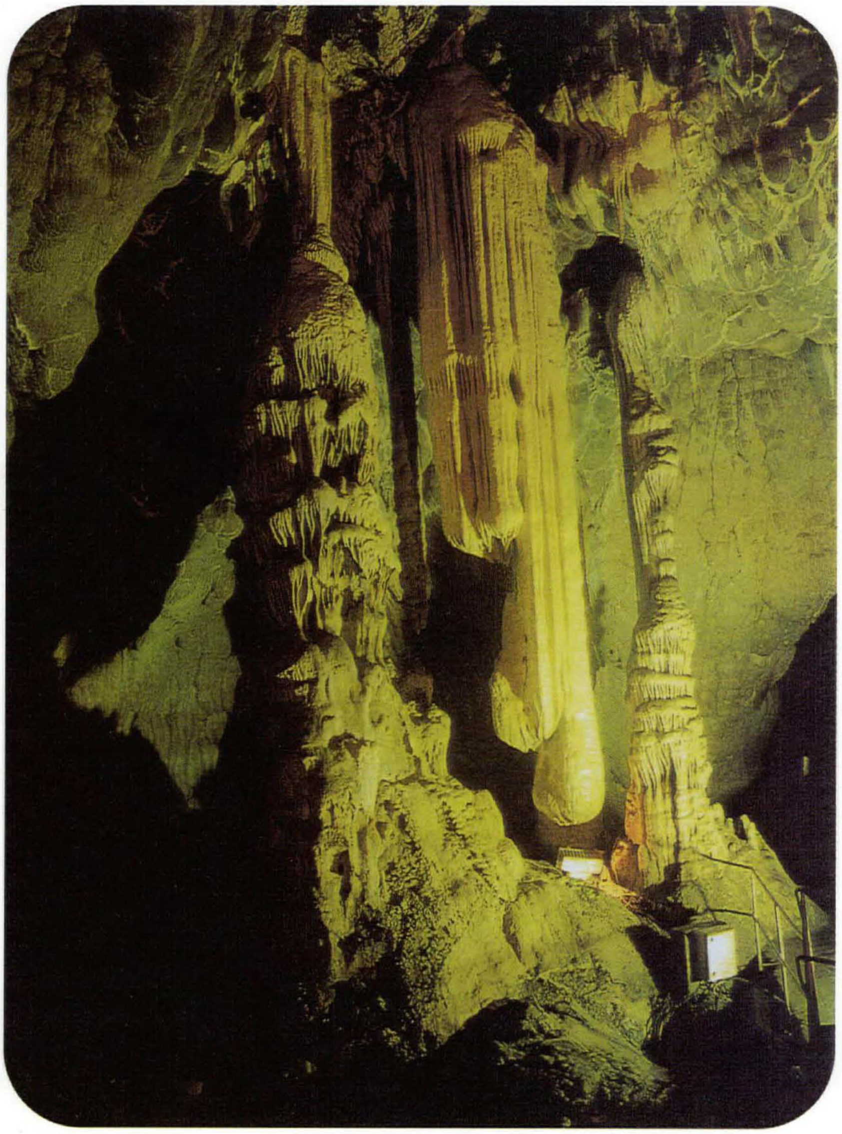
Cave and Karst Science

The Transactions of the British Cave Research Association

BCRA

Volume 26 Number 1 April 1999



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 appropriate expert assessment 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.

4. Abstracts
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, British Geological Survey, Keyworth, Nottingham, NG12 5GG, UK, and Professor J Gunn, Limestone Research Group, Department of Geographical and Environmental Sciences, The University of Huddersfield, Queensgate, Huddersfield, HD1 3DH, UK. Intending authors are welcome to contact the Editors, who will be pleased to advise on manuscript preparation. Enquiries by E-mail are welcomed, to: D.Lowe@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 be given in full, in alphabetical order, at the end. Thus: Smith, D E, 1969. The speleogenesis of the Cavern Hole. *Bulletin of the Yorkshire Caving Association*, Vol.7, 1-63. Books should be cited by their author, date, title, publisher and where published. 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.

Figures: Illustrations in a number of digital graphics file formats are acceptable for eventual publication. However, as changes to figures may be requested by referees, recommended practice is to provide hard copies with the initial submission and reference hard copies and digital files with the final draft. Authors should contact the Editors to check both the desirability of this approach and suitable file formats before submitting the manuscript. Traditional hard copy line diagrams and drawings must be in black ink on either clean white paper or card, or on tracing paper or such materials as Kodatrace. Anaemic grey ink and pencil will not reproduce! Illustrations should be designed to make maximum use of page space. Maps must have bar scales only. If photo-reduction is contemplated, all letters and lines must be large and thick enough to allow for their reduction. Letters must be done by stencil, Letraset or similar methods, not hand-written. Diagrams should be numbered in sequences as figures, and referred to in the text, where necessary, by inserting (Fig.1) etc. in brackets. A full list of figure captions should be submitted on a separate sheet or on a new page following a hard page break in digital files.

Photographic plates are welcome. Photographs in various digital formats can be handled but, as only a selection of illustrations provided with a manuscript may be included in the final publication, recommended practice is to provide hard copies with the initial submission and reference hard copies and digital files with the final draft. Authors should contact the Editors to check both the desirability of this approach and suitable file formats before submitting the manuscript. Traditional hard copy photographs are equally acceptable and may be good clear black and white prints, colour prints or colour transparencies with sharp focus and not too much contrast. Prints about 15 x 10cm (6 x 4 inches) are best; if in doubt, a selection may be submitted. They should be numbered in sequence but not referred to in the text, except where essential and then only after discussion with one of the Editors. A full list of plate captions, with photographer credits where relevant, should be submitted on a separate sheet or on a new page following a hard page break in digital files.

Tables: These should not be included in the text but should be typed, or clearly hand-written, on separate sheets or on a new page following a hard page break in digital files. All tables, especially those provided in digital form, should use a simple format to allow ready translation into an appropriate publication style. They should be numbered in sequence, and a list of captions, if necessary, should be submitted on a separate sheet or on a new page following a hard page break in digital files. Authors may mark approximate locations for tables, plates and figures, in pencil in the manuscript margins, as a guide to formatting for publication.

Copyright: It is the author's responsibility to obtain written permission where necessary to reproduce all material submitted for publication. Copyright on articles published in *Cave and Karst Science* rests with the British Cave Research Association.

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 26 Number 1 April 1999

Contents

Cover photo:
Ballıca Cave, Tokat, Turkey
For many, the beauty of caves lies not in their chambers, shafts, waterfalls and stream passages, but in the wealth and variety of calcite speleothem formations that they can contain. Unusual and spectacular pendulous stalactites in Ballıca Cave in Turkey (Canik *et al*, this issue) are described by the authors as "leek-shaped" and, together with adjacent columns, they provide a fine illustration of the variety of size, shape and colour that can be displayed by these secondary deposits.

Cave and Karst Science is published three times a year by the British Cave Research Association and is issued free to all paid up members of the Association.
The 1999 subscription rate to Cave and Karst Science is £16.00 per annum (postage paid).
Details of annual subscriptions to *Cave and Karst Science*, and of Association membership, can be obtained from the BCRA Honorary Secretary, Dr John Wilcock, 22 Kingsley Close, Stafford, ST17 9BT, UK.The Association's permanent address is: BCM BCRA, London WC1N 3XX.
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.

ISSN 1356-191X

EDITORIAL

John Gunn and Dave Lowe

In previous editorials we have commented on the unique status of cave science in its reliance upon input from 'non-academic' volunteers. Some of those who assist have a genuine interest in cave science that has grown out of their recreational caving. These individuals may be likened to the 'amateurs' without whom many archaeological digs would not take place, and who form the heart of most wildlife trusts and similar bodies. Sadly, the number of British cavers with such an interest seems to be declining. The proportion of 'professional' academic speleologists [essentially University employees and their students] to non-academic delegates at events such as the British Cave Research Association Cave Science Symposium seems to increase year by year. The 1999 Symposium at Nottingham Trent University, the abstracts from which are published in this Issue, is a case in point, with no papers from cavers unrelated to the University sector. We regard this situation as regrettable, and would welcome suggestions on how the build-up of a more healthy population of 'amateur' cave scientists might be fostered in Britain. As *Cave and Karst Science* has a growing international readership, we would also be interested to learn of related trends in other countries, and of any initiatives to encourage cavers to become better informed scientifically. One initiative that we certainly welcome is a renewal of interest in cave faunas, and we hope that the letter in Forum from Knight and Wood will elicit a good response. Also in Forum is a letter concerning bones handed over to the University of Leicester Department of Geology. Readers who know their history will note that Eli Simpson, a sporting caver and founder of the BSA, was involved in their discovery and excavation. More recently a ' dig' in the Peak District led to an exciting archaeological find, which was reported by Andrew Chamberlain at the 1999 Cave Science Symposium.

In addition to this need to foster a body of 'amateur' cave scientists, there is an equally urgent need for Britain's recreational cavers to become more active in the protection of cave environments. Somewhat surprisingly, there seems to be an attitude amongst some that pollution should be tolerated, unless it is so bad that it actually prevents access to a cave. We are aware of cases where cavers have indicated that they knew who was responsible for illegal dumping [in one case of carcasses], but did not wish to inform the relevant authorities, in case the source of the complaint was traced and access restrictions were imposed by way of retaliation. While acknowledging that such fears may be justified, as borne out by events on Mendip some years ago when certain cave SSSI were notified, there is surely an obligation on us to do everything in our power to protect the underground environment. That environment is very fragile and, whereas all cavers must be aware of the potential for damage to speleothems, there seems to be less understanding of cave life, which can be devastated by levels of pollution that may cause little or no annoyance to recreational cavers. Recently, large amounts of paper, and other waste, have been deposited in the Castleton area of the Peak District. The mounds of waste, and the large numbers of trucks bringing waste into the area, must have been seen by cavers. At least one has said that he assumed it was legal, and hence never mentioned it. Fortunately, another person, having read an appeal for information on pollution in another area [Monyash], telephoned JG to report the Castleton waste and speculate that similar dumping might be the cause of the pollution at Monyash. While this is not the case, a call to the Environment Agency revealed that they were unaware of the Castleton dumping, and the matter is currently under investigation.

The material dumped at Castleton is on the surface, where others might reasonably be expected to take notice, but cavers are the only people who can be expected to provide information about underground situations. Such information must be factual and timely. There is little point mentioning a pollution incident several weeks after it took place, when all evidence has disappeared. In the case described above it seems that liquor from the waste entered Peak Cavern, but was sufficiently diluted by the stream that it was not noticeable at the rising or downstream. However, it may well have wiped out entire aquatic invertebrate communities in the cave, which included at least one nationally notable species. Perhaps we are preaching to the converted, as only those with some interest in cave science, and hence, hopefully, in the protection of cave environments, are likely to have read thus far. However, this is an important issue and it behoves all cavers to think seriously about it.

In bringing this editorial to a close we regret that yet again it is our sad duty to mark the passing of another stalwart of British caving, Bryan Ellis. No doubt other, fuller, epitaphs will appear in due course, but it is particularly appropriate that we recognise Bryan's contribution in this editorial, as he epitomised the type of 'enthusiastic amateur caver' that we would hope to encourage. His particular interest was in cave surveying, a topic about which he wrote various papers and the book *'Surveying Caves'*, a standard reference for several generations of cave surveyors. As an aside, it is worth noting that accurate surveys are essential to most cave research, and their production is one of the most important contributions to science that can be made by the 'ordinary' caver. The word 'research' leads us back to Bryan, as he argued consistently that the whole *raison d'etre* for BCRA was cave research, even if the majority of its members never undertook any! In this we are, inevitably, in full agreement.

Much of Bryan's work for the Association was related to one aspect or another of publications, whether as a contributor, editor or simply as a sales agent. The latter task was passed on only relatively recently to Ernie Shield, and it is one of those sad twists of fate that in the same editorial where we must remark upon Bryan's passing, we have been asked to mention a welcome initiative to make past BCRA publications more easily affordable. As part of the BCRA's 25th Anniversary Sale, all available pre-1996 issues of *Cave (and Karst) Science* and *Caves and Caving* are available to BCRA members for £1-00 per copy (plus postage). Binders that will hold 12 copies of these publications are also being offered for £4-00 each (plus postage). The first 7 titles from the *Cave Studies* series (of which Bryan Ellis was Series Editor) are available at £2-50 each (plus 30p postage), while the excellent *"Limestones and Caves of Wales"*, edited by Trevor Ford, has been reduced from £40-00 to £10-00 for BCRA members, or £15-00 for non-members (plus £3-75 postage in both cases). All of these publications are available from Ernie Shield, at the address given at the foot of the inner back cover.

Finally, tributes to Alfred Bögli and P B Smith in the editorial of Issue 25(3) displaced our normal editorial recognition of those who assisted with the production of Volume 25. Thanks are due to our referees: Simon Bottrell, Andy Farrant, Trevor Ford, Chris Hunt, Stein-Erik Lauritzen, Mike Simms, Tony Waltham, Paul Wood, and all those who worked with Fiona Whitaker to review the thematic papers that appeared in Issue 25(2). Fiona is also thanked, somewhat belatedly, for her painstaking and much appreciated work as Guest Editor of the latter Issue. Finally, we thank Jean Reeve for her continuing understanding and stalwart efforts in dealing with a growing spectrum of desk top publishing aspects, and the Sherwood Press for the high standard of the final product.

CAVE AND KARST SCIENCE Vol 26, No. 1, April 1999
Transactions of the British Cave Research Association

The Inception Horizon Hypothesis in vertical to steeply-dipping limestone: applications in New South Wales, Australia

BCRA

R Armstrong OSBORNE
School of Professional Studies, A22, University of Sydney, N.S.W. 2006, Australia

Abstract: The Inception Horizon Hypothesis has generally been applied to explain cave morphology in horizontal or gently-dipping limestones. When applied to vertical or steeply-dipping limestones, the Inception Horizon Hypothesis offers explanations for many characteristic features of the small impounded karsts found in the Eastern Highlands of New South Wales, Australia. In vertical or steeply-dipping limestones a limited number of pathways through the limestone are available, resulting in the development of multilevel passages and an increased likelihood of modern caves intersecting and/or exhuming palaeokarstic features. The few hydrological pathways through the limestone are easily blocked by sediment, abundant in small, impounded karsts, resulting in flow switching with surface streams and the consequent development of lateral dry valleys. Partial sediment blockage will result in paragenetic enlargement of passages, allowing relatively small streams to produce large, out-of-scale conduits with a "keyhole" cross-section, and paragenetic loops that can be misinterpreted as phreatic loops.

INTRODUCTION

Previous Work

The Inception Horizon Hypothesis (Lowe, 1992; Lowe and Gunn, 1997) seeks to explain the location and growth of the initial sub-conduits from which caves later develop in karstic rocks, by postulating that they are most likely to form along particular lithostratigraphical features called inception horizons. Lowe (1992, p.114) defined an inception horizon as "*...any lithostratigraphically controlled element of a carbonate sequence that passively or actively favours localised inception of dissolutional activity, by virtue of physical, lithological or chemical deviation from the predominant carbonate facies within the sequence.*"

Lowe and Gunn (1997) described four general categories of inception horizon:

> Aquifuge, aquiclude, aquitard and aquifer horizons (commonly, but not always clastic beds);
> Trans-bedding contrasts;
> Acid generating horizons;
> Physically soluble horizons.

Given the high degree of lateral facies change in many carbonate sequences, it is likely that many inception horizons will be discontinuous both laterally and along strike.

Much of Lowe's original work examined the role of inception horizons in relatively horizontal limestones, though the ready applicability of the idea to dipping situations was noted generally and by specific reference to cave development in the Mount Robson Syncline and Bocock Peak areas in the Canadian Rocky Mountains. Ongoing research elsewhere (e.g. Šušteršič, 1997; L Brown, University of Huddersfield, oral communication) has also dealt predominantly with relatively gently-dipping limestone situations. Lowe and Gunn (1997) used the Inception Horizon Hypothesis to discuss the origin of many features commonly found in limestone caves. Although the applicability of the concept to cave development in folded terrain was mentioned, for simplicity all of their diagrams illustrated horizontally bedded situations.

Karst of eastern New South Wales, Australia

Many of the best-known and most cavernous karsts in New South Wales, are developed in small bodies of Siluro-Devonian limestone within the Lachlan Fold Belt, exposed in deeply-incised terrain along the margins of the Eastern Highlands (see Osborne and Branagan, 1988) (Fig.1). The limestones are mainly carbonate shelf/platform facies, overlain by marine muds and volcaniclastic rocks. No evidence has yet been found of exposure and/or karstification affecting these limestones prior to major episodes of folding during the Palaeozoic. With the regional tectonic grain orientated generally north-south, many of these limestones have steeply-dipping beds, which strike north-south and form narrow, elongate outcrops that taper at their northern and southern ends (Fig.2).

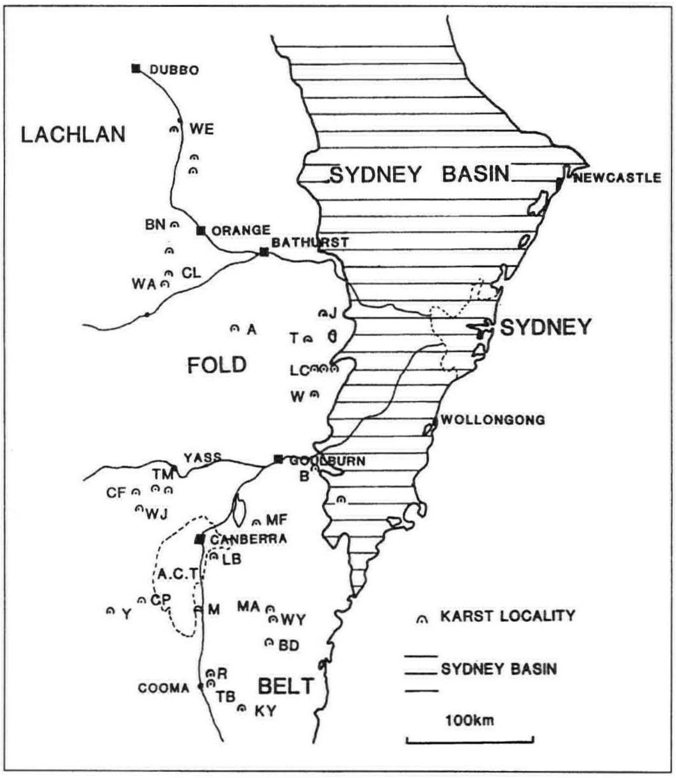


Figure 1. Major cavernous karsts of the Lachlan Fold Belt in New South Wales, after Osborne (1984): A = Abercrombie, B = Bungonia, BD = Bendithera, BN = Borenore, CF = Cave Flat, CL = Cliefden, CP = Cooleman Plain, J = Jenolan, KY = Kybean, LB = London Bridge, LC = Colong, M = Michelago, MA = Marble Arch, MF = Mount Fairy, T = Tuglow, R = Rosebrook, TB = Toll Bar, TM = Taemas, W = Wombeyan, WA = Walli, WE = Wellington, WJ = Wee Jasper, WT = Wyanbene, Y = Yarrangobilly.

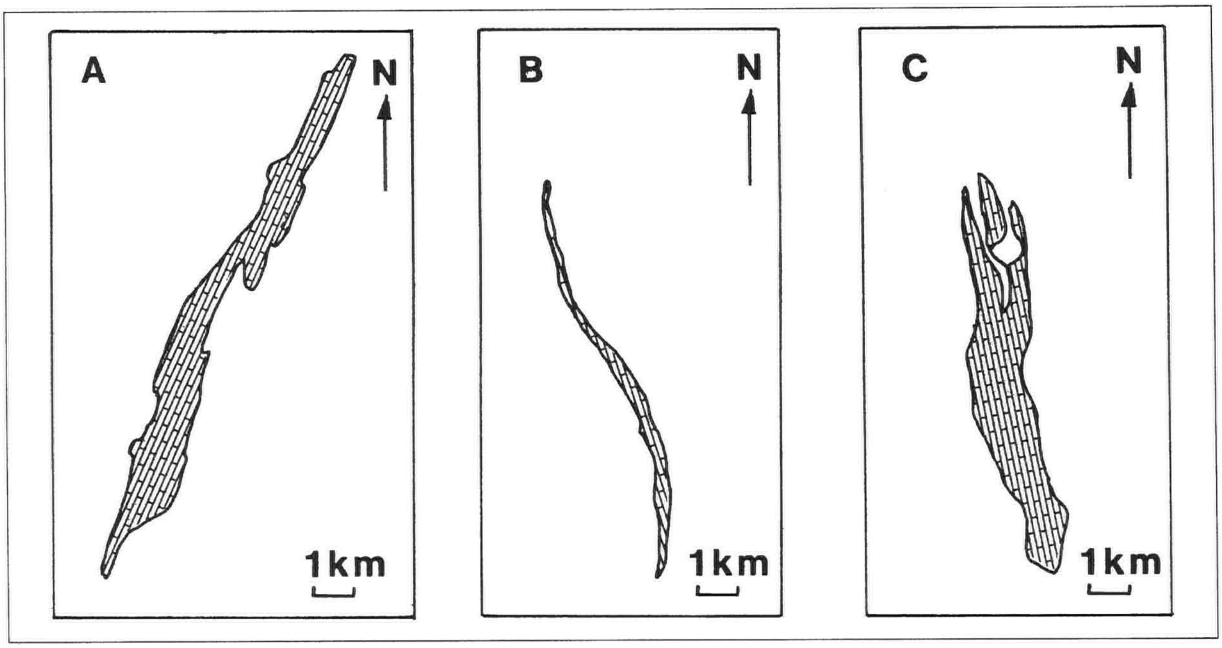


Figure 2. Outcrop maps of limestone bodies forming three of the most cavernous impounded karsts developed within the incised margins of the eastern Highlands of New South Wales. A = Bungonia Caves, B = Jenolan Caves, C = Yarrangobilly Caves. Note the north-south orientation, short strike length, narrow outcrop width and small area of limestone.

Caves are typically developed with their major axes oriented along strike, and many display multi-level passages. Upper level passages are commonly filled, or part filled, with cemented silicic sands and gravels. Sheer limestone cliffs, gorges, dry valleys and natural bridges, locally known as arches, are prominent surface features of these karsts. It is common for caves in these karsts to intersect and expose palaeokarst deposits (Osborne, 1984, 1993b, 1995) and/or have close genetic relationships with hydrothermal ore deposits (Osborne, 1996). In some cases the present cave passages are exhumed ancient passages (Osborne, 1993c). Karsts and caves developed in the more western parts of the Lachlan Fold Belt and in the New England Fold Belt of New South Wales are quite different in character.

Examples

The following examples should be considered as theoretical. Many of the cases discussed to illustrate situations that may arise in vertical or steeply-dipping limestone are based roughly upon real occurrences found within the impounded karsts of New South Wales. However, inception horizons have yet to be investigated in detail in the field in eastern Australia, so any comparison between real places and the idealised examples described remains speculative. Where a case or diagram is based upon a real situation this is indicated in the text, or in the figure caption.

INCEPTION HORIZONS IN STEEPLY-DIPPING LIMESTONES

In the discussion that follows, several simplifying assumptions are made:

1. Inception horizons are widely spaced both physically and stratigraphically within the limestone mass;
2. The limestone between the inception horizons, except where otherwise indicated, is mechanically strong, massive and chemically pure;
3. Despite multiple tectonism, beds and/or planar structures parallel to bedding are the principal features guiding speleogenesis;
4. Other than inception horizons, planar joints are the only features present that can guide or inhibit cave development;
5. There was no karstification, or only insignificant karstification, prior to the limestone being exposed after a major folding event.

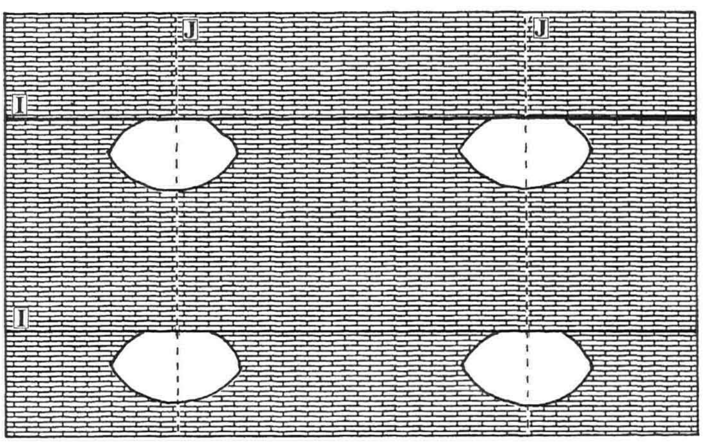


*Figure 3. Cross-section of horizontally-bedded limestone perpendicular to major joint direction showing phreatic passage development. "I" = inception horizons, "J" = joints. The **vertical** position of the cave passages is guided by inception horizons whereas their lateral position is guided by vertical joints.*

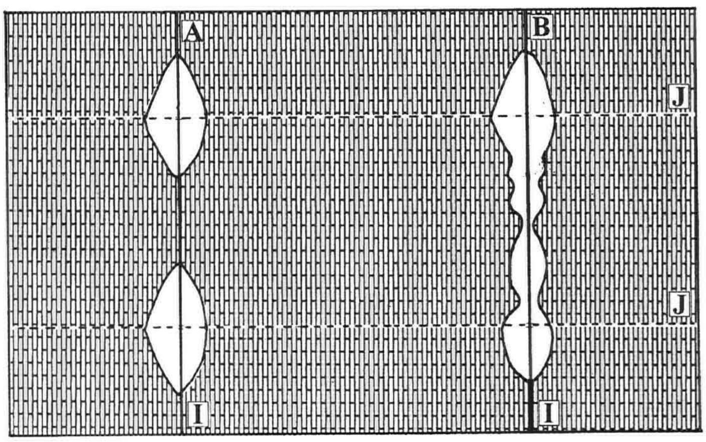


*Figure 4. Cross-section of vertical to steeply-dipping limestone body perpendicular to strike direction, showing phreatic passage development. "I" = inception horizons and their projection through the axes of the caves, "J" = joints. The **lateral** position of cave passages is guided by inception horizons whereas their vertical position is guided by vertical joints and/or hydraulic gradient. In "A" two phreatic passages have developed at different topographical levels along the same inception horizon. In "B" the two passages have been joined by subsequent vadose action.*

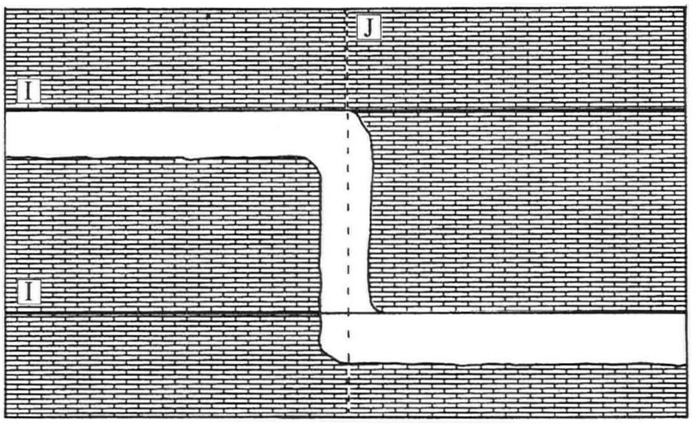


Figure 5. Cross-section of horizontally-bedded limestone body perpendicular to major joint direction showing phreatic cave development. "I" = inception horizons, "J" = joint. Passage guided by upper inception horizon is captured via vertical joint-guided shaft to passage guided by lower inception horizon.

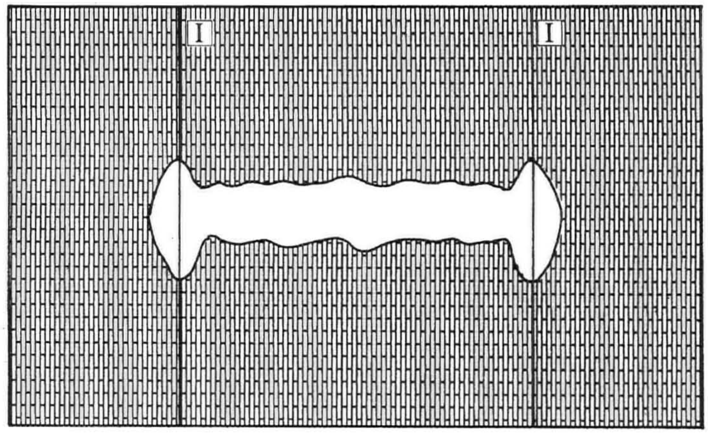


Figure 6. Cross-section of vertical to steeply-dipping limestone body perpendicular to strike direction along line of major cross-joint, showing phreatic cave development. "I" = inception horizons and their projection through the axes of the cave. Passages guided by left and right inception horizons are joined by horizontal (or more likely sloping) passage guided by cross-joint.

Inception horizons and cave development

Two simple situations are considered to compare and contrast the likely influence of inception horizons on cave development in limestones with gentle dip with that in limestones with steep dip, both in massive, compact limestone:

1. Inception horizons are **horizontal** and widely spaced;
   Joints are planar and vertical (Fig.3).
2. Inception horizons are **vertical** and widely spaced;
   Horizontal planar joints may or may not be present;
   Vertical planar joints may be present (Fig.4).

In horizontally-bedded or gently-dipping limestone the vertical position of cave passages is guided by inception horizons, whereas the lateral position of some cave segments may be guided by vertical planar structures such as joints (Fig.3). Following the interpretation of Lowe and Gunn (1997), where conduits exist at more than one level it is likely that upper and lower level conduits began to form at the same time, under artesian or phreatic conditions.

In vertical or steeply-dipping limestone the lateral position of cave passages is guided by vertical inception horizons, whereas their vertical position can be guided either by horizontal planar joints ("A" in Fig.4) (with both upper and lower conduits forming under artesian or phreatic conditions, see above) or by hydraulic constraints acting upon the karst system ("B" in Fig.4). As a result of both of these processes it should be common for conduits to develop at different vertical levels, one above the other, along the same inception horizon.

In horizontally-bedded or gently-dipping limestone, sub-vertical joints will permit caves to develop between one inception horizon and another (Fig.5). Where the bedding is inclined, these connections can lead to the development of phreatic loops.

In vertical or steeply-dipping limestone, vertical joints aligned perpendicular to bedding will permit caves to develop laterally between one inception horizon and another (Fig.6) and will also permit the progressive lateral capture of surface streams running parallel to strike (Fig.7).

Where inception horizons are a significant distance apart stratigraphically (e.g. in pure limestones deposited under constant depositional conditions) there may be a considerable thickness of limestone between conduits, or only a single level of cave development.

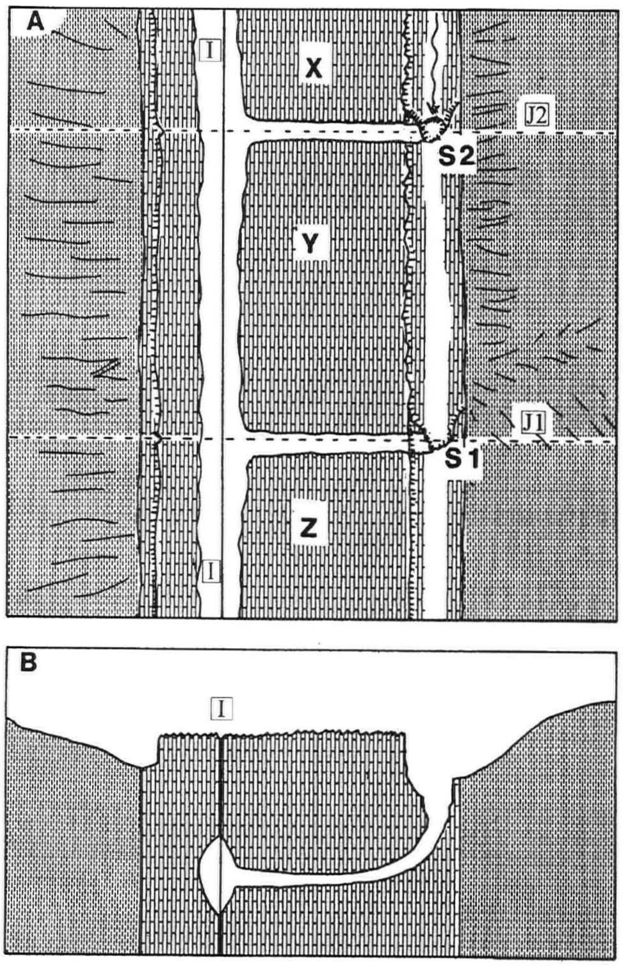


Figure 7. Sequential capture of a surface stream along cross joints, "J1" and "J2" by cave guided by inception horizon in vertical to steeply-dipping limestone. "I" = inception horizon and its projection through the axis of the cave.
A. Plan view. Stream is first captured by J1 and then after further incision by J2. "S2" is the active stream sink and "S1" is the former stream sink. The valley below "S2" is dry. Note caves are unlikely to develop in zones, "X", "Y" and "Z" with no inception horizon and between major cross-joints.
B. Section along plane of joint "J2". "I" is the inception horizon and its projection through the axis of the cave.

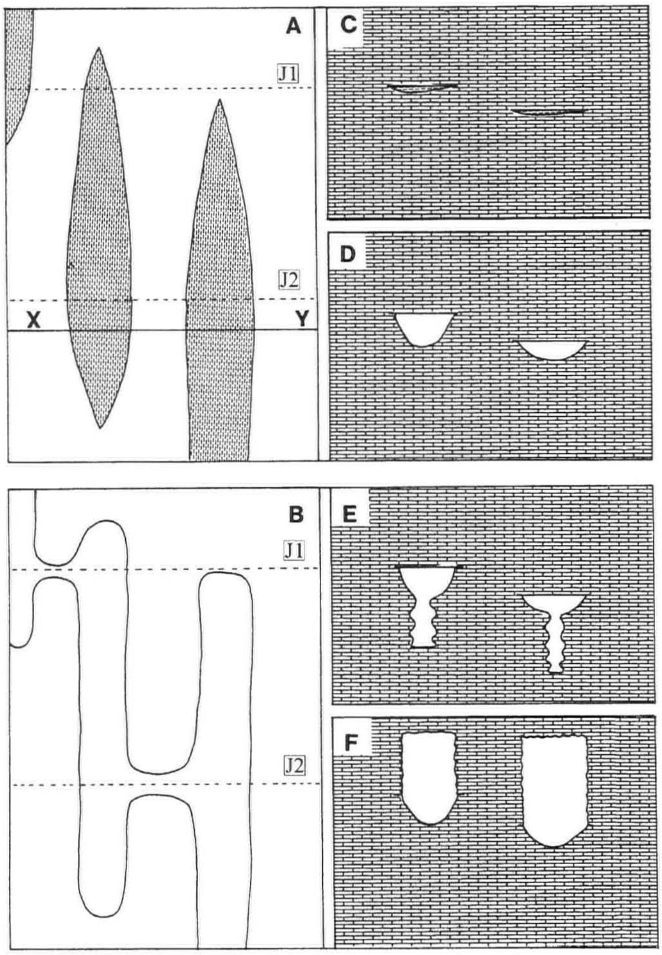


Figure 8. Cave development guided by lensoidal inception horizons in horizontal to gently-dipping limestone. Note similarity of outcome to that shown in Fig. 3.
A. Disposition of inception horizons in limestone body in plan . "J1" and "J2" are vertical plane joints. "X-Y" line of cross-sections "C", "D", "E" and "F".
B. Plan of cave that may develop in these circumstances, note blind termination of passages.
C. Section along line "X" - "Y" showing disposition of inception horizons in limestone mass.
D. Section along line "X" - "Y" showing phreatic/artesian development guided by lensoidal inception horizons.
E. Section along line "X" - "Y" showing situation after later vadose incision.
F. Section along line "X" - "Y" showing situation after later paragenesis.

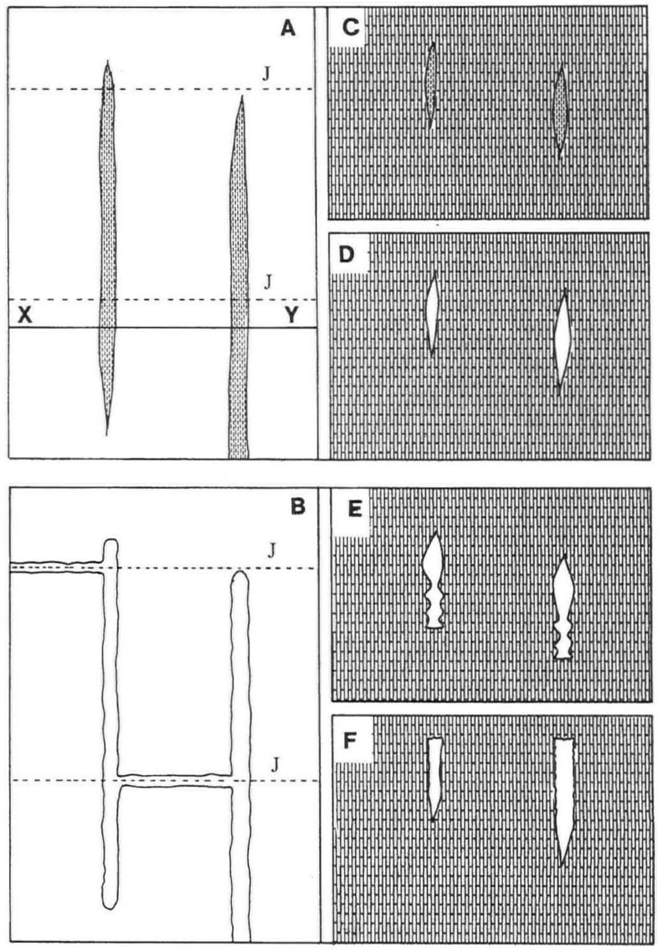


Figure 9. Cave development guided by lensoidal inception horizons in vertical to steeply-dipping limestone.
A. Disposition of inception horizons in limestone body in plan. "J1" and "J2" are vertical plane joints. "X-Y" line of cross-sections "C", "D", "E" and "F".
B. Plan of cave that may develop in these circumstances, note blind termination of passages along strike.
C. Section along line "X" - "Y" showing disposition of inception horizons in limestone mass.
D. Section along line "X" - "Y" showing phreatic/artesian development guided by lensoidal inception horizons.
E. Section along line "X" - "Y" showing situation after later vadose incision.

Wide spacing of inception horizons in vertical or steeply-dipping limestone will result in cave development being restricted (except for cross passages along joints) to those parts of the limestone mass in which inception horizons, and cross-joints intersecting inception horizons, are present. Caves are unlikely to develop in the masses of limestone bounded by the inception horizons and the cross-joints ("X", "Y" and "Z" in Fig 7). This raises the possibility of using the disposition of inception horizons and cross joints to predict where caves are most likely to be located in a particular mass of vertical or steeply-dipping limestone.

Laterally discontinuous inception horizons

In all of the cases above it is assumed, for simplicity, that inception horizons are thin (relative to the rock sequence as a whole) and laterally continuous perpendicular to strike. While aquifuge, aquiclude, aquitard and aquifer horizons (Lowe and Gunn's first category of inception horizon) are likely to be relatively thin features in a carbonate sequence, in many cases they will not be extensive perpendicular to strike. Shale and sand bodies in carbonate sequences are commonly elongate, narrow, lensoidal features, reflecting their mode of deposition. Lateral discontinuity of inception horizons has quite different effects on later cave development in horizontally-bedded or gently-dipping limestone and in vertical or steeply-dipping limestone.

Fig.8 illustrates inception and later cave development guided by narrow lensoidal shale or sandstone bodies in generally massive, horizontally-bedded or gently-dipping limestone. It would be extremely difficult from observation in the cave to differentiate between the situation shown in Fig.8 and that illustrated in Fig.3. Fig.8B shows the plan of a possible cave guided by these discontinuous inception horizons. Vertical joints, "J", permit development of lateral passages connecting between those developed along the isolated inception horizons. One important consequence of this form of development is that cave passages will have blind terminations. Note that later development of the cave, either by vadose incision (Fig.8E) or paragenesis (Fig.8F), is likely to preserve a trace of the inception horizon in the cave walls.

Fig.9 illustrates inception and later cave development guided by narrow lensoidal shale or sandstone bodies in generally massive vertical or steeply-dipping limestone. Although this situation is somewhat similar to that illustrated in Fig.4, there are some significant differences. Firstly, vertically stacked cave passages are less likely to form in this situation and, secondly, subsequent cave development, particularly paragenesis, is likely to destroy all trace of the guiding inception horizon. As in the case of lensoidal inception horizons in horizontally-bedded or gently-dipping limestone, passages will have

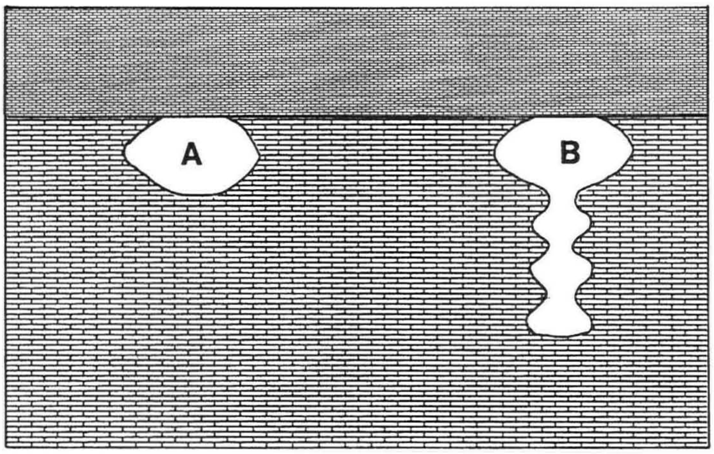


Figure 10. Cross-sections "A" and "B" showing cave development below a lithological boundary in horizontal to gently-dipping limestone. Small brick shading is thinly-bedded generally less-pure limestone, large brick shading is pure massive limestone. In "B" later cave development is generally unaffected by the presence of the thinly-bedded unit.

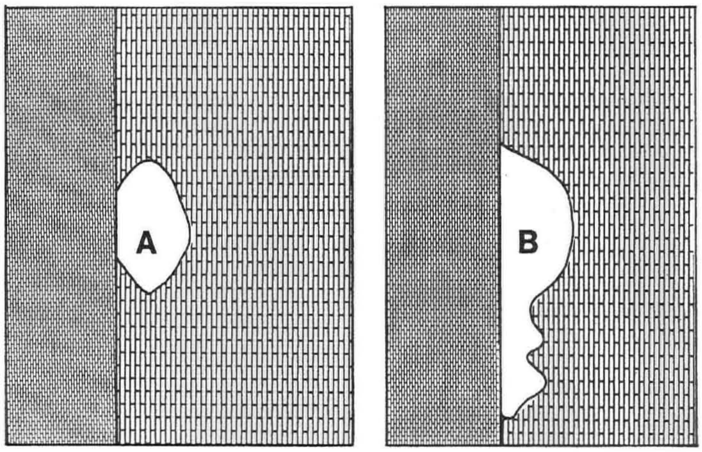


Figure 11. Cross-sections "A" and "B" showing cave development adjacent to a lithological boundary in vertical to steeply-dipping limestone. Small brick shading is thinly-bedded generally less-pure limestone, large brick shading is pure massive limestone. In "B" later cave development is laterally inhibited by the thinly-bedded unit.

blind terminations, but in this case the terminations will be along strike, and hence more puzzling (Fig.9B). Note that later development of the cave, either by vadose incision (Fig.9E) or paragenesis (Fig.9F), is likely to destroy all traces of the inception horizon in the cave roof and floor.

Inception related to lithological boundaries

In all of the cases so far considered the inception horizon is relatively thin and so could easily be removed by post-inception cave development. Inception may also occur at the boundary between massive pure limestone and thinly-bedded, commonly impure, limestone, which may contain acid-generating minerals.

In horizontally-bedded or gently-dipping limestone, caves will develop generally below the boundary, for instance at the upper boundary of an oolitic unit, as shown in Fig.2 of Lowe and Gunn (1997). This type of situation is illustrated in Fig.10. Note that in this situation the upper thinly-bedded unit will have little influence over future cave development, except, perhaps, to inhibit paragenesis.

In vertical or steeply-dipping limestone the thinly bedded unit may exercise considerable guidance over later cave development, both in plan and section (Fig.11). Whereas inception is most likely to occur along the boundary (Fig.11A), later cave development is most likely to extend into the relatively more soluble pure limestone than into the relatively less soluble impure limestone (Fig.11B).

Inception horizons and surface streams

The interaction of surface streams with limestones containing inception horizons is considered under the following conditions:

1. The body of limestone is surrounded by insoluble rocks;
2. Streams rise on insoluble rocks and flow in bedrock valleys before encountering the limestone;
3. Streams must continue to flow over insoluble rocks after their encounter with the limestone.

Where surface streams encounter bodies of gently-dipping limestones perpendicular to strike, particularly if the beds are dipping downstream (Fig.12A), the streams are likely to be captured underground by caves developed along inception horizons. This is less likely to occur if the beds dip upstream (Fig.12B).

Where surface streams encounter bodies of vertical or steeply-dipping limestone, however, cavities developed along inception horizons will not always capture streams underground (Fig.12C) and a limestone canyon may result (Fig.13). If there are cross-joints between a surface stream and an inception horizon (as shown in Fig.7), the stream may be captured progressively upstream, as headward erosion permits access to the cavity via cross-joints farther upstream.

Where a stream crossing a limestone body has not been captured it may flow along strike, at or close to the limestone boundary, producing

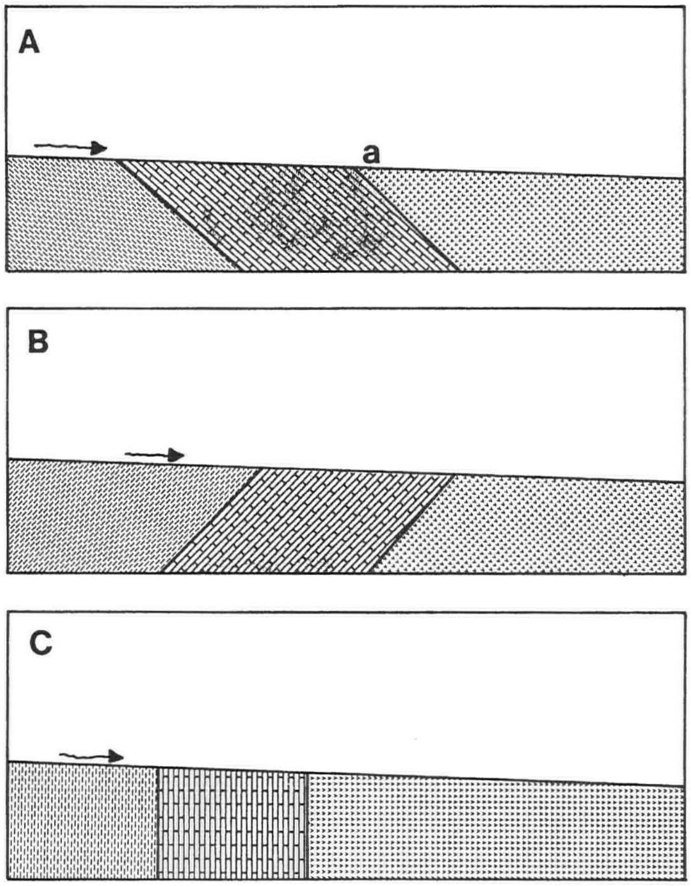


Figure 12. Cross-sections of impounded limestone bodies perpendicular to dip. Assume surface stream flow from left to right. In case "A", with beds dipping downstream, stream capture is likely to occur. Hydrological conditions in limestone will be controlled by headward erosion of the insoluble unit at "a". In case "B", with beds dipping upstream, and "C", with vertical beds, stream capture is less likely to occur, and commonly such streams will cut a canyon through the limestone. Underground capture may occur if there is a major joint perpendicular to strike.

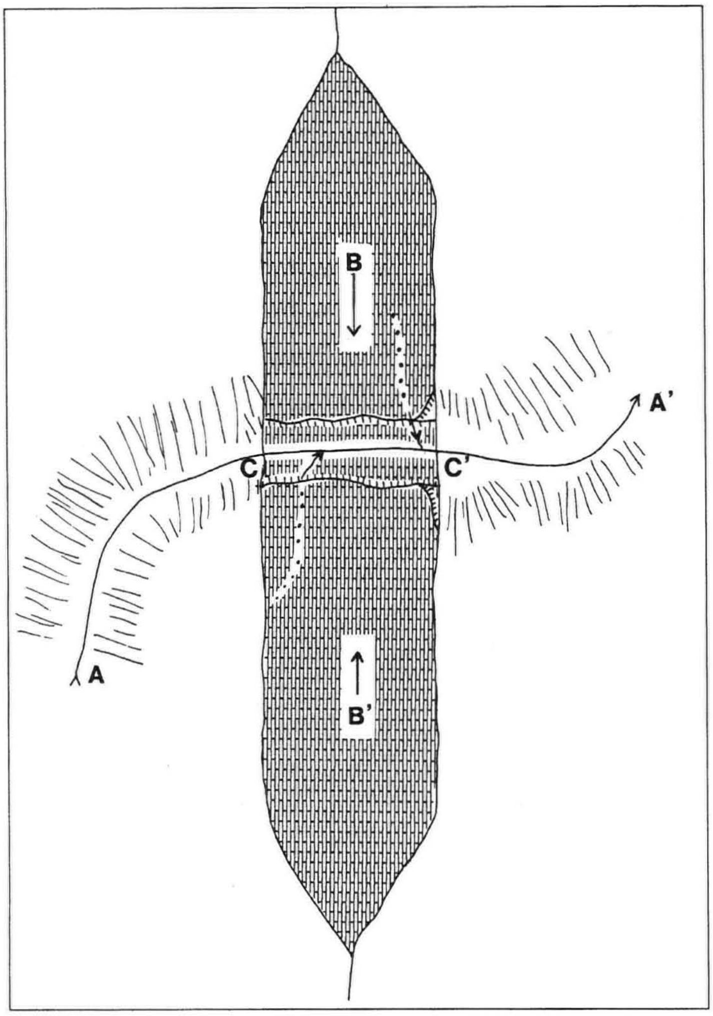


Figure 13. Plan showing stream "A"- " A' " crossing a body of vertical to steeply-dipping limestone perpendicular to strike. Hydraulic gradient in limestone, large arrows "B" and " B' ", is along strike, but towards the stream. Water cannot escape from the stream along inception horizons against the gradient and the limestone is impounded along strike. The stream is not captured underground, but incises a valley or canyon "C"- " C' " through the limestone. Based on Bungonia Caves, New South Wales.

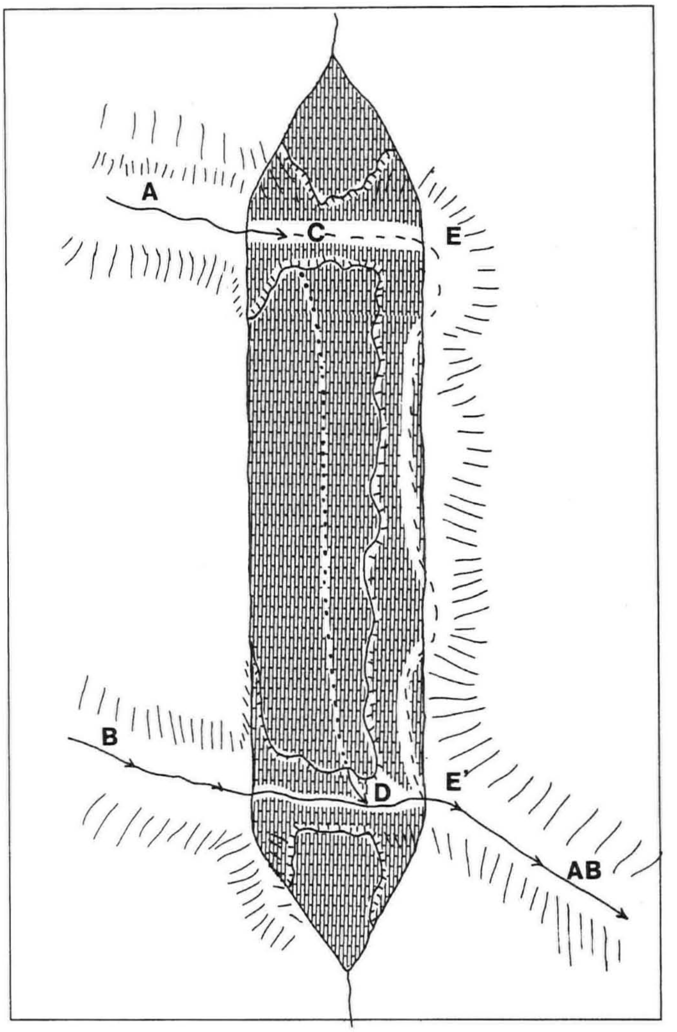


Figure 14. Plan showing vertical to steeply-dipping limestone body traversed by two streams, "A" and "B", both perpendicular to strike. Stream "A" and "B" join to form "A B" at point " E' ". After stream "A" crossed the limestone it flowed along strike close to the limestone boundary forming a marginal valley "E" - " E' " When stream "B" had incised below level of "A", a hydraulic gradient existed and stream "A" was captured along strike at "C", rising at spring "D". As a result " E - E' " became a dry marginal valley. Based on Colong Caves, New South

a marginal valley (Fig.14). A stream crossing the limestone body farther along strike ("B" in Fig.14) may expose initial conduits, allowing the first stream to be captured. This will produce a dry marginal valley along the downstream side of the limestone.

DISCUSSION

Sediment blockages of caves

One important implication of the Inception Horizon Hypothesis is that there are only a limited number of planar surfaces within limestone bodies along which inception will take place. In situations where there is a plentiful supply of clastic sediments in the catchment area, as is commonly the case with impounded karsts, underground pathways through the limestone may become blocked.

In eastern Australia streams sinking into the karsts generally have a non-limestone catchment and carry a range of materials including cobbles and pebbles of silicic volcaniclastic rock, quartz sand and mud derived from the weathering of igneous rocks and flysch. There are historical accounts of major stream caves becoming blocked by log jams as a result of flooding.

In horizontally-bedded or gently-dipping limestone, blockage of hydrological pathways can result in lateral flow-shifting within the same inception horizon, as illustrated in Fig.15. When the pathway developed along an inception horizon in vertical or steeply-dipping limestone becomes blocked the flow will be shifted laterally *and* vertically, commonly to the surface (Fig.16). In many cases marginal valley development along the lateral boundary of the limestone will result, with sequential flow-shifting occurring between underground and surface drainage. Another result could be complete blockage of underground flow paths for a considerable length of time. Osborne (1993a) proposed that complete blockage of underground drainage by sediment at Bungonia Caves, N.S.W., allowed surface incision greatly to outpace lowering of base levels in the caves, resulting in springs becoming perched almost 200m above the floor of the canyon into which they flow.

Exposure of palaeokarst deposits in caves

Ford (1996) noted that it was unusual for modern caves to intersect and exhume filled palaeokarstic cavities, except where the modern caves were the result of *per ascensum* hydrothermal, artesian or stratiform karstification. Caves developed in the karsts of eastern Australia commonly intersect and exhume palaeokarst (Osborne, 1984, 1993b, 1993c, 1995). Whereas there is evidence pointing to *per ascensum* processes in many of these karsts (Osborne, 1996), the behaviour of inception horizons in vertical or steeply-dipping limestone provides another mechanism that is likely to result in more widespread than average intersection and exhumation of palaeokarst.

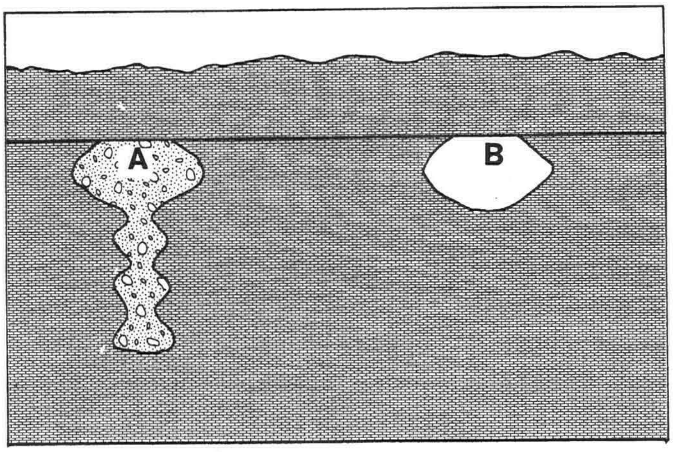


Figure 15. Section showing cave development in horizontally-bedded limestone. When cave at "A" becomes blocked with sediment a new pathway of underground drainage "B" may form following the same inception horizon. It is unlikely that Cave "B" will intersect blocked cave "A".

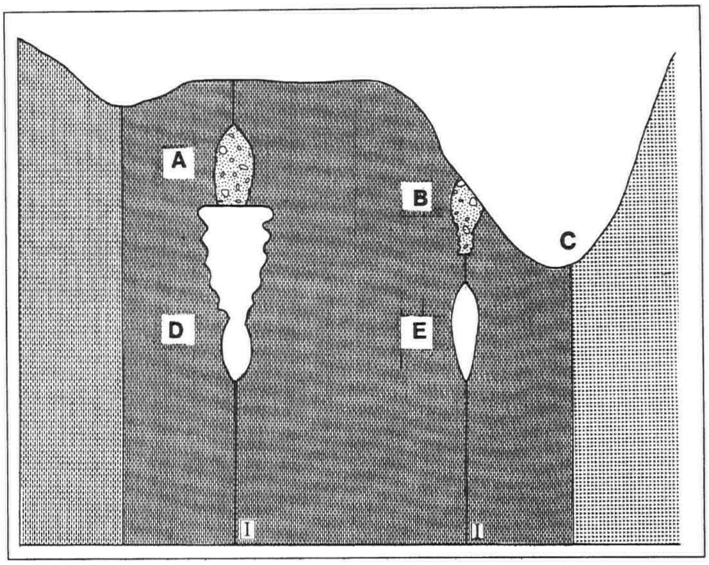


Figure 16. Section showing cave development and the effects of sediment blockage in a narrow impounded body of vertical to steeply-dipping limestone. "I" = inception horizons. Caves "A" and "B" become blocked with sediment, as no other inception horizons are present water formerly flowing through "A" and "B" flows overland excavating marginal valley "C", exposing some of the sediment filling "B" as a palaeokarst deposit. "D" and "E" form in the same inception horizons as "A" and "B" after excavation of "C". In the case of "D" paragenesis following later partial sediment blockage results in the underground exposure of sediment filling "A". Based on Jenolan Caves, New South Wales.

When ancient karsts become filled and/or buried and are later exhumed, situations similar to those illustrated in Figs.15 and 16 will result. With the exhumation of a previously buried karst in horizontally-bedded or gently-dipping limestone, an inception horizon may again become exposed at the surface. If palaeokarst deposits block a previous pathway through the limestone, a new pathway may develop laterally adjacent to the old.

In the case of vertical or steeply-dipping limestone, alternative laterally adjacent pathways may not be available and the only pathway will commonly be one along which caves formed during previous periods of surficial exposure. Exhumed caves, and exposures of palaeokarst deposits in caves, are thus more likely to be found in vertical or steeply-dipping limestone than in horizontally-bedded or gently-dipping limestone. These considerations may explain why exhumed caves and palaeokarst exposures in caves are common in eastern Australia, but are uncommon, for example, in Slovenia, where widespread palaeokarst deposits have been found in natural surface exposures and in expressway excavations.

Development of "keyhole" passages and paragenetic loops

As can be seen in Fig.17, vadose incision of phreatic passages developed along vertical to steeply-dipping inception horizons produces a passage cross-section quite unlike the classical "keyhole" shape.

Passages with a cross-section somewhat similar to that shown in Fig.17 "A" (see also "h" in Fig.52 of Jennings, 1985) do occur in eastern Australian caves developed in vertical to steeply-dipping limestone. These have been interpreted, following the examples in popular texts, as having formed from vadose incision of initially elliptical phreatic pressure tubes. Large passages with cross-sections somewhat similar to the classic "keyhole" at Jenolan Caves have generally been considered to be the product of higher flow regimes in the past, and to form phreatic loops.

Pressure tubes in vertical to steeply-dipping limestone should not, however, take the form of an ellipse with a horizontal axis, but should, as in Fig.17 "B" have the form of an ellipse whose axis follows the dip of the bedding. The development of passages with the classic "keyhole" profile in vertical to steeply-dipping limestone demands a different interpretation. Re-examination of some large "keyhole"-shaped passages at Jenolan Caves (August 1998) revealed several features that are inconsistent with development by vadose incision of a phreatic pressure tube, but are consistent with development as a result of paragenesis, following partial sediment blockage of initial slot-like passage sections.

In cross-section (Fig.17 "C"), the principal morphological features of these passages are:

1. An essentially flat ceiling that has been cut directly across bedding, with no sign of any horizontal joint or any other structure that has guided its development;

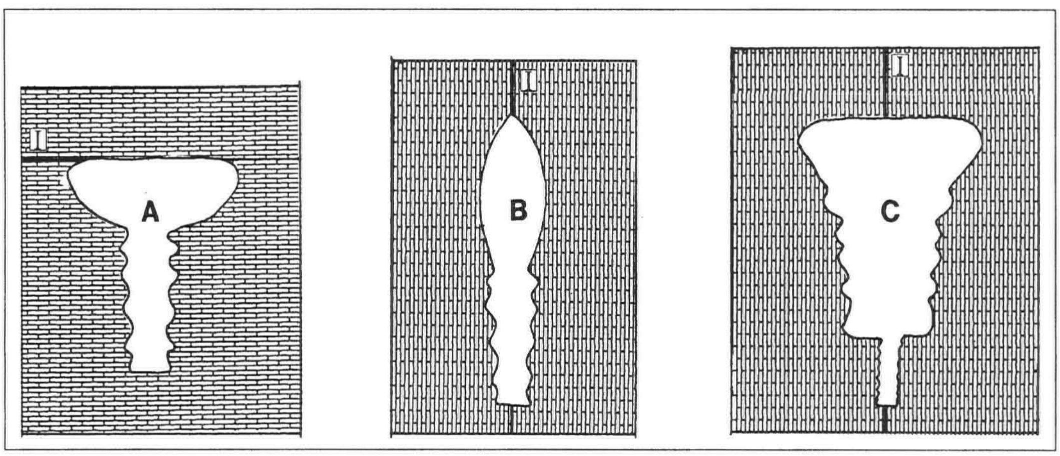


Figure 17. Sections comparing "keyhole" cave passages produced under different conditions. Thick lines are inception horizons. "A" = traditional "keyhole" passage formed by vadose incision of phreatic conduit developed below inception horizon in horizontally-bedded limestone. "B" = elongated "keyhole" passage formed by vadose incision of phreatic conduit developed along inception horizon in vertical bedded limestone. "C" = false "keyhole" passage formed by paragenetic modification of passage like "B" in vertical bedded limestone. Note how flat ceiling truncates bedding.

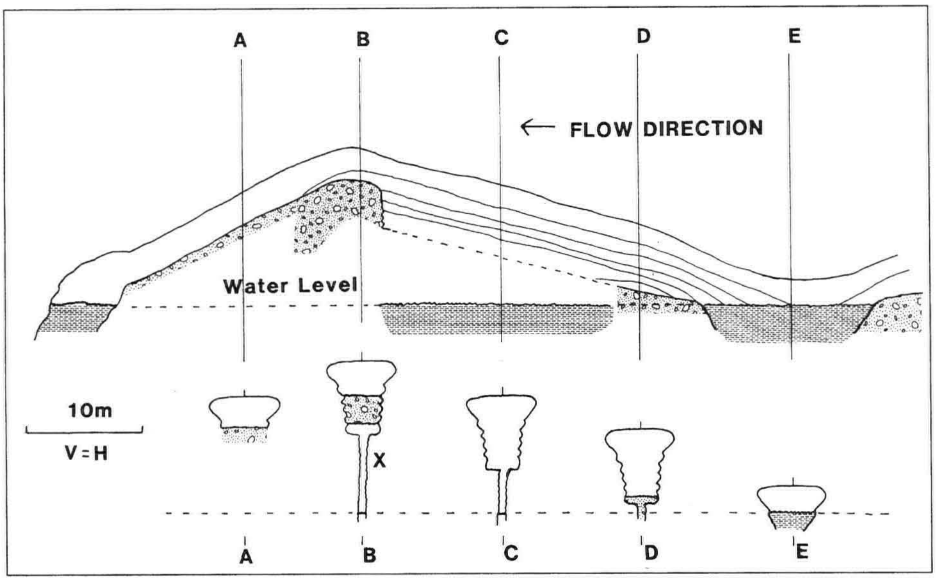


Figure 18. Diagrammatic profile and cross-sections of a paragenetic loop, based on River Cave, Jenolan Caves, New South Wales.

2. An upper, usually widest, section of passage with a curved indentation closest to the ceiling, below which there is an inward-sloping wall. It is this section of the passage profile that has previously been interpreted as the initial phreatic tube, as seen below the inception horizon in Fig.17 "A".
3. Below the wide section is a series of curved indentations in the passage wall. This has previously been misinterpreted as being equivalent to the vadose canyon that forms the lower part of a "keyhole" profile, as seen in Fig.17 "A". It is important to note that this part of the passage in Fig.17 "C" is relatively wider than its equivalent in Fig.17 "A".
4. A sediment floor or, in rare cases, a narrow, in some cases meandering, slot in the centre of a sloping bedrock terrace.

Viewed in long section the passage ceilings can be either relatively level or have a sinusoidal profile (Fig.18), interpreted in the past as forming phreatic loops (see Kiernan, 1988).

The wall indentations, previously interpreted as channel incuts, are not horizontal, but parallel to the roof profile, forming benches that are draped with fine-grained laminated muds, whose dip follows that of the benches on which they sit.

Where the ceilings of the passages are high, the floor is commonly also elevated, and composed of sediment ("B" in Fig.18), generally with only the highest level indentation being exposed above the sediment. The walls of the passage slope inward, resembling the "planes of repose" described by Lange (1963) and Goodman (1964).

It is proposed here that these passage forms result from a partial blockage of the initial slot-like passage (near point "x" in Section "B" of Fig.18), leading to the sediment accumulation forcing water upward into the roof, allowing a planed ceiling to develop, cutting across the bedding. The fine-grained nature of the sediment on the wall niches suggests that this process occurred under a low velocity flow regime. Sediment coating the floor and wall niches protected them from corrosion.

CONCLUSIONS

Many of the observed features of caves developed in the small impounded karsts of eastern Australia can be explained by applying the Inception Horizon Hypothesis to vertical and steeply-dipping limestone. In this context, features such as "keyhole" passages and the loops they form are revealed not to be indicators of past high volume phreatic flows, but as being the result of slow flow over sediment blockages. Lateral gorge formation and intersection and exhumation of palaeokarst should also be expected, forming as a consequence of only limited hydrological pathway availability related to vertical or steeply-dipping inception horizons within the limestone sequence.

ACKNOWLEDGEMENTS

The ideas presented in this paper are the full responsibility of the author. They were largely developed during study leave in Europe from July to November 1997, and amended following fieldwork in New South Wales during August and September 1998. Thanks are due to: John Gunn and David Lowe, for hospitality and assistance rendered in the UK, Tadej Slabe and the staff of the Karst Research Institute, Postojna (in particular Andrej Mihevc and Bojan Otonicar), for their outstanding hospitality and assistance in Slovenia, France Šušteršič for much fruitful discussion, and David Lowe and an anonymous referee, for reading and commenting on the draft text.

REFERENCES

Ford, D C, 1996. Paleokarst as a target for modern karstification. *Carbonates and Evaporites*, Vol.10(2), 138-147.

Goodman, L R, 1964. Planes of repose in Höllern, Germany. *Cave Notes*, Vol.6(3), 17-19.

Jennings, J N, 1985. *Karst Geomorphology*. Oxford: Basil Blackwell. .

Kiernan, K, 1988. The geomorphology of the Jenolan Caves area. *Helictite*, Vol.26(2), 6-21.

Lange, A, 1963. Planes of repose in caves. *Cave Notes*, Vol.5(6), 41-8.

Lowe, D J, 1992. *The origin of limestone caverns: An inception horizon hypothesis*. Unpublished PhD Thesis, Manchester Metropolitan University. 512pp.

Lowe, D J and Gunn J, 1997. Carbonate speleogenesis: an inception horizon hypothesis. *Acta Carsologica*, Vol.26(2), 457-488.

Osborne, R A L, 1984. Multiple karstification in the Lachlan Fold Belt in New South Wales: Reconnaissance evidence. *Journal and Proceedings of the Royal Society of New South Wales*, Vol.117, 15-34.

Osborne, R A L, 1993a, A new history of cave development at Bungonia, N.S.W. *Australian Geographer*, Vol.24(1), 62-74.

Osborne, R A L, 1993b. The history of karstification at Wombeyan Caves, New South Wales, Australia, as revealed by palaeokarst deposits. *Cave Science*, Vol.20(1), 1-8.

Osborne, R A L, 1993c. Geological Note: Cave formation by exhumation of Palaeozoic palaeokarst deposits at Jenolan Caves, New South Wales. *Australian Journal of Earth Science*. Vol.40(6), 591-3.

Osborne, R A L, 1995. Evidence for two phases of Late Palaeozoic karstification, cave development and sediment filling in south-eastern Australia. *Cave and Karst Science*, Vol.22(1), 39-44.

Osborne, R A L, 1996. Vadose weathering of sulfides and limestone cave development-evidence from eastern Australia. *Helictite*, Vol.34(1), 5-15.

Osborne, R A L and Branagan, D F, 1988. Karst landscapes of New South Wales, Australia. *Earth-Science Reviews*, Vol.25, 467-480.

Šušteršič, F, 1997. Poljes and caves of Notranjska. *Acta Carsologica*, Vol.25, 251-289.

CAVE AND KARST SCIENCE Vol 26, No. 1, April 1999
Transactions of the British Cave Research Association

E A Martel and the British Isles

Trevor R SHAW
Karst Research Institute, Titov trg 2, SI 6230 Postojna, Slovenia

Foreword: The main body of this paper is an English translation of a presentation given at the Colloque E A Martel, held at Mende in Lozère on 17 to 18 October 1997, and it appears with the permission of the organizers. Two additions have been made for its publication here:
a) a new section at the beginning introduces Martel and his life's work, and briefly discusses his place in the history of cave study;
b) an appendix provides extra information about the English and Irish members of the Société de Spéléologie, and others associated with Martel between 1889 and 1914.

Abstract: Two of E A Martel's 7 visits to the British Isles are described - a 4-week excursion in 1895 to Ireland, Derbyshire and Yorkshire, and one of 3 days to the Mendip Hills in 1904. Besides new explorations, including the first descent of the 100m-deep wet shaft of Gaping Gill, he mapped other caves and studied several inaccessible underground rivers. The main descriptive publications in both languages are reviewed. Martel's ways of encouraging and helping British cave work are discussed, and also the English and Irish membership of the Société de Spéléologie. Wherever possible new information is given about these Franco-British links, with some new illustrations.

(Received 30 March 1998; Accepted 26 March, 1999)

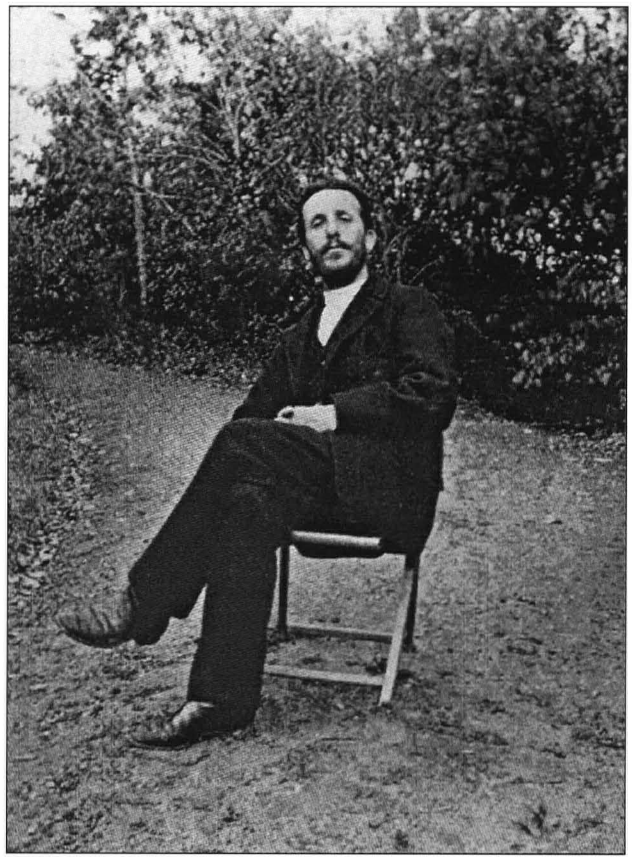
INTRODUCTION

Commonly Edouard Alfred Martel (1859-1938) is spoken of as the father of speleology. Was he and, if so, why? Certainly there had been cave explorers for centuries before his time, and he was preceded by some that had been serious students of cave science, publishing books and papers in the mainstream literature of Europe. The bulk of this paper addresses just one part of his work - his international influence. This introduction therefore seeks to summarise his work as a whole, placing its international part in context.

Martel's explorations were the basis of all his cave work. Without them he would have had nothing with which to influence people, and he would not have had the data to support his ideas on underground water flow and other scientific matters. Indeed, his main objectives were to explore, survey, record and publish, which he did to an impressive extent over many years. The exact number of explorations during his entire career has never been worked out, but has been estimated to be about 1,500. Even by the end of 1893 (after only six years of exploration) he had visited 230 caves. Of the 110 gouffres or vertical caves included in this number, 90 were previously undescended; of 120 mainly horizontal caves, 30 were previously unentered and 45 had not been explored fully. Additionally, he had by then sounded the depths of 35 other shafts in preparation for later descents, and investigated 55 resurgences that proved to be impenetrable. Also by this time, he had surveyed 28km of cave passages himself, while his collaborator had surveyed another 22km.

Most of his discoveries were made in the course of 26 annual "campaigns", from 1888 to 1913, though he continued his cave studies and writing after World War I and up to his death in 1938. The campaigns took place in seventeen countries: France, Belgium, Germany, Ireland, England, Norway, Switzerland, the Czech Republic, Slovakia, Hungary, Slovenia, Greece, Italy, Spain, Turkey, Russia and the USA. Almost all were important. The sheer bulk of the work carried out increased its value even above the intrinsic significance of the individual explorations. All the discoveries were fully published at the time, and it would be tedious to relate the successive achievements here. The duration of the campaigns varied widely from year to year. In 1892 he was able to devote five months to his fifth campaign, which was spread over eleven different departments of France, but in the previous year he had only a very few days available. The eighth campaign, in the British Isles in 1895, is described below.

Experienced as he was in exploring many different kinds of ever more difficult caves, it is only to be expected that Martel developed some of the basic techniques involved. In 1889 he and Gaupillat were the first to use telephones in caves, where they found them useful on deep shafts, especially any that were more than 100m deep. Their apparatus was fairly light for the time, being about 8cm in diameter and



Martel in 1895, the year of his Gaping Gill descent.

weighing 480g, and they used it successfully with as much as 400m of wire. The telephone was used in his Gaping Gill descent. Martel's other claim for originality in equipment was in the cave use of the folding canvas canoe, though Schmidl in 1852 had already used a wooden boat that could be taken to pieces.

The volume and quality of his publications is as impressive as his explorations. He produced some 20 books and 780 papers, many of them in scientific journals of the highest quality. Many of his writings were also translated and published abroad.

With such a remarkable record, how can he not be considered the father of speleology? Of his predecessors, the most important and influential was Adolf Schmidl (1802-1863), who was largely responsible for a flourishing tradition of cave work in the Austrian Empire, complete with cave exploration societies, before Martel's work began[1]. But, Schmidl was involved actively with caves for a mere seven years, and produced only three books and several dozen papers on caves. This is not to say that Martel was necessarily more important. Certainly his achievements were greater, but that was largely the result of the very much longer period that he was active, coupled with the fact that speleology already existed by then as a recognised and organised subject, at least in German-speaking central and southern Europe. Martel had Schmidl's work as his starting point, so it could be said that each of them influenced the development of the subject to the same degree.

Nevertheless the sheer quantity of Martel's work and writing and the very wide extent of his personal contacts ensured that his influence on cave investigation and the people who carried it out was far and away the greater. It is from Martel that there seems to have been a continuous tradition in many parts of the world; direct influence and personal contact can be traced back to him like an apostolic succession. So Martel was surely the father of speleology. Schmidl, with equal certainty, was its grandfather.

MARTEL'S INTERNATIONALISM

Martel was more that just a cave explorer, cave researcher and writer. He also consciously caused the study of caves to spread into countries outside the European core where it was already flourishing. He was a leader who inspired and encouraged people to investigate the caves and karst problems of their own lands.

There can be no doubt about the extent of Martel's personal links with speleology in other countries. Of his 26 annual campaigns of exploration, 19 went outside France in what are now 20 nations and, in addition, he made lecture tours and other visits abroad. At least 61 of his own publications on caves appeared elsewhere in his lifetime. Many of these were papers presented to learned societies, and there were also popular articles and the texts of public lectures; others were simply translations or reprints of work already published in France, showing the interest with which this was regarded abroad.

The Société de Spéléologie, founded by Martel in Paris in 1895, enjoyed high scientific standing from the outset, and it was one means by which he contrived the extension of cave study into an international subject. Foreign membership of the Société was remarkably high. 21% of the founder members lived outside France, indicating the close links already existing before 1895. Between 1895 and 1904 the proportion rose to 29%; in addition three foreign cave societies were members. Many papers by foreign contributors, most of them members, were published in the Société's journal, *Spelunca,* comprising between 14% and 50% of the papers printed in individual years.

In the USA he had little opportunity for physical cave exploration. Nevertheless, he formed close links with speleologists there long before he visited America[2]. In other countries, such as Slovenia, where home-grown cave societies were already active, he participated in their work during his visits, while influencing them in some ways and drawing them closer to their colleagues in other lands. The case in England and Ireland was between these two extremes, with many caves already explored but with no well-established cave societies. Many interesting sites were awaiting exploration and proper investigation and Martel took the opportunity to do some of this. He also visited several other caves to learn regional characteristics and to compare them with those he knew elsewhere. At the same time, he met local people and inspired them by his example, encouraging them into further activity in Britain and causing some of them to join the wider world of the Société de Spéléologie and to submit papers for publication in *Spelunca.*

In studying Martel's relationship with the British Isles, such indirect activities may initially seem less prominent than they were with America. This is because more travels and cave visits are reported, tending to overshadow the less tangible matters of personal influence and consequent future cooperation. Nevertheless this did happen, no doubt mostly initiated while Martel was in the country and then followed up after his return to France.

MARTEL'S VISITS TO THE BRITISH ISLES

Martel is known to have made 7 visits to England. Two of these are important and one of them is very well known indeed. All are part of the pattern of his international life, however, and they all influenced him or his work to a greater or lesser extent. They are summarised here from the "Répertoire chronologique ..." in the recent volume of Martel letters[3], referred to here as *La plume ...*

1870	visited England with his parents at the age of 10 or 11.
1886 (April)	attended a meeting in London.
1888 (July)	in London for at least 4 days.
1889	visited museums in London.
1895 (July-August)	nearly 2 weeks in Ireland and a little less in England, exploring and attending an International Geographical Congress.
1904 (June)	3 days in the Mendip Hills.
1905 (November)	lectured in Leeds and visited the geology museum at Cambridge (about a week).

THE 1895 VISIT

Martel had naturally been in touch with his English colleagues before planning the visit. Early in 1895 Mark Stirrup (Fig.1), an early member of the Société de Spéléologie who had known Martel for many years, informed the Manchester Geological Society as follows[4]:

> *"M. Martel, I should state, desires to extend his explorations to this country, and with that view he wishes to be informed of any caverns of sufficient importance and extent to justify him in sending over the very extensive apparatus which it is necessary to employ in carrying out these explorations. He has to use for this purpose, amongst other things, collapsible boats for navigating underground streams, rope ladders many hundreds of feet in length, and telephonic apparatus for keeping up communication with the surface whilst the explorations are in progress. He has also found it necessary in some cases to be provided with tents, in order to be able to camp out in the absence of proper house accommodation. If there is sufficient inducement to extend his operations to this country he should be informed early, as the arrangements for his summer holiday have to be made some months in advance. It is just possible that he will attend the Geographical Congress in London at the end of July, and then come northward."*

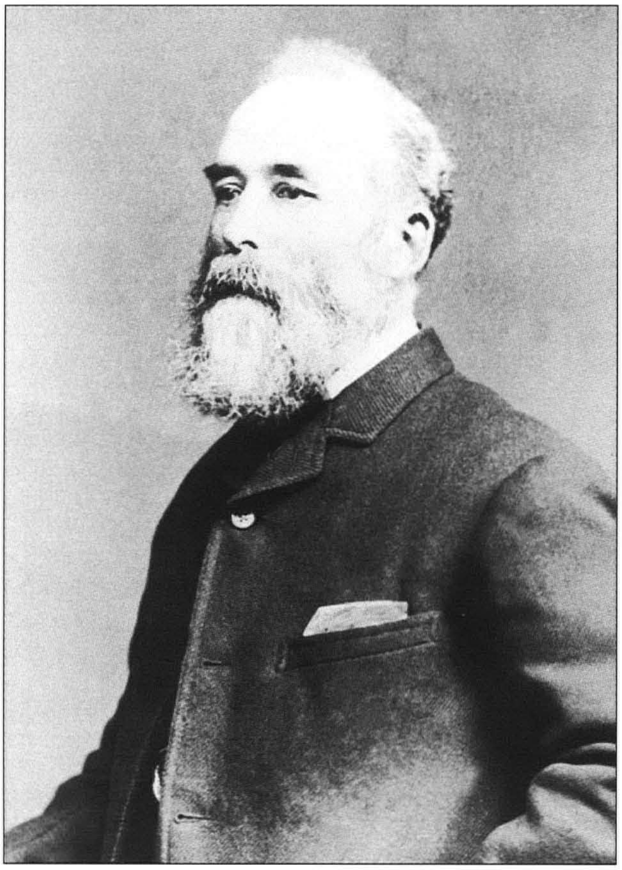


Figure 1. Mark Stirrup (1821-1907). A photograph taken just before he joined the Geological Society of London in 1876. From their archives and reproduced with their permission.

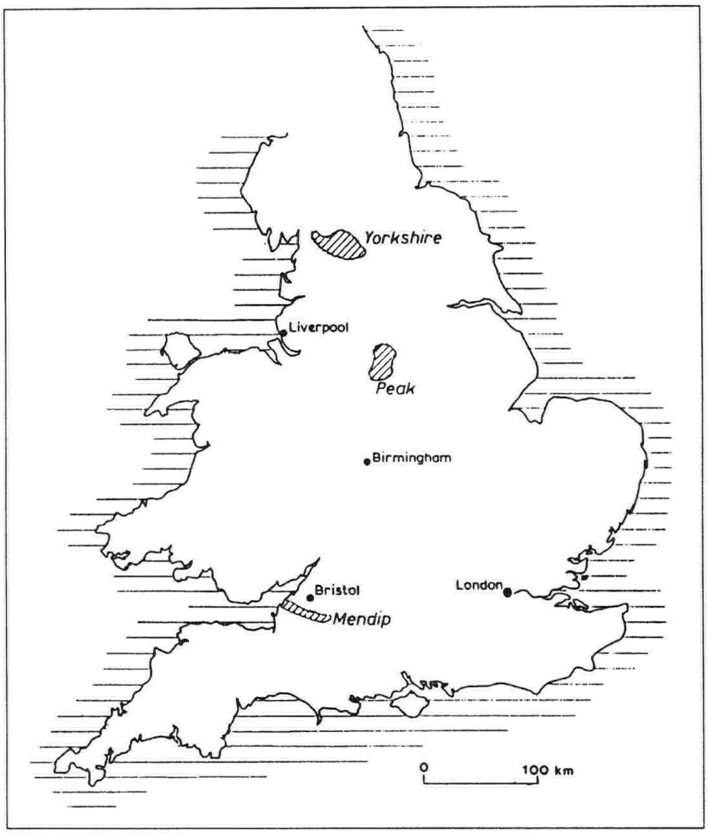


Figure 2. The three karst areas that Martel visited in England in 1895 and 1904.

Stirrup also supplied Martel with information about English caves[5], as did Professor Boyd Dawkins, Dr R F Scharff (another Société member), Lyster Jameson of Dublin and Thomas Plunkett of Enniskillen in Ireland. Martel also made arrangements with James Farrer of Yorkshire (father of Reginald Farrer the Asian traveller and plant collector) on whose land lay Gaping Gill.

A detailed account of what Martel did and saw, retelling it like a story, is not appropriate here. It is readily available in the original published sources and much of it is fairly well known. What is required is an overview of his travels, highlighting the more important parts, together with some assessment of their significance. The sources will not usually be cited in the course of this summary, but they are discussed separately. It is necessary, though, to acknowledge that the dating of the various visits has been taken mostly from *La plume ...*[3]. Many of the dates are evident in the primary sources but the editors of *La plume ...* have also been able to draw on other information. The main places and regions visited are shown in Figs 2 and 3. Martel's route between these places is not known.

He arrived at Edinburgh in Scotland by ship on Saturday 6 July, aged 36, together with his wife Aline. The next day he went northwards by train to the city of Perth and by 12 July he was in Ireland. (This account ignores political boundaries and describes locations in Ireland by reference to counties).

Ireland

From Friday 12 July until the following Wednesday, Martel was in County Fermanagh, at Marble Arch and other nearby caves. He was accompanied by H Lyster Jameson, a young entomologist from the University of Dublin, who studied cave fauna. Marble Arch Cave had not been explored fully before, and they were concerned to establish the complex links between the several underground rivers and the rising. This they did, using a collapsible boat[6], on July 12 and 16. On 14 and 15 July they studied Arch Cave, from which a large stream emerges They also descended the shafts of Noon's Hole and Pollanaffrin. Noon's Hole was sounded to a depth of 47m, but the volume of the stream entering the hole made it impossible to go below 25m that day.

Travelling southwest from County Fermanagh, Martel reached County Mayo on the west coast. Here there is extensive underground drainage in the limestone near Cong, where water from Lough Mask flows towards Lough Corrib, but is inaccessible. There are many small caves and karst springs thereabouts, some of which were surveyed on July 18. A little farther south again, in County Galway, he reported on the 3.5km-long underground river at Gort. Its underground course is hidden, except where visible in collapse dolines and at the bottom of shafts, but accurate measurements enabled him to draw its profile. He also noticed a surface stream that divided into two branches, which then sank separately. *La plume ...* does not provide a date for this visit but it must have been on Friday 19 July, for by the following day they were in County Clare, farther south again.

He was in County Clare for at least two days. On Saturday 20 July he visited the limestone sea cliffs of Kilkee and the so-called "Puffing Caves" where in stormy weather the action of the Atlantic waves forces sea water up natural chimneys in the rocks to form plumes of spray. Next day he was already heading east towards the centre of Ireland, and stopped near Ennis to study the Tomeens, a series of open pits in the limestone revealing the course of a 300m-long river running only about 4m beneath the surface. As he said, it was an example of an underground stream becoming a surface one by roof collapse.

The Mitchelstown Cave in County Tipperary was the subject of a 6-hour visit on 24 July, in which he made a plan of the somewhat complex joint-controlled passage system, totalling over 2km in length. He pointed out that it was thus *"...la plus longue caverne actuellement connue des Iles-Britanniques"* and notes also that at that time it was the only cave in the British Isles in which *"...l'on ait ... trouvé des animaux réellement cavernicoles"*[7]. It was the Mitchelstown "New

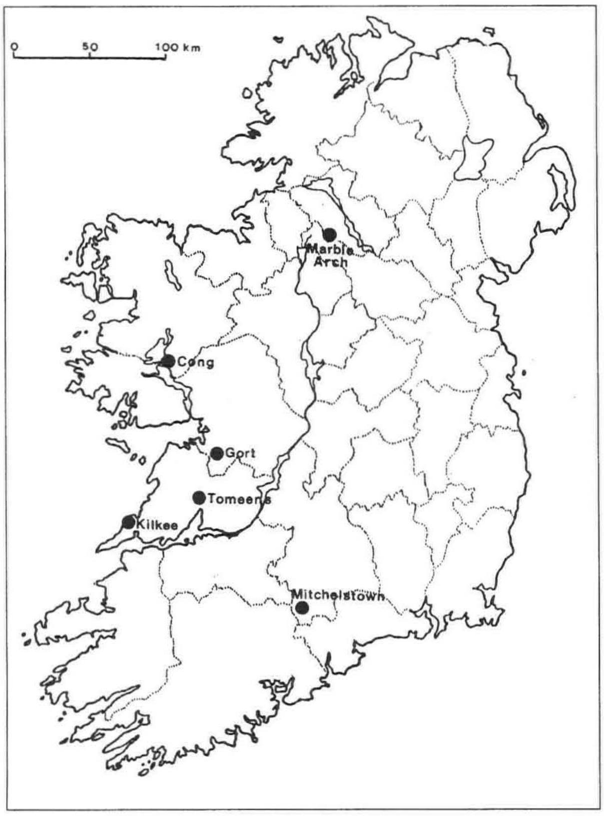


Figure 3. The caves and karst regions of Ireland visited by Martel in 1895.

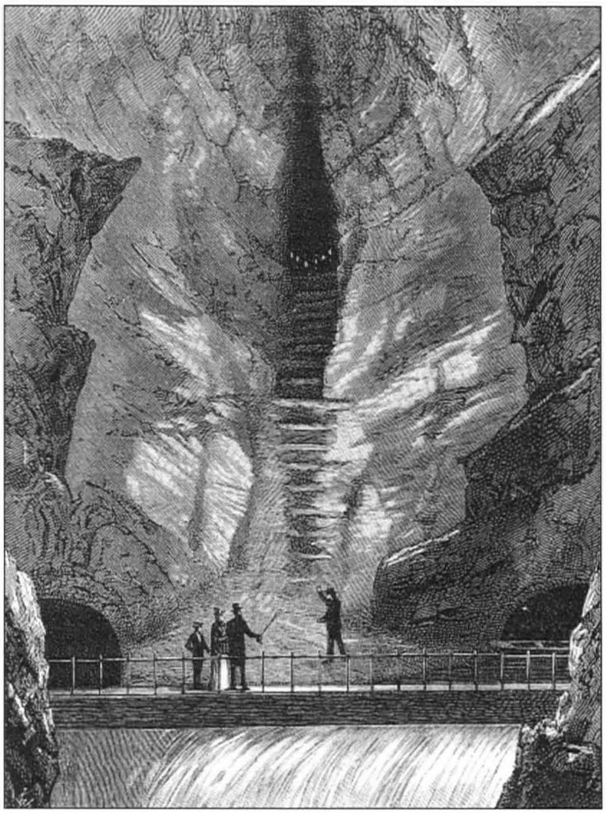


Figure 4. The "Bottomless Pit" in Speedwell Cavern showing the natural aven penetrated by an old lead mine tunnel. From Irlande...[6] p.299.

Cave" (discovered in 1833) that he saw, not the "Old" or Desmond's Cave, close by.

Quite a large part of the 13 days Martel spent in Ireland was devoted to non-karst subjects and much of his book is concerned with its scenery and antiquities. He did, however, visit 5 classic karst sites. Three of these, with the inaccessible underground rivers of Cong, Gort and the Tomeens, are not caves as such but they demonstrate the breadth of his interest in karst problems, concentrating especially on what he found different in Ireland to elsewhere. The caves of Marble Arch and its vicinity, and of Mitchelstown, were the longest and most challenging in Ireland, for Poulnagollum in the Burren of County Clare was not then widely known.

Derbyshire

Martel must have crossed from Ireland to the English mainland the day after his Mitchelstown visit, for between 25 and 27 July he visited and studied 3 major caves at Castleton in the Derbyshire Peak District. These were the Blue John Mine (a natural cave from which "Blue John" fluorspar was formerly extracted), the Peak Cavern and the Speedwell Mine (a natural cavern entered by a lead mine tunnel) (Fig.4). He made plans and sections, more or less complete, of all three caves, carefully noting altitudes throughout, and he described the several karst springs associated with the Peak Cavern system.

> *"Telles sont les observations que j'ai faites dans les trois principales cavernes de Castleton; elles n'ont pas été suffisamment approfondies, et il y reste encore bien des recherches à exécuter. Il doit en être de même dans toutes les autres grottes et pertes des environs, qui attendent, de la part des spéléologues anglais, des investigations perfectionnées, comme celles exécutées, depuis dix ans, en Autriche et en France."*[8]

His short stay in Derbyshire meant that he was unable to visit many other caves but he summarised what he knew of them from the literature. Bagshawe Cavern, 3km away near Bradwell, was the only other one that he did explore and survey, on 28 July. It was not an easy cave and his thorough examination showed that it was not more than 1500m long, rather less than had been thought.

Thus Martel's visits in Derbyshire were all to caves that had long been known, but he measured them, drew plans and sections, and discussed the possible interrelationships of their underground rivers. Also, of course, he added to his own knowledge of caves and karst, in a country where the local climate and the geomorphology were unlike those familiar to him.

Yorkshire

The relentless itinerary meant that on the very next day he was in the limestone Dales district of Yorkshire, staying at the New Inn (Fig.5) in Clapham village, whose visitors' book contained the entry[9]:

E.A. Martel (and Madam)	On Thursday 1st of August
29 July 2nd August 1895	1895 I went down Yaping [sic]
Paris, France	Gill hole, etc.

The main object of this visit was to descend for the first time the 100m-deep entrance shaft of Gaping Gill[10], on the moorland about 4km from Clapham. What particularly fascinated him was that it was still an active water sink:

> *...voilà bien ce qu'étaient jadis tous nos avens des Causses!*

Attempts had been made before but had not been successful, hindered by the force of the stream falling down the shaft and by inadequate equipment.

Martel sounded the depth of the shaft on July 30 but the stream falling over its lip was too heavy for a descent to be made. He had already been in communication with the landowner James Anson Farrer (1849-1925), who had arranged to have the diversion channel on

Figure 5. The New Inn at Clapham, where Martel stayed when he descended Gaping Gill. From a postcard of about 1920 in the collection of Don Mellor, reproduced with his permission.

the moor re-excavated. This had originally been dug to direct the stream water away from the entrance for an earlier attempt, in the 1840s. Re-excavation continued on July 30 and 31, and Martel took the opportunity to visit the nearby caves of Great and Little Douk, Gatekirk, Hurtle Pot and Weathercote Cave, at the last of which he made a measured plan and section. He also examined Ingleborough Cavern, the resurgence cave 146m lower than the entrance of Gaping Gill, where the water reappears.

Martel made his descent on 1 August (Fig.6) and the climb down the long rope ladder took 23 minutes. Having only 80m of ladder altogether, he lowered it well down the shaft and used plain doubled rope for the top 20m of the descent, where he was greatly aided by the pull on his lifeline. He remained at the bottom for 102 minutes, exploring the Main Chamber and making notes (Fig.7). The climb back to the surface lasted 28 minutes. Afterwards Martel handed copies of his sketch plan and section and his notes to Henry Harrison of Clapham, and they appeared two days later in *The Bradford Observer* newspaper, the first published account of the discovery. Harrison, described by Martel as *"...fort aimable et intelligent"*, was the guide at Ingleborough Cavern.

On the very next day Martel was in London attending the 6th International Geographical Congress, at which he spoke on caves, in a lecture that will be referred to again below. On the following Tuesday, August 6, he reached Paris after 32 days away.

The literature of Martel's 1895 excursion

It is not intended here to provide a complete bibliography of the writings on Martel's visit. Most of the references have been listed by Chabert and Courval[10A], though their regional relevance is not always apparent from the titles. The purpose here is to draw attention to the more important and the most complete accounts, together with any others that are useful in some particular way.

The almost immediate publication of details of the Gaping Gill descent has already been mentioned. Printed anonymously in *The Bradford Observer* on August 3[11], it is a detailed factual account of some 1,600 words, with the sketch plan and section reproduced here in Figs 8 and 9.

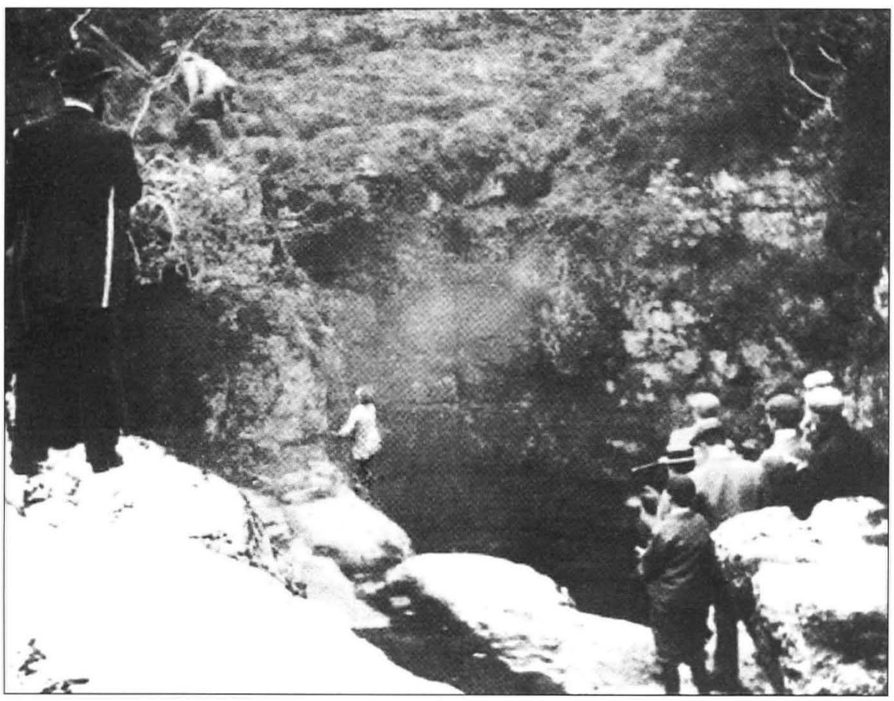


Figure 6. Martel about to descend the 100m shaft of Gaping Gill in 1895. Photograph by John Anson Farrer, reproduced by permission of the present Dr J A Farrer.

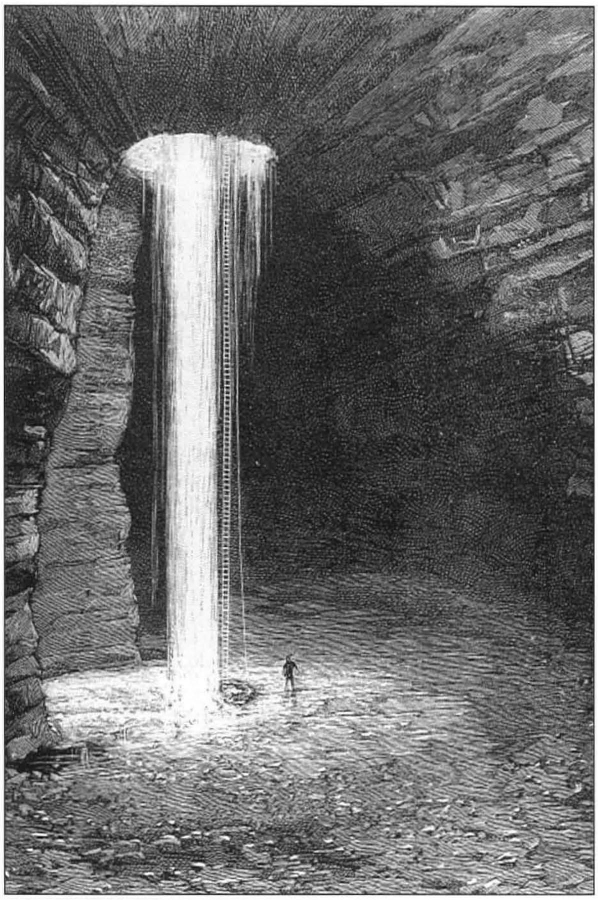


Figure 7. Martel in the Main Chamber of Gaping Gill. From Irlande...[6] p.247.

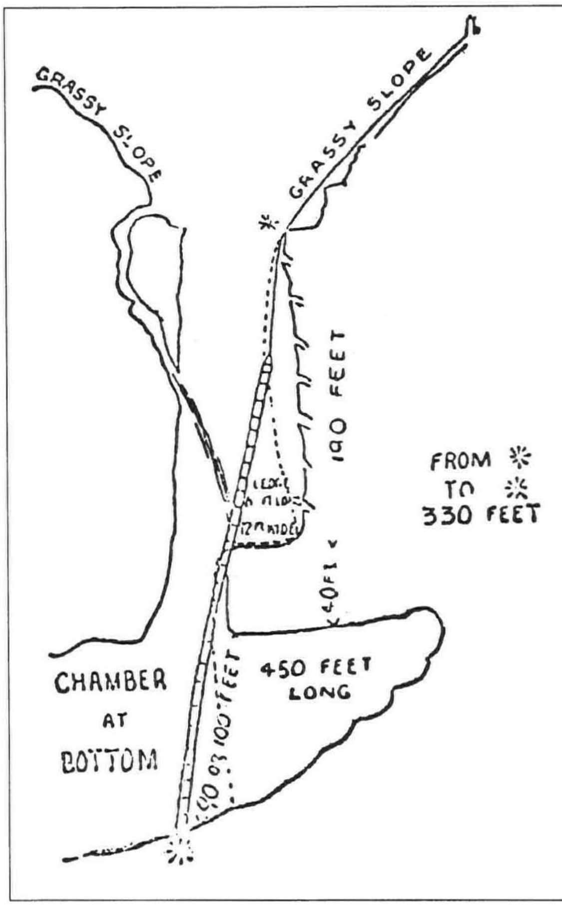


Figure 8. A foreshortened section of the Gaping Gill entrance shaft and part of the Main Chamber at the bottom. Figs 8 and 9 were published in The Bradford Observer newspaper of 3 August 1895[11] where they are described as being "practically reproductions of M. Martel's own sketches".

The fullest account of the entire excursion is, of course, in Martel's own book *Irlande et cavernes anglaises*[6], published in 1897. Much of its text on the Derbyshire caves had already appeared, with minor variations, as part of a paper in *Annales des Mines*[12] in the previous year. The two folding surveys used in the book accompanied this earlier publication. That they had been prepared for the book is clear from the fact that one of them includes the section of the underground Gort river in Ireland, which is not referred to in the *Annales* text. Somewhat similarly the Mitchelstown Cave chapter had appeared in the *Irish Naturalist*[13], also in 1896, and it is the English-language map from there that is used in the book.

Of highest formal status were the two short papers published by the Académie des Sciences, one on Gaping Gill[14] and the other mainly on Marble Arch Cave[15]. Directed at other special audiences were the paper *"British caves and speleology"* published by the Royal Geographical Society in London[16], a report on Marble Arch and Gaping Gill in the *Annuaire du Club Alpin Français*[17], one on the Gaping Gill descent for the Alpine Club in London[5], and the one already mentioned in the *Irish Naturalist* magazine[13]. Most of these appeared before the book was published. So did three articles in the popular French magazine *La Nature*[18, 19, 20], two of which were translated for the *Scientific American Supplement*[21, 22] the same year.

The immediate effect on British speleology

The personal contacts that Martel made in England and Ireland resulted in some cooperation with the French in lectures, publications and other ways. There were also several attempts by Martel, in his lectures and publications, to stimulate more cave activity in the British Isles. Was this successful? That is a difficult question to answer, for cause and effect were probably not clear even at the time, and are still less so now. Nevertheless, in 1904 the noted English cave explorer E A Baker wrote[23]:

"Since 1895 cave-exploring has become a more popular pursuit, thanks largely to the example and enthusiasm of M. Martel. Clubs and societies have taken up the work, many discoveries have been made, and both the scientific and the sporting attractions of cave-exploring have received general acknowledgement."

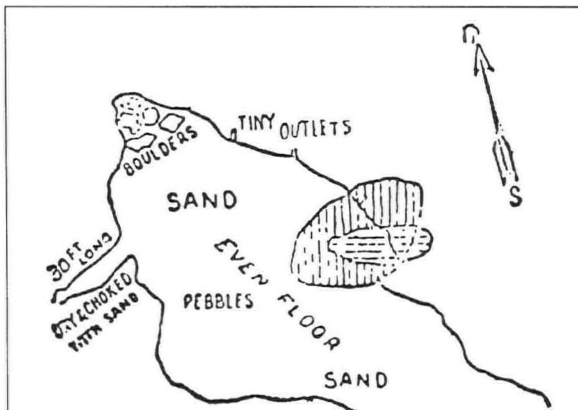


Figure 9. A plan of Gaping Gill Main Chamber based on Martel's sketch and published in The Bradford Observer[11]. The horizontally shaded oval on the right denotes the mouth of the shaft, and the larger vertically shaded area represents its lower end.

Figure 10. Herbert Ernest Balch (1869-1958). Photographed in 1923 by Dawkes and Partridge of Wells.

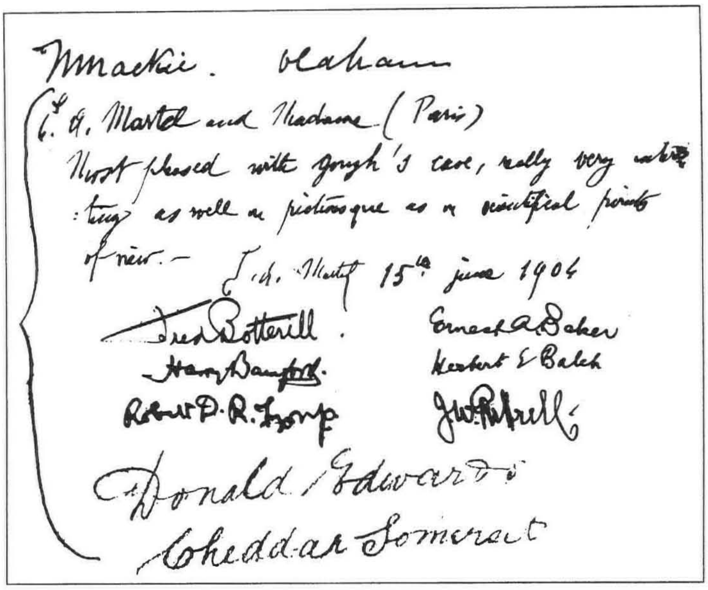


Figure 11. The entry by Martel and party in the Goughs Cave visitors' book[29] on 15 June 1904. Reproduced by permission of the late Douglas Gough.

The Yorkshire Ramblers' Club, formed in Leeds in 1892, was predominantly a mountaineering club, but it also explored caves, though without descending any deep ones before 1895. Its members were already planning a descent of Gaping Gill in the year of Martel's visit, which seems to have taken them by surprise, but *"...much time was absorbed in discussion, and ... the expedition was repeatedly postponed"*[24]. Then, *"spurred on by M. Martel's success"*, an attempt was made in September 1895, but on that occasion they got no lower than the ledge at 58m[24]. When they did reach the bottom, on 9 May 1896, they used a windlass and a boatswain's chair, which made for much more rapid working - only two minutes for the descent and four minutes to come up[24].

Perhaps a more important and long-lasting result of Martel's descent than any national competitive spirit was the psychological effect of knowing that this formidable hole could be overcome without undue difficulty. The Yorkshire Ramblers gained confidence that they too could succeed, which they did the next year and then went on to achieve successful descents of other deep and difficult caves.

1904 VISIT TO MENDIP

In 1904, in addition to his main campaign of exploration in the Dauphiné, Martel came to England again. In May he is said to have been at the megalithic monument of Stonehenge[25], and then he spent a few days on the Mendip Hills of Somerset in June. He was taken into Wookey Hole and the two principal caves at Cheddar; and he visited several cave entrances and other karst sites on and around Mendip, including the big karst spring of St Andrew's Well[26, 27, 28].

He arrived in Wells on Monday 13 June, with his wife. The visit was made at the invitation of H E Balch (Fig.10) and E A Baker, and for some (or probably all) of the time he was accompanied also by J W Puttrell (later to become a member of the Société de Spéléologie) and others (see Fig.11).

The entrances to Eastwater Cavern and Swildon's Hole were seen the next day, and Martel commented on the way in which they had been entered by digging out the chokes that originally blocked them:

> *"C'est par la méthode de la désobstruction artificielle, dont j'ai recommandé l'emploi depuis longtemps, que M. Balch et ses collaborateurs ont pu réaliser, dans les gouffres bouchés, des descentes et des constatations inattendues, le long des écoulements souterrains : à 120 mètres de profondeur (1901) au swallet de Swildon's Hole, dans l'intérieur duquel on a réussi à désamorcer un siphon naturel."*[27]

Wookey Hole and the caves at Cheddar were visited on the Wednesday. The visitors' book[29] of Gough's Cave, Cheddar, has an entry signed by the whole party (Fig.11). Martel's complimentary remarks about the rival Cox's Cave were seized upon by the proprietor. They were quoted in several printed advertisements (Fig.12) and the entire gable end of cottage bore an inscription in large letters : COX'S CAVERN VISITED BY H.M. KING EDWARD VII. MARTEL SAYS THE BEST OF 600 (Fig.13).

There were only these two days of cave visiting and Martel presumably left the next day. There is no indication that he remained in England afterwards, and the Mendip visit seems to have been the reason for his coming. It is clear that he did not set out to make any new explorations in the area; indeed he did very little exploring at all. What then did he aim to do, and what did he achieve? It was always his practice not only to explore caves, but to study them and their associated hydrology. Just as in 1895 he had visited tourist caves in Derbyshire, so in 1904 he studied the characteristics of the Mendip karst. He was particularly interested in the effect of the soluble Dolomitic Conglomerate (which in places covers the limestone) on the major springs.

MAINTAINING CONTACT

So much for Martel's physical activity in the British Isles - the excursions in which he visited caves and studied karst at first hand. There were also other ways in which he sought to ensure that France and England, and indeed the rest of the world, remained in touch on the subject of speleology. These included:

Figure 12. An advertisement for Cox's Cave, Cheddar, of about 1906 (collection of the Karst Research Institute, Postojna).

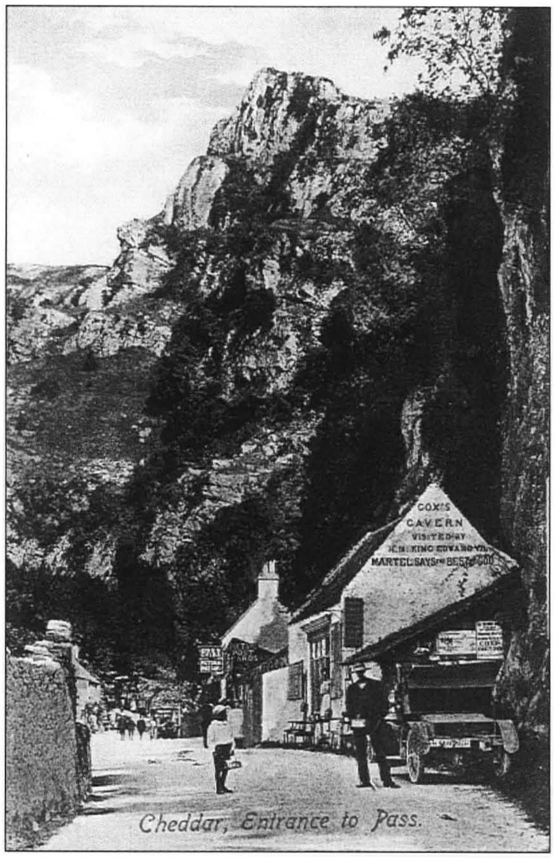


Figure 13. Cox's Cave advertised on a cottage wall nearby, photographed in 1908 (from a postcard in the collection of the Karst Research Institute, Postojna).

a) lecturing in Britain and publication of his own writings there;
b) printing information in France about English and Irish cave work;
c) attracting English and Irish members into the Société de Spéléologie and persuading them to publish in *Spelunca*;
d) maintaining personal friendships, lending material for lectures, and constantly encouraging new work.

Publication in England and about England

Here are a few examples of the way in which Martel kept the subject of caves visible in England, both to specialist and to general audiences:

- his lecture at the 6th International Geographical Congress in London, the day after the Gaping Gill descent[30];
- a popular article on cave exploring in the 1898 volume of *Wide World Magazine*[31] (later reprinted in a book[32]);
- the lecture he gave in Leeds in 1905, on speleology as a modern sporting science[33].

In addition, two lengthy quotations from his writings on French caves were translated in an English book about the Causses, published in 1894[34]. Several of his books were reviewed in England, including *Les Abîmes,* which received an illustrated review by Professor Bonney in the prestigious scientific journal *Nature*[35].

French and foreign readers of *Spelunca* were kept informed about progress in England, as elsewhere in the world, not only by occasional papers printed there but also by shorter notes and reviews of publications. These included lengthy descriptive reviews of the contents of *The Yorkshire Ramblers' Club Journal*[36, 37], of learned society publications[38, 39,40] and of a book on Derbyshire caves[41]. The 1897 descent of Rowten Pot in Yorkshire was described[42] from an English newspaper report[43], supplemented by cross-sections that were not published in England until the following year[44]. Jameson, who had been with Martel in Ireland, wrote on caves in County Leitrim[45].

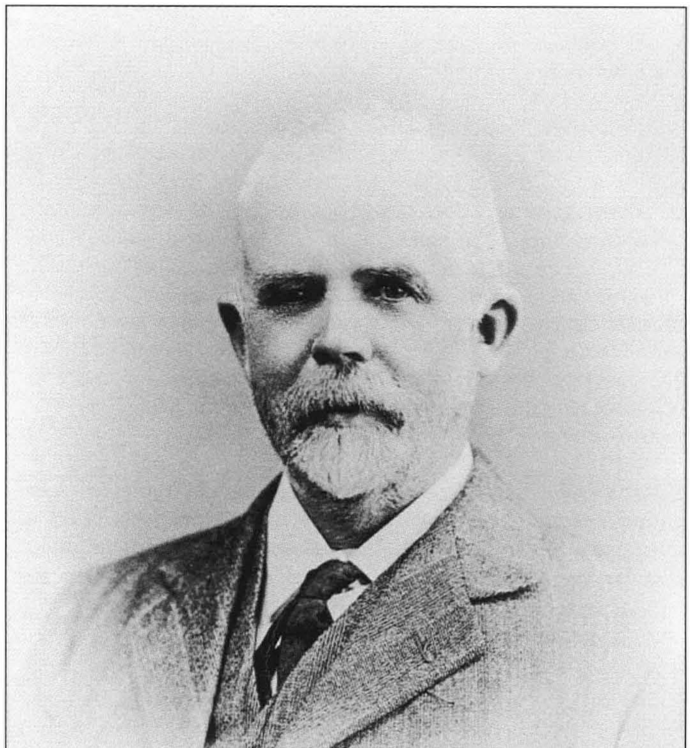


Figure 14. Jonathan Barnes (1855-1927). A photograph taken shortly before he joined the Geological Society of London in 1896. From their archives and reproduced with their permission.

Name	Lived	Known to be member	
Frederick Macotta (London)		1894 - 1904[46] founder member life member	
Mark Stirrup (Cheshire)	1831 - 1907	1895 - 1904[46]	(Fig.1). Fellow of the Geological Society of London (from 1876); member of the Manchester Geological Society[47] (from 1880), President 1896 - 97; wrote on caves[4,48,49,50]
Richard Dixon Oldham (London)	1858 - 1936	1895 - 1909[51]	Fellow of the Royal Society (from 1911); President of the Geological Society of London (1920 - 22); a seismologist who established the existence of the earth's inner core
Robert Francis Scharff (Dublin)	1858 - 1934	1895[52] corresponding member	President, Royal Irish Academy (1903 - 06, 1909 - 11, 1919 - 21); Keeper of the Natural History Collections, Museum of Science and Art, Dublin
Edward Perceval Wright (Dublin)	1834 - 1910	1895 - 1909[51]	(Fig.22). Professor of Botany, Trinity College, Dublin (1896 - 1904); anatomist and geologist; wrote on Mitchelstown caves[53]
Samuel Wells (Goole)		1896 - 1909[51] corresponding member	
Jonathan Barnes (Manchester)	1855 - 1927	1896[54] (or 1897[46]) – 1909[51]	(Fig.14). Fellow of the Geological Society of London (from 1896); member of the Manchester Geological Society (from 1895), President 1901 - 02; wrote on Derbyshire Caves[55] and karst hydrology[56], published in Spelunca[57]
William Cecil Slingsby (Skipton)	1849 - 1929	1897 - 1909[51]	President, Yorkshire Ramblers' Club (1893 - 1903); Vice-president, Alpine Club (1906-08); a distinguished mountaineer who also explored caves
Frederick Lambert (London)	Fellow 1894-1905	1902 - 1904[46]	Fellow of the Royal Geographical Society (from 1894); wrote on Australian caves[58]
William Newbold (Tunbridge Wells)		1907 - 1909[51]	
James William Puttrell (Sheffield)	1868 - 1939	1914[29]	Rock climber and cave explorer[59], see Fig.15
Francis Arnold Winder (Sheffield)	1881 - 1947	1914[60]	Later President, Derbyshire Pennine Club; author of a book on Derbyshire caves[61], a chartered surveyor[62], see Fig.16
Stanley C Philips (Sheffield)		1914[60]	Member of the Derbyshire Pennine Club; see Fig.16

Table I. English and Irish members of the Société de Spéléologie (based mainly on the published membership lists of 1895, 1904 and 1909).

Membership of the Société de Spéléologie

English and Irish membership of the Société is shown in Table I. It will be noticed that four members had joined before Martel's visit in the summer of 1895, one of them as a founder member.

Mark Stirrup (Fig.1), who was also a member of the Association Française pour l'Avancement des Sciences, was in frequent contact with Martel. He drew English attention in 1895 to the formation of the Société[4] and invited anyone wishing to become a member to tell him, so that he could pass on their names. Jonathan Barnes (Fig.14) was joint author of a paper[57] in the Société's *Mémoires,* and a letter from him is printed in *La plume...*[63]. Herbert Ernest Balch (Fig.10), who was Martel's host in Mendip in 1904 and who wrote in *Spelunca*[64] on the caves there, seems never to have been a member.

Personal contact

One of the people Martel met in Yorkshire in 1895 was Thomas Richard Clapham (1837-1909) (Fig.17) who lived at Austwick Hall, 4¼ km from Gaping Gill. As early as 1868 he had tried to explore the cave of Meregill but evidently without much success[65], and he gave Martel much other local information. It was probably on the very day of his Gaping Gill descent (for he was in London on August 2) that Martel presented Clapham with a bound volume of papers by his wife and himself, inscribed and dated August 1895 (Fig.18). They kept in touch, for Clapham sent a letter of thanks for more separata in 1897[66]. Martel retained his affection for the hills near Gaping Gill, and in 1921, when he was 62 and suffering from heart trouble, he wrote to the Yorkshire Ramblers' Club librarian, *"...how glad I would be to enjoy at least 2-3 days camping at Fell Beck Moor"*[67].

Another inscription indicating friendship, or at least respect, is one dated 19 January 1897 (Fig.19) in the copy of *Irlande et cavernes anglaises* that he gave to Matilda Betham Edwards (1836-1919). Miss Edwards was a fluent French speaker, a traveller in many lands and author of five books on France, so it is likely that they had met either in France or at the 1895 Geographical Congress in London.

Martel must have made a strong impression on many people. One of these was Walter Parsons (d. 1944) who attended a dinner party given for Martel by the Yorkshire Ramblers' Club president after the lecture in Leeds on 22 November 1905. He vividly recalled the occasion many years later when he wrote[68]:

> *"I ... had a considerable amount of conversation with Martel himself. I found him to be modest and unassuming with nothing of the voluble loquacity which one sometimes associates with the French. He spoke English with ease but with a pleasing French accent... In appearance he was characteristically French, about 5'9" or 5'10" in height and carrying no superfluous flesh. He looked like a wiry athlete, as he had proved himself to be. To me it was a great pleasure and stimulus to meet and to hear this intrepid Frenchman."*

It is particularly interesting to have this comment about Martel's good English.

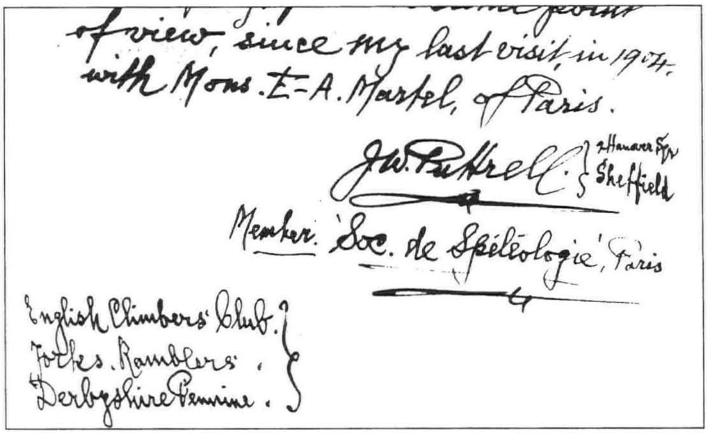


Figure 15. Puttrell's signature in the Gough's Cave visitors' book[29] in June 1914, in which he proudly states his membership of the Société de Spéléologie. Photographed 13 March 1988 by Chris Howes FRPS and reproduced by permission of the late Douglas Gough.

Encouragement and assistance

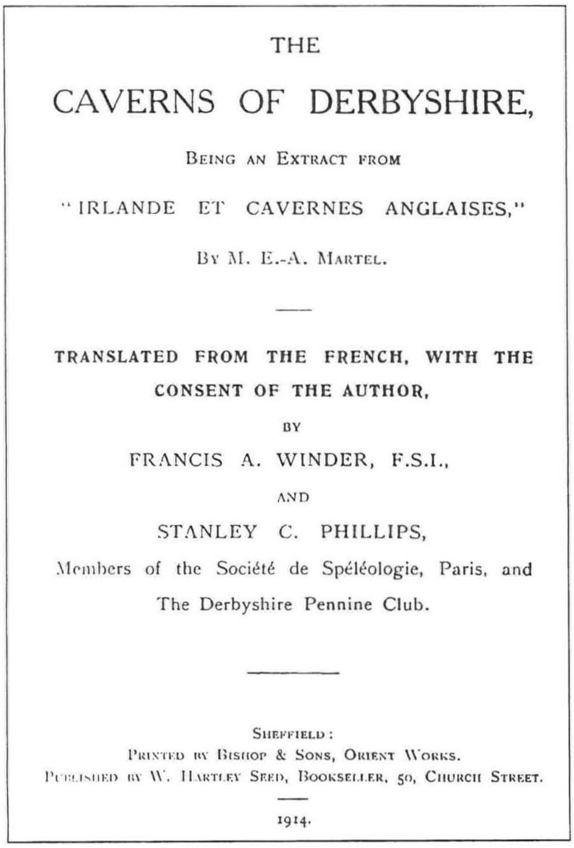
Martel's blunt comment when writing about Derbyshire in 1897 that the English should do some thorough investigation like the Austrians and the French were already doing was quoted earlier. To the international audience of his London lecture given the day after the Gaping Gill descent he said[30]

> *"I hope... that the English speleologists may be ... incited to renewed investigations into the most remote recesses of their caves and swallow-holes, and to a search for their yet unrevealed but certainly existing marvels and instructive phenomena."*

Referring to that lecture two years later in his paper for the Royal Geographical Society[16], he called it:

> *"...a memorandum on the encouragement which ought to be given to researches of all kinds in caves. ... The principal aim of my communication was to attract the attention of English scientific men and tourists to all that still remains to be done and to be found in the natural caves of Great Britain. ... I wish that cave-hunting may now be energetically resumed there by English investigators, to the great benefit of human knowledge and curiosity.*

There were many occasions on which Martel, used to the constant interchanges of information and pictures for books and lectures in France, assisted English cave workers in the same way. The paper that Balch had written for *Spelunca*[64] on caves in the Mendip Hills formed the basis of a chapter in a book a few years later [69]. Among the photographs illustrating it are several taken by Martel. Supply of photographs to and from France seems to have been quite common. A postcard written in English by Martel to Balch on 30 October 1904, and formerly in Wells Museum, makes arrangements for the return of half-tone blocks borrowed from Balch, no doubt those for the seven English photographs previously used in the *Climbers' Club Journal*[70]. The postcard also asks for the loan of some slides for lectures in France. Long before Martel's 1895 visit to England he had lent slides and a map and provided information to Mark Stirrup for lectures on the Causses given in 1890 to the Manchester Geographical Society[49] and the Manchester Geological Society[48]. A few years later Stirrup was again talking to the Manchester Geological Society[50] and *"On the table were laid numerous plans and sections of English and Irish caves visited by M. Martel in July last, and drawn up by him"*. In 1898 Martel wrote to an unidentified person in Ireland[71], thanking him for cave photographs. At the same time he pointed out the exploration and water tracing that were necessary so that "...a nice and special paper" could be published with the photographs in *Spelunca*. His prompting was evidently unsuccessful, for the paper never appeared.



THE

CAVERNS OF DERBYSHIRE,

BEING AN EXTRACT FROM

"IRLANDE ET CAVERNES ANGLAISES,"

BY M. E.-A. MARTEL.

TRANSLATED FROM THE FRENCH, WITH THE CONSENT OF THE AUTHOR,

BY

FRANCIS A. WINDER, F.S.I.,

AND

STANLEY C. PHILLIPS,

Members of the Société de Spéléologie, Paris, and The Derbyshire Pennine Club.

SHEFFIELD:
PRINTED BY BISHOP & SONS, ORIENT WORKS.
PUBLISHED BY W. HARTLEY SEED, BOOKSELLER, 50, CHURCH STREET.

1914.

Figure 16. The title page of the 1914 English version of Martel's account of his Derbyshire visit[60], which shows that the translators were both members of the Société de Spéléologie.

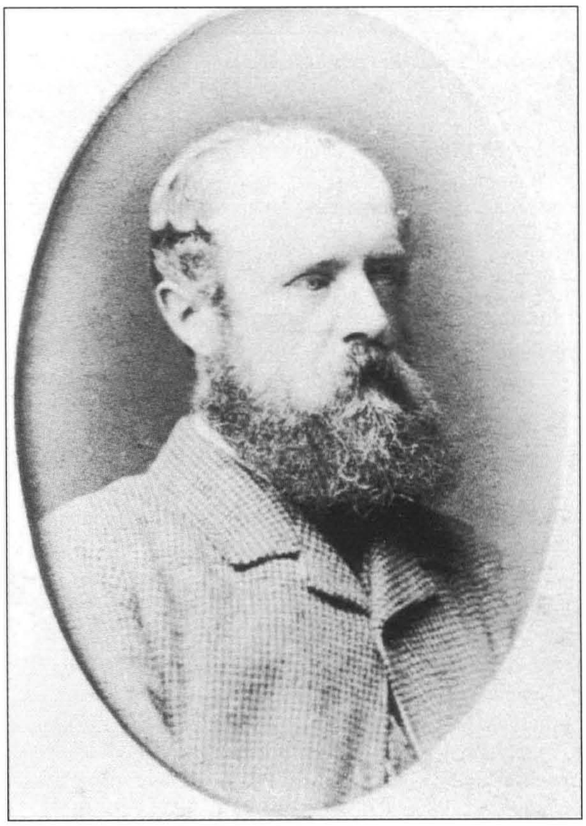


Figure 17. Thomas Richard Clapham (1837-1909) of Austwick, photographed in 1888 or 1889. Reproduced, with permission, from Royal Astronomical Society Add. MS. 94/80.

RECOGNITION OF MARTEL IN ENGLAND

Recognition of Martel in England has been of two kinds:

a) as a valued source of information about British caves;
b) as a great international figure.

In 1914 it was written that: *"It is perhaps difficult to realise that the only comprehensive work on English and Irish caves has not been written in the English tongue."* This comes from the introduction to an English translation[60] (Fig.16) of the five chapters on Derbyshire in *Irlande et cavernes anglaises.* Four corresponding chapters on Yorkshire caves were translated and published in 1951[72]. Most of the text on his Irish explorations has never been translated, though the Mitchelstown Cave chapter did appear in 1949[73], in a different translation to the original one of 1896[13].

An unfailing indicator of the recognition of a great man is the award of honorary membership by societies in his field. These are sometimes difficult to trace, often being reported only in membership lists and formal notices of meetings. It is known that he was made an honorary member of the Yorkshire Ramblers' Club in 1905[74] when he came to England to lecture in Leeds. He also became an honorary member of the Mendip Nature Research Committee when it was founded in 1906[75], and of the Alpine Club[76]. The British Speleological Association, formed in 1935, made him an honorary member almost immediately[77], along with the Abbé Breuil, Karel Absolon, Eugenio Boegan, Benno Wolf, Georg Kyrle and other major figures of cave study. In the following year the Association printed a short biography[78], and in due course a lengthy obituary appeared in *The Yorkshire Ramblers' Club Journal*[76].

ACKNOWLEDGEMENTS

I am particularly grateful to Dr J A Farrer of Clapham for allowing me to reproduce the photograph taken by his predecessor of Martel at Gaping Gill; to Don Mellor the Yorkshire cave historian for information and for providing a photograph of the New Inn at Clapham; to The Geological Society and its archivist John Thackray, in London, for portraits of Stirrup and Barnes; and to The Royal Astronomical Society librarian for the portrait of T R Clapham.

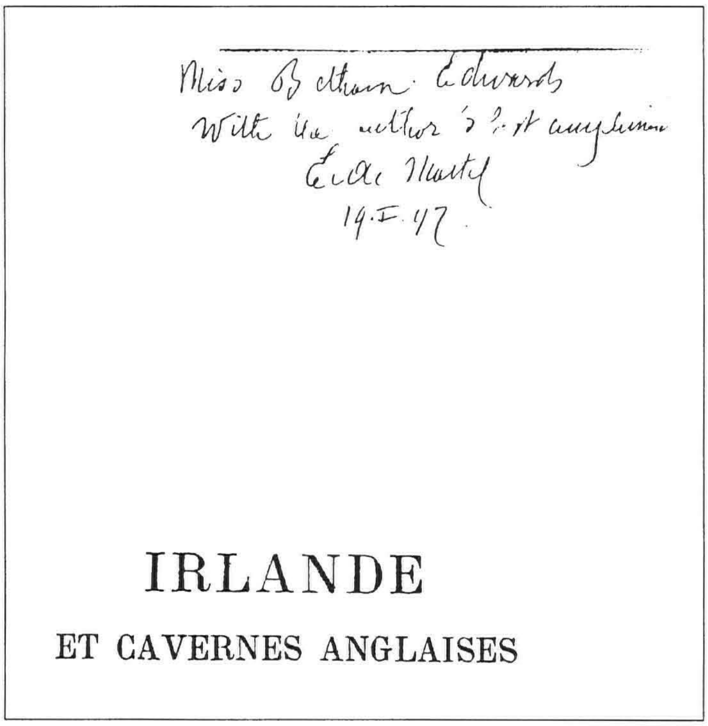


Figure 19. Martel's inscription to Matilda Betham Edwards in a copy of Irlande...[6] *(copy made in 1978; present whereabouts not known).*

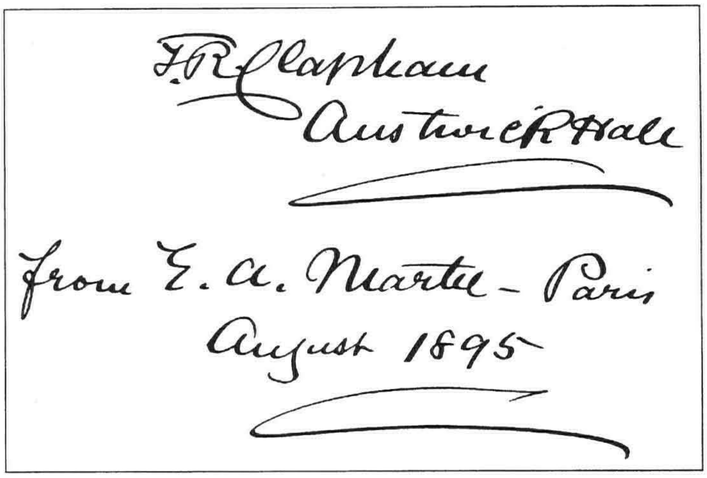


Figure 18. Martel's inscription to Thomas Richard Clapham in a bound volume of separata (in the library of the Karst Research Institute, Postojna).

APPENDIX

MORE ABOUT THE ENGLISH AND IRISH MEMBERS OF THE SOCIÉTÉ DE SPÉLÉOLOGIE AND OTHERS ASSOCIATED WITH MARTEL

Many of the Société de Spéléologie members from the British Isles explored or studied caves there; others were important for different activities. About others again, little or nothing is known and it is hoped that this paper may lead to the appearance of some information about them. It is possible, too, that there were other members as yet unidentified, for the last published membership list was for 1 October 1909[51] and the Société survived until 1914. Its administrative records have not survived, however, so knowledge of the later members depends on coming across references to their membership by chance. Indeed three of those listed in Table I were found in this way.

Nevertheless several of the English and Irish members played a significant part in cave study at the turn of the century, yet are hardly known today. The purpose of this appendix is to provide some details about their lives and work. They are listed here in alphabetical order, whereas in Table I they are arranged in the order in which they joined the Société. Three others are also included here: H Lyster Jameson who, though not a member, accompanied Martel in Ireland; W F Holroyd, joint author with Barnes of a paper published in *Spelunca*[57]; and T R Clapham, friend of Martel and provider of information about Yorkshire caves.

JONATHAN BARNES (1855-1927)

Jonathan Barnes (Fig.14), together with Holroyd, wrote a classic paper on the Blue John Cavern in Derbyshire, with a survey and advanced ideas about speleogenesis and the origins of helictites and botryoidal or coralloid speleothems.

Born in Blackburn[79] on 5 August 1855, he was the son of Henry Barnes, a cotton weaver, and his wife Mary. By profession an analytical chemist, having studied at Owens College (now the University of Manchester), he lived at Broughton near Manchester and worked in the cotton industry. He was also an amateur geologist of some standing, being elected a Fellow of the Geological Society of London in 1896, proposed by Boyd Dawkins and Mark Stirrup[80]. In the previous year he had become a member of the Manchester Geological Society of which he was President in 1901-1902[81]. He wrote on Peak District rocks and their invertebrate fossils, collaborated with Boyd Dawkins on the physical properties of coal, and made a collection of Derbyshire rocks and fossils that went to Manchester Museum. He died on 22 July 1927[82].

Barnes and Holroyd's paper on cave science is a study of the Blue John Cavern[55], carried out from March 1895 to June 1896. Their survey of the cave included roof heights measured by balloon. They argued that the cave must have been formed below the water table and printed sections to show the effect of joints on dissolution. Such an idea had been put forward in Belgium two years earlier by Dupont[83] but, even if Barnes and Holroyd were aware of this, they argued on the basis of their own observations and related their postulated earlier cave water levels to be local surface topography[84]. Probably independent also were their explanations of helictite formation as a result of air currents[85] and of coralloids being formed on hair-like fungi on the cave walls[86]. There was a long and quite informed discussion on the paper, including remarks by John Tym of Castleton, probably the same who descended Eldon Hole in 1873 with Rooke Pennington. Not surprisingly, one of the votes of thanks was given by Mark Stirrup, a doyen of the Manchester cave men. A shortened version of the paper was published in *Spelunca* in 1900[57].

In another paper on Derbyshire karst[56] the same two authors extended their work, measuring the rate of limestone dissolution, water-tracing from Speedwell Cavern to Russet Well near Peak Cavern, and discussing the effect of karst drainage on pollution, and on atmospheric humidity and health in the district.

THOMAS RICHARD CLAPHAM (1837-1909)

T R Clapham (Fig.17) was one of Martel's main informants on the caves of Yorkshire and it was he who was given the inscribed volume illustrated in Fig.18.

Born on 23 October 1837 in the Yorkshire village of Feizor[87], he inherited the nearby Austwick Hall as a child in 1846[88] and his life was fully occupied in managing the estate. Austwick Hall came to him, not from his father, but from a Thomas Clapham[89]. His father, Richard, had been a surveyor [87]. Thomas Richard himself had wide interests in the natural sciences, being elected in 1891 a Fellow of the Royal Astronomical Society, from which he resigned in 1900 [90]. He already belonged to the Liverpool Astronomical Society[91], and one of his few known publications is a short note on the aurora borealis[92]. He died of heart failure on 11 August 1909[93].

Clapham's attempt to explore Meregill Hole in 1868[65] has been mentioned. He was nearly 58 years old by the time he met Martel who acknowledged his gratitude *"...to my friend M. Clapham, of Austwick, who gave me valuable information on all the caves in the neighbourhood"*[94], including Rowten Cave (Kingsdale), Meregill, Alum Pot (where he had the wooden beam across it of the 1870s removed when it became unsafe) and the rising of the Alum Pot water at Footnaw's Hole[95]. Clapham was later to be involved in the underground water tracing project of the Yorkshire Geological and Polytechnic Society in 1900[96]. Like Mark Stirrup, he was one of those who provided photographs for Martel's book[97].

WILLIAM FIRTH HOLROYD (1854/55-1938)

W F Holroyd was co-author with Barnes of the two papers on Derbyshire karst described above, one of them translated and published in *Spelunca*.

Holroyd died on 1 March 1938, aged 83[98], so he was born in 1854 or early 1855. Like his friend Barnes he was an analytical chemist, and he lived near Oldham (in 1895), Broughton (1896), Pendleton (1902) and Eccles (1903)[99]. He also taught geology in many towns of the Manchester district. He was elected Fellow of the Geological Society of London in 1896[100], on the same day as Barnes, but resigned in 1908[101]. His membership of the Manchester Geological Society started in 1895 and he was Vice-President in 1900, but he resigned in 1904 [99]. These resignations suggest failing interest in geology, or perhaps failing health; alternatively his interest may always have been less than that of Barnes, who remained FGS until his death, and who may have been the dominant partner in their research.

HENRY WILLIAM PAUL LYSTER JAMESON (1875-1922)

H Lyster Jameson, as he preferred to be called, accompanied Martel in his Irish visits in 1895. Professionally he was a zoologist and he studied cave fauna in both Ireland and Derbyshire.

Born in 1875[102], the only son of Paul Lyster Jameson, rector of Killencoole, he went to Trinity College Dublin where he took his BA degree in 1896 and became MA and DSc in 1902[103]. So he was still an undergraduate when Martel described him as a young entomologist from the University of Dublin[104]. After graduation he spent a year at the Royal College of Science in London and then went to Heidelberg where be became PhD[105]. Shortly afterwards he went to Ceylon, studying pearl fisheries[105], and then from about 1901 until between 1903 and 1905 he worked at the Technical College in Derby[106, 107], during which time he explored caves again. By 1906 he was at the Transvaal Technical Institute in Johannesberg[107], his health obliging him to live in a warm climate. In 1911 he was back in England, at first with the Board of Education and then from 1916 he is known to have worked for the Board of Agriculture and fisheries in southeast England[105,107]. He died at Wivenhoe near Colchester in Essex on 28 February 1922 at the age of only forty-seven[98].

The first evidence of Jameson's interest in caves is a paper he published on bats at the age of nineteen[108]. This was followed by a definitive study of the distribution of all the bat species in Ireland, including four found in caves[109]. It was Dr Scharff who recommended the young Lyster Jameson to accompany Martel underground in Ireland, and in the same year the Flora and Fauna Committee of the Royal Irish Academy awarded him a grant *"for the purpose of further investigating the cave-fauna"*. He published a detailed account[110] of his exploration of several Irish caves, only some of them with Martel, and listed the fauna collected there. Jameson spent four days in Mitchelstown Cave, though Martel left after only one. He described one other cave, in Co. Leitrim, from a report by O.B. Maffet[111] and this note was reprinted in *Spelunca*[112].

When Lyster Jameson settled in Derby, he joined with J W Puttrell and members of the Kyndwr Club on 4 May 1901 to make the first descent of the Bottomless Pit in the Speedwell Cavern, where he collected the fauna described in some detail by Baker[106]. Then on 1 March 1902 he collected other animals from Peak Cavern[113].

FREDERICK A HEYGATE LAMBERT (active 1894-1905)

Lambert, who joined the Société de Spéléologie in 1902, visited the Jenolan Caves in New South Wales and published a detailed description of them in 1905[58]. He was a Fellow of the Royal Geographical Society, whose records show that he was elected in 1894[114]. In 1896 he was living at Epsom, in Surrey, and by 1921 he was no longer a Fellow. Nothing more is known about him.

WILLIAM NEWBOLD

William Newbold was described in the 1909 membership list of the Société as living then at Tunbridge Wells in Kent, having been elected in 1907. He may have been the "WW Newbould" who became a member of the Yorkshire Ramblers' Club in 1902 or 1903 when he lived in Leeds[115], and who descended Gaping Gill at the weekend 29 May - 1 June 1903[116]. Names were sometimes spelled wrongly in the *Spelunca* membership lists. Kent having no natural caves makes it not unlikely that someone there who was sufficiently interested to join the Société may have come from a limestone region. Puttrell was at the same Gaping Gill meet and became a member of the Société some time after 1909 and the two may have influenced each other.

JAMES WILLIAM PUTTRELL (1868-1939)

Puttrell (Figs 15, 20) explored caves in Derbyshire, Yorkshire and Ireland between 1899 and 1912.

Born on 7 October 1868[117] he spent his whole life in Sheffield, where he worked first in the cutlery business and then ran a firm of house painters. As a rock climber in the 1890, he achieved several new routes in England and spent a few climbing seasons in the Alps before 1914. He died on 14 August 1939[118].

Cave exploring became his major interest from 1900 onwards, especially in Derbyshire. Most of his explorations he described first in newspapers, though some were elaborated in a book[61]. He also visited tourist caves in Austria and Slovenia[59, 119]. Puttrell was an extrovert, even somewhat of a showman, as may be seen from his writing style, his choice of newspapers for publication, and even his pose in Fig.20. His library and mineral collection were given to public institutions at his death.

ROBERT FRANCIS SCHARFF (1858-1934)

Dr Scharff (Fig.21) explored many caves in Ireland, describing them (some with plans) and the bone deposits within them. It was he who recommended Lyster Jameson to accompany Martel.

Born at Leeds in 1858, he studied at the Universities of Edinburgh, London and Heidelberg and became Keeper of the Natural History Collection in the Museum of Science and Art in Dublin. He was President of the Royal Irish Academy in 1903-06, 1909-11 and 1919-21, and also Secretary of the Royal Zoological Society of Ireland. He died on 13 September 1934 in Worthing [118, 120].

Some of Scharff's principal writings on caves are listed in the references. Most interesting historically is one of the first, in 1895[121], for in it he foresees the need for a catalogue of all Irish caves as a preliminary to their proper study. He himself listed 23 caves there, with a location map and with a short bibliography for each. The paper evoked useful supplements by Ussher[122] and Praeger[123] and its bibliography was reprinted in *Spelunca*[124]. Other papers by

Figure 20. James William Puttrell (1868-1939) outside an upper entrance to Peak Cavern on 1 March 1902[152]. He was the first person to enter the cave by this route.

Figure 21. Robert Francis Scharff (1858-1934)[120].

Scharff described caves at Kesh in Co. Sligo[125-128], in Co. Antrim[129], at Edenvale in Co. Clare[130-132] (one of them [131] with cave plans) and the Castlepook Cave in Co. Cork[133,134]. It was Scharff who reviewed Martel's *Irlande et cavernes anglaises* for *The Irish Naturalist*[135].

WILLIAM CECIL SLINGSBY (1849-1929)

As member and President of the Yorkshire Ramblers' Club, Slingsby took part in the first descents of several deep Yorkshire potholes.

He is known mainly as a mountaineer, in Norway (from 1872), the Alps and the English Lake District (from 1885), being Vice-President of the Alpine Club in 1906-1908, and President of the Climbing Club 1904-06 and of the Fell and Rock Climbing Club 1910-12, as well of the Yorkshire Ramblers' Club 1893-1903. Two portraits were published with his obituary[136].

His cave work in Yorkshire was much more than just a token duty by a good President. After being in the surface party at one of the earliest English descents of Gaping Gill in 1896, he was on the first descents of Long Kin West (98m) and Sell Gill Hole (64m) in 1897 and Boggarts Roaring Hole (50m) in 1898. In 1906 he took part in new exploration in Gaping Gill and in 1910 he was one of the surveyors there[137]. His interest in caves in the early years of the Club, when cave exploration was not one of the stated objectives in its constitution, may have encouraged or at least facilitated the very significant work that it did do underground.

MARK STIRRUP (1831-1907)

Mark Stirrup, who had known Martel since 1898 or before and had assisted in the arrangements for his visit to England in 1895, published on the Causses of France, with their caves and underground streams.

Born in 1831, Stirrup (Fig.1) retired early from the cotton trade in Manchester and devoted the rest of his life to science, taking an active interest in the scientific societies of the district. He became a member of The British Association for the Advancement of Science in 1867[107]. In 1876 he was elected a Fellow of the Geological Society of London and wrote on marine erosion and Quaternary geology[138]. Joining the Manchester Geological Society in 1880, he was its secretary for about ten years and its President in 1896-97[99]. In 1885 he was a founder member of The Manchester Geographical Society and he was at once elected to its council [139]. A fluent French speaker, he was a member of the Association Française pour l'Avancement des Sciences and lectured at their 1880 meeting, mentioning the excavations in Yorkshire's Victoria Cave[140]. He travelled much in mainland Europe, and in Italy he was generally taken for a Frenchman. When he died, on 10 June 1907, he left most of his property to the University of Manchester; his collection of rocks, minerals and fossils from Europe went to the Manchester Museum[141].

Stirrup's published papers on the karst of Languedoc[48, 49, 50] were all from lectures given in Manchester and in all of them he acknowledged information and documents provided by Martel. Just when he first met Martel is not known. Not only did he help in the preparations for Martel's English visit, he was also one of those who provided photographs for use in *Irlande et cavernes anglaises*[97].

FRANCIS ARNOLD WINDER (1881-1847)

Winder was an active explorer of Derbyshire caves, about which he wrote a book[61], and a President of the Derbyshire Pennine Club.

Born in Sheffield on 12 April 1881, the youngest son of Edmund Winder (a land surveyor) and Mary Winder (née Wrangham)[142], he became a chartered surveyor and architect. In 1914[60] he was a member of the Derbyshire Pennine Club, and later its President, but little is known of his activities there for the Club's records no longer exist[143]. In 1931 he resigned but he was made an honorary member in November 1947[144]. A month later, on 29 December 1947, he died at Rushley Cottage, Dore, near Sheffield[145].

EDWARD PERCEVAL WRIGHT (1834-1910)

Dr Wright (Fig.22) described his visit to Mitchelestown Cave (Co. Tipperary) in 1857 with the collection of cave animals he made there[53], the first time that Irish cavernicoles had been recorded.

Born on 27 December 1834 in Dublin, the son of a barrister, he entered Trinity College in 1853 and qualified MD in 1862. Meanwhile his interest in natural history was evidenced by his founding *The Natural History Review* in 1854 and remaining its editor until 1866. He had been appointed Director of the Museum in Trinity College in 1857, and Lecturer in Zoology in Trinity College and Secretary of the Royal Geological Society of Ireland in 1858. Then in 1869 he was made University Professor of Botany, a post he retained for 35 years, though his publications show that his wide interests included zoology and anatomy. He died in Dublin on 2 March[146] (or 4 March[147]) 1910.

Figure 22. Edward Perceval Wright (1834-1910)[147].

His visit to Mitchelstown Caves took place in August 1857 with the entomologist Alexander Henry Haliday (1807-1870)[53]. The published abstract of the version he presented at the Dublin meeting of the British Association in that year[148] states that he showed a plan of the cave; this was almost certainly the one made by Thomas Kearney in 1833[149]. Most of Wright's paper was occupied by description and discussion of the cave fauna in the context of discoveries made previously by Schiödte[150] in Postojnska jama. Wright himself visited that Slovenian cave on 25 February 1861 (Fig.23) [151] but is not known to have written about it.

NOTES AND REFERENCES

[1] Shaw, T R, 1978. Adolf Schmidl (1802 - 1863) the father of modern speleology? *International Journal of Speleology,* Vol.10(3-4), 253-267.

[2] Shaw, T R, in press. *Martel et les États Unis.*

[3] Martel, E A, 1997. *La plume et les gouffres. Correspondence d'Edouard-Alfred Martel (de 1868-1936)...* Lozère, Association E A Martel. 607pp. (pp.566-596).

[4] Stirrup, M, 1895. La Société de Spéléologie. *Transactions of the Manchester Geological Society,*Vol 23(7), 163-164 (p.164).

[5] Martel, E A, 1896. The descent of Gaping Ghyll (Yorkshire). A story of mountaineering reversed. *Alpine Journal,* Vol.18(132), 120-125 (p.121).

[6] Martel, E A, 1897. *Irlande et cavernes anglaises.* Paris, Delagrave. 403pp. (The plan on p.23 is dated 12 and 16 July, and p.48 states that rain on 17 July prevented exploration underground; Jameson110, p.97 also states that July 16 was their last day of exploration there. Nevertheless *La plume...* p.574 indicates from another source that the exploration did continue on July 17, to the siphons).

[7] Martel, E A, 1897. *Irlande...,* p.182.

[8] Martel, E A, 1897. *Irlande...,* p.310.

[9] Lowe, G T, 1934. Forty years on. *Yorkshire Ramblers' Club Journal,* Vol.7[=6](21), 169-175 (p.172).

[10] The normal spelling, both before and after Martel's time, has been Gill. The Yorkshire Ramblers and some others, however, spelled it Ghyll from the 1890s until 1932 and it may have been they who caused Martel to do the same.

[10A] Chabert, C and M de Courval, 1971. *E.A. Martel 1859-1938 bibliographie.* Spéléo-Club de Paris. 103pp.

[11] Anon. 1895. Gaping Ghyll Hole fathomed. A subterranean cave. Triumph of a Frenchman. *The Bradford Observer,* 3 August, p.5.

[12] Martel, E A, 1896. Applications géologiques de la spéléologie... *Annales des Mines,* ser. 9, t.10(5), juillet. 100pp.

[13] Martel, E A, 1896. Mitchelstown Cave. *Irish Naturalist,* Vol.5, 101-105.

[14] Martel, E A, 1896. Sur le gouffre de Gaping Ghyll (Angleterre) *C.R. des Séances de l'Académie des Sciences,* Vol.122(1), 51-53.

[15] Martel, E A, 1896. Sur les siphons des sources et des rivières souterraines. *C.R. des Séances de l'Académie des Sciences,* Vol.122(20), 1147-1150.

[16] Martel, E A, 1897. British caves and speleology. *Geographical Journal,* Vol.10(5), 500-511.

[17] Martel, E A, 1896. Sous terre (huitième campagne, 1895) Marble Arch, Irlande, et Gaping Ghyll, Angleterre. *Annuaire du Club Alpin Français,* Vol.22 for 1895, 171-209.

[18] Martel, E A, 1896. Desente du gouffre de Gaping-Ghyll (Angleterre). *La Nature,* Vol.24(1182), 118-123.

[19] Martel, E A, 1896. Les Tomeens (Irlande). *La Nature,* Vol.24(1187), 199-200.

[20] Martel, E A, 1896. Les puffing holes ou trous souffleurs. *La Nature,* Vol.24(1196), 340-341.

[21] Martel, E A, 1896. Descent of the abyss of Gaping Ghyll, England. *Scientific American Supplement,* Vol.41(1054), 16852-16854.

[22] Martel, E A, 1896. Puffing holes. *Scientific American Supplement,* Vol.41(1067), 17050-17051.

[23] B[aker], E A, 1904. M. Martel in the Mendip caverns. *Manchester Guardian,* 11 July, p.12.

[24] Calvert, E, 1899. Gaping Ghyll Hole. *Yorkshire Ramblers' Club Journal,* Vol.1(1), 65-74.

[25] Martel, E A, 1997. *La plume...* , p.581.

[26] Martel, E A, 1904. Sur la résurgence de Wells (Angleterre) et la chronométrie de l,érosion souterraine. *C.R. des Séances de l,Académie des Sciences,* Vol.139(24), 1051-1052.

[27] Martel, E A, 1905. La désobstruction des abîmes Les cavernes des Mendip-Hills (Angleterre). *La Nature,* Vol.34(1698), 23-26.

[28] Shaw, T R, 1988. Martel's visit to Mendip in 1904 part of his international strategy? *Proceedings of the University of Bristol Spelaeological Society,* Vol.18(2), 278-291.

[29] Cheddar Caves visitors [1899-1918]. R C Gough, proprietor. Manuscript now in Somerset Record Office, Taunton. (See Figs 11 and 14).

[30] Martel, E A, 1896. Speleology. *Report of the 6th International Geographical Congress, held in London, 1895,* 717-722.

[31] Martel, E A, 1898. Cave exploring. *Wide World Magazine,* 1, 271-282.

[32] Martel, E.A. [1905?] Cave exploring: An unique and fascinating recreation. 277-280 *in* C L Neil (ed.). *The world's pictorial sports and pastimes.* [Gardner: London.]

[33] Martel, E A, [1909]. Speleology : a modern sporting science. *Yorkshire Ramblers' Club Journal,* Vol.2(8) for 1907-1908, 278-290.

[34] Baring-Gould, S, 1894. *The deserts of southern France an introduction to the limestone and chalk plateaux of ancient Aquitaine.* [Methuen: London.] 2 vols. (Martel, vol.1, 30-38; 48-52).

[35] Bonney, T G, 1895. Caves and swallow-holes. [Review of] Les Abîmes... *Nature, London,* Vol.51(1322), 410-412. Martel's book *La spéléologie ou science des cavernes* was given a short review in *Yorkshire Ramblers' Club Journal,* Vol.1(3), 1901, p.246.

[36] *Spelunca - Bull. de la Société de Spéléologie,* Vol.6(21-22), 1900, 80-81.

[37] *Spelunca - Bull. et Mém. de la Société de Spéléologie,* Vol.6(42), 1906, 276-279.

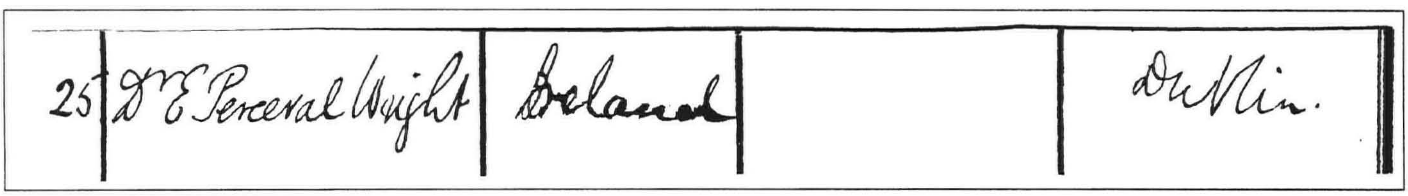


Figure 23. E P Wright's entry in the visitor's book of the cave at Postojna[151] *when he was there on 25 February 1861.*

[38] *Spelunca - Bull. de la Société de Spéléologie,* Vol.4(16), 1898, p.195.

[39] *Spelunca - Bull. de la Société de Spéléologie,* Vol.6(21-22), 1900, p.87.

[40] *Spelunca - Bull. et Mém. de la Société de Spéléologie,* Vol.6(42), 1906, 280-282; 285-286.

[41] *Spelunca - Bull. et Mém. de la Société de Spéléologie,* Vol.6(42), 1906, 273-276.

[42] Anon. 1898. La descente de Rowten Pot (Yorkshire, Angleterre). *Spelunca - Bull. de la Société de Spéléologie,* Vol.4(13), 31-39.

[43] Anon. 1897. The caverns of Craven. Descent of Rowten Pot. *The Bradford Observer,* 10 July.

[44] Cuttriss, S W, 1899. Notes on the caves of Yorkshire. Part II. *Proceedings of the Yorkshire Geological and Polytechnic Society,* Vol.13(4), 433-443 (opp.p.442).

[45] Jameson, H L, 1897. Cavernes du Comté Leitrim (Irlande). *Spelunca - Bull. de la Société de Spéléologie,* Vol.3(9-10), 54-55.

[46] Anon. 1904. Liste des membres au 1er septembre 1904. *Spelunca - Bull. et Mém de la Société de Spéléologie,* Vol.5(37), 193-200.

[47] Dickinson, J, 1907. Death of Mr. Mark Stirrup. *Transactions of the Manchester Geological and Mining Society,* Vol.30, p.117.

[48] Stirrup, M, 1890. Hydrology of the Causses of Languedoc; the gorges of the Tarn, its caverns and subterranean streams. (Being a chapter on denudation and the régime of underground waters). *Transactions of the Manchester Geological Society,* Vol.20(16), 446-458.

[49] Stirrup, M, 1890. "Unknown France." The hydrology of the Causses of Languedoc - the gorges of the Tarn, its caverns and subterranean streams, being a chapter on denudation and the régime of underground waters. *Journal of the Manchester Geographical Society,* Vol.6(1-3), 12-16. [The printed texts of 48 and 49 are not the same although they are of very similar lectures.]

[50] Stirrup, M, 1896. The work of subterranean waters: recent explorations of swallow-holes, caverns, and watercourses of the limestone districts of France [abstract]. *Transactions of the Manchester Geological Society,* Vol.24(3), [53]-54.

[51] Anon. 1909. Liste des membres au 1er octobre 1909. *Spelunca - Bull. et Mém. de la Société de Spéléologie,* Vol.7(57), 305-311.

[52] Anon. 1895. Liste des membres ... au 1er mai 1895. *Spelunca - Bull. de la Société de Spéléologie,* Vol.1, 15-19.

[53] Wright, E P, 1857. Notes of visit to Mitchelstown caves. *Natural History Review* 4, Proceedings of Societies, pp.231-241, 301 and plate XVIII.

[54] Martel, E A, 1997 *La plume...,* p.153 dates a letter enclosing his subscription as before 9 June 1896.

[55] Barnes, J and W F Holroyd, 1896. The mountain limestone caverns of Tray Cliff Hill, Castelton, Derbyshire, with some of their contained minerals. *Transactions of the Manchester Geological Society,* Vol.24(10), 215-252.

[56] Barnes, J and W F Holroyd, 1899. On the influence of subterranean excavations in limestone... *Transactions of the Manchester Geological Society,* Vol.26, 206-219.

[57] Barnes, [J] and [W F] Holroyd, 1899. La Blue-John-Mine a Castleton (Angleterre). *Mém. de la Société de Spéléologie,* Vol.4(23) for 1900, 1-19. [Translation of part of reference 55.]

[58] Lambert, F, 1905. Marvels of the subterranean world (the Jenolan Caves, N[ew]. S[outh]. W[ales.]. *Journal of the Manchester Geographical Society,* Vol.21, 128-139.

[59] Shaw, T R [1996] Puttrellov obisk Slovenije leta 1928. *Na›e jame, Ljubljana,* Vol.37 for 1995, 90-97.

[60] Martel, E A, 1914. *The caverns of Derbyshire, being an extract from "Irlande et cavernes anglaises,"* translated from the French ... by Francis A Winder and Stanley C Phillips, 46 pp. [Sheffield: W Hartley Seed.]

[61] Winder, F A, 1938. An unconventional guide to the caverns of Castleton and the surrounding district, [vi], 81, [i] pp. [Sheffield: W Hartley Seed.]

[62] Winder, F A, 1940. On the track of the "Old Man". *British Caver,* Vol.6, 32-44.

[63] Martel, E A, 1997. *La plume* ... pp.153-154.

[64] Balch, H E, 1904. Les cavernes et les cours d,eau souterrains des Mendip-Hills (Somerset, Angleterre) (explorations de 1901-1904). *Spelunca - Bull. et Mém. de la Société de Spéléologie,* Vol.5(39), 341-377. A facsimile of the manuscript English text that was translated for publication here is reproduced in pp.65-114 of W I Stanton, 1969. *Pioneer under the Mendips Herbert Ernest Balch of Wells.* [Pangbourne: Wessex Cave Club.]

[65] Martel, E A, 1897. *Irlande...* p.369.

[66] Martel, E A, 1997. *La plume...* p.165.

[67] Martel, E A, 1921. *Yorkshire Ramblers' Club Journal,* Vol.4(14), 269. Also reprinted in *La plume...* p.279.

[68] Hooper, J H, 1992. "I know the beggar". *Yorkshire Ramblers' Club Journal,* Vol.11(40), 40-45 (p.44).

[69] Baker, E A and H E Balch, 1907. *The netherworld of Mendip...* xii, 172pp [Clifton: J Baker; London: Simpkin, Marshall.]

[70] Balch, H E, 1904. Cave work in Somerset. *Climbers' Club Journal,* Vol.7(25), 9-20.

[71] Martel, E A, 1987. Transcript of a letter [dated 11 February 1898] from E A Martel to a gentleman in the west. *Irish Speleology,* Vol.4(1), p.4. Also reprinted in *La plume...* p.168.

[72] Martel, E A, 1951. The caverns of Yorkshire: four chapters of the book "Irelande et cavernes anglaises". Translated by J A P[illing]. *Cave Science,* Vol.2(15), 312-325; (16), 349-360.

[73] Martel, E A, 1949. The cave at Mitchelstown. Translation of chapter xi of ... "Irlande et cavernes anglaises' 1897". *British Caver,* Vol.19, 48-52.

[74] *Yorkshire Ramblers' Club Journal,* Vol.2(8) for 1907-1908 [published 1909], p.315.

[75] *Annual Report of the Wells Natural History and Archaeological Society.*

[76] [Roberts, E E] 1947. Edouard Alfred Martel (1859-1938). *Yorkshire Ramblers' Club Journal,* Vol.7(24), 105-116.

[77] British Speleological Association. 1936. *Advanced programme of the first annual speleological conference and exhibition ... [to be held at] Buxton ... July 24th to ... 27th* 8pp. (p.3).

[78] Simpson, E, 1937. E A Martel honorary member of the British Speleological Association. *Caves and Caving,* Vol.1(1), 10-11.

[79] Certified copy of an entry of birth given at the General Register Office for England and Wales. He was not born at Newmills (Derbyshire) as stated in the obituary in *Quarterly Journal of the Geological Society of London,* Vol.85, 1929, lxiv-lxv.

[80] Geological Society election certificate No. 4057. Archives of the Geological Society.

[81] *Transactions of the Manchester Geological Society,* Vol.24(1), 1895, p.26; and Vol.27(8), 1901, p.185. He was not President in 1896 as stated in the obituary in *Quarterly Journal of the Geological Society of London,* Vol.85, 1929, lxiv-lxv.

[82] Certified copy of an entry of death given at the General Register Office for England and Wales. He did not die in 1928 as given by W A S Sarjeant, *Geologists and the history of geology* ...2, 1980, p.485 and by R J Cleevely, *World Palaeontological Collections,* 1983, p.48.

[83] Dupont, E, 1894. Les phénomènes généraux des cavernes en terrains calcareux et la circulation souterraine des eaux dans la région Han-Rochefort. *Bull. Soc. Belge Géol. Paléont. Hydrol.* 7 for 1893, Mém, 190-297.

[84] Shaw, T R, 1992. *History of cave science...* 2nd edn. Sydney, Sydney Speleological Society. xiv, 338pp. (pp.166-167).

[85] Shaw, TR, 1992. *History of cave science...* (p.207).

[86] Shaw, T R, 1992. *History of cave science...* (p.213).

[87] Certified copy of an entry of birth given at the General Register Office for England and Wales.

[88] Speight, H, 1892. *The Craven and north-west Yorkshire highlands....,* 470pp. (p.163). [London: Elliot Stock.]

[89] *Yorkshire Genealogist, Bradford,* 1, 1888, 189-190.

[90] Royal Astronomical Society archives.

[91] Royal Astronomical Society archive 94/80.

[92] Clapham, T R, 1892. Aurora. *Journal of the British Astronomical Association,* Vol.2, p.311.

[93] Certified copy of an entry of death given at the General Register Office for England and Wales.

[94] Martel, E A, 1897. *Irlande...* p.339.

[95] Martel, E A, 1897. *Irlande...* pp.366-369, 381.

[96] Carter, W L and A R Dwerryhouse [1905]. The underground waters of north-west Yorkshire. Part II. The underground waters of Ingleborough. *Proceedings of the Yorkshire Geological and Polytechnic Society,* Vol.15(2) for 1904, 248-292 (pp.249, 267).

[97] Martel, E A, 1897. *Irlande...* p.398.

[98] Certified copy of an entry of death given at the General Register Office for England and Wales.

[99] Information from the membership lists published in the *Transactions of the Manchester Geological Society.*

[100] Geological Society election certificate No. 4065. Archives of the Geological Society, London.

[101] Geological Society Council Minutes, 4 Nov. 1908. Archives of the Geological Society, London.

[102] Praeger, R L, 1949. *Some Irish naturalists. A biographical note-book..,* 208pp. (pp.107-108). [Dundalk: Tempest.]

[103] Letter from Trinity College Dublin library, dated 7 January 1998.

[104] Martel, E A, 1897. *Irlande...* p.20.

[105] S[charff]. R F, 1922. Henry Lyster Jameson. *Irish Naturalist,* Vol.31(5), 49-50.

[106] Baker, E A, 1903. *Moors, crags and caves of the High Peak and the neighbourhood.* 207pp. (p.168). [London: Fisher Unwin.] (This book is more commonly found undated but published in the same year by Heywood of Manchester.) See also Baker, E A, 1901. The descent of the "Bottomless Pit". *The Wide World Magazine,* Vol.8(43), 49-55.

[107] Information from the membership lists published with the *Report[s] of the British Association for the Advancement of Science.*

[108] Jameson, H L, 1894. Irish bats: how to collect specimens with a view to the investigation of their distribution. *Irish Naturalist,* Vol.3(4), [69]-71.

[109] Jameson, H L, 1897. The bats of Ireland. A contribution to our knowledge of their distribution. *Irish Naturalist,* Vol.6(2), 34-43.

[110] Jameson, H L, 1896. On the exploration of the caves of Enniskillen and Mitchelstown for the R.I.A. Flora and Fauna Committee. *Irish Naturalist,* Vol.5(4), 93-100.

[111] Jameson, H L, 1896. Caves in Co. Leitrim. *Irish Naturalist,* Vol.5(10), p.276.

[112] Jameson, H L, 1897. Cavernes du Comté Leitrim (Irlande). *Spelunca - Bull. de la Société de Spéléologie,* Vol.3(9-10), 54-55.

[113] Anon. 1902. Kyndwr Club Notes. *The Climbers' Club Journal,* Vol.4(15), 140-142 (p.141).

[114] Royal Geographical Society. 1896. *List of fellows January 1896.* London, 148pp (p.59).

[115] *Yorkshire Ramblers' Club Journal,* Vol.2(5), 1903, p.71.

[116] Cuttriss, S W, 1903. Gaping Ghyll Hole. *Yorkshire Ramblers' Club Journal,* Vol.2(5), 48-51 (p.51).

[117] Certified copy of an entry of birth given at the General Register Office for England and Wales.

[118] Certified copy of an entry of death given at the General Register Office for England and Wales.

[119] Shaw, T R, 1998. Puttrell's visit to Slovenia in 1928. *Acta Carsologica, Ljubljana,* Vol.27 (in press).

[120] P[raeger], R L, 1934. Robert Francis Scharff. 1858-1934. *Irish Naturalist's Journal,* Vol.5(6), 153-155 and plate 13 opp. p.[125]. He did not die on 11 September as stated by Praeger. The date of death is correct in *Who was who,* Vol.3 [for] 1929-1940 London, 1941, p.1202.

[121] Scharff, R F, 1895. Some notes on the Irish Caves. *Irish Naturalist,* Vol.4(3), 57-59.

[122] Ussher, R J, 1895. Notes on the Irish caves. *Irish Naturalist,* Vol.4(4), 92-94.

[123] Praeger, R L, 1896. Irish caves. *Irish Naturalist,* Vol.5(5), 123-124.

[124] *Spelunca - Bull. de la Société de Spéléologie,* Vol.1(1), 1895, 46-48.

[125] Scharff, R F, 1895. Cave at Ballymote (Kesh), Co. Sligo. *Irish Naturalist,* Vol.4, p.94.

[126] Scharff, R F, 1902. Exploration of Kesh Caves, Co. Sligo, Ireland. *Geological Magazine,* Vol.9, 505-510.

[127] Scharff, R F, 1903. Kesh Caves, Co. Sligo - Report of the Committee appointed to explore Irish caves. *Report of the 72nd meeting of the British Association for the Advancement of Science held at Belfast in September 1902,* 247-252.

[128] Scharff, R F *et al,* 1903. The exploration of the caves of Kesh, Co. Sligo. *Transactions of the Royal Irish Academy,* Vol.32, 171-214.

[129] Scharff, R F, 1903. Animal remains from the Gobbins Cave, Co. Antrim. *Irish Naturalist,* Vol.12, 55-56.

[130] Scharff, R F, 1905. Edenvale Caves, Co. Clare - final report of the Committee appointed to explore Irish Caves. *Report of the 74th meeting of the British Association for the Advancement of Science held at Cambridge in August 1904,* p.288.

[131] Scharff, R F *et al,* 1906. The exploration of the caves of County Clare. Being the second report from the committee appointed to explore Irish Caves. *Transactions of the Royal Irish Academ,* Vol.33B(1), 1-76.

[132] Scharff, R F, 1906. Irish cave explorations. *Nature, London,* Vol.74 (1910), 138.

[133] Scharff, R F *et al,* 1909. On the cave of Castlepook, near Doneraile, Co. Cork. *Report of the 78th meeting of the British Association for the Advancement of Science [held at] Dublin [in] September 1908,* p.697.

[134] Scharff, R F, 1918. The exploration of Castelpook Cave, Co. Cork. *Proceedings of the Royal Irish Academy,* Vol.34B, 33-79.

[135] S[charff], R F, 1897. A French traveller in Ireland. *Irish Naturalist,* Vol.6(2), 45-46.

[136] B[rigg], J J [and E E Roberts], 1930. William Cecil Slingsby. (1849-1929). *Yorkshire Ramblers' Club Journal,* Vol.6(19), 66-69, with portraits opp. pp. 1 and 68.

[137] Craven, S A, 1996. A speleological appreciation of theYRC on the occasion of its centenary 1892-1992. *The Yorkshire Rambler* (6), 32-45 (pp.35-38).

[138] Geikie, A, 1908. Anniversary address of the President. *Quarterly Journal of the Geological Society, London,* Vol.64, l-cxxv (Stirrup obituary pp. lxv-lxvi); and Geological Society election certificate no. 2949.

[139] Brown, T N L, 1971. *The history of the Manchester Geographical Society 1884-1950.* Viii + 102pp. (pp.5, 26). [Manchester University Press.]

[140] Stirrup, M, 1881. De l'antiquité de l'homme dans la Grande-Bretagne. *Association Française pour l'Avancement des Sciences. Comptes rendues de la 9me session 1880* [à] *Reims,* 811-818.

[141] Cleevely, R J, 1983. *World Palaeontological Collections.* 365pp. (pp.276-277). [London: British Museum (Natural History).]

[142] Certified copy of an entry of birth given at the General Register Office for England and Wales.

[143] The records of the Derbyshire Pennine Club are said to have been burnt in a house fire. T D Ford, personal communication 1997.

[144] Letter from T D Ford, dated 3 July 1997.

[145] Certified copy of an entry of death given at the General Register Office for England and Wales.

[146] Desmond, R, 1977. *Dictionary of British and Irish botanists and horticulturalists...,* xxvi + 746pp (pp.678-679). [London: Taylor and Francis.]

[147] Dixon, H H, 1910. Edward Perceval Wright. *Irish Naturalist,* Vol.19(4), 61-63, and Plate XIX.

[148] Wright, E P, 1858. Notes of a visit to Mitchelstown Caves. *Report of the 27th meeting of the British Association for the Advancement of Science held at Dublin in August and September 1857.* Transactions of the Sections, pp.108-109.

[149] *in* Apjohn, J, 1834. On the newly discovered cave situated between Cahir and Mitchelstown. *Journal of the Geological Society of Dublin,* Vol.1(2), 103-111; also reprinted in *The Dublin Penny Journa,l* 3(130), 1834, 203-208 (the plan on p.207).

[150] Schiödte, J C, 1851. Specimen faunae subterraneae; being a contribution towards the subterranean fauna. *Transactions of the Entomological Society of London,* Vol.1(4 & 5), 134-157.

[151] Adelsberger Stammbuch [5] for 1959-65. MS. In the library of the Karst Research Institute, Postojna.

[152] Puttrell, J W, 1902. The secret of the Peak Cavern. *The Wide World Magazine, London,* Vol.9(54), 544-551 (p.545).

CAVE AND KARST SCIENCE Vol 26, No. 1, April 1999
Transactions of the British Cave Research Association

Speleothem deterioration at Cango Cave, South Africa

Stephen A CRAVEN
7 Amhurst Avenue, Newlands 7700, South Africa

Abstract: Cango is a leading South African show cave that has deteriorated markedly, especially during the second half of the Twentieth century. Little pure and applied research has been carried out at the Cave. The historical record, which goes back two centuries, documents the decline of the bat population, the deterioration of the speleothems especially in the proximal part of the Cave, and the exponential rise in the numbers of visitors. Contemporary observation in Cango I and II reveals that many of the speleothems are covered by phosphate material, and that they are better preserved more distally in the Cave. Despite this trend, there are a few isolated active speleothems near the entrance. This evidence supports the hypothesis that the spectacular speleothems were successively formed in the conventional way, corroded by bat guano, and then covered by new calcite. This recent calcite was eventually dissolved when increasing numbers of visitors were responsible for the development of unfavourable climatic conditions.

(Received 08 September 1998; accepted 22 February 1999)

INTRODUCTION

Cango Cave, situated in the Swartberg foothills, 27km north of Oudtshoorn in the (new) Western Cape Province, can be conveniently divided into three sections (Fig.1):

1) Cango I - the first 750m is a show cave and has been known since 1897. The proximal part, as far as the Drum Room, has been open to visitors for two hundred years;

2) Cango II - the intermediate part of the Cave is 300m long and has never been opened to tourists. Although Cango II was not discovered until 1972, there has always been unimpeded movement of air, and of bats, between Cango I and Cango II.

3) Cango III - the terminal part of the Cave - is 1,500m long, and was discovered in 1975 by lowering a sump. This water appears effectively to seal Cango III from the proximal part of the Cave.

The legal owner is, and always has been, the State. Since 1921 the Cave has been managed by the Oudtshoorn Municipality. For two centuries Cango Cave has attracted visitors to Oudtshoorn, where tourism is now the dominant industry. The other tourist attractions in the district are largely dependent on the Cave, in the sense that they are not peculiar to Oudtshoorn.

It is the spectacular speleothems, and the large chambers, that attract visitors to Cango Cave. From the historical record it is evident that the speleothems have deteriorated during the past two centuries. This is confirmed by comparing the speleothems in Cango I with those in Cango II and III; quite clearly those in the show cave have deteriorated markedly. Many have a matt crumbling "dead" appearance, compared with the glossy smooth "live" appearance exhibited more distally in the Cave. This deterioration is most obvious in Van Zyl's and Botha's halls, which most of the tourists visit and which have been open to the public for the longest period of time.

It is therefore indisputable that Cango Cave is not the Cave it was two centuries ago. It has been shown that the intrusion of people is directly and indirectly responsible for speleothem deterioration (Craven, 1994), but the destructive processes have not been described fully.

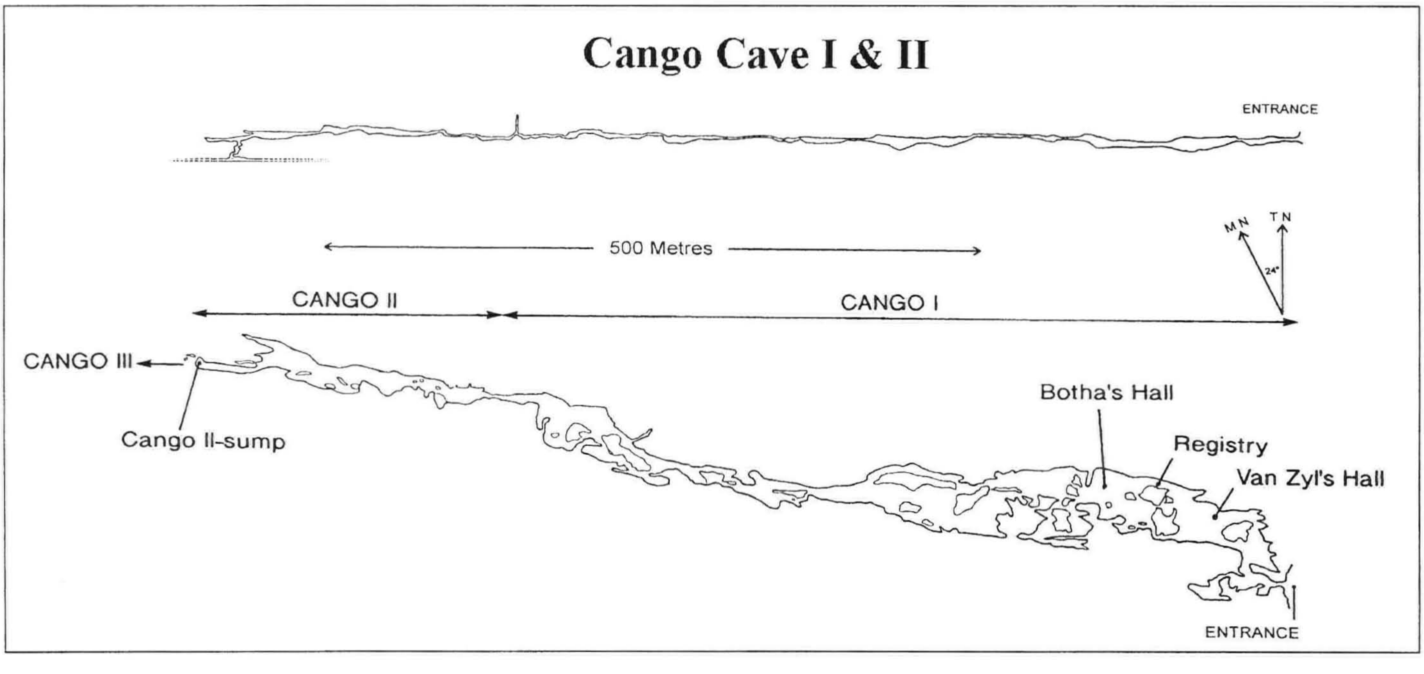


Figure1. Survey of Cango I and II.

THE HISTORICAL EVIDENCE

The date of discovery of the Cave was about 1780 (Craven, 1987), since when the historical record has repeatedly reported the destruction and removal of speleothems by visitors. The first written description of Cango Cave, of a visit in 1808, used the words *"crusty coverings"*, *"pearls and jewels"*, *"like glass"*, and *"an uncountable multitude of bats"* (Faure, 1824). This suggests that as early as 1808 some of the speleothems were dead, but that most of them were still alive.

A visitor in 1816 was most impressed by the bat guano, and was in places *"...prevented from proceeding by huge dunghills ... which covered the walls and ceilings"*, but did not mention the speleothems (La Trobe, 1818). In 1822 the bats were so numerous that, *"... it was with difficulty we could prevent them from extinguishing our lights"* (Thompson, 1827). The bats were still present in 1840, and the speleothems were described as *"... dazzling, sparkling, like diamonds"* (Sherwill, 1842).

It was in 1849 that the first clue to the causes of the deterioration of the speleothems was noted. Freeman (1851) made no mention of the bats. He was greatly impressed with the speleothems, and continued that:

> *"The process of crystallisation is still going forward, but not in all places. ... The stalactite is still gradually forming in innumerable places; in others it has ceased, and the slow process of decay and disintegration is going forward. ... The exterior becomes first moist and clammy, then the crystals are destroyed; the adhesion ceases, and they crumble to powder."*

A similar observation was made in 1853 (Ellis, 1858). Thus it appears that in the middle of the Nineteenth century some of the speleothems were already dead.

"Hundreds" of bats were still present in 1855 (Victorin, 1863). A visitor in 1873 found the speleothem quality to be variable. Some were of a *"... dazzling and sparkling whiteness"*, but others were:

> *"... of a dirty yellowish brown colour. Were it possible to scrape off the yellow coating and expose the white crystals of lime, there is no doubt that the effect would be much improved." (Anon., 1873)*

This description is compatible with the process of phosphate material being *"subsequently covered by younger flowstone ... turned into a hard, brown, resinous material"* (Martini, 1993).

In 1877 the bats were merely *"flitting"* through the Cave (Trollope, 1878), suggesting that their numbers had become considerably reduced during the preceding two decades. Two years later the bats *"...sit in silent wonderment ... into their domain"* (Laing, 1879); but by 1886 they had gone (Anon., 1886), no doubt because of increasing visitor numbers (Anon., 1890). However some were reported temporarily a decade later (Anon., 1896). The bats must have been in residence for a very long time and in huge colonies - the last of the guano was removed as late as 1938 (Craven, 1985).

THE CONTEMPORARY EVIDENCE

A tour through Cango I and II at the end of the Twentieth century reveals that the further into the Cave the speleothems are, the better they are preserved - an observation that was made a century ago (Brown, 1893). In Van Zyl's and Botha's halls most of the speleothems have a grey-white powdery covering of a phosphate material called "apatite" by Martini (1987) (Fig.2), a phenomenon that becomes progressively less common towards the distal end of Cango II. However, as Fleischer and Mandarino (1995) deny the existence of "apatite" as a mineral species, the phrase "phosphate material" is used in this paper to avoid semantic criticism.

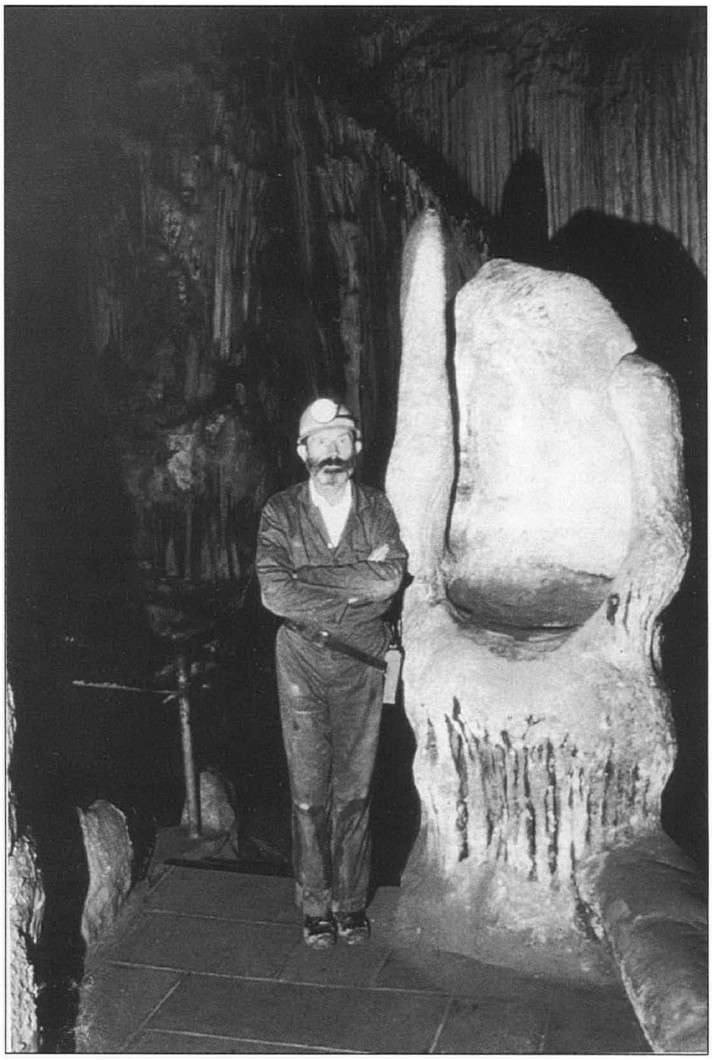


Figure 2. Phosphate material covering a speleothem in Cango I. Photograph by Dr J E J Martini.

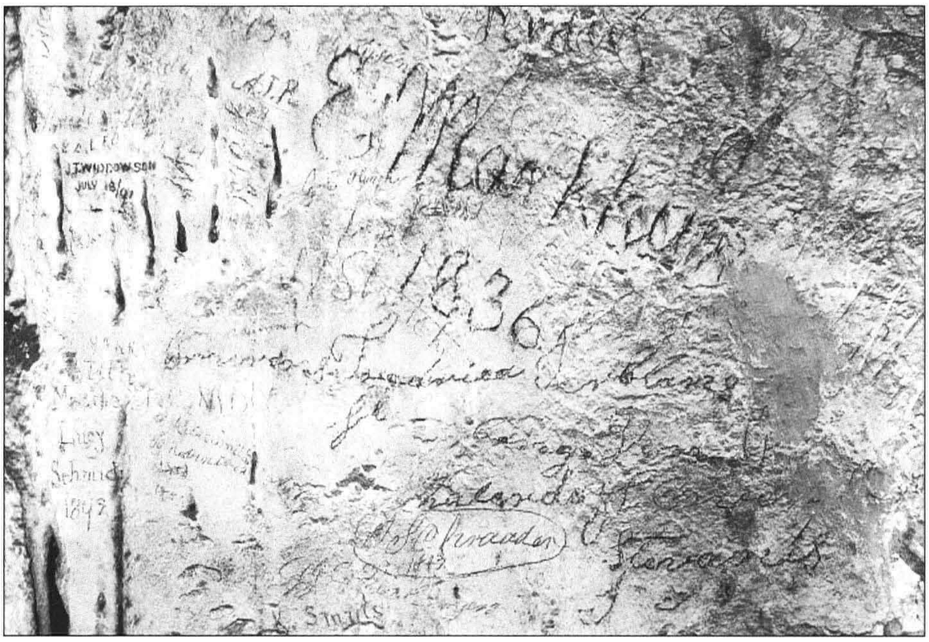
Many of the surviving, active, speleothems have been damaged by lampenflora, Nineteenth and early Twentieth century graffiti, and deposits of dirt. In many places fresh calcite deposits have since covered these disfigurements (Fig.3).

Some bat skeletons are found in Cango II, but there is no guano, suggesting that the bat population there was never large. However, *"A few isolated patches of apatite moonmilk have developed on flowstone"* (Martini, 1987).

No phosphate material has been reported from Cango III (Martini, 1987). This negative observation, and the absence of bat skeletons and guano, indicate that bats never colonised Cango III.

In the mid-1920s a vertical groove was cut in the limestone of the Registry, between Van Zyl's and Botha's halls, to accommodate an electricity cable. This cable was removed three decades ago when the Cave was rewired. The groove now contains a respectable deposit of active calcite (Fig.4). In Botha's Hall there is a well-preserved solitary active flowstone speleothem, surrounded by flowstone that is covered by phosphate material (Fig.5). These observations indicate that, if climatic and other conditions are favourable, calcite will be deposited comparatively quickly.

Figure 3. Calcite covered graffiti in Cango I. Photograph by Mr T J Hall.



DISCUSSION

Biological literature about the chemical composition of bat urine and faeces appears to be wanting. Mammalian physiology differs in detail but not in principle. Human urine contains calcium and phosphate ions; human faeces contain calcium phosphate that originates mostly from the dietary sources (Lentner, 1981). Mineralogical literature confirms that bat guano contains varying but significant quantities of P_2O_5 (Hutchinson, 1950), with a pH as low as 2 - 3 (Martini, 1993). A sample from Cango Cave, analysed in 1921, was said to be of "very medium quality" for agricultural purposes, but details of the analysis were not presented (Anon, 1921).

The nearest source of quantitative data is some 1,500km away, where cave bat guano analyses were carried out in the former Transvaal (Table 1):

Site, near:	P_2O_5 %	Reference:
Soutpansberg	3·81	Ingle, 1908
Potchefstroom	2·82	Ingle, 1908
Wonderfontein	1·71	Ingle, 1908
Wonderfontein	26·55	Ingle, 1908
Wonderfontein	2·26	Ingle, 1908
Elandsfontein	7·40	Ingle, 1908
Ermelo	53·58	Marchand, 1918
Ermelo	55·60	Marchand, 1918

Table 1. Selected cave bat guano analysis data from the (former) Transvaal.

This wide variation in P_2O_5 content can be explained by species and dietary variability and by sampling bias, but nevertheless the analyses serve to confirm the presence of P_2O_5 in bat guano. Unfortunately the dietary requirements of the Transvaal bats were not stated.

Herselman and Norton (1985) have listed the bats reported from the Cango Valley. The only Megachiropterid (i.e. frugivorous bat) is *Rousettus aegyptiacus,* which typically occupies the twilight zone of caves. All other reported bats are Microchiropterids (i.e. insectivorous) viz. *Rhinolophus clivosus, Rhinolophus capensis, Myotis tricolor, Eptesicus melckorum* and *Miniopterus schreibersi.* It can therefore be assumed that the guano in Cango Cave derives from insectivorous bats, confirming observations made by the author in other Cango Valley caves.

This acidic guano, on being deposited directly onto a speleothem, reacts with the calcite, corroding it to produce a phosphate material by a complex chemical process (Neuberg and Grauer, 1957; Martini, 1993; Hill and Forti, 1997).

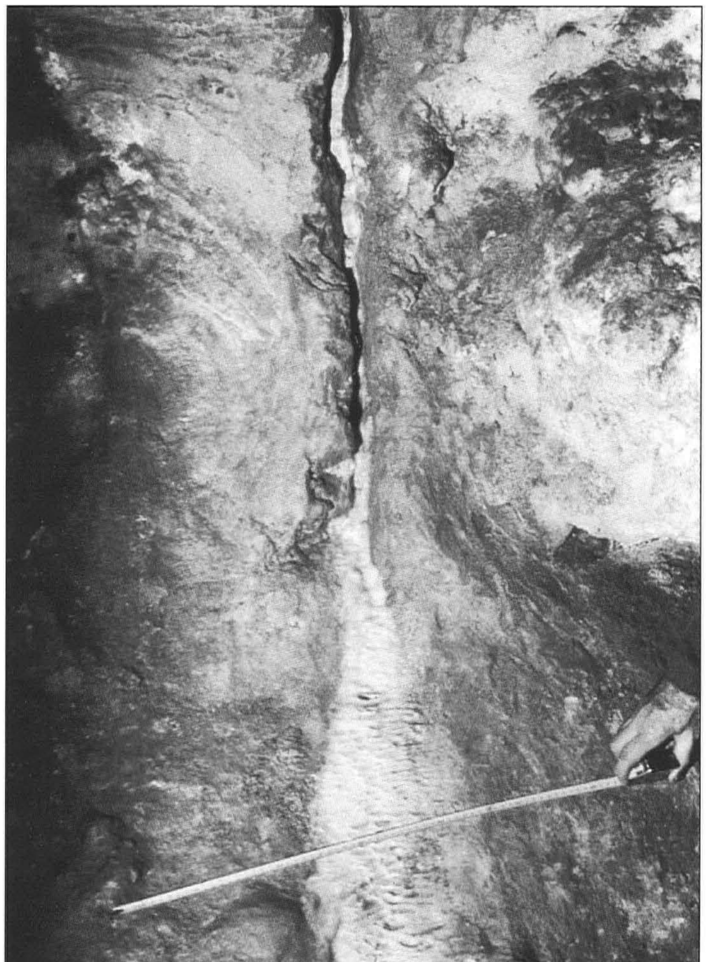


Figure 4. New calcite deposit in the Registry, Cango I. Photograph by Dr J E J Martini.

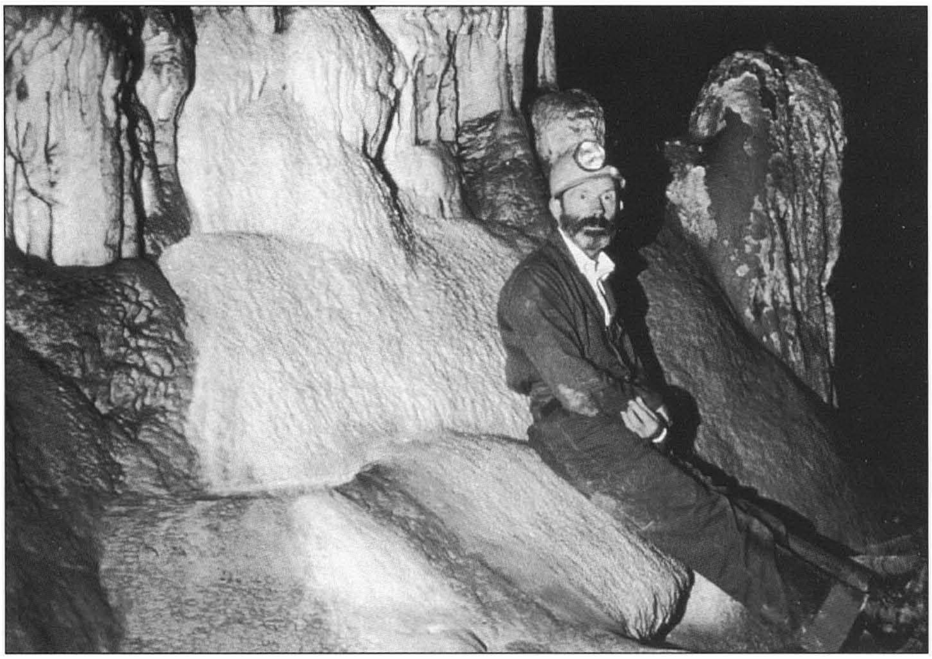


Figure 5. Active speleothem in Botha's Hall, Cango I, with dead speleothems on both sides. Photograph by Dr J E J Martini.

It appears from the attendance figures at Cango Cave (Fig.6) that it was excessive human disturbance that caused the bats to depart. They left their roosts as soon as attendance figures began to rise. The dramatic increase in visitor numbers ensured that the bats never returned, and that deposition of phosphate material ceased.

Cango Cave is a low energy sack cave. The natural energy entering the Cave is very low compared with that introduced by visitors and by the electric lights (Heaton, 1986). It has been shown that large numbers of visitors do raise the pCO_2 in the Show Cave (Craven, 1996), and it can safely be assumed that the relative humidity and temperature will also be increased.

Speleothem deposition is a reversible process that depends, inter alia, on the temperature, humidity and pCO_2 in the cave (Ford and Williams, 1989). There comes a time when increasing numbers of visitors have an effect on the above atmospheric variables, leading to dissolution of the speleothems. Fig.6 shows that there has been an essentially exponential increase in visitor numbers since 1945. It is postulated here that before 1945 there were insufficient visitors to have a significant effect upon the deposition of new calcite over the phosphate material. After 1945 increasing numbers of visitors changed the cave atmosphere to such an extent that the new calcite was dissolved, exposing the underlying phosphate material.

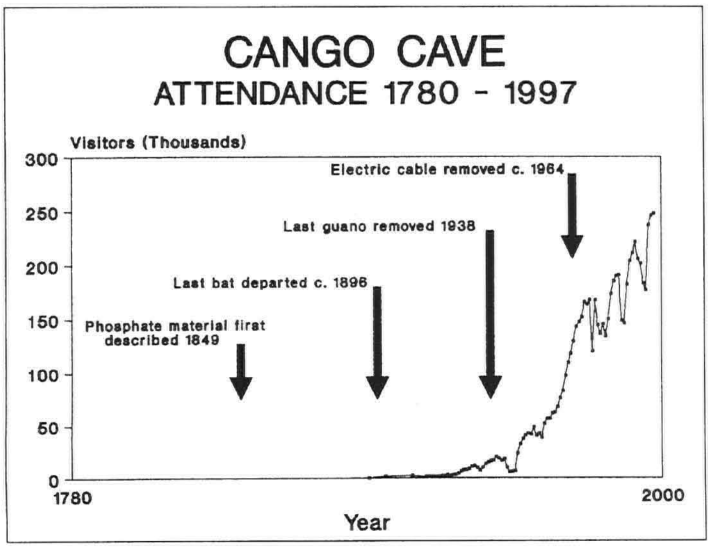


Figure 6. Attendance figures for Cango Cave, with significant events superimposed.

It is not only the Cave atmosphere that controls the deposition and dissolution of speleothems. Other things being equal, a high CO_2 content of the rain water seeping into the Cave will promote calcite deposition, while a low CO_2 content will encourage dissolution (Ford and Williams, 1989). Rainwater CO_2 content is augmented by CO_2 in the soil atmosphere, which depends on the respiration of plant roots, invertebrate fauna and micro-organisms (Gillieson, 1996). Therefore the condition of the speleothems in the Cave also depends on the rainfall, and on the soil and vegetation above the Cave - a concept that was described a century and a half ago (Liebig, 1842). One of the characteristics of most karst landforms is a thin soil cover that is vulnerable to further depletion by human influence, thereby reducing the CO_2 available in the rainwater for speleothem deposition.

The new calcite deposits in the Registry and in Botha's Hall, and the active speleothems elsewhere in the Cave, suggest that if the favourable environmental conditions were to be reintroduced, there would be an attractive show cave in three decades. Their presence indicates that the Cave's atmosphere is locally favourable, and an appropriately high pCO_2 exists in the soil overlying parts of the Cave.

It is not known what and exactly where that supportive vegetation is. The Oudtshoorn Municipality has recently fenced the land over the Cave and excluded domestic grazing animals. It is hoped that this will facilitate the re-growth of the unknown original vegetation that was present before eighteenth century settlers disturbed the veld by their farming practices. Whatever the outcome, on theoretical grounds, any increase in vegetation that will elevate the soil pCO_2 and reduce water losses by transpiration and run off can be expected to encourage calcite deposition within the underlying cave.

Unfortunately, the "scientific study" recently commissioned by the Oudtshoorn Municipality (Grobbelaar *et al*, 1996) failed to define the ideal environmental conditions, manipulation of which could be expected to affect the regeneration of the speleothems (Craven, 1996). It is to be hoped that a more authoritative investigation will be commissioned urgently by the Oudtshoorn Municipality.

This paper is not merely an exercise in academic speleology; it is an exercise in sustainable tourism. If the Cave is allowed to deteriorate further to a condition where it no longer attracts visitors, Oudtshoorn will become an insignificant economic backwater of South Africa.

SUMMARY

The postulated sequence of events for the deposition and deterioration of the speleothems in Cango I and II is therefore (Fig.7a-d):

a) The Cave and its speleothems were formed by normally accepted processes of limestone dissolution and subsequent calcite speleothem deposition (Ford and Williams, 1989).

b) Bats that inhabited the Cave dropped urine and faeces on some of the speleothems, causing conversion of some superficial calcite to phosphate material.

c) When bat populations were reduced or eliminated in response to increasing human disturbance at the end of the Nineteenth century, the Cave climate remained favourable for calcite deposition on top of the phosphate material.

d) Increasing numbers of visitors, especially in the second half of the Twentieth century, brought about an unfavourable change in the Cave climate. This caused re-dissolution of calcite, re-exposing the phosphate material that currently disfigures much of the Cave.

ACKNOWLEDGEMENTS

I am grateful to Professor M E Marker for her useful comments on the early drafts of this paper, and to Dr J E J Martini of the Council for Geoscience in Pretoria for his helpful comments during fieldwork in the Cave. Associate Professor Stein-Erik Lauritzen is thanked for his helpful review comments on the BCRA manuscript.

REFERENCES

Anon, 1873. A Visit to the Cango Caves. *Cape Monthly Magazine n.s.*, 7, 374 - 377.

Anon, 1886. *Grahamstown Journal,* 13 July, p.3.

Anon, 1890. *Oudtshoorn Courant,* 14 January, p.2.

Anon, 1896. *South African Telegraph,* 17 March, p.7.

Anon, 1921. *Oudtshoorn Courant,* 21 November, p.4.

Brown, A S, 1893. *South Africa.* pp. 159 – 160. Sampson Low, Marston & Co., London.

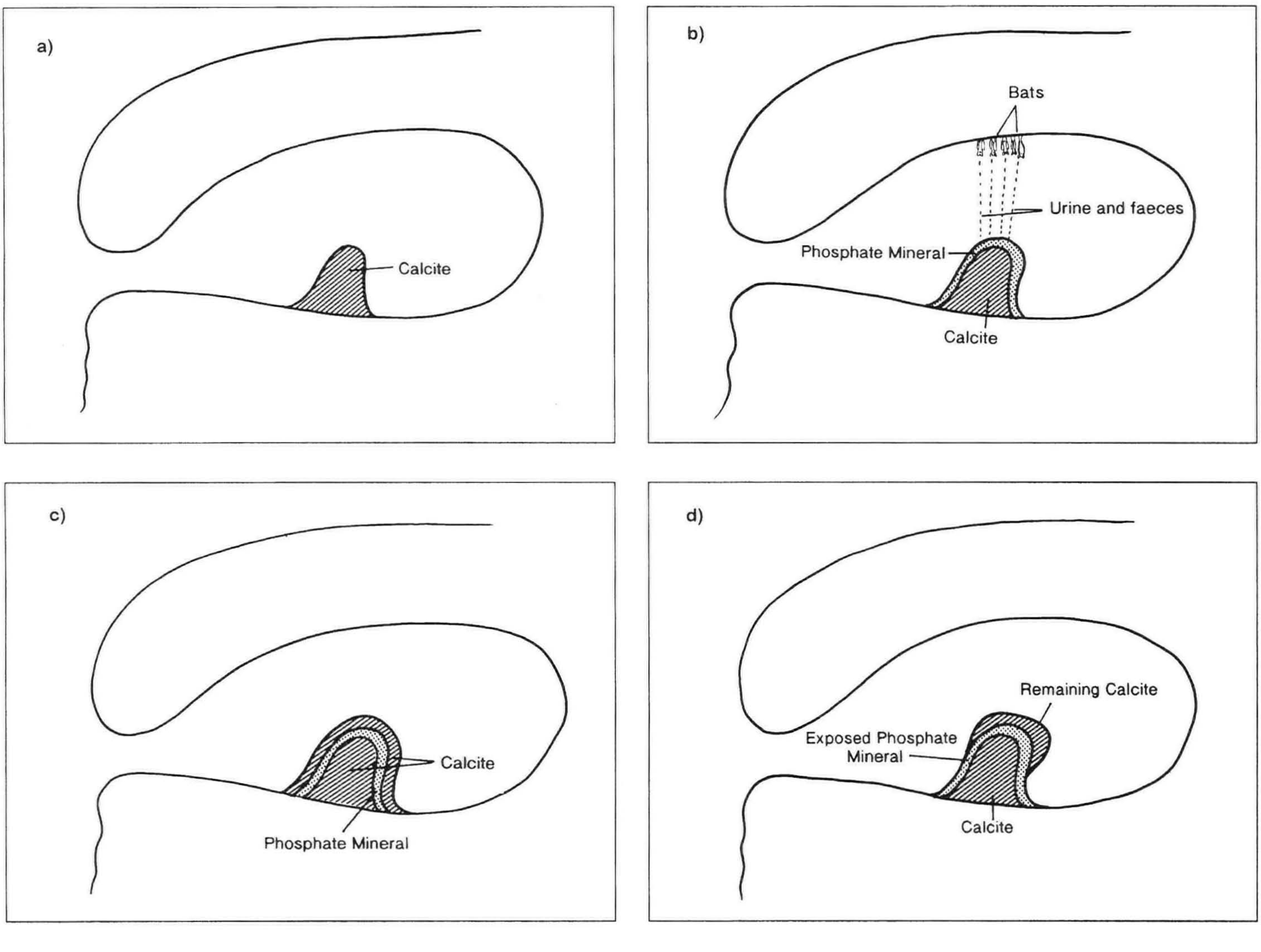


Figure 7. Diagram of the postulated sequence of events.
a) Cave and calcite speleothem before bat colonisation.
b) Bat urine and faeces convert calcite to phosphate material.
c) The phosphate material is covered by calcite after departure of the bats.
d) The calcite cover is later dissolved, re-exposing the phosphate material.

Craven, S A, 1985. Guano in the Cango Caves - an attempt at conservation which failed. *Free Caver,* Vol.21, 12 - 17.

Craven, S A, 1987. The early days of the Cango Caves from the late eighteenth century until 1820. *William Pengelly Cave Studies Trust Ltd. Newsletter,* 50, 25 - 28.

Craven, S A, 1994. Cango Cave, Oudtshoorn District of the Cape Province, South Africa: An Assessment of its Development and Management 1780 – 1992. *Bulletin of the South African Speleological Association*, Vol.34, pp. xi + 136.

Craven, S A, 1996. Carbon dioxide variations in Cango Cave, South Africa. *Cave and Karst Science,* Vol.23(3), 89 - 92. See also *Cave and Karst Science,* Vol.24(1), p.47.

Ellis, W, 1858. *Three Visits to Madagascar during the years 1853 - 1854 – 1856.* p.199. John Murray, London.

(Faure, P S), 1824. Uittreksel van een reisverhaal van een kaapsch meisje, naar de spelonk in het Cango's gebergte. *Nederduitsch Zuid-Afrikaansch Tydschrift,* 1, 446 - 452.

Fleischer M and Mandarino, J E, 1995. *Glossary of Mineral Species.* p.9. The Mineralogical Record, Tucson.

Ford, D C and Williams, P W, 1989. *Karst Geomorphology and Hydrology.* pp.xv + 601. Unwin Hyman, London.

Freeman, J J, 1851. *A Tour in South Africa.* pp.40 – 42. Snow, London.

Gillieson, D, 1996. *Caves: Processes, Development, Management.* pp.71 – 73; 269 – 299. Blackwell, Oxford.

Grobbelaar, J U *et al,* [Dec.] 1996. *Scientific Study aimed at establishing a Management Strategy for the Cango Caves, Oudtshoorn.* 76pp. (Unpublished report by the Department of Botany and Genetics, University of the Orange Free State, Bloemfontein).

Heaton, T, 1986. A Tremendous Range in Energy Environments on Earth. *National. Speleological Society News,* 44(8), 301 - 304.

Herselman, J C and Norton, P M, 1985. The distribution and status of bats (Mammalia: Chiroptera) in the Cape Province. *Ann. Cape Provincial Museums Nat. Hist.* Vol.16(4), 73 - 126.

Hill C (A) and Forti P, 1997. *Cave Minerals of the World.* 2nd edition, pp.163 – 176 and 288. National Speleological Society, Huntsville.

Hutchinson G E, 1950. The Biogeochemistry of Vertebrate Excretion. *Bull. Am. Mus. Nat. Hist. New York.* Vol.96, 381 - 475.

Ingle, H, 1908. *A Manual of Agricultural Chemistry.* 2nd edition, pp.409 – 410. Scott, Greenwood, London.

La Trobe, C I, 1818. *Journal of a visit to South Africa in 1815 and 1816.* pp.51 – 52. L B Seeley, London.

Laing, J, 1879. Cape Archives A872. Commentary by Craven, S A, 1985. The Cango Caves on 20 February 1879 - Visit of Messrs. Thomas Bain and John Laing. *William Pengelly Cave Studies Trust Ltd. Newsletter,* 46, 28 - 30.

Lentner, C, (Ed.) 1981. *Geigy Scientific Tables,* 1, pp.57 – 60 and 153. Ciba-Geigy Ltd., Basle.

Liebig, J, 1842. *Chemistry in its application to agriculture and physiology.* 2nd edition, pp.114 – 115. Taylor and Walton, London.

Marchand, B de C, 1918. Note on the occurrence of a peculiar phosphate of aluminium in a deposit of bat guano. *South African Journal of Science,* Vol.15, 638 - 639.

Martini, J (E J), 1987. Contribution to the Mineralogy of the Cango Caves. *Bulletin of the South African Speleological Association,* Vol.28, 18 - 28.

Martini J E J, 1993. A Concise Review of the Cave Mineralogy of Southern Africa. *Proceedings of the XIth International Speleological Congress, Beijing.* pp.72 - 75.

Neuberg, C and Grauer, A, 1957. The Problem of Solubilization and Precipitation and the Calcium and Phosphorus Cycle in Cavern Formation. *Experientia,* Vol.13(10), 391 - 393.

Sherwill, W S, 1842. A Passage over the Outeniqua Mountains in the Colony of the Cape of Good Hope, and visit to the Cango Caverns in 1840. *Graham's Town Journal,* 20 October.

Thompson, G, 1827. *Travels and Adventures in Southern Africa 1.*138 (reprinted 1967, Van Riebeeck Society, Cape Town, No.48).

Trollope, A, 1878. *South Africa 1.* p.119. Chapman and Hall, London.

Victorin, J F, 1863. *Resa in Kaplandet.* p.148. Albert Bonnier, Stockholm.

CAVE AND KARST SCIENCE Vol. 26, No. 1, April 1999
Transactions of the British Cave Research Association

Formation and features of Ballıca Cave, Pazar, Tokat, Turkey

Baki CANIK [1], Mehmet ÇELIK [1], Suzan PASVANOĞLU[2] and Esfendiar Abbas NOVINPOUR [3]
[1] Ankara University, Faculty of Natural Sciences, Department of Geological Engineering, Tandoğan, Ankara, Turkey
[2] Kocaeli University, Faculty of Engineering, Department of Geological Engineering, İzmit, Turkey
[3] Urumiye University, Faculty of Natural Sciences, Department of Geological Engineering, Urumiye, Iran

Abstract: Ballıca Cave is formed in crystalline limestones. Considering the limited limestone outcrop, the volume of the cave is extremely large. The limestone is unbedded, faulted and fractured, and cracks are filled with calcite. The limestone is composed of 96% $CaCO_3$. Karstic structures in the limestone include karst pits, swallow holes, dissolution funnels and clints, developed on discontinuity planes. The fractured structure and chemical composition of the limestone are the main factors controlling karstification and the formation of stalactites, stalagmites and columns in the cave. The cave comprises two main galleries trending NE-SW (1) and NW-SE (2), and has associated rooms and saloons[1]. The 1st Gallery has an undulating floor, whereas the floor of the second comprises gradually declining levels, related to a series of normal faults. Fallen blocks on the floor of the cave might have broken off as a result of regional earthquakes. Stalactites, stalagmites, columns, flowstones, draperies, macaroni-shaped stalactites, dripstones, pools and cave pearls are present in the 1st Gallery. All of these speleothem types, and a variety of other stalactite shapes including a 6.5m-long stalactite (with no corresponding stalagmite) are also seen in the 2nd Gallery. There is evidence that karstic, tectonic and earthquake episodes have all affected the cave's development. The most significant pieces of evidence are: (a) the presence of surface travertines that are believed to be sourced from seepage waters in the cave; (b) the opening of the cave entrance along the fault; (c) fallen blocks in the cave; (d) signs of horizontal fractures in thick columns; (e) secondary mineral occurrences indicating that for a long time groundwater remained at the Çöküntü Saloon level, along a horizontal line visible in the wall; and (f) long stalagmite-free stalactites in the lower part of the Yeni Saloon. Ballıca Cave most probably began to form 3.4 million years ago and its development has continued until recent times, dependent upon regional climatic conditions.

(Received 31 July, 1998; accepted 15 March, 1999)

INTRODUCTION

Ballıca Cave lies 8km south of Pazar town in the district of Tokat (Tokat H36-c1 quadrangle) in the Central Black Sea region (Fig.1).

Studies of the surface geology and cave mapping were started in January 1992 (Fig.2) and completed in June 1995. Cave galleries were mapped by the Cave Research Society in 1992. Further mapping was conducted in 1994 by a team from the Cave Research Project, under the General Directorate of Mineral Research and Exploration of Turkey (MTA). Incomplete parts of the original map were dealt with when compiling the MTA map (Fig.3).

Ballıca Cave has formed in karstic crystalline limestones overlying metamorphic schists of the Tokat Massif. The surface area of the crystalline limestone mass, under which the cave lies, is about 30 hectares and, as a result of tectonism and karstification, dissolution voids in the deeper part of this outcrop have given rise to the cave. Despite the restricted surface extent of the limestone, the known cave has a length of 680m and covers an area of about 6,500m^2, indicative of extensive karstification.

This study set out to examine the hydrogeological and speleological features of the Ballıca Cave. Even though this phase of the study is complete, the cave will continue to attract many visitors, because all parts of the cave are rich in speleothems.

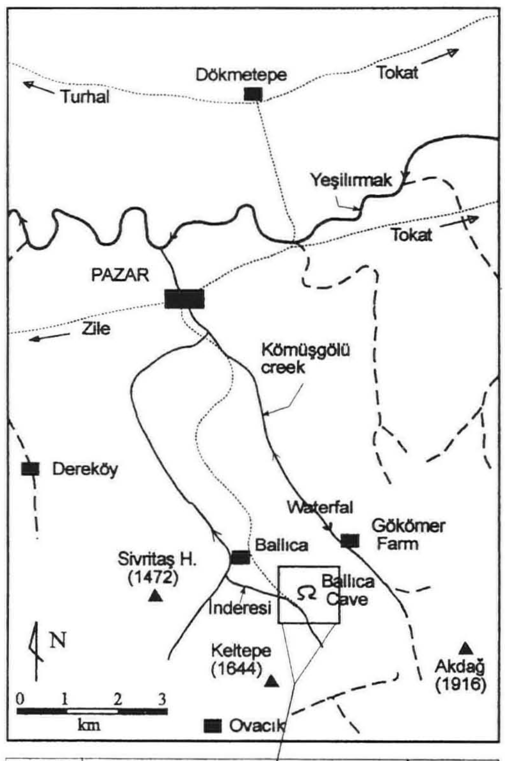


Figure 1. Location maps of the study area.

[1] *Editor's footnote: In the United Kingdom and most English-speaking countries the terms "Chamber", "Room" or perhaps "Hall", would probably be used rather than "Saloon". "Saloon" is retained throughout the paper to maintain consistency with the accompanying cave plan.*

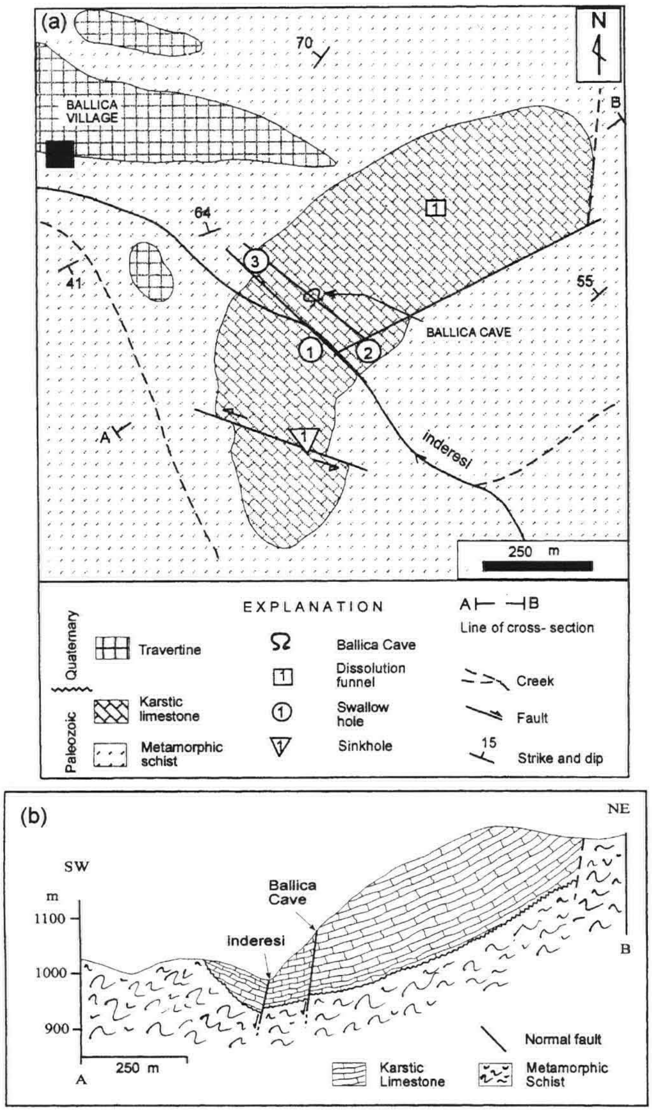


Figure 2a. Geological map of the cave area.
Figure 2b. Geological section at the same horizontal scale as the map.

GEOGRAPHICAL SETTING

The largest river in the region is the Yeşilırmak, running north of the town of Pazar. Other rivers join the Yeşilırmak. İnderesi creek, 50m southwest of the cave, is ephemeral and feeds groundwater to Ballıca Cave. The highest point of the hill composed of the cavernous limestones is 1,306m, and the entrance altitude of the cave is 1,085m. Akdağ, the highest hill in the region, is 1,916m high (Fig.1).

Lush vegetation covers the study area, and its presence causes CO_2 enrichment of rainwater, which percolates into the cave along rock discontinuities. Based on data from the Turhal (Tokat) Meteorological Observatory, the average annual rainfall of the area (1933 - 1990) was 413.4mm.

GEOLOGICAL SETTING

Brown, green-yellow and black schists of the Palaeozoic Tokat Massif cover much of the area around Ballıca Cave. Schistosity surfaces are distinctive in the unit rather than bedding. The schists have a lepidogranoblastic texture and are commonly of phyllite, chlorite-schist, quartz-schist, and calc-schist type (Abbas Novinpour, 1993). They consist mainly of quartz, calcite, chlorite, and sericite minerals, with the calcite displaying pressure twinning. Quartz crystals are partly fissured, showing a cataclastic texture, and fractures and cracks are filled with secondary calcite.

The crystalline limestones are white, beige and pale grey in colour. Mostly they are observed to overlie the schists, but in some cases they also occur as wedges. Bedding surfaces are vague and the limestones are dominated by fracture structures. They are intensely karstified, and the fractures guiding the karstification are generally vertical, providing routes for deep penetration of rainwater. Two main fracture systems, aligned along N30°W (I) and N47°E (II), are mapped in the limestones (Fig.3).

Travertine deposits formed by older karstic springs are also found around the cave. The slope of the travertine deposits is towards the southwest, consistent with old spring water flow directions and the topographic slope. They occur commonly around Ballıca village (Fig.2).

LIMESTONE KARST FEATURES

Ballıca Cave is formed completely within the limestones and the limit of karstification is defined by the basement schists (Fig.2). The fractured limestones display a discontinuous structure. Microscopic studies show that the limestones have a micritic texture and fractures and fissures are filled with calcite that exhibits pressure twinning indicative of metamorphism. Chemical analysis revealed CaO and CO_2 values of 52.45% and 43.55%, respectively (Table 1). The calculated $CaCO_3$ content is 96%. Considering their structural properties and chemical compositions, the limestones appear well-suited to karstification (Pasvanoğlu, 1993).

Sample	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	CaO %	MgO %	CO_2 %
1	0.02	0.49	0.09	54.78	0.29	43.67
2	0.51	0.29	0.48	49.60	4.80	44.12
3	1.45	2.10	0.23	52.98	0.25	42.88

Table 1. Chemical analyses of waters from the recrystallized limestones.

Three swallow holes, one dissolution funnel and one karst pit were found around Ballıca Cave. All these karstic structures are located on discontinuities in the limestones. It was observed that a swallow hole (No.1), with an oval entrance 40 to 80cm-wide and 160cm-high, in İnderesi Creek allows transfer of surface water from the creek into the cave during rainy periods, (Fig.2). In winter, clouds of water vapour emerge from swallow hole No.2, just north of İnderesi Creek. It is believed that this swallow hole is linked directly to the cave. The opening of swallow hole No.2 is 120cm long, 45cm wide in its upper part and 50cm wide in its lower part. The fracture direction of this hole is N15°W. Swallow hole No.3, which was discovered during a road excavation in 1994, lies at the northern edge of the limestone, at the contact between limestone and schist. It has an oval entrance with a height of 70cm and a width of 40cm. It extends towards the cave with an 80° slope. Dissolution funnel No.1, with a height of 45cm and width of 30cm, lies at a higher elevation than the cave entrance, on a fracture with a strike of N68°W and dip of 53° SW. A 1m-deep funnel is blocked by breakdown. The sinkhole (No.1) south of İnderesi Creek is the largest karstic feature around Ballıca Cave. It has an entrance diameter of 110 to 115cm and a depth of about 12m. This sinkhole, which enlarges from its entrance, has a height of 7 to 8m and a width of 3 to 4m at its floor (Canik and Çörekçioğlu, 1985). It is believed to have no link to the cave, and is located in the hillside to the southwest (Fig.2). In addition to the sinkhole, swallow holes, and dissolution funnels, clints to 1.95m in length are also present around the cave (Çelik and Canik, 1996).

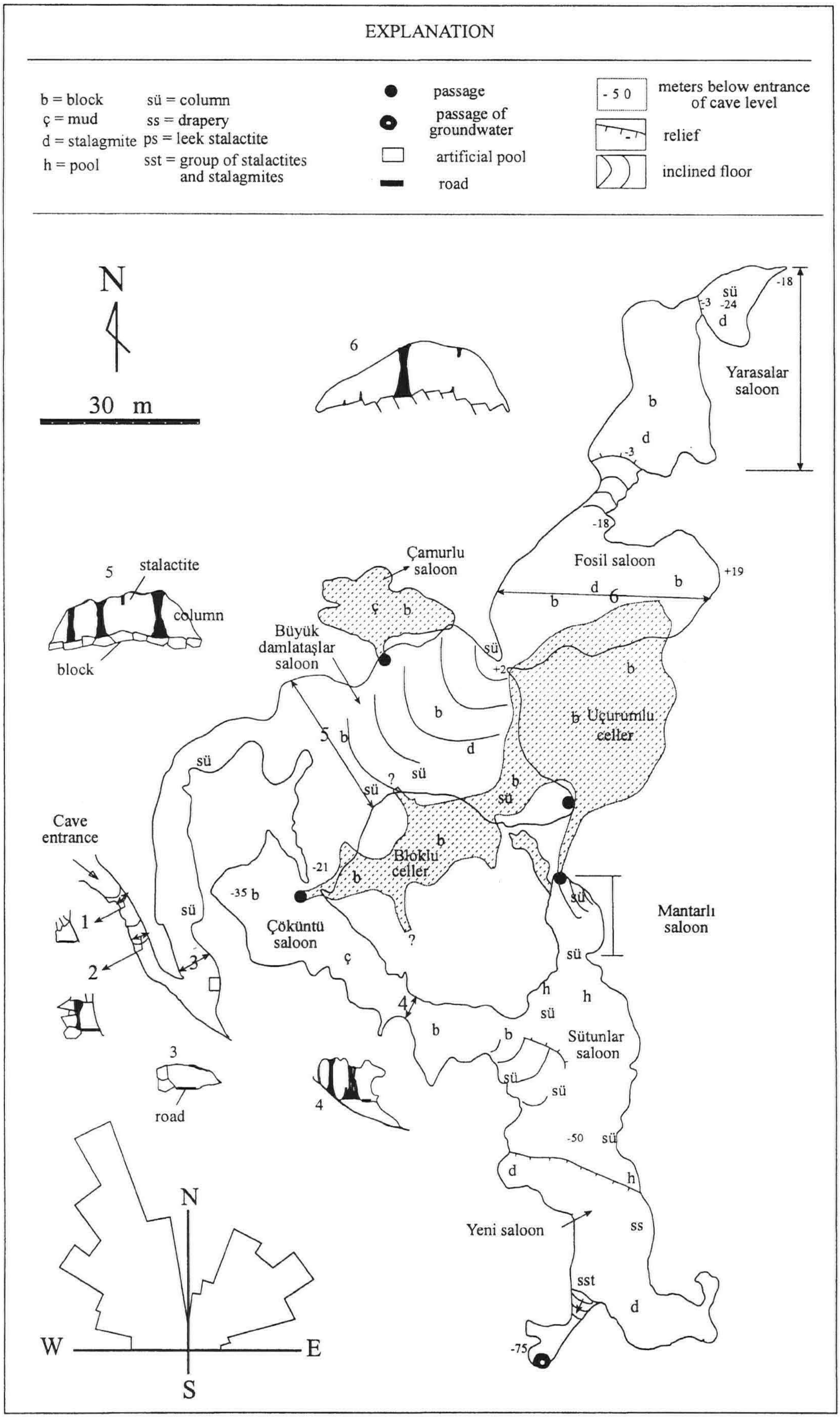


Figure 3. Speleological features of Ballıca Cave.

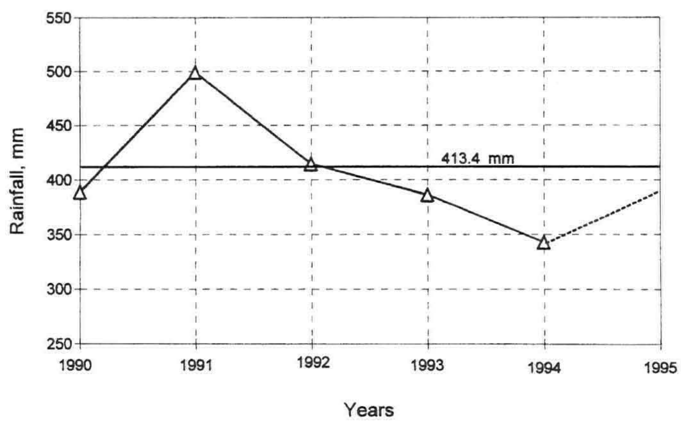


Figure 4. The relationship between rainfall and time (years).

CHEMICAL COMPOSITION OF WATERS FROM THE BALLICA CAVE

Groundwater in Ballıca Cave has a meteoric origin, and includes rainwater percolating through the limestone outcrop and surface water discharging from İnderesi Creek, which cuts the limestone. The groundwater in the cave appears to be ponded, and in January 1992 it was 75m below the entrance, in the deepest part of the cave.

The nearest weather recording point to the study area was Turhal Meteorological Observatory, which ceased operation in September 1995. The highest annual rainfall during the 1990-1995 research period (Fig.4) was 498.6mm. Total rainfall was 296.5mm in first eight months of 1995. It thought that the annual rainfall was approximately 350-400mm in 1995. The average annual rainfall between 1933 and 1990 was 413.4mm (Fig.4), and the average annual rainfall in the study period was almost the same. Consequently, it is concluded that there has been no extreme change of rainfall pattern during the 1933-1995 period.

Chemical analysis shows that the Ballıca Cave groundwater, including percolating waters in the vadose zone, is of calcium bicarbonate type (Table 2 and Fig.5). The total dissolved solid (TDS) content of water in the vadose zone is low in comparison to that of the groundwater. Particularly, SO_4^{2-} and Cl^- have the lowest concentrations. Enrichment of groundwater in sulphate and chloride is explained by sulphate and chloride input to the groundwater during percolation through the vadose zone and contact with organic materials within the cave. NO_3^- has similar concentrations in both groundwater and percolating water. The source of SiO_2 in the waters is probably the quartz-schists (Table 2).

GEOMORPHOLOGY OF BALLICA CAVE

Ballıca Cave has developed mainly in two directions: NE—SW (1st Gallery) and NW—SE (2nd Gallery). These directions are consistent with those measured on fracture systems in the limestones (N38°W and N47°E) (Fig.3). The cave floor declines gradually in the northwest to southeast direction, and extends as a series of irregular levels from the northeast towards the southwest. This suggests repeated tectonic activity during the cave's development (Bögli, 1980).

Breakdown blocks cover the cave floor, particularly in the 1st Gallery. There are also significant amounts of clay and organic material (bat guano). The Çamurlu Saloon and the Cellar in the north of the cave are accessed along connecting landings. Two vertical pipes about 1m in diameter extend from the top of the Fosil Saloon. They become narrower upwards and do not reach the surface.

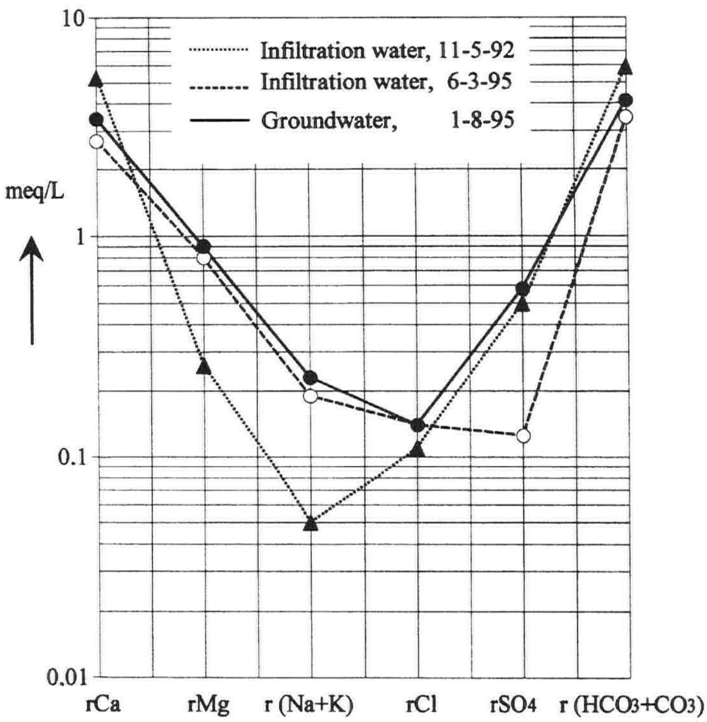


Figure 5. Schoeller diagram for waters from Ballıca Cave.

Pools derived from percolation water are found at the margins of the Büyük Damlataşlar Saloon, Sütunlar Saloon and Yarasalar Saloon. The percolation water flow is insufficient to wash sediment into the cave. There is no river in the cave, although there is groundwater in the southwest part of the Yeni Saloon. Other parts of the cave lie completely in the vadose zone, and hence most of the cave is either vadose or relict, whereas the lower levels characterise an active stage.

CAVE FORMATIONS

When examining the formations in Ballıca Cave, the galleries are best studied in two parts, the 1st Gallery (aligned in a NE—SW direction) and the 2nd Gallery (aligned in a NW—SE direction). Both galleries have different features. The 1st Gallery displays an irregular morphology related to tectonic activity; the 2nd Gallery shows a gradually declining structural level. In the 1st Gallery, structures common to many caves are observed, whereas the unusual structures recorded in the 2nd Gallery mark Ballıca Cave as being different from other caves in the area.

Extensive secondary formations of various types are present from the entrance to the end of the cave. Of these, stalactites (including draperies, dripstones, macaroni-shaped, parachute-shaped, onion-shaped and leek-shaped), stalagmites, columns, flow structures, pools and cave pearls are the most important. The passages and so-called saloons are mostly cut along tectonic lines and, thus, they either change direction abruptly or their levels gradually decline. Because columns are generally formed along fracture lines, they display linear structures that are well recorded in the Büyük Damlataşlar Saloon. Block failure is common in the 1st Gallery, and stalagmites and columns have formed on some blocks. Fractures indicate that seismic activity has affected some parts of the columns, probably after the cave achieved its present form. The floors of small pools at the margins of Büyük Damlataşlar Saloon are covered with cave pearls. Çamurlu Saloon, which is accessed by a vertical passage from the Büyük Damlataşlar Saloon contains blocks, stalactites, stalagmites and small pools. The Fosil Saloon, at the highest point in the cave (+19m), is also connected to the Büyük Damlataşlar Saloon, and

Sample	pH (25°C)	Conductivity µmho/cm (25°C)	Evaporation residual (180°C)	K^+ mgl^{-1}	Na^+ mgl^{-1}	Ca^{2+} mgl^{-1}	Mg^+ mgl^{-1}	B mgl^{-1}	SiO_2 mgl^{-1}	HCO_3^- mgl^{-1}	SO_4^{2-} mgl^{-1}	Cl^- mgl^{-1}	F^- mgl^{-1}	NO_3^- mgl^{-1}
Groundwater 1.8.1995	7.6	345	248	0.4	5.1	68	11	0.5	12	250	28	6	0.2	6
Infiltration water 11.5.1992	7.6	475	324	0.29	0.95	106	3.2	<0.1	44	360	24	4	<0.5	<1
Infiltration water 6.3. 1995	7.6	243	210	0.5	4.3	54	9.5	0.1	15	210	6	5	<0.1	5

Table 2. Chemical analyses of groundwater and waters from the vadose zone.

blocks are also common on its floor. It was probably the first saloon that formed in the cave. The Yarasalar Saloon is accessed from the Fosil Saloon, and its floor is blocky, reflecting the typical of 1st Gallery features (Fig.3).

The 2nd Gallery is separated from the 1st Gallery by the Çöküntü Saloon, which has an inclined floor. The floor level of the Çöküntü Saloon relative to the cave entrance is -35m, and the Blocky Cellar is accessed by a connecting landing. The walls of the Çöküntü Saloon are completely covered with cave formations. Speleothem occurrences along a horizontal line from the wall to the centre of the cave indicate that there was a groundwater rest level within the saloon for a significant length of time, lying about 32m below the present entrance. Karstic features in the 2nd Gallery below this level are younger. Progress beyond the Çöküntü Saloon, towards the Sütunlar Saloon, is made over large blocks. There are pools in the northern part of the Sütunlar Saloon, and its columns are much larger than those in the other saloons.

Beyond the Sütunlar Saloon are the Mantarlı and Yeni saloons. The former is small and connected in turn to the Uçurumlu Cellar, which has a height between 1 and 3m and is extensively covered with blocks. The random scatter of the irregular blocks across the floor of the cellar does not permit easy access for examination of some parts of the cave. Due to the presence of manganese, stalactites and stalagmites in the Uçurumlu Cellar are dominantly dark grey and black in colour. The Uçurumlu Cellar is connected to the Büyük Damlataţlar Saloon, as the Blocky Cellar is connected to the Çöküntü Saloon.

In terms of karstic features, the Yeni Saloon is the most interesting part of Ballıca Cave. In addition to karstic features similar to those found in the other saloons, leek-shaped stalactites, large stalagmite-free stalactites (about 6.5m in length) and onion-shaped stalactites are recorded (Plates 1, 2 and the cover photo). The lowest part of the cave is accessed from the Yeni Saloon by way of a shaft-like route, and the groundwater, which can be seen at two different points, is also reached through a shaft-like landing.

Distinct signs of the influence of groundwater – (1) horizontal cracks in the columns; (2) formation of large stalagmite-free stalactites and (3) travertines forming at the surface – give important indications of some of the cave's stages of development. Linked to item (1) is the evidence of a former groundwater level marked by the limit of calcite formation 3m above the floor of the Çöküntü Saloon. The absolute altitude of this level is 1,053m, whereas the modern groundwater level (January 1992) is 1,010m. The presence of relatively shallow ponds with a low flow regime, or a static level below the item (2) stalactites, hindered the formation of stalagmites but not the higher $CaCO_3$ accumulations. The upper altitude of surface-forming travertines (3) is about 1,120m, and it is thought that these travertines were deposited from waters discharging from the cave. The difference between the upper altitude of the surface travertines and the recent groundwater level suggests that the groundwater level has lowered by at least 110m between deposition of the oldest preserved travertine and the present.

The major development of Ballıca Cave may have been started about 3.4 million years ago, during the Villafranchian Stage) (Steininger *et al*, 1996). Because waters contain more CO_2 during rainy and cold periods, they can more easily dissolve and transport particles of carbonate rock at such times. The later development activity has thus continued in parallel with changes in the regional climatic conditions. Active development is now continuing in a water-filled karstic shaft -75m below the entrance, whereas speleothems are currently growing at other sites. Isotope studies to determine the ages of the speleothem formation are still being conducted.

ACKNOWLEDGMENTS

The authors are deeply grateful to Duran Evren (former Tourism Director in the city of Tokat), the late Etem Çatalbaţ (formerly a journalist from Tokat), Adnan Özmen (the Mayor of Pazar town), Ömer Ţahin (an officer of Pazar town) and Ahmet Samur (a resident of Ballıca village) for their help during the study. Drs Chas Yonge and Dave Lowe are thanked for their helpful comments on the first draft of the paper and for their suggested improvements to the English translation.

Plate 1. Recently formed stalactites and stalagmites.

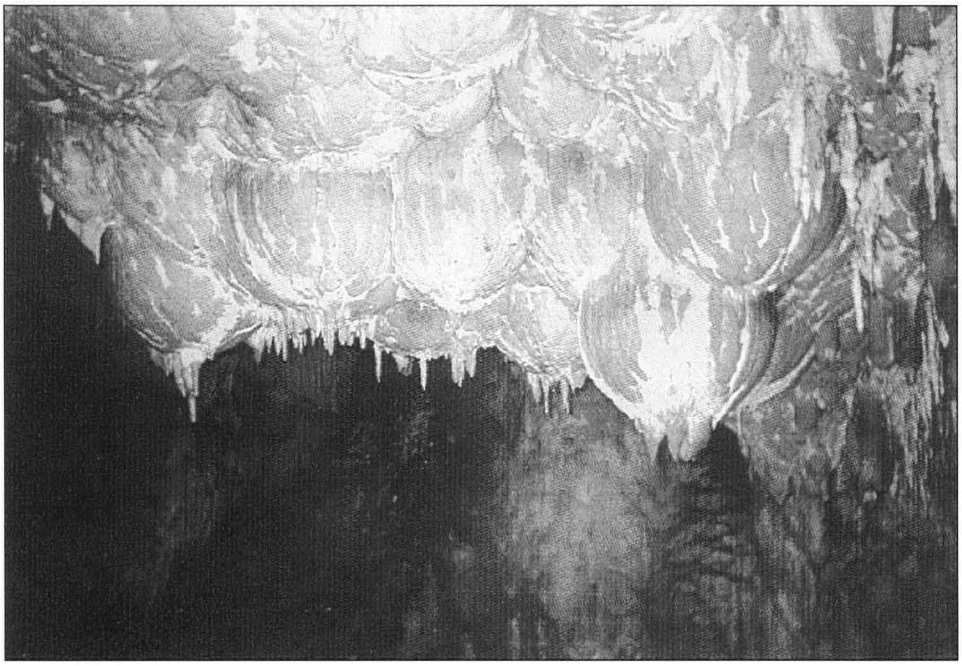


Plate 2 . Onion-shaped stalactites in the Yeni Saloon.

REFERENCES

Abbas Noninpour, E, 1993. *Hydrogeological investigation of Kazova-Tokat.* Ankara University Science Institute, Unpublished PhD Thesis, 250pp.

Bögli, A, 1980. *Karst hydrology and physical speleology* (Translated by June C Schmid). Springer-Verlag, New York.

Canik, B and Çörekçioğlu, İ, 1985. The formation of sinkholes (Obruk) between Karapınar and Kızören-Konya. *Karst Water Resources* (Proceedings of Ankara-Antalya Symposium). IAHS Publication 161, 193-205.

Çelik, M and Canik, B, 1996. *Antalya, Elmalı Polyesinde karst şekillerinin oluşumu ve özellikleri.* SDÜ IX. Müh. Sempozyumu, 29-31 Mayıs 1996, Jeo. Müh. Seksiyonu, Bildiriler, 45-53.

MTA (Maden Tetkik ve Arama), 1994. *Ballıca Mağarası (Pazar-Tokat) ön araştırma raporu ile mimari ve elektrifikasyon uygulama projesi.* MTA Derleme No. 9717, 16, Ankara.

Pasvanoğlu, S, 1993. *Milas (Muğla) Ovasının Hidrojeoloji İncelemesi.* A. Ü. Fen Fak. Jeoloji Mühendisliği Bölümü Suat Erk Sempozyumu, Ankara.

Steininger, F F, Berggren, W B, Kent, D V, Bernor, R L, Sen, S and Agusti, J, 1996. Circum Mediterranean Neogene marine-continental chronologic correlations of European mammal units and zones. 7-46 *in* Bernor, R, Fahlbusch, V and Mittmann, W (Eds), *Evolution of Western Eurasian Neogene mammal faunas.* Columbia University Press.

CAVE AND KARST SCIENCE Vol. 26, No. 1, April 1999
Transactions of the British Cave Research Association

Abstracts of the 1999 BCRA Cave Science Symposium, Nottingham Trent University, 6th March 1999

HISTORICAL CLIMATE RECORDS FROM ANNUALLY LAMINATED STALAGMITES IN POOLE'S CAVERN, BUXTON, DERBYSHIRE, UK

Andy Baker [1], Chris Proctor [1, 2, 3], Lucy Bolton [1] and William L Barnes[2]
[1] Department of Geography, University of Newcastle-upon-Tyne, Newcastle, NE1 7RU, UK
andy.baker@ncl.ac.uk
[2] School of Physics, University of Exeter, Stocker Road, Exeter, EX4 4QL, UK
[3] Honorary Research Fellow, School of Geography and Archaeology, University of Exeter, Amory Building, Rennes Drive, Exeter, EX4 4RJ, UK

Unusually fast growing, orange-capped stalagmites have been demonstrated to grow through the mechanism $Ca(OH)_2 + CO_2 = CaCO_3 + H_2O$. These stalagmites have continuous annual band observed in both visible and ultra-violet light. Two stalagmites that have been deposited over the period 1905-1997 AD have been analysed for (1) variations in annual band structure and (2) variations in luminescence wavelength. For the annual band structure in the two stalagmites, 88% of the years have luminescence laminae that exhibit a near sinusoidal shape with no structural variations. However 10 laminae (12% of total) exhibit a double band structure; these are demonstrated to occur in years with high monthly or daily mean precipitation. It is suggested that high intensity (>60 mm/d) and high quantity (>250mm / month) of precipitation may flush luminescent organic material onto the stalagmites from either the soil or groundwater zones and generate a double lamina. However, not all precipitation events generated double laminae. High intensity events in summer were ineffective due to either a soil moisture deficit and / or interception by the woodland canopy. High rainfall months (>250mm) failed to generate double laminae when preceded by two or more months of greater than 150mm, suggesting that exhaustion of the organic acid supply can occur. When compared to monthly precipitation data for Buxton, laminae shape and the percentage of double laminae of the Poole's Cavern stalagmites are best explained by a centre weighted running mean of the preceding 6 to 7 months precipitation. The palaeoclimate can also be deduced from the luminescence wavelength, since seasonal variations were observed that were formed in the soil the previous summer.

PREHISTORIC CAVE BURIALS IN BRITAIN - AN UPDATE

Andrew T Chamberlain and James Williams
Department of Archaeology and Prehistory, University of Sheffield, Northgate House, Sheffield, S1 4ET, UK
a.chamberlain@sheffield.ac.uk

We currently know of 237 caves in Britain that have produced prehistoric human remains, and there are a small number of new discoveries of burial caves reported each year. Cave sites in all of the caving regions of Britain from northern Scotland to South Devon were used for burial purposes. The most interesting pattern in the data is the chronological one, which suggests that some usage of caves as burial sites occurred in the Late Palaeolithic and the Early Mesolithic but there was a clear peak of activity during the Neolithic (4000 to 2000 BC). More than 100 of the cave burial sites date to the Neolithic period, and it is no coincidence that this is also a time of major demographic and cultural change in Britain, with a transition in subsistence from hunter-gathering to farming, as well as a possible influx of people from continental Europe.

The spatial distribution of burial caves is less clear, but for specific regions like the Peak District, the Morecambe Bay area and in South Wales there is some evidence for spatial clustering in the sites. Whether this relates to patterns of prehistoric settlement is completely unknown, but patterns of raw material utilisation indicate that prehistoric people had an excellent understanding of geology and would very likely have known of the existence of many of the caves in their neighbourhood.

Recent collaborative work by the Pegasus Caving Club and the University of Sheffield at Carsington Pasture Cave in Derbyshire has revealed one of the largest collections of human remains recovered from a Peak District cave site. Preliminary dating evidence, based on study of the fauna and artefacts, suggests that the cave was used as a burial site during the Neolithic. The human remains represent individuals of all ages from newborn to elderly, and some of the bones have cutmarks that indicate post-mortem defleshing and disarticulation of the bodies.

FAECAL INDICATOR BACTERIA IN THE CASTLETON CAVES, DERBYSHIRE, UK

John Gunn and Jamie Tranter
Limestone Research Group, Department of Geographical and Environmental Sciences, The University of Huddersfield, Queensgate, Huddersfield, HD1 3DH, UK
j.gunn@hud.ac.uk

The risk to cavers from Weil's disease is well known, but there appears to have been little research into the health risks to cavers who might come into contact with faecally contaminated karst waters. The closest analogues are investigations of health risks to those taking part in direct-contact recreational activities, such as canoeing and bathing. The link between enteric bacterial (faecal coliform and faecal streptococci) concentrations in such recreational waters and the incidence of disease amongst users is well known, and it is not unreasonable to anticipate a similar risk to cavers. With this in mind a study was undertaken of faecal indicator bacterial concentrations in water draining into, and out of, the Castleton karst. The study showed that the faecal coliform concentrations in the P6, P7 and P8 streams could represent a health risk to cavers using the Jackpot cave, especially during the summer months and during summer/autumn storms. The Castleton springs are less seriously contaminated, but there is a potential health risk to cavers using Peak and Speedwell caverns. The source of the contamination appears to be sheep grazing in the catchment.

PALAEOENVIRONMENTAL RECONSTRUCTION THROUGH A STUDY OF SPORES AND ORGANIC ACIDS IN SPELEOTHEMS

Siobhan McGarry
Open University and University of Exeter, UK
S.F.Mcgarry@open.ac.uk

Speleothems have a distinct advantage over other terrestrial palaeoenvironmental records such as lake and bog sediments, in that they preserve longer records, as their cave environment protects them from destruction by surface erosion. They contain O and C isotopes, organic acids, pollen and spores. They can be dated back to 450,000 years, allowing the terrestrial record of environmental change to be extended up to an order of magnitude further back in time than radiocarbon dating of wetland sediments would allow. As the waters that form speleothems pass through the overlying soil, they pick up spores and organic acids, both of which are associated with decomposing organic matter, and are characteristic of the soil and climatic conditions prevailing at the time. The water eventually enters a cave and deposits calcium carbonate to form a speleothem. The waters of formation also deposit the spores and organic acids, which are then preserved within the calcite. The spores, produced by soil fungi, provide information about the soil type and environmental conditions under which they were living. Different types of organic acids are now known to be related to the degree of humification (state of decomposition) of the soil, which is in turn related directly to climate and vegetation changes. As fungi play an active role in the decomposition of organic matter, the two records may complement each other. In the current study being undertaken, fungal spores from a number of speleothems from throughout Britain have been extracted and identified. The organic acids they contain have also been studied as part of a wider project, in which the pollen record and U-Th ages of the speleothems are also being used in order to build up a clearer picture of environmental conditions at certain times in the past. This is the first time such a study involving spores and speleothems has been undertaken, and the research trip to a lab in the University of Amsterdam, to access the necessary facilities for identification of the spores, was funded by the BCRA. This paper forms part of the report on the findings of the study.

SEDIMENT STUDIES IN SLEETS GILL AND DOWKABOTTOM CAVES, NORTH YORKSHIRE, UK

Phil J Murphy
Department of Earth Sciences, University of Leeds, Leeds, LS2 9JT, UK
P.Murphy@earth.leeds.ac.uk

Sleets Gill and Dowkabottom Caves are situated in Littondale, near Hawkswick, North Yorkshire. Both caves constitute fragments of an ancient phreatic cave system truncated by surface lowering and now out of equilibrium with the present geomorphology (Waltham *et al*, 1997).

Sleets Gill Cave consists of a large (4m diameter) phreatic tube called the Main Gallery accessed via the entrance ramp, one of two examples of abandoned phreatic lifts in the cave. Two immature streamways run parallel to the main passage. The streamway on the northern (up-dip) side is called the Wharfedale Series and consists of 30m of streamway, ending both upstream and downstream in choked sumps. The streamway on the southern (down-dip) side of the main passage is called Hypothermia/Hydrophobia and allows a choke at the end of the Main Gallery to be by-passed into further large phreatic passages.

Grab samples were taken of sediment from both streamways and at intervals along the Main Gallery. Very well rounded granule and pebble grade grains of milky quartz were recorded from all the samples but were far more common in those from the Wharfedale Series. On thin sectioning these proved to be meta-quartzites, showing characteristic undulose extinction and annealed grain boundaries. High grade metamorphic rock pebbles are characteristic of the Millstone Grit facies. The Millstone Grit no longer crops out in the Sleets Gill catchment but such pebbles are recorded from the nearest outcrop on Fountains Fell to the west (Arthurton *et al*, 1988). Black sand grade particles with a sub-metallic lustre are present in all samples. X-ray diffraction analysis revealed a composition of hydrated iron oxide (goethite). Similar deposits are described from South Wales by Gascoine (1982) and are attributed to the leaching of iron compounds from shales overlying the limestone. Ironstone nodules are recorded from the Wensleydale Group shales (Arthurton *et al*, 1988), a small outlier of which survives in the catchment area. A yellow friable iron-rich material also forms discrete particles in the samples. This is believed to be an alteration product of the black hydrated iron oxide, as particles consisting of different proportions of black and yellow material can be found.

Dowkabottom Cave is at a higher elevation than Sleets Gill and an underfit stream utilises the abandoned phreatic passage before entering a much smaller stream passage. The water flow is eventually lost in a boulder choke. Samples from a sediment bank in the small streamway were washed to remove silt and clay grade material. The sand grade grains are more angular than those found in Sleets Gill Cave, but both meta-quartzite pebbles and black and yellow iron rich material are present. Very angular quartz grains, showing conchoidal fractures and cleavage planes are present. These are characteristic of glacial environments (Krinsley and Doornkamp, 1973). Limestone clasts with clearly defined glacial striae are also present, clearly indicating a glacial origin for the sediments. Glacial striae exposed from beneath a protective drift cover on the surface are known to disappear in around a decade (Sweeting, 1966). The limestone clasts must therefore have been emplaced in the cave and isolated from aggressive waters by rapid burial.

Both Waltham *et al* (1997) and Long (1974) comment on the occurrence of 'Yoredale sandstone pebbles' in the sedimentary fill of Dowkabottom and Sleets Gill caves. Analysis of the sediment has revealed the presence of material originating from the Millstone Grit facies. Waltham *et al* (1997) speculate as to whether the sediments were emplaced in the caves when the cover of rocks overlying the Great Scar Limestone was more extensive, or whether they were derived from a partial cover of glacial debris since largely eroded away. The occurrence of striae on limestone particles clearly indicates a glacigenic origin for the sediments. Whether they are from the Littondale ice stream or from a cover of active ice over the Sleets Gill cave catchment area is not known.

Arthurton, R S, Johnson, E W and Mundy, D J C, 1988. Geology of the country around Settle. *Memoir of the British Geological Survey*.
Brook, D, Davies, G M, Long, M H and Ryder, P F, 1988. *Northern Caves Volume 1 Wharfedale and the North-East*. Clapham: Dalesman.
Gilligan, A, 1920. The petrography of the Millstone Grit of Yorkshire. *Quarterly Journal of the Geological Society of London*, Vol.75, 251-94.
Krinsley, D H and Doornkamp, J C, 1973. *Atlas of quartz sand surface textures*. Cambridge University Press.
Long, M H, 1974. Wharfedale. 410-421 *in* Waltham, A C, (Ed) *Limestones and caves of North-West England*. British Cave Research Association.
Sweeting, M M, 1966. The weathering of limestone, with particular reference to the Carboniferous limestones of Northern England. 177-210 *in* Dury, G H, (Ed) *Essays in geomorphology*. Heineman.
Waltham, A C, Simms, M J, Farrant A R and Goldie, H, 1997. *Karst and Caves of Great Britain*. Chapman and Hall.

HOLEY ROCKS AND BOULDERS IN SOCKETS: WEIRD KARST FROM THE WEST OF IRELAND

Mike Simms
Department of Geology, Ulster Museum, Botanic Gardens, Belfast, BT9 5AB, UK
michael.simms.um@nics.gov.uk

Upwardly-tapering vertical tubes (rohrekarren) pierce the underside of limestone blocks and overhangs around the shores of Irish lakes and testify to rapid dissolution of the limestone even where the lake waters are permanently carbonate-saturated. They form by condensation corrosion in the epiphreatic zone of fluctuating lakes. Rohrekarren morphometry is lake-specific and linked to long-term water chemistry. Rohrekarren in persistently carbonate-saturated lakes are narrow while those in lakes which are periodically undersaturated have a broader taper due, in part, to direct dissolution by lake water. The presence or absence of other lacustrine dissolution features provides further evidence of long-term lake-water chemistry.

CONTROLS ON THE ANNUAL GEOCHEMICAL VARIATION OF SPELEOTHEM-FORMING KARSTIC DRIP WATERS AT P8, CASTLETON, DERBYSHIRE,UK

Anna F Tooth
Department of Earth Sciences, University of Keele, Keele, Staffordshire, ST5 5BG, UK
ggd14@keele.ac.uk

The P8 cave, Castleton, has developed at the site of a stream sink in a closed karstic depression, formed at the approximate boundary of the basal Namurian Millstone Grit shales and Dinantian apron reef limestone complex. The near-surface cave is dominated by narrow passageways that have developed along joints. It has a highly fractured subcutaneous zone. The overlying soils vary locally with the topography. Up-slope regions are characterised by thin organic-rich brown earths, whilst down-slope profiles comprise greater thicknesses of clay-rich soils. A monitoring study was performed at the site over a period of one year, from July 1997 to June 1998. Temperature and CO_2 concentrations were recorded each month in atmospheric, soil and aquifer zones. The pH of rain, soil and karst water samples was measured in situ. Samples were retained for laboratory analysis of trace elemental concentrations. Soil gas CO_2 concentrations exhibited a peak in levels coincident with the summer 1997 maximum in ambient air temperature. Values then began to decrease until November 1997 when an increase in levels again occurred, remaining elevated until February 1998. Concentrations subsequently rose steadily towards a second summer peak in June 1998. Soil water CO_2 concentrations were in phase with that of soil gas, though the November 1997 increase was not as pronounced and values were elevated in January, remaining greater than that of the gas phase for the rest of the monitoring period. Analysis of trace elemental composition in soil and karst waters evinced peaks in calcium concentration not only in the summer months of 1997 and 1998, but also during the winter months of January and February 1998. Such a trend in CO_2 and calcium concentrations is related to the rainfall regime. Monthly precipitation increased steadily from September 1997 onwards, with a winter maximum occurring in January 1998. Soil moisture content rose in response to rainfall, attaining maximum levels in the period of November 1997 to January 1998. The high winter soil moisture content is postulated to have stimulated the microbial production of soil gas CO_2, via the decomposition of organic matter, leading to enhanced dissolution of soil carbonate in winter 1998. Since soil and karst water calcium concentrations are in phase, the winter peak in levels cannot be attributed to a time lag occurring between the summer elevation in values and delivery to karst water sites, due to subcutaneous zone aquifer storage. Therefore, rainfall input and duration can be shown to influence soil and karst water calcium concentrations. At this site, rainfall would appear to be as important a control upon karst water chemistry as the temperature-constrained summer growing season. An understanding of the influences of the dominant controlling factors upon karst water chemistry is essential for the interpretation of the geochemical signal of banded speleothems. This study reinforces the implication that the palaeoclimatic signal of the speleothem record must be interpreted in terms of palaeo-wetness as well as palaeo-temperature.

THE DROWNED KARST OF HA LONG BAY, VIETNAM

Tony Waltham
Civil Engineering Department, Nottingham Trent University,
Nottingham, NG1 4BU, UK
tony.waltham@ntu.ac.uk

The spectacular islands and rock pinnacles of Ha Long Bay constitute a landscape of classic tower karst that has been modified by its marine invasion. Fenglin, fengcong and doline landforms are of subaerial origin, dating from the Pleistocene stages of lower sea levels and perhaps from earlier times. The wave-cut notches, many of the base-level caves and much of the cliff undercutting are marine features. Sea-level caves pass through some of the islands and provide the only access to tidal lakes within the fengcong karst. Stratified calcite deposits and shell beds are abundant in the many cave remnants. Elucidation of the geomorphological history, including a comprehension of the record of eustatic sea-level changes combined with tectonic ground level changes, awaits mapping and dating of these cave sediments.

RADON CONCENTRATIONS IN CAVES - AN EVALUATION OF THE PASSIVE CANISTER METHOD

Jo Whistler
Oxford University, Oxford, UK
joanne.whistler@las.ox.ac.uk

The aim of this undergraduate study was to evaluate the passive canister method of Radon 222 measurement in caves. This naturally occurring radioactive gas is both a potential health hazard, and a source of information about airflow and sediment composition in caves. It is important to choose the most appropriate method of determining the Radon 222 concentrations, depending upon the aspect of interest. For the technique used in this study, the Radon 222 was adsorbed onto grains of activated charcoal during exposure of the canister. Back in the laboratory, the radon concentration was determined by counting the gamma-ray emissions of two of the progeny of the radon alpha-decay. A Li-Ge detector connected to a Personal Computer Analyser was used to achieve this, and the Radon 222 concentrations were calculated from the data using various calibration and decay factors. The canisters were exposed at several locations in Cuckoo Cleeves (Mendip Hills, Somerset), where no serious cave-specific difficulties were experienced with the method. An overview of the statistical error analysis was given, and the likely sources of systematic error were described. The statistical error on the results is believed to be small since, when several different peaks in the spectrum were analysed, the derived concentrations were within error bars. This, however, does not allow for statistical error between different samples, and a more thorough investigation would have placed several samples at each site. There were many possible sources of systematic error, and the measured concentrations are unlikely to be very close to the actual values. Some of the systematic errors described could be much reduced but, due to lack of time and resources, this was beyond the scope of the study. One useful aspect of the technique is that it is measuring Radon 222 concentrations specifically, rather than just any alpha emitter that happens to be present. In conclusion, the data collected are likely to be very inaccurate in absolute terms, but the method is useful when relative values are important. The work was carried out as an undergraduate project, supervised by Dr W D M Rae, and won the Magnox Electric Prize for the best Oxford Physics BA project.

COMPUTING DEVELOPMENTS IN CAVE SURVEYING

Wookey
Aleph One Ltd, Bottisham, Cambridge, CB5 9BA, UK
wookey@aleph1.co.uk

This paper ranged widely over recent developments in cave survey hardware and software and data interchange software. Digital instruments are available from Martin Sluka and Silva, making digital surveying systems affordable. Compass calibration experiments are being carried out at Penwyllt. Drawing-up of surveys by computer has also improved, prime examples being the recent survey of Ogof Draenen, and the entries for the UIS Survey Competition. There has been much change in available survey software: Survex (Linux-based, now incorporating blunder detection); Winkarst (GPS tracking, square 3D, VRML); Compass (Phong-shaded 3D with graphics-card libraries, surface modelling); Tunnel (Full cross-sections, Survex-compatible, written in Java); and many others such as Walls, Visual Topo, Toporobot, OnStation, etc. A Cave Data Interchange (CDI) format is being developed.

POSTER PRESENTATIONS

SUBSTRATE PREFERENCE OF MICROBIAL COMMUNITIES IN CAVE SEDIMENTS AND FOREST SOILS IN GUNUNG MULU NATIONAL PARK, SARAWAK, MALAYSIA

Sal Burgess
University of Aberdeen, UK, in collaboration with the Sarawak Forest Department
s.burgess@au.sac.ac.uk

The importance of the soil microbial biomass in maintaining soil fertility through stabilisation of soil structure and control of nutrient cycling is now widely recognised. It is also fundamental as the base of the food web in many ecosystems especially in cave environments in which it can be the most important dietary component. Despite its significance, studies on the microbial ecology of tropical forests are sparse and almost no previous work has been done on the microbial ecology of forest soils and cave sediments in Gunung Mulu National Park, Sarawak. Fieldwork was carried out in Stone Horse Cave (Gua Kuda Batu) and part of the secondary alluvial forest dominated by pioneer tree species, near to an artificial clearing. In biospeleological literature the zonation of environmental conditions from cave entrance to the deep cave is considered to be important in the distribution of cavernicoles. Soil and sediment microbial biomass and activity were measured in situ against the change in environmental conditions (soil matric potential, pH, temperature, nitrate and ammonium-N, total organic carbon (TOC) and light at the soil surface) along prevailing light gradients. In Aberdeen, microbial community composition was determined and a unique substrate-preference test was developed to test the adaptation of the community.

There were differences in the size and activity of the soil microbial biomass between the sites, which often depended on environmental conditions. The total biomass was greater in the forest than in the cave, due to a greater supply of organic matter. The cave entrance was associated with a biomass comparable with both the forest and the cave, which reflected the steep gradient of environmental conditions in this zone. Actual activity also followed this pattern. Fungal and bacterial biomass unexpectedly differed only at the entrance to the cave, in which they were both highly associated with neutral soil pH values and high total organic carbon and available nitrogen. Bacterial biomass was related to light intensity that was seen to be the governing factor of a difference, due to its large effect upon soil temperature. It follows that the bacterial biomass was most influenced at the entrance to the cave by soil temperature. High quality substrates positively influenced both microbial groups.

The matric potential-optimisation of soils and sediments increased the respiration response in two zones and decreased it in a third. The decrease was due to a site not normally limited by water. The two increased soils had high TOC and low pH and one had high available nitrogen, which showed that substrate quality is important to allow a full microbial response when a limiting factor is optimised. Other zones were concluded to have more than one limiting factor.

The environmental conditions that most influenced microbial characteristics were total organic carbon, available nitrogen and soil pH values. The manner in which they affected the microbial communities differed between each site.

The litter bags suffered greater mass loss in the forest than in the cave which was concluded to be due to a greater diversity of microbial community that were better adapted to decompose plant material. The total carbon and nitrogen remaining in the litter was similar in all bags and was therefore utilised to the same extent by both communities over six weeks. The remaining mass was assumed to be recalcitrant carbon compounds.

This study has shown uniquely that the microbial biomass of cave sediments and forest soils is physiologically adapted to utilise indigenous, locally available substrates over easily utilisable laboratory substrates such as glucose. Microbial populations displayed different strategies in response to both substrates. It is proposed, therefore, that the selection of indigenous substrates is a crucial aspect of characterising the kinetics of respiration response of soil microbial populations from different ecological sources.

SUB-SURFACE RADIO LOCATION USING FIELD GRADIENT TECHNIQUES

David Gibson
Institute of Integrated Information Systems, University of Leeds, UK
gibson@mcrosolv.demon.co.uk

Radio-location of cave passages using an induction loop is a standard procedure. Essentially, a horizontal transmitter loop (vertical magnetic dipole) is placed underground and its location and depth below the surface are calculated by taking measurements of field direction and angle using a receiver loop on the surface. This is tedious but, if we were to measure a set of field magnitudes instead of angles and directions, we could de-skill the operation. This would allow us to construct a 'global positioning system' for sub-surface applications such as surveying or search and rescue. A major factor in the simplification of the radio-location procedure is that measurements of field magnitude can be made electronically without adjusting the antenna orientation. This is in contrast to conventional usage, where the operator has to adjust the antenna to a 'null' position and make visual readings of its angle with respect to ground. A second factor is that the 'roving' surface antenna that is used in conventional radio-location can be replaced by three or more fixed antennas at accurately surveyed stations. A further development is to use a ratiometric technique, whereby a field gradient is derived. This is more accurate than a simple magnitude measurement, because knowledge of the transmitter power is not required. Accurate radio-location usually requires that the range be much less than a skin depth. However, a ratiometric field gradient technique allows the operation to be extended to regions where far-field effects distort the field lines and make conventional location difficult. Practical tests at 200m depth using a 4kHz beacon have verified this. Radio-location in mines gives rise to different problems. Frequently, due to the depth of the passages, access from the surface is not possible. But here, too, field gradient techniques could lead to improvements because a fixed receiver antenna allows a much lower bandwidth to be used than is the case with an antenna that requires adjustments to its orientation during the measurement process. An additional problem is that the orientation of the underground transmitter (e.g. a miners belt-mounted device) may not be known. (This is the so-called 'dead body problem'). Limited solutions to this problem already exist, but they do not take into account far-field distortion, nor do they use fully-static antennas. A field-gradient technique offers the possibility of providing a more comprehensive solution to this problem.

AN OLIGOCENE CAVE FILL AT BALLYGIBLIN, CO. CORK, REPUBLIC OF IRELAND

Mike Simms [1] and Mike Boulter [2]
[1]Department of Geology, Ulster Museum, Botanic Gardens, Belfast, BT9 5AB, UK
michael.simms.um@nics.gov.uk
[2] University of East London, UK

TOURISM IN KARST LANDSCAPES

Mike Simms
address as above

EXTRAORDINARY KARST FROM THE SHORES OF LOUGH MASK

Mike Simms
address as above

BONES IN CAVES - HOW DID THEY GET THERE?

Mike Simms
address as above

A BROWN BEAR NURSERY IN CO. LEITRIM, IRELAND

Mike Simms [1] and Nigel Monaghan [2]
[1] address as above
[2] National Museum, Dublin, Republic of Ireland

Forum

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

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

CORRESPONDENCE

Dear Sir,

While preparing a practical on 'vertebrate bone accumulation in caves' for some of our third year undergraduate students, I encountered in our department collection 7 jars of bone concentration [museum accession numbers LEIUG 84240-84243 and 84244-84246]. The locality details for these specimens indicate that they come from a Quaternary 'Rodent Band' of Jubilee Cave, [Settle, North Yorkshire] and Lesser Kelcoe (=Kelcow) Cave, [Giggleswick, Settle, North Yorkshire], respectively. (The square brackets indicate information that has been added to the documentation here at Leicester).

These specimens are part of a collection donated to the University of Leicester by the British Speleological Association, through the good offices of Dr Trevor D Ford. Our records show that the Jubilee Cave concentrate came to the BSA from an 'E Douglas'; the Lesser Kelcoe concentrate seems to have to come to the BSA from an 'E Simpson', in 1932 (or thereabouts).

Examination of the material (coarse fraction of LEIUG 84242) during the practical showed that it contained well-preserved small mammal (probably rodent) bones, especially long bones, as well as a few bird bones and the occasional crinoid ossicle. Although no teeth were discovered in this brief investigation, their presence is recorded in the documentation for sample LEIUG 84243, which was not examined.

A literature review yielded no references that discussed either of these two caves. I would appreciate any information about these caves and their faunas. Alternatively, anyone interested in studying these specimens is welcome to contact the University.

Thank you very much for your time and attention.

Sincerely,

Kim Freedman
Department of Geology
University of Leicester
University Road
Leicester
LE1 7RH
UK

Dear Editors,

Re Cave Ecology

There appears to be an increasing interest in subterranean ecology in British caves, and renewed interest in the recording of species found within them. Information regarding the distribution of subterranean taxa from caves is relatively poor, most having been compiled during the heyday of the Cave Research Group / British Cave Research Association biological sub-committee, largely due to the efforts of E A Glennie and M Hazelton.

In an attempt to increase our understanding of cave geo-ecosystems, co-operation between cavers and scientists is required. Any records of invertebrate taxa or faunal specimens would be greatly appreciated (collecting vials containing preservatives can be supplied if required). However, care and restraint is advised since subterranean environments do not support large numbers of fauna and excessive sampling could seriously degrade the ecology of the system concerned. Each record should be accompanied with the date of the observation and a detailed description of the collection site. This should include the name of the cave, a grid reference for the entrance, and the location of the sampling point within the cave.

We have a particular interest in hypogean records of Crustacea (such as *Niphargus* spp. and *Asellus cavaticus*) and other aquatic macroinvertebrates, such as beetles (Coleoptera). However, most terrestrial fauna can also be identified. Anyone interested in further details should contact either of the authors below.

Lee Knight
No.1 The Linhay
North Kenwood Farm
Oxton
Nr. Kenton
Devon
EX6 8EX
UK
Tel: 01626 891 431

or

Paul Wood
Limestone Research Group
Geographical Sciences
University of Huddersfield
Queensgate
Huddersfield
HD1 3DH
UK
Tel: 01484 472687
Email: p.j.wood@hud.ac.uk

BOOK REVIEWS

Chen Xiaoping and 15 others, 1998. *South China Karst I* [1.Karst Studies of Yunnan; 2.Karst Studies in Western Guizhou]. 247pp.
Published by Založba ZRC, Ljubljana.
Price: US$39.40 (plus postage: Europe US$3.00, outside Europe US$4.00)
Available directly from: Založba ZRC, Gosposka 13, p.p.306, SI – 1001, Ljubljana, Slovenia.
Fax: +386 61 125 52 53
E-mail: zalozba@zrc-sazu.si; http://www.zrc-sazu.si/zalozba

Credit card payments (Eurocard/Mastercard, Visa) and personal cheques (payable to Založba ZRC) are accepted.

This grand, glossy and impressive volume documents a cross between an expedition and a research project (over 1995 to '97) in the karst of Yunnan and Guizhou. It is a product of the Karst Research Institute in Postojna working with Chinese colleagues, and is therefore a significant contribution to China karst research, based soundly on a wealth of karst experience. A bonus is that its colour photos provide probably the best available visual impression of the fengcong cone karst in Guizhou - which is one of the world's key sites for karst geomorphology. The volume suffers from a serious lack of good maps, and also from some rather peculiar English; the latter is hardly surprising from Slovenian and Chinese authors, and credit is due for publishing in the international language.

The Yunnan half of the book concentrates on the Shilin Stone Forest. There is an excess of descriptive detail, with little that is new in deduced concepts of genesis, and no site map. Some morphological details are related to soil permeabilities during their sub-soil genesis, and others are related to sub-vegetation genesis. Lithology is shown to have minimal influence, while the comments on the structural geology say little, but there is a useful mass of data on dissolution processes (gathered by conductivity measurements during rainfall events). Assessed erosion rates are interpolated to indicate that Shilin has evolved over 1.6 Ma (but with no consideration of Pleistocene climatic variations). This fits in with accepted concepts of the long timescales in the evolution of China's karst, while the conclusion that *"Deducting the influence of the rocks, the rainfall is the main motivation of the karst developing."* is hardly controversial.

Also in the Yunnan section, there are notes on the large and impressive show cave of Juxiang (but there is no scale on its survey), and on the hydrology of the nearby Tianshengan area (where caves are claimed to exist, but with no further comment).

The Guizhou half of the book has great pictures and some fascinating items, but its value is generally diminished and locally lost due to a lack of decent location maps. The map shortage is probably one aspect of political dogma, which unfortunately continues to blight scientific research in China. Why else should the key site map (p.145) omit half of the cited locations, and yet include an expanded inset map of China with a national border carefully drawn to include both Taiwan and the disputed Spratly Islands (besides Tibet)? Politics also mean that the British are credited with the exploration of Wujiadong, but no other reference is made to previous and more extensive work by the China Caves Project and its Guizhou University collaborators (who are the political rivals of the local geologists who worked with the Slovene team).

Within the Guizhou section, one chapter describes the karst at Tianshengqiao (Natural Bridge), with surveys of the adjacent caves (all less than a kilometre long). The bridge itself is a most spectacular feature - a slab of limestone (dipping at 20°), 15m thick and 30m wide (and carrying a road), at a height of 136m across a gorge about 50m wide. It is a remnant of cave roof that has collapsed on each side, and has then had its cave floor greatly entrenched by the active river; the height appears to be a world record for a natural bridge. A chapter on the cone karst geomorphology recognises the great age of the cones and the youth of the canyons that cut through them (leaving some spectacular truncated cones). There is nothing new in this conclusion, nor in the results of a minimal survey of cone morphologies. A very readable and well-illustrated chapter on land use in the karst draws attention to the problems of desertification after deforestation and the loss of soil from the cone slopes.

This specialist volume will hardly qualify as a popular read, but it is a useful contribution to the database on China's karst. Anyone going to China, or researching cone karst or stone forests, should definitely check out this book.

Reviewed by Tony Waltham, Nottingham Trent University, Nottingham, UK.

Tectonska zgradba sistema Postojnkih jam. *Tectonic structure of Postojnska jama cave system.* Stanka Šebela. 112pp + illustrations.
Published by Založba ZRC, Ljubljana.
Price: US$21.80 (plus postage: Europe US$3.00, outside Europe US$4.00)
Available directly from: Založba ZRC, Gosposka 13, p.p.306, SI – 1001, Ljubljana, Slovenia.
Fax: +386 61 125 52 53
E-mail: zalozba@zrc-sazu.si; http://www.zrc-sazu.si/zalozba

Credit card payments (Eurocard/Mastercard, Visa) and personal cheques (payable to Založba ZRC) are accepted.

In reviewing this eye-opening monograph I have the advantage of having had the benefit of a guided tour of parts of Postojnska jama with the author. Even before reading and digesting most of the information in the book I was debating some of its contents on site, not only with Stanka Šebela, but also with another eminent Slovenian colleague, Professor France Šušteršič. Whereas a visit to Postojnska jama ought to be on every caver's or cave scientist's "must do one day" list, the added value of a visit and on-site discussions with local experts cannot ever be over-estimated.

Stanka Šebela describes this publication as *"...a synthesis of my structural-geological field investigations of the Postojnska jama cave system ... in the 1991-1997 period"*. Whereas this is doubtlessly unembroidered fact, it is also an understatement of the amount of study (beginning with work towards a doctoral dissertation), interpretation and preparation that must have gone first into building the model presented, and then into producing this impressive publication.

The synthesis presents the state of the art in the study of Postojnska jama, which is currently the longest explored cave in Slovenia at about 20km. Much of what is presented comprises the fruits of "straight" observation and recording – no small task in its own right, even in such a cave as this. The remainder is interpretive. Throughout there is an obvious bias towards study of the role played by (broadly) tectonic structures in guiding the cave's development. This may in part reflect the context of the study undertaken and the background of the author's main mentor during her research, Professor Dr Jože Čar, who is well known for his work on tectonic structures.

Before my visit to Slovenia, John Gunn handed me his own copy of the publication, praising it highly, but saying, *"You'll like this – it doesn't mention inception horizons once!"*. I have to agree with his assessment. I did like it, and the words "inception horizon" are absent. However, careful reading revealed that a number of significant bedding planes, as well as the more eye-catching tectonic features, were recognised as having contributed to guiding the cave's inception and expansion. Faced with the same research opportunity, my approach to looking at the cave's history would have begun from a different point, but I suspect (or hope!) that the final excellent overview might have differed only in emphasis. Whereas I find that I disagree in detail with some aspects of the author's writing and field demonstrations, I would be unable to provide a better overview and synthesis as a working hypothetical model. It would be nugatory to dwell upon such minor differences and equally pointless to attempt to find fault with what is presented. Readers can judge for themselves, on the basis of their own backgrounds and preconceptions! What is clear though, is that much remains to be seen and interpreted in Postojnska jama, and the developmental model will inevitably evolve and improve.

The publication itself is the first I have seen of its type, though its format is so obviously useful that I can't believe it is a new idea. Except where larger format illustrations intervene, each A4 page contains two columns, with Slovene text in the left-hand column and an English translation to the right. Generally, good use is made of column-width illustrations to balance columns where the translated text is shorter or longer than the original. Overall the English text is easy to read, though locally slightly awkward. Some technical/geological terminology has not moved well into English, and a limited number of typographical errors have slipped through the editorial net. In most cases, however, the essence can be grasped without too much trouble, and the minor flaws present only a slight irritation, mainly due to their interruption of the "flow".

Black and white and coloured photographs, many at page width, are present throughout, augmented by tables, line drawings, maps, surveys and projected tectonic data. A minor annoyance to the outsider is that some of the photographic plates (perhaps those not referenced directly in the text) include no caption. Most include captions, however, in Slovene and in English, and though some are minimalist, most of them are adequate. Usually the pictures illustrate points made and cross-referenced in the text, so further details can be located. This can be slightly disruptive, as it has not everywhere been possible to place text reference and illustration on the same page. But these are minor criticisms.

The book will be fascinating throughout to anyone with an interest in detailed cave development studies. However, most of the real "meat" is found close to the end of the volume, where a fold-out cave/geological survey, geological cross-sections and a variety of smaller interpretive maps and plans are located. The use of colour to help clarify these locally complex illustrations is most welcome, and effective. A minor criticism is that the main survey/map is multi-folded and bound into the book, a side effect of which is that it is easily torn or otherwise mutilated during opening and closing both the map and the book. Perhaps the map would have been more useful and usable if left unbound and stowed within a pocket inside the back cover. Presentation of this type of material seems to be an ongoing problem for publishers.

Any criticisms raised above are minor when weighed against the overall quality of the presentation and the work that is described. Though parts of the book, especially some of the photographic plates, would appeal to all those with a love of caves, especially those that have visited Postojnska jama, this is first and foremost a publication by a specialist for specialists. It does not so much provide a guide to how underground geological studies should be carried out, which will vary depending upon context, but it is a testimony to what can be achieved on the back of painstaking observation and data recording. And you don't need to be a structural geologist to appreciate that.

Reviewed by Dave Lowe, Limestone Research Group, University of Huddersfield, Queensgate, Huddersfield, HD1 3DH, UK.

RESEARCH FUNDS AND GRANTS

THE BCRA RESEARCH FUND

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

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

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

GHAR PARAU FOUNDATION EXPEDITION AWARDS

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

THE E.K.TRATMAN AWARD

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

BRITISH CAVE RESEARCH ASSOCIATION PUBLICATIONS

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

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

CAVE STUDIES SERIES - occasional series of booklets on various speleological or karst subjects.

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

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

BCRA SPECIAL INTEREST GROUPS

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

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

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

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

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

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