermott [5], Baruch Spiro [6], Tim Heaton [6], Chris Hawkesworth [7]

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Speleothems contain a rich record of past environmental change, the meaning of which we are learning to unlock. The transfer functions to relate water and speleothem calcite chemistry are becoming better constrained. The hydrological and hydrochemical behaviours of drip waters are complex, but those that display geochemical change also show a clear relation to hydrology and hence the distribution of rainfall through the year. High resolution records of past seasonality are a real prospect.

Recent publications:

Baker, A, Genty, D and Fairchild, I J, 2000. Hydrological characterisation of stalagmite drip waters at Grotte de Villars, Dordogne, by the analysis of inorganic species and luminescent organic matter *Hydrology and Earth System Sciences*, Vol.4, 439-449.

Fairchild, I J, Borsato, A, Tooth, A F, Frisia, S, Hawkesworth, C J, Huang, Y, McDermott, F and Spiro, B, 2000. Controls on trace element (Sr-Mg) compositions of carbonate cave waters: implications for speleothem climatic records. *Chemical Geology*, Vol.166, 255-269.

Frisia, S, Borsato, A, Fairchild, I J and McDermott, F, 2000. Calcite fabrics, growth mechanisms and environments of formation in speleothems (Italian Alps and SW Ireland). *Journal of Sedimentary Research*, Vol.70, 1183-1196.

Huang, Y and Fairchild, I J, 2001. Partitioning of Sr^{2+} and Mg^{2+} into calcite under karst-analogue experimental conditions. *Geochimica Cosmochimica Acta*, Vol.65, 47-62.

Huang, Y, Fairchild, I J, Borsato, A, Frisia, S, Cassidy, N J, McDermott, F and Hawkesworth, C J, 2001. Seasonal variations in Sr, Mg and P in modern speleothems (Grotta di Ernesto, Italy). *Chemical Geology* (in press).

Verheyden, S, Keppens, E, Fairchild, I J, McDermott, F and Weis, D, 2000. Mg, Sr and Sr isotope geochemistry of a Belgian Holocene speleothem: implications for paleoclimate reconstructions. *Chemical Geology*, Vol.169, 131-144.

CHALK KARST: OBSERVATIONS FROM GEOLOGICAL FIELD MAPPING

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Recent geological mapping of the Upper Cretaceous Chalk of southern England has demonstrated that karst features are more widespread than previously recognised. Karst affects the engineering properties and the hydrogeological behaviour of the Chalk. As the Chalk occurs in the densely populated south-eastern half of the country, a good understanding of the geohazards and risks associated with karst features is essential to prevent costly engineering problems and to model aquifer behaviour accurately. The development of a new high resolution Chalk stratigraphy (Mortimore, 1986; Bristow *et al.*, 1997) and its application by the British Geological Survey permits a more detailed assessment of the style, distribution and nature of karst features. Furthermore, improved mapping of the superficial Quaternary deposits that are a major influence on the density and distribution of surface karst landforms allows better prediction of where dissolution features may occur. This improved mapping, coupled with a developing GIS database of karst features, will permit delineation of karst geohazard domains for use by planners, developers, engineering geologists and hydrogeologists.

RECONSTRUCTION OF DEPOSITION EVENTS AT NEPTUNE'S CAVE, NORWAY

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Whereas marine deposits from karst caves in the Velfjord area of central Norway have been reported before, none have previously been dated. The recent discovery of an extensive series of deposits in Neptune's Cave, near Velfjord, has provided the first opportunity for such deposits from an *inland, marine influenced, karst,* cave to be dated. Six types of fossil have been collected and identified from the cave: mammal bones, marine molluscs, barnacles, foraminifera, ostracods and pollen. Some of these were lying within a sediment that is rich in organic matter. Four different samples (animal bone, marine molluscs, organic sediment and barnacles) have been dated using radiocarbon techniques. From the datings, and an understanding of the Late Weichselian de-glaciation and Holocene uplift of the area, a possible sequence of events is constructed that explains the situation and condition of the various deposits. With the removal of the ice burden during the latter part of the Younger Dryas stadial, Fennoscandia started to rebound at a very fast rate initially, so that the cave soon emerged from below sea-level. The radiocarbon dates obtained lie within the ranges anticipated from an assumption about the appropriate sea-level curve for Velfjord.

SOURCES OF POLLEN IN STALACTITE DRIP WATER IN TWO SW-FRANCE CAVES

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Pollen filters were placed under active stalactites in the Villars and La Faurie caves (SW-France) for one year in order to see if pollen grains were introduced by seepage water, and to quantify the pollen fluxes. In Villars Cave, filters that were protected from the cave atmosphere collected no pollen, whereas those that were open collected a few grains, demonstrating that, here at least, pollen was transported by cave air and not by seepage water. In La Faurie Cave, the two protected filters collected a few pollen grains, partially representative of the local vegetation, showing that some pollen enters the cave with seepage water. Pollen grains extracted from three stalagmites in Villars Cave showed that only the stalagmite containing detrital layers contained a significant amount of pollen. Besides pollen, different kinds of plant and animal microdebris, which provide complementary information about the sources of pollen, were found in the filters and in the stalagmites.

THE RELATIONSHIP OF PALAEOKARST TO MODERN CAVE FORMING PROCESSES IN THE TRANSVAAL, SOUTH AFRICA

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The Transvaal of South Africa has evidence of some of the oldest caves in the world, occurring as the in-filled eroded relicts of caves that more than likely began forming some 10 million years ago. Today many of these palaeokarst features lie as inactive mined-out shells, made up of hanging walls of fossiliferous breccia, left after lime mining ceased in the early part of the last century. Many of these caves have yielded fossils of a wide variety of unique hominin lineages, dating back as far as 3.3 million years. Some of these palaeocaves, such as the Makapansgat Limeworks, are completely relict and show no evidence of more modern active cave systems associated with the earlier deposits. At other sites, such as Sterkfontein Cave, a modern cave system has developed directly beneath the eroded remnants of the original cave, and stands as testament to a continuous re-use of the original weak structures in the rock that caused preferential water flow and the speleogenesis of the original cavity. Although they are closely associated with the original cavity, the caves are developed primarily in the dolomite beneath the original cave. At Peppercorns' Cave, for example, the basal flowstone of the original cave is now fossilised on the roof of the modern cavity. In some cases the water flows through the original palaeosediments, carving out channels and re-depositing sediment into the lower cave system or mined cavities. Such processes can be seen at Gondolin palaeocave, where makondos caused by the dissolution of dolomite and breccia around tree roots have deposited both the debrecciated ancient sediment and modern infill sediment into the present cavity. Upward dissolution and collapse are also occurring, with the creation of breccia avens within the ancient deposits. At some palaeocave sites, such as Gladysvale, modern water has used the original conduits to such an extent that an entire cave has now developed within the palaeosediments of the original ancient cave system, creating what are essentially breccia walled caves showing at least two separate phases of cave formation and infill. This type of re-use appears to be associated primarily with caves that develop as slanting rifts along faults, and is demonstrated well at a new cave discovered at Makapansgat in 1998. Murzl's Cave is part of a large echelon fault system, running the length of the Zwartkrans and lower Makapansgat Valley, that has been used repeatedly as a conduit for waterflow, with the current cave formed within the sediments of a much earlier phase of infill. Such re-use of earlier palaeokarst features has an important bearing on the interpretation on the stratigraphy of South African palaeocave deposits, where this successive re-use of palaeokarst conduits may have been active.

PRESERVATION OF SKELETAL REMAINS IN EUROPEAN PLEISTOCENE CAVES: CHANGES TO THE PROTEIN AND MINERAL COMPONENTS OF FOSSIL BONE

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A potential solution to the important questions of modern human evolution and dispersal lies in the use of genetic information from Pleistocene fossil humans, but the retrieval of authentic biomolecular material from these fossils has only rarely proved successful. The extraction of mitochondrial DNA from the Neanderthal individuals from Feldhofer and Mezmaiskaya has been encouraging, but these are isolated results and failure to recover biomolecular material from fossil human remains is much more common.

What makes the successful bones special? The answer lies in several factors affecting diagenesis, principally the biological processes of decay, the burial environment and the cumulative climatic history of the site. We have examined a series of Pleistocene and Holocene skeletal samples in an attempt to establish the unique attributes of specimens that contain well-preserved DNA. Thermal models based on the theoretical rates of decay of DNA provide a baseline for predicting which geographical regions and localities are more favourable for biomolecular survival.

The samples themselves have been subjected to a suite of well-established tests to determine the porosity, crystallinity, histological alteration and collagen content of the bone. The phenomenon of better preservation in caves compared with open sites is being investigated through careful sample selection and thermal monitoring of cave sites. Our results indicate that DNA survival exceeds predictions from theoretical models in particular burial environments.

CLIMATE VARIABILITY IN THE LAST INTERGLACIAL: NEW EVIDENCE USING A HIGH-RESOLUTION SPELEOTHEM STABLE ISOTOPE RECORD FROM LANCASTER HOLE CAVES, NORTH YORKSHIRE

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A speleothem (LH-90-12) from Lancaster Hole, North Yorkshire is used to reconstruct the variation of medium and short-term climate change during the last interglacial period. High-resolution records of $\delta^{18}O$ and $\delta^{13}C$, determined using Laser Ablation Gas Chromatography Isotope Ratio Mass Spectrometry (LA-GC-IRMS), are used as potential palaeoclimate proxies. We compare LA-GC-IRMS technique with results from conventional methods, and demonstrate that this new technique is both accurate and successful in obtaining very high-resolution isotopic profiles rapidly. We observe no evidence for kinetic fractionation, and consider the sample suitable for palaeoclimate analysis. Variation of $\delta^{18}O$ and $\delta^{13}C$ in the main phase of speleothem growth (130.4 to 115.5 ka BP, based on TIMS ^{230}Th ages) suggests that climate was unstable during the last interglacial period. Results indicate a cooling/drying from c.126.5 to 120.9 ka BP, followed by a period of considerable cold/aridity. Rapid warming from 119.8 until c.119 ka BP was then followed by another cooling/drying period until the end of the growth period at 115.5 ka BP. The timing of $\delta^{18}O$ variation is tentatively linked with North Atlantic circulation/SSTs and the GRIP ice-core record. Spectral analysis of the stalagmite $\delta^{18}O$ record reveals a significant periodicity of c.1500 years, similar to that observed in other records of climate change for the last glacial period and the Holocene.

STRATIGRAPHY OF NIAH CAVE, SARAWAK: A VERY PRELIMINARY ACCOUNT

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Niah Cave in Sarawak is famous for its prehistoric archaeology, including hundreds of burials and the oldest morphologically-modern human skeletal material in SE Asia, associated with radiocarbon dates of c. 40,000 bp. This material was recovered in the 1950s, before the advent of many modern investigative techniques. The AHRB and Museums Sarawak-funded Niah Cave Project aims, *inter alia*, to establish the stratigraphic, dating and environmental framework for the 1950s finds. The results of the first field season are described. A provisional sequence of depositional units, resulting from shallow water flows, mudflows and terrigenous sedimentation, has been established. These are probably of Late Pleistocene and Holocene age and provide the context for the ancient human activity at Niah.

SAMPLING ARTHROPOD CAVE FAUNAS

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This talk will deal with some biological sampling techniques such as pitfall traps, bottle traps and hand searching, and examine their advantages and disadvantages. The need for biological recording in cave habitats and the processes leading to species description will be discussed.

GAUGING THE RISK: THE 'FATAL ACCIDENT RATE' AND 'NON-FATAL ACCIDENT RATE' FOR CAVING AND POTHOLING COMPARED WITH OTHER SPORTS IN ENGLAND AND WALES[1]

Peter and Julie Mohr

Red Rose Cave and Pothole Club

How dangerous is caving, and how does it compare with other sports and activities in terms of the risk of injury or death? Most experienced cavers accept that there is some risk, but rationalise it with a rhetoric of 'common sense' based on reliable equipment, training and good caving practice. Nevertheless there are two or three fatal accidents every year. One might wonder how this compares with fatalities in other sports. Is caving safer or riskier than horse riding or skydiving? Indeed, is it possible to make such comparisons objectively? How can a minority activity like caving be compared with a popular sport such as football?

The science of 'risk assessment' has been used to identify the environmental and life-style risks in public health and industry. Recently David Ball (Professor of Risk Management, Middlesex University)[2] has applied these techniques to calculate the fatal and non-fatal accident rates to a range of sporting and recreational activities in a way that allows an objective comparison between different sports. This poster extends Professor Ball's statistical technique to include data for caving accidents in England and Wales.

The 'fatal accident rate' (FAR) is the number of fatal accidents per 100 million hours of activity. The 'non-fatal accident rate' (NFAR) is the number of accidents per 100,000 hours of activity. These calculations are made on a regional basis (England and Wales), over a five to ten year period. These deceptively simple formulae hide a plethora of methodological difficulties and assumptions, which have been discussed in *"Descent"* (April/May 2000). When an allowance for the relatively small number of cavers is made, then it is clear that the FAR is indeed higher than most other sports except air sports; however, the NFAR is relatively low (see table below).

The high FAR should not be used to deter novices but rather to encourage 'safe caving' by promoting club membership, proper training and experienced leadership. All risks are relative, and have to be balanced against the risks of daily life at home and at work, and the advantages of the activity. The FAR for some 'dangerous' occupations such as deep-sea fishing or logging are in the same order as caving, and the risk of using a motorbike is much greater (FAR 500). The benefits of sport for a healthy life are well known. Caving offers one of the few opportunities left for exploration and promotes leadership, teamwork, tenacity, and endurance, all character traits important to society at large.

We are grateful to Professor Ball for his advice and permission to quote his data.

Activity	**No. of deaths** *1988-92*	*Number of occasions adult participation (millions/year)*	***F.A.R.*** *per 100 million hrs. exposure*	***N.F.A.R.*** *per 100,000 hrs. exposure*
Air sports	51	1.0	200	?
Caving*	**11**	**0.43**	**157**	**2.5**
Climbing	51	4-8	30-60	4
Sailing	69	23	20	4
Swimming	191	370	12	2
Riding	62	39	10	3
Fishing	50	37	8	2
Soccer	14	128	2	130
Rugby	2	12	2	290
Badminton	1	59	1	14
Running	9	200	0.6	5
Golf	1	110	0.06	2

Table 1. Comparative fatal accident rates (F.A.R.) and non-fatal accident (N.F.A.R.) for selected sports. England and Wales for 1988-92. [2]

*The caving F.A.R. for the seven-year period 1993 to 1999 has improved to 102.

[1] This presentation is based on an article, 'Gauging the Risk', *Descent* 153, April/May 2000.

[2] Ball, D J, 'Risks and Benefits of Sport and Exercise', *Sports Exercise and Injury*, Volume 4.

BRITISH HYPOGEAN BIOLOGY: RETROSPECTIVE AND PROSPECTIVE

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Animals were recorded from caves in the 19th century, but the period 1935-1975 saw the most intensive and extensive collections. The animals collected were sent to the Biological Recorder of the Cave Research Group (Mary Hazelton), who ensured that relevant experts identified them accurately and authoritatively. She published the results of the identifications in 16 parts between 1955 and 1976. These results showed that the UK has a very small number of cave-restricted (troglobitic and stygobitic) organisms. Of the aquatic fauna, 6 species of Amphipods, 1 species of Isopod, and 1 species of Syncarid are stygobitic. Of the terrestrial fauna there are only a handful of troglobitic insects and arachnids. Nearly all cave animals are accidentally present in the caves, or else troglophilic, i.e. happy in caves as well as on the surface. Thus the communities of troglophilic animals are our most important components. Collembola, mites and diptera predominate. Other than collection very few studies have been completed. The first, and most important, pre-requisite for an advance in the knowledge of UK cave biology is a computer database of the existing records. There are a number of ways of achieving this and they are being actively investigated. Once we have this, it will be possible to determine gaps in knowledge. A series of collections targeted at uncollected sites, important habitats, and prominent species then seems a sensible way onward. It does not seem likely that unspecific collection is warranted.

RADIOCARBON IN SPELEOTHEMS FROM THE BAHAMAS: IMPLICATIONS FOR CLIMATE AND SOLAR/GEOMAGNETIC FIELD VARIATION DURING THE LAST GLACIAL PERIOD

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A stalagmite from a submerged cave on Grand Bahama provides a nearly continuous record of atmospheric radiocarbon (^{14}C) from 45 to 11 thousand years ago (ka). This record, derived using mass-spectrometric U, Th and Pa measurements and accelerator mass-spectrometric ^{14}C ages, offers considerable potential for an accurate and continuous calibration curve and provides valuable information about carbon cycling and geomagnetic intensity. We find elevated atmospheric radiocarbon concentrations ($\delta^{14}C$) for the duration of growth. A broad peak is observed, with highest values between 45 and 33 ka. Superimposed on this peak are several rapid excursions that can only be explained by dramatic shifts in redistribution of ^{14}C in the carbon cycle and/or changes in production of ^{14}C caused by abrupt changes in solar and terrestrial magnetic field modulation. After 26 ka, millennial and sub-millennial variations coincide with abrupt shifts in climate as recorded in the Greenland ice cores. During the last deglaciation, rapid reduction in $\delta^{14}C$ occurred at times of inferred warming and increases in ventilation of the deep ocean.

CRAG CAVE, KERRY: EVIDENCE FOR LATE PLEISTOCENE GLACIAL EPISODES IN SOUTHWEST IRELAND

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Investigations in Crag Cave, County Kerry, have revealed two widespread and altitudinally separated clastic sedimentary units. On examination, the younger of these units consists of two major glaciofluvial gravel bodies, overlain by thick laminated sandy silty clays. The site lies outside the area glaciated during the Last Glacial Maximum (LGM). U/Th dates suggest that the glacifluvial sedimentation at Crag Cave pre-dates the LGM and may be linked with events in Oxygen Isotope Stage 5 or 4.

Note that the following two abstracts have been given slight editorial amendment to "smooth" the English translation, but some parts have been left unchanged rather than risk compromising their original meanings. We apologise to readers if some aspects remain unclear, and to their authors if any inappropriate changes have been made.

THE ANALYSIS AND POSSIBLE GENESIS OF A SILICATE FORM OF MOONMILK SAMPLED IN NIKITSKY CATACOMB NEAR MOSCOW

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Moonmilk is a substance known to mankind since ancient times. A reason to single out moonmilk as a specific form of secondary cave deposits is the characteristic feature of a microthixotropy (or cryptoplastic texture) – the ability of a solid material to become liquid, under even negligible pressure or other modification of the factors affecting equilibrium. Thus, for the moment, researchers combine an extensive group of secondary cave deposits of different composition and genesis under this name. Most moonmilk deposits consist of carbonate material, but can also be formed of sulphates, phosphates, silicates and other minerals. The silicate kind is considered.

Moonmilk was found in the Nikitsky Catacomb, near the Kolokolenka (Belfry) chamber. This catacomb is located in upper-carbon limestone.

The samples were studied for chemical composition, mineralogical composition (by x-ray diffraction), bacteriological composition and SEM observations.

Thus, based on the data obtained, we propose the following hypothesis of moonmilk formation. Respiration of saprophytic organisms in conditions of a laboured diffusion of gases and solutions enriches the material with CO_2. High concentration of carbon dioxide results in enhanced solubility and leaching of carbonates, and partial transformation of a silica-alumina phase. Quite probably metabolic organic acids produced by micro-organisms play a significant part in these processes. The significant role of organic acids in the weathering of primary minerals has been discussed extensively by soil scientists.

Usually silicon is mobile in alkaline conditions and drops out on chemical barrier at change of acidity of solutions. However, as a rule, the conditions for an alkaline hydrolysis of silicates in a limestone are insufficient. We assume, that the local zones of acidity are formed at the expense of a difficult diffusion of carbonic acid formed by respiration of micro-organisms, or as a result of organic acid production. In these conditions the carbonates leave in water solutions, for example, in a case of lateral migration of gravitate waters, and the silicate phase does not variate or is exposed to a weak acid hydrolysis. The part of crystals palygorskite and montmorillonite (contained in residual clay) is blasted as a result of an acid hydrolysis with appearance of amorphous silicon, however, appearances of allophanes or kaolinite does not descend, as the aluminium is strongly mobile. The high motility aluminium is the oblique proof of permanent acid conditions.

A negative relationship means that as soon as a silicate gel appears in a system the organic matter gets immobilized and becomes less accessible for micro-organisms. Besides other peculiarities necessary to point out that the siliceous gel is an excellent absorptive system accumulating any components of the surrounding environment and one may contain a variety of elements not directly related to its genesis. The last fact is a reason that some samples of moonmilk collected by different scientists have unique properties and composition.

THE REASONS FOR HIGH BIODIVERSITY IN KARSTIC LANDSCAPES (AN EXAMPLE FROM THE ARKHANGELSK REGION, RUSSIA)

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Qualitative and quantitative models of the genesis and functioning of north-taiga moraine and unique karst geosystems were developed. They were based on experimental basic studies needed for investigation of the structural parameters of north-taiga moraine and karst geosystems, as well as on the regime observations needed for the study of their functioning. Many parameters of relief, soil mantle, vegetation, soil meso- and micro- biota and also meteo- and hydrological characteristics of surface and underground parts of the karst and moraine geosystems were measured. The proposed model suggests that the lithological and geomorphic matrix of both the moraine and karst landscape were formed during the time of the Valdai glacier degradation, and genetically related to tectonically-induced jointing of gypsum massifs. Litho-geomorphic features influenced the formation of the set of ecosystems - from low-productivity spruce forest with low biodiversity on podzolic soils to lower-productive north-taiga coniferous open woodlands on sulphorendzinas (soils on hard gypsum with low content of nutrients). The ecotone between these ecosystems is high-productivity mixed forest with a high diversity of vegetation, soils, soil macro- and microbiota. The model of its functioning suggests that higher bioproductivity and biodiversity and ecotopes for growing of Red Book species related to the large number of ecological niches these species need and these parameters are supported by specific turnover with high content of nutrients, microclimate diversity and by periodic erosion of upper leached soil horizons and the roots reaching the subsoil horizons enriched by nutrients. The highest levels of biological activity take place during the most humid summers. The moraine landscape is stable in respect to its geomorphic structure, soil mantle and vegetation, and its biota is able to buffer climatic fluctuations - when a dry summer comes after a humid one, the peak of biological activity shifts from well-drained areas to less-drained ones, but generally remains on the same level. In conditions of the extreme development of karst processes, denudation and rockfall predominate. On the basis of Wischmeier model use, the different role of soil processes in the control of erosion were discovered for silicate (hindering role) and gypsum (accelerating one) substrates. Numerical operations on the whole of the data and the series of dating (14C-data and other kinds of dating) made it possible to develop a numerical model of the rate of organic matter accumulation on colluvium blocks - the process regulating status and functioning of karst landscapes.

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Forum

Readers are invited to offer thesis abstracts, review articles, scientific notes, comments on previously published papers and discussions of general interest for publication in the Forum of *Cave and Karst Science*.

All views expressed are those of the individual authors and do not necessarily represent the views of the Association unless this is expressly stated. Contributions to the *Cave and Karst Science* Forum are not subject to the normal refereeing process, but the Editors reserve the right to revise or shorten text. Such changes will only be shown to the authors if they affect scientific content. Opinions expressed by authors are their responsibility and will not be edited, although remarks that are considered derogatory or libellous will be removed, at the Editors' discretion.

CORRIGENDA

The editors apologise to readers, and to the authors mentioned below, for allowing a number of word processing and reproduction errors to appear in *Cave and Karst Science*, Volume 27(2). The text errors were not present at first proof stage, and appear to have been generated by an unrecognised "bug" in the Desk Top Publishing software, which "loses" text across imposed page breaks. An unrelated mistake, concerning dates of receiving and accepting a manuscript, is purely and simply a human error. Finally, the poor quality of a text figure reflects the unlikely combination of inadvertently supplying a substandard "master" to the printer, and the appearance of a "rogue rectangle ", not apparent at page proof stage, within the published figure, which is again assumed to reflect a late-stage software error.

The manuscript of the Report on subaqueous stalagmites, by Andy Baker and Chris Proctor, was received on 19 March 1999, as stated, but was actually accepted for publication on 17 June 2000, not 17 June 1999, as was published. In the same Report the quality of Figure 2 is significantly below that of the art material supplied by the authors. The redundant rectangle beneath the right hand photograph within this composite figure is an introduced artefact, for which we can provide no excuse, but repeat our apology to the authors. Finally within this Report, text was omitted inadvertently in the cross-over from page 79 to page 80. The complete paragraph should read:

RESEARCH SITE

Subaqueous stalagmites were first observed by the authors at Sharkham Point Iron Mine, South Devon, England (Grid Reference: SX 737546). The geology at Sharkham Point comprises a sequence of Mid Devonian shales, tuffs and limestones, extensively affected by Hercynian folding and thrust faulting (Smythe, 1973). Iron mineralization occurs within the limestone on the north side of the headland. The ore comprises haematite, with abundant barite and lesser amounts of calcite, dolomite and quartz, infilling irregular dissolution cavities in the limestone. The wall rock adjacent to these cavities is also extensively haematitised. Between about 1860 and 1875 the ore was worked from surface excavations and from adits dug from the coast on the north of the head (Burt *et al.,* 1984). The research site is a horizontal drainage adit (Figure 1) that is approximately 2.2 to 3.0m wide and 1.5 to 2.5m high, containing pooled water 30 to 40cm deep. The pool waters are held back by a tufa-cemented boulder dam near the entrance. Drainage from collapsed old mine workings at the enclosed-end of the adit provides the water supply, and overflow occurs at the adit entrance during the winter months. Calcite rafts form on the pool surface, predominantly at the outward end, and additional flowstone deposition occurs at the enclosed end, whereas tufa is deposited where the overflow water cascades over rocks at the mine exit.

Turning now to the Forum contribution about Beck Head Stream Cave, by John Cordingley, text was lost in the paragraph bridging pages 93 to 94. This omission would have been particularly difficult to recognise during proof scanning, insofar as the text superficially makes sense as published, only appearing less than sensible when the text is compared to the illustration shown as Figure 2. The full, and much more informative, text reads:

> The Ingleborough Cave Stream (i.e. Clapham Beck) descends from BP3 along J1 to enter the first (shallow) part of the Beck Head Stream Cave Sump, which has enlarged from an inception route along BP2. A further descent of J2 (the Black Hole shaft) allows the water to enter BP1, which it follows through the deeper part of the sump. Because of the gentle northeasterly dip of the bedding this deeper zone rises gradually throughout its 163m length. This passage closely resembles the "Cellar Gallery" in Ingleborough Cave, except that it has yet to be drained (by eventual recession of the Broadbent Falls nick-point). The water then rejoins BP2 by rising up J3, but then re-descends to BP1 via the Broadbent Falls (J4). The remainder of the cave, together with the whole of Clapham Beck Head (see note below), is guided by BP1. The only other possible exposure of BP1 elsewhere in Ingleborough Cave is the passage at the base of the 15m-deep flooded shaft in the "Upstream Passages" (accessed from the Second Gothic Arch).

Whereas we are proud of our recent record of apparently error-free publication (the last published *"Corrigendum"* was in 1997), we are by no means complacent. Probability being what it is, we are reasonably certain that similar errors must have occurred, either unnoticed or unreported, in past issues. If this is the case, we apologise to any authors whose papers or reports have been affected, and we express the hope that any such editing shortfalls have caused no major problems or repercussions

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CORRESPONDENCE

Comments on "Bivalves (Pisidiidae) in English caves" by L Knight and P J Wood (*Cave and Karst Science*, Vol.27(2). August 2000)

Dear Editors,

I read the above article with great interest. Various species of Pea Clams (*Pisidium* spp.) are common and widespread, often locally abundant, in surface waters in Europe including the British Isles. Several species are known from cave habitats in Continental Europe. Their rarity in British cave collections has thus been somewhat mysterious. Now, Knight and Wood present a set of records that, taken as a whole, makes a convincing case that *P. personatum* and probably also *P. nitidum* are bona fide members of our cave fauna, and almost certainly troglophiles. In addition, the earlier records are suggestive that *P. casertanum* too will be added to this list, but it should be pointed out that the old records do not always make it clear whether live animals or merely empty shells, perhaps washed in from the surface, were collected, and so we will have to await the finding of living examples.

The colony of *Pisidium personatum* in Hazel Grove Cave, Beetham, Cumbria (SD 499770) has died out. I examined the site twice in 1999 and again last year, and found only empty shells, many still articulated. However, this does not prove that the colony was unviable: the cave is now polluted by drainage fed from a caravan site, and this may well explain the disappearance of the species. According to Boycott (1936), *P. personatum* is quite catholic in its choice of habitat, but prefers stagnant waters: ditches, marshes, temporary ponds and puddles. It also frequently occurs by itself, as the only bivalve species. Thus, were it not for it being underground, the sump pool in Hazel Grove Cave would otherwise seem to be an unremarkable habitat for this species, and I am now inclined to the view that this used to be a viable cave population. Hazel Grove Cave is within a designated SSSI, and the authorities have been notified of the deliberate pollution of the site.

From the records listed by Knight and Wood, I think that we can draw some conclusions that were not brought out explicitly by the authors. First, the reported colonies of *Pisidium* seem to be found only in food-rich sites, rather than in the oligotrophic (food-poor) habitats that are more usually thought of as typical of the cave environment: witness the notes about mud rich in organic matter at two sites, and the presence of tubificid worms – indicative of similar conditions – at a third. Secondly, the reports show not just the existence of troglophilic populations of *Pisidium,* but point more broadly to the existence of a distinct ecological faunal assemblage characterised by *Pisidium* associated with either *Niphargus* or *Rivulogammarus pulex* exploiting a high-energy (food-rich) hypogean habitat. Although so far we only have three examples of this "*Pisidium* - amphipod Association" – from Devon (*P. personatum + N. aquilex),* Derbyshire (*P. nitidum + R. pulex*), and Cumbria (*P. personatum + R. pulex*) – these are geographically widespread and are similar enough to imply more than coincidence.

By example, Knight and Wood's paper shows just how much there is still to be done, even at the basic level of describing the British hypogean fauna. This is a field where the amateur enthusiast as well as the professional career scientist can make a contribution, and I hope that the recent revival of interest mentioned by the authors will prove to be the herald of the renaissance of British speleo-biology.

One suggestion for future papers of this type is that a note about the location of voucher specimens be included. Critical specimens ought ideally to be deposited in a recognised institutional collection.

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SCIENTIFIC NOTES

HISTOPLASMOSIS IN SOUTHERN AFRICA: AN EPIDEMIOLOGICAL UPDATE

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Abstract: This note gives a short review of the distribution and clinical features of histoplasmosis.

CLINICAL PRESENTATION

Histoplasmosis is a fungal disease caused by the parasitic *Histoplasma capsulatum*, which can have five clinical presentations:

1. **Acute benign pulmonary histoplasmosis (ABPH).**
   This is the commonest form in which the patient presents with an acute febrile respiratory illness, usually between two and four weeks after exposure to the fungus. Provided that the patient is immuno-competent, no specific treatment is necessary; and the patient recovers within four weeks.
2. **Acute disseminated histoplasmosis.**
   In this presentation the fungus penetrates beyond the lungs, and is disseminated via the blood to all parts of the body. This is a serious, potentially fatal, disease that needs energetic treatment using anti-fungal drugs.
3. **Chronic pulmonary histoplasmosis.**
4. **Chronic localised histoplasmosis.**
5. **Chronic disseminated histoplasmosis.**
   This rare presentation is usually diagnosed in retrospect, after death.

DISTRIBUTION

Histoplasmosis was first described in 1905 by an American army pathologist following an autopsy. At that time it was thought to be a rare and inevitably fatal protozoal disease[1]. We now know that the micro-organism is a fungus. It is distributed widely throughout the tropics and sub-tropics, especially the south-eastern United States, central and south America, the Caribbean, central and southern Africa, and the wetter parts of Asia. Most infections are benign and self-limiting.

In the United States the fungus is ubiquitous, being found in soil, bat guano, and bird droppings. Elsewhere *H. capsulatum* is associated only with bat guano (i.e. in caves and abandoned mines), yet some patients give no history of exposure thereto. The fungal spores are inhaled by people who disturb the guano and create a dust. Whether they become symptomatic depends upon previous exposure, quantity of spores inhaled and immune competence.

The first case to be reported from southern Africa occurred in 1942 in a former Southern Rhodesia (now Zimbabwe) mine manager who died from chronic disseminated histoplasmosis[2]. He may have been exposed to bat droppings in his mine.

The next two cases were reported in 1953 in expatriate anthropologists who had excavated caves in Northern Rhodesia (now Zambia). They had visited caves on Twin Rivers Farm, 24km southwest of Lusaka, and Freeman's Guano Caves near the beginning of the Kafue Gorge, and subsequently developed acute benign pulmonary histoplasmosis[3]. This case was investigated at the South African Institute for Medical Research in Johannesburg, which prompted the staff to look for histoplasmosis nearer home. They found ABPH the same year in 15 former Transvaal cave explorers[4]. Since then histoplasmosis has come to be well-recognised in the former Transvaal highveld.

Subsequently ABPH was again reported from Southern Rhodesia (now Zimbabwe) with a definite history of exposure to bat guano[5]. Circumstantial evidence suggests that the fungus may be present in the Northern Cape, where the altitude and latitude are little different from those of the highveld[6].

Histoplasmosis is uncommon in the Cape; indeed for many years it was said not to exist there. One visiting Transvaal speleologist, who was familiar with the disease, doubted that the spores were present in the caves north of Oudtshoorn[7]. It was believed that, the altitude being lower, and the latitude being further south, the environmental conditions were unfavourable for *H. capsulatum*. We now know this to be incorrect. Acute benign pulmonary histoplasmosis was reported from the De Hoop Guano Cave, east of Bredasdorp in 1977[8], and again from the same cave ten years later[9]. This disproved the 1977 theory that the spores had been introduced by visitors from a highveld cave, that the environmental conditions were unfavourable for spore survival, and that the spores would become non-viable. In 1991 there was an outbreak of ABPH among cave explorers in the Swartberg foothills north of Oudtshoorn[10].

As mentioned above, the behaviour of the ubiquitous *H. capsulatum* in the USA is different from that elsewhere in the world where the fungus is associated only with bat guano. In the USA skin testing and antibody studies showed that most people are exposed to the spores, and develop sub-clinical disease that protects them from further infections. Our experience in the Cape has shown that there is no correlation between the clinical and radiological features of ABPH, and the antibody tests - the kits for which are imported from the USA. This suggests that although *H. capsulatum* is morphologically identical throughout the world, its antigenicity varies. This can be explained on evolutionary grounds – bats do not have sufficient range to migrate across the Atlantic and Pacific oceans. Therefore *H. capsulatum* was exposed to different proteins in different parts of the tropics and sub-tropics, and developed different antigens.

The clinical presentation of histoplasmosis is changing with the spread of the human immunodeficiency virus (HIV), which lowers or destroys the ability to resist infections. The Index Medicus database is listing ever-increasing reports of histoplasmosis associated with HIV, which is now being experienced in Cape Town. We have recently had three such cases, only one of which gave any possible history of exposure to bat guano – he had been working in an Orange Free State diamond mine[11].

SUMMARY

Histoplasmosis is well known in Zambia, Zimbabwe, the former Transvaal highveld, Northern Cape and Southern Cape. It has not been reliably reported in the Orange Free State, Namibia, Botswana, Swaziland and Lesotho; and no information is available for Mozambique and Angola.

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FURUNCULAR MYIASIS CAUSED BY *DERMATOBIA HOMINIS* IN A CAVER RETURNED FROM BELIZE

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INTRODUCTION

Myiasis constitutes a parasitic disease, of humans or other vertebrates, that is always secondary to the presence of the larvae of Diptera in a skin wound ("cutaneous myiasis") or in the body ("deep myiasis")[1]. Furuncular myiasis occurring in the Western hemisphere, especially in Central and South America, is usually caused by *Dermatobia hominis*[2], whereas *Cordylobia anthropophaga*, which causes very similar skin abscesses, is acquired exclusively in Africa. The larvae of both species develop at the site where they are deposited. Infection by a third species, *Hypoderma lineatum*, is extremely rare in humans[3]. Its larvae undergo a complex migration through the body before forming raised "warbles" on the skin surface. A number of other Diptera species can also infect humans.

Adult *Dermatobia hominis* are large flies, 2cm in length, with long extremities. They have a dark-blue thorax; an almost rhombic metallic blue abdomen, orange antennae and legs, and dark-brown wings[4]. They live on the nutrients collected during their larval stage, and both fertilisation and oviposition take place during their week-long life. The mated female catches different haematophagus insects (such as day-flying mosquitoes) on the wing, sticking sets of eggs to their abdomens.

An embryo develops in each egg. Though ready to emerge in a week they do so only when the bearer insect settles on a homeothermal being (ie a warm-blooded animal, usually a cow), piercing and penetrating the skin of the new host in about 10 minutes[5]. The clinical presentation is of boil-like skin lesions. Furuncular lesions are generally multiple, and they involve both exposed and unexposed areas of the body [6].

Because of the increased ease and frequency of travel to tropical countries, physicians in European countries are nowadays being confronted more and more commonly with patients displaying the symptoms of parasitic tropical diseases [7].

CASE REPORT

This report concerns a case of *Dermatobia hominis* myiasis in a 34 year old white female caver, recently returned from Belize. During her holiday she visited various caves and carried out some surface explorations in the jungle. After a week she noted two small nodular lesions located on her right knee. The lesions were characterized by erythema, furuncular nodules, local pruritus, a burning sensation and pain. When she returned to Italy an antibiotic therapy was applied, but without bringing about any noticeable improvement. Suspecting an insect bite with subsequent development of abscesses, doctors prescribed a second antibiotic treatment and local application of an oily ointment. This caused the caudal extremities of two larvae to appear, in search of air. The two larvae were then extracted from the skin. Morphological analysis and epidemiological data allowed the larvae to be identified as *D. hominis*. Subsequently the inflammation disappeared completely within a short period, without any further symptoms.

DISCUSSION

Even if not strictly cave-related, furuncular myiasis may constitute a problem to cavers living in, or visiting tropical countries, especially in Central America, particularly as the number of overseas expeditions continues to increase.

In patients who display cutaneous lesions after their return from tropical countries, myiasis has to be considered as a potential diagnosis [3], as otherwise the disease may well be mistaken for furunculosis.

Cutaneous myiasis should be suspected in cases where patients display secreting, non-healing, furuncular skin-lesions, and have a relevant travel history. The patient may remember being bitten by insects. The patient may experience a sensation of movement within the lesion and, in some cases, movement may actually be observed. Both of these indicators add support to the proposed diagnosis. In cases of uncertainty histological evaluation of the submitted fly larvae will allow identification of the causative organism [2], but generally the external morphology of the maggots and observation of the insect's spiracles are sufficient to confirm identity. Correct recognition and diagnosis at an early stage will prevent unnecessary treatment with antibiotics [8].

Careful mechanical extraction of the larvae is the treatment of choice, and the condition may easily be treated, and the extraction facilitated, by application of Vaseline to the insect bite, which cuts off the larvaes' air supply, leading to partial voluntary extrusion of the larvae, as described above.

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EDITORIAL NOTE

The Editors thank Dr Alan Gunn, of Liverpool John Moores University, for his efforts in improving translations, particularly of medical terminology, within the text of the above Report. Dr Gunn also provided the following brief notes, which are included here to complement the points in the authors' original Report.

1. The maggots will also infect a wide range of other mammals, so anyone taking pets to or from affected regions (or smuggling monkeys, etc) should be aware of the risks, including that of introducing the insect to previously unaffected areas.
2. The maggots develop over a period of 6 to 12 weeks, after which they burrow out and find a place to pupate in the soil. Wounds should heal after the maggot(s) have departed.
3. Like all abscesses, those caused by developing maggots provide a potential site for bacterial infection.
4. If not treated, the abscesses caused by *Dermatobia hominis* can become infested by the maggots of another fly, *Cochliomyia hominivorax*, the New World Screw-worm. Infection with the latter species, which lays its eggs in any wounds, even tick bites, can be extremely serious, even fatal.
5. Treatment with antibiotics alone will not remove *D. hominis* larvae, but may be useful, as the abscesses commonly become infected with bacteria.
6. It is not a good idea to try extracting *D. hominis* larvae by squeezing them out. The shape of the larvae and their backward-pointing spines make this a difficult task. As the authors suggest, coating the larva's airhole with Vaseline, petroleum jelly, or any similar substance will encourage the larva to turn around and remove itself.
7. The Report highlights the importance of taking precautionary measures, such as using insect repellents, in affected parts of the world.
8. Although the insect has the specific name *'hominis'*, it is actually more important as a parasite of cattle. Where there are large numbers of cattle there is a potentially greater risk of becoming infected.

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BOOK REVIEWS

Yuan Daoxian and Liu Zaihua (Editors), 2000. *Global Karst Correlation*. Science Press, Beijing and New York [ISBN 1-880132-32-X] and VSP, Utrecht and Tokyo [ISBN 90-6764-286-X], 1998.

As the final report of the 1990-94 International Geological Correlation Program (IGCP) Project 299, *"Geology, Climate, Hydrology and Karst Formation"*, this volume is a very welcome addition to the comparative karst literature, and it whets the appetite for future volumes reporting the outcomes of subsequent projects (IGCP 379 – *"Karst Processes and the Carbon Cycle"*, 1995-99, and the recently instituted IGCP 448 – *"World Correlation of Karst Geology and its Ecosystem"*). Intended for a specialist karst audience, it aspires to laudable goals, and it should be in the library of every karst scientist.

The 16 chapters begin with an introduction to the project and finish with a perspective on karst science, both by Professor Yuan Daoxian, the distinguished senior editor from the Institute of Karst Geology at Guilin. In some senses, these are among the most rewarding contributions, since they address the broad scope of the project, in which context other chapters fall disappointingly short. In between is a collection of regional and topical reports, some fresh and pertinent, others repetitive or wide of the mark.

The goals of IGCP 299 were lofty and diverse, and this is reflected in the resultant volume, although not always positively. As reported by Professor Yuan, the objectives were fourfold:

- To identify the global differences in karst feature complexes and to clarify the regularities of their distribution.
- To study the relationships between karst feature complex, karst processes and the geological, climatic and hydrological background.
- To reconstruct the course of paleoenvironmental change from karst records.
- To apply the experiences of evaluation, prediction, and exploitation of natural resources and environmental protection to various karst areas.

In retrospect, this was perhaps too sweeping a remit, and it is to the editors' credit that the text is as coherent as it is. Nonetheless, as with most multi-author compendia, it remains uneven in scope, focus and writing, and it ultimately delivers as much frustration as satisfaction, essentially because it promises so much yet, with few exceptions, fails to deliver the goods. Is it a worthwhile volume? Absolutely. Does it attain its aspirations and reflect its title accurately? Regretfully, I think not.

Professor Yuan's opening account of the project sets the scene nicely, yet immediately one wonders whether a single volume can do justice to the aspirations described therein. Nevertheless, the discussion of karst feature complexes (KFCs) and the karst dynamic system (KDS) is stimulating, and the accounts of the project's field excursions are valuable, particularly for those who were unable to participate. Likewise, the concluding chapter provides a perspicacious overview of the project's achievements, and provides a clear link to the subsequent IGCP endeavours.

Professor Dreybrodt's contribution, *"Principles of karst evolution from initiation to maturity and their relation to physics and chemistry"*, I found to be one of the most challenging in the volume, examining as it does the role of limestone dissolution kinetics in the genesis and evolution of karst cave conduits. Well written, rigorous and stimulating, it provides a theoretical and experimental standpoint from which to view karst development, although the casual reader will be hard-pressed to discern quite how this relates to global karst correlation.

Chapters 3 through 15 represent the core of the volume, with a mix of thematic studies and regional karstland accounts. All have their merits, although few provide any real **correlation**, or even much comparison, and one fails to see why some are included here at all. Some are merely regional descriptions, and even here the selection criteria are unclear. Why, for example, nothing on Central America, and why does Vietnam serve as the lone representative of Southeast Asia? And to what extent does the chapter on the Friars Hole Cave System provide any real representation of North America or make a meaningful contribution to global karst correlation?

This said, each of these chapters has its merit, although it is often difficult to reconcile this with the overall theme. Chapter 3, *"Karst morphogenesis in the Arctic: examples from Spitzbergen"*, for example, provides a valuable proxy for karst conditions in high latitudes under Pleistocene stadials and interstadials, and relates clearly to the theme of environmental influence and change. This again comes to the fore in the commendable chapter 15, reporting on speleothem luminescence records from Bulgaria, the US and Canada.

Of the regional accounts, some are valuable because they deal with karstlands that have not received much attention previously in the English or other international literature. Chapter 4, on the Urals, and chapter 5, on the Baltic Republics, fall into this category as, to some extent, does chapter 14, although this deals with only a small region of karst in western Brazil. Similarly, the chapters on Vietnam (10) and Romania (11) are of considerable interest, although it is unclear quite how they contribute to the overall goal of the volume.

Chapter 6, *"The karst geomorphology and hydrogeology of Great Britain"*, and chapter 12, *"Typical karst area – Skocjanske Jame, Slovenia"*, both make interesting reading, but neither contributes a great deal to the central theme, nor does either report on substantial new research relevant to the topic. Chapter 8, *"Karst of Japan"*, is a nice account too, but one wonders whether Japan, where the total area of karst is only about 1,654km^2, or 0.44% of the national territory, really merits inclusion in a tome purporting to provide 'the big picture'.

Two regional accounts, chapter 9, *"Karst of China"*, and chapter 13, *"Karst and caves in Australia and New Guinea"*, are more successful as vehicles for regional, even global correlation, in part because of the extensive and diverse land areas that they consider. Other regional accounts at comparable scales and employing consistent criteria would have made this a more cohesive volume. I am reminded of how useful it would be now to have a new, updated encyclopaedia of the world's major karst regions to complement Herak and Stringfield's dated (1972) and regionally restricted *"Karst: important karst regions of the northern hemisphere"*.

Given the international array of authors, the volume is well produced, with fewer linguistic difficulties and errata than might have been anticipated. The references on page 248 to uvulas caused me momentary confusion and subsequent amusement, but such slips are exceptions in a text that appears otherwise to have profited from diligent proof-reading. Likewise, the illustrations are generally of good quality, and the photographs are mostly excellent, although that on the front cover does the volume little justice.

The inconsistency of Global Karst Correlation might be blamed on the editors, but that would be unreasonable. Given the geography of participation and contribution, they have put together a report that reflects the international tapestry of karst research and reminds us of the common cause.

My disappointment at the unconformity of the volume's title, goals and accomplishments is tempered by my appreciation of the wealth of regional and systematic information that is incorporated, such that I would recommend this book to anyone with an interest in karst. Ultimately, it doesn't deliver that for which one might have hoped, but it certainly sets the stage for future global comparative karst research, and for that the authors and editors are to be commended.

Reviewed by Professor Mick Day, Department of Geography, University of Wisconsin-Milwaukee, USA.

Wilkens, H, Culver, D C and Humphreys, W F (Editors), 2000. *Ecosystems of the World Volume 30: Subterranean Ecosystems.* Elsevier, Amsterdam. 791pp, Hardback only, ISBN 0-444-82299-2 Price: US$ 254.50; NGL 486.00 (Euro 220.54).

This is a timely and long-awaited book, which provides a valuable synthesis of research on subterranean ecosystems across the globe. The book could not be described as a text book on cave ecology, but is rather a collection of introductory and research papers from some of the most pre-eminent scientists working in subterranean environments around the world. The book comprises 35 chapters that are divided into 8 sections, starting with a valuable background and glossary that the reader will find particularly useful when reading later chapters. Other sections are divided into unequal parts devoted to the different types of subterranean biota, adaptations to subterranean life, the trophic basis of subsurface ecosystems and the evolution of subterranean organisms. The final two sections of the book deal with individual studies of particular cave and aquifer systems, and with the conservation of cave ecosystems.

The book deals with all the major types of subterranean ecosystems and the organisms found within them, from karstic caves and aquifers to volcanic lava caves, ice caves and shallow hyporheic habitats associated with riverine systems. This does mean that a number of chapters may be of limited interest to those purely interested in cave ecosystems. However, the material contained within the chapters clearly demonstrates the breadth of work being undertaken in this exciting and expanding area of research. I would especially recommend the book to geologists, geomorphologists and hydrologists, since it provides an extremely accessible and informative academic reference resource.

The editors and publishers have clearly spent a long time preparing and organising this book and as a result the reader is led logically through the chapters. Anyone, even with little or no previous knowledge of subterranean biology, could pick up this book and learn all the fundamental points in the first few chapters. The fine details, such as the systematic list of genera and the 84-page index of authors, organisms and an extensive general index, make this book a remarkable resource.

Section two of the book starts with three readily accessible chapters on karstic and pseudokarstic habitats, interstitial habitats associated with shallow unconsolidated sediments, and anchialine cave ecology. This is followed in the third section by three chapters devoted to subterranean organisms. Two of these chapters deal with invertebrate groups including insects and crustacea. They are well illustrated with line drawings and a limited number of black and white plates. The final chapter in this section deals with fish and amphibians, highlighting many of the morphological differences between epigean and hypogean forms. Bats and birds are not included within this section, since they enter and leave the subterranean environment freely. However, their importance in terms of the trophic structure of many tropical caves is acknowledged widely in later chapters.

Section four of the book provides an overview of the adaptations of subterranean organisms to their environment. The five chapters provide overviews of issues associated with the effects of continuous darkness, adaptations to interstitial and true groundwater life and acoustic communication in cavernicolous plant hoppers. Two chapters stand out - the first on the ability of cave organisms to cope with food scarcity and the second on the role of aggressive behaviour in subterranean organisms. The adaptations evolved by organisms range from the morphological development of longer appendages (antennae and legs) that increase the effectiveness of foraging, starvation resistance and reduced energy demands associated with low metabolic rates. In addition, life history changes lead to lower growth rates, increased longevity, delayed reproduction and the production of fewer and bigger eggs. It appears that many subterranean organisms have developed aggressive behaviour in caves to obtain food, to reproduce and to maintain a territory. This behaviour is particularly fascinating since epigean forms tend to loose these traits in the absence of light. These chapters highlight the detailed studies that have been undertaken to examine these organisms.

The fifth section of the book is devoted to the trophic basis of subsurface ecosystems. The eight chapters start with a clearly written overview (including all the definitions of the biological terminology) that provides the foundation for the following chapters. This is the largest section of the book, and includes some of the most detailed studies undertaken. The chapter topics are diverse, ranging from guano communities in tropical caves and fallout of arthropods in volcanic habitats, to the role of chemolithoautotrophic micro-organisms in subsurface environments. This final theme, developed in a case study of Movile Cave (Romania), provides a detailed study of one the most important biospeleological sites known. The reader is led through different aspects of the cave formation, evolution, the trophic structure of the ecosystem, and the fauna within the system. A chapter on aquatic fauna associated with plant root mats in Australia provides an equally fascinating study of the ability of life to flourish in subterranean systems. Major advances have been made in the study of trophic structures of ecosystems and food-webs in recent years. Some of these advances have been put to good use in several studies, including those in anchialine caves in the Yucatan Peninsula (Mexico). The use of stable isotopes of carbon and nitrogen enables the distinction between different plant communities (vascular or algae), even when transformed to detrital material in soil (sediment) in caves. In addition, consumer communities reflect the carbon or nitrogen fingerprint of their food. As the authors of the chapter highlight, "You are what you eat".

The sixth section examines the evolution of cave organisms, providing a review of theories advanced to explain the development of troglomorphic characteristics. Case studies of the fish, *Astyanax fasciatus* (Characidae), and the freshwater shrimp, *Gammarus minus* (Gammaridae), provide examples of adaptation and differentiation between epigean and hypogean populations. Other chapters examine the colonization and speciation of terrestrial and aquatic cave fauna, and explore the issues associated with isolated populations of organisms in caves (relicts). These populations may be the result of the subterranean environment providing a refuge from environmental extremes associated with epigean environments. This section of the book can be a little heavy going in one or two places, not least because it is theoretical and controversy remains surrounding some of the issues. However, throughout the chapters, any key terms have been defined clearly, and this is a credit to all those involved with preparing and editing the book.

Section seven is devoted to case-studies of particular sites, and comprises two sub-sections, the first dealing with groundwater habitats and organisms associated with riverine aquifers, and the second devoted to cave systems. Arguably additional case studies of individual systems such as Movile Cave (Romania), Frasassi Caves (Italy) and numerous other examples are provided in earlier chapters. However, this chapter provides information regarding some interesting and unique systems such as temperate ice caves, lava tunnels on Lanzarote (Canary Islands) and the Segeberger Höhle (Germany) containing the endemic coleoptera *Choleva septentrionis holsatica* (Cholevidae). The remaining two chapters are devoted to caves and the hypogean fauna from the Cape Range Peninsula and Barrow Island (Northwestern Australia) and cave fauna in southeast Asia. Both demonstrate the sophisticated and holistic nature of contemporary biospeleogical studies, and how it is possible to integrate many of the themes examined in previous sections of the book.

The final section provides three chapters devoted to the conservation of cave, karst and subterranean communities. This is arguably the weakest section of the book, providing case studies from Australia and North America, with a final chapter reviewing issues associated with biodiversity, vulnerability of subterranean habitats and relevant conservation legislation, primarily from a European perspective. Relatively little information on the impact of show-cave development is provided e.g., Lampenflora associated with lighting. Many other topics such as quarrying, and pollution associated with organic and inorganic materials, clearly develop issues highlighted in earlier chapters. Within the full assessment this is a minor deficit, which should not be held against the book as a whole.

For many BCRA members, one major disappointment will be that the book has no major entry for any British cave. This is a reflection of the relative lack of interest in biospeleology in Great Britain in recent years, and arguably also a reflection of the lack of any high profile British organisms. The price of the book may also be a major limitation to its circulation, and will certainly deter most with only a casual interest in cave biology. However, the book is almost certainly the best synthesis of recent research - highlighting a number of exciting advances - that will hopefully provide a catalyst for further research in Britain. The varied chapters demonstrate that research associated with subterranean environments has made major advances and in many ways is at the cutting edge of modern biological and ecological research. I found reading the book exciting, and carried it around almost continually for four weeks. It is now firmly on my bookshelf but in a position of easy reach for reference. It is a **must** for any cave biology enthusiast and cave club library.

Reviewed by Paul Wood, Department of Geography, Loughborough University, Loughborough, Leicestershire, LE11 3TU, UK.

THESIS ABSTRACTS

TOOTH, A, 2000

Controls on the geochemistry of speleothem-forming karstic drip waters.

PhD thesis, Karst Hydrogeochemistry, Keele University, School of Earth Sciences and Geography, Keele, Staffordshire, ST5 5BG, UK.

Research was performed at Crag Cave, Castleisland, southwest Ireland, and P8 Cave, Castleton, Derbyshire, in order to determine the main factors responsible for modifying rainwater geochemistry during flow through soil and karstic aquifer zones. Monitoring was performed on a daily basis in summer and winter at Crag Cave, and on a monthly basis over one year at P8 Cave. At both sites, biannual peaks in karst system Ca^{2+} concentrations occurred due to: (i) promotion of microbial CO_2 production by increased summer temperatures, and (ii) retardation of gaseous exchange by ponding of elevated winter rainfall input leading to an unseasonable build up in soil zone CO_2. Therefore, speleothems at both sites may form biannual bands in hydrological years subject to elevated winter rainfall input.

In addition to variations in carbonate weathering due to fluctuations in CO_2 levels, cation yields in Crag Cave matrix soil water were controlled by dolomite dissolution (Mg^{2+}), plant uptake (K^+), and evapotranspiration balanced by enhanced winter marine aerosol input (Na^+). Strontium isotope analysis indicates that Sr^{2+} was derived from a 50:50 silicate/carbonate mixture, whereas the relatively light $\delta^{13}C$ signal was related to direct evolution of CO_2 into the aqueous phase in water-logged pores.

Within the Crag Cave aquifer variations in karst water geochemistry were controlled by dilution, flow switching, prior precipitation of calcite, and dolomite dissolution along the flow path. Strontium isotope analysis indicates that dissolution in the aquifer dominated, with Sr^{2+} being sourced from a 25:75 silicate/carbonate mixture. Light karst water $\delta^{13}C$ values were constrained by the supply of light soil gas to the aquifer.

Elevation in the Mg/Ca and Sr/Ca ratios in the Crag Cave speleothem record compared to present day analogues indicates that the former Holocene climate was drier, whereas heavier $^{87}Sr/^{86}Sr$ ratios and $\delta^{13}C$ values suggest variation in soil hydrology over time.

SMITH, H, 2000

The hydro-ecology of limestone springs in the Wye Valley, Derbyshire

Unpublished PhD thesis, Geographical Sciences, University of Huddersfield, Queensgate, Huddersfield, HD1 3DH, UK

This thesis presents a syn-ecological study of limestone spring-dwelling macro-invertebrates within the River Wye Valley, Derbyshire. Investigations are carried out into the major environmental controls on the community composition within the springs, and physicochemical and hydrological patterns are examined at several spatial scales. Macro-invertebrate communities are analysed in relation to major habitat variables, using a variety of multivariate techniques, which indicate that the major environmental gradient is related to flow permanence. Some taxa are characteristic of springs with a permanent or an intermittent flow regime, although the majority of the fauna occurs in both habitat types. The results of three case studies highlight the stochastic nature of the community structure within the springs, and infer that the species assemblages are partly determined by the pattern of physical habitats in the individual sites and the ecological requirements of the component species. The spring biocoenoses are composed of lotic, lentic, crenobiontic and crenophilic species, along with species adapted to hygropetric and temporary aquatic environments. Of 93 taxa identified from the spring habitats, 3% are crenobiontic and 47% are crenophilic (obligate and facultative) in the study area. Although rare species, such as the endangered coleopteran *Hydroporus obsoletus* were collected, the majority of the species found in the springs are found in other lotic habitats. Examination of Trichoptera and Chironomidae communities in relation to measured environmental variables indicates that different parameters may be of importance for different groups of taxa, and physical variables such as the presence of leaf litter and woody debris (proxies indicating the major energy base within a spring) also appear to be determinants of the faunal communities within the springs. The community composition changes significantly along the length of the springbrooks, as predicted by ecological theory. The biological communities in the Wye Valley springs are distinct from those of the trunk stream, the River Wye. The biological significance of these small sites may be much greater than at first suspected, and the communities in the springs make a significant contribution to the biological diversity of the study area. The overall findings of the project are examined in relation to the conservation and protection of these unique and little-studied habitats, and suggestions are made as to how to achieve conservation and protection in the Wye Valley.

RESEARCH FUNDS AND GRANTS

THE BCRA RESEARCH FUND

The British Cave Research Association has established the BCRA Research Fund to promote research into all aspects of speleology in Britain and abroad. Initially, a total of £500 per year will be made available. The aims of the scheme are primarily:

a) To assist in the purchase of consumable items such as water-tracing dyes, sample holders or chemical reagents without which it would be impossible to carry out or complete a research project.
b) To provide funds for travel in association with fieldwork or to visit laboratories that could provide essential facilities.
c) To provide financial support for the preparation of scientific reports. This could cover, for example, the costs of photographic processing, cartographic materials or computing time.
d) To stimulate new research that the BCRA Research Committee considers could contribute significantly to emerging areas of speleology.

The award scheme will not support the salaries of the research worker(s) or assistants, attendance at conferences in Britain or abroad, nor the purchase of personal caving clothing, equipment or vehicles. The applicant must be the principal investigator, and must be a member of the BCRA in order to qualify. Grants may be made to individuals or groups (including BCRA Special Interest Groups), who need not be employed in universities or research establishments. Information about the Fund and application forms Research Awards are available are available from the Honorary Secretary (address at foot of page).

GHAR PARAU FOUNDATION EXPEDITION AWARDS

An award, or awards, with a minimum of around £1000 available annually, to overseas caving expeditions originating from within the United Kingdom. Grants are normally given to those expeditions with an emphasis on a scientific approach and/or exploration in remote or little known areas. Application forms are available from the GPF Secretary, David Judson, Hurst Farm Barn, Cutler's Lane, Castlemorton, Malvern, Worcs., WR13 6LF, UK. Closing dates for applications: 31st August and 31st January.

THE E.K.TRATMAN AWARD

An annual award, currently £50, made for the most stimulating contribution towards speleological literature published within the United Kingdom during the past 12 months. Suggestions are always welcome to members of the GPF Awards Committee, or its Secretary, David Judson, not later than 1st February each year.

BRITISH CAVE RESEARCH ASSOCIATION PUBLICATIONS

CAVE AND KARST SCIENCE - published three times annually, a scientific journal comprising original research papers, reviews and discussion forum, on all aspects of speleological investigation, geology and geomorphology related to karst and caves, archaeology, biospeleology, exploration and expedition reports.
Editors: Dr. D J Lowe, c/o British Geological Survey, Keyworth, Notts., NG12 5GG, UK and Professor J Gunn, Limestone Research Group, Dept. of Geographical and Environmental Sciences, University of Huddersfield, Huddersfield, HD1 3DH, UK.

CAVES AND CAVING - quarterly news magazine of current events in caving, with brief reports or latest explorations and expeditions, news of new techniques and equipment, Association personalia etc.
Editor: Hugh St Lawrence, 5 Mayfield Rd., Bentham, Lancaster, LA2 7LP, UK.

CAVE STUDIES SERIES - occasional series of booklets on various speleological or karst subjects.
No. 1 *Caves and Karst of the Yorkshire Dales;* by Tony Waltham and Martin Davies, 1987. Reprinted 1991.
No. 2 *An Introduction to Cave Surveying;* by Bryan Ellis, 1988. Reprinted 1993.
No. 3 *Caves and Karst of the Peak District*; by Trevor Ford and John Gunn, 1990. Reprinted with corrections 1992.
No. 4 *An Introduction to Cave Photography;* by Sheena Stoddard, 1994.
No. 5 *An Introduction to British Limestone Karst Environments;* edited by John Gunn, 1994.
No. 6 *A Dictionary of Karst and Caves*; compiled by Dave Lowe and Tony Waltham, 1995.
No. 7 *Caves and Karst of the Brecon Beacons National Park;* by Mike Simms, 1998.
No.8 *Walks around the Caves and Karst of the Mendip Hills;* by Andy Farrant, 1999.

SPELEOHISTORY SERIES - an occasional series.
No. 1 The Ease Gill System-Forty Years of Exploration; by Jim Eyre, 1989.

BCRA SPECIAL INTEREST GROUPS

SPECIAL INTEREST GROUPS are organised groups within the BCRA that issue their own publications and hold symposia, field meetings etc.
Cave Radio and Electronics Group promotes the theoretical and practical study of cave radio and the uses of electronics in cave-related projects. The Group publishes a quarterly *technical journal* (c.32pp A4) and organises twice-yearly field meetings. Occasional publications include the *Bibliography of Underground Communications* (2nd edition, 36pp A4).

Explosives Users' Group provides information to cavers using explosives for cave exploration and rescue, and liaises with relevant authorities. The Group produces a regular newsletter and organises field meetings. Occasional publications include a *Bibliography* and *Guide to Regulations* etc.

Hydrology Group organises meetings around the country for the demonstration and discussion of water-tracing techniques, and organises programmes of tracer insertion, sampling, monitoring and so on. The group publishes an occasional newsletter.

Speleohistory Group publishes an occasional newsletter on matters related to historical records of caves; documentary, photographic, biographical and so on.

Cave Surveying Group is a forum for discussion of matters relating to cave surveying, including methods of data recording, data processing, survey standards, instruments, archiving policy etc. The Group publishes a quarterly newsletter, Compass Points (c.16pp A4), and organises seminars and field meetings.

Copies of BCRA publications are obtainable from: Ernie Shield, Publication Sales, Village Farm, Great Thirkleby, Thirsk, North Yorkshire, YO7 2AT, UK.
BCRA Research Fund application forms and information about BCRA Special Interest Groups can be obtained from the Honorary Secretary: John Wilcock, 22 Kingsley Close, Stafford, ST17 9BT, UK.