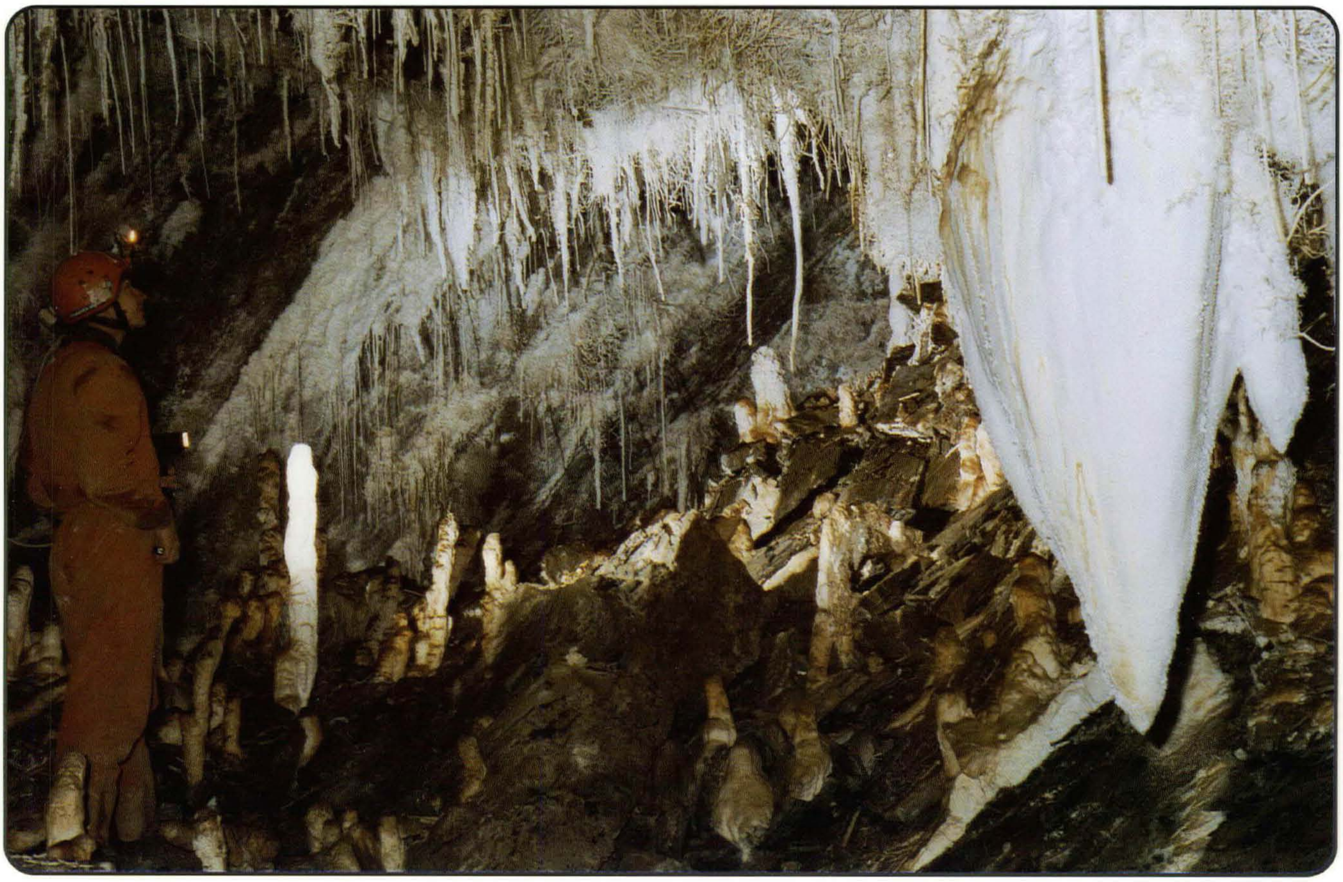
Cave and Karst Science

The Transactions of the British Cave Research Association

BCRA

Volume 28 Number 3 December 2001



Aragonite deposits, Bohemia Cave, New Zealand
Caves of the Umphang District, Thailand
Speleothem date, Malham Cove, UK
The BSA and Eli Simpson
Cave Rescue statistics
Abstracts

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:

1. Papers
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.

2. Reports
Shorter contributions, normally 500-3,000 words, on aspects of karst/speleological science, as listed above, or more descriptive material, such as caving expedition reports and technical articles. Manuscripts will be reviewed by the Editorial Board unless the subject matter is outside their fields of expertise, in which case assessment by an appropriate expert will be sought.

3. Forum
Personal statements, normally up to 1,000 words, on topical issues; discussion of published papers, and book reviews. Where appropriate, statements should put forward an argument and make a case, backed-up by examples used as evidence.

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Authors (or supervisors) of undergraduate or postgraduate dissertations on cave/karst themes are encouraged to submit abstracts for publication. Please indicate whether the thesis is available on inter-library loan. Abstracts of papers presented at BCRA (and related) conferences or symposia are also published.

Manuscripts may be sent to either of the Editors: Dr D J Lowe, c/o British Geological Survey, Keyworth, Nottingham, NG12 5GG, UK, and Professor J Gunn, Limestone Research Group, University of Huddersfield, Queensgate, Huddersfield, HDI 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.

Notes for Contributors

These notes are intended to help authors prepare their material in the most advantageous way, so as to expedite publication and reduce both their own and editorial labour. Time and effort are saved if the rules below are followed.

Text: All material should be presented in a format as close as possible to that adopted by *Cave and Karst Science* since 1994. Text should be typed double-spaced on one side of the paper only. Subheadings within an article should follow the system used in *Cave and Karst Science*; a system of primary, secondary and, if necessary, tertiary subheadings should be indicated clearly. Initial manuscripts may be supplied as hard copy, as a suitably formatted text file on computer disk, or as an E-mail attachment (addresses above) in appropriate format. Where possible the final revised text should be submitted on computer disk or as an E-mail attachment, although paper copy remains acceptable. It is recommended that, where text includes unusual characters or equations, a hard copy highlighting non-standard features be provided as a guide for the Editors. Most modern PC-based word processing packages can be translated but, if in doubt, please consult one of the Editors. Apple Mac disks are accepted, but cannot be dealt with routinely and may cause delays.

Abstract: All material should be accompanied by an abstract, stating the essential results of the investigation or the significance of the contribution, for use by abstracting, library and other services. Occasionally such abstracts may also be published in *Caves and Caving*.

References to previously published work should be given in the standard format used in *Cave and Karst Science*. In the text the statement referred to should be followed by the relevant author's name and date (and page number if appropriate) in brackets. Thus: (Smith, 1969, p.42). All such references cited in the text should he given in full, in alphabetical order, at the end of the manuscript. Thus: Smith, D E, 1969. The speleogenesis of the Cavern Hole. *Bulletin of the Yorkshire Caving Association*, Vo1.7, 1-63. Books should be cited by their author, date, title, where published and publisher. As there is no readily available listing of abbreviated titles, and as references to publications in languages other than English are becoming more common, periodical titles should be written in full. Failure to provide full and unambiguous Reference information may lead to a delay in publication.

Acknowledgements: Anyone who has given a grant or helped with the investigation, or with the preparation of the article, should be acknowledged briefly. Contributors in universities and other institutions are reminded that grants towards the cost of publication may be available, and they should make the appropriate enquiries as early as possible. Expedition budgets should include an element to help publication, and the Editors should be informed at the time of submission.

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Speleological expeditions have a moral obligation to produce reports (contractual in the case of recipients of awards from the Ghar Parau Foundation). These should be concise and cover the results of the expedition as soon as possible after the return from overseas, so that later expeditions are informed for their planning. Personal anecdotes should be kept to a minimum, but useful advice such as location of food supplies, medical services, etc, may be included. preferably as a series of appendices.

Authors will be provided with 20 reprints of their own contribution, free of charge, for their own use.

If any problems are perceived regarding the nature, content or format of the material, please consult either of the Editors before submitting the manuscript.

Cave and Karst Science

TRANSACTIONS OF THE BRITISH CAVE RESEARCH ASSOCIATION

Volume 28, Number 3 December 2001

Contents

Cover photo:

Large massive aragonite stalactite at the Albeřice Corner of the DAC in Bohemia Cave, New Zealand (see article by Tásler et al. in this issue)

Photo by Radko Tásler

Cave and Karst Science is published three times a year by the BCRA and is issued free to all paid up members of the Association. The 2001 subscription rates to *Cave and Karst Science* are £16.00 (UK) and £18.00 (overseas) per annum (postage paid). Details of Association membership and annual subscriptions can be obtained from the BCRA Membership Secretary, Lynne Bailey, British Cave Reserach Association, Hafod Swn-Y-Dwr, The Dardy, Crickhowell, Powys, NP8 1PU, UK (E-mail address: membership@bcra.org.uk). The Association's Registered Office address is: BCRA, The Old Methodist Chapel, Great Hucklow, BUXTON, Derbyshire, SK17 8RG, UK. (E-mail address: enquiries@bcra.org.uk). Individual copies and back issues of *Cave and Karst Science* can be obtained from BCRA Publication Sales, at the address shown at the foot of the inner back cover.

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EDITORIAL

John Gunn and David Lowe

The *Cave and Karst Science* Editorial was an innovation that we introduced in 1994, when we took over the editing of the journal from Trevor Ford. Over the years some of our editorials have provoked correspondence, debate or the occasional word of congratulation or rebuke at a meeting. However, our overall impression is that the inclusion – or not – of an Editorial has not attracted universal applause, but nor has it provoked universal apathy!

As we have mentioned before, the Editorial is the last part of the *Cave and Karst Science* to be written, and we usually think long and hard about the topic(s) that we wish to air. In the case of the current Issue the thought process has gone on for more than two weeks and nothing has yet been committed to disk, perhaps because we are both, yet again, overwhelmed with the demands of other work. Rather than delay things even further we propose to leave this issue essentially without targeted editorial comments. We would welcome any suggestions as to whether or not this is a good thing, and this will help us decide whether or not to continue producing editorials in future issues.

Again we apologise for ongoing delays in production and assure readers and contributors that *Cave and Karst Science* Volume 29, Number 1 is already well advanced. Also, as is customary in the final Issue of a Volume, we wish to record our appreciation of all those individuals without whom we could not have produced the present Volume.

Our long-time colleague Jean Reeve stood down after completing the Desk Top Publishing of Volume 27. Once more we thank Jean for the workload she carried, the standard that she achieved and, above all, her good humour during her seven years on the team. Becky Talbot has taken over Jean's DTP role. As our year has been filled by even more distractions than previously, we feel that Becky has done well to come to terms so rapidly, not only with the format and esoteric content of the journal, but also with our idiosyncratic working practices and publishing requirements.

Once again we have benefited from the freely given support of a large group of reviewers / referees, without which much of our work would be impossible. Whereas we place great value upon the support given by all members of the editorial team, we should stress that, because of the types of material being submitted, several members receive many more manuscripts than do others. Thus, the alphabetical list below does not necessarily reflect the actual levels of effort, time and goodwill committed by individual members of the Editorial Board *(sensu lato)*. We apologise if, in this last minute compilation, anybody has been inadvertently overlooked. Thanks to:

Andy Baker
Simon Bottrell
John Cordingley
Russell Drysdale
Trevor Ford
Dave Gillieson
Chris Hunt
Bogdan Onac
Art Palmer
Martyn Pedley
Graham Proudlove
Peter Rowe
Trevor Shaw
Dean Smart
Tony Waltham
Paul Wood

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The British Speleological Association (1935 – 1973) and its founder, Eli Simpson: with particular reference to activities in the northern Pennines of England

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7 Amhurst Avenue, Newlands 7700, South Africa.

Abstract: An account is given of the origins and early history of the British Speleological Association, which can be traced back to Eli Simpson's first cave visit in 1901. The formal founding occurred in 1935, following which, despite its name implying a national organization, it never achieved national status with universal support. Its heyday was from 1939 to 1945, when the activities of other northern clubs went into abeyance. Thereafter it declined rapidly, losing members to new and established clubs, and it eventually merged with the Cave Research Group of Great Britain in 1973 to form the British Cave Research Association.

(Received 20 September 2000; Accepted 16 July 2001)

INTRODUCTION

The British Speleological Association (BSA), which existed from 1935 to 1972, was Britain's first national speleological organisation, and is therefore of great historical importance. Its founder, and leading light throughout his life, was Eli Simpson (1884 – 1962), who was a controversial figure in the caving world. It is therefore very difficult to avoid re-presenting potentially biased opinions and statements deriving from his many contemporaries who were interviewed during the course of this research, especially those who were involved in the BSA's post-war decline. This paper therefore concentrates on the first two decades of the BSA, with only a brief summary of its subsequent decline and demise.

ORIGINS: 1901 - 1935

Eli Simpson, the man who influenced the northern English caving scene for a quarter of a century until his death in 1962, was born in Ossett, Yorkshire, on 16 September 1884. His father, John William Simpson, was described in the parish register as a *"manufacturer"*; his mother was Elizabeth Simpson[1]. There is no indication of what his father was manufacturing; but it must have been on a small scale because the family address, Brook Street, Ossett, is a stone working-class terrace house typical of the Victorian era. Neither his birth, nor his baptism on 15 October 1884, was recorded in the local newspaper. By 1893 the family fortunes seem to have improved, since Kelly's Directory records that John William Simpson was a *"private resident"* at East Ardsley. In

Figure. 1. Eli Simpson and Fred Botterill at Timpony Joint in 1903. Photo by Simpson (courtesy BSA collection).

Professor Leo S Palmer	University College, Hull	Chairman
Dr S Bryan Adams	Bristol University	
Mr A Leslie Armstrong	Warrington	
Mr Harold Brodrick	Birkdale, and Yorkshire Ramblers' Club	
Mr Charles R Hewer	University of Bristol Speleological Society	
Mr F A Holmes	Buxton	
Dr Robert G S Hudson	Leeds Cave Club and Leeds University	
Dr J Wilfrid Jackson	Manchester University	
Mr James W Puttrell	Sheffield, and Derbyshire Pennine Club	
Dr Arthur Raistrick	Durham University	
Professor H H Read	Liverpool University	
Mr G H Hill	Buxton Museum	Joint Secretary
Mr Eli Simpson	Austwick	Joint Secretary

Table 1: Members of the BSA organising committee

1902 J W Simpson was described as a *"cloth merchant"* at 21 Sefton Avenue, Beeston Hill, Leeds, and the following year he acquired premises as a *"woollen manufacturer"* at 16 York Place, Leeds[2].

In 1905 or 1906 John William Simpson moved his family to 44 Sefton Terrace, Beeston Hill, Leeds - an end terrace house overlooking Crossflatts Park. In those days it would have been a nice house in a desirable area. The business was moved to 46 Park Place, Leeds.

Eli Simpson was educated at Leeds Modern School, whose premises were then in Cookridge Street. There is no record of the dates between which he attended; but he did win the Suddick Cup for sport in 1899 and 1900[3]. Simpson was an accomplished athlete and footballer, and used to play for Beeston Hill Parish Church Association Football Club. He was such a good player that he was excused having to attend church every Sunday[4]! He later played for a club in Morley, and also won gold and silver medals for running[5].

Figure 2. Eli Simpson in Jib Tunnel, Gaping Gill, in August 1908. Photo. by Miss L E May Johnson (courtesy J W Kay Esq).

It is not known how Simpson came to be interested in caves. One version of the story is that he and a girl friend went to Ingleton on Midland Railway excursion tickets. They walked up Chapel-le-Dale onto Ingleborough. Simpson found a cave and crawled in. At the end of the day he had ruined his suit, lost his girl friend and gained a love of speleology[6]. His first recorded caving trip was at Stump Cross Caverns in 1901, with Fred Botterill; and his next was a return visit in 1903. The following year he was caving with Frederic Haworth, and by 1905 he had formed his own club – the Yorkshire Speleological Association[7]. He had already commenced his self-appointed task of recording caves in words, photographs and surveys.

It is not clear why Simpson did not explore caves with the Yorkshire Ramblers' Club, the only other Yorkshire club then involved with cave exploration. The minute book states merely that, on 27 October 1903, he was found to be insufficiently qualified for membership[8].

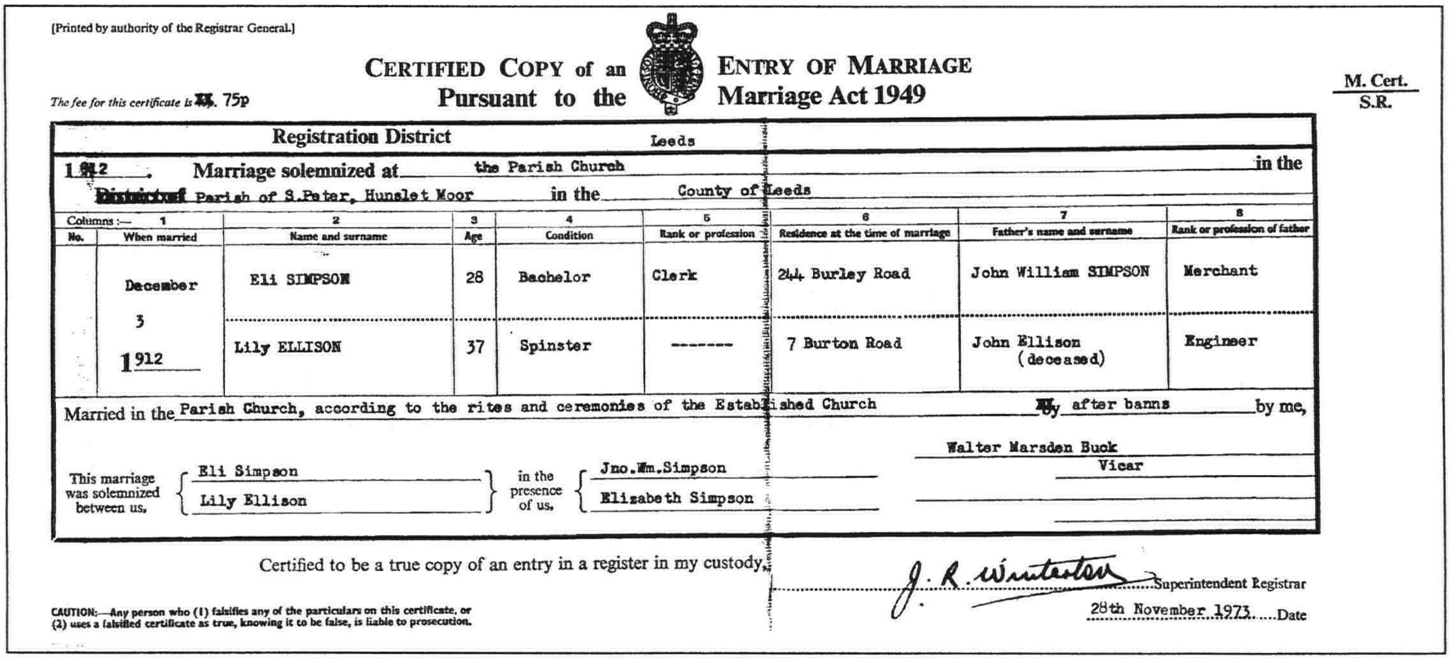
In 1912 Simpson moved to 244 Burley Road, Leeds and on 3 December that year, aged 28, he married Lily Ellison, a 37-year-old spinster of 7 Burton Road, Leeds. Her late father, John Ellison, was described as an *"engineer"*. At that time Simpson was earning his living as a *"clerk"*.

On 11 December 1915 he enlisted in the Royal Army Ordnance Corps (027737 Private Simpson, E), but was not called up until 13 February 1917. He served in Mesopotamia from 25 September 1917 until 13 August 1919. While on active service he acquired the malaria from which he suffered intermittently for the rest of his life, and a gun backfired, blinding his right eye. He was transferred to the Class Z Army reserve on 12 November 1919, and eventually demobbed with the British War and Victory medals on 31 March 1920[9]. He returned to his wife at 244 Burley Road.

During the following year Simpson acquired Lilac Farm at Mickley, near Ripon, with the intention of rearing poultry. At the same time he became Secretary of the Village Institute, and was instrumental in converting some derelict property into suitable accommodation for the Village Institute. To raise funds for this conversion, Simpson ran a

President	Vacant Sir Arthur Keith to be invited
Vice-President	Dr J Wilfrid Jackson
Chairman	Professor Leo S Palmer
Secretary-Treasurer	Mr G H Hill
Recorder	Mr Eli Simpson
Council	Dr S Bryan Adams Mr A Leslie Armstrong Mr Blackburn Holden II Mr F A Holmes Dr Robert G S Hudson Mr James W Puttrell

Table 2: 1935 officials and committee of the BSA.



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M. Cert.
S.R.

Registration District Leeds

1912. Marriage solemnized at the Parish Church in the ~~District of~~ Parish of S.Peter, Hunslet Moor in the County of Leeds

Columns:— 1 No.	1 When married	2 Name and surname	3 Age	4 Condition	5 Rank or profession	6 Residence at the time of marriage	7 Father's name and surname	8 Rank or profession of father
	December 3 1912	Eli SIMPSON	28	Bachelor	Clerk	244 Burley Road	John William SIMPSON	Merchant
		Lily ELLISON	37	Spinster	-------	7 Burton Road	John Ellison (deceased)	Engineer

Married in the Parish Church, according to the rites and ceremonies of the Established Church ~~by~~ after banns by me,

This marriage was solemnized between us, Eli Simpson, Lily Ellison

in the presence of us, Jno.Wm.Simpson, Elizabeth Simpson

Walter Marsden Buck, Vicar

Certified to be a true copy of an entry in a register in my custody.

J. R. Winterton Superintendent Registrar

28th November 1973 Date

CAUTION:—Any person who (1) falsifies any of the particulars on this certificate, or (2) uses a falsified certificate as true, knowing it to be false, is liable to prosecution.

Figure 3. Eli Simpson's marriage certificate, 03 December 1912.

dance band called *"The Californians"*, whose banjo player was a Mrs Ellis. Lilac Farm, like many enterprises at that time, was not profitable. To keep it going, Mrs Simpson sold off her property in Leeds house by house[10]. When she had sold her last house in 1928, Simpson sold Lilac Farm, left his wife, and returned to Leeds with his lady banjo player to keep house for him.

While in Mickley Simpson did no caving. The nearest he came to a cave was on 11 October 1925, when he stayed at the Hill Inn in Chapel-le-Dale[11].

When in Leeds, Simpson used his parents' home, 44 Sefton Terrace, as an address for correspondence; but the electoral registers do not record him as living there. Although he had done no caving since 1912, he had not lost his records. When, some time during 1931, he read in a newspaper that the Leeds Cave Club had been formed, he presented himself for membership. His first meet was at Alum Pot on 12 - 13 September 1931. He was so knowledgeable about caves that he was elected President at the second annual general meeting on 10 January 1932. However, the Leeds Cave Club had lady members, and was more concerned with socializing than with speleology. Simpson disapproved strongly of their whist drives and other non-speleological activities. Matters came to a head during the Easter 1932 meet at Lost John's Hole, when Simpson upset most of the members present. A special general meeting was held on 24 May 1932. Simpson failed to attend to explain his conduct. He was asked to resign on the grounds that he had by then moved to South View, Austwick, and was unable to attend the club meetings [12].

Shortly afterwards, in 1932, Simpson joined the Craven Pothole Club[13], but soon resigned because he and Thomas (Tot) Lord were incompatible. In the same year, Simpson was elected *"Cave Secretary"* of the Settle Naturalists and Antiquarian Society [14]. In 1933 he was Chairman of the Archaeological Research Section of the same Society[15]. Thereafter he caved more or less independently of the clubs, often with Peter B Binns and F Peter Longbottom[16]. They were pupils at Silcoates School near Wakefield. Binns' aunt, Harriet Byles, lived in Austwick, and she had introduced the boys to Simpson.

Up until the middle of the 1930s all cave exploration had been done by individuals or by small groups operating completely independently of each other. There was little, if any, co-operation, and the publication of results was far from satisfactory. Although the Yorkshire Ramblers' Club had a high quality printed Journal, its members were doing little original cave work to put in its pages[17]. The Gritstone Club Journal appeared irregularly, and had a very small circulation only among the members. The Craven Pothole Club published its work in the Skipton newspapers. The members of the Northern Cavern and Fell Club shunned publicity. There was a similar lack of communication between cavers in different parts of the country, and between the archaeologists, geologists, biologists and other scientists with an interest in caves.

For several years Simpson had realized the futility of this wasted and duplicated effort that was inevitable without some coordinating body. During the early 1930s he had been corresponding with leading cave explorers and scientists in England and abroad, with a view to founding

President	Sir Arthur Keith, FRS
Vice-Presidents	Mr Miles C Burkitt (Cambridge) Dr J Wilfrid Jackson (Manchester) Dr R R Marett (Oxford)
Chairman	Professor Leo S Palmer (Hull)
Secretary/Treasurer	Mr G H Hill (Buxton)
Deputy Treasurer	Mr C Wyndham "Digger" Harris (Wells)
Recorder	Mr Eli Simpson (Austwick)
Council	Dr S Bryan Adams (Bristol) Mr A Leslie Armstrong (Warrington) Mr Blackburn Holden II (Barnoldswick) Mr F A Holmes (Buxton) Dr Robert G S Hudson (Leeds) Dr J Wilfrid Jackson (Manchester) Mr Hywel Murrell(Croyden) Mr Arthur H Ogilvie (Torquay) Mr Sydney J Pick (Leicester) Mr James W Puttrell (Sheffield) Mr Walter M Sissons (Sheffield)
Honorary Members	Professor K Absolon (Czechoslovakia) Cav. Eugenio Boegan (Italy) Professor l'Abbé H Breuil (France) Professor Georg Kyrle (Austria) Dr George Grant MacCurdy (USA) Monsieur E A Martel (France) Professor D H Obermaier (Spain) Professor W J Sollas (Britain) Mr A Vandebosch (Belgium) Dr Benno Wolf (Germany)

Table 3: Officials and committee, first BSA annual speleological conference, 1936.

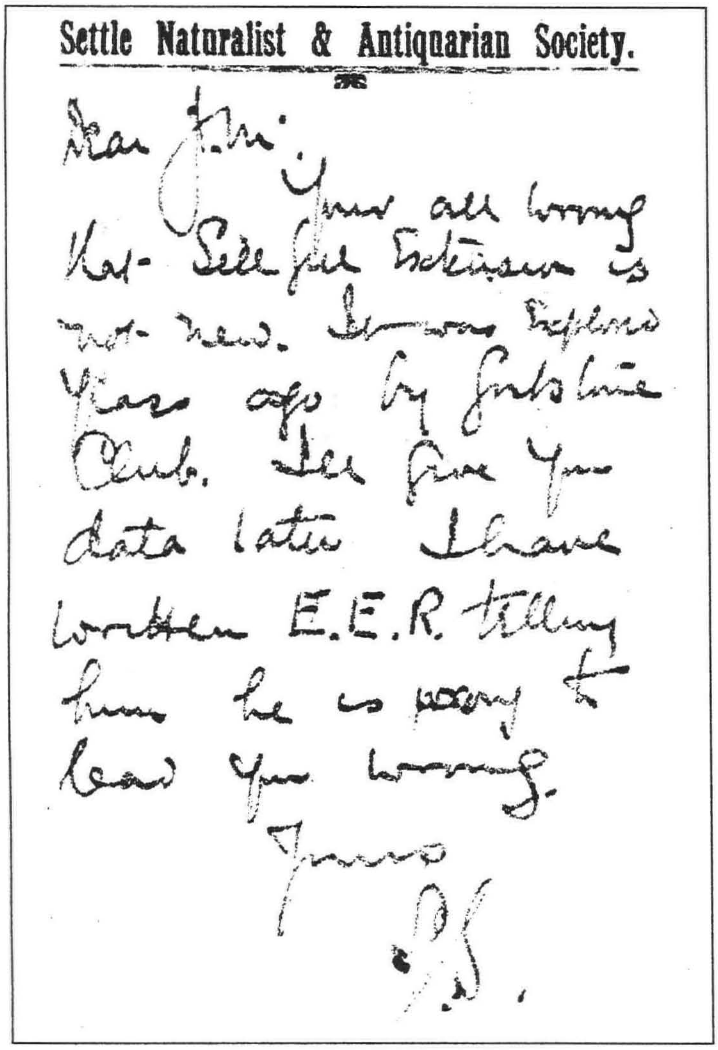

Figure 4. Eli Simpson's legible handwriting of 30 January 1933 (courtesy Mrs B D Butterfield).

a national caving organisation. This would represent the interests of cavers at government level, publish a journal, provide field headquarters, and have a library that would be THE repository of all speleological knowledge.

1935 - THE FOUNDING OF THE BRITISH SPELEOLOGICAL ASSOCIATION

On 1 July 1935, Simpson announced his plans for the British Speleological Association[18]. The members of his organizing committee included an impressive number of academic cavers (Table 1).

With much newspaper publicity they called a meeting at 15.00 hours in the Museum, The Wardwick, Derby on 27 July 1935 . Simpson's enthusiasm was infectious; and the meeting founded *"a National Association for the furtherance of all matters pertaining to Speleology"* viz. the British Speleological Association. The officials and committee elected were as shown in Table 2.

Encouraging letters were read from caving organisations in France and Italy, from the University of Paris, and from the National Museum of Wales. The Royal College of Surgeons sent a message of approval. The Times conferred respectability on the meeting in the form of a favourable editorial comment [20].

1935 - 1939: EARLY YEARS

After this meeting Simpson returned to Austwick, running the BSA and continuing his cave work. A later newspaper story announced that Simpson was going to investigate old lead mines, and that he would therefore be grateful for the loan or gift of any old mine plans [21]. Arthur Raistrick replied that the law required old mine plans to be deposited with the appropriate government department for safety reasons. The BSA could never be a substitute for the Department of Mines, and mine plans must remain without its scope[22]. This is the first indication that all was not well within the BSA, even allowing for professional jealousy among academics. Raistrick had a long-standing interest in lead mining [23].

At the first general meeting of the BSA, held at Sheffield on 14 December 1935, members were told that *"remarkable progress"* had been made. Dove Hole Caves in Lancashire had been scheduled, and protected by the Government. Negotiations were progressing with the Ministry of Health committee on Inland Water Survey for the BSA to record all accessible underground water in caves[24]. Professor L S Palmer was working on an electrical method for detecting caves. Membership was satisfactory with 4 life members, 40 ordinary, 2 associate and 8 clubs. The constitution was approved (Appendix 1); and the members were promised a journal *"shortly"* [25].

In 1936 the BSA formed regional sub-committees, including one for Yorkshire with Norman Thornber as Chairman. Clubs represented included the Craven Pothole Club, Bradford Pothole Club and Derbyshire Pennine Club[26]. In 1938 the Yorkshire sub-committee prepared a list of more than 300 caves, with details of their owners and tenant farmers, thereby facilitating access[27].

On 24 - 27 July 1936 the BSA held its first annual speleological conference and exhibition at Buxton Town Hall. The British caving world had seen nothing like it before. There was extensive publicity before and during the four-day event[28]. Selected delegates were entertained at a reception given by the Mayor of Buxton. Those attending were given an elaborately printed 34-page programme containing the timetable, describing the exhibits and summarising the lectures. There were two simultaneous lecture programmes - one scientific and the other sporting. Field trips were organised to local caves. One interesting item in the programme is the list of officials and committee (Table 3), which indicates that Simpson's contacts extended far beyond the English Channel.

In later years Gustav Abel, Franco Anelli, Norbert Casteret, Robert de Joly and Mario Paran all accepted honorary membership.

Simpson continued to live at Austwick, and to keep the Association records and library in his house. He devoted the rest of his life to caves - exploring caves, surveying caves, photographing caves, and lecturing on caves. Every scrap of information about caves that came his way was noted in the voluminous records. Well-wishers gave him money and books for the BSA[29]. No one objected that the Association's library was kept in Simpson's house; after all Simpson was the BSA. All this time he was living without visible means of support, though on occasion he did charge a fee for taking people underground[30]. It was common knowledge in Settle that he was being financed by Miss Adeline Montagu who, by then, had moved to High Borrans near Windermere. When she died on 11 October 1952 she left him £5,000 for the furtherance of his speleological work.

From 8 - 22 May 1937 the BSA held a big meet at Gaping Gill, using the Craven Pothole Club's winch, with Blackburn Holden II in charge. The Craven Pothole Club and Yorkshire Ramblers' Club co-operated by cancelling their Gaping Gill meets that year. As usual, the event received much publicity. It was the biggest camp ever held there. Over 300 descents were made by members of the BSA, Bradford Pothole Club, Craven Pothole Club, Derbyshire Pennine Club, Leeds Cave Club, Leeds Pennine Club, Mendip Research Organisation, Northern Cavern and Fell Club, Oldham Cave Club, Rotherham Cave Club,

During the meet, on 16 May 1937, a London engineer, Eric Hensler, was crawling alone through the Booth-Parsons Crawl when he noticed that the crawl appeared to be longer than it should be. His compass indicated that he was moving in a southeasterly direction, and that he was therefore no longer in the Booth-Parsons Crawl. The crawl was so narrow that he could not turn round. He therefore continued crawling for 400m until he reached a stream passage with gradually increasing height. Here his carbide lamp failed; and it was only by good luck that he was able to grope his way back to his bag containing spare lights and matches. After an absence of five hours, Hensler made an uneventful but tedious journey back to the Main Chamber. The discovery was named "Hensler's Passage" in his honour, and B Monty Grainger, F Peter Longbottom, F Davis and Peter B Binns surveyed it in 18 hours on 17 and 19 May 1937[31].

That same month the BSA leased Cragdale - a large stone-built house on the east side of the main road through Settle - as a national headquarters[32]. The anonymous owner, now known to have been Ellern Cochrane Robinson of Windermere[33], leased the top floor for £1 per week nominal rent. The ground floor housed the Curlew Tea Rooms. Simpson moved in with Mrs Ellis and with the Association library and records. To raise the necessary £500 for conversions, the lady members formed a sub-committee. Their President was Lady Boyd Dawkins, and the Honorary Joint Secretaries were Miss Nellie Kirkham (of Derbyshire lead mining fame) and Miss Adeline Montagu. By the end of September 1937 they had raised a mere £46-11-0 [£46.55][34].

At the beginning of July 1937 there appeared the long awaited journal, under the title *"Caves and Caving"*. Optimistically, three thousand copies were printed, but the print order was reduced to 1,500 for the second number. Its 40 well-produced pages, edited by Simpson and Harry J Scott (who subsequently, in April 1939, founded and edited the Yorkshire Dalesman), contained a selection of sporting, scientific and historical papers by distinguished authors. The second number, of 40 similar high-quality pages, appeared in October 1937[35]. Three more appeared in 1938.

The Buxton conference had been so successful that the second annual conference was held at the University of Bristol on 23 – 26 July 1937. As before, a glossy programme was distributed, listing the exhibits, excursions, lectures and timetable. The list of distinguished names at the front was even longer. The survey of cave waters for the Ministry of Health was progressing satisfactorily. Simpson was organizing the work in Yorkshire; and leaders had been appointed for the other cave areas. The Scheduling of Caves Committee had recommended several caves for preservation, and its listings had been accepted by His Majesty's Office of Works. The catalogue of cave finds scattered in museums throughout the country was nearing completion[36]. Zoological research had commenced under the guidance of the University of Hull.

Another innovation in 1937 was the continental cave tour, organized by Charles R Hewer, who was then living in Estonia. Seventeen members saw caves and met cavers in Germany, Czechoslovakia and Austria during July and August[37]. The BSA was so pleased at the response of its members that Hewer arranged a tour of Belgian caves in April 1938[38].

It was the turn of Yorkshire to host the Association's third annual conference and exhibition at Giggleswick School from 30 July to 3 August 1938. Again there was a glossy programme, and the newspaper publicity exceeded that for the previous conferences[39]. Progress recorded at that meeting included a grant of £200 from the Royal Society for a geophysical Megger earth tester for detecting caves. Two trustees had been appointed - Captain Geoffrey H Swift (the proprietor of White Scar Cave) and Miss Adeline E Montagu of Windermere. Two caves had been discovered in 1938 – Buzzer's Pot in August and Pint Pot in September.

Although the BSA was making progress, it by no means enjoyed the support of all cavers, and its finances were in a very precarious position. With the benefit of hindsight, it is clear that one of the Association's great mistakes was to organize meets in competition with the established clubs. A club would think twice before affiliating to an organization that was likely to poach its members. Indeed, at a general meeting of members held on 15 October 1938, poor club support was mentioned, with a plea from a sporting member that the BSA should confine itself to scientific activities[40].

Re the Formation of a

British Speleological Association

Members of the Organising Committee

Chairman :
Prof. L. S. Palmer, D.Sc., Ph.D.
(University College, Hull)

Prof. H. H. Read, F.G.S., (University of Liverpool)
Dr. B. Adams (University of Bristol)
Dr. R. G. S. Hudson, F.G.S. (University of Leeds)
Dr. J. W. Jackson, F.G.S., (University of Manchester)
Dr. A. R. Raistrick. F.G.S., (University of Durham)
A. L. Armstrong, Esq., Warrington
H. Brodrick, Esq., J.P., F.G.S., Birkdale
C. R. Hewer, Esq. (British University Speleogical Society)
F. A. Holmes, Esq., J.P., Buxton
J. W. Puttrell, Esq., F.R.G.S., Sheffiield.

Honary Secretaries :
G. A. Hill, F.S.A., The Museum, Buxton
E. Simpson, Austwick, via Lancaster

Figure 5. Title page of the invitation to attend the meeting to form the BSA on 27 July 1935 (courtesy Dr T R Shaw).

The other great mistake was the absence of effective financial control. The BSA contained many regional and scientific sub-committees, each of which spent money while leaving it to others to raise money. The only regular sources of income were the 10 shillings and 6 pence [52_p] and 5 shillings [25p] annual subscriptions. The journal made a loss; the annual conferences lost money, and the various scientific and quasi-governmental projects needed finance. The proverbial last straw was Cragdale, which - despite the efforts of that sub-committee - was completely beyond the financial resources of the BSA.

An emergency special general meeting of the BSA was held at Leicester on 15 October 1938, to consider the financial position of the Association[41]. The Treasurer did not attend. The meeting discussed the desirability and feasibility of either raising subscriptions or of reducing expenditure by relinquishing Cragdale. At the end of the meeting there appeared further evidence of the lack of co-operation between the Settle cavers. Tot Lord complained that many northern members, including himself, had been refused admission to the records at Cragdale. Simpson denied this. The disagreement seemed to be connected with an old map of Ingleton that Simpson had acquired, and which Lord desired for his museum[42]. Indeed, at that time there were no less than four rival museums at Settle, belonging to the BSA, the Pyg Yard Club, the Settle Naturalists and Antiquarian Society and to Giggleswick School[43].

BRITISH SPELEOLOGICAL ASSOCIATION

President - - Sir ARTHUR KEITH, F.R.S.

THE FIRST ANNUAL

SPELEOLOGICAL CONFERENCE

AND

EXHIBITION

of Photographs, Surveys, Prehistoric remains, Geological specimens, etc., from British and Foreign caves

WILL BE HELD AT

BUXTON, DERBYSHIRE

FROM

FRIDAY, JULY 24th, to MONDAY, JULY 27th 1936

Section A.

Lectures on the **Excavation of Caves,** and the study of their prehistoric contents.

Section B.

Lectures on the **Exploration of Potholes,** and the study of their structure and formation.

Excursions to local caves.

Many leading authorities on the caves of this and other countries are contributing to the Sectional Programmes.

The Conference is open to the Members of the Association free, and to the general public on payment of 5/-. A Preliminary Programme with further details will be forwarded on application to the Honorary Secretary and Treasurer—Mr. G. H. HILL, The Museum, Buxton, Derbyshire, England.

Figure 6. Notice of the BSA's first annual speleological conference and exhibition, 24 - 27 July 1936 (courtesy Dr T R Shaw).

Despite Simpson's attitude, some people went to considerable effort to help the BSA, no doubt believing that the BSA was greater than its Recorder. Thus, Tot Lord, who ran the Pyg Yard Club, was a member of the Association. The Settle Naturalists and Antiquarian Society was affiliated to the Association. The Craven Pothole Club joined, but later resigned in 1938[44]. Members of other clubs published their work in the Association's journal[45]. Finally, Giggleswick School was the venue for the 1938 BSA annual conference.

The BSA kept Cragdale. It was the journal that was sacrificed. The fifth and final issue of *Caves and Caving* appeared in 1938. The fourth annual conference on 5 - 9 August 1939 at Swansea was as lavish an affair as usual. A provisional advance programme was printed and distributed before the event. Another meet at Gaping Gill was organized for Whitsuntide 1939. At the same time Leslie Armstrong led a foreign tour to France. The scientific work had continued as before; and a hostel for members had been opened at Settle Guildhall. The 1939 annual general meeting resolved to purchase Cragdale as a permanent headquarters for the Association.

In theory the BSA was to provide an information service for its members and for its member clubs. Many members were pleased to receive information from the records at Cragdale but, again illustrating the uncooperative attitude of many cavers at that time, few were prepared to return the compliment by reporting their discoveries. Simpson defended his organization of caving meets, in competition with the established clubs, by saying that if the clubs would not supply him with information he would go and get it for himself. This policy resulted in the discovery of many new caves and potholes; but the price paid was the degeneration of the BSA into what some people dismissed as *"just another northern cave club"*.

Eli Simpson was one of those rare gifted self-taught people who, like Christopher F D Long of Stump Cross Caverns and White Scar Caverns fame[46], had a brilliant speleological brain. He had the happy knack of being able to select the best place to dig for a cave, and he usually produced results. His one great error of judgement was at Easegill and Casterton Fell. After surveying Bull Pot of the Witches in 1932, and after prospecting there with Mabel Greenwood and Bill Fairbank in 1935 and 1936, Simpson concluded that he *"did not think there were any extensive caverns in the neighbourhood left undiscovered"*[47]. On BSA field meets Simpson decided when and where to dig. His assistants, commonly schoolboys who were unlikely to question his direction, did the work.

However, the first of these BSA discoveries, Hensler's Passage in Gaping Gill, as mentioned above, was serendipitous. That same month, August 1937, Peter B Binns, F Peter Longbottom and R Legge of the BSA dug where the stream sank in the enormous chamber of Sell Gill Hole, and discovered the first small chamber. The following weekend members of the Leeds Cave Club found the second small chamber; and on the third weekend a Mr J E McGowen entered the third and final small chamber[48].

In March 1938 Arthur Gemmell and Peter B Binns waded into the canal in Old Ing Cave. They stopped where the roof became low, and where they could hear running water ahead. Gemmell returned during that summer with G Monteath, and was the first man to wade through the canal to dry land on the far side[49]. They were stopped by a sump 93m further on.

The second BSA discovery of 1938 was the inlet passage half way down the Lost John's master cave. E Jack Douglas of the Northern Cavern and Fell Club first entered it in July; and the following month C P Weaver and Harry Shaw of the Association crawled 558m along it[50].

During the Easter holidays of 1939, Simpson led a BSA meet at Hull Pot. Those present included Arthur Gemmell, who did most of the surveying, Norman J Dunnington, H Waite, G Monteath, G T C Bottomley, Harold V Dunnington, F Schofield, Robert D Leakey, C E Wray, Harry Shaw and Frank "Buzzer" Butterfield. Although Lantyshop Cave was said to have been marked on the 1847 Ordnance Survey map, Monteath became the first man to squeeze through the narrow slit 28m in, closely followed by Gemmell. Butterfield, Norman J Dunnington, Gemmell, Monteath and Shaw dug with little further success around this cave[51].

Also discovered during the same meet were High Hull Cave (after Arthur Gemmell had diverted the water), Stot Rakes Cave, where the Yorkshire Ramblers Club erroneously claimed a first descent the following month[52], and Glass Moss Cave. Routine exploration and survey were done in Hull Pot, High Hull Pot, Little Hull Hole, Little Hull Cave, Hunt Pot and New Pot.

WAR YEARS: 1939 – 1945

Most of the war-time cave exploration in the northern Pennines was carried out by members of the BSA led by Eli Simpson, as the other clubs had gone into abeyance. When war was declared, the Association held an emergency Council meeting at Sheffield on 9 September 1939. It was decided that, because of the extensive travelling and correspondence necessary for the proper administration of the Association, it would be in the best national interest if activities were to cease until the end of hostilities. The liquid assets were to be handed to the Trustees for safekeeping, subject to the payment of the rent for Cragdale. No subscription was to be demanded until hostilities ceased. In fact, the Chairman, Professor L S Palmer, did not transfer the money to the Trustees; instead he froze the bank accounts. Simpson was asked to be temporary Honorary Secretary.

Simpson realized that these arrangements would finish the Association, which was rapidly losing members to the armed forces. Most of those who remained at home were busy with the war effort. He therefore ignored the Council's resolution to go into abeyance, and ran the BSA on a much lower budget with subscriptions raised locally and administered by himself. The first economy was Cragdale, which was vacated towards the end of 1940. Simpson moved across the road to more modest premises in Commercial Yard, but retained the same postal address: *"Duke Street, Settle"*. He was by then so well known that letters addressed to *"E Simpson, England"* were eventually delivered. As far as Yorkshire was concerned, Simpson abandoned scientific work, and concentrated on cave exploration. Routine meets were held throughout the war years; and much new cave passage was discovered. Annual reports were printed and distributed to members.

Of the Association's war-time discoveries, the first was Christmas Cave on Giggleswick Scar. Bob Leakey, Harry Shaw, Dorothy Stone and Jean Wright were about to eat their 1939 Christmas dinner at the Royal Oak in Settle, when the local poacher asked if they would please rescue his ferret, which was trapped in a cave. Leakey obligingly crawled into the hole indicated by the poacher, followed by Dorothy Stone. The ferret was rescued from a small, decorated cave. The entrance was sealed on the way out, and has not been rediscovered since[53].

The first major wartime discovery was Simpson's Pot in Kingsdale. The entrance had first been noticed by Simpson before the First World War, and had been forgotten for over three decades until the Easter 1939 BSA meet had recalled it to mind. It is remarkable that, although the entrance is not inconspicuous, and is within 100m of the Turbary Road, it was not entered until 1940. Simpson sent J Greenwood and Harold Burgess to prospect, and they found two holes. Greenwood found a fissure down which he dropped to a stream, but was stopped before long by a tight corner. Back on the surface he found Burgess 46m away contemplating a low opening, almost completely obscured by vegetation, in the side of a doline. They crawled into a respectable little cave, which soon enlarged. After two short pitches, a pool of water under a low roof stopped them. On the way out they met R D "Bob" Leakey. He passed the wet crawl and came to a high, narrow and descending fissure. Where the stream disappeared down this fissure, Leakey traversed over "The Pit" and proceeded until stopped by a 6m pitch.

On the next day Leakey returned to the cave with Arthur Gemmell, C E Wray and others. The 6m pitch was rigged. Leakey descended and disappeared round the corner. He found a 5m pitch that could be descended by traversing into a fissure. Immediately beyond was Storm Pot - a very wet 9m pitch, at the bottom of which was a sump. During the next week Leakey returned to the sump and probed it with a stick. He discovered that the stream flowed out through a narrow crack, and that there was a draught in the opposite direction through the same crack. Leakey decided that the crack could be enlarged by *"gentle persuasion"*, and for the next three weekends shot holes were drilled and the Blasted Hole enlarged. While this was going on, Gemmell, Burgess and Greenwood surveyed the cave already explored.

After the third blast, on 27 April 1940, Leakey and Burgess crept through the enlarged hole into a large passage that brought them to the top of an 8m pitch - Carol Pot. The following Sunday, seven members returned with Leakey in charge, and carrying 62m of ladders and ropes. At the top of Carol Pot, Leakey, Gemmell, J Gilmour and C Lewis Railton continued, while the other three returned to the surface. They descended Carol Pot into a narrow rift passage, down the 5m Shuffle Pot, 6m Lake Pot and the 8m Aven Pot. At last they arrived at the anticipated big pitch, but the bulk of the tackle had been left at the

THE B.S.A. HEADQUARTERS

"CRAGDALE" Photo—E. SIMPSON

All communications relating to the Records of the British Speleological Association should be addressed to The Recorder, "Cragdale," Settle, Yorkshire.

BRITISH SPELEOLOGICAL ASSOCIATION

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Figure 7. Cragdale, Duke Street, Settle, the headquarters of the BSA 1937 - 1940. The building still exists as the police station. Photo by E Simpson.

Blasted Hole! After the tackle had been fetched, Lewis Railton squeezed through the narrow slit onto the ladder, and made the first descent via Simpson's Pot into the penultimate chamber of Swinsto Hole[54]. A member of the Leeds University Climbing Club fell 15m receiving cuts and severe bruises[55].

Simpson next directed the attention of the BSA members to Hull Pot. This large fault-guided hole in which two streams sink had been known for centuries, but no one had been able to follow the water. In the northeast corner of the quarry-like depression is a pool fed by the Hull Pot Beck, which disappears down a fissure in the upper passage. On 25 May 1940 Leakey examined this pool. After removing a choke of flood debris, he entered a very narrow fissure with water up to his shoulders. The passage became too narrow, but could be seen to continue. It was wider below the water surface, so Leakey took a deep breath, dived, and came up in a 60cm air space. This gave way to a bedding plane, which ended at the top of a pitch. On 8 and 9 June 1940 a large working party was summoned to build a permanent concrete dam in the upper passage, replacing the temporary dam built on 16 May 1940. This lowered the water sufficiently to allow Leakey and Harry Shaw to descend the 34m pitch, while Harry Grey and C J Dolberry worked the lifelines. Exploration stopped at a sump. On the following weekend Leakey and Gemmell descended and surveyed, while Barbara Binns and J H Greenwood worked the lifelines[56].

During the winter of 1940 - 1941 the Association tried to find and re-open the Old Turf Pits Shaft on Grassington Moor. They failed to find the shaft; but D Corner and B G White did report Mossdale Scar, at the base of which the largest stream in the area, Mossdale Beck, sinks. On 11 May 1941 Bob Leakey, D Corner, Bessie Grey, Ken Grey, Dorothy Stone, B G White and Jean Wright tried to force their way through several possible entrances. Success came to Leakey, who accidentally

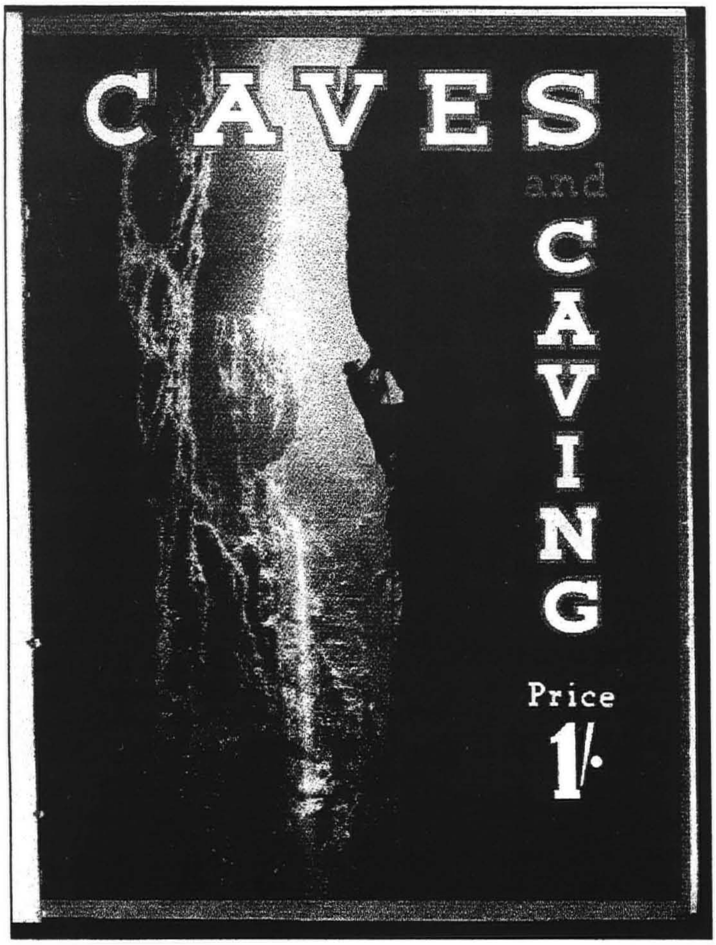


Figure 8. Cover of the first issue of Caves and Caving, July 1937.

dropped his pipe through a fissure. While retrieving it he found the way through the Scar into Mossdale Caverns. From May to September that year Leakey made many visits with the above members and with Marjorie Beasant, Harold Burgess, Peter Elsdon, H Gray, Mollie Lodge and Harry Shaw. The surveys showed 6km of passage - a splendid achievement because, although no tackle is necessary, the going is extremely difficult, and in wet weather the place fills to the roof with water[57].

The BSA continued to be very active during 1942. In June D M Boothman, J B Clough, Robert T Clough, D Corner, and B G White made a systematic search for Dove Cave, Kettlewell, which had been lost for nearly a century[58]. They found it in an old mine level. Farther south, near Mossdale, Corner and White descended P2a - a 31m pitch ending in a choke. On Newby Moss in August, T C Bilsbury, Nellie Kirkham, J Parkes and G M Taylor dug out the 31m-deep Lever Pot. In March and April, Harald James Lexow Bruff (the Greenhow lead miner), L Bodlender, N L Liles, Jack O Myers and J B Stott had an abortive dig at Burhill near Stump Cross Caves[59].

The major event of 1942 was the exploration and survey from August to December of Quaking Pot, on the northern flank of Ingleborough. Its entrance had been known for centuries, and its stream had been investigated in the early years of the twentieth century by the Yorkshire Geological and Polytechnic Society. The first partial exploration was made in 1932 by Simpson and Ernest Clarkson, who penetrated as far as the top of the first pitch. In August 1942 T C Bilsbury, Barbara Binns, D M Boothman, W W Brown, Harold Burgess, J B Clough, Robert T Clough, J Firth, Ken Gray, Nellie Kirkham, J Parkes, H Procter, Harry Shaw, R Simpson and G M Taylor worked their way through narrow fissures and large avens to a constricted stream passage 65m below the surface[60].

The summer of 1943 was very wet; and the amount of fieldwork done by the Association therefore declined. Molly Lodge, in a solo effort, dug out the right-hand branch in the upper reaches of Great Douk Cave. She crawled through, and emerged on the surface through a narrow slit very close to Middle Washfold Cave, which had been discovered in 1906 by Davis Burrow and R F Cook of the Yorkshire Speleological Association[61]. Despite the bad weather, Simpson had been able to maintain his *"new cave every year"* policy.

It is remarkable that during the previous half century, when cave explorers had been visiting the Allotment area regularly, no one had taken a proper look at the conspicuous doline at the southern end of the Birkbeck Trench. In 1943 Arthur Gemmell drew it to the attention of the BSA, and Bob Leakey, D M Boothman, Harold Burgess, Ken Gray, Richard Hylton, Molly Lodge and Jack Myers did the exploration and survey. In the initial stages the going was narrow; farther in it was wet. The major obstacle to exploration was a large boulder choke completely obstructing the passage. After six pitches and 400m of passage, the final sump was reached 78m below the surface. The original name chosen was A.G. Pot, for its discoverer, but to appease those who do not like eponyms, it was later changed to Grange Rigg Pot[62].

The Association's discovery for 1944 was Disappointment Pot, first explored as far as the sump by Simpson and Blackburn Holden II on 16 March 1912. During the 1938 BSA Conference, Graham Balcombe failed in an attempt to dive this sump. He kept to the left-hand wall and entered a water-filled cul-de-sac. On 22 January 1944, while on leave from the army, Bob Leakey visited the sump with Barbara Fidoe and no diving equipment. He removed his clothes, filled his lungs with air, put his torch into his mouth, and entered the sump. Probing with his feet revealed an air space, where he refilled his lungs and proceeded to

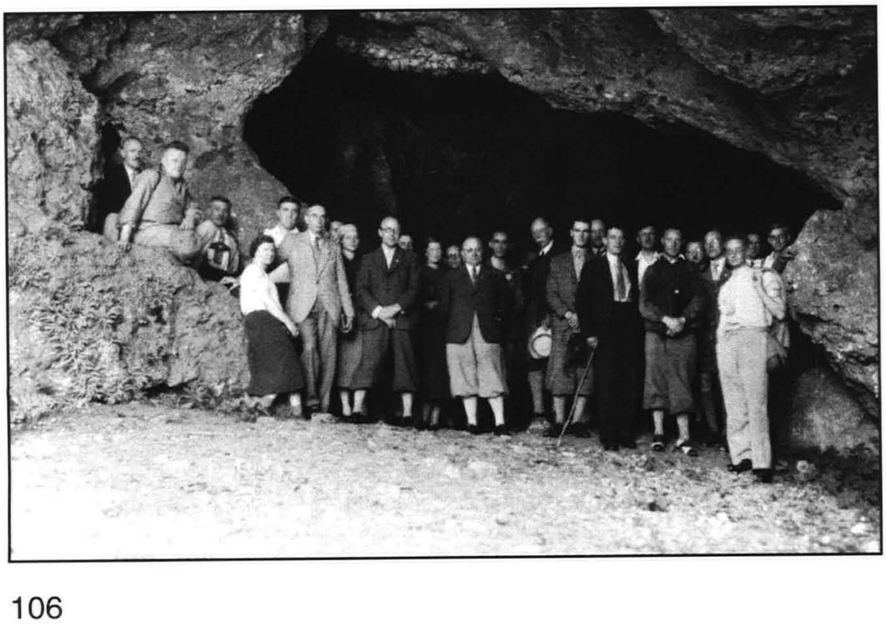


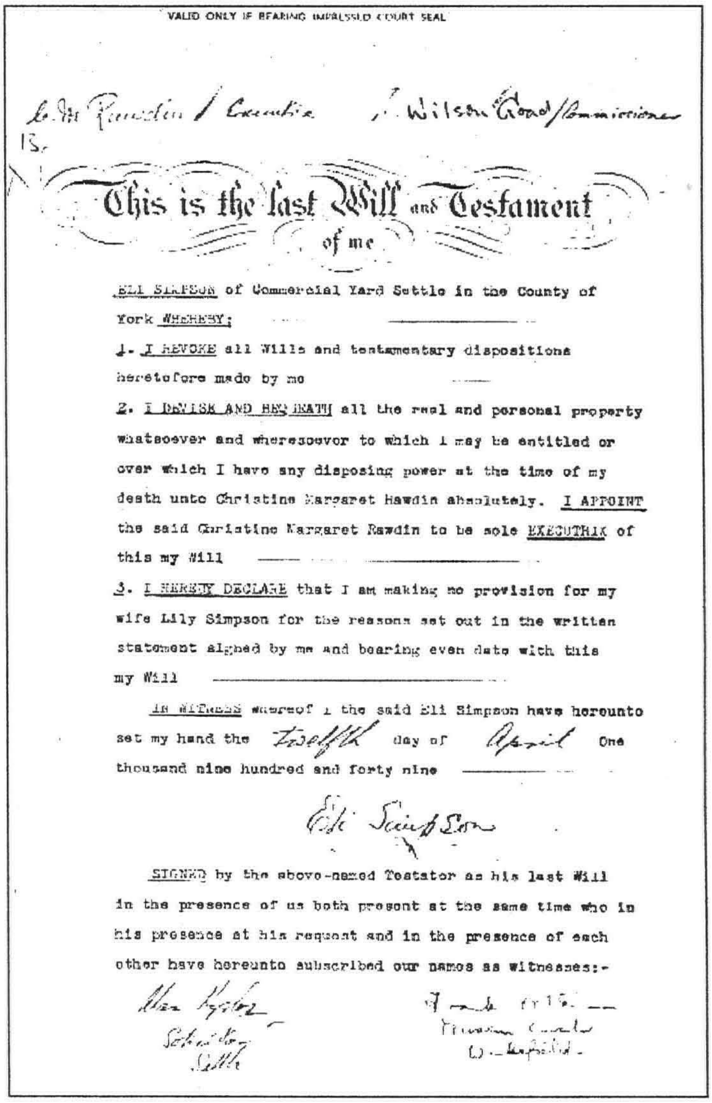
Figure 9. Twenty-five members of the BSA Continental Cave Tour of 1937 (courtesy Dr T R Shaw).

another air space. About 31m from the point where he entered the sump, he crossed a gravel bank into open passage beyond. By removing the gravel he was able to lower the water level sufficiently to permit a comparatively dry return journey. Leakey then had to return to his army unit; so it was left to G Bradshaw, Harold Burgess, J B Clough, Ken Gray, Katherine (?Kathleen) Halstead, Richard Hylton, A Jeeves, Molly Lodge, Jack Myers and R H Simpson to complete the exploration and survey. Beyond the sump, which by then had become a pool, the stream passage descended fairly rapidly down five pitches into Hensler's Passage in the Gaping Gill system[63]. Exploration was completed by March 1944.

On 1 April 1944 two Nelson schoolboys, Stanley Jeeves and Alan Smee, with G M Bradshaw and R Simpson entered Disappointment Pot in wet weather. There was later some dispute as to whether or not they were members of the Association. They certainly descended with the knowledge and approval of Eli Simpson. On the way out there was too much water to permit ascent of the first pitch, so they waited until the water subsided before surfacing the following afternoon. Being tired, they then slept in a barn at Clapdale Farm. Meanwhile Simpson, realizing that they were overdue, sent out a private search party on the evening of 2 April. The rescuers found no trace of the missing cavers. Having received enquiries from the boys' parents, the Settle Police, against the wishes of Simpson (who claimed that everything was under control), insisted that the Cave Rescue Organization be called out. The Organization team found the missing youths on 3 April, sleeping in the barn[64].

After the Disappointment Pot incident the BSA held a meet at Hunt Pot in August 1944. At that time Hunt Pot ended in a boulder choke, through which the stream disappeared at the bottom of the second pitch. During this meet J G Clarke climbed over the choke and disappeared into a roof passage that led to a pitch. On the following day Clarke and G Boldock descended this new 12m pitch to a chamber with no exit. Jack Myers did the survey[65].

Ken Gray celebrated the end of the war on 15 August 1945 by inheriting a dig that had been started by the Craven Pothole Club on the Allotment in 1944. Further digging led to a 9m pitch, at the bottom of which was a narrow fissure. There followed many weekends of digging and blasting by G Bradshaw, Harold Burgess, Jim Leach and others before the fissure was finally penetrated the following year. In honour of the day on which it was rediscovered, the cave was called V.J. Pot[66]. The nearby Marble Pot was excavated by the Association again in 1945, but the rains came and washed in all the excavated debris!


VALID ONLY IF BEARING IMPRESSED COURT SEAL

This is the last Will and Testament of me

ELI SIMPSON of Commercial Yard Settle in the County of York WHEREBY:

1. I REVOKE all Wills and testamentary dispositions heretofore made by me

2. I DEVISE AND BEQUEATH all the real and personal property whatsoever and wheresoever to which I may be entitled or over which I have any disposing power at the time of my death unto Christine Margaret Hawdin absolutely. I APPOINT the said Christine Margaret Rawdin to be sole EXECUTRIX of this my Will

3. I HEREBY DECLARE that I am making no provision for my wife Lily Simpson for the reasons set out in the written statement signed by me and bearing even date with this my Will

IN WITNESS whereof I the said Eli Simpson have hereunto set my hand the Twelfth day of April One thousand nine hundred and forty nine

Eli Simpson

SIGNED by the above-named Testator as his last Will in the presence of us both present at the same time who in his presence at his request and in the presence of each other have hereunto subscribed our names as witnesses:-

Figure 10. Last will and testament of Eli Simpson, dated 12 April 1949 (courtesy D C Mellor Esq).

PRE-1945 EXPLORATION ELSEWHERE IN THE BRITISH ISLES

The BSA drew much of its support from, and did much of its work in, Yorkshire, no doubt because Simpson lived in the Yorkshire Dales, which had more known caves than any other part of Britain. However, members were not inactive in other parts of the British Isles.

Mendip Hills (Somerset)
In 1936 Graham Balcombe and Jack Sheppard continued their famous pioneer diving explorations at Swildon's Hole[67].

Devonshire
Four members surveyed Pridhamsleigh Caves near Ashburton in June 1937[68].

Peak District, Derbyshire
Nettle Pot was dug intermittently, descended and surveyed to -150m between 1935 and 1950[69], Bagshawe Caverns were extended in June 1937[70], and the Peak Cavern survey was completed in June 1947[71].

South Wales
Porth-yr-Ogof was surveyed in September 1936[72], and in September 1937 four members penetrated 1,570m into Dan-yr-Ogof[73].

Eire
BSA members were busy in County Clare during 1935[74].

DECLINE: 1945 - 1973

Thus Simpson, with no help from the Association's Council, had brought the BSA through the war with a good list of discoveries to its credit. However, Simpson always regarded Council as a hindrance, especially when it did not ratify his decisions. Membership rose from 11 in 1941 to 114 in 1945. There was a corresponding improvement in the finances. In 1942 the BSA had, for the first time in its history, an excess of income over expenditure. Simpson had to pay the price for his success. The BSA had degenerated from a national speleological organisation into a northern caving club with a branch in Yorkshire and a second branch in Derbyshire.

After the war ended, it was some time before cave exploration became as popular as it had been towards the end of the 1930s. Simpson continued to run the Association. He antagonized so many members that in 1946 and 1947 there were many resignations. Other members were expelled by Simpson. These former sporting members of the Association formed the Northern Pennine Club, the Northern Speleological Group and the Red Rose Cave and Pothole Club. The

Figure 11. Undated portrait of Eli Simpson.

former BSA scientists formed the Cave Research Group of Great Britain, whose founders, having learned from the Association's mistakes, wrote clauses into the constitution restraining the Group from organizing caving meets and from owning caving tackle. That Group, therefore, in no way competed with the established caving clubs.

The BSA continued to hold conferences from time to time, but they never received the support and status that the pre-war conferences enjoyed.

Eli Simpson continued to run the BSA, but it never regained the national importance implied in its name. He was known universally, to both supporters and detractors, as *"Cymmie"*, and remained BSA Recorder and *de facto* librarian until his death on 1 February 1962. During his 78 years of life he amassed the finest speleological library and archives that Britain had ever seen. It is a great tragedy that this collection was dispersed after his death. The remnants, held in the library of the British Cave Research Association in Matlock Bath, are but a shadow of its former glory. In 1973 the BSA disbanded formally, and merged with the Cave Research Group of Great Britain to form the British Cave Research Association.

SCIENTIFIC WORK

The BSA did not confine its work to cave exploration. Some of its members were active in scientific research, and the Association's journals, Caves and Caving (1937 – 1938), followed by the longer lived Cave Science (1947 – 1973), were the first to report ongoing cave research, as opposed to cave exploration, in Britain[75].

The traditional focus of cave research in Britain was archaeology and anthropology, topics that featured in several review articles in the Association's journal[76]. Other early research activities were[77]:

1. A survey of the more important underground rivers and streams, with a view to assisting the Inland Water Survey Committee of the Ministry of Health. This had importance for the conservation of water supplies[78].
2. Water tracing using a dye that, unlike the traditional fluorescein, did not require continuous human observation at all the possible risings.
3. Systematic study of aquatic fauna for which collecting apparatus was to be issued to all member clubs.
4. Cave flora studies[79].
5. Consideration of speleogenesis[80].

CONCLUSION

It is very difficult to write objectively about Eli Simpson, and therefore about the British Speleological Association. Indeed, it is impossible to separate the two. One eminent historian, who knew him well, described Simpson as *"sometimes infuriatingly difficult"*, and *"with little or no diplomacy"*[81]. This unfortunate personality made him, and therefore the BSA, many enemies and contributed to the Association's decline. It is for this reason that Simpson has, with the exception of his obituary in the Association's journal[82], received little credit for his great contributions to British speleology.

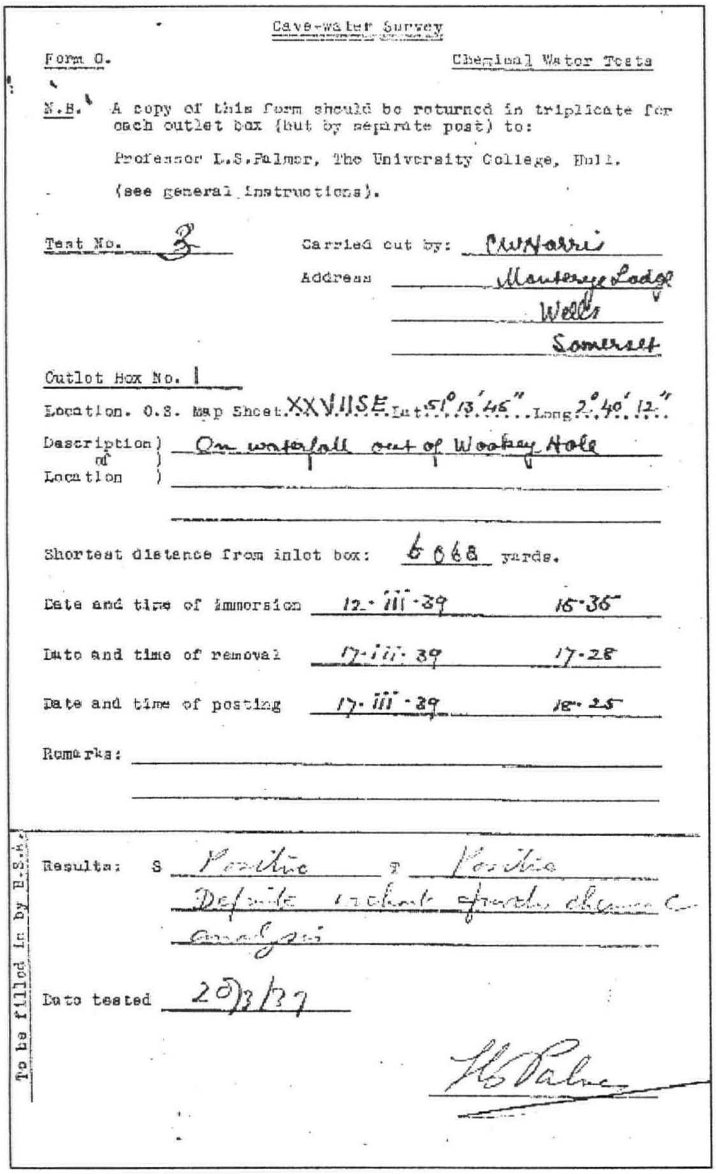
Simpson devoted most of his long life to caves and, realizing that there are limits to that which individuals and small groups can achieve, motivated for and founded the first national British speleological organization, which thrived for a decade and which survived for a further 28 years. He also amassed the most comprehensive collection of speleological literature, viz. books, archives, photographs and surveys, that had ever been seen in Britain. Simpson had a very detailed knowledge of the caves under the northern Pennines of England, and was the first to discuss the mechanism of their formation[83].

For the first three decades of its existence the BSA was the greatest publisher of speleological literature in the country with, especially after 1945, Simpson doing most of the soliciting of articles, cutting of stencils, collation and distribution of journals. The publications, annual conferences and their Proceedings, and overseas tours, provided fora through which kindred spirits could exchange ideas and publish their work, be it sporting or scientific, at home or overseas.

The BSA also served British speleology by translating where necessary, and publishing, substantial papers by foreign scientists and explorers. Among them work by Gustav Abel, Walter Bieses, Eugenio Boegan, André Bourgin, Max Cosyns, Walter von Czoernig-Czernhausen, J Fraipont, Gunnar Horn, Robert de Joly, Kazimierz Kowalski, Maurice Laures, Paul Marres, Édouard Martel, Jean Noir, F Oedl, W Prinz, Fernando Termes, Felix Trombé and A Vanderbosch, was represented.

Another BSA contribution to the speleological literature was the publishing of the annual Speleological Abstracts, the first edition of which appeared in 1964, covering the largely British literature for 1962. The last issue of this valuable bibliography (for 1968) was published in 1971. Nevertheless the concept persisted. A similar literature service was resuscitated by Ray Mansfield and Tony Oldham, with the literature for 1969 *et seq.* under the title *"Current Titles in Speleology"*, which was eventually taken over by the Swiss Speleological Society in 1993. Indeed, that Society's bibliography uses the Association's original title, *"Speleological Abstracts"*.

The Second World War would have had a devastating effect on the BSA had it not been for Simpson. Most of the active members had joined the armed forces. Simpson, being too old for active service, remained at home. The BSA, managed by Simpson with schoolboys and members on leave, was the only active speleological organisation in Yorkshire, and with many new discoveries to its credit.



Cave-water Survey

Form O. Chemical Water Tests

N.B. A copy of this form should be returned in triplicate for each outlet box (but by separate post) to:

Professor L.S.Palmer, The University College, Hull.

(see general instructions).

Test No. 3 Carried out by: CWHarris

Address Monterey Lodge, Wells, Somerset

Outlet Box No. 1

Location. O.S. Map Sheet XXVIISE Lat 51°13'46" Long 2°40'12"

Description of Location: On waterfall out of Wookey Hole

Shortest distance from inlet box: 6068 yards.

Date and time of immersion 12·iii·39 15·35

Date and time of removal 17·iii·39 17·28

Date and time of posting 17·iii·39 18·25

Remarks:

To be filled in by B.S.A.

Results: S Positive T Positive

Definite [illegible] chemical analysis

Date tested 20/3/37

[signature]

Figure 12. The BSA Cave Water Survey record form (courtesy Dr T R Shaw).

Despite his unfortunate personality, Eli Simpson had a beneficial influence on British speleology for half a century. For many years after his death his influence continued to be felt in British speleo-political circles. Although the BSA longer exists, having merged in 1973 with the Cave Research Group of Great Britain to form the British Cave Research Association, Simpson's legacy to the international caving fraternity thrives as that latter organization.

ACKNOWLEDGEMENTS

The British Speleological Association was a highly bureaucratic organization, and produced voluminous minutes and other documents from which much of this paper has been prepared. Oral and written evidence was obtained from many former BSA members and other contemporaneous witnesses, including Fred S Booth, Robert M Brench, Harold Burgess, Frank and Barbara Butterfield, Ernest Clarkson, Cliff Downham, Bill Fairbank, Violet Farrer, Monty Grainger, Reg Hainsworth, Charles Hewer, Mrs J N Hudson, C W Lawrence, Charles H Leach, Jim Leach, Peter Longbottom, Jack Myers, Ian Plant, Christene M Rawdin, Reg Riddick, Tom Sykes and Sam Waller.

A particular note of appreciation is due to Trevor Shaw, whose comments greatly improved and expanded the original manuscript, and who supplied much information and copies of relevant documents.

Figure 13. The BSA's rubber stamps for its annual conferences, 1936-1939 (courtesy Dr T R Shaw).

APPENDIX 1: CONSTITUTION OF THE BRITISH SPELEOLOGICAL ASSOCIATION

1. Name

The name of the Association shall be the "British Speleological Association".

2. Objects

The Objects of the Association shall be the furtherance of all aspects of speleology.

3. Constituents

The Association may consist of Honorary Members, Life Members, Ordinary Members, and Associate Members together with associated Societies, Clubs, Libraries, Museums or similar bodies.

a) Honorary Members shall be persons who have accomplished work of outstanding merit in Speleology. Such persons shall be nominated by Council, and shall enjoy all the rights of an Ordinary Member.

b) Life Members shall enjoy all the rights of an Ordinary Member.

c) Ordinary Members shall have the rights of attending and voting at all meetings of the Association; of attending the Annual Conference; of nominating candidates as Officers and Councillors, which nomination shall be forwarded in writing to the Secretary at least two months before the Annual General Meeting; of serving, if elected, on the Council; of receiving a copy of all publications issued by the Association during their membership either gratis or at such nominal price as the Council may determine.

d) Associate Members shall only have the right of attending all meetings of the Association and the Annual Conference.

e) Associated Societies, Clubs, Libraries, Museums and similar bodies shall have interests similar to those of the Association and shall enjoy all the rights of Ordinary Members, which rights shall be exercised through two Representatives. Furthermore each subscribing member of such Associated Society, Club, Museum or similar body shall have the right of attending all meetings of the Association, subject to 4 (f) below.

4. Subscriptions
The subscriptions to the Association shall be as follows:-

a) Honorary Members shall not be required to pay any annual subscription.

b) Life Members shall pay a compounded subscription of five guineas.

c) Ordinary Members shall pay an annual subscription of half a guinea.

d) Associate Members shall be under the age of 21 or shall be full time students at a recognised educational institution and shall pay an annual subscription of five shillings.

e) Associated Societies, Clubs, Libraries, Museums, and similar bodies shall pay an annual subscription of one guinea.

f) Members of Associated Societies, Clubs, Libraries, Museums and similar bodies may attend the Annual Conference on payment of five shillings.

5. Session
The Session of the Associated *[sic]* shall coincide with the calendar year.

6. Meetings
An Annual Conference on Speleology shall be arranged during which the Annual General Meeting of the Association shall be held. Such other meetings (including lectures and field meetings) as may from time to time be deemed desirable shall be arranged. The President or Chairman of Council shall preside at all meetings of the Association.

7. Agenda
The report of Council and the audited balance sheet for the previous session shall be presented and the election of Honorary Members, Officers and Councillors for the coming session shall take place at the Annual General Meeting.

8. Activities
The Activities of the Association may include

a) The collection and circulation of information pertaining to speleology.

b) The publication of a periodical which may include the Report of Council and balance sheet, such papers contributed to the Annual Conference as the Council shall decide, a summary of speleological work carried out during the year, and any other contributions approved by Council.

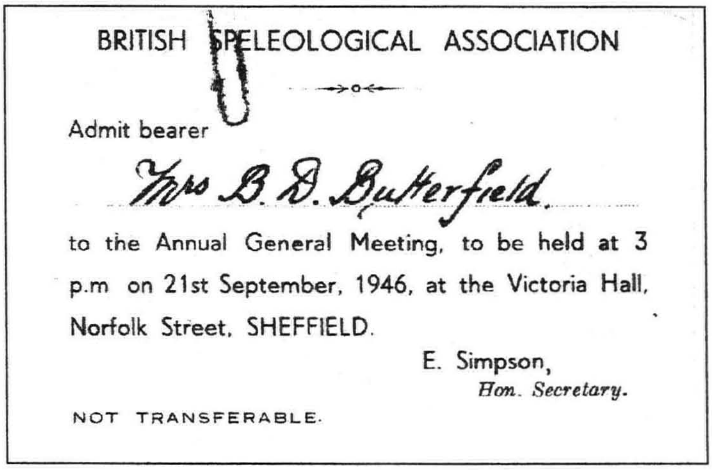
c) The translation and publication of foreign works on Speleology.

d) The direction and guidance of cave exploration and excavation.

e) The registration and disposal of cave material.

f) The exploration and excavation of caves in this and other countries.

9. Officers
The Officers of the Association shall be the President, Vice-Presidents (who shall include, ex-officio, Past Presidents), Chairman of Council, Recorder, Secretary and Treasurer, and such other Officers as the Association may appoint.


BRITISH SPELEOLOGICAL ASSOCIATION

Admit bearer

Mrs B. D. Butterfield

to the Annual General Meeting, to be held at 3 p.m on 21st September, 1946, at the Victoria Hall, Norfolk Street, SHEFFIELD.

E. Simpson,
Hon. Secretary.

NOT TRANSFERABLE.

Figure 14. Admission ticket for the 1946 BSA annual general meeting. These were issued by Simpson to ensure that non-members did not attend (courtesy Mrs B D Butterfield).

10. Management
a) The Management of the Association shall be vested in a Council consisting of the Officers, excluding the Vice-Presidents, together with twelve Councillors who shall be elected annually.

b) Five members of the Council shall form a quorum at a Council meeting, and ten members of the Association who are entitled to vote, shall form a quorum at a general meeting.

c) At the end of the Session the Recorder, Secretary and Treasurer shall submit reports to Council.

11. Functions of Council
The Council shall:

a) Submit nominations for the Officers and Councillors to the Annual General Meeting.
b) Submit, when necessary, nominations for Trustees in whom to vest the properties of the Association.

c) Submit a report to the Annual General Meeting.

d) Take such steps as it deems advisable to further the objects of the Association.

e) Coopt *[sic]* to its numbers, fill vacancies, and appoint sub-committees, as and when occasions may arise.

f) Make arrangements for the Annual Conference on Speleology.

g) Approve all matter for inclusion in the publications of the Association.

12. Property
All Properties (including buildings, administrative equipment, technical apparatus, books, records, photographs, etc., of the Association shall be vested in two or more Trustees or Trustee Corporation, who shall be nominated by Council and appointed at the General Meeting.

13. Finance.
a) The Accounts of the Association shall be audited by one or more auditors appointed at the Annual General Meeting preceding that at which the accounts are to be presented.

b) All life subscriptions shall be invested either in trustee securities or in permanent property of the Association.

c) The expenses of general management shall be paid out of the current funds of the Association.

d) No gift, bonus, dividend or division in money shall be made out of the funds of the Association to or between any of its Members or Associated Societies, Clubs, Libraries, Museums or similar bodies.

e) Grants of money for specific speleological activities may be made to Members or Associated Societies, Clubs, Libraries, Museums or similar bodies if approved by Council.

14. Changes of Constitution

Changes in the Constitution of the Association may be proposed by any Ordinary Member, and such proposed changes shall be submitted for approval at the next Annual General Meeting or at a General Meeting specially convened for that purpose, if at least two months' notice be given in writing to the Secretary.

APPENDIX 2: CHRONOLOGICAL LIST OF BRITISH SPELEOLOGICAL ASSOCIATION NORTHERN PENNINE CAVE DISCOVERIES 1935 – 1945.

DATE	CAVE
1-Aug-36	Far Douk No.1 to Great Douk.
16-May-37	Gaping Gill - Hensler's Passage.
Aug-37	Sell Gill Hole - antepenultimate chamber.
Jul-38	Huff's Pot, Feizor .
Aug-38	Gaping Gill - Hensler's Passage extension.
Aug-38	Lost John's master cave - inlet passage.
Summer 1938	Old Ing Cave - end of the canal.
Aug-38	Buzzer's Pot.
Sep-38	Pint Pot.
1939	High Hull Cave.
Easter 1939	Little Hull Hole - extension.
1939	Lantyshop Cave.
1939	Stot Rakes Cave.
May-39	Glass Moss Cave.
Dec-39	Christmas Pot.
Jun-40	Simpson's Pot.
Jun-40	Hull Pot.
1941	Mossdale Caverns.
Early 1942	Dove Cave (rediscovery).
Aug-42	p2a.
Dec-42	Quaking Pot.
1942	Lever Pot.
1943	Grange Rigg Pot.
Aug-43	Hunt Pot - third pitch.
Oct-43	New Pot.
Mar-44	Disappointment Pot.
Aug-44	Hunt Pot - final chamber.
15-Aug-45	V.J. Pot.

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Speleothem decoration of giant domes in Bohemia Cave (New Zealand)

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Abstract: Giant domes in Bohemia Cave contain a vast number of speleothem formations, 90% of which comprise aragonite, with hydromagnesite accumulations and coatings. The aragonite formations are very young, ranging between -2390 and -2250 years, according to U-Th series analyses. Aragonite appears in typical gravitational forms as well as in complex eccentric shapes. Calcite, microscopic dolomite, opal, Fe and Mn hydroxides, gypsum and sepiolite are all present in small amounts. The greatest concentrations of formation occur on and in the vicinity of the contact between underlying weakly weathered shales (phyllites) and overlying marbles. Bohemia Cave probably contains the largest known accumulation of cave aragonite in the world.

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INTRODUCTION

In 1990, members of the Czech Speleological Society discovered Bohemia Cave on the South Island of New Zealand. A report edited by Tásler (1991) contains a detailed account of the course of the expedition. It also includes a description of the cave, an outline of the geological setting and of cave development, a general description of the formations, and several comments about the geomorphology and karst development.

During 1994, 1997 and 2000, the Czech Speleological Society organized two follow-up expeditions, and New Zealand speleologists undertook several smaller scale trips to the cave. Several kilometres of passages were discovered (Tásler, 1995, 1997), and Bohemia Cave was connected to the higher Rhapsody Cave (Tásler, 1998).

LOCATION AND CHARACTERISTICS OF THE CAVE

Bohemia Cave lies in the Mt Owen Karst Region, within Nelson Province, which covers the southwestern part of New Zealand's South Island. The lower entrance lies at the tree line, at an altitude of 1,250m a.s.l.; the upper entrance (Rhapsody Cave) is situated in rugged rocky terrain at 1,430m a.s.l.

The broad region comprises weakly metamorphosed limestone and dolomitic marble of the Upper Ordovician Mount Arthur Group (Coleman, [Ed.], 1981). These units are folded disharmonically into recumbent folds and reverse faults, with fold axes striking dominantly southwest–northeast (Wopereis, 1988). Phyllites of the Pikiruna Schist and Flora Formation form the basement in the area (Suggate, 1978).

The total length of the Bohemia Cave system is 10.6km. Its depth, measured from the upper entrance, is 713m. The cave can be subdivided into three principal parts, which are geomorphologically unique. An intricate network of relict phreatic passageways ranging from narrow channels to tunnel-shaped corridors many metres high and wide forms the first part. Larger passages are commonly largely sediment filled, and locally rejuvenated in the vadose zone. All cavities in this part of the cave are developed in marble and they lie within the approximate vertical interval 1,250 to 1,300m a.s.l.

Meanders, canyon-like passages (typically with streams), chimneys and shafts developed in marble form most of the second part of the system. Similar cavities continue even above the level of the fossil phreatic passages (see connection of Bohemia and Rhapsody Cave – Tásler, 1988). A narrow meandering passage that descends steeply from the lowest point of the giant domes to the terminal sump is also included in this part.

The third part of the cave comprises a system of giant domes and ongoing passages developed on an inclined contact between underlying shales/phyllites and overlying marbles. The Dream of Albeř ice Cavers (DAC), a system of gigantic chambers (or one single irregular chamber - depending upon definition) dominates among all the other chambers. It is 810m long, its width ranges from 50 to 110m and its height is from 4 to 20m. The speleothem formation study was conducted here. Temperature in the cavities ranges from 5.1 to 5.5°C, based on repeated measurements.

Plate 1. Rare calcite was found in "dead" yellowish decaying anthodites on the surface of the aragonite stalactite.

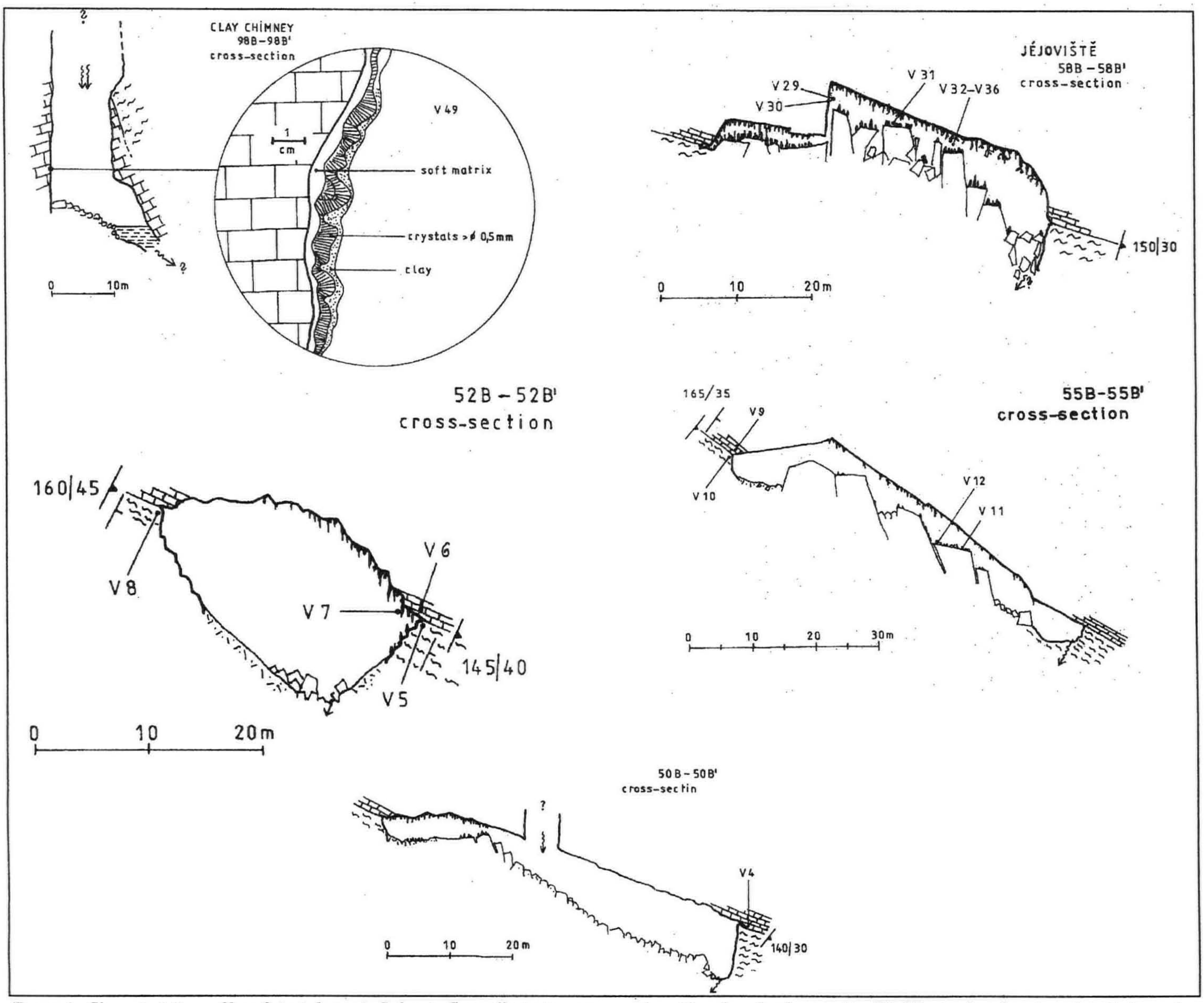

Figure 1. Characteristic profiles of giant domes in Bohemia Cave, illustrating common depositional mode of aragonite. V4, V5, etc, show location of studied samples.

GEOLOGY OF THE DOMES

Overlying carbonates are represented by weakly metamorphosed grey to black limestones (marbles). Commonly the units are laminated, and limonitized pyrrhotite is found near the contact. The carbonates undergo block disintegration and newly-formed calcite is present in many fissures. Grey, green to black, locally strongly-weathered, shale forms the non-karstic basement (Tásler and Tomášek, 1999). Lenses of secondary (secretory) quartz are developed on foliation planes. Irregular thin bodies of tuffite are also found within these rock units. The shales and phyllites are intensely weathered and thus predisposed to disintegration, followed by rapid erosion of the clayey residue. Debris accumulates near the walls.

A dipping surface (160/40), affected only locally by transverse dislocations (see Fig.3) with minimal vertical displacement, forms the contact between the carbonates and the non-karstic basement. On the southeastern walls of the cave domes the contact plane between weathered non-karstic rocks and the overlying marbles displays modern lineations that indicate motion in the direction of dip.

RESEARCH METHODOLOGY

A total of 67 petrological samples was collected from the cave, including several samples from its immediate vicinity. The set collected consisted of the basic host rock petrological types (47 samples) and speleothems (total 20 samples). Most samples were collected at the contact between marble and phyllite. Eight additional samples were collected during an extremely difficult climbing campaign on a vertical face of heavily weathered, clayey non-karstic rocks within the cave passage. Representative samples of phyllite and shale were collected through the entire dome profile, i.e. from the upper contact with the carbonates to 15m below, which is the maximum extent revealed by erosion.

To protect the cave ornamentation, only representative samples smaller than 1cm were collected from speleothem formations. The only two exceptions were a specimen of a massive aragonite formation and a complex form of locally widened eccentric fibres.

Mineral analysis was based both upon a previous detailed X-ray structural examination and upon a suite of another 33 speleothem samples, studied in detail using an energy dispersive analyzer of X-ray radiation (EDAX). The study included visual inspection of samples at magnifications of 30-2000x (scanning electron microscope), analysis of the total sample surface, and point or small area analysis of individual grains or mineral phases. The number of analyses reached a total of 200 determinations and required a total of 4 instrument-days of microprobe time. Microphotographs were taken of individual samples. In addition polished thin sections were made from 16 important rock and speleothem samples for petrologic identification and wet chemical silicate analysis. Due to high costs, neither the microchemistry of aragonites nor the stable isotopes were analyzed during this phase of the research.

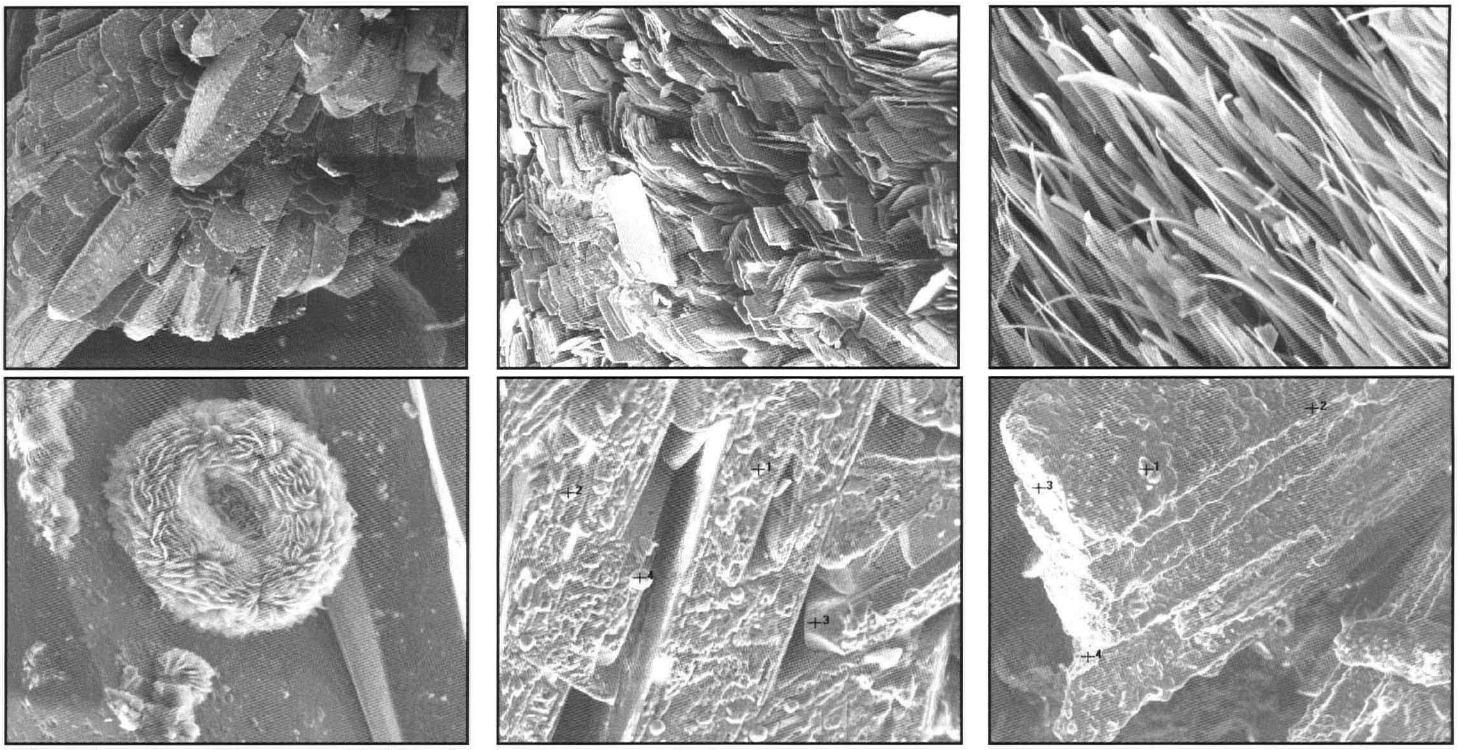

Plate 2. Microphotos (A Langrova and V Cilek) of dominantly aragonite speleothems.
Microphoto 1 (top left): Coarse-grained aragonite partly covered by clay mineral and opal coatings (sample 29a2).
Microphoto 2 (top centre): Chisel-shaped aragonite crystals from a recent white anthodite (sample 34a).
Microphoto 3 (top right): Grass aragonite from the interior of an aragonite (sample 36c).
Microphoto 4 (bottom left): Hydromagnesite wreath on aragonite needle (sample 21a1).
Microphoto 5 (bottom centre): Authigenic dolomite laminae and grains on corroded aragonite needles (sample 25c).
Microphoto 6 (bottom right): Opal coatings on aragonite needles (sample 28b).

Two characteristic samples of aragonite speleothem were analysed by standard $^{230}Th/^{234}U$ series techniques (alpha-particle counting) at the Uranium-Series Laboratory of the Institute of Geological Sciences of the Polish Academy of Sciences in Warsaw (sample preparation by J Kadlec and T Niwicki; analyses by H Hercman) to obtain U-Th series datings. Both samples have unusual high uranium content – 14.2 and 23.5ppm – possibly caused by elevated content in surrounding non-carbonate rocks. For comparison, the flowstones from (for example) the Moravian Karst (Czech Republic) contain around 0.05ppm U. Both dates are very low – 2250 years for the upper part of a massive aragonite crust and 2390 years for the core of a large aragonite stalagmite collected in the lower third of an originally almost 2m-high formation. Due to the high uranium content the amount of measured radioactive isotopes is also unusually high, helping to ensure that accurate age data were obtained.

OCCURRENCE, LOCATION AND EXTENT OF ARAGONITE SPELEOTHEMS

Aragonite formations are present throughout the entire cave with the exception of the entrance section, which is affected by frost action. However, the highest concentration is found in the giant domes (DAC), where detailed study was conducted.

The vertical extent of the formations is apparent from the cross-sections (Fig.2). Formations are concentrated mostly on the ceiling (see Fig.1) and, to a lesser extent, on chamber floors formed by huge blocks falling from the ceiling. Most of the formations are near the contact with the non-karstic basement or on the ceilings above the contacts on the higher north-northwest sides of the domes (see Fig.1). Here formations cover the ceiling continuously across an area of several hundred square metres.

Speleothems occur also at the south-southwest sides of the domes, i.e. where the main active stream flows through the shales and phyllites. Speleothem covers phyllites only to a limited extent, except for surface accumulations of hydromagnesite. The larger stalactites and especially stalagmites could not have formed here because of rapid erosion of the unstable clayey cave floor.

An enormous amount of relict broken, yellowish, speleothem is found beneath the collapsed ceiling blocks. The maximum thickness of the debris accumulation is estimated to be around 15m. Locally the undersurfaces of large and small blocks, collapsed from the original ceiling, can be inspected, and these are coated nearly continuously with speleothem.

Figure 1 represents the surface extent of the largest speleothem accumulation. Rich speleothem deposits cover more than 70% of the cave ceiling and 50% of the cave floor. Due to the large size of the dome it is difficult to evaluate areas where less than 70% of the area is covered by speleothems. In many places the ceilings are beyond the extent of "reasonable" illumination by carbide lamps, and some sections of the dome could only be evaluated from slides and videos shot under special short-term illumination.

Although the method of evaluating surface extent of speleothem is not totally satisfactory, it is probable that the DAC chamber(s) carry aragonite speleothems over a ceiling area exceeding 30,000m^2 and a floor area greater than 6,000m^2. These estimates do not include broken relict speleothem found under the collapsed ceiling blocks. The chamber and the cave itself are probably the richest in the world with respect to the amount of aragonite. It should be noted that the aragonite content was documented only in the giant domes, which form just part of the entire Bohemia Cave system.

MACROSCOPIC CHARACTERISTICS OF SPELEOTHEM FORMS

Formations are typically snow white, only older specimens that are inactive or broken off are dirty yellow in colour (exceptions are noted further on in the text). Speleothems can be divided into the following groups, according to their morphology:

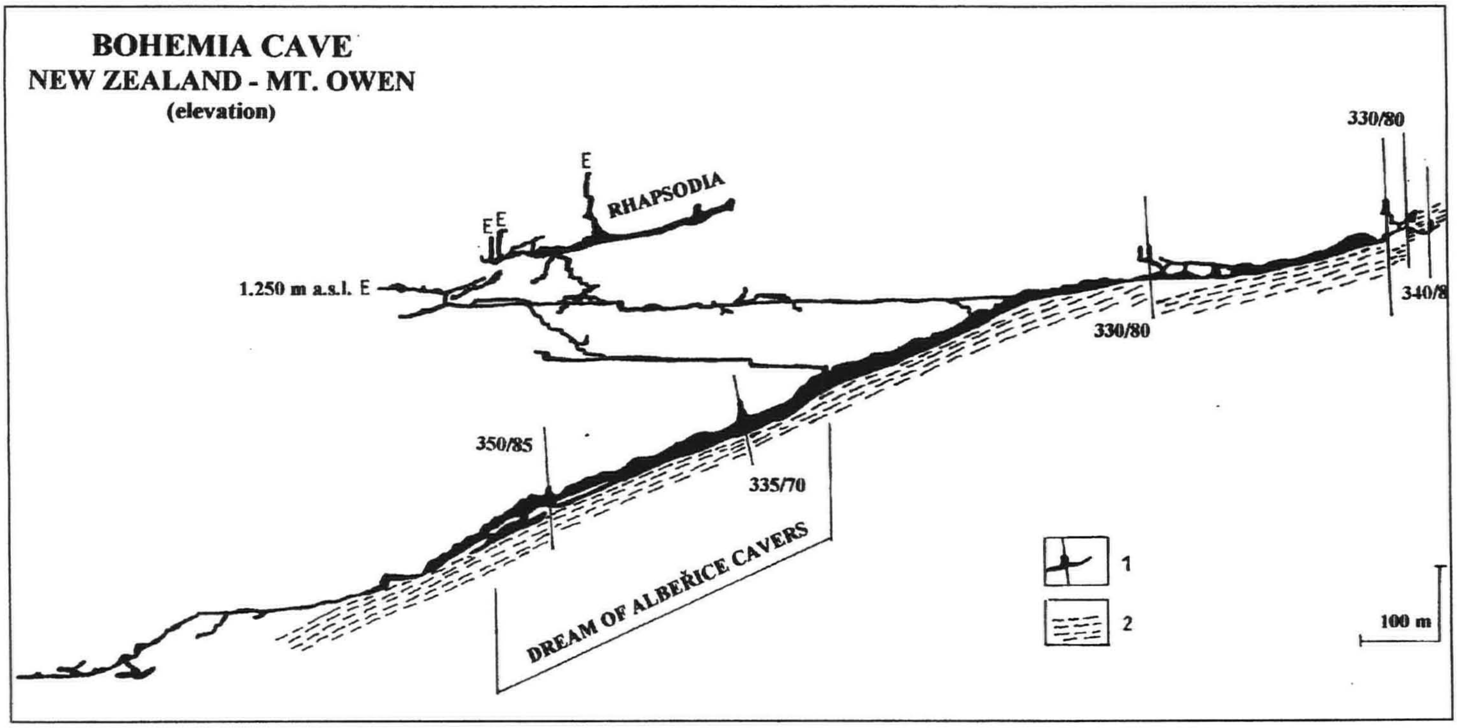

Figure 2. Longitudinal section of Bohemia and Rhapsody caves. 1 - generalized cave passages; 2 non-karstic basement; 330/80 etc, - faults

Gravitational forms:
g1 — stalactites, straws
g2 — stalagmites
g3 — columns
g4 — sinter films

Eccentric forms:
e1 — clumps of fibres of "flos ferri" type (Hill and Forti, 1997);
e2 — individual eccentric fibres;
e3 —anthodites;
e4 — straight stalks;
e5 — transitional and irregular forms.

Other forms:
x1 — soft "quark-like" material;
x2 — crystal coatings.

Stalactites belong to the most widespread gravitational form. They reach lengths of 1.5m, with the most common width being less than 20cm. A large number of various carrot-shaped bulges and cones, with diameters reaching 0.75m at the root are also present. Stalactites are commonly variously twisted, and other forms included in the e2 to e5 groups grow on their surface. Clusters of classic straws, reaching a maximum length of 1m, are present in a few places. Many of them can be found lying broken on the floor. Typically they are tangled together with variously twisted stalactites and eccentric fibres from groups e2 and e5. Straws growing up to 10cm from the tips of individual aragonite fibres belonging to group e2 are one of the more peculiar forms.

Stalagmites (g2) are common in places where the ceiling is rich in formations. They are up to 1.8m tall and their diameters reach 0.5m. In places stalagmite heaps may form. Stalagmites are commonly tilted due to settling of their basement, and new generations grow on their surface. The stalagmite centre, as seen in a perpendicular cross-section, is typically coarsely recrystallized.

Columns (g3) are rare and are found only exceptionally in places with the highest concentration of formations. They reach a maximum diameter of 1m, but mostly they are of similar thickness to the stalagmites.

Sinter films (g4) several millimetres thick irregularly coat the carbonate and phyllite walls in the areas with the highest concentration of formations. Sinters several centimetres thick are found in only one place (Phyllite Meander) and they are of exceptionally bright yellow hues.

The largest number of clumps of "flos ferri" fibres (e1) is found in the Albeřice Corner. E1 forms occur mostly on the ceilings, but also grow on the bodies of the more massive forms of stalactites, or on their roots. The largest clumps have a volume of 0.3m^3 and in places they are penetrated by straws.

Together with variously twisted stalactites, individual eccentric fibres (e2) are the most common formation. They grow all over the ceilings, as well as on stalactites, commonly terminating straws and forming "antigravitational" hooks. Shapes range from the simply intertwined to extremely intricate tangles formed together with stalactites and "flos ferri". Fibres reach a length of more than 0.5m and can be distinguished from the "flos ferri" fibres on the basis of their different thickness. Whereas "flos ferri" fibres are regular and 2-3mm thick, fibres of e2 type have variable thickness, commonly with bulges developed at their tips. The fibres have a well-developed central channel and their diameter rarely exceeds 3mm. However, one can also find fibres 0.5mm thick (!) without a central channel.

Anthodites (e3) are omnipresent, even on massive stalagmites. Their size is in the order of a centimetre, and they are variously eccentrically twisted. No central channel was visible to macroscopic examination.

Straight stalks (e4) mostly fan out from a central point, with diameters from 2 to 3mm and lengths reaching 0.5m. They can be found both on the ceilings and on more massive stalactites. Stalks commonly form crazy tangles, together with formations of the e1 and e2 types.

Forms having flat to oval, hollow, variously twisted or straight shapes are classified as transitional ones (e5). Their diameter is in the order of several mm. They accompany, in smaller amount, nearly all forms that grow on the ceilings.

Soft "quark-like" [similar to "curd cheese"] material (x1) identified as hydromagnesite (see below) irregularly covers parts of the ceiling, the bodies of stalactites and individual fibres. The hydromagnesite moonmilk can commonly be found at the terminations of stalactites, fibres and bulges, as spherical to cauliflower-like shapes with a maximum diameter of 2cm. Accumulations form irregular layers up to

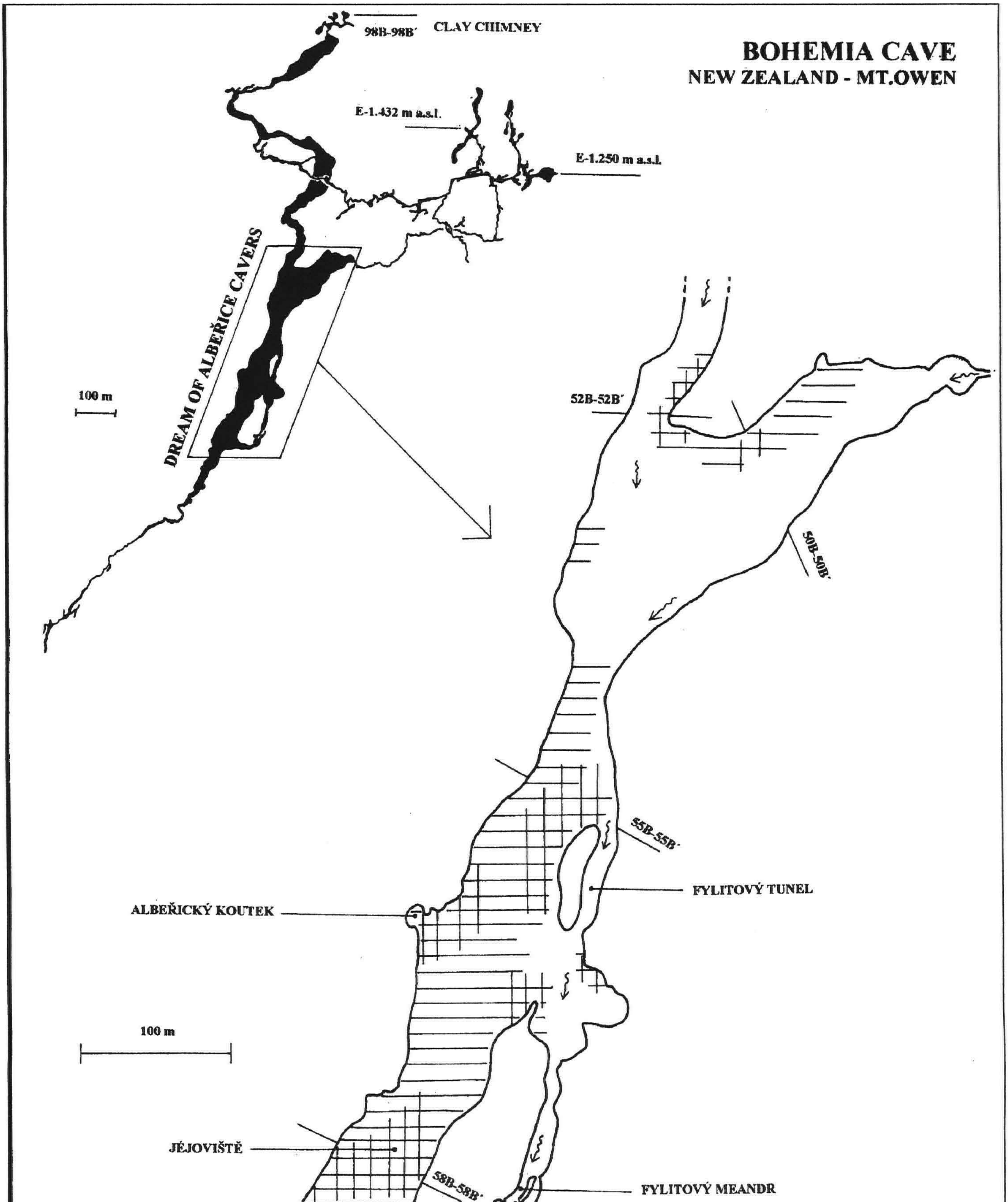

Figure 3. Approximate extent of surfaces covered by aragonite speleotherms in the giant doems of Bothemia Cave. 1 - more than 70% of the total ceiling area is covered by aragonite; 2 - more than 50% of the total floor area is covered by aragonite. 52B-52B', etc - selected cross sections (see Fig.1)

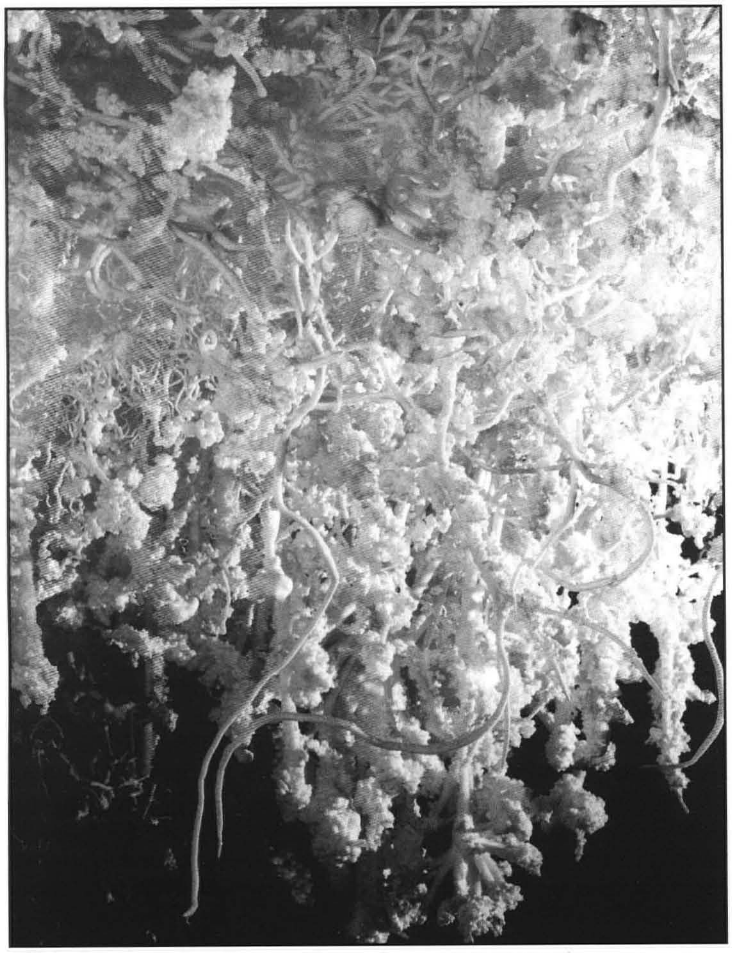

Plate 3. Aragonite cluster with a volume of about 0.3m³. Single hollow aragonite threads are visible at the front. Other threads are coated in hydromagnesite, with "cauliflower" aggregates.

several centimetres thick. "Quark-like" forms coat several tens of square metres of phyllites in the Albeřice Corner.

Clearly separated crystal coatings (x2) in the order of a few millimetres, and clusters of needle-shaped crystals can be found principally on the ceilings and overhanging walls. For this reason they are difficult to study. Their presence was generally observed together with collapsed massive formations. Crystals were in some cases coated by a clay film, but such specimens were collected outside the giant domes (see Fig.1, cross-section 98B-98B' Clay Chimney).

MINERALOGICAL RESEARCH

Bohemia Cave is rather uniform from the point of the mineral phases present. Minerals found in speleothems include authigenic aragonite, calcite, hydromagnesite, dolomite, gypsum, opal and sepiolite, together with allochtonous minerals represented by quartz, various clays, hydromuscovite and iron hydroxide. Yet the amount of aragonite formations surpasses the imagination – according to preliminary calculations Bohemia Cave contains more aragonite than would several hundred Ochtinská caves (a cave in the Slovak Karst that is listed in the UNESCO Natural Heritage List) put together! Aragonite formations totally dominate in the DAC dome(s), forming probably more than 90% of all the speleothems. Calcite and hydromagnesite are relatively common, whereas other minerals –opal, gypsum, sepiolite and dolomite – were detected only in the form of microscopic inclusions.

Calcite

Calcite is found in several forms as an admixture in aragonite speleothems:

- as a thin, white or semitransparent film coating aragonite dripstones;
- as bulging sections of non-gravitational formations, or finally;
- as inlays several millimetres thick and as infiltrations.

The exact amount of calcite can be estimated only with difficulty. Yet, according to fractures on collapsed formations, calcite (which can be identified by its excellent cleavage, whereas aragonite displays very irregular cleavage) regularly accompanies aragonite, but is almost always present in a strongly subordinate position.

Hydromagnesite

Hydromagnesite can be found in forms analogous to those present in other caves of the world as white, chalky to "quarky" bundles, similar to moonmilk. Their size ranges from several millimetres to more than a centimetre, and their shape is similar to "hydromagnesite snow" coatings as well as to "cauliflower" forms. Hydromagnesite is presently considered to be the third most common carbonate cave mineral (after calcite and aragonite), and is typically tied to magnesium-rich environments (Hill and Forti, 1997). Findings in Bohemia Cave do not deviate in any way from this overview. Yet, microscopic forms similar to "wreaths" mounted on aragonite needles are exceptionally impressive.

Dolomite

Dolomite was found during microscope analysis and identified solely on the basis of chemical composition and habit. It occurs as lamellae several micrometres thick and as semi-spherical coatings on aragonite needles. Dolomite does not form by direct degradation of hydromagnesite, but precipitates from solution. Surfaces to which dolomite is attached are commonly corroded and/or "pitted", suggesting that precipitation is either tied directly to corrosion of aragonite or to changes in the chemistry of the solution. The cave area lies within a monsoonal zone, so distinctive hydrological regimes are to be expected. Dolomite is relatively rare as a cave speleothem mineral and, if present, is commonly found associated paragenetically with hydromagnesite (Hill and Forti, 1997). Dolomite was observed in Bohemia Cave as small crystals on fibres and as "flos ferri" forms, revealed by scanning electron microscope.

Opal

Aragonite formation in caves is commonly tied to evaporation and thus also to the development of opal coating (for discussion see stable isotope data in Cílek and Šmejkal, 1986), which is also the case in Bohemia Cave. Recent opal was found in the form of thin (several millimetres thick) coatings on aragonite needles and fibres. At 100x to 200x magnification, aragonite crystals appear to be covered by thin "mud" consisting of more than 90% opal with an irregular, commonly mottled, admixture of Fe and Mn hydroxides. Opal may also occur as minute globular forms.

Iron and manganese hydroxides:

These are fairly rare and not widely distributed. They appear as large rusty spots (several millimetres) in which the Mn hydroxide content does not exceed 7 mass % (EDAX identification). They are more common as allochtonous admixtures in the form of minute rusty shards of Fe hydroxides flushed in from higher up in the cave.

Gypsum

This was found in the form of small (only 5-20 micrometres) crystals growing on opal coatings. Gypsum is relatively rare, but a certain small sulphate content (0.2 – 1.4 mass %) is found fairly commonly in samples of aragonite needles. Pyrite cubes and pyrhotite were found in the dark tuffitic rocks of the lower sections of DAC. The intensive weathering of these rocks may lead to sulphide weathering followed by gypsum formation.

Sepiolite:

This normally relatively rare cave mineral is found fairly commonly in Bohemia Cave, in the form of very fine coating and irregular grains up to several millimetres in size. Sepiolite typically appears as irregular flakes trapped on the surface of, or between, aragonite needles. Sepiolite is very similar in appearance to other clay minerals. Even though identified only on the basis of chemistry the determination of this mineral is considered soundly established, as analyses conducted on different samples yielded results identical to the sepiolite standard. The character of sepiolite as an accessory in bulk samples does not allow XRD identification.

Sepiolite is associated with magnesium-rich rocks, and in some cases it might be released from marbles during weathering. More probably it may form as an autochtonous mineral, as the surface morphology suggests. The latter possibility is more common in pseudokarst cavities than in karst proper (Hill and Forti, 1997). It must be remembered that a significant part of Bohemia Cave formed in non-karstic, strongly weathered phyllites, from which sepiolite may also be released as a weathering product.

Allochtonous minerals

Hydromuscovite is a very common product of the weathering of local phyllites. Platelets of mica are easily transported by karstic waters and, due to their shape, they settle extremely slowly (a similar situation was observed in Ochtinská Aragonitová Cave; Cílek *et al.*, 1998). The long residence time within karst waters is probably responsible for the overall or partial hydratation of muscovite. Finally, together with dripwater, the mineral reaches the surface of sinters and irregular aragonite needles as more or less isolated grains.

Aragonite

The form of macroscopic aragonite is extremely variable, ranging from massive, 1m-long and more than 10cm-thick dripstones and flowstones to amazingly tangled forms, hangers, worm-like shapes, straws, needles, sprinklings of fine aragonite crystals and combinations of all the above. Similarly, a whole world of aragonite needle-like crystals of various shapes and degrees of corrosion is visible under binocular or electron microscopes. Correlation between the macroscopic external shapes of speleothems and the microscopic habits of crystals is hard to find. It must be borne in mind that microclimatic conditions can change, not only within individual cave chambers, but even in a cave niche. For example, in a maze of aragonite fibres, the conditions of carbon dioxide release, capillary transport and solution evaporation are different at the root and at the end of fibres.

The appearance of massive white dripstones and flowstones with velvety lustre is basically the same – recrystallized needles broadening in a parallel fashion, typically without traces of calcite or other minerals. Calcite, as distinguished by perfect cleavage, if present, is sharply separated and located at the base of flowstones or, in contrast, on the surface of dripstones. Aragonite flowstones sometimes cover ("flow over") fine fibrous tangles of "flos ferri". Three principal types of crystals can be distinguished:

1. Needle-shaped crystals originate either from slightly weathered, older aragonite aggregates or can be quite regularly found on straws and fibres. Crystals are commonly broadened, with a well-developed terminus. Typically the crystals are corroded. Opal and dolomite were found only in association with needle-shaped crystals.
2. Chisel-shaped crystals dominate on snow white, young aggregates of "flos ferri", on straws and on fibres. Aragonite is developed in the form of flat elongated platelets, with thickness up to twenty times larger than width. In places platelets surround older needle-shaped crystals. Typically they are not corroded, and may be accompanied by sepiolite.
3. Grass aragonite, i.e. fine, typically bent, aragonite needles with ends commonly oriented in the direction of dripping water, was found inside straws and hollow helictites.

A striking feature of the aragonite formation is the apparent youth both of massive flowstone crusts and aragonite stalagmites, as determined by U-Th series dating. In both cases the age of aragonite is similar –2390 and –2250 years. The geomorphological features of the cave and young age of aragonite decoration evidence a period of fast, relatively recent, speleothem development.

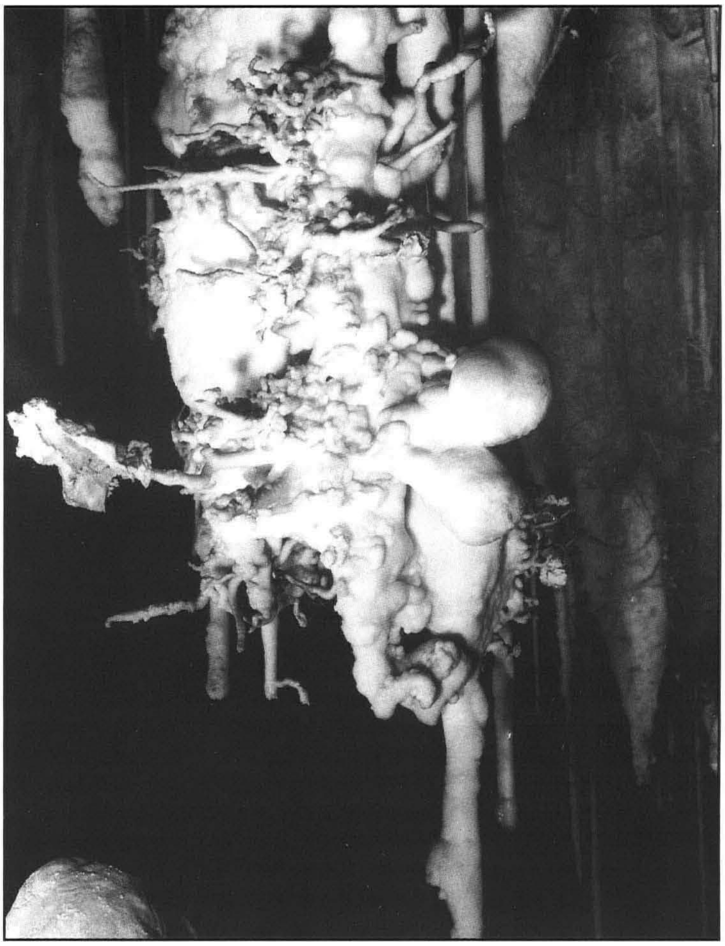

Plate 4. Thickened aragonite forms with anthodites.

DISCUSSION

Details of aragonite genesis cannot be resolved without costly C and O stable isotope investigation. Nevertheless, previous observations (Hill and Forti, 1997; Frysia *et al.*, 1998; Cílek, 1998) and various other works provide two principal, mutually interrelated causes of aragonite formation in caves:

1. Mg ions suppress calcite crystallization and therefore encourage aragonite growth. Direct analysis of karst waters (conducted *in situ* by D. Havlíček) and analysis of surrounding rocks both suggest increased amounts of Mg. Mg is present as a common component in hydromagnesite. The content of Mg^{2+} in karst solutions was found to reach 1.18 – 4.29mg/l, with an average of 2.40mg/l (Havlíček and Tásler, 1999).

2. Microclimatic factors. Massive aragonite is relatively common in caves with average temperatures above 12°C. The principal factor controlling aragonite formation is slow water evaporation in closed caves, together with slow air circulation and humidity near 100%. In such environments aragonite commonly forms from waters slowly rising or infiltrating through capillary action. The reservoirs of many such waters are loams or porous sediments. Seasonal bias of precipitation is sometimes considered as an important factor. Water released e.g. during spring melting or after the arrival of monsoons displaces solutions that, during the course of drier weeks and months, became supersaturated not only with calcium carbonate, but also with Mg, Sr and other components that are released into solution relatively more slowly. Such enriched complex solutions enter the closed cave environment affected by minimal evaporation.

Probably all these factors played a role in aragonite precipitation. The underlying presence of weathered phyllites, with a revealed thickness reaching 15m, is considered to be an extremely important factor. Phyllites are strongly weathered, brittle and can be broken by hand. The

Plate 5. Aragonite aggregate of flos ferri type. The stalagmites are also composed of aragonite.

Plate 6. Beet-shaped stalactite with individual threads - all aragonite.

thickness of phyllite debris reaches several metres. Weathered phyllites formed principally of disintegrated mica aggregates represent an optimal medium for long term entrapment of pore karstic solutions including Mg-compounds and precursors of opal, gypsum and sepiolite (the latter, as previously mentioned, is more common in pseudokarst than in carbonate caverns). These atypical solutions are released into the cave environment after arrival of the rainy season, and preferential crystallization of aragonite occurs. Currently, work is focusing on further evaluation of this hypothesis.

CONCLUSION

1. The giant (DAC) dome in the Bohemia Cave System represents not only one of the largest cave chambers in the world but probably also the largest aragonite cave on earth, considering the amount, area covered and variety of forms. More than 30,000m^2 of the ceiling and 6,000m^2 of the floor are covered by aragonite speleothems.
2. Two characteristic samples of aragonite decoration were analysed by $^{230}Th/^{234}U$ series standard techniques (alpha-particle counting). Both samples have unusual high content of uranium – 14.2 and 23.5ppm, caused possibly by its elevated content in surrounding non-carbonate rocks. Both dates are very low: –2250 years for the upper part of massive aragonite crust and –2390 years for the core of a large aragonite stalagmite collected in the lower third of an originally almost 2m-high formation.
3. The geomorphological features of the cave and young age of aragonite decoration evidence a period of fast contemporary speleothem growth.

ACKNOWLEDGEMENTS

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Field observations from some caves in the Umphang District, Tak Province, Thailand

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Abstract: Basic scientific observations, including measurements of air and water temperature, oxygen and radon concentrations, from caves in a scientifically poorly known karst area in Umphang District, Western Thailand, are described. The results, which illustrate what can be achieved by a small expedition of non-specialist cavers, provide the first evidence of low oxygen and radon concentrations in Thai caves. The results are discussed in the context of published data from other Thai caves. Cave surveys are also presented.

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INTRODUCTION

Encouraged by an earlier visit in 2000 (Ellis and Barrett, 2001), Shepton Mallet Caving Club (SMCC) mounted its second expedition to Thailand between December 26 2000 and January 10 2001. The study area on this occasion was based around the small town of Umphang in Tak Province (approximately 16°01'N 98°52'E, altitude 500m a.m.s.l.), western Thailand, close to the border with Burma (Myanmar) (Fig.1).

In addition to exploring the area for caves and surveying any finds, a conscious decision was taken at the expedition planning stage to conduct some basic scientific research. This report describes the measurements made and their relation to the local karst environment. Other aspects of the expedition are reported elsewhere (Barrett *et al.*, 2001).

GEOLOGY AND TOPOGRAPHY

Geological boundaries in the area around Umphang appear to be rather complex, but are aligned approximately northwest-southeast (Royal Thai Survey Dept., 1992). Thus, from east to west, over a distance of just 20km the age of the rocks is shown as changing from Silurian-Devonian, to Carboniferous-Permian, to Triassic-Jurassic. More recently Meesook and Grant-Mackie (1996) have examined the Jurassic lithostratigraphy of the area in some detail. These sources lead us to conclude that the caves discussed below are in Permian rocks. We are working to clarify details of the geology of the caves at the present time.

Limestone is seen in isolated towers and cliffs in the upper Mae Nam Mae Klong valley, about 40km north of Umphang. More substantial hills and cliffs develop to the south of here. Cave entrances are visible in these outcrops but none were investigated. To the west of Umphang, in the Umphang Wildlife Sanctuary, there are large limestone cliffs along the valley of the Huai Nong Luang. Limestone and extensive tufa deposits are also seen at the Tee Lor Su waterfall, a local tourist attraction, 15km southwest of Umphang. An extensive area of karst also exists farther to the south, between Umphang and the village of Ban Palatha, at an altitude of over 800m. The cave depth potential here may be up to 400m. This area will be the subject of a subsequent expedition.

The general topography of the study area is one of thickly vegetated hills (at altitudes of 600 - 1000m) interspersed by broad, gently rolling, plains and shallow valleys (Fig.2).

Higher ground is covered in a mixture of mixed deciduous forest, bamboo thickets and giant pampas grass, but is also dotted liberally with heavily weathered limestone outcrops and boulders. Lower slopes were commonly subject to cultivation (e.g. sweetcorn and sugar cane) but otherwise were just thick scrub or savannah grassland. Small (c.2m-wide) streams (many clearly seasonal) and the rare meanders of the larger (c.6m-wide) Mae Nam Mae Klong cut across the lower ground.

CLIMATE

November to February is the cool-dry season in Thailand. Thus, the yearly-average rainfall figure for Western Thailand of 1400 - 1500mm, which is almost comparable to that of NW England, is really compressed into a 6-month period. Flash floods in seasonal streambeds are the inevitable result, and the expedition found numerous examples of massive flood debris at stream sinks and in cave watercourses. This would not be an area to attempt to cave in during the wet season (May to October). Thirty-year mean climatic data for Umphang, sourced from the Thai Meteorological Department, indicate a temperature range of 17 - 31°C with relative humidity almost constant at 76 - 78%. The upper bounds of these data are certainly in keeping with those experienced by the expedition, though some night-time temperatures dropped as low as 11°C (Table 1).

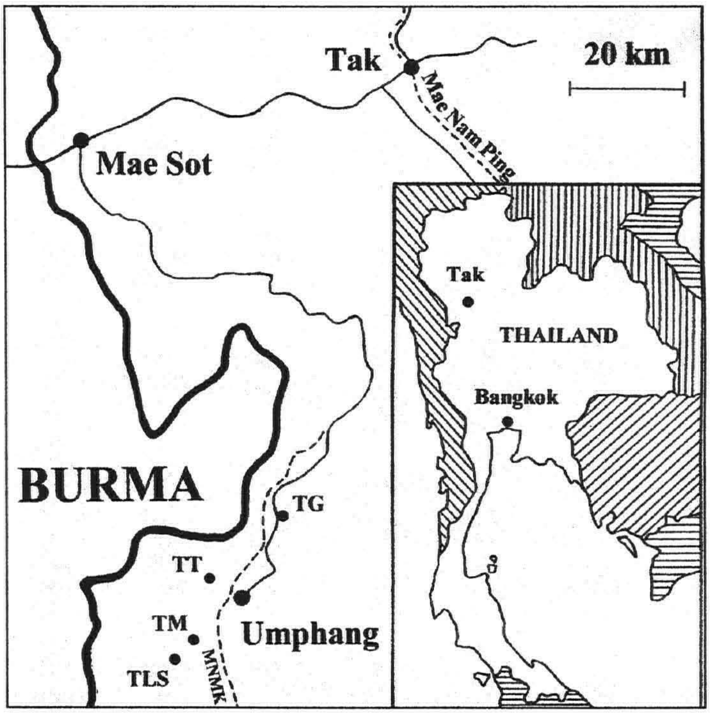

Figure 1. Map showing the expedition location. Key: MNMK = Mae Nam Mae Klong river, TG = Tham Glab, TT = Tham Takobi, TM = Tham Mutalu and TLS = Tee Lor Su waterfalls.

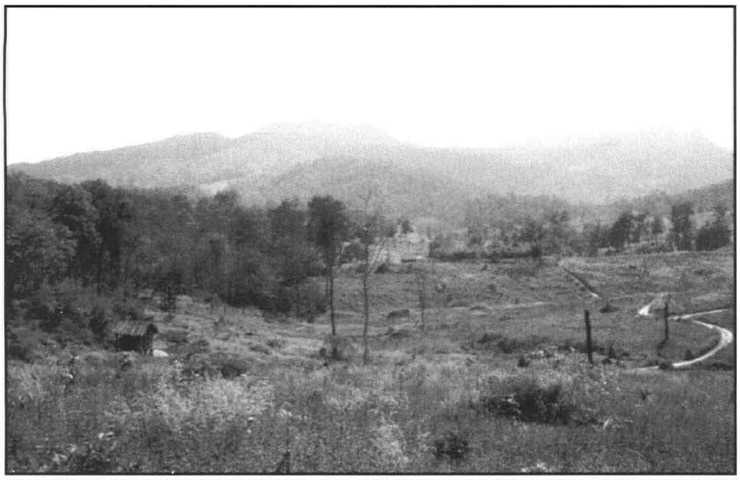

Figure 2. Typical karst landscape around Umphang.

REGIONAL HYDROLOGY

Drainage in the study area appears to be relatively simple; everything south and east of the border with Burma (Myanmar) and west of the watershed with the Chao Phraya basin empties into the southward flowing Mae Nam Mae Klong river. This is joined by several tributaries south of Umphang, including the renowned Kwai Noi, before flowing into the Bight of Bangkok approximately 300km to the southsoutheast. The water from the three caves discussed below resurges in tributary valleys that then feed into the Mae Nam Mae Klong.

Active swallets were found at Tham Takobi (Monk's Cave) and at Tham Glab, and seasonal swallets were found beside the track through the Sanctuary to Tham Mutulu. The Spider Entrance to Tham Takobi is also a major seasonal sink.

No water tracing was conducted, but active resurgences were found for Tham Takobi (we explored the stream from sink to rising) and for Tham Glab (at the opposite end of an isolated limestone hill to the sink). A small resurgence was also found beside the Mae Nam Mae Klong just east of Tham Glab. This water may come from a nearby cave to the north that the expedition did not locate but learned about from local villagers. A dry resurgence was found for the small stream in Tham Mutalu. Trekking and rafting literature mentions several hot springs along the banks of the Mae Nam Mae Klong in the gorges to the south and also in the hills about 15km to the southeast of Umphang. These local publications also mention a cave called Tham Mood a few kilometres south of Ban Palatha where there is said to be an underground river. This may be the same cave explored and surveyed by Delannoy (1982), who called it Tham Mae Nam Yough, but the identification evidence is contradictory.

CAVES

Tham Takobi

This cave is well known to the local villagers and is also widely advertised as an eco-tourist destination by trekking companies. Monks inhabit one entrance. Although mentioned by Dunkley (1995) we believe our expedition was the first to explore the cave in any detail. It consists of three distinct levels (see below) and to date fourteen entrances have been identified (Fig.3). The system has one major sink near what the expedition termed Monk's Cave. In six days the expedition surveyed 5760m of passage in this cave, making it currently the fifth longest cave known in Thailand (Smart, 2001; Price, 2001).

Pothole

This 10m deep pothole is located to the west of the Tham Takobi streamway. At the bottom of the entrance shaft there were two small chambers, but no way on.

Swallet Cave

A large swallet entrance at the end of a deeply incised seasonal streambed that led to about 45 m of low passage. The underground stream fed into the surface stream issuing from the Tham Takobi resurgence.

Through Cave

The water resurging from Tham Takobi passes through this 30m-long cave in order to reach the surface stream, which then flows south to the Mae Nam Mae Klong river.

Tham Glab

This cave is located in an isolated limestone hill 15km to the north of Umphang (Fig.4). A small stream sinks at the eastern end of the outcrop and resurges 500m away at the western end, before flowing along on the surface into the Mae Nam Mae Klong River. Local farmers occasionally mine bat guano from the cave, or use it to store rice.

This cave was only brought to the attention of the expedition on its last day in the field. Anecdotal information claims that it is 1 km long, and the expedition explored about 500 m of this. The entrances were fixed by GPS and a Grade 1 sketch survey was made (Fig. 5).

Tham Mutalu

This cave is located within the Umphang Wildlife Sanctuary and permission to visit it must be sought from the appropriate local authorities. Surveyed to a length of 665m the cave has some interesting features and formations (Fig.6). It ends at a slightly draughting mud fill in crawling passage that is presumed to be very close to the surface. Italian cavers explored this cave in 1995 (Anzanelli and Cadamuro, 1996), and gave it the name Tham X.

GEOMORPHOLOGY AND CAVE HYDROLOGY

Although the separation between Tham Glab in the north to Tham Mutalu in the south is some 20km, all three caves lie within a narrow altitude range of 500m to 590m.

Tham Takobi is formed on three main levels:

High Level (*altitude 560 - 570 m*)

Bamboo Ladder Cave is a large heavily decorated passage that appears to be the oldest part of the system. There is possibly an extensive system at this altitude overlying Tham Takobi, though much of it may

Date	Temperature (°C)		Evaporation	Rainfall	M.S.L. pressure [1]	Relative humidity [1]
	Max	Min	(mm)	(mm)	(mb)	(%)
28-Dec	29.4	10.9	3.63	0	1013.98	78.1
29-Dec	29.4	11	1.03	0	1012.51	78.3
30-Dec	30.2	14.5	3.04	0	1011.24	76
31-Dec	30.5	15.2	4.05	0	1011.47	75.5
1-Jan	30	13.4	2.83	0	1011.19	75.5
2-Jan	30	12	3.83	0	1011.5	77
3-Jan	29.5	14.3	3.22	0	1012.5	78.3
4-Jan	29	11	2.3	0	1013.07	77.6
5-Jan	30.4	11	2.19	0	1013.13	76.3
6-Jan	30.2	11.8	2.71	0	1012.98	76.6
7-Jan	30.2	14.1	2.46	0	1011.68	80.5
8-Jan	30.6	16.4	2.48	0	1010	78.6
9-Jan	31.2	17	3.23	0	1010.75	77.3

Table 1. Contemporary climatic data recorded by the Umphang Hydro Meteorological Station (altitude 456m above mean sea level). Notes: (1) Average value (observed at 3-hour intervals).

have been eroded away. Bedding Cave is an entrance that was not explored but that is at the same altitude as Bamboo Ladder Cave. 140m of passage was surveyed at this level.

Relict Level (*altitude 530 - 540 m*)
Tourist Cave, the Southern High Level and Shrine Passage are the main components of this level. Although dry in the dry season, water does flow through some of these passages in the wet season. Local sources told that waist-deep water is occasionally encountered in the Tourist Cave entrance. Spider Entrance is a major wet season sink from the large doline to the east of the Tourist Entrance. The floor of the Southern High Level Passage is mud and there are two distinct tide marks on the walls. Shrine Passage appears to be drier than the other parts. Water probably enters this level through a combination of backing up from the bottom of the cave and overflowing from Monk's Cave. 3959 m of passage was surveyed at this level.

Active Level (*altitude 505 - 525 m*)
The Monk's Cave, the Northern and Southern Dolines and the Main Streamway comprise the passages on this level. In the wet season the stream that normally sinks just before Monk's Cave would appear to overflow into Monk's Cave. Since the small streamway in the Northern Doline would not be able to take much water it overflows through the vadose rifts of Flood Overflow to rejoin the streamway downstream of the restriction. Water also probably flows from Monk's Cave along East Passage to Tourist Cave as this is low, muddy and damp at the Tourist Cave end. 1659 m of passage was surveyed at this level.

In low water conditions the surface stream sinking outside the Monk's Cave entrance reappears in the upstream sump pool in the Northern Doline cave and then flows through restricted passages via the Southern Doline cave before reaching the Main Streamway. The stream flow rate in the Northern Doline and the Main Streamway was determined (using a floating marker) to be approximately 0.1 cumecs (m^3s^{-1}) at both locations. However the Main Streamway has evidence of flooding to the roof along most of its length. This clearly demonstrates that the cave is required to channel a much larger volume of water than was evident during the expedition.

It is estimated that a flow rate of 1 to 2 cumecs would be sufficient to cause the system to start backing up from the restricted passages between the Northern Doline cave and the upstream end of the Main Streamway (2 m^2 passage area multiplied by 0.5 ms^{-1} plus an additional factor to allow for the greater flow in flood). Alternatively, from a 1:50,000 map (US Army, 1969) the catchment area for Tham Takobi is estimated to be 14km^2. With an average annual rainfall of 1.5 m (Source: Thai Meteorological Department) a total of 21 million m^3 of water has to travel through the cave in a year, of which just 1.6 million m^3 (0.1 cumecs x 60 secs x 60 mins x 24 hrs x 181 days) goes through in the dry season (November to April). This leaves 19.4 million m^3 to traverse the cave in the wet season (May to October) giving an average flow rate of approximately 1.2 cumecs (19.4 million / 184 days / 24 hrs / 60 mins / 60 secs). The average wet season volumetric flow is thus an order of magnitude greater than that in the dry season. Water would therefore backup and flow through the higher levels of the cave for the majority of the wet season and evidence for this is seen in the Relict Level passages.

A rounded cobble fill was seen in the Tourist Cave, occasionally forming false floors but was also seen on the walls in various places (Fig. 7). It was also found on the floor and walls of Tham Mutalu and in the roof of Swallet Cave. It is likely that at one time passageways at the Relict Level were filled with sediment and that has now been eroded away.

The mechansism of speleogenesis in Tham Takobi is not clear. Whilst the cave resurges in a valley to the south-west, and so could have been formed by successive downcutting, it has been pointed out to us that the cobble fill could be evidence of a paragenetic origin (Smart, 2001). In

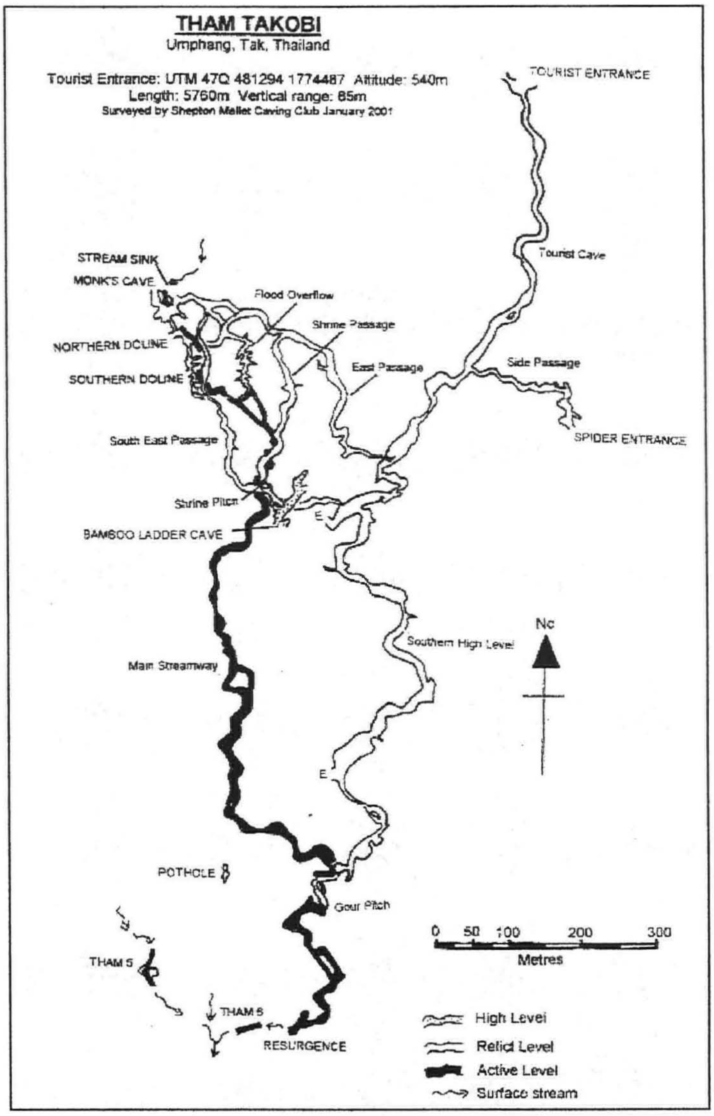

Figure 3. Survey of Tham Takobi. BCRA Grade 3c.

addition, though the average declination of the Relict and Active Levels in Tham Takobi (based on the survey data) is around 1·5° to the South, we understand that most pre-Quaternary formations in the Western mountains of Thailand are steeply dipping. (We did not find any unequivocal evidence as to the dip of the limestone in Tham Takobi, nor did we see any evidence of faults or folding). It has been suggested to us that what may have appeared as vadose passage in near-horizontal beds is in fact passage of paragenetic origin in steeply dipping strata (Osborne, 1999). If true then the age relations of the different levels in the cave may not be that straightforward to interpret.

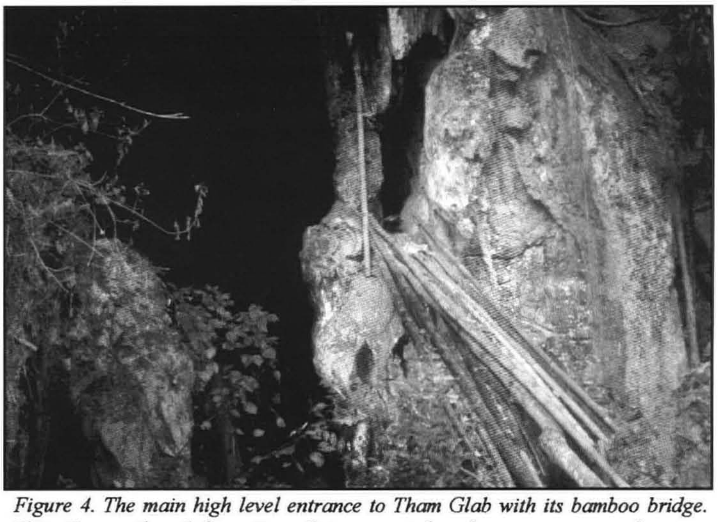

Figure 4. The main high level entrance to Tham Glab with its bamboo bridge. Note the weathered formations that suggest that there was once a far more extensive system than that present today.

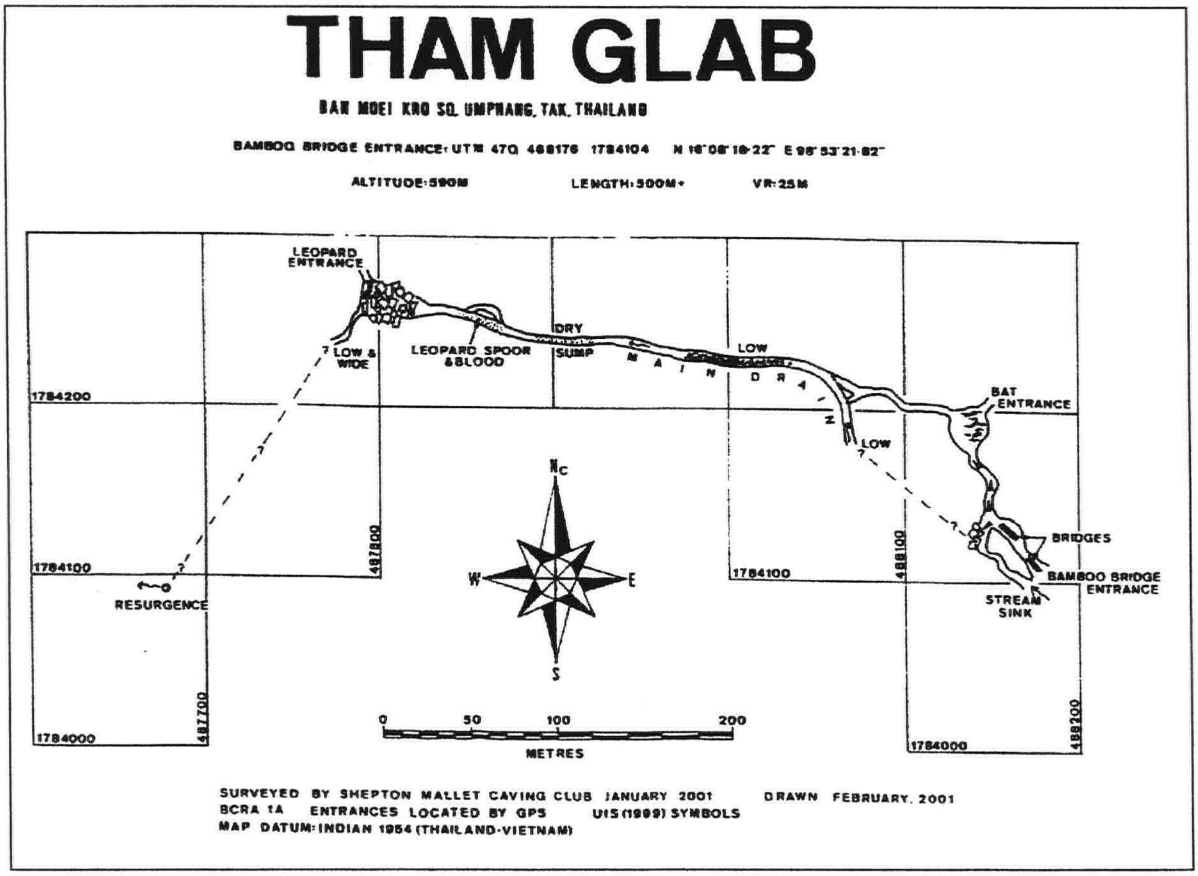

Figure 5. Survey of Tham Glab.

SCIENTIFIC OBSERVATIONS

Three of the expedition team members had scientific training to varying standards that they used in their normal occupations. Usefully their expertise covered physical and analytical chemistry, and geology. One of these was also an amateur lepidopterist. Not wishing to get tied up in the bureaucratic problems surrounding specimen collection, it was decided that the focus of the expeditions scientific endeavours would be the cave atmospheres, any watercourses discovered and any fauna encountered.

BIOLOGY

As is usual in Thailand the caves were well populated with various trogloxenic and trogolophilic species (Fig. 8). No specimens were taken, but it is hoped to expand this field of study on future expeditions. The following fauna were observed:

THAM TAKOBI:

Diestrammena sp. (Orthoptera: Raphidophoridae), *Heteropoda* sp. (Aranae: Sparassidae), *Scutigera decipens* (Chilopoda), plus Diplopoda, Diptera, Chiroptera and Pisces.

THAM MUTALU:

Diestrammena sp. (Orthoptera: Raphidophoridae), *Scutigera decipens* (Chilopoda), plus Coleoptera, Dictyoptera, Squamata and Chiroptera.

THAM GLAB:

Leopard *Panthera pardus* (Carnivora: Felidae) plus Chiroptera

The team exploring Tham Glab were also warned that the area around the cave was a known habitat for the King Cobra (Reptilia: Squamata: Elapidae: *Ophiophagus hannah*).

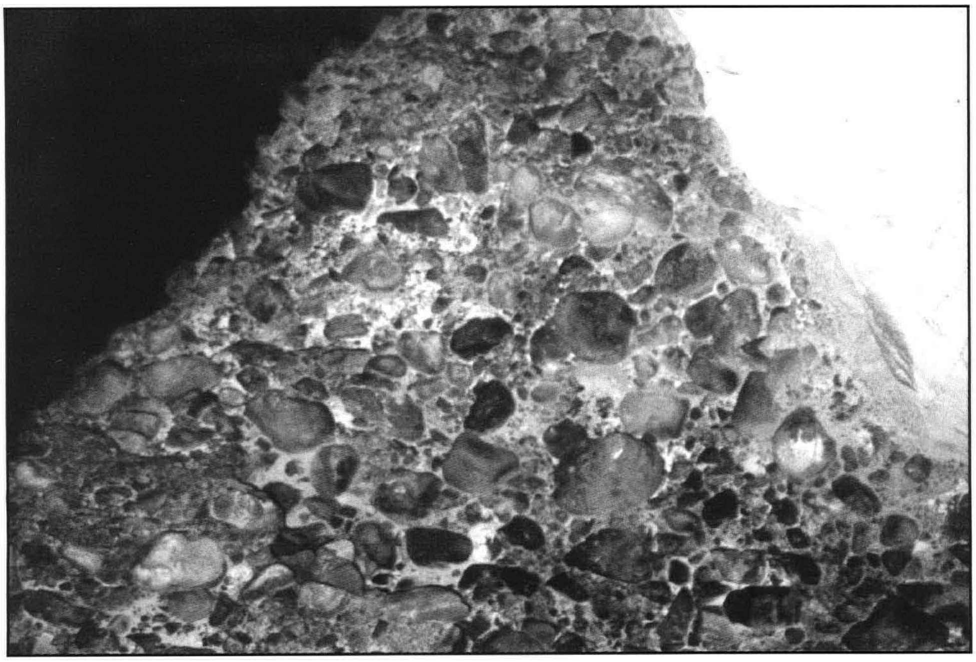

Figure 6. Example of the cobble fill seen throughout caves in the area.

Cave	Location	Temperature (°C)	Altitude (m)
Tham Takobi	Junction of the passage from Spider Entrance with Tourist Cave	20.5	533
	Junction of Tourist Cave with Southern High Level (near Backdoor Ent.)	21.2	536
	In Southern High Level, about halfway to the Side Entrance	20.4	533
	In Shrine Passage	22	529
	Northern Doline	18.2	520
	Southern Doline	19.1	515
	In the Main Streamway, upstream of the pitch in from Shrine Passage	22.6	511
Tham Mutalu	120 m along the main passage	21.8	504
	260 m along the main passage	24.3	505
	360 m along the main passage	24.4	505
	400 m along the main passage	24.5	507
	460 m along the main passage	24.6	507
	530 m along the main passage	24.6	509

Table 2. Air temperature data recorded in selected locations in Tham Takobi and Tham Mutulu. Altitudes are best estimates based on barometric and GPS measurements and the survey data.

AIR TEMPERATURE

Air temperature data were recorded in Tham Takobi on December 31 2000 and in Tham Mutalu on January 7 2001 using a handheld portable digital platinum resistance thermometer (Table 2). The outside air temperature reached 30.2 °C on both days (source: Umphang Hydro Meteorological Station). Outside surface (ground level) temperatures were measured at 20.1°C and 24.8°C respectively.

ATMOSPHERIC OXYGEN CONCENTRATIONS

The rationale for these measurements came from recent reports in the caving press, and from the experiences of the earlier SMCC expedition (Ellis & Barrett, 2001), of bad air problems in Thai caves. Indeed, not long before the expeditions departure there was a report that six Thais had suffocated in Tham Lijia near the town of Sankhlaburi, only 100 km south of Umphang (Smart, 2000).

Oxygen concentrations measured in Tham Takobi on December 31 2000 are presented in Table 3. The instrument used was factory-calibrated to give a normal atmospheric reading of 20.9%.

The lowest concentration recorded in Tham Takobi was 20.1 % in the narrow, lower-level, connection between East Passage and the Tourist Cave on January 1 2001. This passage would appear to sump in wet weather and was damp and muddy at the time of the measurement. Otherwise the levels monitored in Tham Takobi are much as might be expected for a multi-entrance system with large passageways. Local Thai tourists were encountered in the Tourist Cave using candles as their only source of illumination! In contrast, the survey team in Tham Mutalu encountered serious oxygen depletion in two locations, the lowest concentration being just 13%. It is notable that this cave does not have multiple entrances and that both danger areas led into minor (possibly blind) series. The return expedition intends to take a carbon dioxide meter to supplement future oxygen readings.

WATER CHEMISTRY

Water temperature measurements were made in three locations along the streamway in Tham Takobi, and water samples were collected from two locations using plastic bottles that had previously contained locally sourced drinking water. These samples were subsequently analysed for conductivity and pH using modern handheld instruments calibrated with ready-made standard solutions (see Appendix for details). The results are shown in Table 4.

RADON CONCENTRATIONS

Although several studies of cave radon concentrations have been conducted throughout the world, we were not aware of any conducted in Thailand before. We elected to use the same indirect detection method that has been successfully employed previously (Reaich & Kerr, 1991). This utilises a plastic marketed under the name TASTRAK to record the tracks of α-particles emitted by the radioactive decay of radon nuclei. For comparison we also exposed a Radosure™ detector normally used for domestic/industrial radon monitoring (also supplied by Track Analysis Systems Ltd, Bristol, UK). This works on the same basis but was processed independently by TASL. Measurements were only made in Tham Takobi due to the logistical problems associated with the need to expose the detectors for several days and then collect them. The results are shown in Table 5.

The apparently higher reading recorded by the Radosure™ detector is probably an indication of the overall precision of these measurements and as such is not statistically significant given the different types of container and undoubted variations in the processing and counting methods employed by ourselves and TASL.

Compared to previously published data (which indicate kBq/m^3 levels) the radon levels measured in Tham Takobi are very low. To put the readings in perspective, the UK Government "action level" for commercial premises is 400 Bq/m^3.

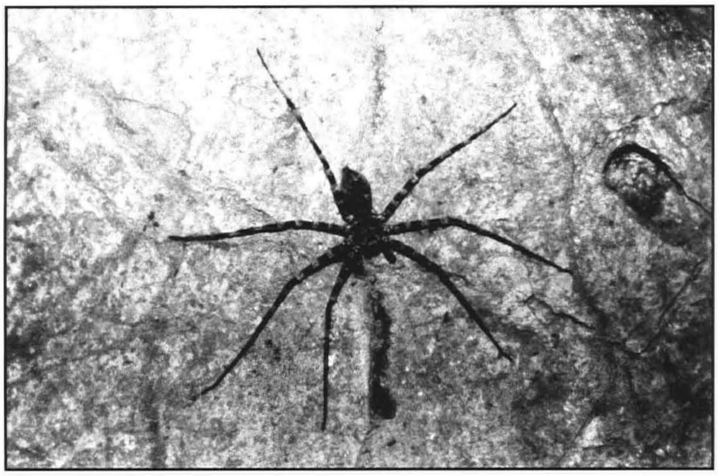

Figure 7(a). Spider. Sparassidae: Heteropoda sp. found near entrances.

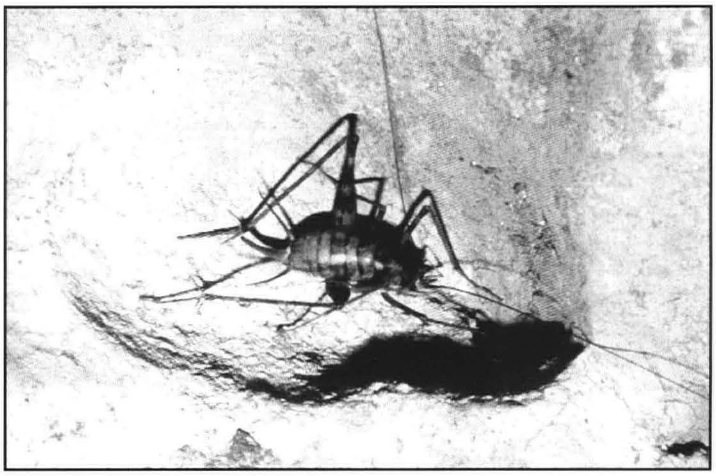

Figure 7(b). Cave cricket. Possibly Raphidophoridae: Diestrammena sp.

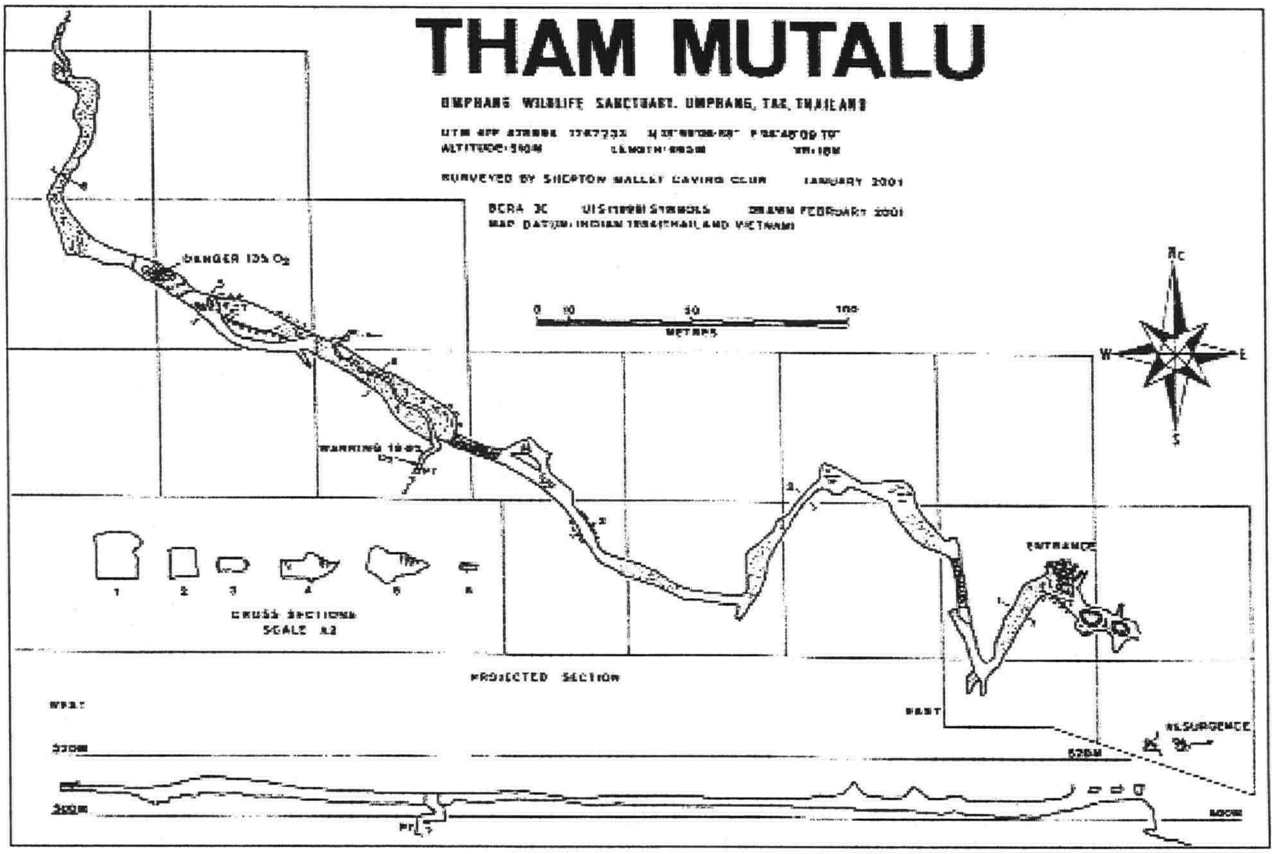

Figure 8. Survey of Tham Mutalu. BCRA Grade 3c.

DISCUSSION

Some published data for cave air and water temperature, water chemistry, carbon dioxide and oxygen concentrations from these and other Thai caves is summarised in Table 6.

In terms of the local environment, Tham Takobi is a multi-entrance system with a good draft and an active streamway situated in a partly deforested region. Conversely, Tham Mutalu is a single entrance cave in a heavily wooded valley.

Cave Air Temperature

The measurement of 18.3°C in the Tham Takobi Northern Doline (altitude 520 m) on the January 1 2001 is among the lowest recorded air temperatures in a Thai cave. The lowest reported reading is from a shaft, designated P1, on Doi (Mount) Chaing Dao at much higher altitude. Temperatures down to 16°C have also been recorded from caves in the Thung Yai Naresuan Sanctuary 50 km to the south of Umphang but at altitudes of around 1100 m (Smart, 2001). However published air temperatures from other Thai caves at higher altitudes are not as low as our measurement. This suggests a broader climatic effect, or possibly an effect related to the degree of insulation provided by overlying vegetation. Certainly the Expedition took place during the coolest season of the year. It also seems reasonable to assume that a multi-entrance system, such as Tham Takobi, would be more likely to respond to seasonal climatic variations.

The air temperature of Tham Mutalu is also at the low end of the range of Thai cave air temperatures, but on average a couple of degrees warmer than Tham Takobi even though the external air temperature at both locations was quite similar when the measurements were made. Whilst this may be attributable to a relative lack of ventilation, in this instance the air temperature noticeably increased as the oxygen concentration decreased (Tables 2 & 3). Deharveng has also noted this relationship between higher air temperature and high carbon dioxide or low oxygen concentrations. It appears to be a general phenomenon independent of altitude (Fig. 9).

Cave Water Chemistry and Temperature

Tham Takobi also has one of the lowest recorded water temperatures in a Thai cave. However few temperature measurements appear to have been made in other major Thai stream caves, though we understand that water temperatures down to 16.5°C have been measured in caves in the Thung Yai Naresuan Sanctuary (Smart, 2001). As in the case of Tham Takobi, these readings are close to the recorded cave air temperature.

External air and water temperatures are of course subject to diurnal variations. Cave air and water temperatures will be affected by these external variations but in an unpredictable and site-specific manner (depending on direction and volume of airflow, stream flow, etc). Thus whilst we observed a small (order 2°C) rise in cave air and water temperatures over the period of a week which mirrors a comparable trend in the mean external air temperature it does not follow that this trend would necessarily apply elsewhere. This has implications for future measuring strategies: 1) water temperature readings should always be accompanied by simultaneous air temperature readings, 2) the time of the measurements should always be recorded and, 3) external air temperature readings should be recorded at the same time (this being particularly important if comparisons are to be drawn between different caves).

Comparing the cave water chemistry data from this expedition with that of Deharveng, *et. al.* the pH and conductivity readings fall within the ranges recorded from elsewhere in Thailand. The data imply that the surface waters are not aggressive (borne out by the pH readings) and suggest that the local karst is not particularly mineralised.

In Tham Takobi the conductivity measurement in the main streamway near Shrine Pitch is double that taken in the Northern Doline sump. The volumetric flow of the stream was measured at 0.1 cumecs at both locations so a tributary passage is ruled out. It is also unlikely that this increase is caused by stagnation of the water as open streamway was followed for nearly the entire 350 m between the two sampling points and there are no sumps or lakes between the two sites. More sampling is required of both surface and cave waters before we can explain this phenomena.

Cave Carbon Dioxide and Oxygen Concentrations

'Normal' air contains 20.90% oxygen, 0.03% carbon dioxide and the remaining 79.07% is mainly nitrogen plus water vapour and the rare inert gases.

Cave and location within cave	O_2 (%)	Cave and location within cave	O_2 (%)
Tham Takobi		**Tham Takobi**	
Junction of the passage from Spider Entrance with Tourist Cave	20.9	In the Southern High Level, about halfway to the Side Entrance	20.9
Junction of East Passage with Tourist Cave	20.9	In Shrine Passage	20.8
Tham Mutalu		**Tham Mutalu**	
Outside of the only known Entrance	21	400 m along the main passage	20.5
120 m along the main passage	20.9	Hole in floor 440 m along the main passage	13
260 m along the main passage	20.6	460 m along the main passage	20.2
In side passage to P7, 330 m along the main passage	18.6	530 m along the main passage	20.5
360 m along the main passage	20.6		

Table 3. Atmospheric oxygen levels recorded in selected locations in Tham Takobi and Tham Mutulu.

High concentrations of carbon dioxide have been extensively reported from caves in northern and western Thailand. In addition to anecdotal reports of foul air in caving reports quantitative results have been published by Deharveng, et. al. from the four French scientific expeditions. It is known that other expeditions, such as the Combined Services Caving Association expedition to Kanchanaburi (Smith, 1995), took readings with Dräger tubes, but the results have not been published.

The highest carbon dioxide concentration measured in Thailand by Deharveng, *et. al.* (1988) was 8.5% from Tham Kubio in Khon Kaen province and concentrations of 3.5% to 5.0% are not unusual in Thai caves. High carbon dioxide concentrations have been recorded from caves in the provinces of Kanchanaburi, Tak, Mae Hong Son, Chiang Mai, Khon Kaen, Chaiyaphum, Lampang and Phetchabun which are all in western, north-western and north-central Thailand. In Mae Hong Son and Chiang Mai provinces high carbon dioxide concentrations were also encountered outside of the caves in the dolines. Apart from a blind side passage in Tham Nam Lot in Chumphon (Deharveng *et. al.*, 1988) and anecdotal evidence regarding two caves in Tai Romyen National Park in Surat Thani (Harper, 1998) high carbon dioxide concentrations have not been recorded from peninsular or southern Thailand

James (1977) gives four generalisations on the occurrence of carbon dioxide in caves:

1. In a given caving area there will be only one or two isolated foul air caves.
2. Foul air is most likely to be found in caves in the tropics.
3. Foul air may be encountered in caves in any rock: lava, sandstone, limestone, etc.
4. Caves that are subject to periodic flooding followed by long periods of low rainfall or drought are more likely to contain foul air.

Generalisations 1, 2 and 4 apply to the occurrence of carbon dioxide in caves of Umphang.

James lists six sources of carbon dioxide in caves:

1. Diffusion of gaseous carbon dioxide through the soil and rock into the cave.
2. Evolution of carbon dioxide from cave waters.
3. Production of carbon dioxide by micro-organisms.
4. Respiration of plants and animals.
5. Burning of hydrocarbons.
6. Volcanic gases.

James also notes that floods and steady rain help disperse carbon dioxide accumulations (by allowing more carbon dioxide to dissolve, bringing air into the cave and creating turbulence in the cave atmosphere). Indeed the air is often fresher in many Thai caves at the end of the wet season (Smart, 2001). However, most exploration is done during the dry season because many of the caves are inaccessible during the wet season.

Deharveng, *et al.* (1987) notes that those regions where high carbon dioxide concentrations are found have a long and distinct dry season, thicker soils and forest cover on the surface compared to the tropical rain forest environment of southern Thailand. The exact mechanism by which the carbon dioxide enters and concentrates in the caves is unknown for certain. It is possible that wet season floods bring a large quantity of organic material into the caves which is then broken down by micro-organisms raising the carbon dioxide concentration, depleting the oxygen concentration and creating heat.

In some cases it is possible that the carbon dioxide is transported into the cave in streams as high concentrations have been noted in active river systems (e.g. Tham Susa, Mae Hong Song) and some cave waters (e.g. Tham Sai Yok Noi and Tham Nam, Kanchanaburi).

Of the possible sources the production of carbon dioxide by micro-organisms appears to be the most likely in the case of Tham Mutalu as there is not a perennial stream in the cave and the cave is not a major bat roost. Further evidence for the micro-organism source is the reduced oxygen concentration due to the aerobic respiration of the organisms. There did not appear to be an excessive amount of organic detritus in the cave (leaves, tree trunks, etc.), but parts of the main passage are floored with a black mud which possibly has a high organic content. Our experience of high concentrations of carbon dioxide in other regions of Thailand (Tham Sing Toh and Tham Kum, Chaiyaphum) was also in caves that had seasonal streams and large deposits of dark mud, though the high concentrations of carbon dioxide in Tham Kum may also have been partly due to the large number of bats roosting in the cave.

The oxygen meter used on our expedition has provided the first direct oxygen concentration readings from Thai caves. This data would have been more valuable in conjunction with carbon dioxide concentration

Location within cave	Estimated flow [1] (cumecs)	Temperature (°C) Water	Air	Water hardness [2] (mS/cm)	(ppm) [3]	pH [2]
January 1 2001 Stream from the sump pool in the Northern Doline	0.1	18.3	18.2	231	115	7.5 -7.7
January 5 2001 Stream in the Southern Doline		18.5	19.1			
January 5 2001 In the Main Streamway, upstream of the pitch from Shrine Passage 4	0.1	19.7	22.6	453	226	7.3 -7.5

Table 4. Water chemistry for selected locations in Tham Takobi. Notes: (1) These two determinations were made by different personnel. (2) Measured on the surface on January 6 2001. Sample temperatures ranged from 26.5 - 24.0°C due to changes in air temperature during the measurements. (3) Approximate calculated TDS as $CaCO_3$. (4) These temperature measurements were made on December 31 2000.

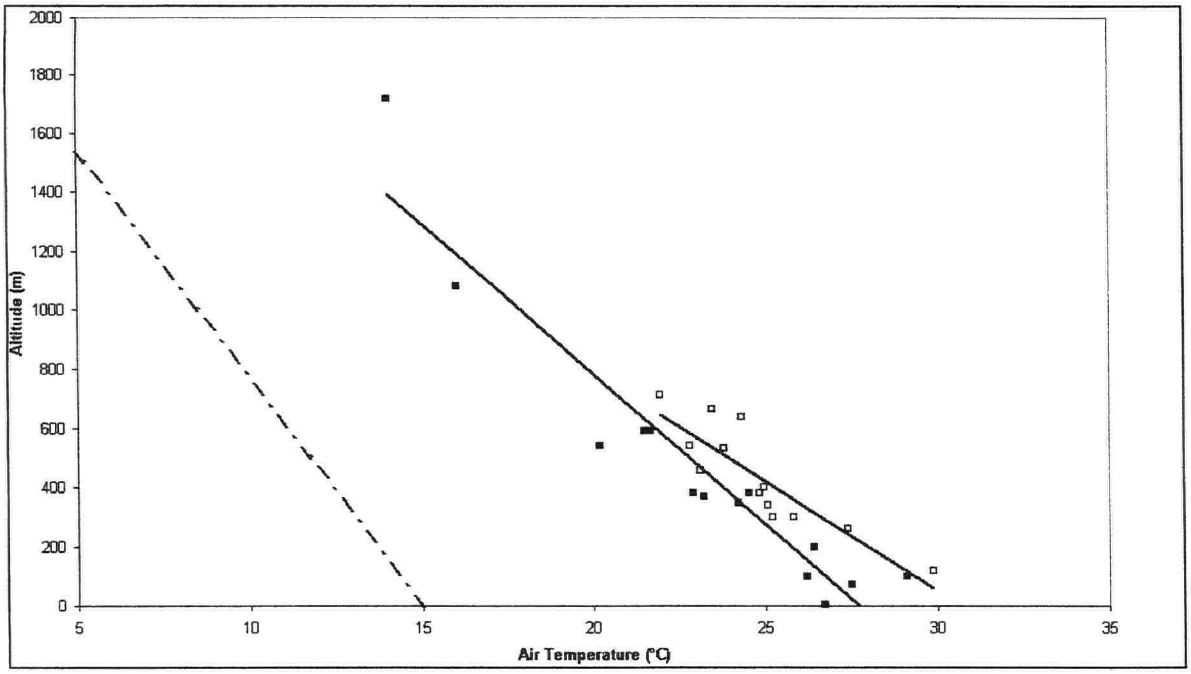

Figure 9. The variation of Thai cave air temperatures with altitude. The data have been separated into those caves with low (filled squares) or high (open squares) CO_2 levels (see Table 6). Trend lines have also been added for each case. For comparison, the chain dashed line represents the normal atmospheric variation based on the 1976 US standard Atmosphere model (Lide, 1996) at latitude 45°N.

data and it is hoped to have a carbon dioxide meter on the return expedition. On this expedition low oxygen concentrations were measured in Tham Mutalu. An oxygen concentration of 18.6% was recorded at the top of an undescended pitch whilst 13.0% was recorded in a hole amongst boulders in the floor of the main passage.

The concentration of carbon dioxide at the end of blind side series, in narrow rifts or at the bottom of pitches is a widely reported phenomenon, not just in Thailand although anecdotal information seems to suggest that the problem is relatively common there. It arises because carbon dioxide is 1.5 times denser than air (and the molecules are 3 times heavier) and because the rate of diffusion of carbon dioxide molecules is just 80% of that for air molecules (Graham's Law). These factors offset the normal osmotic driving force for mixing and so, in the absence of any other external factors (such as a draught, or the passage of animals or humans), lead to the establishment of a concentration gradient from the floor up. Of course, the floor may also be the site of foul air production in the first place and this may result in carbon dioxide being produced at a faster rate than it is lost by diffusion.

As noted earlier the air temperature also increased as the oxygen concentration decreased. This is to be expected. At one atmosphere pressure and 27°C the specific heat capacity, C, of air is 1 $JK^{-1}g^{-1}$ and its thermal conductivity, k, is 0.026 $WK^{-1}m^{-1}$. The equivalent figures for carbon dioxide are $C = 0.8$ $JK^{-1}g^{-1}$ and $k = 0.017$ $WK^{-1}m^{-1}$ (Lide, 1996). Recalling from standard thermodynamical theory that C is just the rate of change of heat energy with temperature, it follows that less heat energy is necessary to bring about a given temperature increment in carbon dioxide than is needed to bring about the same temperature change in air. But, at the same time, carbon dioxide is a poorer thermal conductor than air; i.e it is a better thermal insulator. Hence a carbon dioxide atmosphere will warm quicker and retain that warmth longer. This is of course one of the foundations of the global warming argument.

A similar argument can be extended to the rock in which the cave is formed (for calcium carbonate $C = 0.8$ $JK^{-1}g^{-1}$, and $k = 4$ to 25 $WK^{-1}m^{1}$ depending on crystallographic orientation), and a stream (for water $C = 4$ $JK^{-1}g^{-1}$, $k = 0.61$ $WK^{-1}m^{-1}$). The rock will respond faster to changes in temperature than the stream, but the latter will retain a temperature change longer.

Cave Radon Concentrations

To the best of our knowledge these were the first radon measurements made in a cave in Thailand and possibly from any cave in South East Asia. The concentrations recorded are low compared to data from cave systems in other countries [see Table 7]. Radon concentrations have been shown to vary on a diurnal and annual basis in other regions so we are unable to draw any conclusions from just one set of data. The low radon concentration is probably due to the well-ventilated nature of Tham Takobi but also suggests that there is not a source of radon is this limestone. We intend to conduct further radon studies in the region on future expeditions.

CONCLUSIONS

With the increasing portability (and reduced costs) of modern scientific equipment it is now feasible for even quite limited caving expeditions to undertake a very useful range of measurements for a relatively small financial outlay. Such data not only contributes to the sum of geographical and speleological knowledge but also can provide important clues to help direct cave exploration.

Location within cave	Date first exposed	Exposure (hours)	Radon concentration (Bq/m^3)
Control	Not exposed in cave		10
Outside of the cave near the Backdoor Entrance	December 31 2000	168	100
In Shrine Passage just past the pitch into the Main Streamway	December 31 2000	165	220
Near the junction of East Passage with Tourist Cave	December 31 2000	167	210
		167	558 [1]
In Southern High Level, about halfway to the Side Entrance	December 31 2000	166	160

Table 5. Atmospheric radon levels recorded in selected locations in Tham Takobi. Notes: (1) Reading from Radosure detector.

Cave	Province	Location Water	Altitude a.m.s.l. (m)	Air Temperature (°C)	Water Temperature (°C)	Water pH	Water Conductivity (mS/cm)	Water $[CO_3]$ (mg/l)	Cave Air pCO_2 (%)	Cave Air pO_2 (%)	Reference
Tham Keaw	Chaiyaphum	16°00'N 101°26'E	350	24.3-24.1					Normal		Deharveng, et al. (1988)
Tham Kum	Chaiyaphum	16°35'N 101°50'E	420						High		Ellis & Barrett (2001)
Tham Lam Chi	Chaiyaphum	16°22'N 101°30'E	590	21.6-21.7					Normal		Deharveng, et al. (1988)
Tham Ngoem 1	Chaiyaphum	16°36'N 101°49'E	380	24.3-24.6					Normal		Deharveng, et al. (1988)
Tham Ngoem 2	Chaiyaphum	16°36'N 101°49'E	370	23.2					Normal		Deharveng, et al. (1988)
Tham Sing Toh	Chaiyaphum	16°34'N 101°49'E	380	22.9					0.58	20.6	SMCC (2002)
				24.8					>5.00	15.8	SMCC (2002)
Tham Narm Lei	Chaiyaphum		300		23.5	7.8	546	400			SMCC (2002)
Tham Ban Ngoem	Chaiyaphum		300		24	7.7	616	420			SMCC (2002)
Tham Chiang Dao	Chiang Mai	19°23'N 98°56'E	455	21.8-24.4	20.8-23.4	6.65-7.47			0.1-2.9		Deharveng, et al. (1986)
P1, Doi Chiang Dao	Chiang Mai		1720	14							Deharveng, et al. (1986)
Tham Tab Tao	Chiang Mai	19°42'N 99°06'E	620						High		White (1988)
Tham Nam Lot	Chumphon	10°13'N 98°56'E	100						High		Deharveng, et al. (1988)
Tham Lawa	Kanchanaburi	14°17'N 99°00'E	120	29.5-30.2					0.5-0.8		Deharveng, et al. (1987)
Tham Sai Yok Noi	Kanchanaburi	14°15'N 99°04'E	300	25.0-25.4	24.5	6.25-6.35	472-481	448-462	0.7-5.0		Deharveng, et al. (1987)
Tham Nam	Kanchanaburi	15°75'N 99°08'E	350		21.3	6.53	492	414	1.9-4.8		Deharveng, et al. (1987)
									7.5		Deharveng, et al.(1988)
Tham Phra That	Kanchanaburi	14°25'N 99°05'E	500						High		Deharveng, et al. (1988)
Tham Kubio	Khon Kaen	16°49'N 101°58'E	340	24.4-25.7	24.6				<8.5		Deharveng, et al. (1988)
Tham Pha Thai	Lampang	18°36'N 99°54'E	400	24.0-25.9					0.09-6.5+		Deharveng, et al. (1986)
Tham Hud	Mae Hong Son	19°32'N 98°16'E	715	20.9-23.0					4.3-5.0		Deharveng, et al. (1987)
Tham Kaeng Khao	Mae Hong Son	19°25'N 97°59'E	300	25.8					2.2-2.3		Deharveng, et al. (1987)
(Tham Ru Hoa Koa)				25.9-26.2	26.3				1.0-1.6		Deharveng, et al. (1988)
Tham Lot	Mae Hong Son	19°34'N 98°17'E	650		23.9-25.1	7.82-8.04	155-245	113-183	Normal		Deharveng, et al. (1987)
									High		Wilton-Jones (1988)
Tham Nam Hu	Mae Hong Son	19°32'N 98°16'E	640	24.3					1.8-3.0		Deharveng, et al. (1987)
Tham Nam Mae Lana	Mae Hong Son	19°34'N 98°13'E							High		Dunkley & Brush
Tham Pha Mon	Mae Hong Son	19°30'N 98°17'E	620-710		21.1-22.3	7.00-8.03			0.14-3.52		Deharveng, et al. (1986)
			620-710	23.4-23.5		7.8	252	167	1.5-3.0		Deharveng, et al. (1987)
Tham Plaa	Mae Hong Son	19°25'N 97°59'E	300		23.2	6.6	214	223	Normal		Deharveng, et al. (1987)
Tham Susa	Mae Hong Son	19°28'N 98°08'E							High		Boland (1992)
Tham Phet	Phangnga	8°32'N 98°35'E	60		24.9-26.0	7.75-8.13	101-295	78-287	Normal		Deharveng, et al. (1987)
Tham Poung Chang	Phangnga	8°26'N 98°31'E	20		25.7-26.6	7.75-7.87	100-288	92-191			Deharveng, et al. (1987)
					25.4-26.0				0.05-0.15		Deharveng, et al. (1988)
Tham Sombat	Phetchabun	16°36'N 101°08'E	260	27.4					High		Deharveng, et al. (1988)
Tham Mai Lap Lae	Phetchaburi	12°37'N 99°39'E	200	26.4					Normal		Deharveng, et al. (1988)
Tham Kaeo	Prachup Khiri Khan	12°11'N 100°00'E	70	27.5					Normal		Deharveng, et al. (1988)
Tham Sai	Prachup Khiri Khan	12°11'N 100°01'E	100	29.1					Normal		Deharveng, et al. (1988)
Tham Phrakayang	Ranong	10°19'N 98°46'E	5	26.7					Normal		Deharveng, et al. (1988)
Tham Huai Sit 2	Surat Thani	8°50'N 99°30'E							High		Harper (1998)
Tham Men	Surat Thani	8°50'N 99°30'E							High		Harper (1998)
Tham Mae Usu	Tak	17°17'N 98°10'E	150		24.7				Normal		Deharveng, et al. (1988)
Tham Loe Pu	Tak		590	20.8-21.6	20.3-21.9	7.6-8.2	332-354	220-240	0.06-0.1		SMCC (2002)
Tham Mutalu	Tak	15°59'N 98°48'E	510	21.8-24.6					High	13.0-20.9	Ellis, Barrett & King (2001)
				23.3-23.8					1.06->5.00		SMCC (2002)
				21.9					0.08		SMCC (2002)
Tham Takobi	Tak	16°03'N 98°49'E	540	18.2-22.6	18.3-19.7	7.3-7.7	231-453	115-226	Normal	20.6-20.9	Ellis, Barrett & King (2001)
				19.5-22.1		7.5-7.6	169-248	120-140	0.08-0.18		SMCC (2002)
				22.8					>5.00		SMCC (2002)
Tham Sua	Yala	6°31'N 101°14'E	100	26.2					Normal		Deharveng, et al. (1988)

Table 6. Summary of published cave temperature, water chemistry and atmospheric data from Thai caves. The table is ranked alphabetically by the province. Adjectival assessments of carbon dioxide levels are given where the authors comment on them.

The caves explored were warm and mostly dry, although those with watercourses were clearly subject to seasonal flooding. Multi-entrance systems presented few environmental problems, but cave explorers in Thailand should exercise great care in possibly blind or confined passages or shafts due to the very real possibility of severe oxygen depletion. In the absence of specific monitoring equipment a noticeable rise in the cave air temperature, perhaps coupled with an increase in respiration rate, should be viewed with caution. Radon levels were found to be at least an order of magnitude lower than those reported from some caves in the UK.

The expedition also found that, despite the lack of an identifiable indigenous caving culture, caves in rural Thailand have an important part to play in the lives of both the local human and animal populations. The humans use them for shelter, for worship, and for storage. Resurgent watercourses often form drinking water supplies for isolated

Cave(s)	Region and Country	Radon concentration (Bq/m³)	Reference
Various mines	Forest of Dean, UK	12 - 385	Febry (2000)
Tham Takobi	Tak, Thailand	160 - 558	Ellis, King & Barrett (2001)
Various caves	Portland, UK	10 - 974	Hyland (1995)
Various caves	Mendip, UK	99 - 3621	Hyland (1995)
Big Sink	Forest of Dean, UK	3400 - 6500	Febry (2000)
Gyokusen Cave	Okinawa, Japan	100 - 8000	Tanahawa, et. al. (1997)
Box Mines	Wiltshire, UK	8500	Reaich & Kerr (1991)
Eastwater Cavern	Mendip, UK	9250	Reaich & Kerr (1991)
Tourist Caves	Australia	10000	Lyons, et. al. (1998)
Grotte de Motiers	Jura, Switzerland	60 - 14000	Farine (1997)
Cuckoo Cleeves	Mendip, UK	12000 - 19000	Reaich & Kerr (1991)
Various caves	South Wales, UK	127 - 19968	Hyland (1995)
Tourist Caves	New Zealand	21000	Lyons, et. al. (1998)
Various caves	Clare, Ireland	165 - 21062	Ellis, et. al. (1995)
Various caves	North Pennines, UK	14 - 27136	Hyland (1995)
Various caves	Peak District, UK	9 - 46080	Hyland (1995)
Various caves	Kirktov Massif, Russia	48000 - 77000	Gunn (1991)
Various caves	Venezuela	820 - 80100	Sajo-Bohus, et. al. (1995)
Giants Hole	Derbyshire, UK	155400	Middleton, et.al. (1991)
Various caves	Arabika Massif, Russia	33000 - 203000	Gunn (1991)
Various gypsum caves	Podolia Massif, Russia	164000 - 443000	Gunn (1991)

Table 7. Compendium of cave radon concentration data from around the world.

communities. For many of the same reasons we found an abundance of wildlife; insects, reptiles, small mammals and, indirectly, evidence of large mammals too.

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APPENDIX

Details of the scientific equipment used. Items identified by an asterisk were purchased with BCRA grant aid.

Digital platinum resistance thermometer (accurate to ±1° over the range −20 to +150°C) (Camlab)

Hanna Instruments Primo-5 conductivity meter with automatic temperature compensation (accurate to ±2% over the range 1 to 1999 µS/cm) (Camlab)

pHBoy KS501 digital ISFET/KCl sensor pH meter with automatic temperature compensation (accurate to ±0.1 units over the range pH 2 to 12) (Camlab)

* Conductivity and pH calibration solutions (Camlab)
* Neotox Mk5 O_2 portable gas monitor (Zellweger Analytics)
* Radosure calibrated radon detectors and TASTRAK slides (Track Analysis Systems)

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An analysis of cave rescue statistics, Dales area, UK, 1935 to 2000.

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INTRODUCTION

Data from incidents attended by the Settle–Ingleton Cave Rescue Organisation between 1935 (when it was founded) and 2000 have been analysed according to type and frequency, and the results tabulated below. The word 'incident' – as opposed to 'accident' – is used intentionally. This is because, on several occasions, the CRO was alerted to make a preliminary investigation when cavers were reported overdue, but were met with close to the cave entrance, late but not in any trouble. It should be borne in mind that the incident categories, although appearing well defined, are actually far from being clear-cut. One obvious example is that the difficulty of recognising a boundary between descriptions of exhaustion and exposure necessitates such incidents being considered together. Rather less obviously, questions might arise such as: *"Did the victim succumb to the cold as a result of lying shocked, hurt, and immobile after a fall – or did he/she fall as a result of incipient exposure?"*. If the cave happened to be in flood at the time of the incident, this tricky question becomes still trickier!

Except in the case of fatal accidents, which are categorized separately, no attempt has been made to distinguish between incidents or accidents on the grounds of their severity. Thus, category three consists entirely of relatively trivial incidents. Bearing in mind the above qualifications gives some idea of the sort of problems that are likely to be encountered underground.

DISCUSSION

Table 1 lists the incidents attended by the CRO in order of frequency (except for the final two categories) The fourth column shows the percentage of the total number; and the final column shows the percentages that would result, if the (trivial) incidents in Category 3 were disregarded.

Perhaps the most surprising aspect of the data in Table 1 is the high number of flooding incidents (Category 1) comprising nearly a quarter of the total (or just over 25% of those where assistance was required). The Yorkshire Dales is an upland area of high rainfall, where the run-off after rain can be very rapid. As a result, many of the caves are prone to flooding. Nevertheless, it appears that the speed and severity of flooding following rain are commonly grossly under-estimated by cavers. Fortunately, the most likely consequence of being caught out by rising water levels (depending, of course upon the exact location), is a prolonged and cold stay underground. Unfortunately, certain caves – and sections of other caves – can be transformed into veritable death traps by heavy rain and rapid run-off, and there have been six fatal accidents in the Dales from this cause (see below).

Less surprising, perhaps, is the high number of falls, which comprise Category 2. Many Dales caves contain lengthy, sub-horizontal passages, inter-connected by vertical shafts ("pitches") up to 100m deep, which provide considerable scope for falling down them for various reasons. Once, the most common type of incident involved cavers falling from ladders while not lifelined (or not lined properly). This is now becoming very uncommon, with most cavers using single rope techniques (SRT) on all but the shortest pitches. Most such accidents seem to have happened on short, easy pitches – i.e. the sorts of places that engender a sense of false security. Tiredness, lack of concentration, carelessness or pure bad luck can also play their part in such incidents. For example, one unfortunate caver fell to his death down a hole in the floor of South East Passage, near the foot of the 30m (100') pitch in Bar Pot. This hole lies on the main 'tourist' route to Gaping Gill Main Chamber, but has, over the years, grown from an innocuous-looking hole to one that occupies more than half the width of the floor of the passage – with no obvious indication of its ~40m (130') depth.

Category 3 includes minor incidents of parties being reported overdue by worried friends or relatives, but not, in fact, in need of help from the CRO.

Category	Nature of incident	Number	Percent	Number excluding category 3	Percent excluding category 3
1	Floods	127	22.48	127	25.55
2	Falls	120	21.24	120	24.14
3	Overdue/thought missing	68	12.04	N/A	N/A
4	Exposure/exhaustion	58	10.27	58	11.67
5	Lost/light failure	44	7.79	44	8.85
6	Falls while abseiling	31	5.49	31	6.24
7	Rock falls	23	4.07	23	4.63
8	Got stuck	15	2.65	15	3.02
9	Sump diving	9	1.59	9	1.81
10	Unable to climb out	6	1.06	6	1.21
11	Unable to prusik out	5	0.88	5	1.01
12	Left underground (!)	3	0.53	3	0.6
13	Trapped beyond rock fall	2	0.35	2	0.4
14	Miscellaneous	53	9.38	53	10.66
15	Died while on rescue	1	0.18	1	0.2
	Total	565	100	497	100

Table 1: Incidents attended by the CRO, 1935 - 2000.

Nature of incident	Number	Percent	Number of deaths
Falls	14	26.92	14
Diving	9	17.31	11
Floods	7	13.46	12
Rock-falls	6	11.54	8
Falls / abseiling	4	7.69	4
Exposure / exhaustion	3	5.77	3
Died on rescue	1	1.92	1
Unable to prusik out	1	1.92	1
Miscellaneous	7	13.46	8
Total	52	100	62

Table 2: *accidents in which cavers died.*

Category 4 incidents involved people getting into trouble through tiredness and cold, leading to exhaustion and exposure. It would appear that in most such cases better preparation, equipment, or knowledge could have prevented the trouble. However, this is not the whole story, as in several cases the problem was exacerbated – or, indeed, caused – by flood water.

Many non-cavers believe that caves are labyrinthine complexes, where venturing without paying out a ball of string will lead to disaster. This, of course, is nonsense, but there are a few Dales caves – most notably the Easegill System with its forty-plus miles of passages – where it would be easy to get lost without a sound knowledge of the system, careful observation, or a guide. In Category 5, getting lost and light failure have been put together, as it is not always easy to decide whether a party became lost because their lights petered out, or whether the lights failed as a result of wandering around aimlessly while lost! Fortunately, none of the people involved came to serious harm, though in 1979 a caver was missing for 55 hours in the Gaping Gill System.

The accidents in Category 6 – falls while abseiling – have been differentiated from those in Category 2 to see whether the advent of SRT on the British caving scene had any effect on the type and number of accidents. In fact, until 1992 there seemed to be no obvious increase in the total number of incidents that could not be ascribed to a general increase in people going underground. However, in that year there was a spate of incidents of this type, four occurring in the space of a few weeks. Two similar accidents occurred in both 1993 and 1996. Sadly, another, with fatal consequences, occurred in 1997 – at Lancaster Hole – when a caver evidently became detached from the rope at a re-belay and fell c.25m. There have also been unfortunate accidents, such as in 1985, when someone dropped off the end of the rope while descending the 220' pitch of Rowten Pot. He survived, albeit badly hurt.

Another widespread misconception is that caves are unstable places, liable to collapse without notice. Generally speaking, the caves of the Dales are fairly stable places, where rock-falls are relatively rare. Further, areas of instability are commonly quite obvious, so that, for example, people take extra care when negotiating boulder-chokes. Nevertheless there are areas of instability in several of the caves, and there have been a number of accidents as a result of rock-fall. Some evidence suggests that, on occasion, accidents have been at least partly caused by the people involved. For example, one individual became entombed when the boulder-choke he was digging at the end of Crackpot Cave collapsed. He was extricated at some considerable risk to the rescue team, with injuries that were, in the circumstances, relatively minor.

Location	Number	Percent of total	Number excluding Category 3	Percent excluding Category 3
Easegill System	85	15.04	72	14.49
Gaping Gill	82	14.51	61	12.27
West Kingsdale System	73	12.92	70	14.08
Alum Pot	63	11.15	60	12.07
Ireby Fell Cavern	31	5.49	29	5.84
Others	231	40.88	205	41.25
Total	565	100	497	100

Table 3: Incident location, 1935 - 2000

A widespread fear among non-cavers appears to be the possibility of getting stuck in tight little spaces underground. By and large, however, it seems that if you can get into a hole, the chances are that you can get out again. Nevertheless, there have been 13 such incidents to make up Category 8. The most celebrated of these, perhaps, was when an individual contrived to get stuck, or rather trapped beyond a tight section of passage, on the night of the CRO's 50th anniversary celebration in 1985.

Sump diving (Category 9) is clearly a very specialized aspect of caving, with its own inherent dangers. As might be expected, all the incidents that constitute this group have resulted in fatalities.

Generally speaking, most people who descend vertical pitches have the wit and forethought to ensure they have some means of getting back up again. Even so, there have been 11 incidents in which cavers have found themselves at the bottom of a pitch, unable to climb back out (category 10) or to prusik back out (category 11). Further comment is, perhaps, unnecessary.

As for Category 12 – well, with friends who would leave you underground, who needs enemies?

Both of the incidents in Category 13 involved cavers getting trapped beyond a rock-fall, without being injured by it.

The 'miscellaneous' section, Category 14, consists of a hotchpotch of otherwise unclassified one-off incidents. Perhaps the oddest of these was the case of the youth whose helmet and lamp fell off in a very easy cave. Straightening up in surprise, the poor fellow impaled his head on a stalactite. Fortunately, it seems that he was more shocked than hurt. Another example involved cavers who could not get through the narrow 'Slit' in Simpson's Pot, but could not retreat from the cave because they had pulled their abseil rope down after them. There have also been several cases of illness underground (such as the caver who, in 1982, suffered a fatal heart-attack in Diccan Pot), and occasional examples of cavers being stranded because someone removed their tackle ... and so on.

The single incident in Category 15 is one of the saddest episodes in the history of the CRO. On the night of 22/23 March 1986, Dave Anderson died while searching in flood conditions below the big pitch in Rowten Pot, for two cavers reported overdue on a diving trip in the Kingsdale Master Cave (which connects via a sump with the bottom of the pot). Dave was posthumously awarded the Mountain Rescue Committee's Distinguished Service Certificate.

FATAL ACCIDENTS

From Table 2 it can be seen that the most common cause of death in the caves of the Yorkshire Dales has been from falls. As noted previously, it seems likely that the single most common cause, overall, is that of cavers falling from ladders while not properly lifelined (or not lifelined at all).

Sump diving, with only 9 accidents (~1.6%) of the total is, however, second in the list of fatalities. Perhaps this is an inevitable result of the nature of cave diving – non-fatal incidents or accidents are probably rarely heard about outside diving circles, such as the case of a diver being rescued presumed dead, and subsequently resuscitated. Most such accidents resulted in the death of one diver, but in one tragic accident in 1976 three divers died in the same incident. Unusually, these three were free diving without 'SCUBA' equipment.

Flooding in the caves of the Yorkshire Dales accounts for seven fatal accidents. This bare statistic obscures the unfortunate fact that in one such accident – in Mossdale Caverns in 1967 – six experienced cavers died, making it one of the worst ever caving accidents in this, or any other, country.

Location	Number of accidents	Number of deaths
Gaping Gill	8	8
Easegill System	7	9
West Kingsdale System	7	7
Alum Pot System	6	6
Rest	24	32
Total	52	62

Table 4: Location of fatal accidents, 1935 - 2000

Rock-falls account for only about 4% of the total number of incidents. Nevertheless, six fatal accidents have included eight deaths. The clear message is that, whereas incidents involving rock-fall are rare, when they do occur, the consequences are likely to be serious.

Falls while abseiling have caused the deaths of four people, and exposure/exhaustion killed three cavers in three incidents.

The death of Dave Anderson while taking part in a rescue attempt has been mentioned above.

The fatal accident in Category 11, unable to prusik back out, happened in 1989. A caver climbing out of the Jib Tunnel route in Gaping Gill Main Shaft somehow became 'hung up' on his rope. It was a winter day, and he died because he was hanging in, or very close to, the icy-cold waterfall that was pouring down the shaft.

Year/Years	Number of separate incidents per numbered Category															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
1935-1940	1	3	—	—	—	—	1	—	—	—	—	—	—	1	—	6
1941-1945	—	1	—	—	—	—	—	—	—	—	—	—	—	1	—	2
1946-1950	1	1	—	1	—	—	—	—	—	1	—	—	—	1	—	5
1951-1955	1	4	—	1	1	—	1	1	—	—	—	—	—	1	—	10
1956-1960	1	6	—	1	1	1	1	1	—	1	—	—	—	1	—	14
1961	—	2	—	1	—	—	1	1	—	—	—	—	—	—	—	5
1962	4	2	2	—	1	—	—	—	—	—	—	—	—	2	—	11
1963	5	—	2	2	1	—	—	—	—	—	—	—	—	—	—	10
1964	—	2	3	1	—	—	—	—	1	—	—	—	—	—	—	7
1965	3	—	1	1	2	—	—	—	—	—	—	1	—	—	—	8
1966	3	4	—	2	—	—	—	—	—	1	—	—	—	—	—	10
1967	3	5	—	—	2	—	—	—	—	—	—	—	—	—	—	10
1968	2	1	1	—	1	—	1	—	—	—	—	—	—	—	—	6
1969	2	1	1	2	—	—	1	—	—	—	—	—	—	—	—	7
1970	4	3	3	1	—	—	1	—	1	1	—	—	—	1	—	15
1971	1	3	2	1	—	—	3	—	—	—	—	—	—	—	—	10
1972	3	1	3	—	—	—	1	—	—	—	1	—	—	—	—	9
1973	6	1	3	2	—	—	—	1	—	—	—	—	—	1	—	14
1974	2	1	—	1	—	1	—	1	—	—	—	1	1	—	—	8
1975	9	4	2	—	1	—	2	1	—	—	—	—	—	—	—	19
1976	2	4	2	1	—	—	1	—	1	—	1	—	—	1	—	13
1977	3	4	10	4	1	—	1	—	—	1	—	—	—	2	—	26
1978	5	3	2	—	2	1	—	—	—	—	—	—	—	3	—	16
1979	4	5	2	1	2	—	—	1	—	1	—	1	—	1	—	18
1980	—	5	1	4	3	1	—	—	2	—	—	—	—	2	—	18
1981	3	6	1	1	1	—	—	—	—	—	1	—	—	1	—	14
1982	6	3	—	—	—	2	1	—	—	—	—	—	—	2	—	14
1983	4	6	—	2	—	—	1	—	—	—	—	—	1	1	—	15
1984	—	2	2	—	2	—	—	—	—	—	1	—	—	1	—	8
1985	3	5	1	1	2	3	1	2	1	—	—	—	—	2	—	21
1986	10	1	—	3	1	1	—	—	—	—	—	—	—	3	1	20
1987	3	4	2	2	2	1	—	—	—	—	—	—	—	2	—	16
1988	6	1	1	2	1	—	1	1	1	—	—	—	—	1	—	15
1989	4	5	4	1	4	3	—	—	—	—	1	—	—	3	—	25
1990	4	3	3	2	—	2	—	—	—	—	—	—	—	—	—	14
1991	2	1	—	1	3	—	1	1	—	—	—	—	—	3	—	12
1992	6	—	—	2	2	4	—	—	1	—	—	—	—	—	—	15
1993	2	3	3	1	1	2	—	1	—	—	—	—	—	4	—	17
1994	3	4	1	1	—	—	1	1	1	—	—	—	—	1	—	13
1995	—	3	2	1	1	1	—	—	—	—	—	—	—	2	—	10
1996	1	3	—	1	1	2	—	—	—	—	—	—	—	1	—	9
1997	2	1	1	1	—	1	1	—	—	—	—	—	—	4	—	11
1998	2	1	4	4	1	1	1	—	—	—	—	—	—	3	—	17
1999	—	2	1	3	3	2	—	—	—	—	—	—	—	—	—	11
2000	1	—	2	2	1	2	—	2	—	—	—	—	—	1	—	11
Totals	127	120	68	58	44	31	23	15	9	6	5	3	2	53	1	565

Table 5: Trends over time

The 'miscellaneous' incidents include:

* two cases of bodies being found underground;
* three cases of death due to heart attack;
* one case of a caver who got into trouble while wearing a fibre-pile suit and swimming in a sump pool;
* the case of two cavers who, it appears, entered an area where they had been blasting before the fumes had cleared, and were overcome by them.

INCIDENT LOCATION

Table 3 indicates the most common sites for significant caving accidents in the Dales. At first glance, it might be interpreted as a list of the most dangerous caves in the Dales, but, in fact, it is nothing of the sort. It is, more realistically, a list of some of the most popular ones. In addition, the first four are multi entrance systems, so it is as though the list includes nearly twenty caves rather than just five.

The caves listed are, indeed, popular because of their 'quality'. The Easegill System is one of the world's longest, and contains a complex set of passages that are not only interesting in their own right, but allow a variety of through trips to be made. Gaping Gill's Main Chamber is a spectacular place, justly popular as the objective of many trips. The West Kingsdale System comprises a set of linked caves that are interesting and sporting (too much so in wet weather!) and, again, allow for through trips to be made. The Alum Pot System finds favour at all levels of competence and experience – the Main Shaft is a very spectacular hole, whereas the associated Long Churn Caves provide a good introduction for novices. No doubt Ireby Fell Cavern features because it is an interesting and sporting cave without, on the face of it, any real difficulties. However, in wet weather, floodwater can cause problems, particularly on the pitches, which - though short - can get very wet. It is highly likely that its very ease of descent tempts people to 'bite off more than they can chew'.

It is interesting to note that Gaping Gill, although second in the list for incident location, drops to fourth place when considering only those incidents where assistance was needed – ie, leaving out Category 3. At the same time, the West Kingsdale System moves up to the number two position. It appears that the figures for Gaping Gill are somewhat skewed by the large number of 'overdue' incidents involving trips to Bar Pot. This entrance provides relatively easy, all-weather (more or less), access to the system, but is relatively remote (as far as British caves are concerned). This latter factor causes many groups to underestimate the time that a proposed trip will take. On the other hand, the caves of West Kingsdale are very accessible, and provide good sporting trips. The main problem here seems to be the way in which the active streamways respond very rapidly to rainfall and consequent run-off.

The locations of fatal accidents show a somewhat similar distribution, with Gaping Gill and the Easegill Caves System accounting for eight deaths each, the West Kingsdale System for seven deaths, and Alum Pot for six (Table 4).

TRENDS OVER TIME

Figure 1 shows the cumulative number of incidents attended by the CRO over time, and Figure 2 shows the same data presented rather differently – lumped together in five-year lots. Table 5 shows how the type of incidents dealt with have changed over the 60 years of the CRO's existence – or, rather, it shows how little change has occurred in the type of incidents! Close scrutiny reveals that, until 1973, falls were the most numerous incident, closely followed by flooding, with the latter taking over in that year. These positions changed again in 1980, but in 1986, floods once again took over, and have stayed in prime position ever since. It is likely that, with ladder climbing going almost completely out of fashion, this situation will stay the same for the foreseeable future. However, it is possible that falls while abseiling will take over from falls while ladder climbing. Perhaps the most obvious feature of the table is that as SRT has caught on in Britain there has been an increase in this type of accident, highlighting the single incident in the years 1956–60 as something of an anomaly.

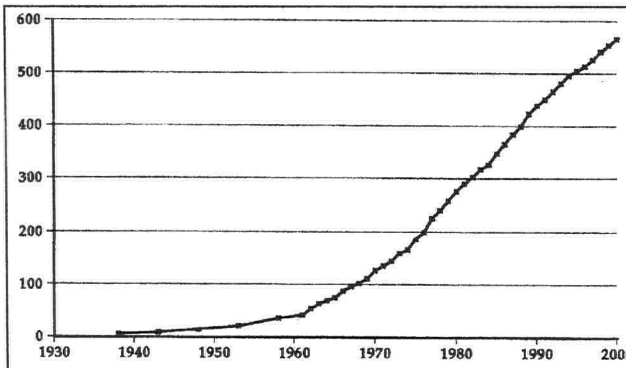

Figure 1 The cumulative number of incidents attended bythe CRO over time

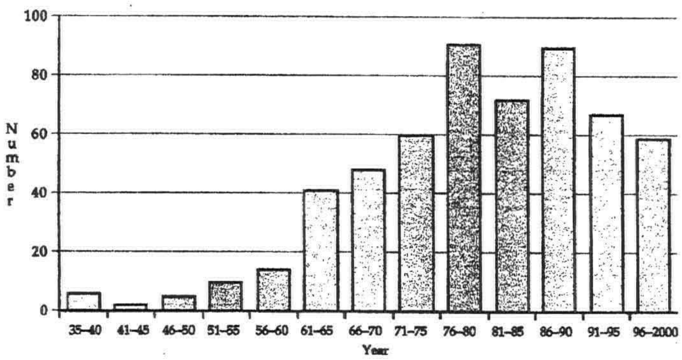

Figure 2 Number of incidents attended by CRO in five-year lots

CONCLUSION

Close study of the incident reports reveals – or, at least, strongly suggests – the following two points:

- First, many of the accidents occurred in bad weather. This is most obviously true of those in Category 1, indeed almost by definition. However, in many other cases it seems likely that bad weather played a significant role, as cavers had to struggle against excessive amounts of cold water, succumbing to exposure or falling from ladders as a result.

- Second, it appears that many underground accidents could have been avoidable. For example, whereas not all floods are predictable, many of the accidents in Category 1 could probably have been avoided if those concerned had had a better knowledge of how quickly and dramatically caves can respond to rainfall. It has already been mentioned that many of the falls in Category 2 occurred on relatively short easy pitches. It appears that many accidents could have been avoided by the use (or perhaps correct use) of a lifeline on all pitches where a ladder was used.

APPENDIX
FATAL ACCIDENTS IN CHRONOLOGICAL ORDER

	Number dead	Total number of deaths
1) 1936 Alum Pot: caver hit by falling rock	1	1
2) 1939 Rowten Pot: caver fell, then fell into pool and drowned	1	2
3) 1946 Grange Rigg Pot: caver died of exposure/exhaustion	1	3
4) 1947 Gaping Gill: body found	1	4
5) 1951 Penyghent Pot: caver died of exposure/exhaustion	1	5
6) 1955 Alum Pot: caver fell down Dolly Tubs Pitch	1	6
7) 1959 Dow Cave: rock fall in Dowber Gill Passage	1	7
8) 1959 Bar Pot: caver fell down pitch	1	8
9) 1962 Alum Pot: caver fell from the Bridge	1	9
10) 1963 Marble Steps Pot: caver drowned	1	10
11) 1964 Lancaster Hole: caver drowned in sump	1	11
12) 1967 Alum Pot: caver fell	1	12
13) 1967 Mossdale Caverns: 6 cavers drowned in flood	6	18
14) 1967 Sunset Hole: caver fell on 50-foot pitch	1	19
15) 1969 Meregill Hole: caver died of exposure/exhaustion	1	20
16) 1969 Easegill Cave System: caver killed by falling rock	1	21
17) 1970 Keld Head: diver drowned	1	22
18) Weathercote Cave: caver killed by falling rock	1	23
19) 1971 Swinsto Hole: caver fell	1	24
20) 1974 Gaping Gill: caver fell when abseil rope broke	1	25
21) 1975 Ireby Fell Cavern: caver fell	1	26
22) 1976 Alum Pot: non-caver fell down Main Shaft	1	27
23) 1976 Langstroth Pot: three cavers died in short sump	3	30
24) 1979 Cote Gill Pot: two cavers died from breathing blasting fumes	2	32
25) 1980 Bull Pot of the Witches: caver died diving sump	1	33
26) 1980 Easegill Cave System (Top Sink): caver died when abseil rope 'came free'	1	34
27) 1980 Keld Head: caver died diving sump	1	35
28) 1982 Gaping Gill: caver fell – (abseiling / lost control)	1	36
29) 1982 Diccan Pot: caver died of heart attack	1	37
30) 1982 Sunset Hole: caver died in flood	1	38
31) 1982 Ireby Fell Cavern: caver died in fall	1	39
32) 1982 Gaping Gill: caver fell down South East Pot	1	40
33) 1985 Hurtle Pot: diver died in sump	1	41
34) 1985 Lancaster Hole: caver died swimming in sump pool	1	42
35) 1986 Rowten Pot: CRO member died on rescue	1	43
36) 1986 Dale Head Pot: caver drowned in low crawl in flood	1	44
37) 1986 Gaping Gill: non-caver fell down Main Shaft	1	45
38) 1988 Cave at Stone Rigg: diver died in sump	1	46
39) 1988 Easegill Cave System: three cavers died in rock fall	3	49
40) 1989 Gaping Gill Main Shaft: caver 'hung-up' when attempting to prusik out	1	50
41) 1990 Kingsdale Master Cave: caver drowned in sump after earlier fall	1	51
42) 1991 Sell Gill Holes: caver died of heart attack	1	52
43) 1992 Joint Hole: sump diver drowned	1	53
44) 1993 Kingsdale Master Cave: caver drowned in flood	1	54
45) 1994 Lost John's Cave: caver died in rock fall	1	55
46) 1994 Old Ing Cave / Birkwith Cave: diver died in sump	1	56
47) 1994 Old Ing Cave: caver drowned in flood	1	57
48) 1995 Calf Holes: 'caver' died of heart attack when stuck in Hainsworth's Crawl	1	58
49) 1995 Gaping Gill Main Shaft: boy (non-caver) fell to death	1	59
50) 1996 Quaking Pot: caver fell ~11m to death on second pitch	1	60
51) 1997 Lancaster Hole: caver fel ~25m to death while abseiling (problem at re-belay)	1	61
52) 2000 Lancaster Hole: caver swept away by flood water in Main Stream Passage	1	62

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A uranium series date from Malham Cove Rising, North Yorkshire, UK

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Malham Cove is one of Britain's best known karst landforms. It is a large crescentic, overhanging cliff, 80m-high, with a large spring at its base (Fig.1). The hydrology of the area has a long history of investigation that started in 1879 (see Smith and Atkinson, 1977, for a summary), but relatively little accessible cave passage has been explored in the area (Brook *et al.*, 1996). The spring at the base of the Cove was first dived in 1953 (Butcher, 1953), but it was not until the late 1980s and early 1990s that the 1.6km-long cave system behind the Cove was explored (Fig.2). Descriptive accounts of the cave system (Malham Cove Rising) are given by Monico (1995) and Cordingley (1994). Malham Cove Rising is at present the longest explored cave system in the Malham karst drainage basin.

There are two entrances to the Malham Cove Rising. The Main Rising is located in the centre of the permanent spring at the base of the Cove, and the Flood Rising lies 30m to the east at the head of a normally dry streambed. Behind both risings the conduits combine and enter the much larger main conduit of Aire River Passage via two mainly excavated routes. Development has been guided by two bedding planes, and water flows up the very gentle dip, resulting in the deepest parts of the system being at its most northerly extremity. Conduits immediately behind both the Main Rising and the Flood Rising are relatively immature compared with the Aire River Passage. The main (older) development of Aire River Passage is presumed to emerge at a large truncated entrance currently buried behind talus some 30m west of the Main Rising.

Divers noted speleothems underwater at a depth of 2.4m, between 8 and 20m from the Flood Rising entrance (Fig.3). The occurrence of the speleothems indicates that a lower water level was maintained in the cave system some time in the past. This inference is supported by an observation of desiccation cracks on sediment banks that are now under water further inside the cave system (Cordingley, 2000).

The Cove has a complex polygenetic origin, partly old waterfall and partly a glacial step (Waltham *et al.*, 1997). Downstream of the Cove the wide valley is glacially over-deepened, and valley fill deposits maintain the present water level in the cave system. Conduits behind both the Main Rising and Flood Rising have a bedrock floor at approximately 2.5m depth, and there is no evidence of the system having been drained below this level. Over-deepening of the valley, which resulted in the partial drainage of the cave system, must have occurred prior to the speleothem growth in the Flood Rising. Sediment responsible for maintaining the present water level in the cave system must post-date the speleothem growth.

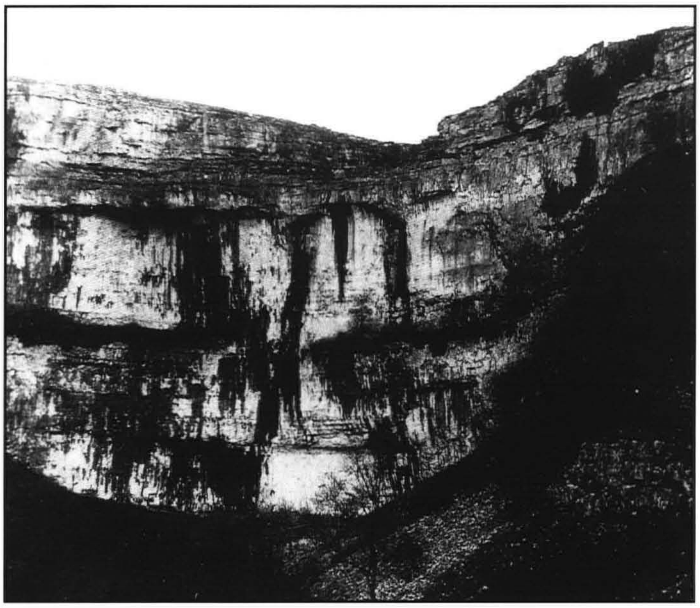

Figure 1. Malham Cove

A sample of speleothem material from a stalagmite curtain 9m inside the cave at a depth of 1.7m was removed and assayed by uranium series disequilibrium alpha counting methods (Table 1), yielding an uncorrected age of 35,600 +3600/-3500 years BP. If a correction is

Sample	Concentration, ppm		Chem Yield, %		$^{234}U/^{238}U$	$^{234}U/^{238}U_0$-#	$^{230}Th/^{234}U$	$^{230}Th/^{232}Th$	Estimated Age (ka)	
	U	Th	U	Th					Uncorrected	Corrected*
MCS1	0.08	0.02	28	20	1.32±0.07	1.35 ±0.08	0.283±0.024	4.7 ± 1.1	35.6 ±3.6	27.3 ±5.6

Table 1: U-Th analysis of Malham Cove cave sample, MCS1
Errors are 1 standard deviation based on counting statistics.
The $^{234}U/^{238}U_0$- ratio is the estimated ratio at start of growth.
* The corrected age is based on the assumption that the initial value of the $^{230}Th/^{232}Th$ ratio was 1.25.
For experimental details and general data treatment see Ivanovich and Harmon (1992).

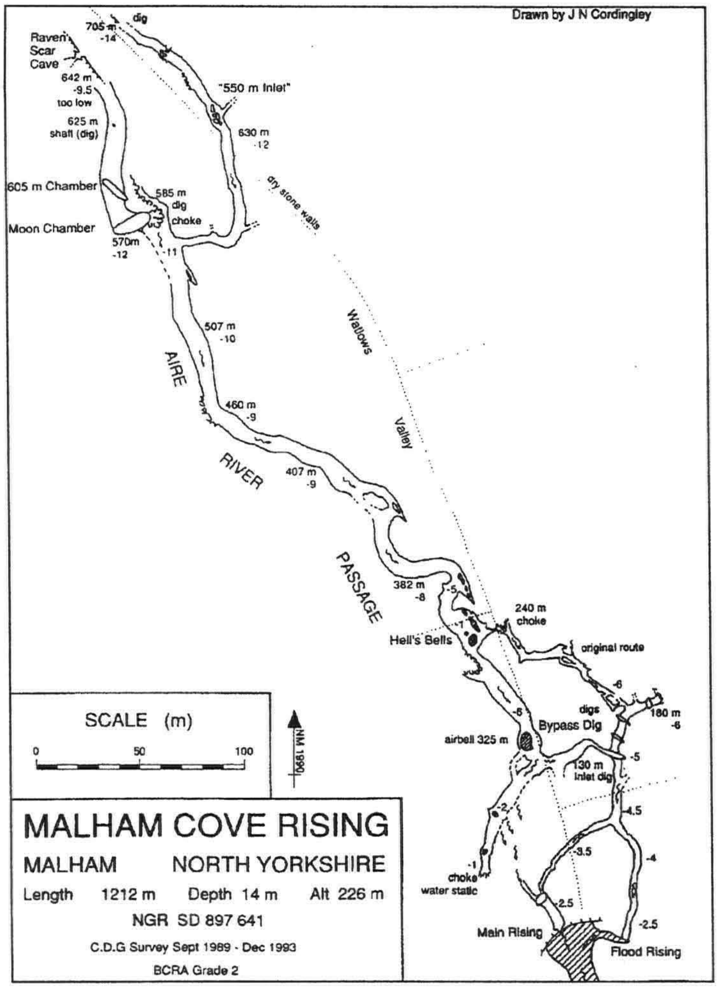

Figure 2. Survey of the known cave passages behind Malham Cove Rising, with selected surface features superimposed.

made for the small amount of detrital thorium, using an assumed initial ratio of 1.25 (see Ivanovich and Harmon, 1992), then the age shifts to 27,300 +/- 5600 years BP. Effectively the analysis averages across several internal layers of the speleothem. Outer (younger) layers of the sample had to be removed before analysis because they were porous and were judged likely to be isotopically disturbed.

Yorkshire Dales speleothem sample dates falling within the period covered by these two values are not common. Sutcliffe *et al*., (1985) report a flowstone of 29 ± 2ka from Stump Cross Cavern. Gascoyne *et al*., (1983) and Gascoyne and Ford (1984) report flowstone of 29.4 ± 2.2ka from Ibbeth Peril Cave, and Victoria Cave has a thin flowstone layer of 25.5 ± 3.6ka on its back wall. The statistical summary of speleothem growth frequencies compiled by Baker *et al.*, (1993) shows a slight rise at about 29-26ka in an otherwise low growth period. Speleothems from the relict phreatic conduit of Bill Taylor's Passage in the Lancaster Hole - Ease Gill Caverns cave system show that more active growth occurred in the Yorkshire Dales from 44 to 35ka (Gascoyne *et al*., 1983). Gaping Gill flowstone and stalagmites have ages ranging from 38 to 50ka (Gascoyne *et al.*, 1983). These dates fall within the Mid Devensian (50 to 26ka BP, Bowen *et al.*, 1999), pre-dating the major ice expansion of the Late Devensian at around 23 to 20ka. The peak at about 40-42ka in the curve derived by Baker *et al.*, (1993) is thus identified with the Upton Warren Interstadial. The Late Devensian glaciation (the Dimlington Glaciation of Waltham *et al.*, 1997) was responsible for the scouring of the Yorkshire Dales to produce the classic glaciokarst seen today (Waltham, 1990).

The overdeepening of the glaciated trough downstream of Malham Cove must pre-date the Mid Devensian (50-26ka) warm stage and be the product of an Early Devensian or older glaciation. This suggests that although the glacial step of the Cove existed in some form prior to the last glacial maximum there were no substantial deposits at the base of the Cove before 27ka. This is in agreement with other evidence, which suggests that most of Britain was substantially ice free for most of the Devensian, until the Glacial Maximum at around 23-20ka.

ACKNOWLEDGEMENTS

This research was supported by a grant from the British Cave Research Association Research Fund. The authors thank Mr J N Cordingley for bringing the occurrence of speleothems in Malham Cove Risings to their attention, and for providing Figure 3. The Natural Environment Research Council (NERC) is thanked for providing the resources to set up the U-series laboratory in the Department of Archaeology at Liverpool University.

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Figure 3. Stalagmite curtain now under water. Nine metres from the entrance of the Flood Rising.

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Forum

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ABSTRACTS FROM KARSTOLOGIA FOR 1999

Karstologia 33 (1999)

Paleokarst fillings and tectonics in the Marseille area, France
Raymond MONTEAU
The paleokarst fillings in the Riou and Frioul archipelagoes, the coastal ranges of Marseilleveyre (Calanques) Notre Dame de la Garde (the Bay of Marseille) show several examples of various tectonic mechanisms due to compressive stresses. A chronology of the various phases is described: compartment process, overlapping, tilting. These deformations and the several after-episodes observed can be dated between the Lower Eocene and the Upper Pleistocene, but it is still difficult to give a more precise date. The Tertiary fillings show the action of local decompression and tilting in some cases. In the detailed study of the karstic lithified deposits two kinds of tectonised sequences are shown in connection with the local tectonics.

Use of karst water resources: the town of "Penne-de-Tarn", Tarn, France
Claude BOU
Water collecting in the commune of Penne was meant to offer an option to the polluted and scarce water resources of the Liassic limestone aquifer layer through a planned and reasonable exploitation of the Jurassic reserves. Three underground streams actually supply the whole commune territory – the largest in the Tarn department – with good water that does not suffer any summer depletion. The civil engineering work, the electro-mechanical fittings, the proper fixtures that followed the preliminary surveys were made by unpaid amateur cavers from several clubs of the caving district committee gathered in the ATEK (Association Tarnaise d'Etudes Karstiques). Different methods and techniques have been used to collect water on the following three sites:

- the underground stream of Cabeou and the building of a storage dam of 500m^3 which was put into service in 1984 on the limestone plateau of the Garrigue;
- the undergroung stream of Amiel where a 25m-deep well was drilled through hard rock and which has supplied the village with water since 1985;
- and the underground stream of Madeleine, whose pumping station protected by a dam has increased the water resources of the right bank of the Aveyron river since 1989.

The "marble glaciers" of Diego de Almagro (Chilean Patagonia). Example of a subpolar karst in hyperhumid climate
Richard MAIRE and Ultima Esperanza team
The karst areas of Chilean Patagonia have remained virtually unknown until now because of their remoteness and very inhospitable climate. They are mainly located in two islands, Diego de Almagro and Madre de Dios, between latitude 52° and 50° South, with a subpolar and stormy climate "tempered" by heavy oceanic precipitation (7m/year). In Diego de Almagro the Permian and Carboniferous limestones and dolomites have been transformed into marbles with lamprophyre dikes through contact metamorphism. Situated in the outer part of the archipelagoes, these long and narrow outcrops (0.5–2km wide) are located between volcano-sedimentary formations of Upper Paleozoic (West) and the Mesozoic Patagonian batholith (East). The corallian paleoreefs are part of an accretionary prism of the Gondwana paleo-continent. The surficial and underground karstification is one of the most spectacular ones in the world. The karren (lapies) caused by the heavy rains can be 1–4m wide and several hundred metres long for the solution runnels. Moreover, we can often observe solution karren both due to rain and wind direction: flat karren (horizontal laminar flow), cascading ripples (sloping laminar flow) and profiled solution forms. The surficial solution velocity is about 3mm/50 years (from old painting traces near the quarry of Guarello, Madre de Dios); and the lamprophyres dikes (Diego de Almagro) put in relief through corrosion indicate a 40-60cm surficial solution since the melting of Pleistocene glaciers.

Some karst corrosion chemical mechanisms in relation with H_2O, $CaCO_3$ and CO_2 equilibrium
Baudouin LISMONDE
The classical influences of physical parameters and mixing corrosion are presented to study the equilibrium of the water-air-limestone chemical system. The frequent observation of cave levels in the mountain karstic systems is often associated with the greater facility of dissolution, near the water table. Some chemical mechanisms are analysed to show the greater karst corrosion on this level. Increased air pressure induces an increase in the saturation pCO_2 of the water. Two confinement coefficients are used to analyse the role of a limited quantity of air in contact with water.

The first (k) is the water mass/water + air mass ratio, the second (kn) is the mass of CO_2 in water/mass of CO_2 in water and air ratio. These two ratios show that the latter coefficient varies with air pressure, but is proportional to the varying pCO_2.

Conditions of underground water circulation in the gypsum karsts of the French Inner Alps
Bernard COUTURIER, Jean-Claude FOURNEAUX, Laure SOMMERIA
The Triassic gypsum outcrops are widespread, in the French Inner Alps. They are often found in large heaps between two structural units. Karstic landforms with sinkholes and collapse zones are visible even when they are covered with glacial deposits or fallen rocks. There is also much evidence of underground flows, but the springs do not have any karstic characteristics. The water tracings (two examples) show that the local tectonics have a great influence in the subterranean circulation conditions. At "La Norma" in the Arc valley (Maurienne) the water infiltrated in a large sinkhole supplies several small springs after transit in a fissured aquifer. The spring flow is well regulated. At "Le Clou" in the upper Isère valley (Tarentaise) several sinkholes with loss of ephemeral streams during melting snow supply a large fissured aquifer. There is no spring with karstic features either. The water infiltrated in a sinkhole has been found in several springs during a very long period of time. Whereas the upper part of these aquifers are really like a karstic aquifer, with large stream channels, on the contrary the deeper

part is like a fissured aquifer with large water dispersion and low velocity. The fissured and porous aquifer has a throttling action and explains the absence of true resurgence. The underground water flow is unbroken between the different aquifers but permeability decreases according to the depth. These phenomenon are in connection with tectonic activity and the inter-penetration of the different geological formations at the bottom of the gypsum layer.

Karstologia 34 (1999)

Study of karst and caves in Kaokoland (Namibia)
J E J MARTINI, J C E MARAIS and J IRISH
The authors describe the dolomite karst of Kaokoland, an arid region of Namibia, which had been very poorly investigated speleologically. The geomorphology, the karst hydrology and the water chemistry are reviewed. Although the karst area is large, caves are scarce and usually reduced to single large chambers. Integrated networks of passages are apparently missing. Seven caves are described in detail, including their mineralogy which comprise rare species. The Kaokoland karst is compared with other ones developed in more humid areas of Southern Africa. A speleogenetic model is proposed, which involves mixing of near surface ground water with anoxic sulphide-rich water of deep origin and could explain the very localised formation of large cavities.

Hyrogeological studies in Yucatan (Mexico)
Christian THOMAS
The submerged karsts also know as plain karsts are highly developed in the Yucatan peninsula. Cave diving explorations, physical and chemical measurements (water discharge, chemical analysis of the water, water table altitude, a.s.o...) allow an indirect estimation of the main hydrogeological parameters of these karsts: infiltration ratio, fresh water reserves, pollution by the salty water, tide influence, karstic erosion... Comparisons are given with other karsts: Lifou (French New-Caledonia) and Nullarbor.

Stalagmites: environmental and climatic high resolution archive
Yves PERRETTE
Since the late 80s, the detailed study of speleothem has developed from the crossing of two main approaches; one comes from the questions of speleologists confronted with magnificent cave scenery, the other comes from citizen questions about climatic and environmental changes.

The aim of this paper is to show the diversity and the relevance of the data collected by such studies on stalagmitic samples from the Vercors – France. The knowledge of the chemical processes of the H_2O – $CaCO_3$ – CO_2 system in the perspective of the karst infiltration leads to questions about the role of the "supstrat". This word has been used to describe the "roofrock" rather than the bedrock. So, to better understand the different modes of drainage in karst, a global hydrologic study of the Choranche cave vadose zone has been realised, e.g. seepage water rates have been monitoring. These recent studies allow us to model the structural and functional hydrologic network of such a well-developed karst system. Actually we demonstrated the hierarchisation of the drainage and the relation between a transmissive system and a capacitive one. They have been used to propose a graphical typology leading to a better appreciation of the various environmental interests of speleothems. Understanding the processes of speleothem environmental and climatic archiving, needs to know the processes of calcite crystal growth. They are briefly presented through some usual fabrics like columnar, palissadic or dendritic ones and through the optical relation between macroscopic colours and crystalline porosity. It is the evolution of these crystalline features, which creates the laminae. To explain what are laminae, the different type of emission by a solid after a laser irradiation are shown. It justifies the choice of two kinds of laminae measurement i.e. reflectance and fluorescence. Then, results of spectroscopic studies which show a covariation between Mn_2+ concentration, the maximum intensity wave length of fluorescence spectra and the reflectance trend, allow us to consider reflectance measurement as a water excess proxy. This experimental approach is confirmed by the infra annual laminae. The hydrological interest of "visible" laminae (i.e. reflectance one) is increased by the fluorescence "invisible" laminae. In fact, the presence of a wide diversity of organic molecule in the calcite lead us to consider the fluorescence lamina as a temporal proxy controlled by the annual leaf fall and biopedological degradation. To measure these two proxies, an original experimental set has been developed in collaboration with the PhLAM laboratory (Lille, France).

Particularly, this experimental set-up permits to realise simultaneously a reflectance and a fluorescence image. The data collected are processed and are analysed in the frequency domain. All these data allow us to extract different proxies from speleothems. These proxies have been studied for some Vercors samples. We present the global environmental and climatic data archiving of the post-Wurmian (isotopic Stage 1) warming. At a higher resolution, the Vercors climate forcing is shown through the spectral analysis of the reflectance of a well laminated sample. The solar ($T = 22$ y) and atmospheric (NAO, $T = 17$ y) forcings are clearly distinguished. The climate analysis of this sample is limited by an anthropic mask. We show the similarity of the crystal facies evolution of two samples located around the Alps but far from more than 100km. We would like to interpret this changes as an archiving of the post Little Ice Age warming but here too, Man interfere with climate to induce environmental changes. We show an example of the possibility for distinguishing climate from anthropic changes in environmental evolutions. The wealth of data of the speleothem allows us to appreciate the environment stability of the Vercors, which is confirmed in the spectral analysis of the growth rates of a Gouffre Berger sample.

The diversity of the data collected in speleothems is directly linked to the diversity of the way of archiving in a karst system. It is why only a global approach seems to be relevant for answering environmental hydrological or morphological karst questions.

The notion of "karst" introduced into French scientific literature
Christophe GAUCHON
During the symposium ALCADI 96 in Postojna, Professor Ivan GAMS appealed to all the participants to study the way in which the notion of "Karst" had been introduced into respective countries and adopted by speleologists and geographers. In France, the specific phenomenon of the eponymic Karst, as the Zirknitz Lake (Cerknisko Jezero), have been known about and described since the end of the 16th century. But it required a big step to go from these descriptions to an understanding that the Karst might be a model capable of explaining the hydrology and morphology of such regions. In the early 19th century, naturalists and geologists began to recognise the particularities of the hydrography in limestone regions, and went as far as to propose the Jura or the Causses as models. In 1879, probably for the first lime, Marius Bouvier, a French civil engineer, used Karst as a pattern to explain and describe the impluvium of the famous Vaucluse spring (Provence). It is known that E-A Martel disliked this word of "karst" and argued strongly in favour of "causse"; but despite this, Cvijic was generally considered most representative, and Karst was quickly adopted for all the scientific french works.

The deformations of the Zeuzier arch-dam (Valis, Switzerland). Extraordinary geotechnical and hydrogeological problems and questioning over a possible part of karstification
Jean NICOD

[No abstract provided.]

ABSTRACTS FROM KARSTOLOGIA FOR 2000

Karstologia 35 (2000)

Karstic landscape of the Gramat Causse (Lot, France)
Jean-Noël SALOMON
The Gramat Causse and its surroundings offer an exceptional range of landscapes, which have long made the area renowned. Nevertheless, only a few natural sites (Padirac, Rocamadour, Pech Merle...) are currently shown to their advantage for and by the tourist industry. The aim of this paper is to show that, beyond these jewels, there exist many other natural sites for which it is worth making a detour. They simply have to be known and made known to others. In an area undergoing serious economic problems due to agricultural changes, "ecotourism" provides a promising and attractive

alternative, as has been illustrated by the creation of the Quercy regional natural park. It is in this context that the development of the karst legacy should be given impetus and the water resources, which are more and more valuable and another asset of the area, should be protected.

Which is the dimension of the karstic massif of Sainte Baume (Bouches-Du-Rhones, Var; France)? Elements for a spatial and fractal theory of the karst
Philippe MARTIN
The dimension of the surface of Sainte Baume and its neighbourhood is close to 2.2. This value has been obtained from the study of 5 contour lines (from 400 to 800m) and 5 topographic profiles (3 N - S and 2 E - W). 3 methods were used for contour lines: box counting (D_B); the information dimension (D_i) and surface - perimeter relation ($\Delta_{(P)}$). Three methods have been used for topographic profiles: the power spectrum (D_{SPEC}); statistics R/S ($D_{R/S}$) and variogramme (D_{VAR}). Average results are:

(D_B) = 1.20; D_i = 1.23; ($\Delta_{(P)}$) = 1.32; D_{SPEC} = 1.17; DR/S = 1.24; D_{VAR} = 1.23. Thus, the surface of Sainte Baume and its neighbourhood is fractal. It means, theoretically, that Sainte Baume can be characterised by an infinite surface in a bounded volume. This first approach focuses on a karst surface approach; a cave systems approach will be presented in a following paper (in this review).

This result raises numerous geomorphologic questions. How to calculate a specific erosion? How to think forms in a theoretical frame, which could be developed out of the Euclidean geometry conventions? How to think an essentially irregular morphology? Elements of answer are brought on a theoretical plan. They constitute the first elements of a karst geometrical theory. Calculation of the specific erosion points out the problem of the size of the surface used. Due to fractal theories, this size is relative to the observation scale used. To be significant, specific erosion calculation needs the use of an efficient scale, in regard of the erosion processes studied. Furthermore, specific erosion expresses only a balance of mass, not a morphogenesis. It corresponds to a chronological approach of the karst.

Two dynamics can be distinguished in surface morphogenesis. In one hand, increase of the mean slopes is named spatial differentiation, in another hand, decrease of this value is classically called: aplanation or levelling. These 2 dynamics imply the wearing away of spatially various materials. It takes place essentially around thalwegs during the differentiation stage, around the crest during levelling. Thus morphology, space are important factors of the dynamics in the work. Space is not only a support, but an actor in morphogenesis.

The high-alpine Kanin karst (Julian Alps, Slovenia-Italy). State of knowledge and new data on present functioning and Plio-Quaternary evolution of the karstic structures
Philippe AUDRA
Kanin is a high-alpine karst located in the Italo-Slovenian Julian Alps. Its surface was elaborated by the Quaternary glaciers and includes some inherited discreet Tertiary morphological features. Recent dye tracing has shown that the structural setting permits water infiltrated in Italian catchments to contribute to Slovene springs. Hydrodynamic and physico-chemical water analyses show extremely quick transfers of water during snow melt or heavy storms; these create spectacular overflows, such as the Boka spring, which emerges as a 100m-high waterfall. The phreatic zone, linked to the impermeable dam of the Soča valley, does not significantly slow these transfers. Nevertheless, it contributes to the occurrence of low water levels during recession periods, giving highly mineralised water after long resident periods. The presence of very deep and developed karst systems is explained by the combination of advantageous factors: thick and jointed limestone, important height gradient, and considerable precipitation. Paleomagnetic dating in one of the largest systems (Črnelsko brezno) attributes some glacial sediments to the Lower Pleistocene period. Their configuration seems to show that this karst system is pre-Quaternary.

Corrosion of ceiling pockets associated with pressure of confined air
Baudouin LISMONDE
A new mechanism for tube formation in the neighbourhood of the water table is proposed. It is applied to the genesis of ceiling pockets. The rising of water confines the air of ceiling pockets. The CO_2 pressure increases. The air compression is almost isothermic and induces a mist. The drops of the mist capture the CO_2 by a diffusion process. The mass transfer of CO_2 from air to drops, then to water, induces a vigorous corrosion of the limestone. For example, $1m^3$ of air (at $pCO_2 = 3.10^{-3}$) with a compression of 1 bar (10m) produces a maximum calcite dissolution of 1g. A rough computing model for the ceiling pockets' growth is also presented.

Springs and karstic hydrosystems in arid and semi-arid areas. A geographical essay
Jean NICOD
The patterns of the main springs and hydrosystems in the deserts and surroundings are sorted, according to their geomorphological situation (piedmont, coastal or inner plateau), to structure of the aquifers and working of groundwater (storage capacity, artesian systems) and to the hydrochemical criteria particularly the solute load in Mg^{2+}, SO_4^{2-} and Cl^-.

From the best known examples, the main problems on the genesis and working of the karstic hydro-systems in arid environment are discussed:
- the incidence of tectonic stress and paleokarstic and paleoclimatic inheritances;
- the recent periods of recharge (in Northern Sahara and the Near and Middle East);
- the interactions in ionic solutions and hyper-karstic processes: particularly with the strong acid, H_2SO_4, the "double solvency effect", and the mixing water corrosion near the salt water wedge in the coastal karsts.

New data about the deformations of the Zeuzier Arch-Dam (Switzerland)
Andres WILDBERGER
[No abstract provided.]

Karstologia 36 (2000)

Morphology and roughness of karstic surfaces. Contribution to a spatial and fractal theory of karst landscapes
Philippe MARTIN
This text proposes a theoretical, hypothetical and speculative approach of the transformation of earth's surfaces. This reflection is based on the notion of otherness. Our approach uses two oppositions: levelled / roughness and karstic / non karstic.

The dimension of the roughness surfaces is understood between 2 and 3. The dimension of the surfaces of levelling is close to 2. Quantifications showed that massifs are limited by surfaces more or less irregular. In certain cases, the erosion transforms so a surface of levelling into rough surface. In that case initial shape is not preserved. The levellings on the karstic massifs (outliers often) seem better preserved (karstic immunity) than on the other rocks. This conservation would explain a weak value of the fractal dimension of air surfaces of karsts tested always with the same protocol (relation $S \alpha P^{\Delta}$).

They were compared with the surfaces of reliefs of basal complex. Three ideas summarise the results obtained:
[1]The average of fractal dimensions of karsts are smaller than those of the relief of basal complex.
[2]The dispersal of the mean values of surface of karst is lower than the dispersal of the mean values of basal complex.
[3]Distance between minimal and maximal values for karsts is much bigger than distance between minimal and maximal values for basal complex.
To explain the weak roughness of karsts we made three hypotheses:
[a] These fragments would correspond to zones still not affected by erosion (time problem)
[b] In such a system some changes on a plan would prevent changes on the another plan (spatial problem)
[c] Initial shape is replaced by a similar shape (Platon's Parménide).

The endokarst is described empirically and by analogy with the fractal model of Sierpinski's sponge as a unique surface infinitely folded up in a limited volume. So the growth of the karstic spaces in the endokarst, increases almost until infinity, the size of the internal surface of the karst.

To find a theoretical base at the roughness and at the extreme size of these surfaces, we studied the report between the growth of a volume and the growth of the surface, which limits this volume. Three theoretical models show that if surfaces do not change, volume to be affected by unity of surface grows strongly.

Eroded volume depends on the size of the exposed surface. If the eroded volume depends on the size of the exposed surface, then time to erase a mountain could be, in theory, infinite. This is not acceptable because a massif can be erased in about 200 Ma. According to analogies with different morphogenesis (physical, biologic), we make the hypothesis that fractal character, of surfaces of the massifs corresponds to the necessity of increasing, as much as possible, the size of the surface subjected to the erosion so as to decrease the time of destruction of the relief.

This is coherent with the idea of a system far from the balance, which tends to join the state of balance as quickly as possible by developing specific morphologies.

Distance between the relief and the lower limit of the potential of erosion is then introduced as a factor being able to explain the small roughness of high continental surfaces.

The reduction of the volume by erosion is cause (and not consequence) of the decrease of the roughness. The surface can become less rough because volume decreases. The surface of levelling constitutes the final morphology, which is transformed only very slowly. In this perspective the dynamics allows only the fulfillment of spatial rules. In the case of the karst, because of the existence of the subterranean part of the karstic surface and its roughness, it is not useful that air part becomes very rough. Levellings would be preserved by geometrical uselessness to destroy them. They would not correspond to forms in respite as implies him the temporal analysis (hypothesis [a]), but to forms corresponding to a particular balance (hypothesis [b]) who would even be locally transformed (karstic levelling) into the same shape (hypothesis [c]).

This theoretical plan supplies with more an explanation on the visible contradiction between the speed of the karstic erosion and the durability of levellings.

Karstic phenomena in a mine gallery of Rincon Blanco (Argentina)
Silvia P. BARREDO
The Rincon Blanco subbasin is located in San Juan Province, Argentina, between 69° 15′ west by 31°4' to 31° 33′ south and is characterised by a non-marine continental infilling. During Tertiary times it underwent compressional deformation folding it into a tight north-south trending syncline. The whole sedimentary sequence is comprised of coarse-grained units interfingered with sandstones and shales. In particular, these latter were deposited in an alkaline lake and are composed of carbonate and organic rich strata. These characteristic lacustrine facies bear bituminous shales widely known as "Rincon Blanco oil slates". During the 1950s and 1970s, they were densely explored resulting in a number of galleries that presently are abandoned. They were cut in the bituminous rocks exposing west-east and southeast-northwest systems of minor faults and local fractures. These discontinuities permitted the inflow of meteoric waters through the overlying layers and into these artificial caves, thus resulting in carbonate cement dissolution, and, re-precipitation as tiny stalactites, stalagmites, thick travertine deposits in the floor with incipient microchannels accompanied by pools (gours) with pearls and botryoid-like concretions. Several solutional speleothems are also found and correspond to ceiling and wall pockets and floor pits. This phenomena seemed to be related to acidic water coming from small discharges and flowing through the network of integrated tectonic openings to the innermost tunnel sections where humid air reaches saturation. Water trickling resulting from condensation produces erosional features and, together with dropping and occasional flows, the speleothems. Events of slight flow turbulence in some enlarged fractures are also inferred by the presence of ceiling and floor dissolutional features.

The massif of Arbailles (West Pyrénées)
Nathalie VANARA
The Arbailles massif (200 - 1200m) is located in the French north face of, Atlantic side. It forms a folded 165 square-kilometres unit of Jurassic and Cretaceous limestones under an oceanic climate of altitude (2000 mm/year). Observations jointly made on the surface and in the numerous underground galleries allow an accurate correlation of alternate surrective and karstic periods. The dismantled cavities and deposits pockets of the upper surface show two series of minerals, those from weathered marly-Albian limestones and others supplied from the conglomerates pudding-stones of Mendibelza. During the Miocene, the Arbailles massif is a low area of tropical erosion on the side of the main mounts. Its surrection caused the scouring of the alterites cover, the formation of fields of karstic butts and a definitive drying of the fluviatile paleosystem.

The different levels of dried valleys and the karstic hydrographic systems are successive stations of the karstic levels of origine. Paleomagnetic datations in Etxanko Zola and U/Th datations in Nébélé show that the surrection has been of about 500m since the lower Pleistocene. At the present time, water collection is made through drainage systems without any connection to the fossil topography.

Three aquifers can be distinguished: in lower Cretaceous, in Jurassic and in north and south limits. They are water-repellent because of more or less impermeable screens. Waters are aggressive in summer and at equilibrium or lightly undersaturated the rest of the year. The modern human activities create a recent destabilisation of the environment with local erosions of grounds and an increasing turbidity of springs. An accurate study in the fail of Istaurdy allows a measure of the effect of deforestation for the whole massif.

Cango Cave (South Africa)
J.E.J. MARTINI
The author describes a small karst area in the extreme south of the African Continent, with special reference to the Cango Cave, which is a major tourist attraction. Compared with the other karsts of Southern Africa, this area is unique. The karst is typically exogenic, with caves forming by stream disappearance into swallow holes, where the thalweg intersects steeply dipping Precambrian limestone. Wet caves are vadose, with only short phreatic segments and exhibit rectilinear, longitudinal sections. Passages are low, but wide with bevelled ceilings, often terraced. This peculiar morphology is typical of the caves developing exactly on the water-table and seems to be controlled by the abundance of sediments introduced from the swallow holes.

If one excepts a short active lower level, Cango is a dry cave of the same type than the wet ones. It is practically linear in plan and in profile, with a length of 2.6km from entrance to end for a total of 5.2km of passages. The age of the speleogenesis has been estimated as early Pleistocene from the entrance elevation, which is in between the altitude of the actual thalweg and the one of the Post African I erosion surface, which started to be eroded during the Upper Pliocene. This relatively young age is in contrast with a Miocene model, which was accepted by most of the previous authors. Cango is well adorned with speleothems, in particular with outstanding abundant shields, monocrystalline stalagmites and pools coated with calcite crystals. In the first chambers from entrance, the speleothems have been deeply corroded by bat guano, with deposition of hydroxylapatite. Previously this corrosion was attributed to resolution due to several rises of the paleowater-table. The meteorology is discussed, in particular the high carbon dioxide, which indicates that the cave is poorly ventilated and which constitutes a problem for management and conservation.

ABSTRACTS FROM KARSTOLOGIA FOR 2001

Karstologia 37 (2001)

Homages to Philippe Renault (1925-2001)
Richard MAIRE and Yves QUINIF
[No abstract provided.]

Geological history and karst records: the massif of Siou Blanc and surrounding areas (Provence)
Jean-Joseph BLANC
Presentation about a middle-elevated karst (625-650m) in a temperate mediterranean climate excavated into an important Bathonian to Coniacian

limestone and dolomitic sequence (500m to 900m). Tectonic and pedological factors induced the deep drainages, dolines and uvalas alignments, vertical vadose networks. The observations applied to doline fields give a discrimination of several epikarstic morphologies: little cone-shaped dolines, lobate, bucket, circular or elliptical dolines pits, asymetrical-falling dolines, collapsed-dolines, uvalas elongated along fault lines and megadolines. These states are the results of various processes from the Upper Miocene to actual time. Suspended and disconnected poljes (Limate, Valbelle) were originally induced by paleo-networks with an East to West orientation, at the Miocene; then, these formations were shifted slightly by reactivation of the fault displacement (Messinian) in relation to a volcanic event (Evenos). The karstification of Siou Blanc massif and its environments, after the bauxitic paleokarst (Albian), shows an exceptional polygenic evolution in relation to the dynamic of the Mediterranean margins.

Buridan's Donkey, the principle of Curie and the chimney effect (airflow in a u-shaped cavity)
Baudouin LISMONDE
In a U-shaped cave there is airflow in winter. This phenomenon is a beautiful example of physical broken symmetry. In summer, it is possible to observe a pendulum oscillation of cold air in a U-shaped cavity.

The Moselle piracy: new chronological data from U/Th dating of speleothems
Benoît LOSSON and Yves QUINIF
The Moselle piracy is one of the most important changes of the hydrographic network in Lorraine (France). For a long time, this phenomenon has been presumed to be relatively recent (at the end of the Mid Pleistocene) because of the well preserved fluvial morphologies and deposits. With new relations between the above ground and subterranean parameters in the piracy area, the capture has been dated from 300 ka by the U/Th method on speleothem. This evaluation reveals an earlier time for the phenomenon, and is more precise than those proposed up to now. The latter were derived from the North-European glacial chronology and one thermo-luminescence date obtained in the downstream valley of Meuse. In fact, the improvements in absolute datings, through different methods and U/Th in particular, lead geomorphologists to abandon the simple relation between the glacial-interglacial periods and the accumulation-erosion processes in rivers.

Study of an ice cave working during on climatic cycle: site of Autrans ice cave (Vercors) – preliminary results
Anne-Sophie PERROUX
This underground ice work comes in the framework of high-resolution environmental records in underground deposit research. With this aim, we have chosen the Autrans ice cave to analyse an ice core. In a preliminary research about the ice cave and its working in comparison to climatic variations, we have two informations: there are two types of working, of dynamic from season to season, and the cave morphology is very important for draughts.

Lapies forms and micro-reliefs. Morphometric and morphogenetic approach on the Totes Gebirge (Austria)
Marton VERESS and Gabor TOTH
There were made M 1 : 10 scale morphological map about 6 karren ground surface part of Totes Gebirge in Austria. The notion of karren inselberg and mesa is determined and these remain surfaces are typified. The karren inselberg and mesa forms, developed by rinnens, were examined in detail. These can be developed as the end of ancillary rinnen, with attachment of ancillary rinnens and main rinnens, and with imitation and real capture of bends. After the examination of solution together (it can be possible with taking into consideration of development and place of escarpments and rinnen bottom drainage divides during solution together) can be determined the method of developing of karren inselberg and mesa forms and formation sequence of the different karren forms. The solution history of each ground surface part can be given after getting the information about relative developing ages. Such maps were made with taking into consideration of relative developing ages of different karren forms, the solution history of environment of mesas can be shown.

Hydrocompaction, solution, suffosion and piping as processes of forming depression contours
Jean-Christophe PELLEGRIN and Jean-Noël SALOMON
The authors of this note provide a definition for four processes (hydrocompaction, solution, suffosion, piping) which, although different, are likely to result in comparable surface morphologies, such as closed hollows. They attempt to clarify the specific features of each of these processes.

Karstologia 38 (2001)

Sustainable management of a mountain lake: a speleological contribution by tracings above Kõnigssee (Berchtesgaden Alps, Bavaria, Germany)
Jean-Jacques DELANNOY, Guido PLASSMAN, Rolf APPEL, Hans KRAFFT and Rachid NEDJAÏ
Two dye tracings were made in Simetsberg massif, a part of Steinernes Meer ("Rocky sea") in Western limestone Alps, in the heart of Berchtesgaden National Park (Bavaria, Germany). The goal was to determine drainage direction and characteristic so as to assess the Königssee vulnerability, which represents on the first hand high ecological value (oligotrophe high quality water) and on the second hand one of the most famous tourist spot in Bavaria (800,000 visitors / year in St-Bartolomä). This study was managed by Berchtesgaden National Park in collaboration with French karst scientists. The first goal was to put in evidence the Salzgrabenhöhle outlets, this cave being one of the most important in this alpine area. The second goal was to trace three lake sinkholes on the high massif, one being close to a main mountain cottage, which could constitute a pollution source for both surface and underground water. These projects put in evidence a direct high transmissivity connection first between the sinkholes and the Salzgraben cave and secondly with the Königssee lake. A catchment control is necessary for lake conservation.

Erosion and runoff on a bare karst: subpolar islands of Patagonia (Chile)
Fabien HOBLEA, Stéphane JAILLET and Richard MAIRE
During Ultima Patagonia project (2000) on Madre de Dios island karst (chile), runoff and erosion characteristics have been measured and followed on the field, to explain the hypertrophy and particularity (profiled shapes) of the marble and limestone karrens. Hydrologic and morphologic measures have been made on a little catchment ($100m^2$). In this subpolar oceanic context, it appears that evaporation rate on bare karst is low despite the strong wind and consequently runoff activity is particularly strong. These measures are compared to those made on karst tables and dykes originating from differential corrosion, that show moreover the wind part in the development of wind-profiled karrens, a special karst landscape unknown up to now. Surface karst denudation is about 100mm / ka.

Karstic geosystems of the Causses in SW Middle Atlas (Morocco): Interference between geomorphologic and hydrogeologic factors
Yahia EL KHALKI and BRAHIM AKDIM
The karstic geosystems of the Causses in the Middle Atlas present a number of old and present karstic landforms. The interference between karstic geomorphology and the process of deep karstification find expression in an important development of sinkholes and collapse zones.

Inventory and spatial distribution of these superficial karstic landforms show a very close relationship with the apparition of saline springs. Water chemistry and the exported rock tonnage are analysed and point out the importance of caverning, which takes place in Triassic gypsum and salt formations.

Deposits and superficial formations of the Larzac central: morphological roles and interest for the palaeo-landscape reconstruction
Laurent BRUXELLES
The study of post-Jurassic deposits, superficial formations which stay on the plateau or are preserved in caves permits us, together with the morphologies of landscape, to reconstitute the main steps of morphological evolution of this part of the Larzac.

In particular, the discovery of numerous witnesses of Cretaceous cover, marine and continental, let us know the first morphogenesis of the Grands Causses. After the bauxite episode, Coniacian transgression fossilized a differentiated palaeotopography under one hundred metres of sandy limestone.

After, the erosion of this deposits and the transit of various alterites, allogene or autochthonous, show further morphological steps. These formations can constitute a real cover and contribute to the development of karstic levellings.

Residual formations, associated with levels of shelves, regulate lowering of karstic surface between Eocene and Miocene, before the canyon digging and the development of karstic reculées. Then, between Miocene and Quaternary, karst de-clogging changes radically the evolution of the plateau surface and let appear poljes, dolines and underground network. Only some specific areas can keep their cover of alterites and maintain, temporally, an old functioning.

Evidence of the "renard" phenomenon during exceptional floods of the Boulet-Blagour springs (Causse de Martel, Lot)

Jean-Paul FABRE and Alain PERRINEAU

Every three or four years there is an exceptional flooding, different from the numerous floods observed each year at the Boulet and Blagour karstic springs. Not only is the intensity of this phenomenal flood different but so is its mechanism. Its interpretation needs the realisation of a reduced model that displays a mechanism similar to the "renard" effect or fluidisation, well known by hydraulicians (dam construction) and ignored until now by hydrologists.

ABSTRACTS BCRA CAVE SCIENCE SYMPOSIUM, SCHOOL OF EARTH SCIENCES, UNIVERSITY OF LEEDS, LEEDS, UK, MARCH 2002

Bats in British caves

Prof. John ALTRINGHAM
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We have known for a very long time that many bat species in temperate parts of the world hibernate in caves during the winter months. It is also not unusual to find occasional bats in caves during the summer. I will review what we already know about bats and caves, showing why underground sites are so important to bats and how they fit into a bat's life history strategy.

Recent studies have now shown that very large, transient populations of bats are visiting caves and other underground sites in late summer and autumn - an event we call swarming. I will describe some of our recent work on late summer swarming activity in the Yorkshire Dales and North Yorks Moors National Parks. Swarming can be a very spectacular event at some caves and may well prove to be a critical time in the life of many of our cave roosting bats. Bats appear to visit key sites to mate, and may travel considerable distances to get there. Catchment areas can be large and in some instances the visiting bat population may be a significant proportion of the region's total for some species.

Caves have traditionally been surveyed for bats by underground, winter inspection, and few bats are usually seen. It is probable that most individuals of most species hide in crevices and are missed, leading to an underestimate of the bats present. Surveys by echo location recording and trapping at cave entrances in autumn, the period leading up to hibernation, suggest we need to re-evaluate the importance of many caves to bats.

Engineering impacts of karst:
A review of some engineering aspects of limestone weathering, with case studies from Devon and Ireland

Christopher PRESDEE
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The research aims to review the nature of karstic limestone terrains and the implications for engineering practices as a result of the uniquely difficult ground conditions they present. Case studies are included to highlight two very different, yet apparently common, engineering problems on karst. This abstract deals only with Linhay Hill Quarry in Ashburton, Devon, where pinnacled rockhead and clay infilled dissolution pipes present problems in the extraction and processing of the limestone for use as aggregate.

The quarry has been in existence for over a hundred years and the current owners are drilling and blasting the Devonian limestone and processing it for a variety of purposes, notably as aggregate for concrete, macadam and unbound applications. In the quarry, the rock is fairly evenly bedded and dipping towards the east. Near the ground surface it is extensively dissolution weathered, to form a karst surface that is now buried by more recent deposits. The extensive karst topography gives considerable problems, currently on the north side, where the intimate mixture of dissolution weathered limestone and later infilling clays and sandy sediments makes drilling and blasting difficult, and the clastic residue contaminates the limestone material.

On the basis of the work carried out, the following summary of findings is presented:

- Using published engineering classification schemes (Waltham, 1999), the Chercombe Bridge Limestone in and around Linhay Hill Quarry has been classified as Class III to IV Karst ('Mature' to 'Complex' Karst).
- The origin of the karst is proposed to be the result of a combination of sub-tropical climate and localized valley conditions in the early "Tertiary". Subsequently, weathering and erosion of the Dartmoor granite and adjacent Cretaceous rocks provided fluvial sediment to infill the dissolution channels and cavities in the limestone.
- The physical effects of weathering have been shown to reduce the strength and density of the limestone while increasing the water absorption. This has implications for the quality of aggregate produced in the quarry.
- The chemical effects of dolomitisation and dissolutional weathering have been shown to produce a highly variable material in the quarry. Residual insoluble minerals were found to be distributed randomly, and they exhibited typically high densities, high absorptions and high clay and iron oxide/hydroxide contents.
- The nature of the infilled, karst together with the effects of weathering mentioned above has significantly affected the workings of the quarry with considerable cost implications. they are listed (in no particular order) as follows:
  - Overburden stripping is extremely time consuming and costly.
  - Drilling times are increased when drilling through clay infilled fissures/cavities.
  - Blast hole surveying techniques must be enforced due to the variable ground.
  - Blast charge restriction must be enforced, resulting in reduced primary fragmentation.
  - Dolines are induced in the surrounding farmland.
  - Increased cost of washing/scrubbing clay coated 'contaminated' rock.
  - Clay materials are not always removed, resulting in reduced efficiency of processing plant.
  - The quality of aggregates is impaired by variable rock properties and the presence of clay.
  - Implications for concrete and mortar include potentially reduced workability, strength and durability.

Passage wall coatings in active phreatic conduits in the Yorkshire Dales

Phillip MURPHY
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In active phreatic conduits in the Yorkshire Dales, rock surfaces are coated with a characteristic dark brown slime. This material is absent in areas subject to direct abrasion by moving sediment (Murphy and Cordingley, 2000). The brown material is believed to be derived from peat in the surface catchment of the cave system and supports a population of bacteria and other microorganisms.

Recent work in the Main Passage of Joint Hole, a completely flooded cave system in Chapel-le-Dale, North Yorkshire, revealed two distinct and adjacent scallop distributions (Murphy, Hall and Cordingley, 2000). A possible explanation for these phenomena is that the scallops on the roof and walls of the passage have been protected by the presence of the brown coating. Active scallop formation may only be occurring on the floor, where the coating is removed due to the scouring effects of sediment movement.

Murphy, P J and Cordingley, J N, 1999. Some observations on the occurrence of channel karren-like features in flooded karst conduits in the Yorkshire Dales. *Cave and Karst Science*, Vol.26, No.3, 129-130.

Murphy, P J, Hall, A and Cordingley, J N, 2000. Anomalous scallop distributions in Joint Hole, Chapel-le-Dale, North Yorkshire, UK. *Cave and Karst Science*, Vol.27, No1, 29-32.

Rockhead Spring, Buxton: Karst water from a bottle!

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Rockhead Spring is some 2km southeast of Buxton on the western bank of the River Wye, close to its junction with the Cowdale dry valley (SK08657225). Until the mid 1970s water from the spring, which has also been known as Cow Dale Spring and Pig Tor Spring, was pumped by a hydraulic ram to Cowdale village, where it formed the potable supply. The hydrochemistry of the spring was studied by Noel Christopher from 1977 to 1979 and by David Raper from 1986 to 1988. Both found the chemistry to be remarkably stable. In 1997 the owner of the spring commissioned further research that led to a successful application for recognition of the spring as a natural mineral water and the granting of an abstraction licence. A pipeline linking the spring to a new bottling factory was completed in the autumn of 2001, and production will commence early in 2002. The paper will present details of the hydrogeology and geochemistry, together with the process of obtaining recognition as a mineral water.

Chaos and non-linearity:
Drip-water hydrology at Stump Cross Caverns, Yorkshire, England

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Stump Cross Caverns is an upland cave situated in a highly fractured inlier of Carboniferous limestone in northern England. The site has a long history of previous research that has focused on bone deposits, the dating of speleothem growth, carbon-isotope studies of speleothem calcite, and pollen records preserved in stalagmites. This research aims to make a long term (4 years of data to date,with data collection continuing) integrated study of drip-water hydrology and geochemistry at the site, with emphasis on stalagmite-forming drip-waters where the stalagmites themselves might later be used for palaeoclimatic analysis.

Five sensors have been deployed in the caverns since 1998, at drip sites that have a wide range of discharges. The drip-water sensors work on a vibrating drum principle, every time a drip falls onto the drum it vibrates and this signal is converted into an electrical pulse and a record of the pulses is downloaded to computer every 15 minutes. All of the stalagmites monitored in the Stump Cross project have a different response to surface climate. Sites with a higher mean drip rate have a greater drip variability and a more rapid response to surface rainfall. More surprisingly, four sites (stalagmites 1, 2 and 3 and flowstone 7) show a non-linear response, with very rapid increases in dripping after some high intensity rainfall events. For stalagmite 3 this is despite a relatively low mean drip rate. All three stalagmite sites have regular "candlestick" stalagmites forming beneath them.

Relatively slow (>40 drips/hour) drip rate sites in Stump Cross Cavern show similar non-linear properties to those previously observed at a larger scale (10-100km2) in karst springs in the French Pyrenees. Further research is needed to see if similar non-linearities occur at such low drip rates in other cave sites, for example with a greater depth below the surface and different geology and geological structure. Additionally, further statistical treatment of Stump Cross results, using non-linear techniques, is in progress. Results suggest that for the stalagmite palaeoclimatologist, there is a choice. The first choice is to work with very slowly dripping sites (<<40 drips/hour at Stump Cross), where non-linearities are unlikely but where any climate signal is smoothed/lagged. The second choice is to work with faster dripping sites, but with an understanding of the individual non-linear drip-hydrology of the sample and how to interpret its impact on stalagmite geochemistry and growth.

Karstic plumbing deduced by combined modelling of hydrological and hydrochemical data (Browns Folly Mine, UK)

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Two of the incentives for improving our understanding of the vadose zone of karstic aquifers are the need to model the behaviour of pollutants and the drive to find proxy indicators for palaeoclimate in speleothems formed from drip-waters. Specifically, quantitative knowledge of karstic plumbing could generate a predictive capability. Models of karstic plumbing can be approached by combining hydrological and hydrochemical data.

Here we report on a study on data from the disused limestone mines under Browns Folly, Bathford, near Bath, which contain a number of dripwater sites, associated particularly with major open joint systems. The drip sites offer a range of hydrological behaviours that fall within the seepage flow and seasonal drip categories of previous authors, and there is an overall correlation between variation in drip rate and mean drip rate. A sub-set of sites exhibits hydrological behaviour that is clearly tied to major rainfall input events. Such sites also display distinctive variations in geochemistry with drip rate. At low drip rates there is either an evidence for increased prior calcite precipitation in the aquifer above the drip (decrease in Ca), or an increase in Sr/Ca or Mg/Ca from inferred low discharge sub-sections of the aquifer, or both.

Quantitative modelling of three sites representing the full range of mean drip rates has been approached by a box modelling approach with finite time steps, initially calibrated by hydrological response to rainfall events, but tuned by the geochemical data. The results allow different conceptual models of karstic plumbing to be evaluated. In particular the relative importance of macropore flow routes through soils, and fissure flow in relation to seepage flow can be determined, and possible geometries of coupling of different flow routes can be assessed.

The creepy tale of Garrod's Pit

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When Dorothy Garrod excavated Et-Tabun Cave, Levant, in the 1930s, she uncovered a very long record of palaeolithic culture and two sets of skeletal remains that have become central to the Neanderthal debate in the Near East. As excavations proceeded she also uncovered a dip in the strata where, curiously, stone flakes also lay conformably with the dip. Further digging revealed this to be a pit, the bottom of which was never reached. The sediment pit, acting like a trap, must have developed at, or soon after, occupation - and repeatedly. Only a sand creep process can explain the phenomenon and very similar features were detected at nearby El Wad and at Kebara down the coast. We present palaeomagnetic direction data that help to explain this odd phenomenon - but the underlying cause is unknown.

Survey work in Albania: the prehistoric caves of Luigi Cardini.

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In 1999, during research into the 1930s Italian Archaeological Mission to Albania, a collection of finely illustrated archaeological notebooks was found in Rome. The notebooks were the work of the Italian mission's prehistorian, Luigi Cardini, and they showed that between 1930 and 1939 Cardini had explored the whole of southwestern Albania in search of prehistoric deposits. With the help of Albanian guides he had mapped and recorded over 60 natural caves and rock shelters, carrying out trial excavations within those showing signs of early human habitation.

Following the discovery of Cardini's notebooks, archaeologists from the Institute of World Archaeology and the Albanian Institute of Archaeology carried out two new surveys in southern Albania, with the aim of re-locating Cardini's caves and highlighting his work. The surveys had a good degree of success and managed to re-examine and assess many of the remote caves, the majority of which had only been re-visited by shepherds and had not been examined archaeologically since the 1930s. The preliminary results suggest that many of the caves still contain some of the best-preserved prehistoric deposits known in Albania today, and hold great potential for future research.

Stable isotope studies of speleothem from South African hominid sites

Philip HOPLEY
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Oxygen and carbon stable isotope analyses of Plio-Pleistocene flowstones from South Africa have the potential to provide insights into the diagenetic history, palaeoclimatic conditions of speleothem formation, and aspects of hominid palaeoecology. Petrographic and isotopic data indicate the presence of primary calcite, primary aragonite, and diagenetic fabrics of secondary calcite replacing aragonite. Preliminary data on Total Organic Carbon (TOC) of humic acids trapped in fluid inclusions within the speleothem, indicate fluctuations between C_3 and C_4 vegetation cover in the vicinity of the caves. Discrepancies between the $\delta^{13}C$ values of the organic carbon and carbonate components of the speleothem may indicate that some of the speleothem carbonate was precipitated in isotopic disequilibrium with respect to $CO_{2(g)}$ in the soil atmosphere. A combination of stable carbon isotope data from analyses of bulk carbonate, TOC and of specific organic compounds, may enable the creation of a record of Plio-Pleistocene vegetation change with implications for hominid habitats, migration and speciation.

Ryedale Windypits

Richard MYERSCOUGH
Centre for Lifelong Learning, University of Hull, UK. [Ryedale Windypits Forum Co-ordinator.]

The Ryedale Windypits, located in the Hambleton Hills within the North Yorkshire Moors National Park, have attracted archaeological and geological interest since the Rev. Buckland first described "Buckland's Windypit" in the 1800s. For the past 50 years they have been popular with cavers, and a number of new pits (for example "Blood Windypit") have been discovered and named. Recently their importance as bat roosting sites has been recognised, and many are now protected by SSSI status. The name is derived from the air that commonly rushes from the pits, especially on windy days. This phenomenon, which is now seen as having had a ritual significance to our ancestors, has parallels in the Roquefort sur Soulzon caves of Southern France and in the 'windholes' of Africa.

The Windypits are vertical fissures or 'gulls' in rocks of the Upper Jurassic Corallian Group, formed by block slides associated with cambering along spring lines at the junction with the underlying Oxford Clay Formation. They tend to form along scarp slopes, fault scarps and valley sides, and differ from the more horizontal fluvial caves in the area, such as Kirkdale Cave. The concentration of Windypits in the Hambleton Hills, west of the River Rye, is now seen to be due to stress fracturing associated with tectonic features.

Recently the Windypits Forum was set up to co-ordinate past and present research, and includes members from many disciplines and agencies: archaeologists, biologists (with interests in bats, spiders and moths), cavers, conservation bodies (English Nature and the National Park), geologists / geophysicists, landowners (Duncombe Park Estate) and Museums (Ryedale and Scarborough). Research projects presently undertaken or planned include: aerial photograph survey, seasonal bat swarming, geophysical investigations, museum specimen search, human bone dating and analysis, as well as continuing underground exploration. A recent application to the Channel 4 'Time Team' was, unfortunately, unsuccessful.

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, Worcestershire, WR13 6LF, UK. Closing dates for applications are: 31August and 31 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 31 January each year.

BRITISH CAVE RESEARCH ASSOCIATION PUBLICATIONS

CAVE AND KARST SCIENCE - published three times annually, a scientific journal comprising original research papers, reports, 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, Nottingham, NG12 5GG, UK, and Professor J Gunn, Limestone Research Group, University of Huddersfield, Queensgate, Huddersfield, HDI 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: Clive G Gardener, 23 Landin House, Thomas Road, London, E14 7AN, 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 BCRA Honorary Secretary: John Wilcock, 22 Kingsley Close, Stafford, ST17 9BT, UK.