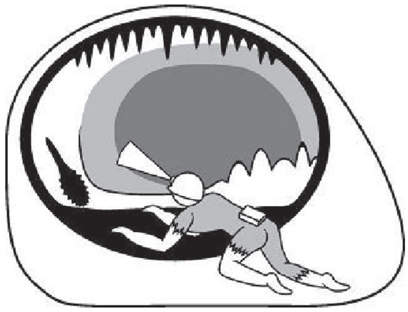
Karstaway Konference



Proceedings of the

27th Biennial Conference
Australian Speleological Federation Inc.
Sale, Victoria 4 - 9 January 2009

Edited by Susan White & Glenn Baddeley

Caving Club of Victoria

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White, Nicholas & White, Susan. 2014. Karst in Proterozoic dolomite, Pungalina Station, Northern Territory, Australia- its significance and management. IN Whie, S. & Baddeley, G. (Eds), 2013, Karstaway Proceedings, Proceedings of the 27th Biennial ASF Conference, Sale Victoria 4-9 January 2009 Victorian Speleological Association Inc., Melbourne.

Cover: Art work for the conference logo by K.G. Grimes

KARSTAWAY PROCEEDINGS

Editorial

These proceedings have taken some time to put together after the January 2009 Karstaway Konference in Sale, Victoria. Our apologies for this delay. Our thanks to the authors who have patiently submitted material and then waited for further progress.

The papers incuded in this volume are those for which complete papers have been provided to the editors. Those which were not provided in complete form, are represented by their abstracts. Some papers have figures and illustrations; others have not. Other activities such as the Trivia Quiz, Photographic Competition and Awards are also included after the papers and workshops.

Although some papers represent material that has been subsequently published elsewhere, this volume is produced to represent the range of material presented to the 80+ people who attended the conference. Several workshops have also been written up. The volume is illustrated with photos taken during the conference.

We especially thank Marg James for her patience. We also thank Marg's and Alice White's meticulous attention to detail when doing the proof reading; an onerous task at the best of times.

Susan White & Glenn Baddeley.

Editors.

Preface

We present the proceedings of Karstaway Konference, the 27th biennial conference of the Australian Speleological Federation, held in January 2009 at Sale in Victoria. These proceedings have taken some time to produce; but as any half decent winemaker knows, it's better to take the time to let everything happen as it should, rather than to rush it and not do it properly.

We chose to locate Karstaway near the well known classic "hard limestones" of East Gippsland, although Victoria also has extensive cave and karst areas in the west of the state. The best known cave and karst area in Gippsland is undoubtedly around the small town of Buchan, but the enormous popularity of this region with summer tourists made it necessary to hold the conference a little further away, and in a larger population centre with appropriate conference facilities. Hence Sale, which is still within easy reach of the main karst areas. Any closer to the limestone and we would all have been elbowed aside by the holiday visitors who flock to visit our celebrated tourist caves.

Nearly ninety people attended Karstaway, representing every Australian state and a host of different organisations and caving environments. Like all ASF conferences it offered opportunities for groups and individuals all over the country to showcase their special projects, large and small, and for our technical wizards to demonstrate unimaginable uses for old and new technology. And of course we got to hear about all those wonderful discoveries made by determined and hard working speleos who had been too busy caving to write about what they'd been doing.

ASF is older than many of the cavers who are its members. Yet there are still old cavers around who joined at its very beginning, so we have not yet lost contact with our earliest foundations. At each conference we move on a little, acknowledging our earlier achievements and building on them as new generations discover the lure of the unknown, and the challenges and pleasures of sharing what they do and find with other like minded characters.

We all appreciate the chance to share, compare, learn and be amazed by the things that are happening outside our own little patch, and we enjoy meeting with other speleos from other places who are doing things differently to the way we do at home, wherever home may be.

Isn't that what conferences should be all about?!

Margaret James

Karstaway Konference Committee Convenor

Contents

The ORC, the AAS and You

Greg Andrews, Membership Manager
Outdoor Recreation Centre, Vic. Inc.

Abstract

The Outdoor Recreation Centre (ORC): The ORC is the central hub for all providers of outdoor recreation-based activities within Victoria. Its mission is to advance the cause of outdoor activities in Victoria through communication, networking and representation

Recognition and support of existing peak and community organisations enables the ORC to support the many outcomes and experiences available from the outdoors.

Where necessary, the ORC provides a single point of contact to and from the outdoor industry when liaising with state government departments in the areas such as community participation, land management (access) and regulatory influences.

The ORC provides Victorians with the opportunity to contribute towards initiatives in the outdoors that may affect them, as they arise. The ORC Committee of Management is made up of nominees from member organisations.

The Adventure Activity Standards (AAS)

AAS are voluntary guidelines for undertaking potentially risky activities in a manner designed to promote:

- Safety for both participants and providers.
- Protection for providers against legal liability claims and criminal penalties.
- Assistance in obtaining insurance cover.

The AAS have been established as minimum standards for organizations conducting outdoor recreation activities for dependant groups, where participants have a level of dependence upon the leader(s).

The necessity for minimum standards has arisen as the outdoor recreation sector continues to develop 'best practice'.

The AAS originated in Victoria and have been in place here for 5 years. All of the states around Australia are now introducing their own AAS.

This session will:

- Give an overview of the work the ORC is currently involved in, as well as where we can assist our members.
- Introduce you to the concept of what the AAS are and update you on future plans.
- Give ideas and tips on how to constructively contribute to the AAS.

Introduction

The Outdoor Recreation Centre (ORC) was established in 1988 by industry peak bodies and associations. The ORC is a central hub for all providers of outdoor recreation-based activities within Victoria. Recognition and support of existing peak and community organisations enables the ORC to support the many outcomes and experiences available from the outdoors.

Where necessary, the ORC provides a single point of contact and a single voice for the outdoor industry when liaising with state government departments in the areas of community participation, nature based and adventure tourism, land management (access) and regulatory influences. Likewise, these state government departments are enabled to communicate to the outdoor industry via the ORC.

The ORC's membership of the Outdoor Council of Australia (OCA) ensures that Victorian organisations are informed of national developments such as conferences, leaders' registration, standards and events as well as being networked to interstate counterparts. The ORC provides Victorians with the opportunity to contribute towards initiatives in the outdoors that may affect them, as they arise.

The ORC Committee of Management is made up of nominees from member organisations. It currently comprises representatives from Adventure Guides Australia, Australian Camps Association, Bushwalking Victoria, Scouts Australia (Victoria Branch), Swinburne University, Tourism Alliance Victoria and the Victorian Outdoor Education Association.

Our Mission Statement

To advance the cause of outdoor activities in Victoria through communication, networking and representation.

What the ORC can do for you!

Information

The ORC is in a unique position of being a part of all the major components of the outdoors in Victoria. We are in regular contact with public and personal recreation, education, tourism, camps, government and peak bodies across Victoria and Australia. This means that if you have a question, we can answer it.

Advocacy

If you have an issue that you want help with, perhaps even some representation, we can help you. It could be to government or other organisations (such as peak bodies) and on any issue relevant to our mission. For example, land access and safety are current topics.

Recreation House

Recreation House provides a physical centre for members including offices, meeting rooms, storage and a conference area. Currently four tenants and the ORC's own staff reside at the Westerfolds Park location. There is one available office and an extension is proposed to accommodate the Australian Camps Association. The conference room is currently available to all members free of charge and ample parking is available. We are even located inside a park, right on the Main Yarra Trail and the Yarra River.

Outdoors Victoria Update

The Outdoors Victoria Update is a monthly email that updates you on current industry-wide news and information that concerns the outdoors in Victoria. This resource also enables members to communicate events and initiatives with other members.

Forums

We run a range of forums and workshops throughout the year. Recent examples are a risk management seminar, an industry round table, and guest speaker sessions. A focus for the coming year will be upon empowering and developing community/not-for-profit groups. All of these events also provide members a great opportunity for networking with your peers.

Vehicle purchase and leasing

The ORC is currently engaged in talks with some car manufacturers on making fleet and leasing deals available to ORC members.

Conferences, workshops, industry days

Throughout the year there are a number of conferences, workshops and the like on a range of topics. We know that members struggle to attend them all. If there is a relevant event, seminar, forum or conference that members would like more information on, we can attend and provide a report for you. We attend local, interstate and national events so that our industry is informed of the latest ideas and trends.

Adventure Activity Standards (AAS)

The ORC is the Guardian of Victoria's Adventure Activity Standards. These are a suite of industry approved state-wide guidelines for safety and the environmental impact across the most popular adventurous activities. They provide clarity on common risk management and environmental practices expected by organisations providing adventure activities for dependant groups.

An important and ongoing part of this initiative is the AAS Technical Committee, made up of nominees of members from across the industry and government. Its role is to collate and assess any feedback and suggestions on the AAS, which is done as a continual process.

Additional AAS can and are being developed as needs arise, as suggested by events, government and/or members. AAS are being developed across the country. South Australia, Tasmania, Western Australia, Tasmania, Queensland and New South Wales have all introduced AAS.

Industry Mapping

Last year we completed an industry mapping report that is available to members upon request. The report outlines what outdoor experiences, activities, organisations, training and regulation are currently available within Victoria. Essentially this report provides context and benchmarks for coordinated development of the industry. The report is available from the ORC via email as a 70 page document that includes a summary.

Governance

The governing board of the ORC is the Committee of Management. A part of ORC membership is not just the ability to vote at the AGM and on special resolutions, but also to stand for a position on the Committee.

The operational side of the ORC is managed by an Executive Officer, on behalf of and reporting to the Committee of Management. Available staff resources currently include the Executive Officer, Membership Manager (both full time) as well as a Project Officer (consultant), bookkeeper and IT support.

Adevnture Activity Standards (AAS)
Why Develop AAS?

In Victoria the AAS was developed to help answer the questions raised by government departments, commercial activity providers, community groups, leaders and other stakeholders. Land managers (Crown and private) need to understand what is happening on the land they manage or own. The problem was not a lack of standards, but rather an excess of different standards.

In addition to the initial reasons to clearly document these expectations, the extent that external stakeholders required increased confidence in, or knowledge about, this industry changed in 2001 due to insurance concerns.

Specifically this included:

- Public liability insurance increased significantly (Feb - Jun 2001). SLE withdrew from recreation, tourism and amusement insurance creating increased demand for industry standards (Dec 2001).

- A National Government (SCOR's) 'Review of Australian Insurance' suggested "…among other outcomes…" a need for independent industry operating standards (Mar 2002).

These and other issues posed a significant threat to the ability of organisations to deliver activities.

What is the status of the AAS?
Are they Law and could they become Law?

In Victoria, AAS are **voluntary** guidelines for undertaking potentially risky activities in a manner designed to promote:

- Safety for both participants and providers.
- Protection for providers against legal liability claims.
- Protection for providers against criminal penalties.
- Assistance in obtaining insurance cover.

AAS are NOT statutory standards by law. Legal liability for injuries or property damage is primarily governed by the Law of Contract and Negligence. These are described within the AAS. The AAS describe what activity experts across commercial, non-commercial and education fields deem to be a reasonable minimum in planning, competency/experience, equipment and environmental care for conducting group activities.

In the absence of AAS, the courts must attempt to draw what is the duty of care by finding relevant experts and other documentation.

The simplest way to think of the AAS is that they are a tool that any organisation or individual may use.

Who was involved in Victoria?

The Steering Committee initially governed the entire project. This was made up of representatives from the following agencies:

- Government agency funding consortium (Sport and

Recreation Victoria, Parks Victoria, Dept. of Sustainability and Environment, Tourism Victoria)

- Department of Education and Training
- Verve Knowledge and Skills (Victoria's ITAB)
- Tourism Alliance Victoria
- Australian Camps Association
- Tourism Accreditation Board of Victoria
- Victorian Work Cover Authority (as observers)

Who else contributed? Significant additional direction has also been provided by:

- Insurance Underwriters & Reinsurers
- Insurance Industry Council of Australia
- Risk management consultants
- National and international outdoor recreation organisations
- Victorian Police (Search and Rescue & SOLO Squad)

The Process

Each AAS was developed through workshops with specialists in each activity. These involved representatives appropriate for the activity from:

- Commercial (private operators)
- Non-commercial (Scouts, Scripture Union, Police Search and Rescue, YMCA, VSA)
- Peak bodies (Surfing Australia, Australian Canoeing)
- Training providers (TAFE, University, RTOs)
- Individuals

How were the AAS finalised?

Firstly, the AAS benchmark existing operating standards (where they exist) and agree on relevant standards. Before being finalised, the AAS have been:

- Agreed as reasonable by the working group for each activity.
- Reviewed by a wide cross-section of activity participants online at www.orc.org.au.
- Reviewed by the ORC Committee.
- Reviewed by the AAS Steering Committee.
- Reviewed by the AAS solicitor.

How are AAS implemented?

As they are completed they are posted on the ORC website and are free to download. No hard-copy documents are issued; the current copy is the copy on the website. AAS have been adopted as license criteria by land managers such as Parks Victoria, Philip Island and Great Ocean Road management committees. AAS have been included as activity conditions for accreditation schemes (nationally). Insurers and courts now have an industry-endorsed benchmark to begin to measure accountability.

What this means!

- Community groups and individuals have easy access to industry standards.
- Training (independent or in-house) should become more consistent across activities and the state, and potentially the country.
- Organisations, parents and leaders can be more confident that activities are run appropriately.
- AAS compliment the following national initiatives i.e. The National Training Package (VET Qualifications) and the National Outdoor Leaders Registration Scheme (NOLRS).

Organisational Accreditation

By ensuring that the AAS complement the work being done at a national level and by other states, the outdoor recreation and adventure tourism industry can better demonstrate a united and professional approach. This is because:

- All group activities have the same benchmark, rather than the safety being defined by profitability, ill-informed leaders or the land manager.
- All group activities are better protected against small claims.
- There can be statewide (and hopefully national) consistency for insurers and land managers.
- Participants can have confidence that they are being appropriately accounted for, by being able to check for themselves.

What is happening now?

AAS will continue to be developed and need ongoing feedback to maintain relevance. Discussion among government and industry of possible national implementation has led to AAS in NSW, Queensland, South Australia, Tasmania and Western Australia developing AAS. Continuing to raise awareness of the AAS will strengthen confidence in the industry in both commercial and non-commercial activity providers. The ongoing process requires continued industry support and input.

Finally

The answers to the 'frequently asked questions' in Victoria can be accessed via the AAS section of www.orc.org.au. As these are industry standards we encourage everyone to discuss issues which may affect them and to provide us with your opinions.

Remember that these are broadening awareness of existing standards and expectations rather than imposing anything new. That is not to say that some aspects are not new to some!

The website to access all Victorian AAS information is www.orc.org.au.

How to get involved and have a say?

In Victoria, all contact for the AAS is done by submission on the AAS section of www.orc.org.au.

For those states developing their own AAS, contact your state's industry organisation.

The best thing to do is get your organisation involved in their development on ongoing maintenance. The AAS will happen regardless, so it is best to be heard now rather than later.

Note: In 2013 ORC was replaced by Outdoors Victoria. The AAS exist on the Outdoors Victoria website outdoorsvictoria.org.au/

Recent exploration in Jones Ridge Cave (DD-4) at Drik Drik, Western Victoria

Glenn Baddeley,
Victorian Speleological Association Inc.

Abstract

The 25m deep DD-4 doline has been known since the early 1900's and was notable enough to be shown in profile on the parish geology map of 1929. In December 1995 cavers became aware of a small entrance at the base of the sheer sided doline which led into an active stream passage heading upstream beneath Jones Ridge. The ridge is an uplift about 10km long running parallel to the Glenelg River, consisting of a thin recent volcanic flow atop Miocene Gambier limestone, tailing off into Quaternary dune limestone down to the river.

Since 1995 the Victorian Speleological Association has run nearly 30 trips to explore the stream passage and higher level dry areas of the cave, resulting in about 2400m of surveyed passage. Much of it is extremely muddy and wet and there are about 30 rock-falls and some pools and cascades to negotiate. Two kilometers into the cave the stream emerges from a sump pool which is only a few hundred metres from a stream sink (DD-18) on the east side of the ridge. Efforts are continuing to push the sump, with the hope of further negotiable passage, which may extend through to DD-18. The stream continues downstream from the DD-4 entrance but human passage is currently blocked by rock-fall beneath the doline only a few metres in. The stream appears to continue to a small resurgence at DD-25, about 2km distant near the Glenelg River, but this has yet to be confirmed. There have been some interesting discoveries in the cave, including a big loop in the stream passage, a whale bone, shark teeth, unusual mud stalactites, several waterfalls up to 4m high, side passages, and evidence of bat habitation in the past. Studies have been done on water chemistry and levelling.

Surface exploration has added about 25 new karst features to the Drik Drik area, but no other significant caves. The limestone is nearly all on private farm land and cavers continue to foster very good relations with the land owners.

***Figure 1** Entrance passage DD-4 2004 (Photo:Ken Grimes)*

***Figure 2** Entrance passage and muddy stream DD-4 2004 (Photo: Ken Grimes)*

A Nullarbor Exploration Project

Ken Boland, Daryl Carr, Susan White
Victorian Speleological Association

Abstract

Areas of sometimes one, two or three hundred square kilometres were suspected to be untouched by any existing tracks, and to contain no known features. During previous survey expeditions the idea grew from thinking about known caves at and beyond the tree line, to studying such an area in some small primitive way so as to ascertain whether there might be some matters of interest. Consequently a solo three day walk was undertaken, and about ten small features were found, some being small caves. At the same time it became evident that the method would be futile for anything more than a minute sample of the whole plain.

Discussion led to the acquisition of a conventional tri-axis aircraft. Methods and processes were developed for efficient data collection both in the air and on the ground. In time further work produced verification of the validity of the processes.

Annual results since 2000 have varied but a firm commitment is producing results. There is no one aim other than to document what is there, though other aims may emerge in time, also serendipitously. Documentation is itself a major part of the daily expedition, while some characteristics are emerging from the data and experience gained.

Introduction

Our aim has been to examine large areas of the Nullarbor Plain, particularly those not often frequented, and to document all that is found.

Background

Years of experience gained by many people, including not only cavers, has led to a common acceptance that many blowholes and caves do exist, and can be found anywhere on the plain. However detail about such a commonly accepted belief has been sketchy at best, with little firm information as to location, frequency of occurrence, evenness of distribution or type of feature, and documentation has been sparse. Moreover the focus has, at times, been to discover new sporting caves, with little interest in documenting the many other features seen in the process.

Figure 1 *Flightstar in the air*

Ken's own experience started with several visits to see known caves. While interesting, nevertheless no further knowledge was added. Surveying became the new focus, with some ten years spent mainly on one cave, Thampanna, 6N206. It was during this period that an awareness developed concerning several large areas, some in excess of a thousand square kilometres, where no visible tracks existed and no features were known.

In 1999 an initial exploratory solo walk of three days was undertaken in an area south of Old Homestead Cave, 6N83, and during this some nine small caves were found. A GPS was carried, but was still in the "randomly inaccurate" mode and the greatest finding was that the method was limited. At one time, two small entrances 11m apart were impossible to see from each other's entrance. Saltbush! There had to be a better way.

By 2000 a small aircraft had been acquired (Fig. 1). A simple single seat viewing platform, with conventional wing, tail and rudder, little weight and lots of power, *Flightstar* was adaptable to the conditions common on the bare plain, but effective methods were, as yet, far from developed. Simply securing the aircraft during high winds and storms called for a radical approach to aerodynamics. Nevertheless a simple form of grid search was initiated, a primitive recording method devised, and America very kindly removed the "GPS randomiser" giving us position accuracy of a few metres instead of a hundred or more. We were set to begin!

Figure 2 *Ken is ready to record features*

Methods

Equipment carried on the aircraft is simple and minimal: a notepad fixed to the right knee, a GPS in bracket on the left knee (Fig. 2), three pencils in a clip within easy reach, an antenna for the GPS, sundry spares, rations and water, distress flare, and a device to raise a storm in Canberra if rescue became a priority. Cameras are definitely not carried except for a dedicated mission: the pilot is already managing an aircraft, a fastidious engine, varying wind conditions en route, location and search pattern, precision marking of locations, and enigmatically cryptic notes with the fourth hand. Enough is definitely enough! Ground reports show an increased accuracy over the years, and there is now a justified confidence that very little is missed. While the bare use of human eyes may sound too simple, we are confident that the eye is so controlled by its "on-board computer" that the developed "software" far outclasses any non human equipment currently available. Some of the development is definable, but there do seem to be factors involved that are not easily understood. Many times Ken has made ground visits simply to compare with the aerial view. The basic classifications judged from the air are mainly **Holes**: small to large; **Entrances**: where this appears to be the case; **Dolines**: shallow to deep, wide to small; **Rockholes**: places where water is visible, or appears to be possible; **Villages**: points where several animal tracks meet; and other sightings as the need arises, so that every detail detected is recorded, even if it is unlikely that all points can be inspected by a ground party.

Some points are not visited. This may be simply due to lack of time, but may be because of the sheer distance involved, the isolation of just one feature, the proliferation of tyre shredding bluebush, or the possibility of marking the surface unnecessarily for little purpose. Whereas initially we placed our annual search areas, around a thousand square kilometres, in adjoining positions, now we prefer to sample areas more widely representative.

How a feature search is organised and the results processed

Prior to the trip

- CEGSA issues the VSA a block of cave numbers (N numbers).
- The year's search area and base camp sites are selected (Fig. 3).
- Information sought on any existing (known) features from the CEGSA records and other sources.
- Permits applied for e.g. S.A. Nullarbor areas require a scientific permit from the relevant state government department in Adelaide. We have now had permits yearly for several years. Decisions as to what other information might be needed to collect data for and appropriate sample collecting requests added to the permit application. Liaison with Parks SA organised.
- Expedition logistics, equipment, transport, fuel, water, participants, communal catering, risk management organised. These tasks are shared.

Search methods and documentation

- Once we are all set up in camp, Ken (our pilot), plots the day's search pattern and enters this search pattern as a route into his GPS. A new route is made for each new search pattern. Ken will fly along these daily routes (Fig. 4). As a part of risk management for the expedition, copies of the intended route for the day are available in camp.
- As the route passes over or near any karst or other features Ken "marks" these on his GPS and writes the basic details of the feature into a flight log book.

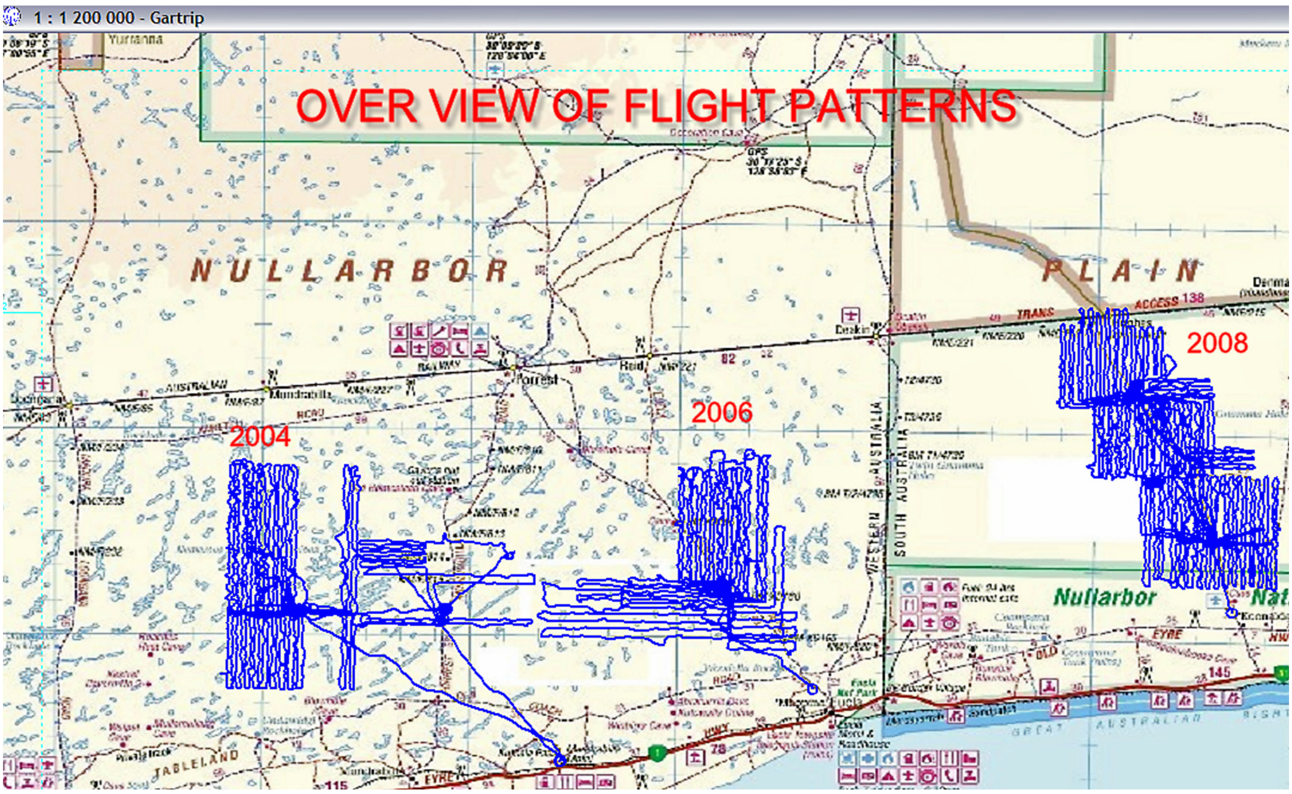


***Figure 3** Overview of flight paths showing areas searched. This information is used in conjunction with track information to choose each year's search area.*

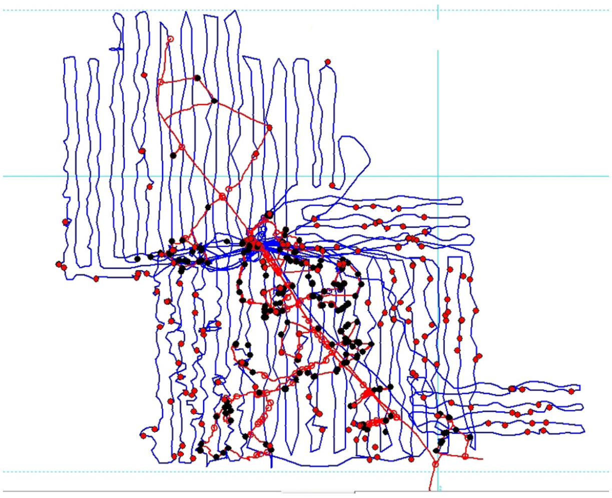


Figure 4 *Overview of flight tracks and surface tracks. Not all are shown.*

• On return to camp Ken edits his flight log by assigning a “K” number to each of the GPS marks. Thus WP 001 of the first flight will be assigned K nnnn, (n) being the next highest K number above the previous flight’s K numbers. (e.g. in year A, the K numbers may finish at K 1234; the next year’s K numbers will start at K 1235). This edited information is called "Ken's Raw Data". Ken then passes his GPS and flight log book to the data team.

• Using the Gartrip program, Ken's GPS is down loaded. Both WPs and the actual flight tracks are saved and archived as Ken’s raw data. Each flight's raw data will be retained unedited in file.

• A copy of the raw data is then used as the source for editing in Gartrip. The basic WP numbers are replaced with a K number and a short description is entered into the edited WP. The WP position information is not changed. This data is now called “Processed Data’ and is filed ready for loading each day into the expedition members' GPS units.

• The field teams organise the areas to be checked, who is going where and with whom, what transport (4WD plus walking, walking only, motorbikes) is being used for each party and what gear might be needed. Ground parties go out for most of the day. Information as to where the ground parties are going to search is put on the "where are you" board. Risk management actions are organised. Parties are expected back in camp by dark.

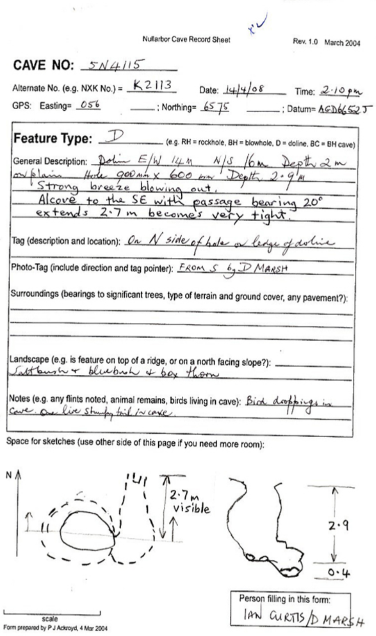
• A standard cave reporting form is used by the field teams (Fig. 5). On-site information of the feature, mapping information and the more accurate ground tested GPS location are entered on the form. If the feature warrants it, an N number is allocated and tagged on the feature. No tags have been attached after 2011; we now rely on GPS position and have dropped the 5 designation using just N nnnn. Area and feature images are taken.

• Each evening the processed data and any GPS tracks are collected ready for printing in an information sheet or many sheets known as the *Morning Herald* (Fig. 6). All (including updated) WPs and tracks are printed over a calibrated map of our annual search area. The *Herald* also lists the K number locations and comments. Later as more information flows in, the K numbers are updated to N numbers and the positions are refined by field corrections. This data is archived in day files and a copy is used for later modification with new day’s field data.

• The *Herald* is a daily progressive record of the expedition’s finds, results, tracks and where we have been or not. It is therefore a valuable planning aid. Occasionally the A4 size page print does not show all features clearly so detailed print outs can be provided on request to help sort out confusing areas.

• To check the actual ground coverage, the pilot has extra print outs which show his actual flight paths over the search area.

• The completed cave report forms are collected by the data team each evening. Copy of the WP lists in Gartrip is updated with the new field reports and refined GPS locations and altitude. Where appropriate the K numbers are replaced with N numbers, or if the feature had no prior K number, the N number and details are recorded and noted



Nullarbor Cave Record Sheet Rev. 1.0 March 2004

CAVE NO: 5N4115

Alternate No. (e.g. NXK No.) = K2113 Date: 14/4/08 Time: 2·10 pm

GPS: Easting= 056 ; Northing= 6575 ; Datum= AGD66 52J

Feature Type: D (e.g. RH = rockhole, BH = blowhole, D = doline, BC = BH cave)

General Description: Doline E/W 14 m N/S 16 m Depth 2 m on plain Hole 900 mm x 600 mm Depth 2·9 m Strong breeze blowing out. Alcove to the SE with passage bearing 20° extends 2·7 m becomes very tight.

Tag (description and location): On N side of hole on ledge of doline

Photo-Tag (include direction and tag pointer): FROM S by D MARSH

Surroundings (bearings to significant trees, type of terrain and ground cover, any pavement?):

Landscape (e.g. is feature on top of a ridge, or on a north facing slope?): Saltbush + bluebush + box thorn

Notes (e.g. any flints noted, animal remains, birds living in cave): Bird droppings in cave. One live stumpy tail in cave.

Space for sketches (use other side of this page if you need more room):

N 2·7 m visible 2·9 0·4

scale

Person filling in this form: IAN CURTIS/D MARSH

Form prepared by P J Ackroyd, 4 Mar 2004

Figure 5 *Standard Field report form*

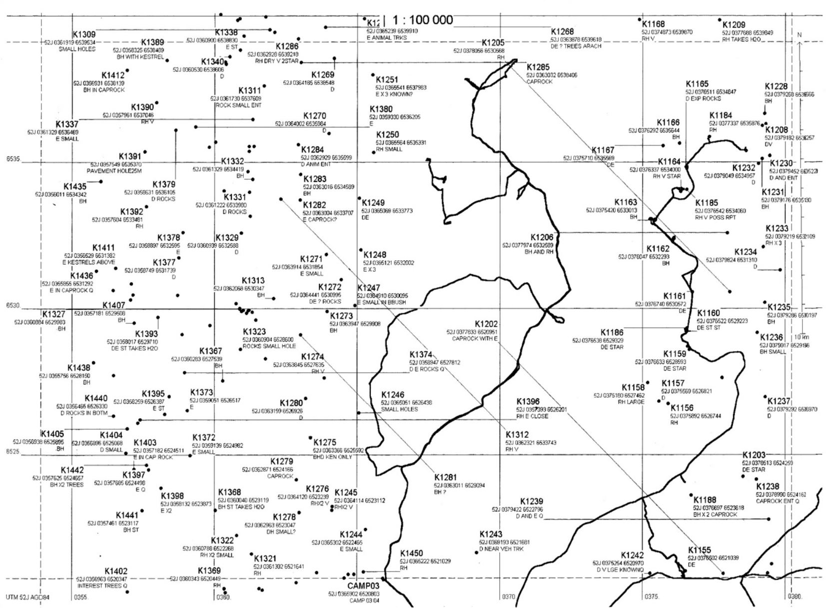


Figure 6 *Section from the Morning Herald. This shows information for the “ground truth” crews to check.*

as having no K number. If the K feature is of no significance, i.e. a rabbit hole or shadow or bush, the feature is recorded as K nnnnV The V indicates the K feature was visited but not numbered. V or visited features may be imaged and re-GPS'd for records. A K number that is not located is simply recorded as "not found".

- The entire GPS track data is down-loaded from each member's GPS each day. This data is archived in the individual members GPS file folders. These tracks are then added to an existing working file thus building up the coverage map.

- After each flight, Ken returns with the results and the data process is repeated. Each step in the original data is archived. Copies are used for editing each day, the edited day copies are also archived. Copies of the edited day data are combined to give progressive result information. Hopefully data is not lost with this process and queries or errors in data entry etc can be traced back to the source data.

- The new *Herald* is printed each day and GPSs are updated with the latest progressive data. The report forms are filed for yet more processing back at home. So each day the information cycle builds up.

Follow up back in Melbourne

- Back home, all of the cave report form information is entered into an Excel hyper-linked spread sheet. The archived data, cave area and tag images, scans of the original cave report forms and cave maps are also entered into the spreadsheet.

- Maps are drawn up and lodged with VSA records.

- Updated documentation is submitted to CEGSA for inclusion in the database.

- The spread sheet and other additional information and summaries are sent to Parks South Australia and a report submitted to the department that issued the permit.

- The whole exercise starts again for the following year.

Discussion and Conclusions

In the past, discoveries were primarily the result of checking along the tracks and the use of aerial photographs, which picked up the larger dolines. This resulted in exploration bias as the concentration of known caves has been predominantly near tracks. Although new caves are still found by this method, the use of the ultralight aircraft has resulted in a much wider area explored and documented. The ultralight flies closer to the ground and is able to identify smaller entrances than aerial photographs.

The potential for analysis of the distribution of cave and significant karst features is significant. When combined with Google Earth and satellite imagery analysis, some interesting patterns of cave distribution may be identifiable.

The aerial reconnaissance is supported by cavers who 'ground truth' the GPS locations. If a site has a feature this is surveyed and documented (numbered, described, surface photographed). Sometimes the GPS sites are "fake" i.e. bushes, shadows, and at other times extra entrances are found and documented. The data is submitted to CEGSA for inclusion in the main database. Some hundreds of blowholes and caves have been added to the database over the past 10 years.

The expedition varies in numbers between 10 to 16 people. The best number has been found to be about 12. The expedition logistics has developed into a pattern (Fig. 7), which suits the main participants, and people wanting to join need to contact the organisers very early in the year. Support from VSA has been gratefully received and the group now has participants from a number of ASF clubs.

We are into our tenth year, the group is fairly constant, we have new wing fabric, and about 95 years should complete the job.

(Photographs are from the authors.)

Figure 7 *View of 2008 camp*

The Thailand Project: 25 years of Progress, a Personal Retrospective

John Dunkley
Highland Caving Group

Abstract

Many, if not most of the caves of Thailand were known locally for centuries, but not much recorded in speleological sources. In 1982, after several private trips to Thailand, the peripatetic Austrian caver Heinrich Kusch published a list of 94 known caves, some known to Australians such as Andrew Pavey and Mike Bourke. In that same year I made a reconnaissance trip to the north of the country. The project blossomed after a paper at the 1984 ASF Conference, and over the next 15 years a sustained effort resulted in 18 small and 8 large Australian expeditions, with up to 15 participants. As local residents were gradually attracted, several further expeditions followed with Australian participants, and other foreign expeditions arrived, mostly from France and the UK.. John Spies and Nopparat Naksathit received ASF Awards of Distinction for their contributions. The superb and highly recommended book "Caves of Northern Thailand" drew heavily on the work of these expeditions.

Major achievements included:

• an increase in the number of documented caves from 94 in 1982 to over 2,000 in 1997 and about 4,000 today.

• developing a national cave numbering and documentation system.

• exploring and surveying the then two longest caves in mainland South-east Asia.

• surveying over half of the then 34 longest caves in Thailand.

• discovering the tallest column in the world and the discovery of two new species of blind cave fish, which eventually starred in the Planet Earth TV series.

• locating numerous unrecorded sites of prehistoric coffin sites.

• about 60 publications, including 5 books, 10 management reports, 24 speleological articles, 15 scientific papers in Helictite, Cave Science, Australian Archaeology etc. and an entry in the Encyclopedia of Cave and Karst Science.

• assisting and inspiring local interest in cave exploration, documentation, conservation and sound management.

In the last decade the Australian work was continued by British expatriates Dean Smart and Martin Ellis along with Shepton Mallet Caving Club (UK). Working partly with Dean's records, Martin has a prodigious fund of information on Thailand's caves. The project is an exemplar of what can be achieved by a sustained effort, and there are still numerous leads to be followed throughout the country. Despite the many publications and now several valuable websites (notably Martin's), this is the first overview of the project other than a privately produced, lighthearted retrospective produced only for 30 or so participants.

Introduction

Twenty-four years ago I presented a paper at the ASF Conference in Hobart on the potential for speleological exploration in Thailand. While there have been over 60 publications deriving from the ensuing Thailand expeditions, this is the first overview of the whole project other than for a nostalgic record printed privately in 1999 for expedition participants only. This is a summary of a more comprehensive account of the Project to be published in Caves Australia in 2009 with a complete bibliography.

Not that we were first on the scene. Many caves in Thailand have been known to the local community for more than a thousand years, and monks explored deep within caves such as Tham Tab Tao north of Chiang Mai, but until very recently there was little indigenous interest in systematic documentation of caves and karst. As late as 1982, the efforts of Austrian caver Heinrich Kusch, who had travelled widely in Thailand, resulted in a list of only 94 recorded caves. By 1997, when I produced *The Caves of Thailand,* there were 2,000. We now know of about 4,000, still a fraction of the potential. Kusch didn't appreciate that even then there were probably more than 100 caves at least partially developed and open for a form of tourism in Thailand. Nor did I, until I witnessed the arrival in 1983 of 4 large tour coaches at the great cave at Chiang Dao, north of Chiang Mai, where perhaps 10 or 12 souvenir and noodle shops were reliant on the domestic tourist trade.

But further out in the remoter provinces there were vast tracts of virtually unexplored limestone. This paper summarises how the Australian-led Thailand Caves Project contributed over a 25-year period, so it's inevitably personal. Indeed, there's nothing new here. I have to emphasise also that the Project was an idea and an ideal, not an institution. It grew organically, shooting branches from exploration to surveying, geomorphology, archaeology, prehistory and to conservation and management.

Beginnings

I first visited Thailand in 1969, noting the limestone outcrops near Kanchanaburi from a sedate wood-fired steam train, but it was late 1981 before a friend in Canberra teamed me up with some Thai contacts for a visit to northern Thailand's caves. Not so long ago, but mass tourism had not yet arrived: we travelled by local bus, motor-bike and the ubiquitous *songthaew*, visited tourist caves in Lampang and Chiang Mai provinces, and stayed in hill tribe village houses and local Chinese hotels. Only later did we move on to aircraft and 4WDs. But in the shadow of Doi Chiang Dao, a solid limestone peak towering 1,700m above the plains north of Chiang Mai, I first heard the rumours of vast limestone plateaus and sinking streams near Mae Hong Son to the west.

It was time for some research. Caving is full of the joy of discovery, moments of elation, a certain amount of obsession, and maybe the reflected pleasure of publication. Many of us have experienced moments of serendipity or perhaps even epiphany in our caving careers. One of my serendipitous moments came in the National Library in Canberra in the winter of 1982. Poring over their maps for potentially karstic areas of northern Thailand, I searched for depression contours. Well, there they were. Four of them. One hundred metres each. A four hundred metre deep doline draining over 400 square kilometres!

Around the same time an article appeared in Geo Magazine about the drug trade in far north-west Thailand. I made the acquaintance of the author, John Spies, and in late 1983 we reconnoitred the area, discovered Nam Lang Cave and explored 3.5km of its massive passages in a single day. From there it all developed. Still suffering an adrenaline rush, I flew straight back from Bangkok to Melbourne, ferried across to the 1984 ASF Conference in Hobart, and gave a talk. Four people came out of the audience and signed up for an expedition: Kevin Kiernan, Dorothy Nichterlein, John Taylor and Kerry Hamilton. We left 4 months later, in May 1985. It was the beginning of a long and fruitful era.

Outcomes

In all, there were 8 major expeditions and 18 smaller ones emanating directly from this Project and led from Australia. Most took place before 2000 but individuals who had participated joined or led other expeditions later in a few cases. The earlier trips concentrated on Mae Hong Son province which, except for a seminal archaeological dig by Chester Gorman in 1969, was then virgin territory for westerners and difficult of access. Shorter side-trips expanded to the better-known but still little documented provinces of Kanchanaburi and Phangnga, and later to Phitsanuloke where Australian cavers were instrumental in surveying Thailand's now longest cave, and to Nan with Thailand's deepest. We even diverted to Myanmar, still the only significant caving expedition to that benighted country.

In the early trips we discovered and surveyed over 50km of new caves including the deepest, 10 of the then 17 longest in the country, and the tallest column in the world (61.5m).

In time 7 books, 22 research papers and about 30 articles were published as a direct outcome, along with 6 unpublished reports to management authorities. Kevin Kiernan alone published 14 professional papers, primarily geomorphology and archaeology, notably drawing attention to the coffin sites which proved to be between 1,000 and 2,000 years old. But there were lighter, less focused side trips to places such as to Phangnga and Three Pagodas Pass.

Kerry Hamilton and John Taylor discovered two new species of troglobitic cave fish in the genera *Nemacheilus* and *Homaloptera*, one of which eventually starred in the Caves episode of the BBC's Planet Earth TV series. The 30 seconds of included footage of the "angel-fish" as the Thais called it, or "waterfall-climbing fish" (*H. thamensis* n.sp.) as we referred to it, involved perhaps a couple of man-months of work for just 30 seconds of broadcast footage! John Spies made his own video of the production of this segment of the program.

As a base we used the renowned Cave Lodge at Ban Tham ('Cave Village') in Pang Ma Pha district. We owe a great debt to its owner, Australian expatriate John Spies and his then wife Diu Wilaiwan Intikat for organisation of the early expeditions. John insists he 'converted' to caving as the result of our trips. Aided largely by their enthusiasm, linguistic skills and local knowledge we surveyed caves, documented coffin sites of Mae Hong Son province and encouraged professional study and management which had previously been totally lacking. When we started there were no published records of the existence of the coffin sites in northern Thailand, although several studies had been made of those along the Khwae Noi (River Kwai) in Kanchanaburi Province. John later put huge foot-slogging effort into locating new coffin sites in particular, promoting scientific research, conservation and sound management of Thailand's caves and karst, and gaining wide respect from Thai authorities for his expertise and advice. This eventually led to a grant of $300,000 from the Thai Research Fund for professional research and protection of the sites in the province's Pang Ma Pha district. In 1997 ASF honoured their work with Awards of Distinction to John and to National Parks officer Nopparat Naksathit. John's Award can still be seen hanging in Cave Lodge.

In 1995 John Spies, Elery Hamilton-Smith and I ran probably Thailand's first workshop on cave and karst management at Erawan National Park in Kanchanaburi province (Fig. 1).

In 2006 the Thai Research Fund sponsored a superbly illustrated book called *"Caves of Northern Thailand"*, available in both Thai and English versions. Drawing on some of our earlier work, this is a far more comprehensive and enlightening book than the name suggests and is highly recommended to the general reader. Though not available in Australia, it can be obtained through Amazon. It includes ASF's Minimum Impact Caving Code and should go a long way towards raising consciousness of the cultural and natural heritage significance of Thailand's karst resources.

The exploration of the caves of Mae Hong Son province paralleled the march of Thailand's economic development. In 1982 the dirt track from Pai and Mae Hong Son had not been improved since it was built by the Japanese in the 1940s, huge bamboo completely covered its narrow footprint in places, it was often impassable in the wet season, there was no sealed road within 50km,

Figure 1: *Thai Cave Tourism Workshop*

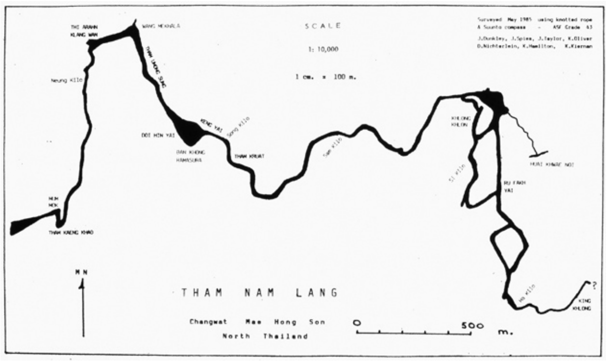


Figure 2: *Map of Than Nam Lang*

and almost no motor traffic. There was no electricity in Pang Ma Pha (indeed Pang Ma Pha district as such did not exist), only 3 or 4 tiny shops, and the access 'road' morphed seamlessly into the rammed earth floor of the one noodle shop in Ban Soppong. There were only one or two primary schools, no government agencies, nowhere to stay other than on the floor of a village headman's house. There simply weren't any tourists, not even backpackers. We were shown spectacular sites like the Spirit Well (a huge collapse doline above Tham Nam Lang) (Fig. 2) and told we were the first foreigners to see it. Barely a few dozen western adventurers had ever seen Tham Lot, now a major tourist attraction. In places there were still a few vestiges of hunting and gathering societies. And there were still many hectares of opium poppies (Fig. 3).

The infamous Golden Triangle soon graduated from drugs to tourism. Cave Lodge appeared in 1985. By the turn of this century Mae Hong Son was taking Boeing 737s . The road was sealed and now sports several passing lanes. Most families own at least a motor cycle, with several pick-up trucks in every village, and everyone has TV. Tham Lot is on the itinerary for numerous coach tours, hosting tens of thousands of tourists every year, providing employment for 40 or 50 local residents, while

Figure 3: *Opium Poppies in northern Thailand*

the restaurant can handle probably 200 at a time, and you can even kayak through the cave. At Cave Lodge microwaves, freezers, satellite cable television, running hot water and a more upmarket clientele and their 4WDs have arrived, displacing many backpackers and replacing their $2 a night bamboo and thatch dorms with cement bungalows, en-suites, fans, wide menu choices and even selected Australian wines (!).

It gave me and many others great satisfaction to see that our expeditions led to so much local interest. Inevitably though, in time our pre-eminence passed to others. Dean Smart found employment for several years with the Royal Forestry Department as a cave specialist. On Dean's return to Britain, Martin Ellis bought his records and is the current guru and a wonderful fount of knowledge. Martin has published extensively in Shepton Mallett Caving Club's Journal and has nearly 4,000 caves on his database. He believes there are still several times as many awaiting discovery, and maintains a long list of leads.

Why was it so successful?

We never considered mega-expeditions, generally leaning to Eric Shipton's minimalist model of self-reliance. Our largest contained only 15 people, most had only half as many and many had only 1 or 2. The Thailand Project was unusually productive for several reasons:

1. The advent of cheap air travel.

2. A country where foreigners with strange habits and motives were welcomed, often with curiosity but never disdain or antagonism.

3. A country with reliable and universally good public and private transport.

4. We concentrated on a thorough exploration of just one major karst area, with only minor forays elsewhere.

5. We had reliable local logistical support to provide a base and sustain the effort over many years.

6. There was a growing local environmental awareness translating into official recognition and support.

What lessons are there?

• It's best not to become too tightly organised; be flexible and organic. The Thailand Project was an idea, not an institution.

• Time spent in reconnaissance is seldom wasted. Or, as the military tells us: 8 Ps - proper prior planning and preparation prevents piss-poor performance.

• Small expeditions, even solo ones and especially reconnoitres can be very efficient, flexible and productive.

• Official sponsorship has limitations and may be more trouble than it's worth. We never sought any.

What stays in the mind; pieces of nostalgia

Conductors on the government Bor Kor Sor buses, leaning out the front door as they round up prospective patrons, or waving furiously as the bus overtakes and cuts in front of trucks, cars, songthaews, samlors, motor cycles and buffalo.

Sipping Singha or Mekhong and Nam Soda in the restaurant car of the Chiang Mai Express, or on the verandah of Cave Lodge.

The wonderful seafood lunch buffet at the Talay Thong Restaurant in the Siam Intercontinental Hotel, sadly now demolished for a shopping mall.

Breakfast at sunrise and drinks at sunset on the riverside terrace of the Oriental Hotel in Bangkok (not that we ever stayed there, although Martin Ellis tried it once!)

Floating down the Nam Khong, cooling off under the travertine waterfalls below Susa Cave, or basking in the river below Nam Lang.

Kevin's ability to write (and publish) a 20-page paper on mangroves, mountains and munching molluscs, based (so it seemed!) on 20 minutes of field work

On seeing the Spirit Well for the first time and being told by the Lahu that we were the first foreigners ever to go there.

Staggering out of Nam Lang Cave at 3am to an instant nourishing meal and hot drinks prepared by the Thai camp assistants.

The infamous Miami Hotel on Sukhumvit 13 in Bangkok. Readers might be interested to know that this historic relic of the Vietnam War R&R days is still operating and unchanged, although the ghastly air-conditioners were replaced in the 1990s. I have even heard that the transvestite at reception is still there!

Finally …

I eventually tired of the Project; just grew out of it. By the turn of the century the forest, the hill-tribe villages, the caves, the coffin sites, the atmosphere and the excitement remained but were now shared with and enjoyed by many more people, and in that sense diminished. Mass tourism arrived and others took over the exploration. I felt a bit out of place. The obsession had faded and the Great Adventure wasn't quite the same. But I wouldn't have missed it for quids. It was a high point in my life and, I know, of others who went, and therefore were bitten or smitten.

One of the reasons for giving this talk is to emphasize that the world still has plenty of karst areas where similar results could be obtained by motivated speleologists without the strictures of China. Exploration doesn't have to be of the gung-ho hard-man variety evidenced in Abkhazia, Mexico and Patagonia. In our region I investigated Myanmar and the Philippines in the wake of the early Thailand expeditions. In 1988 four of us published a report on what remains the world's only real speleological expedition to Myanmar, but the country is still largely undocumented despite widespread limestone occurrence. Indonesia and the Philippines still have massive potential notwithstanding logistical and political problems. Laos is now relatively easy to visit, with some truly huge caves and massive potential despite several major expeditions. There are local sensitivities to take into account, but several Pacific Islands beckon: only a little and nothing definitive has been published on Niue and the extensive caves in the Cook Islands where there have not been any strongly focused expeditions. The more daring might turn to the Solomons or rethink New Guinea. For something really exotic further afield, very little attention has been given to Central Asia since the end of the Soviet Union, despite greatly improved access. There is some impressive looking limestone in the Pamir Mountains of Tajikistan.

In Thailand, though, there is still huge potential.

Photos by the author

Figure 4: *(Below) One of the expeditions waiting! Who can you recognise?*

Cave Tourism Brochures

John Dunkley[1, 2] & Scott Melton[2]
[1] Highland Caving Group
[2]Jenolan Caves Historical & Preservation Society

Abstract

Ephemera is characterized by being of a public nature, often mass produced and freely distributed, but equally mass discarded, of little or no intrinsic value at the time. Postcards and books are post-trip souvenirs, often kept for many years, and many have become collectables. Brochures are usually pre-trip advertising and publicity, more frequently discarded and overlooked. The National Library of Australia has a section devoted to ephemera and has mounted several exhibitions including, for example, superb early posters promoting our caves.

Brochures can be useful measures of social history and of the way our caves were promoted and displayed. They record a move from package tours to more individual programs; they reflect on changing values such as standing on decoration, smoking in caves, provision of disabled facilities; there are changes in the promotional language utilised; there is a rising emphasis on special interest tours, attractions or themes such as music, adventure tours and regional attractions. They throw light on the history of caves no longer shown to the public, such as Scotts, Baldocks, Cammoo, Nettle and Arch. Privately owned caves often differ from publicly owned ones by promoting an incorporated gift shop, restaurant, motel or other profit centre.

Interesting Australian and foreign brochures will be displayed including some quirky examples: a Jenolan one advising that "cabin trunks and hat boxes cannot be conveyed as luggage"; a woman in swimsuit next to a column; the bathrooms of Samcheok; the American obsession with safety and comfort; and appeals to Ripley or the Guinness Book of Records in the quest for biggest, tallest or whatever.

Introduction

Cave brochures must seem a rather mundane subject to be talking about. They are handed out free, and they're usually discarded afterwards. They are, after all, nothing more than advertising matter. They cost nothing, so perhaps they're worth little. They are ephemeral. In a breakdown of the spectrum of tourism experiences, brochures fit into the anticipatory stage, and are followed by the stages of travel to the site, on-site experiences, return travel and recollection. People who actually visit the caves advertised may well buy postcards, books, pens, patches, T-shirts, jewelry, snowdomes and all manner of souvenirs afterwards as gifts, mementoes or recollections of a pleasant trip. Quite a few of us collect such memorabilia. But not much attention has been given to pre-trip advertising and publicity media like brochures.

Caves are major regional attractions in some parts of the world, particularly in China (which hosts over 40 million cave visits a year!), Slovenia (with up to 1 million visitors a year just to the Postojna area), Missouri (with 20 competing show caves) and Thailand (where I estimate several million cave visits a year, mostly to Buddhist sites but with a growing promotion of adventure tours). Brochures are one of several media demonstrating contrasting cultural approaches to cave interpretation; in China particularly the very names of many caves highlight cultural differentiation.

Australian cave tourism in the modern sense, began in the late nineteenth century largely by word-of-mouth, through Cook's Australian Wonderland, centenary celebratory books such as Cassell's Picturesque Australasia and Andrew Garran's Picturesque Atlas of Australasia, and occasional lengthy newspaper articles analogous to the confected travel sections in today's newspapers, including the excellent articles in the Illustrated Sydney News. In May 1905 the quaintly titled NSW Department of Intelligence established a State Tourism Bureau to promote tourism, and shortly afterwards the first cave tourism brochures appeared. Other states rapidly followed suit. Because trains were the usual mode of travel, many early brochures promoted caves as part of a package offered by the various Railways Departments, which were developing extensive travel departments. The first newspaper advertisements also date back just over 100 years. Promotional advertising expanded rapidly with cheaper printing, especially of photographs, the growth of the middle class, paid annual vacations, and the advent of rail excursion fares. As motor transport spread, there was a gradual move to increasing promotion of the caves themselves, and a corresponding growth in brochures.

So, what value do cave tourism brochures have?

Mainly, they provide another window of insight into the way our caves were promoted and displayed, into changing social habits and values, and to comparative interpretation and presentation practices. They have been utilised by writers about tourism history generally. Some illustrated examples from this presentation include:

• Information on caves no longer shown to the public, including names given to decorations etc. e.g. Scotts, Baldocks, Jersey, Cammoo (Fig. 1), Exit Cave (adventure tours) or until its recent reopening, the old Nettle and Arch at Jenolan.

• Changing transport methods to the caves. The move from package tours e.g. with train included or stops on the Blue Mountains, to more individualised programs as cars became more common (Fig. 2). Gradual changes due to technological changes e.g. horse and coach versus organised motor tours. The Caves Express, and train tours to Mole Creek, Buchan (Fig. 2) and Naracoorte.

• Changing prices e.g. how Jenolan widened the gap between prices of Lucas Cave and of more restricted caves like Ribbon, to market the latter as a premium experience. There were even changes in name - Ribbon Cave became the Blue Ribbon Tour, part of Imperial Cave became Diamond Cave Tour. In both cases prices increased markedly as new marketing niches were exploited. Similarly, new owners decided that Capricorn Caverns marketed better than Olsens, and Careys better than Goodradigbee (Fig. 3). At Waitomo, staid advertis-

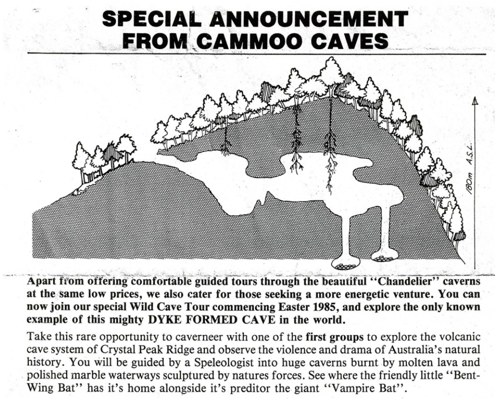
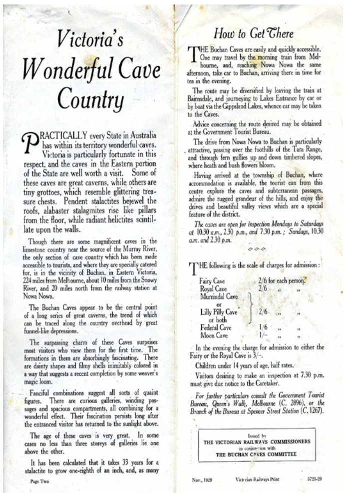
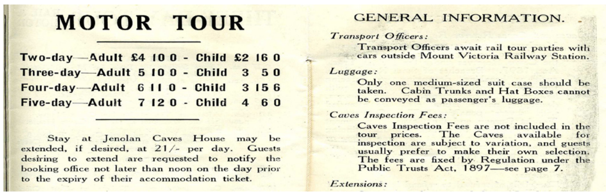


Figure 1: Brochures showing information on the now closed Cammoo Caves at Rockhampton





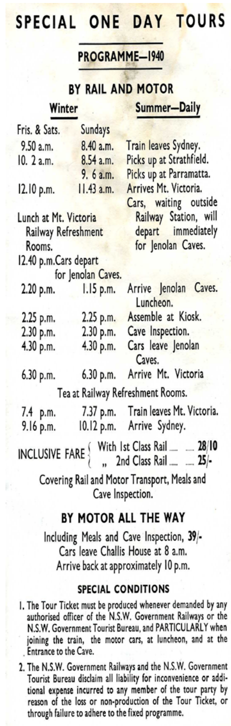
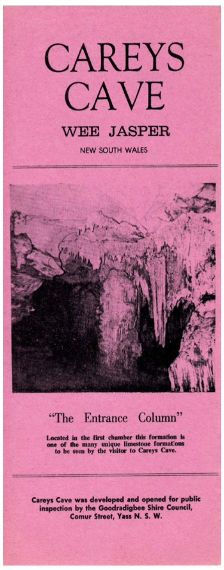
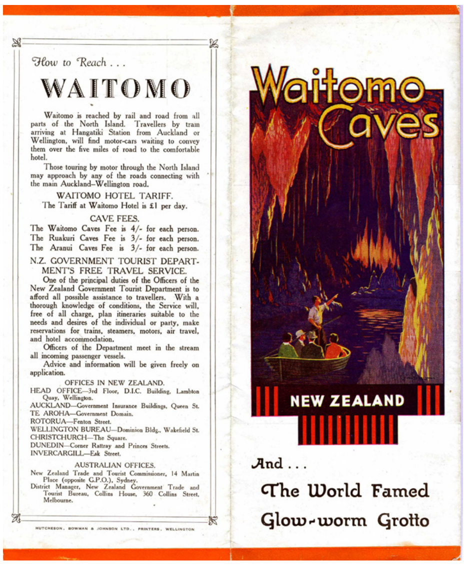


Figure 2: Brochures showing changes in information on transport to and from the caves; Jenolan and Buchan





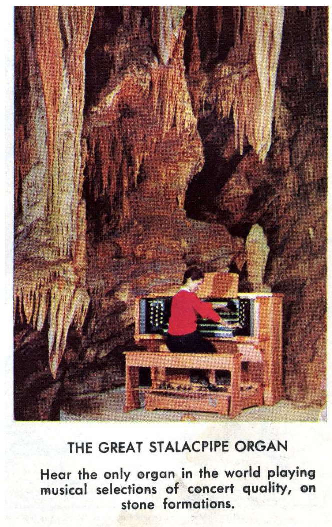


Figure 5: Luray Caverns in Virginia advertising its Stalacpipe Organ, where the organ's hammers struck selected stalactites; a practice no longer encouraged.

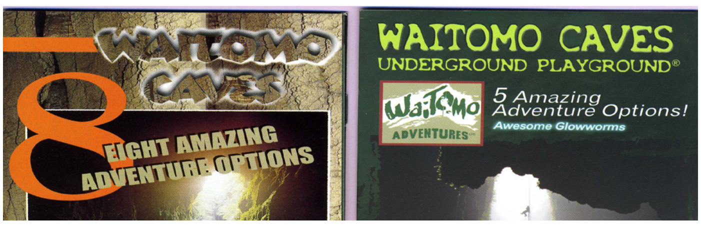


Figure 3: Changes in marketing practices at Careys Cave, Wee Jasper (NSW) and Waitomo (NZ)

ing of the "world famed glowworm grotto" expanded to more aggressive promotion of "underground playgrounds" and "eight amazing adventure options" (Fig. 3).

• New directions in marketing – at Naracoorte, Victoria Cave became Victoria Fossil Cave to cater for a boom in public interest in the fossils. Other examples include Jenolan promotions such as the many anniversaries of various discoveries; "The other Wilson", etc. Jenolan has in general marketed its history better than any others in Australia. It is also instructive to compare earlier and later marketing focus with that from the 1980s era when it was called Jenolan Caves Resort, administered by the Department of Leisure, Sport and Tourism, and emphasised tennis courts, fitness trails and a camping ground. An increase in special-interest tours can be tracked through some brochures

• Changes in the language of advertising – "inspections" became "tours", "tours" became "adventures". Nevertheless, in many cases florid language such as "a place apart and enchanted … surcharged with mystery" (Jenolan, 1930) (Fig. 4). and "a symphony in stone" (Yarrangobilly) (Fig. 4) has not changed with terms like the current (2008) "magic happens here".

• Reflections on changing practices – things that aren't done any more (or shouldn't be). Some brochures show visitors touching the formation, standing or climbing on decoration, or offer overnight adventure camping in caves (in the USA, we might add!). Luray Caverns in Virginia used to advertise widely its Stalacpipe Organ, where the organ's hammers struck selected stalactites! (Fig. 5) Han-sur-Lesse in Belgium apparently still features someone lighting a flaming torch and dashing down an underground rockfall trailing ash. Regulations were often cited: facilities for the disabled, smoking and eating in caves, preference given to guests of Caves House (Jenolan) for certain cave tours, and restricted opportunities for photography (which eased as faster film and digital cameras became available).

• Inside, many caves look much the same to visitors. Product differentiation therefore became important. New Zealand's Te Anau Cave claimed to be "the only known example of a living cave that may be visited by the public anywhere in the world", while caves like Postojna (Slovenia), Cumberland (USA) and Dragon Palace (China) make much of their featured underground electric transport by train, open car and boat respectively. There is a widespread American penchant to claim the "biggest", "tallest", "most spectacular" or whatever (Fig. 6), and appeals to Ripleys or the Guinness Book of Records (caves such as Bridal Cave and Lost Sea)

• Because most tourist caves there are privately owned, American brochures frequently place great emphasis on the ubiquitous gift shop, restaurants, and frequently a motel and other facilities which serve as profit centres (Fig. 7). Indeed, in many such, the peripheral attractions are a greater revenue source than the cave itself. In the UK, Wookey Hole devotes less than 10% of its brochure to the cave itself, promoting instead an Edwardian Fairground and photo studio, a Penny Arcade, a magical mirror maze. The nearby Cheddar Showcaves brochure similarly has more to say about cream teas and cheddar cheese, rock climbing, orienteering and open top double-deck bus tours than about the caves. Australian cave sites are usually more traditionally oriented, probably because most are in public ownership, and they have only recently realised the need for some form of product differentiation.

• There are sometimes quirky comments on values and concerns of the times – examples are given of a woman in swimsuit beside a cave pool at Luray Caverns (Fig. 8); the bathrooms of Samcheok in Korea (Fig. 8); soothing the American fastidiousness about safety and comfort, even warnings that "cabin trunks and hat boxes cannot be conveyed as passengers' luggage" (Jenolan).

Despite the millions produced, old tourist brochures generally are not easy to find, precisely because of their fleeting nature and minimal market demand. On the other hand, for those contemplating starting a collection, cave brochures have one other advantage over most other speleological ephemera in these days of eBay: current ones can be obtained free!

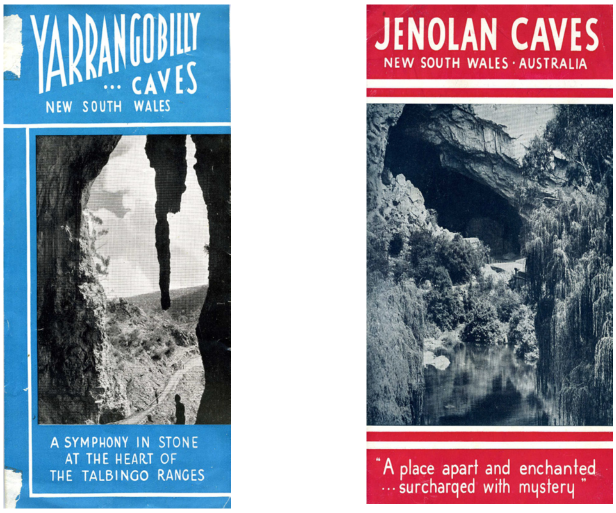


Figure 4: *Florid language used to describe cave tour experiences at Jenolan and Yarrangobilly*

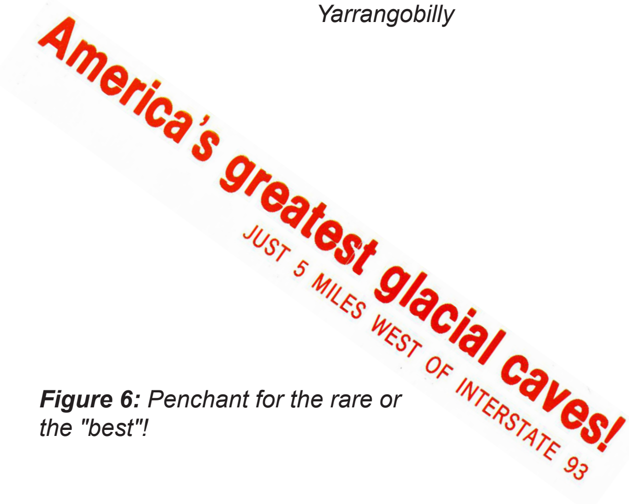


Figure 6: *Penchant for the rare or the "best"!*

Figure 7: *Brochure showing gift shop in an American cave brochure*

Figure 8: *Quirky information a) woman in swimsuit beside a cave pool at Luray Caverns, b) toilets in Korea and c) shrines at Ave Maria Grotto in Alabama*

The Real Cost: Some Principles of Risk Management

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Abstract

The ASF Safety, Leadership and Risk Management (SLARM) is a committee that exists to serve the needs of ASF members and represent these to karst managers, landholders and others who have an interest in caves and caving. This paper sets out some of the basic principles that have been (or should be) applied to develop the ASF Safety Guidelines.

Risk assessment is only part of risk management. Risk management begins with the fundamental attitudes that define acceptable situations and behaviours. What does it mean to be an ASF member? What does ASF expect of its members and leaders? The idea of duty of care and responsible leadership from the perspective of new members needs to be clarified. Does this change over time? How and why?

This paper introduces some of the basic principles of risk management, starting with risk assessment – what do all the words mean anyway? This is followed with an overview of how, where and when ASF members can address these risks; and finishes with a brief look at the consequences of poorly managed risk for members.

The application of these principles is Management Practice and will be explored in a workshop at the ASF conference.

Caroline Forrest undertaking a tricky manoeuvre in the SpeleoSports. Photo: D. Carr

The Buchan Story

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Abstract

The Buchan caves were first recognised and described by Stewart Ryrie in 1840. They were given little attention until the Stirling expedition of 1889 and the subsequent efforts of J.H. Harvey and others to ensure that the caves were protected and made available to tourists. Hotelier J.H. Wyatt and others conducted tours on a more-or-less casual basis for some years, citing Jenolan as an example of what should be done. This was taken up by geologist A.E. Kitson. Frank Moon arrived home after working on the Western Australian goldfields and commenced exploration of the caves. Kitson then arranged for him to be employed and in due course he discovered "Jenolan's Rival" – the Fairy Cave.

Frederick Wilson, former and long experienced manager of Jenolan Caves was then appointed to undertake the development of Buchan Caves for tourism access and to manage the caves reserve. At that time the normal tour route was by way of a train to Sale, a boat trip on the Gippsland Lakes, and a coach journey to Buchan. The responsible oversight was placed in the hands of a Committee of Management for many years but today Buchan Caves Reserve is managed by Parks Victoria.

Although somewhat hidden away, Buchan was recognised and investigated by a remarkable diversity of people, each of whom played their own part in the very complex history. This paper will simply introduce many of these people, and briefly outline their role at Buchan.

Discovery

Buchan received its first whitefellas in 1838, when Edward Bayliss and his associates, fleeing from the drought on the Monaro, arrived at Buchan. Bayliss then returned with the intention of taking up land at Buchan, but he was beaten by John Rhodes Wilkinson who took up that land on the day prior to his arrival. Bayliss then retreated and established Gelantipy station. Neither stayed for very long nor left much of a mark. There is little really known about their brief tenure (Adams, 1981).

Stewart Ryrie was commissioned by the government to undertake a review and survey of the Monaro region. Although his manuscript report (Ryrie, 1840, cited in transcript Gippsland Heritage Journal, 9:11-17) has survived, it is somewhat disappointing in its lack of details. He does describe the forest at Murrindal as being "full of caves" and describes one which he entered on 7 April 1840 (Ryrie, 1840, cited in transcript Gippsland Heritage Journal, 9:11-17). Peter Ackroyd carried out a painstaking analysis of Ryrie's story and draws the somewhat tentative conclusion that the cave entered was most likely M22, The Garage (Ackroyd, 2006).

It must be assumed that later settlers were aware of the presence of the caves, but there is little evidence of them entering caves and the potential interest of the caves remained more or less unrecognized.

The Grove Reminiscences

In 1867, C.H. Grove was appointed as overseer of Buchan Station, at that time owned by John Alexander Rose, and remained in that position until 1873. Grove was an intelligent and inquiring man, and left behind a one hundred page manuscript of his reminiscences. This has proved to be of considerable value to historians, as the only detailed account of everyday life at that time. He was later elected to the new Tambo Shire Council in 1882. His reminiscences include the story of an unusual cave incident. Sheep belonging to the Riddle family of Gillingal Station were destroyed on order from the Agriculture and Stock Inspector as the flock was infected with scab. Although Riddle had expected compensation to be paid, this did not eventuate, and

> ". . .This so preyed upon the mind of Riddle that he went at least partially demented, and had an idea that everyone who came near him desired to do him personal injury. From this time forward, he used to live principally in a cave some short distance from the homestead, and only coming home after dark, during stress of weather or when he required a fresh supply of food or clothes." (Grove, c1873: 19-20)

Beginnings of Cave Tourism

Not surprisingly, the caves were well known to John MacLeod, manager of Buchan Station from 1845, who also held a range of public offices. Doubtless many other early residents were familiar with them, and probably many shared in leading parties of visitors to them.

The first explicit references to Cave Tourism appeared in R.S. Broome's Tourist Guide. In his first edition (1882) there was only a brief reference to the 'famous Buchan Caves' being accessible by coach from Bruthen. One can still see the site of the coaching stop near Boggy Creek at some distance to the West of the current Buchan road crossing. A similarly brief reference to guided tours of the caves can be found in Pickersgill (1885: 106).

In Broome's third edition (1886), he refers to the Pyramids and the underground course of the Murindal (sic) River, then to " . . . Wilson's Cave, situated in a pretty nook, is entered by a small opening which gradually leads to a spacious chamber vying in size with the interior of the exhibition building, with side passages and anterooms of considerable magnitude. Provided with candles and kerosene torches, we follow our leader . . . our guide here teased out a quantity of stringy bark and saturating it with kerosene, applied a match, and in a twinkling of a second we were looking at thousands of stalactites and stalagmites . . ." (Broome, 1886**).**

He also mentions Spring Creek Cave and that "The Murndal (sic) also possesses features of interest but time prevented us from visiting other caves that have been recently discovered." (Broome, 1886). Finally, he noted

"Two well appointed hotels standing on either side of the river." (Broome, 1886).

Another account (*Tambo and Orbost Times*, 19 Nov 1887) describes a visit to Spring Creek Cave, guided by T. O'Rourke and using only candles for illumination. The same writer also visited the Murrindale (sic) Lead Mines, which were entered through a natural cave and which had also broken into a further cave. This was followed by visits to two other nearby caves and to both ends of the underground course of the Murrindal River.

It is clear that at least some of the caves were known to local residents and used for their own recreation. For example, on Easter Monday 1891,

> " . . . a picnic to Wilson's Caves took place and almost every local inhabitant put in an appearance. The caves were lit up and a number of songs rendered in the underground regions. Refreshments galore were provided and a thoroughly appreciated outing was the result." (Tambo and Orbost Times, 2nd May 1891)

Similarly, a party of singers from Bruthen visited the town to present a charity concert and were entertained at a picnic in Wilson's Caves. (*Tambo and Orbost Times*, 23 Feb. 1895)

Joseph Wyatt was one of many miners of Cornish stock who settled in Buchan and other parts of East Gippsland. He managed mines at both Murrindal and Buchan and then became the licensee of the Cricket Club Hotel and in this capacity played a major role in Cave Tourism. In due course he became secretary of the Buchan Progress and Tourism Association.

The First Scientific Investigation

As a result of the growing interest in visiting the caves, James Stirling, a geologist from the Victorian Mines Department was asked to inspect the caves. He was accompanied by J.H. Harvey of the Public Works Department. Although one can only speculate as to why Harvey was chosen, factors which may have led to his presence include the fact that he was a senior engineer and so could represent his Department's interests; his expertise as a noted (amateur) photographer and his enthusiastic interest in caves. They were supported by two assistants from Stirling's own staff and by Mr Kellie who was the telephone operator from Buchan.

They explored and mapped Dukes Cave, O'Rourkes Cave (now B-2, Moons Cave), Spring Creek Cave, Wilsons Cave, Dixons Caves, and Moons Cave (M-13, also known as Murindale Cave). Harvey provided four photographs of Wilsons and Dixons Caves which appeared in Stirling's published report (Stirling, 1889).

Like all cave investigations of the period, there was a preliminary attempt to find and identify fossils in the cave floors. This appears to have been based upon the well-known discoveries by Rankine at Wellington, N.S.W., and the ensuing investigations and descriptions by Sir Thomas Mitchell and Richard Owen. The results at Buchan were disappointing, although again Harvey took a fine photograph of an attempted excavation.

Harvey also continued his interest in caves, visiting Jenolan soon after the Buchan investigation and on other occasions. He endeavored to arrange for Jeremiah Wilson to visit Buchan, but the Victorian Government was not willing to pay the cost of travel. However, Harvey continued to argue for action to develop Buchan as a cave tourism destination.

A.E. Kitson and Protection of the Caves

A further scientific examination of the caves was carried out by A.E. (later Sir Albert) Kitson in 1900 and again in 1907. In his relatively detailed report, he recommended a series of land reservations to provide for protection of the caves (Kitson, 1907). A report from the director of the geological survey (Dunn, 1905) summarised Kitson's work and supported his proposals for reservations. A series of regulations designed to protect the caves was enacted in 1901 (Government Gazette, 26 July 1901: 2891), but these were too late and not implemented because of the absence of any on-site management.

Following his first visit, he engaged Joseph Wyatt as a contractor to provide for gating and lighting of Spring Creek, Dicksons Caves and Wilson Cave. He also discussed with Wyatt the possibility of accepting a position as overseer of the caves but this did not eventuate. (Bailey, 2007, Hansford, 2008: 49-51).

Other important caves were discovered and/or recognised during this period. Thomas Slocombe had gated the major cave on his property at the Basin and protected it from damage from the mid 1880s. Kitson commended this action and supported Slocombe's work.

The Advent of Frank Moon

Frank Moon was born at Buchan and developed a remarkable prowess and reputation as a horseman, swimmer and runner. However, he found little opportunity for employment and so sought his fortune as a prospector and miner. This culminated in working at Kalgoorlie, where he took up cycling, the major means of transport in the Goldfields region, and won the annual race. The cash award enabled him to return home to Buchan (Hansford, 2008).

In 1906, while seeking some other outlet for his restlessness, he turned his curiosity to the caves. He commenced by exploring what was then known as O'Rourke's Cave, clearly unaware at that time of Stirling's work. He thus claimed discovery of the cave and it was re-named in his honor.

"Another large cave has been found within half-a-mile of our Post Office. It was discovered by Mr Frank Moon and is over 700 yards long. A stream over five feet in depth runs through the cave. The water contains fish but they are quite white in appearance. The stalactites and stalagmites are quite perfect and every care will be taken to prevent wanton destruction of the cave's beauties." (Bruthen & Tambo Times, 3rd October 1906).

John Flynn (later famous as Flynn of the Inland) was at that time a theological student and missioner. He was sent to Buchan and became a close friend and often companion of Moon, assisting him in his exploration. He was also a keen and able photographer and developed an impressive array of photographs of the Buchan area and its caves. (McPheat, 1963; Coates, 2006).

Frank was then engaged by Kitson as field assistant and in February 1907 was appointed as Crown Lands Bailiff with the responsibility of being 'Caretaker and Tourist's Guide at Buchan Caves'. This proved to be a major turning point for both Frank and the caves. A key early event was the discovery and entry to Fairy Cave. In announcing his discovery, Frank wrote "*I feel convinced now that I have Jenolan's rival!*" (Hansford, 2008).

It was soon recognised that the new cave needed appropriate infrastructure to provide protection against damage. Frederick J. Wilson, formerly at Jenolan, was appointed as manager with the responsibility of designing and developing stairways, paths and lighting. Frank initially resented this appointment and so there was some conflict between the two men, but in the longer run, they developed a mutual respect for each other.

Frank Moon was a highly intelligent, kindly and gentle person. He was passionate about each of his interests – caves and horses in particular. He was exuberant in expressing his interests and convictions. Sometimes, his exuberance overcame his sense of reality and he told great stories of his caves. One of the family once said to me, "Pop never let the truth stand in the way of a good story!" The great example came at the time of his retirement when two Melbourne journalists arrived at Buchan to interview him and write a feature story of his caving experiences. Frank saw the opportunity for a prank and retold a story from the great French cave explorer Norbert Casteret.

His enthusiasm really put Buchan on the tourism map. He was born to be a promoter. He also devoted a lot of attention to working out how to treat various visitors. I recall him telling me that he had never read very much until he was responsible for telling the story of the caves to visitors. He realized that in the early days it was generally only the educated people who were interested in visiting Buchan and could afford to do so. He started reading so that he could talk with visitors on equal terms, and then became almost as devoted to books as he was to caves (Hansford, 2008: 19-20)

Fred Wilson was in some ways very different. He was almost painfully shy and reticent. He was a task-focused man who worked very hard and with great skill. He also had a great sense of the beautiful; his development of the caves at Buchan (and before that at Jenolan) demonstrates his remarkable sensitivity. One of the nice indications of this is that he had no choice but to remove a number of stalagmites in order to build the pathway through Royal Cave. He re-located a number of these in the pool known as the Font of the Gods so that they joined with three already standing in the pool to become the Twelve Apostles.

He also showed a remarkable commitment to conservation not only in his own work but in bringing up his children. His daughter told me he taught them that they should never kill any animal, even pests or other threatening animals like snakes or spiders. His belief which he transmitted to them was that all animals had their place on earth just as much as people did. He was a man of great integrity but because of his reticence and modesty, often did not get credit for his great accomplishments.

In 1908, journalist Frank Whitcombe produced a *Guide to the Buchan Caves and Gippsland Lakes.* Many commentators and reviewers consider it to be one of the finest guidebooks published in Australia. Even to day, one can identify with the experiences of the tour as described by Whitcombe.

The Photographers

Caves often attract photographers, and Buchan succeeded in capturing the interest of some of Australia's most interesting photographers. They helped to ensure a more adequate history than would otherwise have been available and they played a great role in supporting Frank's promotion of the caves.

J.H. Harvey was a perfectionist and as an amateur won an immense number of awards for his work. He virtually always used wet plates. Don Pitkethly of Kodak explained to me that this meant he could take a photograph, develop it on site and if he was not satisfied with it, he could simply clean it off the plate, re-coat the plate with fresh emulsion and re-take the view until he was satisfied. This could readily be interpreted as a conservative approach to methodology, but The National Library has a stereograph taken by Harvey at Jenolan with the inscription in Harvey's handwriting 'These images were taken on the first roll of the new celluloid film imported to Australia.' So, we really have to recognise that even this innovation was only part of Harvey's constant search for perfection. (Davies & Stanbury 1985: 94-95)

Norman J. Caire was a professional equivalent of Harvey with the same search for perfection (see Pitkethley & Pitkethley, 1988). He was commissioned by Whitcombe (1908) to provide quality photographs for his guidebook. At Lakes Entrance, he met Howard Bulmer as a young man just beginning his career as a photographer and Caire recruited him to help in the task and shared the credit with him (Kerr, 1992: 125-126; Squires et al., 1990: 10).

Howard Decimus Bulmer commenced a life-time commitment to and passion for Gippsland photography. He took photographs during Moon's first exploration of Fairy Cave and returned to Buchan regularly (Squires et al., 1990: 6-8).

At the same time, he had rivals of considerable note. *James H.A. MacDougall* came to manage the South Buchan Post office and established Walden Studios. He pursued this practice both in Gippsland and then at Margaret River in Western Australia. But he then moved on and developed a life devoted to being an Australia-wide wandering missionary and insurance agent. Families who insured their home and farm with him were presented with a large photograph of their home and property. These are now a source of fascination for rural historians. (Squires et al., 1990: 52-53).

Finally, *George Rose* established the Rose Stereographic Company. Of course, caves were great opportunities for stereographic pictures, but Rose photographed everything and probably produced more stereographs, lantern slides and postcards than anyone else. (Blum, 2008).

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Elery Hamilton-Smith and Stan Flavel at the conference. Photo: D. Carr

Tenison-Woods: Australia's First Karst Scientist

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Abstract

In March 1857, Father Julian Tenison-Woods arrived in Penola (South Australia) as a newly-ordained parish priest. Over the next ten years, he rode to and fro across his immense parish, carrying out his responsibilities as a priest, and making a significant contribution to the development of the church in Australia.

But at the same time, he was a keen observer of the natural environment, including the karst landscape and the caves beneath it. His first publication appeared in 1857 and in 1862, his Geological Observations in South Australia, principally in the district south-east of Adelaide was published in London. This is a landmark publication in speleology, although that was only one of the topics upon which he wrote.

He discussed the prevailing theories of that day about caves and karst, but also described his own observations and understandings, a number of which have been validated by recent research. By the time of his early death in 1889, he was recognised as one of the leading natural historians of the country.

One remarkable aspect of his crowded and creative life is that he was subject to continuing illness which was only properly diagnosed in 2006!

Early Years

Julian Edmund Woods was born on November 15th, 1832 at Southwark in London. Little is known of his father, James Woods, who was of Irish origin and, although qualified as a barrister, turned to journalism as a senior reporter and sub-editor of the London Times. He appears to have been nominally a Roman Catholic, but with a marginal commitment to the church. His mother, Henrietta Maria Saint-Eloy Tenison, came from a distinguished family, many of whom were clergy in the Anglican Church and one Thomas Tenison was Archbishop of Canterbury. Their relationship to the church remains obscure, although Julian claimed at one stage that his mother had converted.

Julian was baptised in the Catholic faith and, although he did not use the name Tenison until his mid-twenties, he was actually christened Julian Edmond Tenison Woods. He also claimed to have grown up as a Protestant and later converted to Catholicism. His early life story is full of such ambiguities and contradictions, raising a number of problems to his many biographers (O'Neill, 1929; Press, 1979, 1981, 1989, 1994). This first section will focus primarily upon Julian's spiritual development, as that provided his foundation as a human being, out of which his science germinated.

He found schools a difficult environment and gained much of his education from his father. This involved encouragement of his wide reading, including the classics in Greek and Latin, discussions about history and public affairs, learning to play the piano and to draw, and studying natural history. Thus, his father gave him a sense of broad and open inquiry and of self-education, but underlying this, a great love of reading and writing.

In 1848, Father Frederick Oakely came as a new priest to the Southwark Church. Oakely led him into fully adopting the Catholic faith – a confirmation from which he never wavered. He came to see Oakely as the first of his central spiritual mentors, writing many years later in a still unpublished manuscript (as quoted by Press, 1994, p. 26): "He was a singularly gifted man, a most attractive writer and eloquent preacher. His loving and lovable nature gave him a large circle of warmly attached friends, while his great powers of conversation, many accomplishments and wonderful musical talents made his society most delightful. His disposition was lively and even playful, enjoying a joke and hearty laugh as much as most men . . ."

It is particularly interesting to recognise these very qualities in descriptions of Julian himself as a priest in South Australia (e.g. in Hepburn, 1979: 107-109).

During his work with Fr Oakely, he was subject to frequent illnesses, and this interfered with the austerity and discipline required of a novice. In due course, his recurrent illness led the Passionist order to grant dispensation from his vows and to advise he seek some milder rule. He was devastated by this decision, but counselling from Fr Faber, a famous theologian and friend of Oakley provided the support and direction he needed at this time. On Faber's advice, he moved to France and the Marist novitiate. Again, his bouts of illness persisted and he was advised to give up the rigors of study. His disappointment was relieved by the offer of an appointment to teach English in the Marist College at La Seyne-sur-Mer. Here, he benefited immensely from the spiritual advice and teaching of the college director, now St Peter Julian Eymard. He saw Eymard as probably the greatest of his spiritual mentors, and wrote (again from the unpublished memoirs, Press, 1994, pp. 46-47): "He was certainly a saint, with the sweetest patience in all his dealings with the members of the college. . . he was a man also of the deepest spiritual knowledge, with a recollection and a spirit of piety which shone in all his actions. He was a tall thin man, with the face and expression of an angel. Though rather shy and reserved, his conversation was charming and instructive . . . He helped me so much to be more resigned to the will of God and less uneasy about the future. Thus he helped me more than even Father Faber or any of my spiritual directors always excepting Father Oakeley. Father Eymard was in my mind as great a saint as Father Faber, but differing completely from him. He was shy and retiring with a deep hidden devotion, a spiritual life with the spirit of the Blessed Eucharist, for the honour and adoration of which he founded his order." (Memoirs, p. 179).

In due course, he returned to his family in London and Julian was introduced to Bishop Willson of Tasmania who invited him to migrate with a view to his later ordination. His time in Tasmania was disappointing so he travelled to Adelaide and visited his brother James, later appointed as director of the South Australian Roads Board. Here he spent some time regaining his health, and working as a journalist with the Adelaide Times, but still endeavouring to find a place where he could continue his theological training and progress to ordination.

In due course, he met Bishop Murphy, and on his advice, enrolled at St Aloysius, the Jesuit College at Sevenhills. Here he recognised the principal, Fr Tappeiner SJ, as a still further mentor in his developmental progress, and also developed a close friendship with Fr Hinteroeker SJ. He not only continued and deepened his theological education, but also undertook courses in mineralogy and geology. After this final study of some six months duration, he finally attained his long-held ambition and was ordained as a priest at St Patrick's Church in Adelaide.

Priest and Scientist

Shortly after ordination he was sent to a parish of some 35,000 square kilometres, based at Penola, but extending to Portland in Victoria, and along the coast to Mount Gambier and Robe, thence north to Bordertown. He rode his horse ceaselessly throughout the region, visiting virtually every family, and steadily building the spiritual influence of his own church. At the same time, he constantly recorded his scientific observations of the region.

It was here that he almost immediately commenced his scientific writing, but even those who criticised him generally recognised that he never departed from or fell short in his spiritual duties. He was constant in his own spiritual observances, leadership of his widely scattered parishioners, and his efforts to develop the necessary church buildings. He always claimed that the priesthood was always his first consideration and science followed as he was able to find time. But the accusation of neglect of his spiritual responsibilities often arose, particularly from those who objected to his individualistic thinking.

He soon made many friends within the limestone coast region and two of these played a particularly important role in his on-going inquiry. Adam Lindsay Gordon had a great love of riding and shared many of Julian's journeys across the parish. He was also a great poet and classical scholar, so the two friends would share in their joy of the classics while riding. It appears that this friendship led in turn to a further friendship with Samuel Pratt Winter of Murndal.

Samuel Pratt Winter arrived in Victoria with the Henty family in 1837 and squatted on what became Murndal station. Although a somewhat isolated aristocrat in his personal behaviour, it is particularly interesting that the first building erected on the site was a small hut that would serve as a schoolroom for his shepherds and for the aboriginal people of the region. He often travelled with a small retinue of staff, generally of aboriginal origin. In about 1841 the original building was replaced with a permanent one of local stone. The rest of the now sprawling homestead was built over and around this. The old stone building was later lined with timber and is the present day library (Kiddle, 1961, Forth, 1991). Although Winter was an atheist, he enjoyed the company of, and conversations with, Tenison-Woods. He not only made his own library that included Lyell's Principles of Geology available to Julian, but also purchased books when visiting London, specifically for Woods' use.

Woods' first scientific publication on Australian geology dealt with metamorphic rocks in the Clare district north of Adelaide. An extensive article soon followed this on the Mosquito Plains (Naracoorte) Caves, which appeared in the South Australian Register of 29th March 1858. Most of this article was actually included in his later book (see below) and the 1858 article has generally been overlooked, even though it contains historically important material.

His most important work in the Naracoorte area was *Geological Observations in South Australia: Principally in the District South-East of Adelaide* (Tenison-Woods, 1862). This book ranged widely over the geology of South Australia but, in particular, included chapters on the limestones of the South East, three chapters on the volcanoes and three on the caves. The first of these was based very largely in summarising the then authoritative work of Lyell (1830-1833) but the second two dealt with Julian's own observations in the South East region. It is important to recognise that one or more pages of the original manuscript were apparently lost. There is a significant discontinuity in the text in both the 1858 newspaper article and *Geological Observations* (page 331). This discontinuity has on several occasions lead speleologists to search for an assumed further series of cave passages. Other writings on the region and related topics included Tenison-Woods (1859, 1866, 1879a, 1879b, 1879c). Woods claimed in letters to his friends that he had found it impossible to locate a photographer who might provide him with illustrations for publication purposes. He said: "One might as well expect to find a newspaper on the streets of Peking as an itinerant photographer in the South east". However, he obviously succeeded and although it has so far been impossible to identify the photographer, or even to discover the source of the originals, copied by historian Les Hill, there were in fact three photographs taken. The illustrations by William Archer that appear in *Geological Observations* were based upon two of these.

In reading *Geological Observations,* one can readily detect an intellectual struggle between acceptance of Lyell's ideas, as those of the then most significant author on geological principles, and his own observations. Lyell's work was very largely based upon caves in the hard rock limestones of Europe that are totally different in geological history, geomorphology and general character from those of Naracoorte.

His major mistake in interpreting his observations was in relation to the polje at Swede's Flat near Bordertown that he wrongly explained as a former coral atoll, while at the same time accurately recognising the character of its hydrology. Fortunately, Woods' individualism would not allow him to suppress his own views. He clearly identified the dune ridges as being of aeolian origin, although many of his contemporaries argued for a marine deposition origin. He recognised the extent to which the fossil deposits in the cave were a result of many episodes of seasonal flooding. He also rejected strongly Buckland's theory of the biblical deluge as the origin of fossils, even though he had at one time accepted it. Similarly, he rejected the prevailing theory of the day that caves were excavated by underground rivers and pointed to their phreatic origins (although not using that term). He also, again without specifically enunciating it, indicated an awareness of syngenetic development (pp. 347-348). This was more than a hundred years prior to its proper scientific recognition.

In recognising the mammalian fossils buried under the flowstone in the so-called second chamber of Blanche Cave (Fig. 1), he correctly reported that they were all of relatively recent origin and not comparable to the discoveries of Mitchell at Wellington Caves. He did recognise that one bone discovered elsewhere in the region was, perhaps, more comparable with the Wellington material. He also recognised that the common assumption that the fossils were a result of the caves acting as pitfall traps was largely wrong. He realised that the fossil deposits resulted from dead animals, bones and sediment being washed into the caves during periods of high water levels and flooding.

The Miocene limestones of the region, with their wealth of marine fossils, almost certainly provided the starting point for his long-term studies on the geo-history of the Australian Tertiary (see Press, 1994, pp. 261-274). During the course of these studies, he described and named several hundred species of molluscs and some other marine fossils. He also moved into reviewing the botany of the region with the support and encouragement of Baron Ferdinand von Mueller. From this he was able to utilise the patterns of vegetation distribution to map the underlying soils and related them to his work on regional geology.

By the time he left Penola and went on his further somewhat tumultuous career within the priesthood, he was recognised widely as one of Australia's most expert natural historians. His work demonstrated a quality of geological understanding far ahead of his contemporaries. This is congruent with Player's (1989a, 1989b) findings in reviewing and assessing the whole of his scientific research. The incredible breadth and diversity of his research is clearly indicated by the bibliography in Press (1994, pp. 261-274).

I believe he fully warrants recognition as Australia's first karst scientist. Much of his thinking which was seen as being at best ill-informed or somewhat eccentric, has been fully vindicated, particularly over the last 30 years.

His continuing career in science never abated, but regrettably he found it increasingly difficult to locate himself within the organised Church. His individualism all too often challenged the place of Bishops and as Press (1989) said, "Bishops . . . preferred to forget a priest who could not be slotted into any familiar category." So, he spent many years, often engaged in conflict, and being passed from diocese to diocese as a wandering missioner.

Geological Observations was very positively reviewed and widely respected. Sections were reprinted in Europe particularly in the various editions of Hartwig' s Subterranean World. His book was perhaps not so highly regarded in Australia, but some significant individuals managed to ensure that it had a long-term impact. Many scientists quoted it in the course of their own research.

Probably, the most significant line of influence commenced when William Reddan was appointed Caretaker of the Cave Range Forest Reserve in 1886. He made extensive use of Julian's book in developing his own understandings, while searching for, discovering, and exploring a number of new caves. He gave it special attention and proved to have a great creative capacity in the quality of cave management that he established.

He recognised from the beginning that there was a significant opportunity to find older fossils in the caves of the region and was always looking for these while exploring caves of the area. While developing the newly discovered Victoria Cave for tourism purposes, he found some fragments of obviously older fossils buried under the flowstone floor. He immediately invited the South Australian Museum to investigate these and both Stirling and Zietz visited Naracoorte to do so. They re-examined the fossils in the Blanche Cave on which Woods had reported, then discovered and excavated fragmented material from Specimen Cave. They did not further investigate Victoria Cave to any extent, as this would have interfered with tourism development.

Recreational caving developed in South Australia during the early 1950s. Mrs Agnes Needham (Reddan's daughter) told the pioneer cavers of that period (including myself) a great deal about the history of her father's work and in particular, introduced us to Geological Observations. It provided a wonderful basis for our own investigations and we succeeded in locating all the many caves described by Woods. Our understandings of what we found were initially based upon Woods' thinking and we were then able to predict further locations simply on the basis of our growing understanding of the geological structure.

Continuing exploration led Rod Wells and Grant Gartrell to discovery of the Victoria Cave Fossil deposits. When a small group were engaged to draft the first Management Plan for the Naracoorte Caves, it was recommended that the site be nominated for World Heritage Inscription. In due course this was done, and of course accepted.

Wellness and Illness

One of the great mysteries to all of us who studied Julian's work was the severity of continuing illnesses which he suffered. Although this had delayed his ordination, he never allowed it to diminish his energy or to distract him from his commitment to both his role as a priest and his scientific investigations. None of the contemporary diagnoses make any sense in the light of modern medical knowledge. Whenever I have written or spoken of his work, I have always ended by pointing out the immensity of his accomplishments vis-a-vis the continuing illness with persistent pain and discomfort which he suffered.

When I made this statement at a conference held in 2006 at the Mary MacKillop Information Centre at Penola, Pamela Tobin introduced herself to me by saying "I can help solve your mystery about Julian's illness." She is one of the descendents of Julian's brother, James Woods. Like Julian, she has suffered a continuing series of serious illnesses, but she has also maintained an unbelievably active life as a nurse, and as a very proactive member of her Church. Being a nurse, she recognised that there must be a common basis to her medical problems and set out to obtain a full and accurate diagnosis. It took some years before she found a doctor who recognised the cause of the family illness. A number of family members have now been formally diagnosed as suffering a specific (and rare) form of B-cell immune deficiency that is transmitted genetically. The mode of transmission means that some 50 per cent of each generation of the family will inevitably suffer from this deficiency and the resulting illnesses.

Understanding the active lives of Julian, Pamela and many other family members can be illuminated by the work of medical sociologist, the late Aaron Antonovsky. A key turning point in Antonovsky' scholarly career was when he turned away from questions about what made people ill to the questions about how people remained well. Thus, he turned from studying disease to studying wellness, and in particular to why some people remained well even when suffering extreme stressors that made many others very ill.

Antonovsky established a research program amongst thousands of people all over the world so that his results were tested in a very wide range of cultures. He summarized his findings in developing the concept of Sense of Coherence (SOC). He saw this as being an interrelated group of three themes or components in human experience. The first he saw as Comprehensibility – having a well integrated view of one's own place in the world and of seeing that world as being relatively consistent, predictable or explicable. The second is Manageability - the feeling that one has the resources available (either internal or external) to cope with the demands or challenges that we face, and the third is Meaningfulness - the sense that life is sufficiently meaningful for a person to be motivated to address and engage with whatever comes. Many similar sets of ideas in human thought have been enunciated and discussed, but one of the unique elements of Antonovsky's work is the thoroughness of his research evidence. He focused very clearly on coping and wellness and his arguments are very pertinent to understanding the response of Father Julian and other family members to their own very numerous challenges. (Antonovsky, 1987).

So, we can now not only diagnose Julian's illnesses, but also explain why he and some other family members have been able to cope extremely well. We have recently joined in a celebratory family reunion at which Pamela and I were able to fully explain the family experience. We also have a paper ready to go to press which tells the whole story.

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Figure 1: *Caves, Mosquito Plains, Second Chamber*

The CDAA, Training and Diving in Mt Gambier

Andy Higgins
Cave Divers Association of Australia

Abstract

The Cave Divers Association of Australia (CDAA) was formed in the 1970's after several fatalities in the Mt Gambier region. Needing a formal training agency to train open water divers in overhead environment and to control access for qualified divers to safely dive caves in Australia, the CDAA now has three levels of rating for cave divers.

Each of these ratings has prerequisites and extensive theory and practical sessions to assess the standard of each diver and to prove they are competent in the environment they will be trained for. Deep Cavern is the start of the ladder, followed by Cave and then Penetration (Advanced Cave), which is the highest award that can be obtained in cave diving training.

Cave diving training in Mt Gambier allows premium training sites for instructors to teach in and students can continue their diving here post course.

We'll have a look at some of these sites with training standards and the expectation of CDAA members diving these truly magnificent sites.

Slope Hydrology, Karst Drainage and Water Quality Related to Land Use: Great Western Tiers, Tasmania

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Abstract

In the Mole Creek fluviokarst in north-western Tasmania, conduit dye tracing experiments since 1966 failed to show any discrete source of Parsons Spring. Further, since 2001, this previously perennial spring has become intermittent in discharge. This change follows the establishment of 636 ha of eucalypt plantations since 1995 above the spring, including where Quaternary slope deposits obscure the limestone geological contact with overlying rocks.

In this 2008 study, evidence of a zone of diffuse recharge of Parsons Spring was sought. Water quality was compared and contrasted between Parsons Spring and other sites in the study catchment and a resurgence in a nearby reference catchment over different flow conditions and in response to a rainstorm. Results show that the study spring has a mixed recharge regime and complex discharge controls, including diffuse and conduit hydrological components. Parsons Spring is probably the main wet season overflow spring of a distributary system connected to the phreatic aquifer underlying the area. Apparent chemical "signatures" in the study spring's waters indicating soil disturbance implied the presence of an epikarst reservoir beneath the slope deposits cultivated for plantation establishment. Given their location, extent and growth stage, the plantations should substantially reduce aquifer recharge by 2013-2018 as interception of recharge increases. The consequent reduction of available aquifer yield implies economic stress for the rural community and compromise of karst ecosystems.

Keywords: Epikarst hydrology, chemical signatures, aquifer recharge, catchment land use, Northern Tasmania, Great Western Tiers.

Introduction

The recognition of different compartments to karst aquifers and research into their relative proportion and characteristics and behaviour of waters of those compartments has been carried out over the last few decades. Since the 1970s, research has been conducted on epikarst and vadose water percolation. Prestor and Veselic (1993) and Aley (1997) reported complex controls on temporal spring response to precipitation events, related to aquifer compartments. In the context of the dependence on groundwater of communities living on karst, Kranjc (2000) and Aley (2000) suggested there remains the need for more research on karst hydrology, water quality and measures for its protection.

In the Mole Creek karst of north-western Tasmania (Fig. 1), the principal settlements are the towns of Mole Creek, population 223, and Chudleigh, population 400

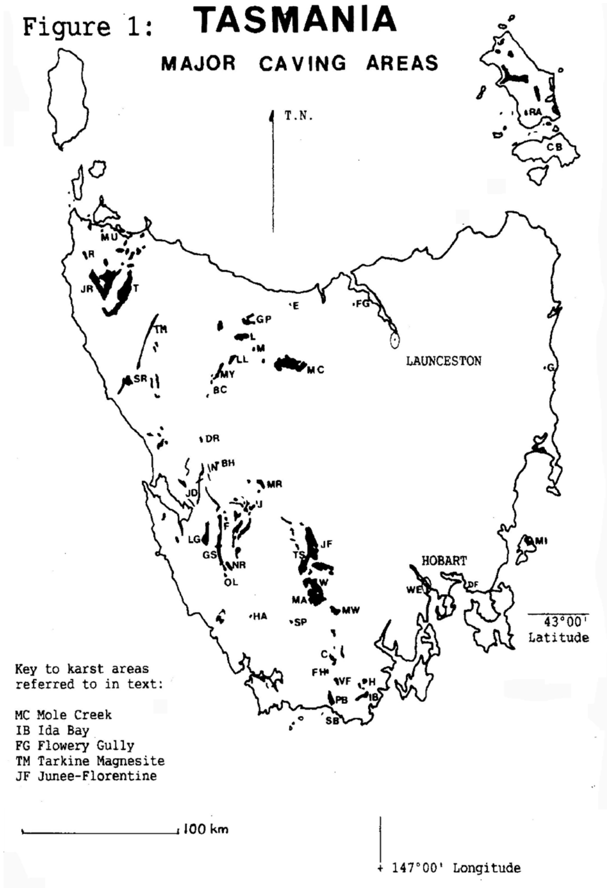


***Figure 1:** Locality of the Mole Creek karst study area, from Lichon, 1993*

(at census, 2006, Australian Bureau of Statistics, 2008). Intensive rural enterprise including mixed farming, forestry, limestone mining and tourism coexists with well-documented, heritage-listed and outstanding karst landforms (Meander Valley Council, 2005). Limestone crops out over approximately 10 km (north-south) by 26 km (east-west), between approximately 200 and 600 m in elevation (Kiernan, 1989 & 1995). However, much of the catchment lies above the limestone on the Great Western Tiers (GWT) escarpment (Fig. 2). Permanent surface water is scarce in the valley, but several subsurface drainage systems are known (Kiernan, 1989).

In the Lobster Rivulet drainage system, Parsons' behaviour changed from perennial to intermittent, following the conversion of 636 ha of mainly native forest to forestry plantations over the adjacent escarpment since 1995 (Fig. 2). This provided the impetus to investigate the spring's hydrology. Since decades of conduit dye tracing failed to identify any discrete source(s) for this major spring, the present study sought evidence of

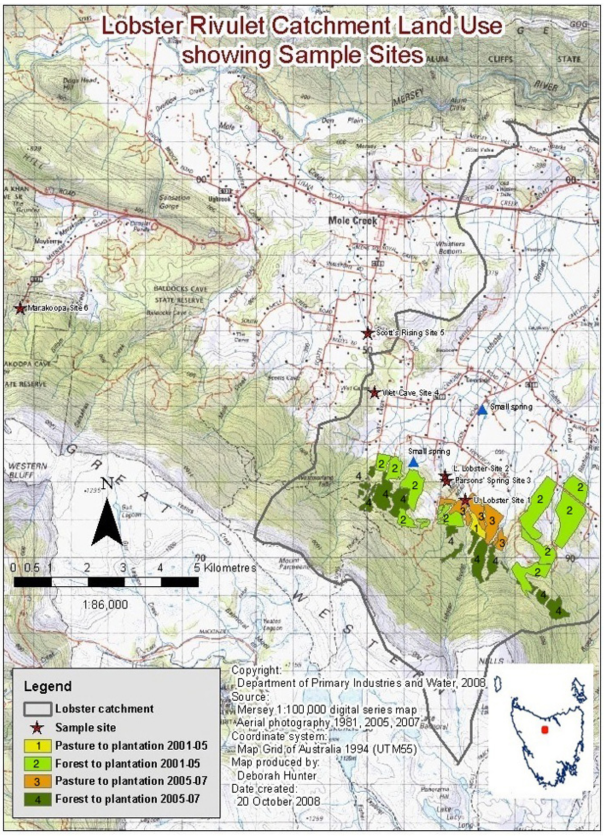


Figure 2: *The study setting, including the Great Western Tiers escarpment, Lobster Rivulet catchment (outlined), the four sample sites of the study catchment, the phreatic spring Scotts Rising (Site 5), the reference spring Marakoopa Cave, to the west (Site 6) and two small episodic springs. Land use change on the lower escarpment is shown ("Forest to plantation 2001-05" includes a minor conversion in 1995).*

diffuse recharge through the Quaternary slope deposits by identifying any land use "signal" associated with forest clearance, burning and cultivation. The objectives included to determine the nature of the Parsons Spring's aquifer and its likely recharge zone from analyses of the chemical and physical properties of its waters and a spring discharge hydrograph in comparison to similar analyses from a "reference" spring and in contrast to analyses of other nearby waters. The reference spring was Marakoopa Cave's resurgence about 13 km to the west (sample site 6). The small, permanent cave stream originates on slopes that remain cloaked by native forest. The other sample sites were the Lobster Rivulet 700 m and 50 m above the confluence with Parsons Spring water (sites 1 and 2), Parsons Spring (site 3), Wet Cave resurgence (a vadose cave) and Scotts Rising (a phreatic resurgence) (sites 4 and 5) (Fig. 2).

Climate, geology and geomorphology of the Mole Creek karst and its catchment

Up to 1320 m in altitude, the Great Western Tiers (GWT) form the northern escarpment of the Central Plateau above the Mole Creek valley (Fig. 2). The climato-geomorphic system is currently fluvial, however, in the past it has been glacial, glaciofluvial and periglacial (Kiernan, 1995). The annual precipitation ranges from 1111 mm in the valley (Bureau of Meteorology, 2007) to >1600 mm in the upper catchments due to orographic effects, and has a Mediterranean, seasonal distribution. Annual average daily temperatures range from minima of 3-6 ^{o}C to maxima of 12-15 ^{o}C (Bureau of Meteorology, 2008). Drought prevailed in the region at the commencement of this study.

Ordovician age, dark grey, fossiliferous and coralline Gordon limestone, of over 90% purity $CaCO_3$, occupies the Mole Creek syncline (Jennings, 1963; Fig. 3). Permian-Triassic Parmeener Supergroup (PSG) sediments (slate, mudstone, shale, sandstone, tillitic conglomerates and siltstone) up to 600 m thick lie unconformably upon the older rocks. A 200-300 m thick Jurassic dolerite intrudes into the PSG sequence, with block faulting, epirogeny and warping. Further Tertiary epirogeny and block faulting of the combined block resulted in the substantial elevated Central Plateau mass. Subsequent erosion down to the resistant dolerite has left the cap of the Central Plateau, with a northern scarp of about 1000 m elevation over the valley floor (Jennings, 1963). The Lobster Rivulet follows a perpendicular fault over the Plateau margin.

Quaternary periglacial processes resulted in extensive solifluction of saturated regolith, mantling or extending "tongues" of dolerite-derived taluvium over surfaces peripheral to ice sheets. Below the altitude of the Triassic geological contact, Quaternary mantles include sandstone fragments. Periglacial activity occurred to about 600 m elevation, although talus and solifluctate are found to about 450 m (Jennings, 1963; Davies, 1965; Burrett & Martin, 1989). Glacio-fluvial mantles extend over the limestone contact in the vicinity of the study spring (Calver et al., 1995; Fig. 3). Therefore, waters from the sample sites may be expected to yield weathering products of the limestone, dolerite and PSG sediments in their catchments.

Mid-Pleistocene glacial ice likely extended very close to, or overrode, the present sites of caves (Jennings & Ahman, 1957 and Jennings, 1967, in Kiernan, 1989). Younger gravels overlie some glacial deposits. The overall result is that glacial outwash and piedmont fans of gravels in a sandy matrix have diverted drainage to some of the valley margins, facilitating solutional processes in adjoining limestone outcrops (Kiernan, 1989). Part of the generally northerly course of the Lobster Rivulet is deflected along the hill-flank toward the north-west, proximal to Parsons Spring.

The maximum limestone topographical relief is about 350 m. It is intensively karstified, with complex hydrogeological systems (Kiernan, 1995). New cave discoveries still occur and knowledge of the hydrology remains incomplete. About 400 caves are currently known (Stephen Blanden, pers. comm., October, 2008). A wide range of surface and subsurface landforms is present, including hums and the Loatta and Mayberry poljes (Kiernan, 1989). The terrane is consistent with the classification "fluviokarst" (Jackson, 1997).

Water tracing experiments have shown the courses of underground streams frequently bear little relationship to the surface topography. The Mole Creek itself "double-breaches" the divide between the Lobster and Mole valleys. Two or more separate streams may share some catchment areas and groundwater conduit routes commonly vary with flow stage, periods of high discharge

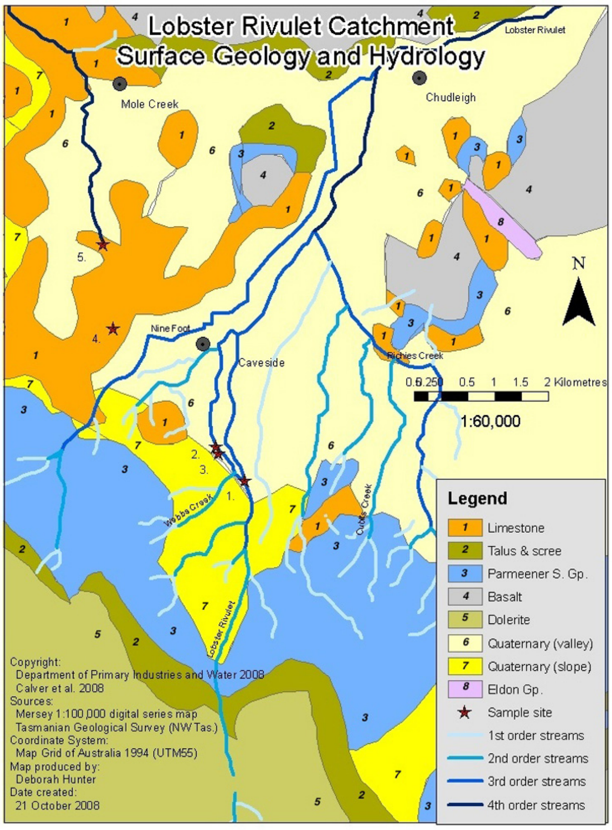
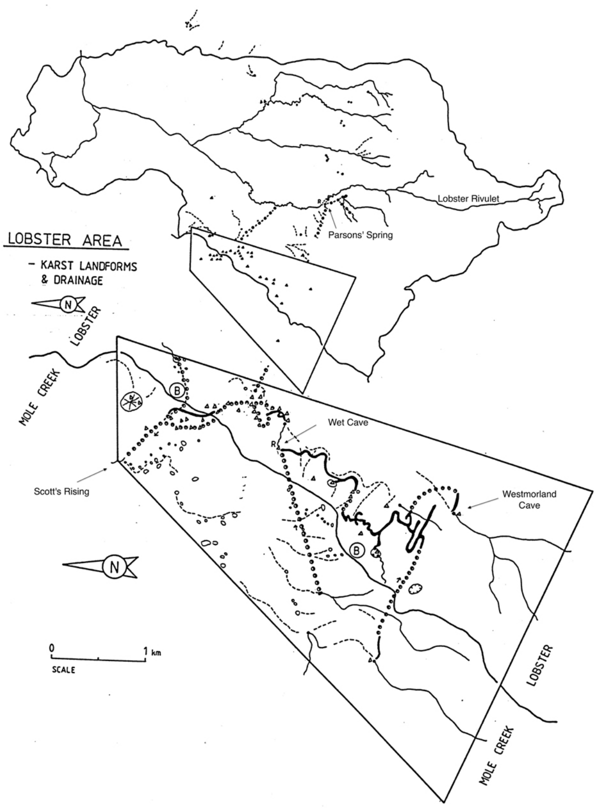


Figure 3: *A simplified surface geology and hydrology of the eastern extent of the Mole Creek karst. Parsons Spring is sample site 3. The reference spring (not shown) lies to the west.*

activating older, higher routes (Kiernan, 1989 and 1995: Fig. 4).

The results of previous conduit dye tracing experiments involving possible tributaries to Parsons Spring are shown in Table 1. No diffuse traces have been attempted.



Water resources, land management issues and karst conservation

The intimate relationship between karst (its environmental processes and integrity) and water, results in the susceptibility of karst aquifers to adverse impacts of land use in the recharge zone (Kiernan et al., 1993; Aley, 2000; Sharples, 2006). White (1988) suggested the most important problem in karst terranes is tillage and soil loss. Karst conduits transmit and store sediments, and may become blocked by sediments (Kiernan et al., 1993). Karst catchment disturbance can release metal ions from adsorption on clays and from complexation by organic acids (Lichon, 1993).

Recently, recurring drought and the prospect of anthropogenic climate change have added impetus to Australian research into catchment water yields and the role of catchment land management. Regarding stream flow reduction risks, Van Dijk et al. (2006) suggest climate change poses the greatest risk, followed by afforestation and groundwater pumping. In the TasLUCaS model demonstrated in small Tasmanian catchments, Brown et al. (2006) considered the age of regrowth forests and

Table 1: *Results of dye tracing experiments using stream sinks, Lobster/Mole karst systems.*

Origin	Date/ stage	Path	Destination	Reference	Notes
Lobster above sink	1966 low flow	Bypassed Wet-Honeycomb window?	Lobster downstream in 3-4 days (lingered for 6 days) and Scotts Rising	Gleeson (SCS), 1976, in Kiernan (1984 & 1989b)	Trace at Scotts Rising may be attributable to tracing in Wet system two weeks previously
Kelly's Pot	July 1976	Direct then upper Wet system	Herbert's Pot and Wet	Gleeson, (SCS), 1976, in Kiernan, 1984	Fluorescein 220g
West-morland	Nov 1976	Direct then upper Wet system	Herbert's Pot and Wet	Gleeson (SCS), 1976, in Kiernan, 1984	Fluorescein 670g
Stream downslope of Kelly's	1974	Direct	Upstream Wet	Gleeson (SCS), 1976, in Kiernan, 1984	Fluorescein 115g
Kelly's	1974	Direct	Shishkebab	SCS, in Kiernan, 1984	Fluorescein 900g
Sink near Herbert's entrance	1964	Unknown	"Wet cave stream"	Jennings and James (TCC), 1967, in Kiernan, 1984	
Prohibition	1984	Not Cobbler Cooler, Cycops, Glow-worm, Baldocks, Baldocks Spring, Sassafras Spring E or Sassafras Creek below Spring E.	Unknown	Kiernan, 1984 (p 133), 1989a & 1989b	Prohibition dye tracing was unsuccessful; may flow to Sassafras or Mayberry, although deflection along the strike to Mole is suggested (Kiernan, 1995)
Flower's Pot and Gimli's Grotto			Unknown	Kiernan, 1995	Waters may join Prohibition; the combined waters may flow to Scotts Rising
Waterworks Caves			Unknown	Kiernan, 1984 (p 171), 1989a & 1989b	Waterworks may flow to one of the springs below Scott's Cave or Scott's Rising

Figure 4 (left): *The Mole and Lobster drainage systems of the Mole Creek karst (Kiernan, 1989). Thick dark lines represent known caves, rows of dots proven hydrological connections and dots with dashes presumed hydrological connections.*

Water sinking in the bed of the Lobster Rivulet is presumed to pass north-west along the strike to join the Mole system, emerging at Scotts Rising at the left on the inset. Two proven breaches (B) of the surface divide are shown.

plantations was a major influence on their water use. Stream flows increase while stands are young, however a progressive decrease follows when such land use change is compared to a no-change scenario. Sustained reductions in catchment flow yield were predicted with 95% confidence over the 35 year model. Kuczera (1987) and Watson et al. (1999) found that in Victorian mountain ash forests regenerated after major disturbance, catchment yield reduced by 500 - 600 mm at 20 - 25 years of forest age, in a 2000 mm annual rainfall regime. However, no Australian models reviewed during the present study accounted for karst. The evaluation of karst aquifers to enable appropriate water resource management requires identification of aquifer characteristics including dynamic storage, rates of recharge and specific and sustained yield (White, 1988). Considering the unavoidable predicted impacts of anthropogenic climate change on effective precipitation, hence aquifer recharge, other human-induced stresses could seriously reduce the capacity of karst systems to adapt (Sharples, 2006).

Most surface streams of the Mole Creek karst either travel underground for much of their courses or are intermittent in nature, seasonally disappearing into their beds (Kiernan, 1989). Water sinking along the middle reaches of the Lobster Rivulet has been assumed to travel north-west with the limestone strike beneath the plain to join the Mole Creek in its underground course (Kiernan, 1995; Fig. 4). Summer and autumn flow has been diverted into a braid of the Rivulet (the Little Lobster) to bypass the streamsinks and maintain flows in the lower reaches. No permanent hill-flank springs exist in the study catchment, although for several generations until 2001, Parsons Spring maintained flow into the middle reaches of the Lobster Rivulet on the family farm through the summer-autumn season (Desley Parsons and Joe Parsons, pers. comms., September 2008). Episodic springs rise nearby after prolonged rain. Several farm and local community scale water schemes reticulate water from above the limestone geological contact and an unknown number of bores draw upon the valley aquifer. Bore sinking requires no permission and no records are kept of bores by the Department of Primary Industry and Water (D. Rockliff, DPIW, pers. comm., October 2008).

Much of the Mole Creek karst and its catchment is used for forestry and agriculture. Formal conservation reserves include a western portion of the GWT escarpment and several small, discrete reserves, including land parcels recently purchased or placed under Nature Covenants under the Mole Creek Karst Forest Program (Parks and Wildlife Service, 2004; Department of the Environment and Water Resources, 2007). This tenure mosaic remains intrinsically problematic for the effective conservation management of karst features, processes and resources that commonly extend across tenures (Kiernan, 1989, 1995; Parks and Wildlife Service, 2004; Eberhard, 2007). While the sensitivity of karst hydrogeological processes are now better recognised, much is still to be realised in actual land management practices (Kiernan et al., 1993; Eberhard and Houshold, 2002; Kiernan, 2002a; 2002b; Gray, 2004).

Concurrently with new sensitivity classifications and development constraints being incorporated into the redrafted municipal Planning Scheme, land classed in 2008 as high sensitivity karst in the study catchment has been undergoing plantation establishment. However, forestry is exempted from municipal development planning and approvals processes (Meander Valley Council, 2005; 2008).

Karst hydrogeology considered in the study setting context

The vadose hydrologic zone in mantled karst like the Lobster Rivulet catchment includes the epikarst (weathering zone), where water moves mainly by gravity or capillary action, equivalent to the subcutaneous zone elsewhere (Williams, 2008). Initial solutional processes may widen the fissures, but due to chemical saturation, the solutional aggressiveness of percolation water is limited with depth. Porosity and permeability reduce vertically, and leakage to the conduits below is slow (Klimchouk, 2000). Epikarst in pure crystalline limestone like that of the study setting typically develops to about 10 m depth, delaying recharge over extended dry periods. Meteoric and up-slope throughflow water typically ponds in an under-drained perched aquifer that sustains distal tributaries of caves and small perennial hill-flank springs (Williams, 2008). Vadose water movement can be anisotropic and travel substantial distances (Palmer, 2007), pathways varying between storms and seasons (Toran et al., 2006).

In contrast to vadose flow, conduits in the phreatic zone may rise and fall along an undulating reach, generally at shallow depths at or just below the water table. Smaller passages tend to feed into major trunks where the water table is lower than in the spaces surrounding them. Surrounding spaces can store and later return flood water to the main trunk in the same way bank storage functions in rivers. Downstream branching is rare except where sedimentation of the spring outlet forces diversion to overflow springs (Palmer, 2007; Fig. 5). River water may intrude in a flood pulse into an estavelle conduit that operates as a spring in wetter seasons (Ford and Williams, 2007).

An epikarst aquifer may sustain the phreatic aquifer of the Lobster Rivulet valley during periods of low aquifer recharge. Parsons Spring, which is partly blocked by sediments, could be the main outlet of a distributary

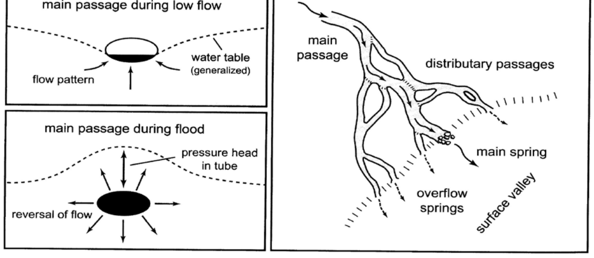


__Figure 5:__ Conduits of distributary springs, from Palmer (2007, pub. Cave Books). At the top left, the trunk conduit under low flow conditions drains the surrounding aquifer, in the same way that streams drain bank storage. However, during a flood pulse (from the feeder system or an intruding river surge), the flow reverses (lower left). The hill-flank distributary system shown on the right illustrates the trunk conduits of a main spring and overflow springs. Such conduits may operate as estavelles, allowing incursion of surface river flood pulses.

conduit system subject to river invasion during flood pulses of the Lobster Rivulet and/or to discharge related to exceeded storage capacity in the phreatic aquifer (Fig. 5). The spring discharges at the hill-flank 4 m higher and 100 m distant from the Lobster Rivulet and at least two episodic springs discharge nearby (Fig. 2).

Methods

Rainfall records for Caveside 1.5 kms east of Parsons Spring were collected using a Nylex cylindrical rain gauge. Rainfall records for Marakoopa were collected by Parks and Wildlife Service staff at the office 400 m north of the cave entrance from 1989 to 2005 and from 2nd August to 27th September 2008 using the same model gauge. Marakoopa rainfall records from 18th March 2005 to 25th September 2008 were collected from a DPIW automatic station (Eberhard, 2008, unpublished), although the data were incomplete. Interpolation covered the gaps, using means from earlier rain gauge data for Marakoopa and adjusting for percentage of the mean as recorded at Caveside for that day or month. Rainfall statistics for each catchment were based upon the same period of record for consistency.

A temporal sequence of aerial photography (1953-2007) was examined using a Wild ST4 stereoscope for evidence of karst surface features in the Lobster Rivulet catchment about the geological contact of the limestone. A limited ground search for karst features was made. GIS analysis (ESRI ArcGIS v9.2) of the aerial photography tracked and quantified catchment disturbance and related it to the hydrogeology. Plantations (<20 ha) currently under development proximal to the lowest point in the catchment were ignored. Ground control points used in georeferencing aerial photography and feature locations were fixed using a Garmin GPSmap76CSx. A photographic record was made of each site at the time of each sampling.

The community's utilisation of local water resources was documented from oral and published history.

The six sites sampled during 2008 were "upper" Lobster Rivulet (site 1), "lower" Lobster Rivulet (site 2), Parsons Spring (site 3), Wet Cave (site 4), Scotts Rising (site 5) and Marakoopa Cave (site 6). A total of four flow stages was sampled: "drought" (21st March), "first flush" (6th April), "base flow" (27th July) and "post-peak" (26th September). At the time of the first sample set, Parsons Spring was dry. The last sample set was taken after the rainstorm response discharge peak recorded at the study and reference springs.

Water samples for inorganic analyses were collected in acid-washed polyethylene containers. Samples were placed in cool storage within 0.5 hours and transferred to refrigeration pending analysis as rapidly as possible. Samples were collected mid-flow at the stream sites and 80 cm beneath the surface at the springs, avoiding sediment mobilisation. Temperature was measured at the time of each sampling at the depth of sampling, excepting for the drought set.

Discharge was calculated for the study and reference springs during the storm response from velocity, cross-sectional area and stage (depth) measurements. Stream velocity gauging was by OTT Current Meter No. 46051 Type 10.002, using propeller No. 1-45430, propriety propeller housing oil and a mechanical revolution counter. Velocity was calculated using the manufacturer's equation for this propeller and range of revolutions: $v=25.52n+0.4$ (cm s^{-1}), where n= number of revolutions per second (>0.76) and v= velocity (cm s^{-1}). Stage was measured using a metre staff for the larger Parsons Spring flows and a plastic ruler for smaller Marakoopa Cave flows. Gauging was limited to five velocity measurements at the less variable and larger study spring. Several intermediate stage measurements were taken at the reference spring in addition to velocity gauging. Calibration was by use of a rating curve of discharge versus stage and the regression equation enabled stage conversion to discharge (Goede, 2008, unpublished). Storm response was sampled over about 22 hours on 26th and 27th September at Parsons Spring (5 samples) and Marakoopa Cave (8 samples); 5 Marakoopa samples were selected for ICP-MS analysis.. Wet chemistry was performed for all samples. Samples L (Parsons Spring) and G (Marakoopa Cave) were selected to represent "post-peak" flow stage.

Wet chemistry analyses were conducted at the Newnham campus laboratory (University of Tasmania). Alkalinity >20 mg $CaCO_3$ L^{-1} was determined by titration to total alkalinity endpoint using screened methyl orange (Method 2320, Greenberg et al., 1992). Dissolved solids were analysed by Method 2540C and suspended solids by Method 2540D (Greenberg et al., 1992). Chloride determinations were carried out for a rainwater sample at the request of DPIW and sample G using a Waters ion chromatograph with M-45 pump, model 430 conductivity detector and IC-Pak anion column (4.6 mm x 5 cm). Determinations were by external standard and the detection limit of 0.10 ppb or 1.03x10-4 mg L^{-1} was calculated from the manufacturer's stated "area reject" (5,000,000).

Inductively coupled plasma mass spectrometry (ICP-MS) for cations was carried out at the Central Science Laboratory of the Hobart campus of the University. Measurements were carried out using an ELEMENT High Resolution ICP-MS (Finnigan-MAT, Bremen, Germany). Prior to analysis an Indium internal standard was added at a final concentration of 100ppb, and unfiltered samples were acidified with a small amount of ultra-pure nitric acid (final concentration ~0.2%). Solids were then settled overnight. The samples were usually analysed within 1-2 days of receipt (A. Townsend, pers. comm., October 2008). Samples were not analysed for organic materials, anions including Cl^- or $Si4^+$ cations, and a proportion of analysed cations probably remained adsorbed on settled clays and organic matter in ICP samples.

Approximate charge balances were calculated for all samples excluding the drought sample set by converting ppb concentrations to molarity and assigning charge. Given the limited ICP analyses, some assumptions were made within reason, including the maximum oxidation number assumed for multivalent metals, that the presence of S represented a net negative charge of $^{2-}$ due to speciation as $SO4^{2-}$, that similarly, P represented $H2PO^{4-}$ and that measured alkalinity was effectively wholly due to HCO^{3-}. Trace metals detected at concentrations of <1.00 ppb were disregarded. Cl^- was included in sample G.

Hydrographs and chemographs were constructed for the springs' storm response.

Relationships in the proportions of elements in possible "tracer/signature" groups representative of limestone (Ca, Na, Mg, S, Sr, Ba, Mn, Ti and Rb; Hughes, 1957; Burrett & Goede, 1987; Lichon, 1993; Jackson, 1997), dolerite (Ca, Na, Mg, S, K, Al, Fe, P and V; Leaman, 2002), a metals group (Al, Fe, Mn, Ti, P and Zr) and highly variable elements (Ca, Mg, S, Sr, B and Sc) were tested between sample sites (155 tests per element group). Alkaline earth/alkali ratios were calculated from molar concentrations. Concentrations of the highly insoluble Al, Ti and Zr were compared and contrasted between the springs.

Data was collated and handled using Excel spreadsheets (Microsoft Office 2008).

Results and discussion

Precipitation recorded for Caveside (ASL 319 m) and Marakoopa (ASL 444 m) for the three years to the date of the storm response monitoring, was 75% of the long term mean. This suggests drought alone was unlikely to have caused the change in discharge behaviour of the spring. Demand on the aquifer by bores requires further research.

No surface karst features could be identified from aerial photography in the study catchment. Access restrictions prevented a ground search for features on the slopes west of the Lobster Rivulet. No features were found on the eastern slopes upon inspection on 24th August 2008. However, epikarst may be present with or without such evidence.

In addition to upslope recharge, efficient autogenic recharge of the phreatic aquifer underlying the valley is suggested by the presence of a series of 120-150 mm diameter soil pipes in 2 m high banks of layered gravels and fines cut into by the Lobster Rivulet between sample sites 1 and 2. However, the efficiency of any aquifer drainage over about 5 km and 30-40 m altitudinal range to Scotts Rising (if such a connection exists) is dependent on the capacity of any connecting conduits, and the fall of the surface topography to Chudleigh is only 50 m over 8 km. Although confirmation by flow gauging over a series of water years is recommended, observations suggest that the discharge of Parsons Spring and any associated distributaries is probably limited to periods when the recharge rate exceeds the drainage capacity of the phreatic aquifer and/or the pumping from bores. Parsons Spring is probably the main overflow spring to the phreatic aquifer. In March, months of the Spring's inactivity concluded as if a threshold was reached, upon which the Spring represented the majority of flow in the middle reaches of the Rivulet until a winter surface base flow from upstream was established. A small episodic spring at 320 m elevation was flowing on 24th September, while another at 280 m elevation was inactive on 4th October (Fig. 2). The possibility of further episodic springs requires investigation. Sample site elevation differences are shown in Figure 6.

Although the 1995 plantation on the western flanks of the Lobster Rivulet, proximal to Parsons Spring, is of an age where substantial water interception is to be reasonably expected (Van Dijk et al., 2006), it represents a small fraction of the total areal extent of plantations, most of which were established since 2001. Younger plantations intercepting less water than the forest they replaced, and remnant native forest under which the hydrology should not have changed, surround the 1995 plantation. However, given the total extent of newly established plantation and its location, upslope karst aquifer recharge should reduce substantially by 2013-2018 (Brown et al., 2006).

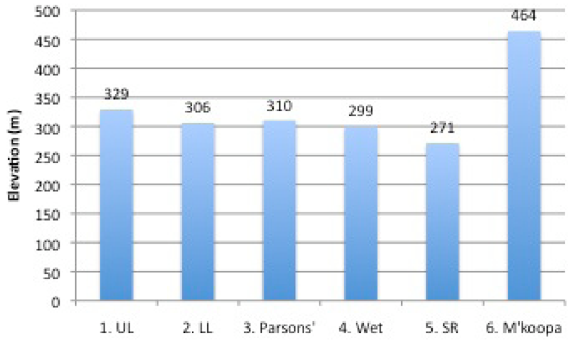


Figure 6: *Sample site elevations.*

Temperatures and wet chemistry results are given below for the four flow stages (Table 2).

The presence of travertine on the stream bed and the low range in temperature of the water at Parsons Spring over the course of the project with respect to other karst sites supports a karst aquifer residence time generally sufficient to equilibrate the tested parameters with the host rock. Generally, the karst sites varied less in water temperature than the two fluvial sites, Upper and Lower Lobster. Parsons and Wet Cave varied the least and Scotts Rising had the warmest water throughout. Marakoopa's lower temperatures reflect fast vadose flow associated with the steep gradient of this cave.

The two river sites differed in pH, with Lower Lobster having the greater range and the higher readings in drought and flush. Of the karst sites, Scotts Rising had higher pH values than Parsons Spring throughout the study, Lower Lobster and Wet had very similar pH throughout the study and Marakoopa varied the least.

Table 2: *Results from wet chemistry for flow stages. Alkalinity is expressed in mg $CaCO_3$ L^{-1} (bracketed entries should be regarded as <20) and suspended, dissolved and total solids are expressed in mg L^{-1}.*

UL	Temp (°C)	pH	Alkalinity	S. solids	D. solids	Tot S
Drought		6.31	(5)	0	11	11
First flush	11	7.44	(18)	0	0	0
Base flow	7	5.67	21	0	494	494
Postpeak	7.6	7.07	(14)	0	88	88
LL	**Temp (°C)**	**pH**	**Alkalinity**	**S. solids**	**D. solids**	**Tot S**
Drought		6.92	(13)	4	47	51
First flush	12.5	7.55	30	0	4	4
Base flow	8	5.56	20	0	45	45
Postpeak	7.6	7.04	(15)	5	73	78
Parsons	**Temp (°C)**	**pH**	**Alkalinity**	**S. solids**	**D. solids**	**Tot S**
Drought N/A						
First flush	9.5	7.67	56	6	40	46
Base flow	8	5.27	36	0	72	72
Postpeak	9	6.88	33	0	67	67
Wet	**Temp (°C)**	**pH**	**Alkalinity**	**S. solids**	**D. solids**	**Tot S**
Drought		6.91	64	29	2	31
First flush	9.5	7.62	56	0	42	42
Base flow	8	5.47	33	0	66	66
Postpeak	7.9	7.01	28	0	22	22
SR	**Temp (°C)**	**pH**	**Alkalinity**	**S. solids**	**D. solids**	**Tot S**
Drought		6.80	26	8	337	345
First flush	13	7.94	126	2	102	104
Base flow	10	5.59	84	2	115	116
Postpeak	9.3	6.89	70	4	143	147
Mara	**Temp (°C)**	**pH**	**Alkalinity**	**S. solids**	**D. solids**	**Tot S**
Drought		6.80	54	12	54	65
First flush	9.5	7.63	40	0	29	29
Base flow	7	5.68	41	2	73	75
Postpeak	7.6	6.82	28	0	93	93

Uncertainty in alkalinity determinations per sample set (relative standard deviation):
Drought: +/-11%
First flush: +/-0.69%
Base flow: +/-0.46%
Post-peak and chemographs: +/-0.57%
Glassware and analytical balance tolerances: +/- 0.18%

The lowest pH values for all sites were recorded in base flow, with Parsons Spring the lowest (5.27), while the highest pH values were recorded in flush, the highest and second highest being Scotts Rising and Parsons (7.94; 7.67) (Table 2).

In alkalinity, Upper and Lower Lobster varied little, from lowest in drought to highest in base flow, except Lower Lobster's alkalinity rose notably in first flush. Parsons Spring's flush-high alkalinity declined through the season. Wet Cave's alkalinity was drought-high, declining through sampling. Scotts Rising had higher alkalinity throughout than the other sites. However, its lowest reading, in drought, contrasting with the other karst sites was probably due to the precipitation of colloidal carbonate. Marakoopa's alkalinity varied little and was lower than Wet Cave's in drought. Parsons' values were higher than Marakoopa's in flush and post-peak flows.

Suspended solids throughout the study were generally low. The highest values, at Wet Cave (29 mg L^{-1}) and Marakoopa (12 mg L^{-1}) in drought were probably due to streambed sediment disturbance and/or colloidal calcite. Parsons was highest in suspended solids in first flush, when dissolved solids were lowest. The highest reading for dissolved solids, at Upper Lobster in base flow (494 mg L^{-1}), was probably due to analytical error. Scotts Rising otherwise carried the highest dissolved solids throughout, its drought reading being the second highest (337 mg L^{-1}). Charge balance calculations were of little utility in data evaluation. Metals, particularly silicon, and anions untested by ICP-MS resulted in substantial negative and positive imbalances. The inclusion of Cl^- in one of the equations was of little effect.

The ICP-MS results for the flow stages are shown in Table 3 (See Appendix 1 & Table 2). Alkali metals and alkali/alkaline earth metals ratios for flow stages are shown in Figure 7.

Ca/Mg and (Ca+Mg)/(Na+ K) ratios are important in helping distinguish karst ground water from other sources. The large phreatic spring, Scotts Rising, consistently had higher values than other sites in both ratios,

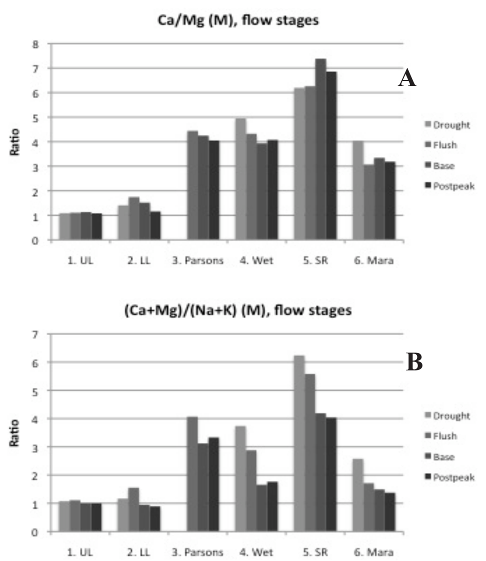


***Figure 7**: Alkali and alkaline earth ratios for all sample sites over all flow conditions.*

explained by long residence time in the aquatic $CaCO_3$/H_2O/CO_2 system. Fluctuating ratios at the other sites are consistent with origins of the water. Upper Lobster varies little, the karst sites Parsons Spring, Wet Cave and Scotts Rising are consistently high, and Marakoopa, with its steep hydraulic gradient and short throughflow time, has the lowest values of the karst water sources. Lower and Upper Lobster had similarly low drought (Ca+Mg)/(Na+K) ratios. The ratio was higher at Lower Lobster in the flush but higher at Upper Lobster in base and post-peak flows. All Ca/Mg ratios at Lower Lobster were higher than for the corresponding period at Upper Lobster.

All sites were highest in major limestone element concentrations in drought, declining with each sampling, excepting for Lower Lobster, highest in flush. Given the corresponding relatively high alkalinity and pH, inconsistent with that of Upper Lobster, it is suggested that a karst aquifer outlet discharges into the Lower Lobster stream bed with the first seasonal rains until winter surface flow is established from upstream.

Substantial epikarst storage is inferred for Parsons Spring and Wet Cave, whose (Ca+Mg)/(Na+K) ratios increase again with post-peak conditions. Wet Cave's Ca/Mg ratio also increases, however calcium was probably precipitating in the system at Parsons and upon efflux, either due to supersaturation with calcite or common ion effect from high solute load in the epikarst.

It is reasonable that the relatively immobile multivalent metals and phosphorus should be lowest in concentration during drought. Conduits store sediments, which can adsorb cations, particularly the more immobile elements. The substantially higher concentrations at Lower Lobster and Parsons in post-peak flow than other sites suggest a land use signal as recharge arrives from the cultivated wider catchment. Parsons' particularly strong signal in these metals in flush flow adds support for the presence of a substantial subcutaneous aquifer.

Parsons Spring's and Marakoopa Cave's storm response discharge, temperatures, wet chemistry results, alkali and alkali/alkaline earth metals ratios, ICP-MS results and Al, Ti and Zr chemographs are shown in Tables 4 and 5 and Figures 8 and 9. Light rain showers fell across the escarpment from 9.30 and cleared by noon, before heavier rain set in at 1.30 pm. Skies cleared across the escarpment by 4.20 pm and remained clear. Note that measurements and sampling commenced after Marakoopa's response began.

A pulsating discharge can be observed in the storm response at Marakoopa, from response to the earlier showers, the break in the precipitation, then the heavier rainstorm, with little lag in peak and recession. The discharge response is reflected in the dissolved solids load peaking with the recession of the first discharge peak. Little epikarst storage is evident. In contrast, Parsons Spring's dissolved and suspended solids load is still increasing, and following the recession of the distinct peak, the discharge is sustained. The initial temperature and alkalinity decline at Parsons ahead of the discharge peak suggests an initial invasion of a pulse from the Lobster, displacing water that had equilibrated with the host rock. Temperature and wet chemistry measurements

Table 4: *Results from wet chemistry for the two springs' storm response. Alkalinity is expressed in mg $CaCO_3$ L^{-1} and suspended and dissolved solids are expressed in mg L^{-1}.*

Parsons'						
Time	Sample	pH	Temp °C	Alk	DS	SS
11.37 am	I	6.94	9	34	85	8
1.55 pm	J	6.9	8	32	56	2
3.5 pm	K	6.9	8.5	34	49	0
6.05 pm	L	6.88	9	33	67	0
7.52 am	3	6.93	8	36	80	41
Marakoopa						
Time	Sample	pH	Temp °C	Alk	DS	SS
10.15 am	B	6.68	7.7	34	104	0
10.39 am	C	6.7	7.7	35	63	0
11.43 am	D	6.74	7.6	34	85	0
12.45 pm	E	6.78	7.7	32	173	0
2.43 pm	F	6.77	7.7	33	104	5
4.25 pm	G	6.82	7.5	28	93	0
5.25 pm	H	6.85	7.6	32	66	36
8.50 am	6	6.86	7.1	31	71	5

Table 5: *Results of ICP-MS analyses for the two springs' storm response (ppb).*

Marakoopa	B	D	E	G	6
	10.15 am	11.43 am	12.45 pm	4.25 pm	8.50 am
Ca	10044	10093	8874	8581	9153
Na	4487	4513	4415	4412	4411
Mg	1699	1686	1658	1634	1679
S	984	954	916	916	972
K	388	420	373	494	354
Al	61	61	55	62	45
Fe	36	34	33	37	30
Sr	33	33	31	30	31
Ba	10	10	9	9	9
B	4	4	4	4	4
Mn	1	1	1	1	0
Zn	1	2	1	4	1
Ti	1	1	1	1	1
P	2	1	2	2	2
Rb	0	0	0	0	0
Ni	0	1	0	1	0
V	0	0	0	0	0
Cr	1	1	0	0	0
Cu	0	1	0	2	1
As	0	0	0	0	0
Sc	0	0	0	0	0
Co	0	0	0	0	0
Zr	0	0	0	0	0
Parsons	**I**	**J**	**K**	**L**	**3**
	11.37 am	1.55 pm	3.50 pm	6.05 pm	7.52 am
Ca	9139	9030	9164	9282	10090
Na	1929	1857	1873	1841	2003
Mg	1392	1374	1378	1390	1445
S	333	315	321	307	342
K	240	183	209	255	271
Al	290	257	288	322	220
Fe	212	194	210	249	174
Sr	15	15	15	15	16
Ba	5	5	5	6	5
B	2	2	2	2	2
Mn	9	8	9	10	7
Zn	5	2	2	4	2
Ti	9	5	6	8	5
P	4	3	4	5	2
Rb	1	1	1	1	1
Ni	1	0	0	1	1
V	1	1	1	1	1
Cr	1	1	1	1	1
Cu	1	1	1	1	1
As	0	0	0	0	0
Sc	0	0	0	0	0
Co	0	0	0	0	0
Zr	0	0	0	0	0

suggest the spring's discharge towards the peak was then replaced by karst aquifer water. Following the heavier rain, Ti, Al and Zr concentrations rose, probably released from adsorption on sediments stored in the Spring's trunk aquifer conduits, then these concentrations decline again as pH rises substantially and discharge rises modestly, probably representing the arrival of epikarst water. Ti, Al and Zr concentrations are much lower and less variable at Marakoopa. In the chemographs of Ca/Mg and (Ca+Mg)/(Na+K) ratios, Parsons Spring has higher values overall, indicating a substantial karst aquifer influence. Marakoopa's ratios decline until the rapid vadose storm flow subsides, while the increasing contribution of epikarst water at Parsons is apparent from the rising Ca/Mg. Further, compared to Marakoopa, the sustained discharge at Parsons indicates the relatively large areal extent of the recharge zone. Suspended solids continue to increase at Parsons while declining at Marakoopa. It is suggested the 1.30 pm rainstorm activated the distal reaches of Parsons recharge zone, sending sediments through the system, lowering temperature and raising pH and Ca/Mg, accompanied by a sustained, modestly increased discharge, limited by epikarst porosity.

Coefficients of determination were calculated from linear regressions of ppb concentrations in the selected element groups (metals and P, limestone, dolerite and "highly variable" elements) between the reference and study springs and other sites. These relationships were examined for any indications of vadose quickflow and flushed aquifer storage water (similar to base flow) (Table 5). Being chemically aggressive, as the water has little time in contact with limestone, quickflow can potentially mobilize metals and phosphorus. Marakoopa's apparent lack of any substantial storage aquifer, indicated by rapid discharge response and subsequent recession behaviour with showers, provided useful contrast in identifying possible compartments of Parsons Spring's aquifer. Of the most significant of these relationships (R2>0.950; p<0.001), the storm response/post-peak relationships were the most informative.

For Marakoopa, the relative proportions of elements in all the tested groups were strongly related to those of the other vadose cave site, Wet Cave. Results were inconclusive for relationships with the waters of other sites.

Parsons Spring had strong relationships with Lower Lobster for the metals and P group, with Scotts Rising for the limestone and dolerite groups and with Wet Cave for the highly variable element group (Ca, Mg, S, Sr, B and Sc). It is suggested Parsons and Lower Lobster share a recharge zone or system that mobilises elements of the metals and P group; Parsons and Scotts share the signs of limestone and dolerite weathering in their systems, while Parsons relationship with Wet Cave for the variable element group suggests their recharge zone overlaps.

Throughout the storm response, Marakoopa most strongly related with the first sample from Parsons' storm response, excepting for the metals and P group, for which Parsons' discharge peak sample best relates with

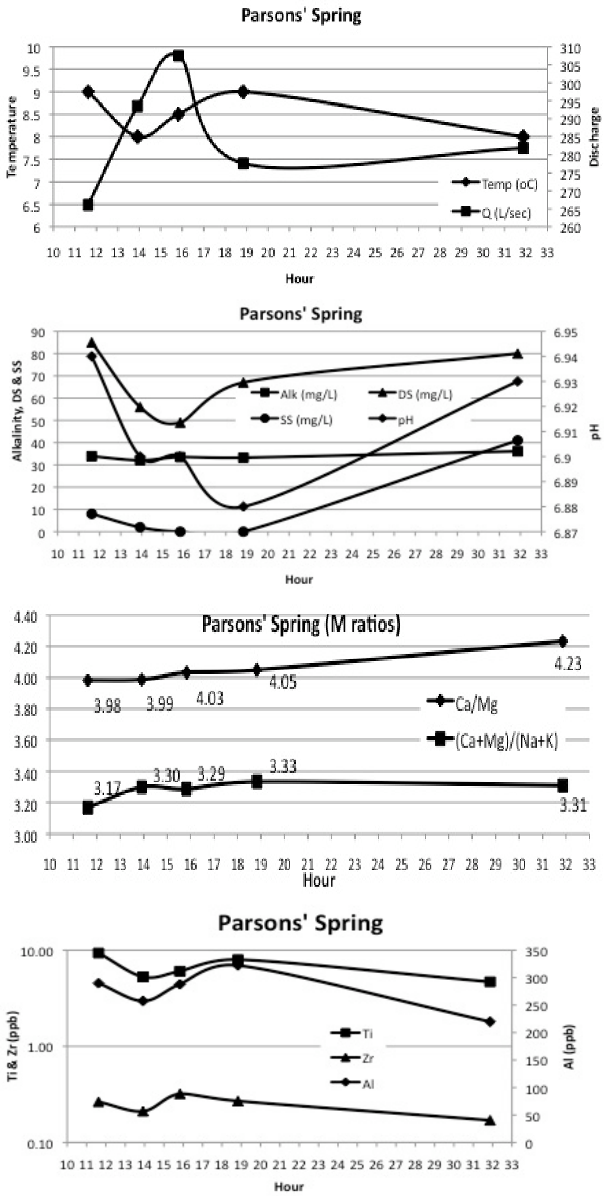


Figure 8: *Parsons Spring storm response hydrograph and chemographs.*

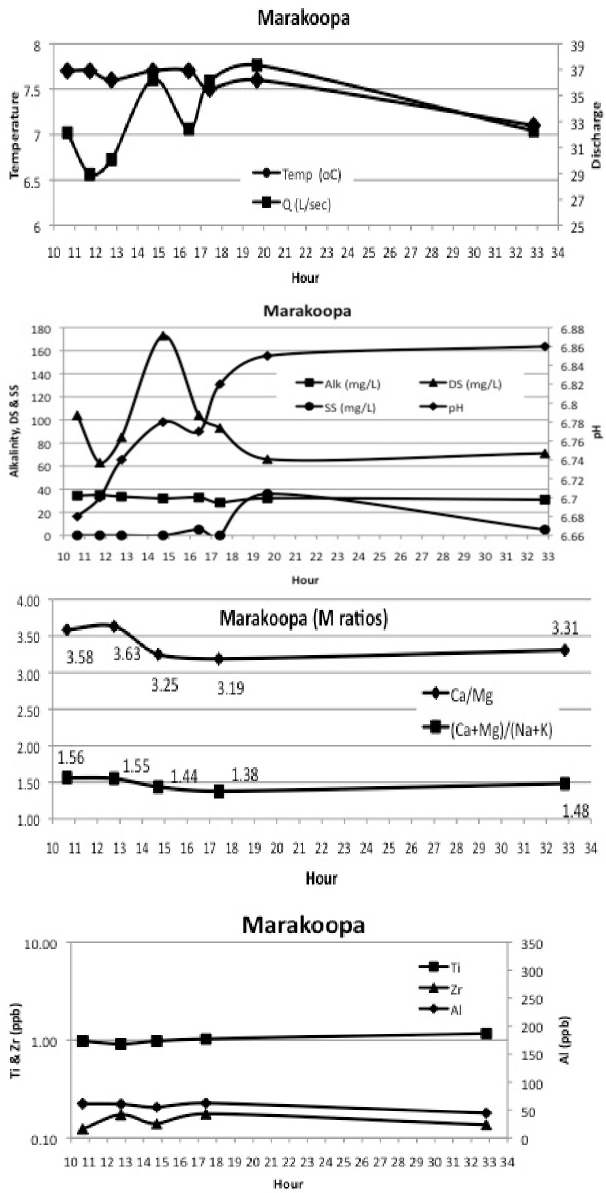


Figure 9: *Marakoopa Cave storm response hydrograph and chemographs.*

Marakoopa's samples. The data set suggests Parsons Spring does not initially transmit water of long residence time during a rainstorm. The implication is that at least one quickflow route operates at Parsons during storms, flushing the relatively easily mobilized elements from the soluble, crystalline aquifer host rock and weathering allogenic sediments. Marakoopa's first pulse discharge is most like Parsons' waters with respect to the host rock and escarpment sediments. As suggested by the sustained post-peak discharge and alkalinity, falling temperature and rising pH, dissolved solids and suspended solids, Parsons sustained recharge is largely drawn from a subcutaneous aquifer farther afield (Figs 8 and 9).

Conclusions

Measurements of chemical and physical parameters across flow conditions and through spring storm responses provide valuable information on the nature of karst aquifers and their recharge zones. Long term familiarity with the local hydrology and local residency allowed best use of limited research time and resources. Further sampling and statistical analyses over a period of years would give more reliable information.

Parsons Spring probably drains a complex mixed recharge karst aquifer. It is considered that catchment extent across the escarpment and recharge regimes are variable, and flow routes and direction are anisotropic, varying between rainstorms and seasons. It is considered a perched epikarst reservoir maintains base flow in Parsons Spring, and a shallow valley water table in proximity to the hillslopes invokes an overflow threshold behaviour in the Spring. The existence of other small episodic springs suggests a distributary spring system exists, of which Parsons Spring is the main outlet. The Spring appears to operate as an estavelle, with invasion of water from the Lobster Rivulet during initial storm response.

Parsons Spring's recharge and hydrology may be compromised by anthropogenic influence. The recent change from perennial to intermittent discharge of Parsons Spring may be due to blockage of vadose conduits of the epikarst and/or conduits beneath it, changed flow routes and increased pumping from the phreatic aquifer. Reductions in aquifer recharge are reasonably expected by 2023 as plantations age. Compromise of sensitive hydrological processes coupled with climate change probably pose economic risks for the rural community and risks to aquatic ecosystems.

In order to enable improved management of the available resource, it is recommended that further research defining the recharge zones and flow regimes of the aquifer be conducted so that an investigation of the sustainable yield of the Lobster Rivulet basin karst aquifer can be carried out. It is essential appropriate modeling be applied, for example in the 2009 formal assessment of the Mersey-Forth catchment in the Tasmanian Sustainable Yields (TasSY) Project (CSIRO, 2008).

In order to optimize aquifer resilience in the face of likely climate change, catchment management prescriptions could be revised. This work could form the basis of a solution, the aim of which is the sustainable water supply for both the community and the karst ecology.

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Debbie Hunter at Karstaway Konference. Photo: B. Downes

Appendix 1 Table 3: *Results from ICP-MS analyses for flow stages (ppb).*

Drought

	1. UL	2. LL	3. Parsons	4. Wet	5. SR	6. Mara
Ca	2962	3739		22523	44711	16265
Na	2885	2932		3863	4425	4240
Mg	1652	1612		2760	4377	2443
S	516	538		1053	1370	722
K	254	364		494	595	472
Al	8	25		10	3	24
Fe	22	63		7	3	14
Sr	10	12		48	85	42
Ba	2	2		14	22	10
B	3	3		4	5	4
Mn	0	1		0	0	0
Zn	1	0		0	2	1
Ti	0	0		0	0	1
P	1	2		2	1	1
Rb	0	0		1	1	0
Ni	0	0		0	0	0
V	0	0		0	0	0
Cr	0	0		0	0	0
Cu	0	1		0	0	0
As	0	0		0	0	0
Sc	0	0		0	0	0
Co	0	0		0	0	0
Zr	0	0		0	0	0

Flush

	1. UL	2. LL	3. Parsons	4. Wet	5. SR	6. Mara
Ca	2620	6257	15460	16780	39523	10121
Na	2416	3428	2471	3839	4357	4243
Mg	1435	2175	2111	2354	3827	1999
S	344	1095	510	1045	1310	670
K	273	350	341	469	603	424
Al	47	48	370	51	133	87
Fe	52	73	232	64	97	56
Sr	9	17	21	39	76	27
Ba	2	3	7	12	20	7
B	3	4	4	6	5	5
Mn	2	9	8	2	5	51
Zn	1	1	4	1	4	1
Ti	1	1	8	2	58	2
P	1	50	8	7	5	4
Rb	0	1	1	1	1	0
Ni	1	1	1	1	1	1
V	0	1	1	0	0	0
Cr	1	0	1	0	1	1
Cu	0	1	1	0	1	0
As	0	0	0	0	0	0
Sc	0	0	0	0	2	0
Co	0	0	0	0	0	0
Zr	0	0	0	0	0	0

Base

	1. UL	2. LL	3. Parsons	4. Wet	5. SR	6. Mara
Ca	908	3886	11154	10352	31423	11447
Na	2978	3725	2399	4287	4467	5477
Mg1	560	1553	1592	1597	2582	2077
S	501	786	392	1018	1176	1072
K	269	310	228	353	712	409
Al	93	118	96	89	59	67
Fe	61	76	52	52	39	36
Sr	14	21	21	35	79	43
Ba	3	5	5	11	19	12
B	4	5	4	6	6	6
Mn	1	3	2	1	3	1
Zn	3	2	4	3	15	5
Ti	2	2	1	2	3	1
P	1	2	3	4	10	3
Rb	1	1	0	1	1	1
Ni	2	1	3	4	15	5
V	1	1	0	0	0	0
Cr	1	0	1	0	0	1
Cu	1	1	1	1	3	1
As	0	0	0	0	0	0
Sc	0	0	0	0	0	0
Co	0	0	0	0	0	0
Zr	0	0	0	0	0	0

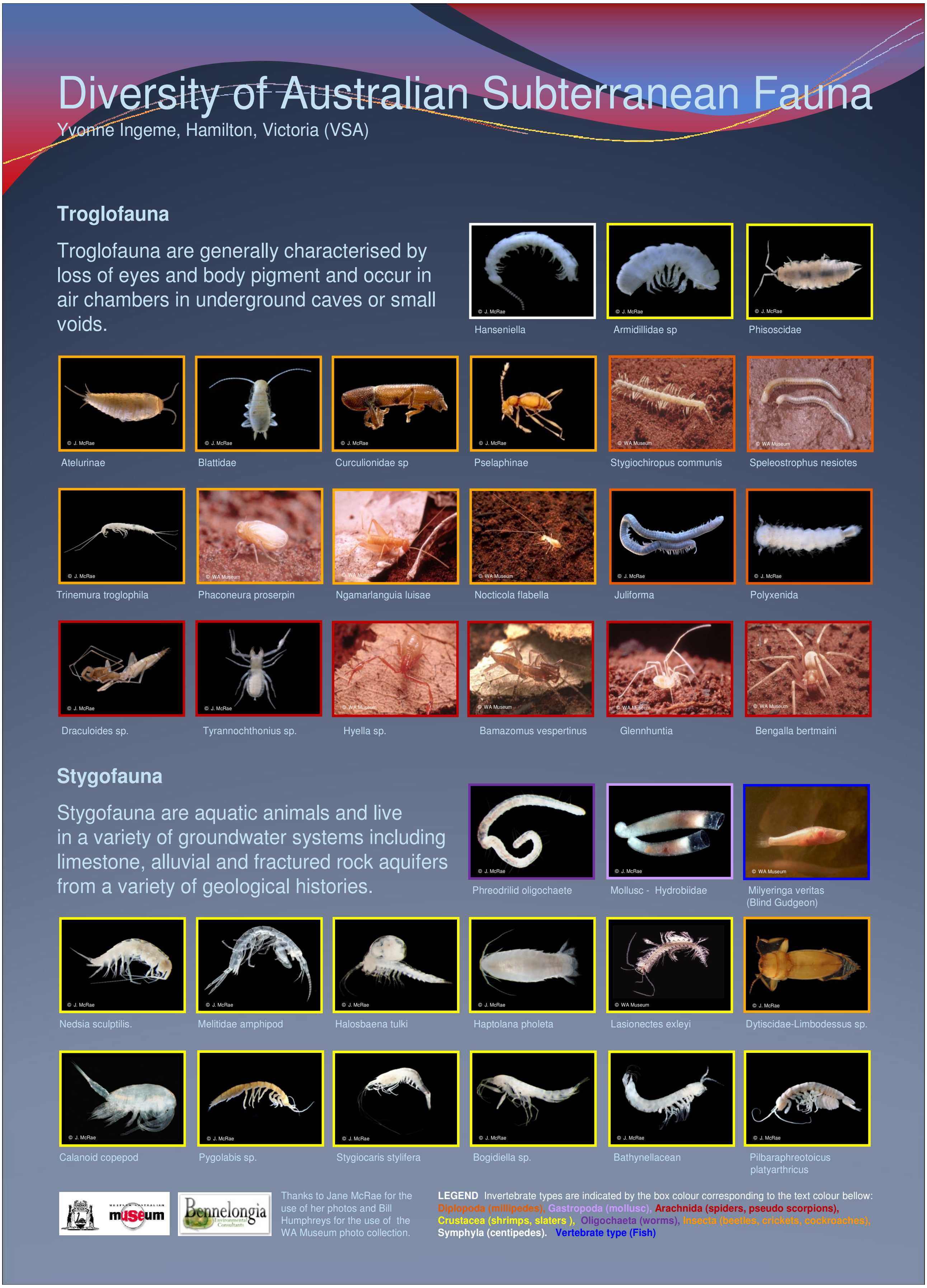
Post peak

	1. UL	2. LL	3. Parsons	4. Wet	5. SR	6. Mara
Ca	2036	2187	9282	8186	21911	8581
Na	2123	2436	1841	3079	3310	4412
Mg	1143	1145	1390	1218	1938	1634
S	294	372	307	762	884	916
K	213	314	255	399	439	494
Al	87	132	322	51	50	62
Fe	65	96	249	37	61	37
Sr	8	10	15	24	48	30
Ba	2	3	6	7	12	9
B	2	3	2	3	4	4
Mn	1	2	10	1	3	1
Zn	1	2	4	1	3	4
Ti	1	3	8	2	1	1
P	23	3	5	2	2	2
Rb	0	0	1	0	1	0
Ni	0	1	1	0	1	1
V	0	1	1	0	0	0
Cr	0	1	1	0	0	0
Cu	0	1	1	0	1	2
As	0	0	0	0	0	0
Sc	0	0	0	0	0	0
Co	0	0	0	0	0	0
Zr	0	0	0	0	0	0

Diversity of Australian Subterranean Fauna

Yvonne Ingeme
Victorian Speleological Association, Inc

Pictorial display of a selection of Australian Stygofauna and Troglofauna aimed at raising awareness of the biodiversity of subterranean fauna that exists within Australia.



Subterranean Fauna Communities that are Groundwater Dependent Ecosystems

Yvonne Ingeme
Victorian Speleological Association Inc.

Abstract

Stygofauna are tiny aquatic animals that live in a variety of groundwater systems including limestone, alluvial and fractured rock aquifers from a variety of geological histories and are clearly part of Groundwater Dependant Ecosystems. They are likely to be negatively impacted by activities that reduce groundwater tables. Western Australia (WA) is currently leading the way in Australia, in both surveys and taxonomy and has identified a great diversity of subterranean fauna, with some areas now regarded as Global Hotspots. Although subterranean fauna are routinely assessed in WA as part of the Environmental Impact Assessment process, this is not the case in other states, which often omit stygofauna from groundwater monitoring due to lack of identification information. Currently, Victoria appears to be oblivious to the existence of stygofauna. To overcome this situation, a three staged approach to sampling is outlined, where investigations progressively increase in complexity. The approach includes using low cost sampling of bores and springs to determine stygofauna presence, sorting into major groups and then progression to detailed taxonomic identification. A brief description of sampling methods is provided. The paper also provides information regarding potential subterranean fauna habitat within karst systems.

What are Subterranean Fauna?

A variety of animals have become adapted to living in subterranean habitats and are generally characterised by loss of body pigment and eyes. These include troglofauna which occur in air chambers in underground caves or small voids and stygofauna which are aquatic animals and live in a variety of groundwater systems including limestone, alluvial and fractured rock aquifers from a variety of geological histories. Stygofauna are 100% groundwater dependant (Humphreys 2006a) and as such will be the focus of this paper.

Generally most stygofauna are unpigmented, elongate, small (most less than 0.5mm long) and adapted to living in dark and generally confined spaces. Many have developed elongated feelers. Australian groundwater aquifers support a diverse fauna, largely consisting of crustaceans but it also includes worms, insects, gastropods, mites and fish (Humphreys, 2006a). Photos of some of the species can been seen in the poster (Ingeme, 2009) as part of these proceedings and also on the web sites provided below.

Biodiversity of Australian Stygofauna

Groundwater was once considered to be "biological deserts" but is now proving to be surprisingly rich in species, many of which are new to science (Tomlinson et al., 2007).

Western Australia contains a great diversity of subterranean fauna, with some areas now regarded as Global Hotspots for subterranean biodiversity. It is estimated that the Pilbara contains up to 550 species of stygofauna (DEC, 2008) which far exceeds the 300 stygofauna species recorded from all the cave systems of the United States. The Western Australian Yilgarn and Goldfields region also contain more species of subterranean beetle than anywhere else known in the world (Watts & Humphreys, 2006, in EPA WA, 2008). In some cases the level of biodiversity discovered is a reflection of the level of survey effort.

Humphreys (2006b, pp.2) also states that "while there is an increasing literature on the characteristics, origins and distribution of Australian stygofauna, for most regions of Australia, no data is available. The data show that Australia has a diverse groundwater fauna, but the focus of knowledge is in the rangelands, particularly in Western Australia where subterranean fauna are routinely considered in the environmental review process."

The groups of stygofauna so far known to occur in Australia are shown in Table 1.

Values of Stygofauna

Besides adding greatly to Australia's biodiversity, stygofauna are believed to play an important role in maintaining the quality of groundwater and providing ecosystem services, including keeping pore spaces open to assist movement of groundwater (DEC, 2008). They may prove to be valuable indicator species as measures and early warnings for groundwater health.

Stygofauna are believed to play an important role in maintaining the quality of groundwater as they generally feed on bacteria and biofilm. Bacteria have a recognised role in the bioremediation of some pollutants (Gounot, 1994, in Tomlinson et al., 2007), and therefore the stygofauna grazing on the bacteria and biofilms may stimulate these bioremediation processes (Mattison et al., 2005, in Tomlinson et al., 2007). Stygofauna feeding, movement and excretion are likely to play a role in the transfer of organic matter through aquifers (Hancock et al., 2005, in Tomlinson et al., 2007) and so helping to transform nutrients and maintain water quality (Tomlinson et al., 2007).

Stygofauna Habitat

Characteristics that make good stygofauna habitat include pore spaces in the rock and disolved oxygen in the water (0.5-1mg/L^{-1}) (Hahn, 2006). Ground water salinity needs to be less than 60,000mg/L^{-1} (note that freshwater lying above a hypersaline lens may support stygofauna) (EPA WA, 2008). They may occur in very deep ground water. Metazoan communities, comprising obligate subterranean animals, are known to occur in aquifers to a depth of at least one kilometre (Humphreys, 2002)

Stygofauna are highly likely to occur in limestone aquifers, but are also known to occur in alluvial and fracture rock aquifers from a variety of geologies. But as

***Table 1** Known Australian stygofauna taxa*

Taxon	**No. of Families**	**Further info. on Families or species**	**Description**
Platyhelminthes: Turbellaria	1		
Annelida: Polychaeta	1	Phyllodocida (Nereididae)	worms
Annelida: Oligochaeta	2	Tubificida	small aquatic earthworms
Mollusca: Gastropoda	1	Neotaeniglossa (Hydrobiidae), Basommatophora (Planorbidae)	snails
Arachnida: Acarina	2	Momonidae,Mideopsidae	mites
Insecta: Coleoptera	1	Dytiscidae	diving beetles
Vertebrata: Pisces	2	Blind cave eel (Ophisternon candidum), Blind Gudeon (Milyeringa veritas)	eels fish
Crustaceans			
Syncarida	4	Parabathynellidae, Bathynellidae, Anaspidacea	Tubular animals with unformed legs
Remipedia: Nectiopoda	1	Speleonectidae	
Copepoda: Calanoida	3		Tiny prawn-like crustaceans
Copepoda: Cyclopoida	1		
Copepoda: Harpacticoida	7		
Copepoda: Misophrioida	1		
Ostracoda: Myodocopida	1		Small seed-like animals with calcified shells
Ostracoda: Podocopida	5		
Peracarida: Spelaeogriphacea	1	Spelaeogriphidae	
Peracarida: Thermosbaenacea	1	Halosbaenidae	
Amphiopoda	9	Perthiidae, Hadziidae Neoniphargidae, Hyalidae, Paramelitidae, Eusiridae, Paracalliopiidae, Melitidae, Bogidiellidae	Shrimp like
Isopoda	8	Oniscidea, Tainisopidea, Amphisopididae,Asellota, Phreotoicidea, Cirolanidae, Tainisopidea	Slater like
Decapoda	3	Atylidae	

Pilbara (P)

Estimate. >500 species stygofauna compared to 300 sp stygofauna in cave systems all USA

Yilgarn Calcrete (Y)

More species of subterranean beetles than anywhere else in the world

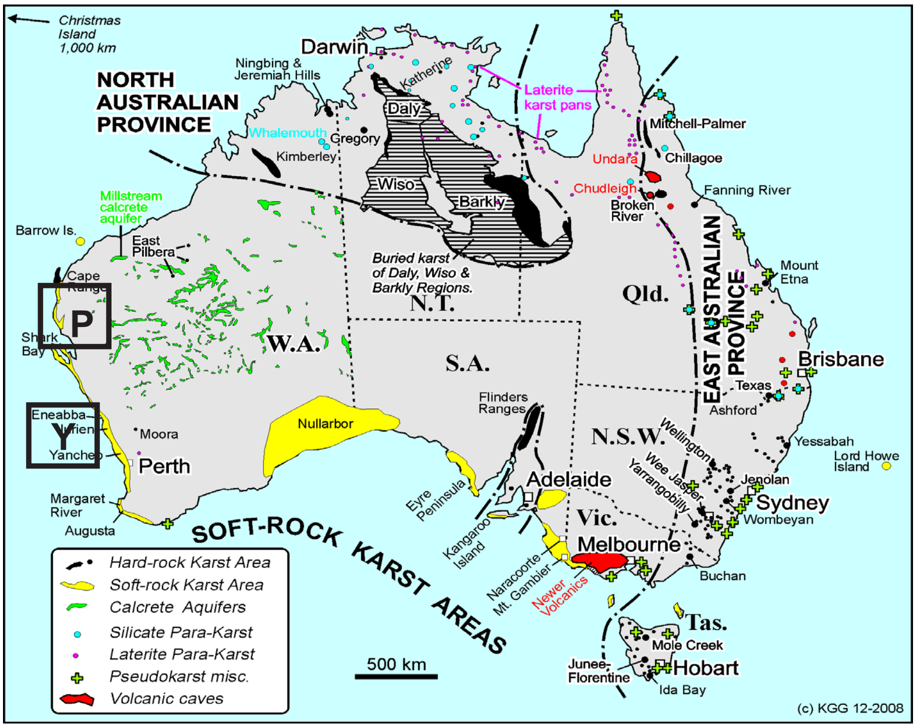


***Figure 1:** Karst Areas of Australia (after a map by KG Grimes)*

a starting point for potential habitat a map, (Fig. 1) indicates the known karst areas of Australia and the global biodiversity "hot spots" for stygofauna.

Threats

Stygofauna are clearly part of Groundwater Dependent Ecosystems, and are likely to be negatively impacted by activities that reduce groundwater tables such as extraction and harvesting or dewatering for mining along with outright habitat removal through rock extraction.

Threats to Stygofauna therefore include water abstraction, artificial filling and contamination of aquifers (including the clogging of pore spaces by mobilisation of fine sediments (Hancock, *et al.* 2005, in Humphreys, 2006b).

Depending on the location of the aquifer containing stygofauna, additional threats may also include sewage or effluent, pesticides, fertilizer, hazardous materials via accidental spills or deliberate dumping (Lewis, 2002).

Perhaps the most significant threat currently operating is the complete ignorance of the stygofauna's existence by land managers and regulatory agencies causing them to be ignored in assessment processes. This stems from the fact that very few areas have documented the presence of stygofauna (Humphreys, 2006b).

Case in Hand – An Application For a Groundwater Bulk Entitlement

In 2008, a Victorian water authority applied to the Water Minister for a bulk entitlement to annually extract an ***average*** of 7000 million litres of groundwater from a borefield. This is a large volume of water, enough for 35,000 homes a year. To date the environmental assessments have only considered the "terrestrial" Groundwater Dependant Ecosystems (GDEs) (D.S.E., 2008) The ecosystems that are 100% dependant on groundwater, the stygofauna, were not included in the assessment process.

An adequate environmental assessment process is critical to make informed and appropriate management decisions. A sound understanding of the possible species and communities present within and reliant on the aquifer is necessary to determine possible threats posed by actions such as extraction. This information is required to develop mitigation measures to prevent or minimize the threats.

Current knowledge and understanding of stygofauna

Humphreys (2006b) provides a number of references recognising the diversity of stygofauna on the western plateau of Australia with Thurgate *et al.* (2001a, 2001b, in Humphreys, 2006a) collating data from south-east Australia.

While the knowledge and understanding of Australian stygofauna is largely coming from the great diversity of species of the Pilbara and Yilgarn regions, limited research elsewhere in Australia indicates that significant stygofauna occur in other parts of WA and in NT, SA, TAS, QLD, NSW and Christmas Island (Humphreys, 2006b). Victoria is notable in its absence from this list. It is very likely that it is the lack of survey effort that is resulting in this lack of records. Seek and you shall find!

In a report by Humphreys (2006b) to the Australian State of Environment Committee, he notes that the focus of stygofauna research and hyporheic systems over the years have been respectively the Western Australian Museum and University of New England, with it broadening in recent years to include SA Museum, WA CALM, Queensland Natural Resources & Mines, Universities (Western Australia, Adelaide, Flinders) and consultancy bases. The focus of groundwater fauna research is present or developing in NSW, Queensland and SA. Victoria is again a notable absence from these research lists

A current study being undertaken by Flinders University SA, has found a wealth of stygofauna including new species belonging to Amphipoda (Neoniphargidae Bogidiellida, Chiltonidae, Melitidae), Isopoda (Heterias), Syncarida (Bathynellacae, Anaspidacae), Gastropoda (Hydrobiidae), Copepoda (Cylopoidea, Harpacticoidea),

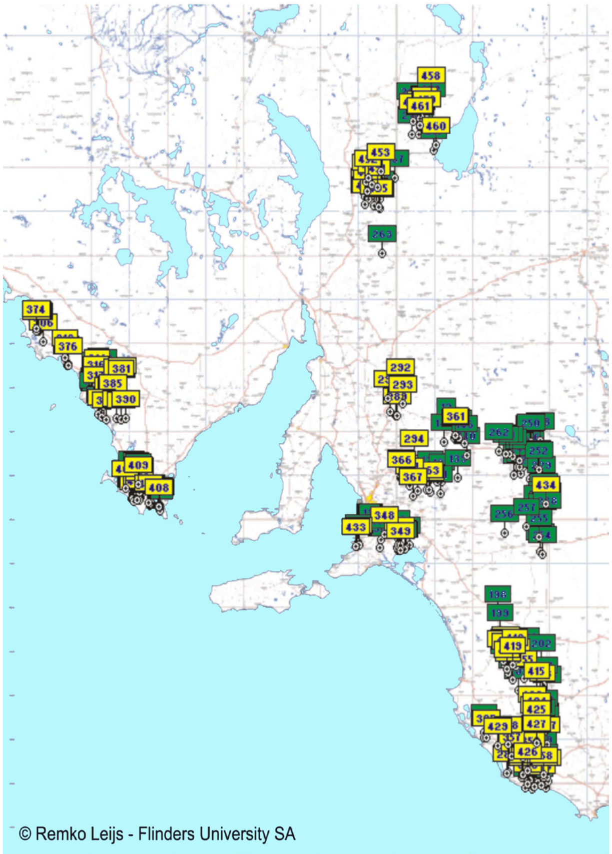


Figure 2. *Groundwater Stygofauna sampling sites in South Australia showing where stygofauna have so far been found.* ***Legend*** *Yellow Stygofauna present Green No stygofauna found*

(Map provided by Remko Leijs – Flinders University SA, January 2009)

Ostracoda and Oliochaeta (Roudnew and Leijs, 2008). Many of the survey sites are close to the Victorian border (Roudnew et al., 2008) (Fig. 2). A similar diversity may therefore be expected to occur in Victoria in the same or similar aquifers.

Legislation

WA is currently leading the way in Australia, in both surveys and taxonomic identifications, but also from a legislative point of view where subterranean fauna assessments and surveys are part of the Environmental Impact Assessment process with the WA EPA developing Guidance Statements. The EPA WA (2003, pp 5) Guidance Statement No. 54 states that "The EPA will require proponents to undertake a survey for stygofauna when a project may potentially have a significant impact on groundwater levels, groundwater quality, or subterranean cave and void systems."

Water resource policy in Australia is co-ordinated through the Council of Australian Governments (COAG), which agreed that water must be allocated for environmental use in 1994 (ARMCANZ, 1996, in Tomlinson *et al*., 2007). There is national agreement within Australia to manage groundwater better (COAG Task Force on Water Reform, 1996, in Humphreys, 2006a) with one of the key principles being that natural ecological processes and biodiversity are sustained and that water uses are managed in way that recognises ecological values (ARMCANZ, 1996, in Humphreys, 2006a). Obligate subterranean aquatic species, the stygobites, are clearly part of the most dependant groundwater ecosystem (Hatton and Evans, 1998, in Humphreys, 2006a) and need to be considered.

It is now becoming urgent to ensure that these Groundwater Dependant Ecosystems are fully assessed before they are threatened with extinction. Climate change and the current reduced rainfall and associated reduced groundwater recharge and increasing demand and extraction of groundwater are potential threats to these ecosystems. Groundwater allocations must be carefully assessed and regulated to maintain ecological sustainability.

"Escalating groundwater exploitation is outstripping social and scientific understanding of the sustainability of this resource" (Tomlinson et al., 2007, p 1317). A three staged approach for sampling has been put forward as a means of progressing our knowledge and understanding of the biodiversity of these ecosystems.

A Three Staged Approach To Sampling Stygofauna

Tomlinson et al. (2007) advocate a three staged approach to sampling, described below, where investigations progressively increase in complexity. It is seen as a means of overcoming the current situation of omitting stygofauna from groundwater assessment and monitoring because there is insufficient information for the interpretation of survey results.

1. This involves firstly establishing the presence of stygofauna using simple low cost sampling methods, monitoring bores, wells and springs. This should be the minimum compulsory assessment. Assessment of bore water is viewed as providing a representative sample of the associated groundwater aquifer. Hahn and Matzke (2005) undertook tests comparing the first water pumped from within the bore cavity and that sucked in from the aquifer as pumping continued. The results strongly suggested that bores contain all species found in the aquifer, albeit in different proportions.

2. The second stage is to identify the main types/groups of invertebrates present and the diversity of species present, even if it is just grouping the specimens and identifying them as species 1, 2, 3, etc. This is very useful, as early indications are that these groups differ in their tolerance to water-table fluctuations.

3. The final stage involves more detailed quantitative sampling and using taxonomic specialists to identify the specimens collected.

1. Establishing the presence of stygofauna

Using simple low cost sampling methods to monitor bores, wells and springs. This can be achieved using weighted plankton nets lowered down into a well, water pumped through a fine mesh, or simple "stygofauna traps" being left for several days. More information regarding sampling methods is available from the EPA WA web site, or the web page for the PASCALIS project, viewed 2009.

Weighted plankton/haul nets The net is lowered to the bottom of the bore, agitated vigorously to stir up the bottom sediments and benthic dwelling animals and then slowly retrieved. At least six hauls are required, and to increase the chances of capturing the size range of fauna (most between 0.3mm to 10mm (DEC, 2008)), half the hauls should be undertaken with 50µm net and the other half with 150µm net. The contents of each net haul should be emptied to prevent loss of specimens. Washing down the walls of the net ensures all specimens are collected. Net diameters should be two thirds the diameter of the bore to allow upward movement of fauna when lowering the net.

All samples collected should immediately be preserved in at least 70% ethanol (100% analytical grade ethanol if undertaking DNA analysis) (EPA WA, 2008).

Pumping and filtering This method may recover more animals but it is more time consuming, requires expensive equipment, is not suitable for very deep bores and may damage the animals collected. Different pumps cause different levels of damage to specimens. EPA WA (2008) provides more detailed information.

It is recommended that the volume of water pumped and filtered is either 300 L or three times the bore volume (eg. the purging water), whichever is greater (EPA WA 2008) Hancock and Boulton (2007, in EPA WA, 2008) have shown through sampling in eastern Australia that 300 L yields at least equivalent numbers of stygofauna to net-hauling.

Stygofauna traps are rarely used because they are more time consuming. They need to be set and left several days before collection, and so require more trips to be made. They generally consist of a suitably weighted and baited container being lowered into the bore and left for a few days. There is a risk of taxonomic bias as they appear to preferentially capture larger animals such as isopods and amphipods and generally miss the animals in the sediments (Hancock, 2007, in EPA WA, 2008).

In all cases, all samples collected should immediately be preserved in the field in at least 70% ethanol (100% analytical grade ethanol if undertaking DNA analysis) in fully labelled containers and taken back to the laboratory for detailed and careful sorting under dissecting microscope to ensure that nothing is missed (EPA WA, 2008). The EPA WA (2008) web page contains useful information on how to make sorting a bit easier.

The collected fauna can often be seen with the naked eye, so their existence, and that of GDEs can be determined in the field. This small effort would help alert the public to the presence of life in aquifers, confirm GDEs, and stimulate research and management attention towards groundwater ecology.

2. Identify the main invertebrate types/groups

Under a microscope, the preserved animals can be sorted into similar looking types or "morphotypes". The number of morphotypes provides some indication of the diversity and also allows broad comparisons to be made over time in an area. With some training, it is possible to distinguish the major groups of invertebrates. Some web sites and references are provided at the end of the paper to assist with identification and grouping.

3. Undertake more detailed studies using specialist taxonomists and quantitative sampling.

These more detailed studies are required to determine conservation issues and truly assess the biodiversity. This data is required to address issues such as: spatial and temporal variations of species abundance and diversity; correlations of community composition with physical and chemical variables; and application of the data to determine environmental water requirements.

Sampling for stygofauna in caves

Before any collection of fauna occurs, you need to ensure that all necessary fauna collection permits have been obtained from the relevant authorities, such as Department of Sustainability and Environment in Victoria and possibly Parks Victoria depending on land status. Populations of invertebrates in caves are often very small so collection may have a big impact. Initially photos may be the lowest impact method for the initial stages of recording what fauna occurs within caves.

Cave systems may support both stygofauna and trolgofauna that may then form part of groundwater dependant ecosystems. Caves may provide a variety of habitats for these species. Using the Victorian cave in far south west Victoria, Jones Ridge Cave DD4, as an example, the types of habitats that it provides include a flowing permanent stream, a waterfall that helps aerate the water, several pools that provide additional refuge habitat during low flow and particularly during drought, moist mud substrate the provides both food and shelter, and a sump that again provides refuge habitat during low flow and drought, but also plays a significant role influencing the climate (air flow and humidity) within the cave. Other caves may also contain root mats that provide both food and habitat within the cave, bringing additional nutrients into the cave.

Troglofauna and stygofauna in caves can be found with careful searching of the habitats mentioned above. Sampling might also involve the use of troglofauna traps, baiting, or using nets etc in streams or pools. Stygobiont animals that find refuge in the benthic layer may be captured by disturbing the sediment and filtering the water immediately down stream of the disturbed area. This can be achieved using a Surber sampler, a Hess sampler, or even a pond net (Fig. 3).

Caves and Habitat Protection

As cavers and speleologists, we need to be aware what else may be living in the cave and how our actions may adversely impact on those species. This may include stirring up mud in the stream, increasing the turbidity, the settling sediments may then smother niche habitats such as under and between rocks and may also impact the overall health of species. Artificially removing or damaging significant features within the cave, such as sumps, may have very adverse impacts by altering the hydrology and climate within the cave.

Detailed assessment including biological assessments should be undertaken and evaluated before rash ad hoc damage and destruction to caves, such as removal of sumps, or digs, is planned and undertaken.

Acknowledgements

Ken Grimes for providing the map of Karst Areas of Australia

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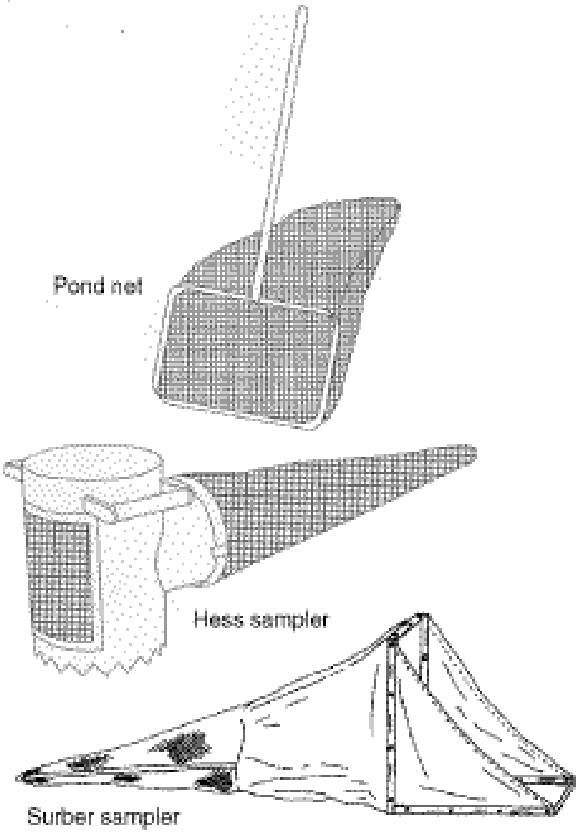

Figure 3. *Aquatic invertebrate sampling equipment. (Source: http://groundwater-ecology.univ-lyon1.fr/nouveau/methodes-souterraines.htm)*

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Useful Web Sites and References

Survey and Monitoring Methods

PASCALIS Protocols for the Assessment and Conservation of Aquatic Life In the Subsurface (ie monitoring protocols) http://www.pascalis-project.com/.

http://groundwater-ecology.univ-lyon1.fr/nouveau/methodes-souterraines.htm.

WA EPA Environmental Impact Assessment Guidance Statements http://www.epa.wa.gov.au/docs/1720_GS54.pdf.

Identification of Invertebrates, Subterranean Fauna

International Symposium of Subterranean Biology (held in Fremantle WA 2008) http://www.issb2008 org.au/gallery/ISSB/Stygofauna.html.

www.mdfrc.org.au/bugguide/resources/macroinvertebratetutorial.htm

http://www.mdfrc.org.au/bugguide/display.asp?type=1&class=19

Amphipods

http://www.mdfrc.org.au/bugguide/display.asp?type=3&class=18&subclass=33&Order=34&couplet=0.

http://www.mdfrc.org.au/bugguide/display.asp?type=9&class=18&subclass=33&couplet=0.

Pilbara Stygofauna Image Sheet

http://www.dec.wa.gov.au/images/stories/nature/science/pilbara/stygofauna/pilbara%20stygofauna%20sheet.pdf.

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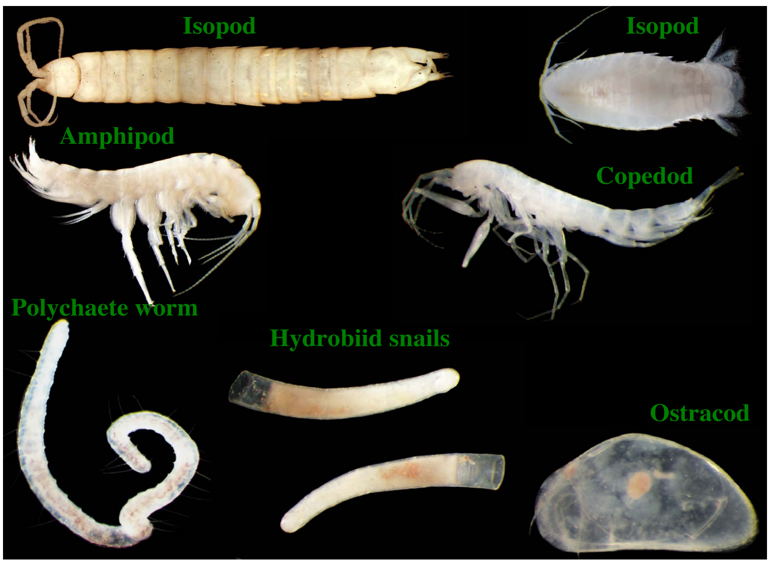

Figure 4 *Stygofauna images from http://www.dec.wa.gov.au/images/stories/nature/science/pilbara/stygofauna/pilbara%20stygofauna%20sheet.pdf*

The Jenolan Caves Survey Project as of 2008

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The Jenolan Caves Survey Project Group is preparing a "State of the Art" survey of the Jenolan Tourist Caves. The only complete survey of the tourist caves was carried out in the early 20th century and was published as a plan and section in 1925. A re-survey was commenced in 1987 and "Walls" (Texas Speleological Society) was chosen for reduction of the survey data because of its simple text file input and Scalable Vector Graphics output that imports directly into Adobe Illustrator. Cave entrances were linked by a surface theodolite network and tied in to the Australian Map grid. Computer drafting was performed using Adobe Illustrator as its brush and symbol libraries allow a consistent style and its layers are maintained when exported to Adobe Portable Document Format (PDF). An aerial surface survey with a resolution of five metres was used to produce a 3D model with the caves below the surface terrain. The current survey plan will be compared with that published in 1925. In collaboration with the Jenolan Caves Historical and Preservation Society naming and location of features has been carried out; so far 567 named features are identified. This detailed examination of the cave features has enabled the creation of "Then and Now" files in which older engravings and photographs have been compared with the present state of the features. The Adobe Illustrator files have additional layers that may be devoted to any particular task such as speleothem cleaning or infrastructure changes such as re-lighting a cave. The plan and surface map have been used to assess the impact of a car park on a cave and in a palaeontological study. It will be argued that for illustrating what visitors will encounter on a traditional or adventure tour, a developed long section and associated sketch is best.

Cave Invertebrates of the Northern Territory

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Due to an accident to the author, this paper was not presented at Karstaway

Abstract

Cave invertebrates from two karst areas in the Northern Territory were sampled during June and July 2006. The karst areas sampled were Pungalina in the Carpentaria region, and Bullita Cave in Gregory National Park. This was the first invertebrate sampling conducted at Pungalina. Invertebrates were sampled in both karst areas using a combination of hand collecting and baited pitfall traps.

Six caves at Pungalina were sampled which revealed a diverse and abundant fauna, particularly associated with guano deposits within the significant cave systems of Totem Pole Cave (PUN-7) and Ballroom Cave (PUN-11). Invertebrate groups collected included arachnids (spiders and pseudoscorpions), Myriapoda (millipedes) crustaceans (isopods, and anaspid syncarids), and insects, with the latter being the most diverse. Insects collected consisted of Coleoptera (Tenebrionidae, Dermestidae, Jacobsoniidae?, Scarabidae), Hemiptera (Reduviidae and Cixiidae?), Orthoptera (Grylloidea), Blattodea (Nocticolidae). The majority of all invertebrates collected were from the transition zone and classified as troglophiles.

Bullita Cave was sampled opportunistically in numerous sections of the cave to allow for possible varied invertebrate distribution within greater than 100 km of surveyed passage. Invertebrates were more abundant within the deep cave zones situated at the eastern and northern extent of the main limestone outcrop. Invertebrate sampling was also conducted in adjacent karst areas. Invertebrates collected included arachnids (araneae, pseudoscorpions, scorpionida) and insects (coleoptera, hemiptera, orthoptera, and diptera). Special note is made of the collection of a troglobitic scorpion (Buthidae: *Lychas*) from the deep zone of Bullita Cave. This single specimen represents only the third confirmed troglobitic scorpion recorded from caves in Australia (excluding Christmas Island).

Cave-Producing Processes in Soft Porous Limestone Regions of Southern Australia

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Abstract

Cave development in the Mount Gambier region, and indeed in soft porous limestones throughout Southern Australia, is very different to that of caves in the massive jointed limestones of Eastern Australia.

The minimal surface relief in Southern Australia is generally associated with caves developed at a single level, often at no great depth below the land surface. Equally obvious is the common single-chamber nature of these caves compared to the greater linear extent of many Eastern caves. Also, it is often clear where surface waters enter a Southern Australian cave, but not where they eventually leave it, in contrast to Eastern Australia where cave effluxes are more common than influxes.

It has long been my view that mixing corrosion has played a far greater role in the development of most caves than has been generally acknowledged, but I am now convinced that this is especially true of the Mt Gambier region in the Lower South East of South Australia. However, the 'solution-tube' features of the Mt Gambier area, which are crucial to the early history of many if not most caves of that region, are not corrosional (solution) but corrasional (abrasion) features. The processes involved in the development of the small Mount Gambier 'solution pipe' caves are of a series with those ultimately responsible for the development of large 'bottle-neck' caves like The Shaft; of large collapse dolines such as Mt Gambier Town Cave (Cave Gardens) and Umpherston Sinkhole; and of the deep 'cenotes' such as Hells Hole.

Key Words: solution pipe, corrasion tube, porous limestone, mixing corrosion, cenote, South Australia, Mount Gambier.

Overview

The 'Solution Pipes' of the Lower South East of South Australia are not solutional in origin at all, but are in fact corrasion features. With apologies to Cliff Ollier (Ollier 1982 p431), we could say that the Solution Pipes of South and Western Australia are a karstographic myth; Corrasion Tubes are however real enough.

These corrasion tubes do show a passing similarity to phreatic cave passages (as the Eastern Highlands show a passing similarity to a mountain range), and they are undeniably tube-like or pipe-like in shape. These facts combined have led to the name 'solution pipe' being applied, and its use has become universal.

Now one can argue that a name is just a name, but our use of language affects our thinking just as much as the converse, and there is a tendency to think that something called a 'solution pipe' is necessarily a solutional feature.

Certain key features give the lie to the notion of a solutional origin or a phreatic setting for what I shall hereafter call corrasion tubes. However, these features do not show up well on cave maps the way we usually draw them, and this (as was the case with Armstrong Osborne's eventual recognition of the true nature of paragenetic loops) has hindered the recognition of their real nature.

Caves and Cave Maps

The features of the way we map caves that have contributed to this lack of understanding are:

- an emphasis on the use of a *projected* plan view for the horizontal plane;
- a single *sectional* view (cross- or developed long-section) in the vertical;
- the near universal absence of even a single horizontal section of appropriate features; and
- the use of multiple sections of passages only to show varying cross-sections, and never to show the *unvarying* nature of a passage.

As illustrated in Figure 1 below, the corrasion tube (if not its remarkable nature) is visible in the long section, but almost disappears in the plan view.

Corrasion Tubes – dominant features

The dominant features which argue against a solutional origin are not all displayed to the same remarkable degree by all examples of corrasion tubes, but are displayed across such a large number of examples as to require an explanation consistent with a theory of the origin of the corrasion tubes.

Very many corrasion tubes display the following properties: incredible constancy of cross-section; remarkable straightness and near-perfect verticality

Though less remarkable than the above properties, the corrasion tubes also display a range of characteristic shapes. The most common shape is circular to sub-circular or oval. Amongst the rest, a figure-8 shape is very common. Whether this represents a true different shape,

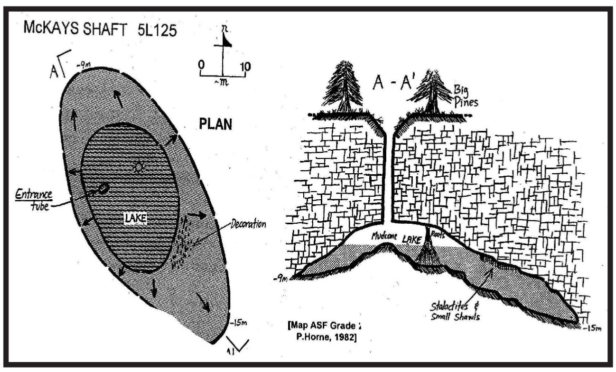

Figure 1: *Map of McKays Shaft (5L125). (Horne, 1993)*

or the overlapping of two sub-circular tubes is a question we shall return to later. For now we shall consider the three features noted above.

Constancy of cross-section

Some idea of the consistent size of the corrasion tubes can be gained from looking at the long sections of the caves, but this gives little idea of either the actual cross-sectional shape or of its incredible constancy.

Typically of a 'diameter' of 0.3 -1.0 m and a (vertical) length of 5 - 15 m, the corrasion tubes usually have walls that are not totally smooth, but display a rippled surface 'texture' at a scale of 1 - 2 cm. Apart from a metre or so at the top of the tube, which may be somewhat widened, and a slight narrowing often seen in the bottom half metre or less of the tube, the size and shape of the tube is typically very constant along its length.

Many if not most of the corrasion tubes display a cross section over most of their length that is constant in both size and shape to within the scale of the surface texturing of the walls – that is, to within a 1 or 2 centimetres.

This is remarkable, and is certainly not typical of cave passages which are of unargued phreatic or solutional origin. Phreatic passages may show a rough consistency of cross-sectional area along parts of their length, and even sometimes a similarity of shape for some distance (e.g. 'tear-drop' joint-guided passages, or oval passages aligned with the bedding), but in my experience phreatic cave passages never show the absolute constancy of size and shape that is so common as to be characteristic of the corrasion tubes.

Remarkable straightness

Although 'linear' features are not uncommon in nature generally, such features when examined more closely usually prove to be distinctly sub-linear. Corrasion tubes are very often truly linear to the degree that can be determined by eye, and to within the 1 or 2 cm of surface texture of their walls. Where they are not linear over their entire length, they often show 2 linear segments with a simple offset part way along. This offset is typically of the order of the tube's diameter or less, so that it is still possible to look through the entire length of the tube.

True phreatic passages *never* show this degree of linearity. Even where they show a fairly regular cross-section it is rarely possible to see more than a few metres along them due to their varying direction – i.e., their lack of straightness. Joint-and-bedding-controlled passages may occasionally display the kind of straightness that is typical of corrasion tubes, but these passages are not solutional features.

The only solutional features which typically display this degree of straightness are those associated with a water surface (e.g. river incuts), and for obvious reasons these are always horizontal or, where rock movement has occurred since their development, sub-horizontal features. They are *never* vertical!

So corrasion tubes appear to be unique amongst cave features in being truly straight and vertical, and are certainly unlike any known solutional cave features in this respect.

Near-perfect verticality

I have not had the opportunity to properly measure the properties of a range of corrasion tubes (cross-section, straightness and verticality), but I have dropped ropes down a fair number of them and many or most appear to be vertical to within a few degrees or less. Although many natural features may typically be sub-vertical (e.g. trees, cliffs, joint planes in sedimentary rocks), few if any are typically truly vertical as is the case with corrasion tubes.

Indeed, corrasion tubes show such a dominating verticality that it may well be true that any deviation from verticality must be due to rock movements since the tube's formation. If this is so, then a survey of the precise angles of a range of corrasion tubes (combined with dating of the material found below them), may well prove to be a method for determining the history of small scale land movements in a region.

Although a generalisation, it is probably true that all natural features which are truly horizontal or are truly vertical have been guided or controlled by gravity. Corrasional processes may be driven and therefore guided by gravity; solutional processes, dominated by random ion transfer processes in a fluid, are not gravity controlled (except insofar as the fluid surface and processes associated with it, such as river incuts, may be horizontal). The evidence against a solutional origin for these tubes, and in favour of a corrasional process, seems to be mounting.

One further important feature of corrasion tubes is that they occur commonly in recent, poorly consolidated limestones such as Tertiary or Quaternary shelly marine limestones or coastal aeolian calcarenites, but never in hard massive Palaeozoic limestones such as are typical of the east coast of Australia. These recent unconsolidated limestones are characterised by their softness, and by high porosities and permeabilities compared to other limestones.

We shall now examine how the development of the corrasion tubes may have been affected or guided by these characteristics of the limestone in which they form.

Features of modern, unconsolidated limestones

The features of modern, poorly consolidated limestones which are relevant to the present discussion are:

- they can be *incredibly* soft;
- they have very high porosity and permeability;
- caprocks can form very quickly; and
- caprocks may be remarkably similar to those on more massive, consolidated limestones.

These features, and the effects they have had on the development and nature of the caves found in the Lower South East of South Australia, are discussed below.

Softness of the rock

'Limestone' is an over-loaded word! It is used to refer to a range of rocks that, apart from broad chemical composition, show probably less similarity to each other than do chalk and cheese. East coast cavers think of limestone as this stuff that, depending how hard you hit it, will break either your hammer or your wrist. Climbing holds are strong and reliable, and while their contents may be delicate the caves themselves are extremely rugged, and the concept of 'sacrificial caves' that can be damaged but not destroyed by Scout, school and army groups at least makes some sense.

The contrast with Western Australian aeolian calcarenites, and the caves developed therein, could hardly be greater. Here I once wondered about the integrity of the rock comprising the ceiling under which I was passing. I tested it with my finger tips and three fingers disappeared into the 'rock' up to the second knuckle! I did not hang about to conduct more tests. Climbing on such rock inside a cave can be more a matter of luck than skill.

Limestone such as is found at Jenolan Caves is so hard as to be virtually immune to mechanical attack except under the most extreme of energetic conditions (e.g. major flood flows with contained abrasive sediments and rocks), and it can be fairly said that most cave features, even if structurally guided, are solutional in form. Even undeniably vadose sections of caves are often modified phreatic passages after lowering of the local water level in that section of the cave.

The converse is true of the very soft South and West Australian coastal limestones, which are typically so soft that mechanical breakdown will rapidly erase any traces of solutional processes which may have operated in their past. It is often only underwater (where they are still operating), or very near the ground surface (where they are preserved in the harder surface caprock) that solutional processes are evident.

Porosity and Permeability

An important characteristic of the unconsolidated marine limestones and aeolian calcarenites is the existence within them of extensive, and extensively connected, pore spaces. The percentage of the rock which is pore space – and which may potentially be occupied by water – is its porosity. The connectedness of these pore spaces determines how readily water may pass through the rock – as through a sponge – and is measured as the rock's permeability.

The high porosity and permeability which are typical of these limestones means that water can move within the rock body (whether as a ground water mass or as meteoric water percolating down through the rock), without the prior development of conduit-type passages within the limestone. The porous and permeable nature of the rock affects the way that water flows through the rock, and ultimately the style and nature of the caves that develop within it.

That ground water movements around Mt Gambier and similar locations are primarily by percolation through the porous limestone, and not by conduit flow as in underground rivers, is supported by two kinds of evidence;

1. Studies of trace elements and pollution movement within the region such as that undertaken by J. D. Waterhouse of the S.A. Department of Mines (Waterhouse, 1984)

2. The complete absence of any long conduit-style caves in the region discovered by either wet or dry cavers.

Thus the typical cave of the Lower South East comprises a single chamber, or a number of highly interconnected chambers within a small geographical area, connected to the surface by one or more sub-vertical entrances. The multi-chamber caves (Snake Hill for example) are generally sub-circular in overall plan (as opposed to being elongated or linear in overall shape), and may represent a number of single-chamber-single-entrance caves which have overlapped or intersected each other.

Exceptions to this pattern exist – most obviously Tank Cave with its several kilometres of grid-network passages and absence of large chambers, and those linear caves such as Morgans Cave which appear to be developed for short distances along near-surface joint structures – and these require a different theory of their origin and development. However, the pattern of caves with a single sub-circular to oval chamber, and one or a few vertical entrances, clearly exists and requires explanation in terms of the regional landscape, climate and rock types.

Development of caprocks

It is my experience that all limestone caprocks are remarkably similar, compared to the wide range of different limestones on which they form. Indeed, the caprock is typically so hard and impermeable as to be similar to the ancient massive east coast limestones which are too impermeable to ever form a distinct caprock layer at all.

The caprock thus often conceals the true softness of the underlying limestone.

It is also noticed, from an examination of road cuttings in the Mount Gambier area, that the caprock develops to a significant depth on any upwards-facing surface in a matter of a few decades. (Overhanging surfaces not directly subject to rainfall and runoff remain soft, with no caprock, on these timescales).

As near as I have been able to determine this caprock constitutes a continuous surface covering, largely impermeable to water, irrespective of at least a thin covering of soil and vegetation. Thus, after development of the caprock, any rainfall tends to run across the surface rather than penetrating the rock and descending to the water table over a large area.

However, the caprock is regularly perforated by half-meter scale holes which allow the rainfall to penetrate the surface, so that at a broad scale there is the lack of surface drainage that is typical of limestone terrains.

Some of these perforations are in the form of corrasion tubes penetrating to caves beneath. It is my contention that the remainder are 'failed' corrasion tubes, and that all are due to the existence of a tree early in the landscape history – i.e. before the caprock was able to form. The 'failed' corrasion tubes are those which have not developed a cave beneath them into which material may fall; the tube has therefore been filled in by sediments descending from the surface.

How Corrasion Tubes get Started

Figure 2 (below) shows a number of similar features appearing in the wall of a quarry near Penola in South Australia. They are in my opinion 'failed' corrasion tubes, and evidence from quarry walls would suggest that such 'failed' tubes are much more common than the 'suc-

Figure 2: *'Failed tubes' in wall of quarry near Penola, SA. (Photo by author)*

cessful' tubes with a cave existing beneath them.

I believe that these features represent the root systems of trees which existed early in the landscape history before the development of an impermeable - and essentially impenetrable - caprock. The existence of similar features in non-carbonate landscapes, as in Figure 3 below, argues that these are not solutional features, but are formed by the mechanical action of tree roots pushing the still-soft sediments aside.

The evidence supporting the contention that the corrasion tubes are due to trees established early in the history of the landscape falls into two categories: the evidence that they are due to or associated with trees; and the evidence that said trees must have existed very early in the landscape history. These two are discussed separately below.

Evidence for a tree-related origin for the corrasion tubes

The evidence for a tree-related origin for the corrasion tubes is circumstantial and not totally conclusive, but is nevertheless quite strong. It comprises:

• the number and distribution in the land-scape of the tubes;

• their size and shape;

• the necessary association of a tree with a hole in the ground for its roots; and

• the apparent lack of any other reasonable explanation.

Figure 3: *Erosion gully and 'failed tube' feature in siliceous sands, near Lake Mungo, NSW. Photo: Wayne Cook.*

The number of corrasion tubes, and their spatial distribution in the landscape where the limestone is reasonably exposed, is not dissimilar to the number and distribution of trees in those areas which seem representative of the natural landscape; and is similar to the apparent distribution of trees in such records as we have of the landscape prior to occupation and clearing by European settlers. An important source of information regarding the latter distribution is in the paintings of George French Angas, dating from the mid to late 1840s, many of which were examined by this author when on display at the Riddoch Art Gallery in Mount Gambier. Angas's paintings also provide interesting evidence regarding pre-settlement water table levels, suggesting that they may not have been as much affected as is generally believed by past and current European land use practices. Of course neither the precise number of existing tubes nor the precise early distribution of trees is known, but the numbers and distribution appear sufficiently similar to not discount the hypothesis of a causal link between the two.

The typical size range of the corrasion tubes, being between 300mm and 1 m, is certainly consistent with the normal diameters of the trees presently found in the landscape.

The shape of the corrasion tubes is normally circular or sub-circular, and this is certainly also true of the trees in the landscape. More compelling, however, is the coincidence between the second most common shape of the tubes and the second most common shape of tree trunks, being that of two overlapping circles, or a 'figure-8' shape. Without having done an actual count, it would appear that a few percent of corrasion tubes and of trees adopt this shape. It seems highly significant that *no other shape is common for either trees or corrasion tubes*.

We know that where a tree exists, a root system exists to support it, and that said root system requires a void in the ground, be it of soil or rock, to contain it. That void or hole, at its top, would be about the size and shape of a typical corrasion tube.

Finally, while a causal association between tree roots and corrasion tubes seems on the face of it to be reasonable, and supported by the evidence quoted above, no other explanation has to my knowledge emerged which is consistent with the all the observed features. Certainly the idea of a solutional origin does not appear to fit the known facts.

Evidence for an origin early in the landscape history

Examination of road cuttings has convinced me that a caprock of significant depth (10 cm or more) forms very quickly on exposed limestone of the porosity and permeability which is typical of the Lower South East. (Whether it forms at a similar rate when under a thin soil cover is still an open question, but there seems no reason to believe that such a soil cover would significantly retard its development; indeed, it may even enhance it by acidifying the water passing through, and hence promoting the dissolution and redeposition of carbonate which appears to create the caprock).

Once the caprock has formed, it is very hard and brittle. It is therefore unlikely that the roots of a tree would be able to penetrate it, and nearly certain that if they did so, then there would be evident cracking of the rock around the resultant hole or tube. Having viewed many tens or hundreds of such tubes, from both above ground and from within the caves beneath them, I have NEVER seen any cracking of the rock around them, nor any secondary evidence such as pieces of the limestone beneath the hole. Where the hole is occupied by an existing set of tree roots, the roots conform to the shape of the hole with no indication of their having modified that shape. Thus in typical ‘corrasion tube caves’, there are often roots penetrating the ceiling of the cave in a circular or sub-circular form (this is typical of dive sites such as The Pines and others, as well as many of the dry caves in the pine forests around Mt Burr and elsewhere). Where there are slot-like holes in cave ceilings, as is the case in apparent near-surface joint controlled caves such as Morgan’s Cave, the tree roots emerge in a fan form along the linear crack. In neither case is there any evidence that the current root system has in any way modified the shape or size of the hole that they occupy.

The above all suggests that the tubes have formed early in the landscape history, while the rock even at the land surface is still soft and ‘crumbly’, rather than hard and brittle. This would place the formation of the initial holes through the surface of the rock in the first few decades of the existence or exposure of that land surface, and thus within the first generation of tree coverage of the landscape. Later density of tree coverage – except where a significant later soil cover has developed – may in fact be limited to that of the original coverage by the need for new trees to re-occupy earlier root holes.

The Role of Mixing Corrosion

Mixing corrosion occurs when two waters of different chemistry (usually, but not necessarily, different CO_2 contents) are mixed. Even if both water sources are individually saturated with respect to calcite, the product of their mixing will be under-saturated and hence will again be aggressive (i.e. able to dissolve more calcium carbonate). This process, responsible for much cave development, is explained in Figure 4 below.

I will argue that ground water moving by percolation through porous rock such as that found in the Lower South East rapidly becomes saturated (and loses its aggressiveness to limestone), and so cannot be directly responsible for the formation of caves far from its point of origin. Cave development requires that some process renew the aggressiveness of the water; and that process usually, and in this case, is mixing corrosion. (Of interest here is Alexander Klimchouk’s ‘Hypogene Speleogenesis’ which clearly relates the development of deep phreatic or hypogene caves to the ‘leakage’ of water between different depth aquifers, or between the surface and deep aquifers – i.e. to at least the possibility of mixing corrosion.)

The actual chemistry of the dissolution of limestone in water (with carbon dioxide present) is surprisingly complex, as Figure 5 below suggests (Dreybrodt, 1988) However the following generalisations are reasonable:

• in an open system (i.e. open to an 'air' surface from which the water can continue to absorb CO_2), the rate-limiting factor for the complete process is the rate at which CO_2 is dissolved into the water, and

• that in a closed system (no access to an 'air' interface to replenish dissolved CO_2), the ovarall rate-limiting factor is the diffusion of ions across a laminar flow interface near the limestone walls.

Seepage flow through porous rock is essentially a closed system. However, even though the actual flow between grains is laminar, the mixing of packets of water at the boundaries of grains makes ions diffuse at the larger scale as though in a turbulent flow. Ion diffusion is therefore rapid, and the process comes to equilibrium (and the water becomes saturated) very quickly – within minutes if not within seconds.

Given that the ‘residency’ time of ground water in its aquifer is usually estimated in terms of centuries or

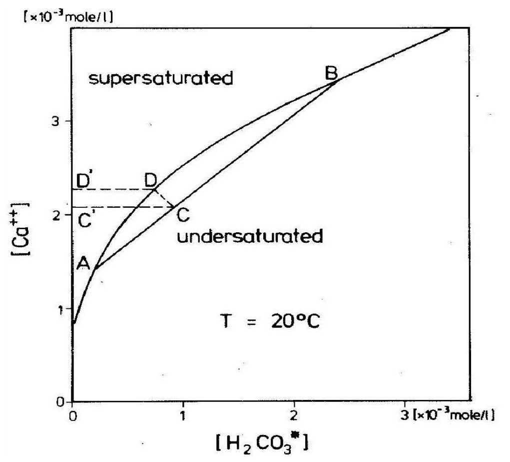

Fig. 2.16. The equilibrium curve divides the $[H_2CO_3^*] - [Ca^{2+}]$ diagram into two parts. *Above*: The curve solutions are supersaturated; *below*: undersaturation exists. Mixing of two saturated solutions (*A*) and (*B*) leads to an undersaturated solution (*C*). The additional amount of Ca^{2+}, which can be dissolved after mixing is given by $\overline{C'D'}$

***Figure 4:** Mixing corrosion with saturated waters. (Dreybrodt 1988 p29.)*

millennia, the statement above that 'ground water …. cannot be directly responsible for the formation of caves far from its point of origin' would appear to be justified.

It is worth noting that while mixing high CO_2 saturated water from the surface with different but also saturated ground water will lead to dissolution and the enlargement of any cave, the descent of high CO_2 saturated water of itself is more likely to lead to the deposition of calcite within a cave (due to off-gassing of CO_2 into the cave atmosphere). Thus it is well decorated caves, rather than large caves, which may be indicative of a past vegetative cover, and high CO_2 content in infiltrating water.

Other Modifiers of Aggressiveness

Mixing corrosion is not the only factor which can change the aggressiveness of otherwise saturated water. Some other factors are considered below.

• Rising CO_2 – usually of volcanic origin – can first increase and later (with reducing pressure) decrease the aggressiveness of ground waters through which it passes. This may have played a role in some of the deeper cave developments in the Lower South East, though not in the development of corrasion tubes and their associated caves.

• Sulphate chemistry can have very significant effects on the aggressiveness of ground water or meteoric waters entering a cave. While this has likely played a role in the Nullarbor, there is no evidence of it having done so in the Lower South East.

• Reduction of the temperature of water generally increases (or renews) its aggressiveness. This is unlikely to be a significant factor.

• Other dissolved ion species (Magnesium, Nitrates, etc) can have complex effects on the aggressiveness of water; however such effects are probably of small consequence except in highly extreme water chemistries.

Where phreatic waters are very still, gravitational stratification of the water body may render the upper part of it aggressive – producing 'un-mixing corrosion'. (I have previously postulated that convection cells based on this process are responsible for the development of the highly conical, half metre scale ceiling cavities found in some of the caves at Naracoorte).

While rising CO_2 and sulphate chemistry can be significant factors in cave development where they occur, mixing corrosion between waters with different CO_2 contents is the generally dominant mechanism producing renewed aggressiveness of water and the development of large cave passages and chambers.

Early Stage Development of a Corrasion Tube Cave

If, as claimed above, the development of an incipient corrasion tube is associated with a tree occupying the landscape prior to the development of a caprock layer, the next question is how and why some of these develop to the next stage; an actual corrasion tube with a cave beneath

The full development of the tube and the development of the underlying cave are intimately linked. The process depends on the tree roots actually reaching the water table, allowing access to the ground water by meteoric water (rain water) entering the hole created by the tree roots (either while the tree still occupies the hole or after the demise of the tree). Mixing corrosion can then occur and a cavity – i.e. a small cave – can develop below the root cavity.

Following the final demise of the tree (or series of trees) occupying the hole, and also following the development of the caprock layer, water is able to freely enter the hole and fall to the (small) cavity below. Two things now occur:

1. While the shape and size of the top of the hole are protected and preserved by the hard caprock layer, the falling water is able to mechanically abrade (i.e. corrade) the still very soft limestone below the surface. Since the water falls under the influence of gravity, the tube ends up with absolutely vertical walls and hence has a regular cross section (shape and size) for its whole length.

2. Mixing corrosion continues to occur in and around the underlying cavity as the rain water enters and mixes with the ground water, thus enlarging the cavity into a full-blown (albeit single chambered) cave. This allows room for the material falling down the tube from the surface, as well as the material abraded from its walls, to be accommodated without blocking the tube.

Hence both the corrasion tube and its underlying cave are formed in concert by the one process. This early stage of the corrasion tube and cave development is illustrated by the example of 5L184 shown in Figure 6.

Of course in many cases sediments will enter the hole at a rate which exceeds the ability of corrosion to either

Systems CO_2–H_2O and $CaCO_3$–CO_2–H_2O

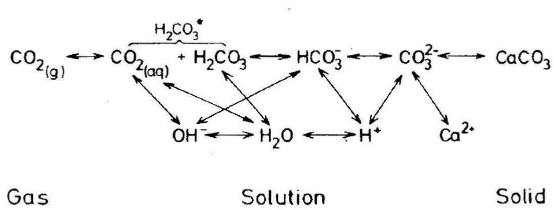

Fig. 4.1. Chemical reactions during dissolution of $CaCO_3$ according to the system CO_2–H_2O (Usdowski 1982)

The generally used reaction equation for dissolution of limestone:

$$CaCO_3 + H_2O + CO_2 \rightarrow Ca^{2+} + 2\,HCO_3^-$$

is such an overall reaction, since it comprises three reactions not appearing explicitly in this equation.

Figure 5: Chemistry of dissolution of Calcium Carbonate in a 'simple' Ca CO_3 – H_2O – CO_2 system. (Dreybrodt 1988 p62.)

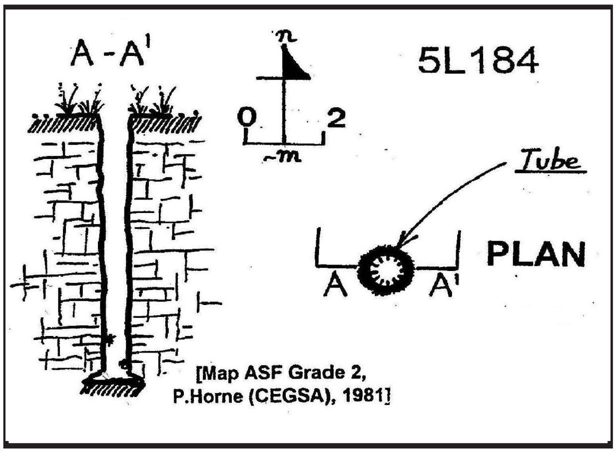

Figure 6: Map of karst feature 5L184. (Horne, 1993).

remove or, alternatively, to create sufficient space for by the enlargement of the cavity. In this case the tube will either fail to complete or will be blocked by the infalling sediments. This is most likely to happen early in the development process; or where there is a large quantity of non-soluble (probably siliceous) sediments; or both. If the tube blocks after the development of a cavity or cave below, then the cavity is likely to remain, but not to further enlarge due to the absence of entering meteoric water to drive the mixing corrosion process. 'Incipient' or 'failed' corrasion tubes (as seen in the quarry wall, Fig. 2, above) appear to be more common than 'successful' corrasion tubes with underlying caves.

Where the tube reaches the underlying water table, and does not become blocked by infalling siliceous sediments early in its history, the enlargement of the underlying cavity or cave is enhanced by the porous and permeable nature of the limestone. This allows the mixed water to actually enter the rock around the existing cavity; thus the cave forming process can proceed much more rapidly than it would in a massive limestone, and dissolution of the cave may stay ahead of the filling of the hole by infalling sediments.

Note that where several trees are close to each other, only one of them need 'succeed' as a cave-forming corrasion tube; it creates the cavity within which material from the other 'incipient' tubes may be accommodated, thus helping the other holes to eventually become 'proper' corrasion tubes. This may explain the number of caves which have (or obviously have previously had) multiple corrasion tube entrances.

The Collapse or 'Cenote Forming' Stage

As the cave or chamber below the corrasion tube gets larger, breakdown of the walls and ceiling will start to occur. This process may accelerate if the water table falls, or the ceiling recedes, sufficiently to remove any support of the rock due to buoyancy.

Regardless of the shape of the resultant chamber, it is a mistake to think in terms of 'dome chambers' or, worse yet, 'collapse domes'. In soft, weak, horizontally bedded limestone such as is found in the Lower South East of South Australia, the relevant structural paradigm is not that of a dome, but of cantilevered beams. Particularly if the bonds between the beds or layers of limestone are weak, each layer will act as a cantilevered beam and is subject to maximum stress - and therefore most likely to break off – where it overhangs the layer beneath. The end result is typically sub-vertical walls, and a flattish or stepped horizontal ceiling which continues to retreat.

If the water table remains high and mixing corrosion continues to occur, then the fallen material will tend to be removed; the 'floor' height will tend to remain stable as the ceiling recedes; and the chamber will get larger. If however the water table falls below the effective floor level (or if the corrasion tube entrance becomes blocked), then the removal of material by mixing corrosion will effectively cease; and since the fallen material takes up more space than it did in situ, the cave will actually get smaller as it rises. Eventually the cave may fill with its own breakdown material, providing support for the ceiling, and halting the breakdown process.

The retreat of the ceiling due to breakdown may also become stalled at a particularly competent layer of rock – such as the caprock – resulting in a large cave still with a (probably shortened) corrasion tube entrance. The Shaft is an example of this type of cave. Alternatively the ceiling may retreat all the way to the surface resulting in a 'cenote' such as Hells Hole, or (depending on the current water table level) a dry cylindrical doline such as Umpherston Sinkhole.

The Complete Development Sequence Summarised

The table below summarises, and Figures 7 to 11 illustrate, the complete development sequence discussed in this paper, from original tree roots to final (wet or dry) cylindrical doline. As discussed above, the process may halt at virtually any of these stages, and for a variety of reasons. In particular, significant amounts of siliceous sediments may enter the cave, blocking either the entrance tube or access to the water table, and preventing further enlargement by mixing corrosion. The cave or doline may then become partly or completely filled by silicates.

Many of the caves of the Lower South East of South Australia appear to represent one or another of the stages in this sequence.

Corrasion Tube Caves – stages of the postulated development sequence:

1. Trees penetrate the still-soft limestone with roots reaching to the water table (Fig. 7).

2. Mixing Corrosion at or near the water table produces a cavity within the rock (Fig. 8).

3. Corrasion Tubes form by water abrading the sides of the root hole, with excess material being accommodated in the existing cavity (Fig. 8).

4. Enlargement of the cavity occurs by mixing corrosion involving meteoric water – possibly enriched in organic CO_2 – entering via the corrasion tube and mixing with the ground water (Fig. 9).

5. Breakdown of the cantilevered beam structure of the chamber causes the walls to become more vertical and the ceiling to retreat upwards (Fig. 10).

6. Continued mixing corrosion of the fallen material at or near the water table allows the chamber to become larger (rather than choking and becoming smaller) as the ceiling rises through the landscape (Fig. 10).

7. Eventually the ceiling may break through to the surface producing either a dry cylindrical doline, or a 'cenote' (a wet cylindrical doline) (Fig. 11).

Note that the use of the term 'cenote' with reference to the open, water-filled caves of the Lower South East may, like 'solution pipe', be misleading and should perhaps be re-considered. There is little if any evidence to suggest that caves such as Hells Hole have formed in the same way as the 'classical' cenotes of the Yucatan. They do not resemble them in shape or form, and importantly are not inter-connected by conduits below the water table. However, they are clearly related to the dry cylindrical dolines of the Lower South East such as Umpherston Sinkhole, Town Cave etc, and should perhaps simply be called wet cylindrical dolines.

Corrasion Tube Caves - some final thoughts

We have established that the intersection of a corrasion tube and its associated underlying cave is not accidental; the two features are geomorphically related. We also know that corrasion tubes can close off due to accumulation of sediment cones in the cave below, but may also re-open due to erosion of those sediment cones.

Such is the nature of the landscape in the Lower South East – flat and generally quite clear – that we can be fairly confident that the overwhelming majority of the open corrasion tubes leading into caves are known. Even within the pine plantations (where obviously the tree cover is denser), most such cave entrances have been found and often fenced off to prevent damage to equipment or, one hopes, to the cave.

Now, while blocked corrasion tubes which intersect a cave may be difficult to locate and identify from above ground, they are generally quite obvious from within the cave. It is a simple (if time-consuming) matter to enter these caves and count the number of open, and the number of blocked corrasion tubes intersecting each cave.

Given this information – the statistical distribution of the number of blocked and the number of open corrasion tubes per cave for those caves where the latter number is greater than zero – it should be possible to make an estimate of the distribution of the number of blocked tubes per cave for those caves where the number of open corrasion tube entrances is zero.

Furthermore, using bulk single grain luminescence dating of the silicates from the sediment cones beneath both blocked and open corrasion tubes, it may be possible to estimate the rate at which the blocking and re-opening cycle of the entrances typically operates, and therefore the percentage of the time that a corrasion tube entrance typically remains open. (The Photon Counting Imaging System, a new variant of luminescence dating technology currently under development by the author, should make such a large single-grain dating project feasible at a future date.)

Finally, by combining the above two estimates, it may be possible to deduce a figure for the total number of caves in the Lower South East of South Australia, with one or more blocked corrasion tubes and exactly zero open corrasion tube entrances. It would then be possible to provide something other than a facetious answer to the apocryphal tourist question: 'How many undiscovered caves are there?'

Acknowledgements

Many thanks to Peter 'Puddles' Horne for his 'Lower South East Cave Reference Book' (Horne 1993), and permission to reproduce the maps that appear in this paper.

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Figure 7: *Development Process Stage 1.*

Tree roots penetrate the soft limestone before the caprock forms.Photo of a quarry wall near Penola, S.A. (Photo by author)

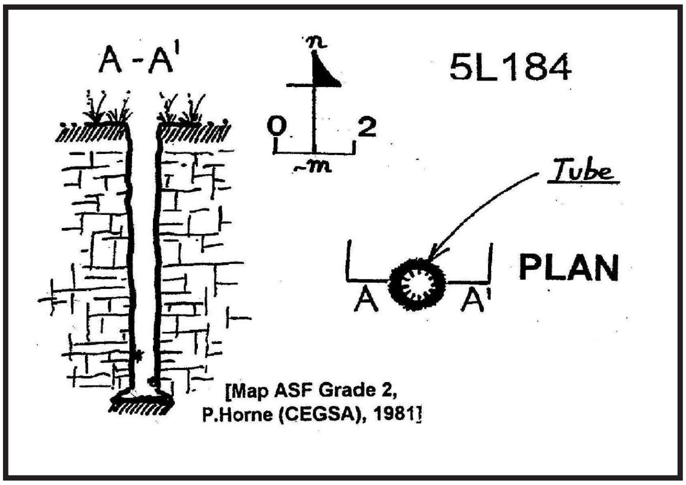

Figure 8: *Development Stages 2 and 3 Corroasion tube forms over small cavity. (Horne 1993)*

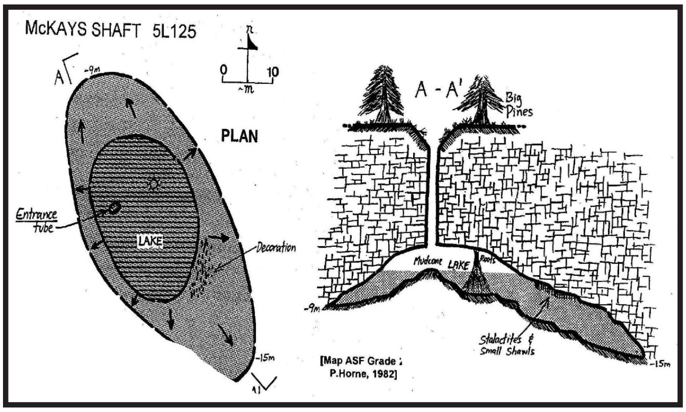

Figure 9*: Development Stage 4. Enlargement of cavity by mixing corrosion. (Horne 1993).*

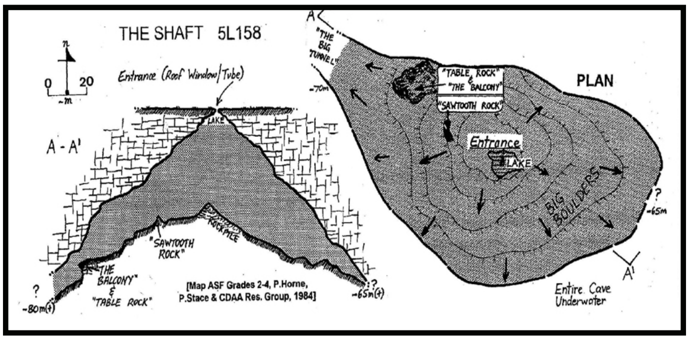

Figure 10: *Development Stages 5 and 6. Wall collapse and retreat of ceiling. (Horne 1993).*

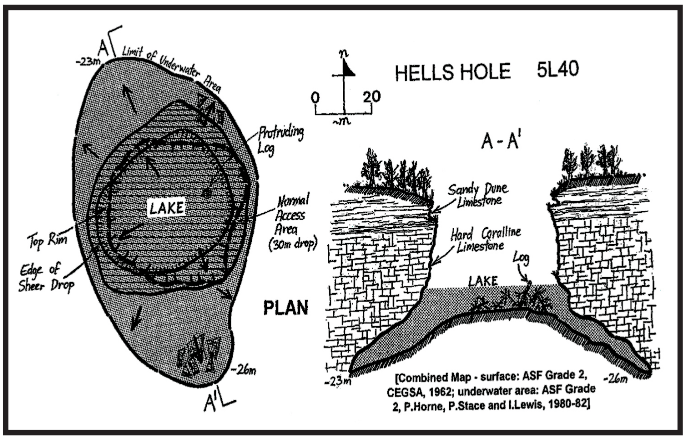

Figure 11: *Development Stage 7. Breakthrough to surface and 'cenote' formation. (Horne 1993).*

Cave Photography with Digital Cameras

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Abstract

Taking photographs in the damp and confined spaces of a totally dark cave is not everyone's idea of fun. A caver can take 'happy snappy' shots with a point and shoot Compact camera using only light from the camera's inbuilt flash, but the images achieved from this type of photography can be very flat and lifeless. To achieve a more in-depth photo with plenty of contrast (Fig.1), a cave photographer needs to become more dedicated to the art of flash illumination in order to capture that 'wow' factor image.

This paper describes in simple terms the fundamentals of digital cameras and main distinguishing features between the three broad classifications: Compact, Prosumer and DSLR. Also discussed is equipment suitable for cave photography and what to look for when purchasing a camera and flash unit.

Other topics covered include choosing the photo subject, composition, lighting, framing the subject, taking the picture and general flash photography tips.

Figure 1: *Caver admires the Ice Cream Cake in Croesus Cave Tasmania.*

Camera fundamentals

A digital camera is basically a box holding a lens which directs light onto a photosensor element which captures the image, then stores it on a memory card as a digital file.

There are two main types of photosensor element; Charge-Coupled Device (CCD) and Complementary Metal–Oxide–Semiconductor (CMOS), which for the purpose of this paper will be collectively referred to as a 'sensor array'.

A camera has basically three adjustable control elements which the operator can play around with if the automatic setting is not used: aperture, shutter and ISO.

The aperture is the variable opening (hole) through which the light passes before reaching the light sensor array. The aperture is defined by numbers such as f/1.2 which is generally the largest opening, and get progressively smaller down to, f/6.4, f/7.1 and f/8. Some cameras may have apertures as small as f/22. Besides controlling the amount of light which reaches the sensor array, the aperture controls the 'depth of field' in the picture, allowing the photographer to determine how much of the image is in or out of focus.

The second adjustable element is the shutter speed which relates to the length of time the sensor is exposed to the light. This is measured in fractions of a second such as 1/60th of a second. For flash photography, most cameras will not synchronise with a flash unit if set faster than around 1/100th of a second. Setting a fast shutter speed (e.g. 1/250) is handy if taking photos of fast-moving objects above ground in bright sunlight. However, to photograph in low light conditions of a cave entrance without using a flash, may require a slow shutter speed (e.g.1/60) to compensate for the lack of light.

The third element is the International Standard Organization (ISO) sensitivity to light number, which is basically how fast the sensor array reacts to the light. A sensitivity of 80 ISO, or 100 ISO is generally the slowest on most cameras and will produce the best quality image. Turning the camera's ISO up to say 1200 ISO in low light conditions will easily capture an image which looks fine on the cameras small Liquid Crystal Display (LCD) screen, however the resulting image will be of poor quality. The reduced quality will become apparent when the image is enlarged on a computer screen as a considerable variation in coloured dots (pixels) particularly within dark patches. This is referred to as electronic 'noise' and can be observed in areas of an image which should be the same colour but are made up of various coloured pixels. Therefore if the subject can be well lit with plenty of flash power, use a low ISO setting such as 80 or 100.

Very few manufacturers currently offer models with less than 5 Megapixels and most have some video capability. Camera memory cards are getting larger and less expensive, thus allowing users to take more photographs and at no additional cost after the initial equipment outlay. Rechargeable digital camera batteries are getting better and lasting longer.

In many respects the technology of digital cameras has surpassed the capabilities of film cameras. The one big advantage is 'instant gratification', that is the ability to instantly review an image which has just been captured and to delete it and take another if the first is not to the photographer's liking.

Digital Cameras

There are three broad categories of digital camera. They are the Compact, Prosumer and Digital Single Lens Reflex (DSLR).

Compact Digital cameras are also known as 'point and shoot' or 'consumer cameras' (Fig. 2). These cameras are the cheapest and most popular with people who don't consider themselves a photographer. The distin-

Figure 2: Examples of Compact Digital Cameras Note that the camera on the far left does not have a viewfinder – it has been totally replaced with an LCD screen on the back to make the camera smaller.

guishing feature is that the optical viewfinder consists of a simple optical system which zooms at the same time as the main lens and has an optical path parallel to the camera's main lens (Fig. 3). The biggest problem is framing inaccuracy as the viewfinder is positioned above the actual lens (often there is also a horizontal offset known as parallex error), so that what is seen through the optical viewfinder is different from what the lens projects onto the sensor (Fig. 4). Increasingly, manufacturers are producing these cameras with LCD screens at the back of the camera which reproduce in real time what the camera lens is seeing. Hence the LCD on the back of the camera is often used to replace the optical viewfinder. Typically the Compact cameras are small and easy to carry but have limitations for the more experienced photographer who wants to be a bit creative. For example most compact cameras do not allow the operator to directly control exposure settings.

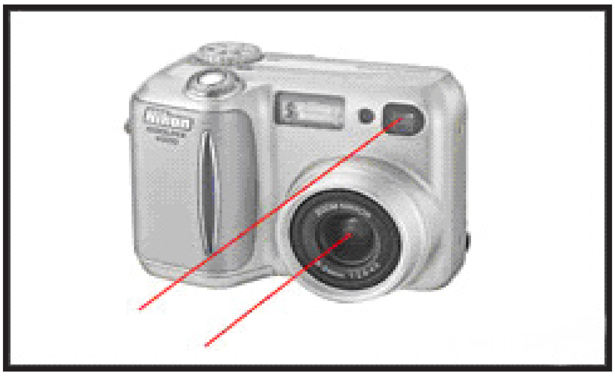

Figure 3: Typical Compact Digital camera. As the optical path of the viewfinder runs parallel to the camera's main lens, what the photographer sees is different from what the lens projects onto the sensor.

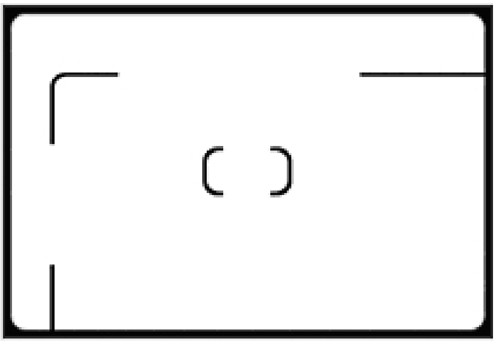

Figure 4: Sometimes optical viewfinders have parallax error lines on them to indicate what the sensor will see at relatively small subject distances (e.g. below 1.5 metre or 5 feet).

Compact digital cameras tend to have very poor optical zoom qualities compared to the better cameras.

Prosumer or Bridge Digital cameras are closely related to high end 'compacts', but they are often confused with Digital Single-Lens Reflex (DSLR) cameras due to their similar body shape and large zoom lenses (Figs 6 & 7). Prosumer cameras fill the niche between the Compact and DSLR. The word Prosumer is derived from a combination of the words professional (SLR cameras) and consumer (compact cameras).

They are comparable in size and weight to the smallest DSLR cameras, but lack the removable lenses, larger sensors, mirror, and reflex system which characterize DSLRs.

Prosumer cameras have a non-removeable zoom lens which is reasonably sealed against dust ingress. Hence there is reduced possibility of dust being deposited on the sensor array, compared to DSLR Cameras with removeable zoom lenses which can act as an air pump and suck dust into the camera body. Any dust on the sensor will significantly reduce image quality

Many Prosumer cameras have LCDs which can be flipped out from the body or angled up or down to make it easier to view while taking low or high angle shots (Fig. 5).

Figure 5: Digital Prosumer camera with a flip and twist LCD.

For those who wear corrective glasses, it is worth checking to see if the viewfinder has a diopter adjustment. This may negate the need to wear glasses while photographing.

Figure 6: *Typical style of camera at the low end of the Prosumer Camera range*

The fact that the camera is totally self-contained (lens, flash, etc) is a big selling point. As there are many features crammed into the average Prosumer camera, it gives plenty of room for the enthusiast photographer to experiment well beyond the auto 'point and shoot'.

Figure 7: *Typical style of camera in the high end of the Prosumer Camera range.*

Digital Single Lens Reflex (DSLR) cameras are generally used by professionals and serious photo enthusiasts (Figs 8, 9 & 10). The cameras basically use a mirror and pentaprism or pentamirror system to direct light from the lens to the viewfinder eyepiece. When the photo is taken, the shutter mirror flips out of the way to allow the light from the lens to hit the sensor array and capture the image. This through-the-lens viewfinder system ensures that what is seen through the eyepiece is captured by the light sensor array.

Heavier than both compact and prosumer cameras, DSLRs give photographers the ultimate in quality, control and creativity. The combination of high quality optics and large sensor arrays (typically 6 to 12 million pixels) provides excellent image definition when the subject matter is correctly exposed and in focus.

Figure 8: *Fixed LCD on a digital SLR - used to view images only after they are saved to memory.*

These cameras can be used in the automatic mode, however using some of the excellent manual features can certainly allow the photographer to be very creative.

The LCD screen at the back of a DSLR camera is used to display the image directly after taking the shot, or viewing images previously saved on the memory card. For this reason it is more difficult to compose a photo with an SLR in very dark caves using a torch to locate the boundaries of the scene as well as looking through the viewfinder (Fig. 8).

Figure 9: *Typical Digital SLR (DSLR).*

Figure 10: *Top View of DSLR.*

Choosing a Digital Camera

Now that the basics of a digital camera operation are explained, one must really take some time to identify what type of digital camera to purchase for underground photography. There are so many makes and models on the market these days. A novice can gain good advice by talking to a professional photographer or fellow cavers who have achieved good photographic results.

A range of issues involving choice of camera and associated equipment, choice of subject, structure of the picture composition and some general points on taking photos in caves need to be considered. These are:

1. Choosing the right camera
2. Choosing flash and slave equipment
3. Pre-checking camera equipment
4. Co-operative models and helpers
5. Subject and composition tips
6. Framing the picture
7. Lighting the subject
8. Taking the picture
9. General tips
10. Tips for composing a photo
11. Pixels, Megapixels and DPI explained

1. Choosing the right camera

It is impossible to list the large number of variables involved, but here are a few simple aspects to consider.

a. Choose a camera which can be operated in a full manual mode if required. This will give full flexibility in overriding the aperture, speed and ISO to allow more creative photography.

b. A camera with low light capability will work better in dim light situations.

c. Make sure the camera has a lens which will cover the full 'field of view' which you are expecting to be captured in the image. A lens covering a range from 28mm to 200mm or more is preferable for those wide angle shots in small chambers, as well as zooming into those further away subjects. Fig. 11 is an example of where the zoom lens was set at 28 mm to capture the full scene in a confined chamber.

d. The Macro focus distance may be important if considering close up photography of cave invertebrates. Many cameras only allow the macro setting when the lens is at its widest angle of view, for example 28 or 35mm. Bear in mind that the functionality of a zoom lens will mean the minimum focus distance from camera to subject increases as the lens is zoomed toward the telephoto end of the lens' range.

e. There must be the option to turn off the camera's double flash related to the "red eye reduction" or additional flashes which may be used by the camera to determine white balance or exposure settings. The camera's multiple flashes will prematurely set off the slave flash units and can result in under exposed images.

2. Choosing flash and slave equipment

Many digital cameras have inadequate inbuilt flash systems and lack a connector for use with an external flash unit. Basic slave units will not synchronise with many digital cameras which use a very rapid series of pre-flashes to perform various functions, such as: red eye reduction, white balance settings, flash power/ duration determination or the camera aperture and ISO settings.

Most cameras will allow the operator to turn off the red-eye reduction flash, however there are many cameras which do not have the option to turn off the pre-flash which sets the camera's white balance or aperture and

Figure 11: *A waterfall when illuminated by several synchronised electronic flash units, appears to be frozen. To get the blurred movement of water, strobe flashes or a constant light source is required.*

ISO. This pre-flash typically fires 100ms (100 milliseconds, or 1/10th second) before the camera captures the image on the second flash. Most slave units will fire on the pre-flash and cannot cycle quickly enough to fire again when the picture is taken 100 ms later. Thus, the extra light from the slave flash does not show up in the digital camera photo. The pre-flash and second flash may be so close together that the photographer only sees the one flash. The camera manual is a good place to find out how to turn off extra flashes.

Some advanced slave units feature a switch, which allows the user to select between several triggering modes used by different digital camera models. This allows them to be used with any camera on the market.

There are a number of slave units commercially available, which connect directly onto the hot-shoe of the electronic flash unit. These work extremely well in caves, out of the camera's line of sight, as they are triggered from the reflected visible light from another camera flash. The Firefly brand slave units are triggered by a pulse of Infra Red (IR) or visible light, but are not set off by torchlight (Fig. 12). As such they are well

Figure 12: *Firefly 2 and 3 – slave units are triggered by IR & visible light.*

Figure 13: *Flash Unit with light sensing eye in base of hot shoe. This determines required flash duration to illuminate subject.*

suited for cave photography and will work in dark areas up to 500 m away from the camera.

It is worth investing in at least one or more good quality slave units to put on electronic flash units. A second hand flash unit from a pawn broker or *Cash Converter* is probably the cheapest way to get started and it is easier on the bank account if the flash gets destroyed in the harsh cave environment.

It is worth paying a little more to get an electronic flash unit with a couple of settings and the smart technology of a light sensor which can cut off the flash when the subject is exposed correctly (Fig. 13).

Another alternative to the visible light or IR triggered slave units is the Radio Frequency slave units which are now available in selected outlets.

3. Pre-Checking Camera Equipment (before going underground)

One of the biggest mistakes is to go caving and clamber all the way in lugging lots of camera gear, only to find the batteries are flat or something has been left behind.

Check that all equipment works before leaving home by setting up a mock photo at night in the back yard or indoors. This can be as simple as checking that the slave flash is firing syncronously (in sync.) with the camera flash and the correct exposure can be achieved. As previously discussed, many Compact digital cameras will not allow the photographer to turn off the automatic double flash setting. An easy test is to take a photo of the electronic slave flash unit set up on the other side of the room. If the photo shows the slave flash firing with a bright light, then the camera and slave are in sync. The next step is to work out what aperture to use in order to achieve a good exposure. Using the flash guide settings is the best place to start, however the final setting can only be fine-tuned in the cave when a photo is being set up.

When purchasing camera equipment, try and stick to equipment which uses the same type of battery, eg. rechargeable AA. This way you don't need to carry as many spare batteries and rationalisation of equipment can help to reduce weight (Fig. 14).

A good battery tester is worth having at hand to do a final check on all camera and flash batteries. Remember

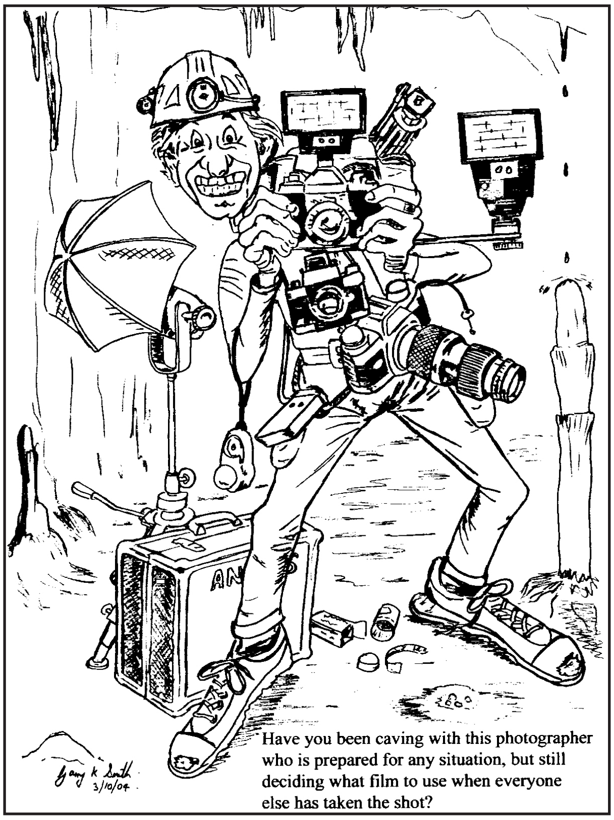

Figure 14: *How much gear do you really need?*

to check the small batteries hidden in the slave units.

4. Co-operative models and helpers

Cave models can make or break a photograph. They need to be co-operative and have plenty of patience to stay in the same position for whatever time it takes to capture the perfect image. This may be while the slave flashes are adjusted or moved and it may involve the model changing positions to suit the composition which the photographer is aiming to portray. A cave model standing in an awkward position or with an un-natural facial expression can be very detrimental to the overall image. Hence, the cave model must be relaxed and comfortable with the reality that they may be in the same place for a period of time.

In some circumstances it may be an advantage to have helpers holding slave flash units at the correct angle and position. This can be a tedious task as the photographer may need the angle or position changed several times during the shoot.

Make sure that all members in your party know the planned trip is a photographic trip if some serious photography is to be undertaken. These trips can yield the best results when time is taken to set up each shot, as opposed to the happy snappy trip where everyone is constantly on the move.

Cave photographers don't particularly have a good reputation with other cavers because of the time it takes to set up and take the desired shot. Hence, it is a good idea while the rest of the party is exploring possible leads in the vicinity, the photographer should use the opportunity to size up the photo subject, get the gear ready with flashes and camera in position. Take a few test shots to check lighting without any cave model in the picture. When all is set, ask the model to step into the picture and take the shot (Fig. 15). Above all, know how all the equipment functions.

Even groups of photographers can work together provided only one person sets off the slave flashes. Once a few test shots are taken to determine optimum aperture with a known ISO (e.g. 100), other photographers are informed of the settings. Everyone focuses their camera on the subject and holds their camera focused (or use manual focus) and framed on the subject. The coordinating photographer counts to 3 before taking the photo to trigger off the slave flashes. At 2 the other photographers take the photo with their cameras set on a 4 or 5 second exposure without a flash from their camera. That way everyone is able to capture the image, possibly from slightly different angles.

Figure 15: *A photographer lines up his subject and checks exposure and flash angles.*

5. Subject and Composition Tips

A good subject is best described as something which is of interest to the photographer and the target audience. There is no real benefit having a well exposed shot of something of little interest. A photo of an often-photographed icon really needs to be an outstanding photograph from a different angle or different lighting conditions to set it apart from the rest.

Incorporating as many of the following elements will increase the chance of making a photo more interesting to the viewer.

a. Include both near and far objects. This will require a good depth of field.

b. Include some aspect which will give a comparison of scale.

c. A dominant feature in a photo should catch the observer's eye and lead it toward the rest of the photo. An example is a person looking toward the rest of the scene or at a dominant feature. Definitely avoid having a cave model looking out of the picture.

d. The 'thirds principal' is a good rule of thumb to use. e.g. a person 1/3 of the way across the photo. However there are sometimes exceptions to this rule of thumb.

e. Don't cut a person off at the knees, ankles or neck; either include a person's head and shoulders to mid chest level, or the whole person.

g. Make sure the model has an acceptable facial expression and is positioned in a good pose. An awkward expression or posture can ruin an otherwise good photo.

h. Get the exposure correct by adjusting the flash units or camera aperture.

i. Make sure there are no reflective tapes or stickers on the model's clothing or equipment.

6. Framing the picture

Using the suggestions mentioned under the heading 'Subject and Composition Tips', set your camera on a tripod so that the required field of view is framed. This may require the zoom lens to be adjusted, the camera tilted on the tripod, or even repositioning the tripod to a new location.

In total darkness it is difficult to see on the LCD screen what the camera actually has in the 'field of view'. To overcome this problem it is a good idea to shine your torch around the intended subject and at the same time watch on the LCD screen where the torch beam spot is. When your torch beam is on the far left of the intended photo, then it should just be seen on the far left of the LCD screen. In this way the beam of the torch can be used to run around the intended boundaries of the photo and the camera 'field of view' adjusted accordingly.

Using this technique is easier if the camera has a flip up or flip out LCD so that the photographer does not have to crouch awkwardly behind the camera or have their eye up to the viewfinder of a DSLR camera. Bear in mind that in caves the conditions for photography are often cramped and just trying to get an eye behind the camera may be very uncomfortable. This is where the prosumer cameras with flip out screens have it over the other cameras.

Figure 16: *Back lighting illumination gives a aura around the subject and provides contrast with reflection off the running water.*

7. Lighting the subject

Despite having superb subject material to photograph, bad lighting can severely diminish the visual impact (wow factor) of a photo.

The complexity of photographing in total darkness is often not appreciated by daylight photographers. The time required to produce a quality flash photo and the effort involved in achieving this can best be understood by a cave photographer or the model who has patiently posed for a photo in cramped, wet and cold conditions for an extended period of time.

So what are some good rules of thumb?

a. Expose the subject well.

b. Have a few dark areas within the frame to give contrast to the subject.

c. Provide side light to give some degree of contrast/ shadow to the objects of interest. This will help give a better depth to the final image.

d. Back lighting can greatly enhance the photo by giving the subject an aura and provide reflections from pools of water (Fig. 16). Avoid flare from a flash unit which is pointing back toward the camera.

e. Make sure that a torch beam is not illuminating any part of the subject in the field of view. A torch beam will produce a spot which is over exposed and will most likely have a colour shift toward the orange if from an incandescent globe or blue if from a LED torch. Compare the difference in images with and without a torch spot (Figs 17 and 18).

f. Avoid harsh shadows which may be prominent in the field of view. The exception is when the shadow is to be a feature of the final image (refer to item 'j'). An example of a bad shadow is shown in Fig.19.

g. Experiment with lighting on one side of the subject and again with lighting both sides of the subject (Figs 21 and 22). Subjects which cast a prominent shadow may require lighting on both sides.

h. Moving the flash angle so that the background wall of the cave remains unlit, will highlight the subject against a black background (Figs 23 and 24).

i. Using a light source at a critical angle to a subject can accentuate features of the subject with shadows (Figs 25 and 26).

j. Shadows cast by the subject can be used to drama-tise or enhance the photo (Figs 27 and 28).

k. Getting the lighting angle correct can produce some excellent results. For example a refracted image of stalagmites will appear inverted in the water drop on a straw (Fig. 29). Note the calcite crystal growing in the water drop. When undertaking macro photography it is often best to use the smallest aperture possible with plenty of flash power.

l. There are many variations of lighting which can be achieved by moving the flash from the obvious position

Figure 17: *The bright orange spot from the photographer's incandescent headlight beam has reduce the quality of the photo.*

Figure 18: *This time the photographer's torch beam has been turned away from the field of view when the photo was taken.*

Figure 19: *A flash position can be very crucial. Note, shadow across cavers face.*

Figure 20: *Flash position has been changed slightly and resulted in better photo.*

Figure 21: *Stalagmite with flash lighting on one side.*

Figure 22: *Stalagmite with flash lighting on both sides.*

Figure 23: *The subject may be perfectly exposed and in focus but the lighting on the wall behind is detracting from the main subject.*

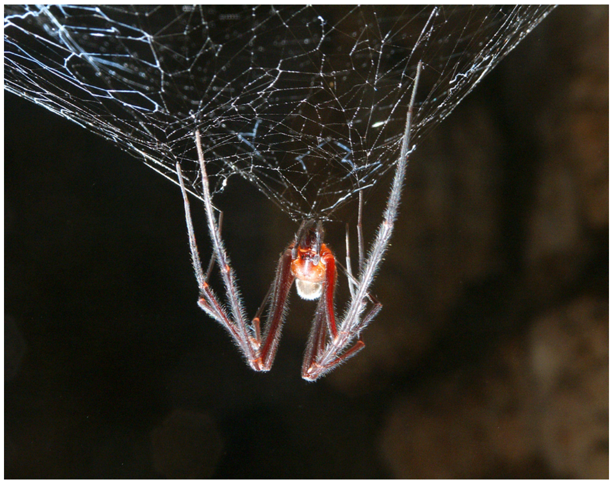

Figure 24: *With the cave wall not lit and flash to the side, a whole new dimension can be observed with some light passing through the spider's body. A small flash on the camera is used to just illuminate the front of spider.*

Figure 25: *Without much shadow the dog skull looks flat.*

Figure 26: *Here the shadow on the dog skull accentuates the facial feature.*

in front of the subject. Figures 30, 31 and 32 depict how the final result can be dramatically changed by moving the slave flash units.

8. Taking the Picture

Assuming the photographer has identified the subject and camera position, consider the following steps when taking the photo:

a. Identify the 'field of view' around the subject for the desired picture.

b. Place the camera on a tripod. The camera can also be hand held if more convenient.

c. Place the electronic flash slave units in appropriate positions to allow for desired lighting effect & exposure.

d. Take a few test shots to check the camera exposure and lighting effect of the slave flashes. Adjust camera

***Figure 27:** Stalactites cast good shadows on the ceiling when lit from behind.*

***Figure 29**: Stalactites on ceiling above can be seen in water drop with correct flash lighting.*

'aperture' settings if required. The electronic flash units may be strategically placed on rock ledges, fitted to tripods or just hand held by someone.

e. Have the 'cave model' (caver who is posing for the photo) positioned in the desired location. Make sure there are no reflective strips on their clothing or equipment. Bright coloured clothing looks better than dark colours.

f. If the pose of the cave model is looking toward the camera, shine your head lamp at their eyes for a couple of seconds. This will dilate their pupils and eliminate 'red eye'. It may also be better to have the cave model's head lamp turned off.

g. The camera may have to be set to a single spot focus mode for cave photos. The photographer shines their head lamp at the main focus point in the field of view and half presses the shutter button down to allow the camera to focus easily on the main subject. The photographer may have to momentarily swivel the camera slightly to focus on an object just off centre of view. Continue to

***Figure 28:** The placement of a flash to give a shadow can add to the effect.*

***Figure 30:** Lighting only from front, but off centre to allow shadow behind straws to make them stand out.*

hold the camera shutter button at the halfway point to maintain focus. Using manual focus is an alternative to the auto focus.

h. The photographer turns off their head torch or points their torch beam out of the picture. This will eliminate the torch spot from the final photo (Fig. 17). It may be more convenient for a photographer's helper to shine their torch for camera focusing and reducing cave model red eye.

Figure 31: *Lighting only from behind subject, which almost blends straws into background wall.*

Figure 32: *Main lighting from behind and small amount of light from the front.*

i. The photographer is still holding the camera shutter button half depressed to maintain the camera in the focused position. If the cave model is ready, push the shutter button all the way down to take the photo. The small inbuilt camera flash will set off all the slave flash units.

j. Check the stored image to verify that the field of view, exposure, model's position and expression is satisfactory.

This all sounds like a long winded process, however once everything is set up, it only takes a few seconds to

Figure 33: *Using a small aperture will produce photos with the greatest 'depth of field'. Note the rimstone dams in the foreground are in focus as well as the cave model further away. This is not possible if a large aperture size is used.*

take extra photos to improve on the original, particularly if the cave model has blinked or a slave unit has failed to fire.

9. General Tips

a. A camera with an adjustable diopter in the viewfinder can be very beneficial to photographers who normally wear prescription glasses. When adjusted correctly there is no need to wear glasses while photographing. However with DSLR cameras the only replay for viewing stored images is on the LCD screen at the back of the camera, so the advantage of the adjustable dioptre is lost if prescription glasses are still required to view the LCD screen. On the other hand many Prosumer cameras have the option to view and edit stored images through the viewfinder. Although the internal viewfinder LCD may be small, there is generally plenty of scope for the photographer to determine the quality of images for editing, hence there may be no need to wear glasses at all.

b. Make sure a head lamp beam is not in the field of view when taking the photo. A headlamp with an incandescent globe will create an over exposed spot which is yellow. A white LED will produce a bluish spot.

c. A camera with 5 or 6 megapixels will produce images (if camera is set at its highest resolution), which can be easily printed up to A4 sheet size. If larger high resolution prints are desired, it is worth considering an 8 or 10 megapixel camera. (Table 1)

d. Always have the camera set on the highest resolution to take every photo. It is often impossible to recreate that perfect shot with a person's expression or lighting effect, but it is very easy to delete a photo which did not work out.

e. To produce images with the greatest 'depth of field' or in-focus range (Fig. 33), use the smallest possible aperture setting to suit the highest available electronic flash output (or other light source).

f. When using an electronic flash with a slave unit to remotely trigger it, make sure the flash's light sensor is not obstructed by a nearby object. The use of a very small tripod to support each flash unit can be a big advantage and eliminate the need to directly place them on the ground or a rock ledge. When hand held, the flash's light sensor (Fig. 13), may inadvertently be obstructed by the holder's finger, resulting in overexposure of the image.

g. Carry camera gear in a good quality camera case which is dust and waterproof as well as shock resistant.

Table 1

Number of Megapixels	Acceptable Print Size (Inches)
2.0	4 x 6 [standard]
3.0	5 x 7
4.0	8 x 10
5.0	9 x 12
6.0	11 x 14
8.0	12 x 16
10.0	16 x 20
12.0	18 x 24

A favourite with many photographers is the Pelican case which comes in a wide variety of sizes and contain foam which can be cut out to exactly fit around equipment.

h. Where possible, avoid long exposure times and avoid using high ISO settings as the electronic noise will reduce the quality of the final image.

10. Tips for composing a photo

As with all photography, "beauty is in the eye of the beholder". It is a subject which is not an exact science, rather something which appeals to the artist (photographer) and the viewer. Here are a few simple tips which could help an amateur.

a. **Framing the subject (composition).** The images in Figures 34 to 37 are used to highlight what the author considers as simple rules of thumb which can be used to improve the framing of a subject. The fourth image (Fig. 37) represents the best composition in the series of figures.

b. Scale of the subject. In cave photos it can often be very difficult to judge how large or small a decoration is. Therefore it is a good practice to add something to the composition which can be used as a comparison of scale (Figs 38 & 39). In this case a caver gives scale.

c. **Photographing from an unusual angle**, can give a different perspective to that of the standard horizontal. I am talking about lying on your back shooting up or being up high and photographing straight down. There are many interesting effects which can be achieved by this method. (Figs 40, 41, 42 & 43).

11. Pixels, Megapixels and DPI explained

A pixel is basically the smallest single component of an image. This includes printed pixels on a page, pixels carried by electronic signals, represented by digital values, pixels on a display device (e.g. LCD) or pixels in a digital camera (photosensor elements - CCD).

The measures of 'dots per inch' (dpi) and 'pixels per inch' (ppi) are sometimes interchanged, but have distinct meanings especially to the printer, where dpi is a measure of the printer's resolution of dot printing (e.g. ink droplet density). For example, a high-quality inkjet image may be printed with 200 ppi on a printer capable of 720 dpi at its maximum resolution.

A pixel is one dot of information in a digital image which collectively consists of millions of tiny dots (Mega = Million) to make up the overall picture. For instance a 3 megapixel image contains approximately 3 million pixels, while an 8 megapixel image consists of 8 million pixels, e.g. a 3 megapixel photo is 2048 pixels wide X 1536 pixels high = 3,145,728 (3 million pixels or 3 megapixels).

If you are only going to print post card prints from a digital image, there won't be any detectable difference in the print from a 3 megapixel image compared to an 8 megapixel image. The graininess is only visible when a picture is significantly enlarged. This is where the 8 megapixel image can be enlarged much more than the 3 megapixel. A good reference to the maximum enlargement from an image is shown in Table 1.

More megapixels is not necessarily better, unless you

Figure 34: *The lighting is good however the caver and decorations of interest are too small in the image.*

Figure 35: *The caver is a better proportion for the image size, but is too central to the overall image.*

Figure 36: *The caver is well framed at 1/3 in from the side of image, but he is looking out of the picture.*

Figure 37: *The caver is well positioned at 1/3 across the image, looking at the most prominent stalagmite which is also 1/3 in from edge of frame. The viewer is first drawn to look at the caver and then to where the caver is looking – toward the prominent white stalagmite.*

Figure 38: *Decoration which is difficult to determine its scale.*

Figure 39: *Adding a caver into the scene gives a much better idea of the scale.*

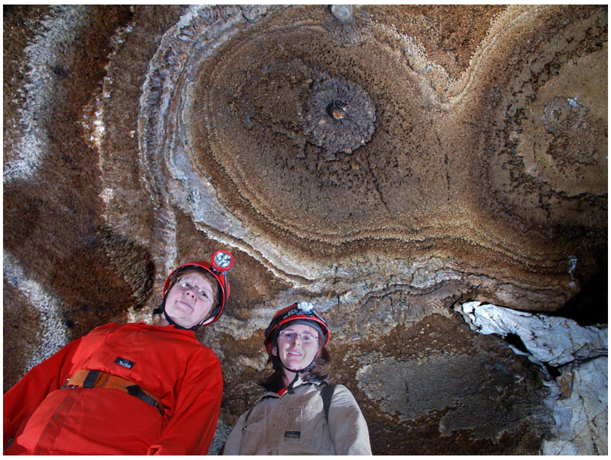

Figure 40: *An ant's eye view of cavers and ceiling decoration.*

Figure 41: *Looking down into an underground stream meander.*

Figure 42: *Looking up from the bottom of an abseil pitch.*

Figure 43*: Looking up into an aven containing shawls and stalagmites*

want to print out large photos. Here are a couple of things to consider before purchasing a digital camera with lots of mega-pixels e.g. 10 or 12 megapixels:

- Images take a longer time to transfer from camera to computer.
- More hard drive space is needed to store images.
- A more powerful computer is needed to view and edit an image.

Conclusion

Cavers who just want to take 'happy snap' photos with the occasional side lit photo can't go past the high-end consumer cameras which have the ability to use some manual modes. Most serious cave photographers would find the prosumer range of camera well suited for almost all conditions, with the flexibility for more creative photography. These cameras have fully manual mode options and often have a fixed zoom lens starting at around 28mm up to 200mm or more. In many respects the modern high end Prosumer digital cameras have features which make them more suited to dusty and cramped cave environments than the professional DSLR.

Photographing a good subject does not necessarily make a good photo. It is essential to pay special attention to the cave model's posture, facial expression and direction they are looking. Equally important is the framing, depth of field and lighting effect on the subject. To achieve good lighting, reliable slave flash units are invaluable to the serious cave photographer.

It is worth making the extra effort to purchase a quality camera and protect it in a strong, water and dust proof case, to take underground. Above all, know intimately how all the camera equipment works and check the operation of everything before going underground.

Acknowledgements

I would especially like to thank photographers, Sonia Taylor-Smith and Murray McKean for their comments and critical reviewing of this paper.

Photos are by the author

Definitions

Aperture An adjustable opening in the lens, through which light passes to reach the light sensor.

Field of view The area covered by a lens; the subject which is included in a photograph.

Depth of field The portion of the image which is considered to be acceptably in focus, extending in front of and behind the position of sharpest focus.

ISO or ASA International Standard Organization (ISO). A rating scale originally used to define film sensitivity, but now is used to rate the sensitivity of the digital camera's light sensor. The higher the number the more sensitive. ISO designation replaces the ASA (American Standards Association), but is numerically identical.

Pixels A pixel is basically the smallest single component of an image. See under heading 'Pixels, Megapixels and DPI explained' for more information.

Further Reading

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Garry Smith delivering his paper. Photo: D. Carr

China Caving Project 2008

Steve Trewavas
Cave Diving Association Australia

Abstract

In April 2008 a contingent of Australian cave divers were invited to the Fengshan area of the Peoples Republic of China to assist with an international caving project. Dry cavers from Britain had previously mapped in excess of 40km of cave in the region. Assistance was sought by the Fengshan government to link several karst windows in what is hoped to be one of the longest underwater cave systems in the world.

This presentation incorporates photographs and video of our discoveries. It will pose many opportunities for those interested in caving in the largest limestone karst plain in the world.

Cave in Fengshan County South China (above)
Divers in pool (left) Photos from presentation.

Extremes of Latin American Caving

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Abstract

Madre de Dios is an island about as far south as you can go before you fall off the bottom of the world or get eaten by sea monsters. It also has some of the most spectacular karst and worst weather that you'll find anywhere on earth. Madre de Dios is the 'raison d'être' for the French caving group 'Centre Terre' that has run three big budget expeditions to the island since 2000. At the northern extreme of Latin America is Mexico where several small, no name, low budget expeditions go each year to explore its deep caves.

Origin of Cenotes near Mt Gambier, South Australia

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Abstract

The Southeast Karst Province of South Australia is notable for its cenotes, collapse dolines containing water-table lakes up to 50m wide at the surface and extending down to 95m below the land surface. They are developed in the flat-lying Oligocene – Early Miocene Gambier Limestone, which is exposed at the surface over much of the province. The cenotes are all characterized by collapse; they have vertical and overhanging sides and are floored by large cones of rubble, which may be overlain by finer grained sediment. Exploration and diving have revealed no major phreatic passages extending off any of the cenotes, despite the fact that typical shallow phreatic joint maze caves, both dry and water-filled, are common in the Gambier Limestone throughout the Southeast Karst Province. Collapse dolines are associated with some of these phreatic caves, but are shallower than the cenotes in that they do not have deep lakes.

The distribution of the cenotes is uneven; they are concentrated in two small areas, each ~3km in diameter, located 5km W and 10km NW of Mt Schank (a few other cenotes are scattered through the province). Within these areas they are distributed along two joint sets, a dominant set trending 320° and a subsidiary one at right angles. These are the dominant regional joint directions.

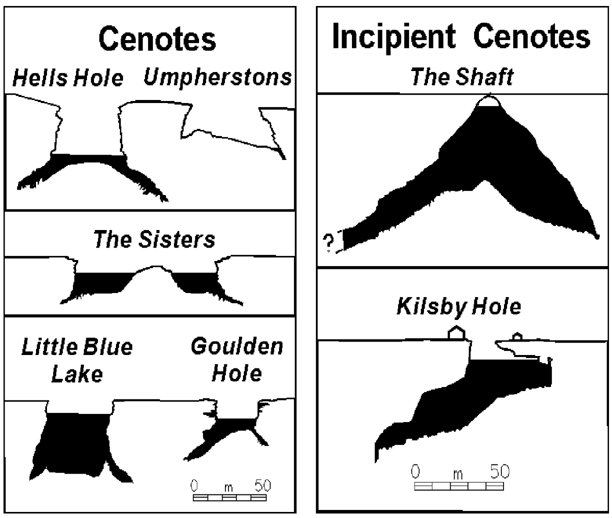
The depth of the cenotes indicates that they represent collapse into large caverns dissolved at or close to the base of the Gambier Limestone; the boundary between the Gambier Limestone and the underlying Tertiary siliciclastics lies at about 100m below ground surface around the cenotes west of Mt Schank. It has been suggested that the caverns were dissolved by acidified groundwater containing large amounts of volcanogenic CO_2, which had ascended up fractures from deep-seated reservoirs related to the magma chambers that fed the Quaternary volcanoes Mt Schank and Mt Gambier. Approximately 10km east of Mt Schank is a CO_2-producing well (Caroline); the isotopic composition of the CO_2 identifies it as magmatic in origin, and it is probably related to the Quaternary volcanics in the area.

Evidence for the influence of volcanogenic fluids on the cenotes comes from strontium isotope analyses of a stromatolite collected at ~8m depth from Black Hole, one of the larger cenotes. Stromatolites grow on the walls of many of the cenote lakes, and are large structures up to 4m long formed of calcite precipitated by the microbial communities growing on their surfaces. In cross-section the calcite of the Black Hole stromatolite shows submillimeter-scale laminations, which may be annual. Detailed sampling of one section of this stromatolite showed that overall it has a $^{87}Sr/^{86}Sr$ ratio of around 0.7088, but one sample has a lower ratio (0.7079), probably due to an input at this time of volcanic fluids, which have a much lower Sr isotopic ratio (0.7037-0.7058 for the Quaternary volcanics of the region). The layer with the anomalous $^{87}Sr/^{86}Sr$ ratio has an age of ~6000 BP, from C_{14} dates on the stromatolite either side of the layer, and assuming a uniform rate of growth. This age corresponds closely to that of the eruption at Mt Schank (6000 BP, based on recent thermoluminescent dating).

Thus the Sr isotope data show the apparent influence of volcanogenic fluids within the cenote lakes during a time of eruption. Larger amounts of fluid, including volcanogenic CO_2, could have been injected during previous eruptions, dissolving the caves that collapsed to form the cenotes.

This paper has been published as.

John A. Webb, Ken G. Grimes, Ian D. Lewis. 2010. Volcanogenic origin of cenotes near Mt Gambier, southeastern Australia, *Geomorphology* 1**19**: 23–35.



Cenotes *(Grimes, K.G. and White, S., 1996. Field guide to karst features in southeast South Australia and western Victoria. Regolith Mapping, Hamilton, Vic.)*

Paleomagnetic dating of Pleistocene cave sediments at Buchan, southeastern Australia

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Abstract

The Dukes cave system at Buchan consists of three horizontal epiphreatic levels, which can be correlated with terraces in the adjacent river valley. The lowermost contains extensive stream-deposited sands, gravels and minor clays, whereas the uppermost has deposits of red silty clay. Paleomagnetic samples from both levels are dominated by magnetite of multidomain size (>10 µm), which has been subject to viscous remagnetisation so a normally-polarised remanence, in the direction of the present field, has replaced any depositional magnetisation. The main depositional magnetic carrier was probably very fine-grained (superparamagnetic) haematite; this is still present in one sample admixed with the magnetite. The coarser magnetite which now dominates the remanence may have grown in-situ, possibly due to bacterial reduction of the sediments. Hysteresis parameters of a few samples from both cave levels indicate an admixture of slightly finer-grained, pseudo-single-domain sized magnetite, which preserves a primary reversed polarity magnetisation. This remanence was presumably acquired some time after sedimentation, during authigenic growth of magnetite in the sediments. Although short intervals of reversed or mixed polarity are known from the Brunhes Chron, these represent only a very small fraction of its duration. Thus cave sedimentation most probably occurred prior to the Brunhes Chron, i.e. before 780 ka. This accords with uranium series dates of >300 ka on speleothems from the upper cave level. The lower epiphreatic level, >0.73 Ma old, is only 2-3 m above the nearby surface stream-bed, indicating that river incision rates have been very slow (<5 m/Ma), and that the sea level and climate fluctuations of the Late Pleistocene left little discernible trace in the Buchan area. The red clays and silts in the upper level are probably aeolian in origin, and represent the onset of aridity in central Australia, dated elsewhere as prior to 0.9 Ma.

This paper was published in 2003 after a presentation at a cave sediments meeting at the Karst Waters Institute.

Reference

R. J. Musgrave & J.A. Webb 2003, Palaeomagenetic Analysis of sediments in the Buchan Caves, Southeastern Australia, provides a pre-Late Pleistocene date for landscape and climate evolution. In Sakowsky, I.D, & Mylroie, J.E. (eds), *Studies in Cave Sediments,* 47- 70. Kluwer.

Joe Sydney negotiating a SpeleoSports obstacle. Photo D. Carr

Karst in Mid-Proterozoic dolomite, Pungalina Station, Northern Territory, Australia – its Significance and Management

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Abstract

Extensive karst is reported from several places in Northern Australia in particular Pungalina Station in the Northern Territory. This previously little known dolomite karst area contains significant karst, which has been explored and documented by the Victorian Speleological Association Inc., since 2005. Since the purchase of the property by the Australian Wildlife Conservancy (AWC) in 2008, VSA has continued this work and provides karst knowledge and management advice to AWC.

Introduction

In the published literature, karstification in dolomite (dolostone) is not as well documented as for limestone and as it is less soluble in natural waters than limestone, cave development is generally less. However, extensive karst is reported from several places in the Northern Territory, Australia and the Transvaal, South Africa (Martini, 2004). A previously little known karst area, of about 150 km^2, in the Mid Proterozoic (Pre Cambrian) stromatolitic and cherty Karns Dolomite on the southwestern coast of the Gulf of Carpentaria (N.T.) contains significant karst including caves.

Although the Karns Dolomite was known to geologists, the karst potential had never had any investigation. As a result the karst was not well known until the Pungalina Station owner Owen Davies started operating it as a Safari Operation in partnership with Kirkhope Aviation. Their interest in the caves was as an additional feature to the usual safari activities for tourists. At that stage they knew of one major cave with bats and a few other smaller caves. Since 2005, VSA has undertaken 5 further expeditions to the area, discovering, exploring and mapping a number of caves and karst features.

Access to the area is very dependent on conditions; a heavy summer wet can limit access and movement around the property. VSA trips as a result, have been in June or early July.

Regional Setting

The area is located in the Gulf Coastal bioregion of the Northern Territory (Fig. 1) near the Queensland/Northern Territory border and the Savannah Way (Highway 1). The Calvert River flows north through the property and terminates in the Gulf of Carpentaria. The currently known karst is predominantly in the exposed dolostone in the catchment of the Karns Creek, a tributary of the Calvert River.

At about16°30' S. latitude, Pungalina has a hot monsoonal climate dominated by distinct wet and dry seasons. The cave temperatures are higher (29-34°C) than the expected yearly average (26.4°C) with cave humidity levels close to 100%. This is possibly due to a combination of summer rain, temperature and the effect of soil heated up by the sun. In some caves, the humidity is such that just moving around causes the moisture to condense as droplets and produce a fog. Some caves flood during the summer monsoonal rains maintaining the high humidity.

The karst areas of the property have a mosaic of open savannah woodland with pandanas and paperbark communities around the creeks and wetlands. Cave entrances often have remnant dry rainforest species not present in

Figure 1: *Pungalina location*

the surrounding savannah woodlands. The diverse habitats support a rich fauna.

Geology and Geomorphology

The karst is developed in the Karns Dolomite, a 100-200 m thick cherty dolostone estimated as being between 1.73 to 1.43 billion years i.e. mid Proterozoic (Pre Cambrian) in age. The Karns Dolomite is only intermittently exposed on the surface in this area as it is overlain in some places, by the very late Proterozoic Bukalara Sandstone, isolated outliers of marine Cretaceous sandstone and claystone and Cenozoic sediments and laterite.

The Karns Dolomite was deposited in a shallow marine, tidal environment, characterised by numerous stromatolitic beds dominated by the genus *Conophyton* (Fig. 2). Such shallow, upper tidal environments have a variety of sediments reflecting the variable depositional depths. These include more siliceous and clay rich beds, now evident only either in cave walls or as surface rubble. The dolomite is relatively flat lying and exhibits only shallow dips and small structural deformations. In the upper reaches of Karns Creek, several hills and tabular plateaux are capped with a massive banded chert, brecciated in places and up to 10m thick. This appears to terminate the dolostone sequence which may be a Proterozoic paleosol residual left after the dissolution of cherty carbonates and subsequently cemented together into a massive rock under the effect of diagenesis or very low-grade metamorphism.

There is a significant gap in the rock history between the cessation of sedimentation in the late Proterozoic and the Cretaceous when extensive sedimentary deposition of sandstones occurred (~ 400 million years of record missing). Either the area had no deposition or, as is most likely, any deposition that occurred during the Pal-

***Figure 2:** Conyphyton stromatolites (S. White)*

aeozoic and early Mesozoic (543 – 146 million years), was minimal and was subsequently completely eroded. There are only small remnants of Cretaceous sediments present, which indicates that the extensive deposition, which occurred, has been subsequently eroded during the Cenozoic. The area has been subjected to more sub-aerial erosion throughout the Cenozoic.

Karst Landscape Development

The geological history indicated that the area was probably covered by sediments in the Cretaceous, but by the end of the Cretaceous, the area was exposed and eroding. Extensive landscape lowering has occurred and the remnants of a higher altitude landscape with large streams and high level caves on the ridge tops, resulting in a landscape inversion (stream cobbles are found on some ridge tops). Much of the karst has the characteristics of a highly eroded landscape where the present features are the relics of previous conditions.

The major relief of the area is seen in the sandstones outcropping to the south and west of the main karst area. The relative relief of the sandstone areas is high – up to 100 m of incision by the Calvert River in places with striking sandstone cliffs. The relative relief of the Karns Dolomite areas is much lower and flatter. The tops of the ridges are 10- 25 m above the rest of the plain.

At least two periods of karst development on the Karns Dolomite have occurred, and there may have been more. The two karst development periods are an upper/older one, which is preserved as remnants on ridge tops e.g. remnant streams, dolines and caves, and a lower/younger one at the break of slope at the foot of the ridge with currently active caves. Other small karst features include degraded dolines and solutional features.

The upper caves are no longer being actively developed, although minor modification is occurring from surface runoff into the caves and degradation of old speleothems (e.g. the Totem Pole in Totem Pole Cave (PUN-07) (Fig. 3) and deposition of newer formation in other parts of the cave. The younger and currently active karst development stage is occurring with the formation and modification of narrow, joint controlled maze-like caves lower on the ridges, forming especially where surface runoff drains underground through joints and fractures, at the break of slope near the base of the ridges. These are the main caves in the region and have concentrated areas of decoration and calcite formation, interspersed with extensive areas showing solutional features such as rills. These caves also take extensive water during wet seasons and most have evidence of episodic flooding and active solution. There is extensive evidence in the form of small water sinks and degraded dolines and hollows, that the area was a more impressive karst landscape in the past.

The surface of the dolostone ridges has extensive karren especially as kamanitzas or pans rather than solutional rills. The stromatolites are often "picked out" by solution.

Modern tufa deposits occur in the bed of a small creek near the present homestead. These indicate that the river is highly saturated in calcium carbonate and at specific places is capable of deposition.

Groundwater outflow points were observed close to Karns Creek and the Calvert River and more must occur during the wet season, as evidence of outflow was found in a few places. The warm (~28º C) Bubbling Springs which flow regularly all year round suggest that the ground water flow is slow, buffered by the residual overburden covering the karst as well as by the nature of the wet cave network, which is probably not well integrated.

Caves and karst

Over 50 caves, 20 significant dolines, 2 poljes and several karst springs have been documented. More detailed work is needed.

The caves were initially found from the local knowl-

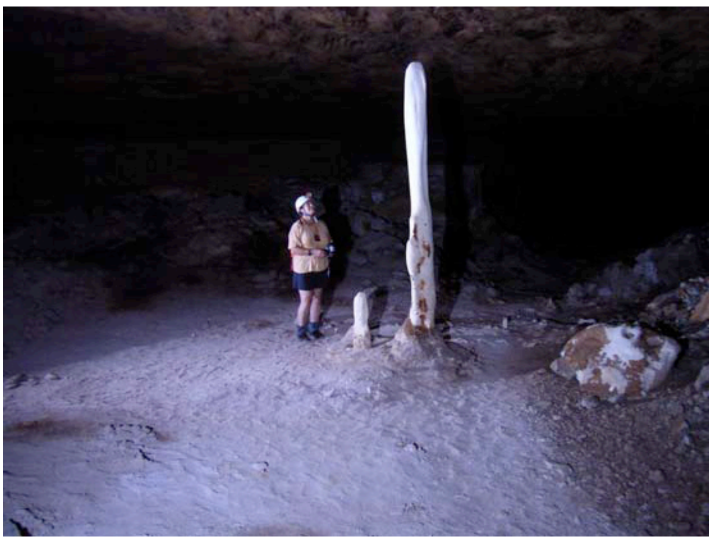

***Figure 3:** Totem Pole in PUN -7 (D. Carr)*

edge of Owen Davies and subsequently from locations of dolines viewed from the air and from air photos. Since the first expedition, exploration has been by walking to likely places at the break of slope between ridge and plain where there are some discharge caves. On ridges the presence of green vegetation is often associated with sheltered dolines sometimes with caves present.

The caves are generally shallow phreatic, joint and/or bedding plane controlled passage networks. Passage roofs are often flat (Fig. 4). Two cave levels can be identified: a dry upper series in the high grounds and residual hills, and an active lower one on the plain and in the valley bottoms. The caves contain aragonite and/or calcite speleothems, sometimes with chert breccia, which show evidence of repeated phases of deposition and re-solution. Chert replacement of the stromatolites has occurred and these are then in relief as the dolostone is dissolved (Fig. 5).

Cave and Karst Values

Extensive solutional karstification is found in dolomite at Pungalina. This is regarded by many karst geomorphologists as unusual, e.g. Ford (2004) states that in dolostone "surface land forms are more limited in type and scale" and that "caves large enough for human entry are quite rare". This makes the dolomite karst areas of the N.T. such as Pungalina, significant. There is a potentially long time for karst to develop and there is no evidence of intense tectonic activity in this area, although more intense faulting and folding occur to the west. Some faulting and relatively gently warping has occurred but the dolostones are relatively flat lying. The preliminary information from speleothems indicates that there is significant potential for detailed climatic information to be obtained. This is particularly important as there is a dearth of appropriate sites in the Australian tropics for such work. The presence of a previously unknown colony of Ghost bats (*Macroderma gigas*) and the presence of large numbers of the rare Orange Leaf-nosed bats (*Rhinoncteris aurantius*) (Fig. 6) indicates important biological values. Initial studies of the invertebrates indicates a predominance of guanophiles (T. Moulds, pers. com.) but perhaps more work will find other invertebrates. Finally the caves are really spectacular if hot and sticky, but the bubbling karst springs (Bubbling Springs) are a pleasant end to hard caving days.

Figure 4: *Raft Cave PUN-23 passage shape (D. Carr)*

Figure 5: *Chert replacement of stromatolite in cave roof, Conyphyton Cave, PUN-36 (D. Carr)*

Conclusion

Significant caves and karst have been discovered, explored and documented in a remote area of Australia with difficult access. The whole exercise is an excellent example of how caver-initiated exploration and documentation on a series of self-funded expeditions can add to the understanding of caves and karst and assist with their management.

Acknowledgements:

Pungalina Safaris (Kirkhope Aviation and Owen Davies), Australian Wildlife Conservancy and the Victorian Speleological Association expeditioners 2005 - 2008.

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Figure 6: *Orange leaf-nosed bat on cave roof, Conyphyton Cave, PUN-6 (D. Carr)*

Karst and Pseudo-karst in Victoria: an Overview

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Abstract

This paper will give an overview of the many caves and related landforms known in Victoria, but will concentrate on the karst and pseudokarst of Gippsland.

Some are true karst but others are volcanic caves and pseudokarst. These features have scientific, recreation, aesthetic, conservation and education values and are an important part of the state's heritage. The karst and pseudokarst features are the result of the following natural processes: solution, precipitation, volcanism, weathering, piping, and wave action. Some karst is buried under the volcanic flows of western Victoria.

Solution and precipitation, primarily of carbonate rocks is the single largest group. These fall into two groups, widely separated in geological time: karst in the Palaeozoic limestones, mainly in the eastern part of the state, and that in Cainozoic limestones which are found from East Gippsland to the South Australian border. The next largest group is the volcanic caves of the Western District Volcanic Province, many of national and international geological significance. Significant caves are found in a range of other rock types including granitic rocks, quartz sandstones and silcrete.

Introduction

This overview paper will provide an introduction to the various karst and cave areas of Victoria with special emphasis on their geological setting. It is a minor revision of the chapter in the Guidebook for the 20th ASF Conference, Vulcon (Baddeley, 1995). The areas in East Gippsland are described in more detail in the Guidebook for this conference.

Victorian Cave Types

Victorian caves are not particularly notable in the ways that people often regard karst features. They do not rank amongst the longest, deepest, or largest cavern size in any type of ratings. Few caves have outstandingly spectacular speleothems, although there are some caves with very beautiful decoration. However, there is a great variety of caves in Victoria, both in type of host rock and in cave form.

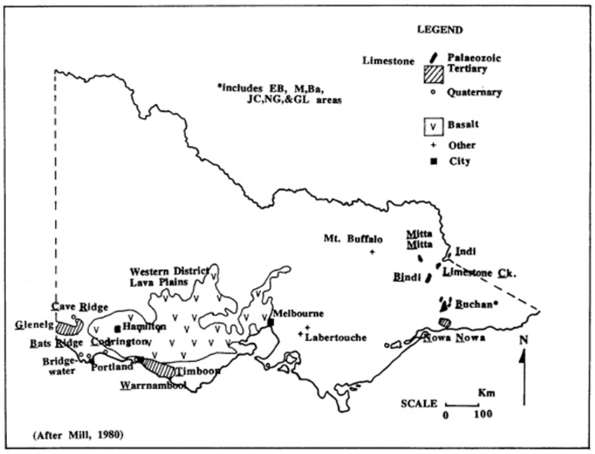

Figure 1: *Map of cave and karst areas of Victoria.*

The vast majority of the karst areas in Victoria are to the south of the Great Dividing Range. To the north are the flat, dry plains of the Murray Basin where conditions conducive to cave formation are rare, and so there are very few caves (Fig. 1).

Victoria has limestones ranging in age from the Cambrian to the Quaternary. Only limestones from the Silurian, Devonian, Tertiary and Quaternary are pure enough and extensive enough for caves.

There are five major categories of cave and karst landscape described; only two of these are in limestone (White, 1990).

1. Palaeozoic limestones

Caves are found in both Silurian marbles and Devonian limestones of Eastern Victoria, which tend to be pure (high $CaCO_3$ content), massive, well jointed and in areas of relatively high relief and annual rainfall. Most of them are impounded karst where areas of soluble rock (limestone) are completely surrounded by non-soluble rocks. Such topography gives good conditions for the formation of karst landforms. The caves in these areas consist of three main types:

Figure 2: *Decoration in Royal Cave (B-6), Buchan (Photo N.White).*

(a) Stream Passage Caves Formed by perennial and intermittent streams, some examples show older abandoned high levels. Many are well decorated (Fig. 2) but not all are. Good examples include the tourist caves at Buchan, Wilsons Cave (EB-4) and Scrubby Creek Cave M-49 (Fig. 3).

(b) Vertical Potholes These vary from blind shafts, e.g. Baby Berger (M-14), to complex examples with both vertical and horizontal development, e.g. Honeycomb (M-41), Jam Pot (M-48) (Fig. 4) and Exponential Pot (M-125). Again there is a great variety of decoration.

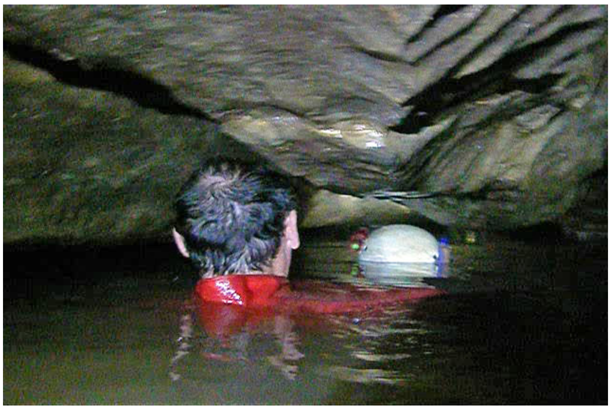

Figure 3: *The sump in Scrubby Creek cave (M-49) (Unknown photographer)*

These caves form as a result of solution along the intersection of joint planes.

(c) Collapse Caves These caves formed due to the collapse of roof material, e.g. Anticline (M-11).

Karst areas where such caves are found include the Buchan Valley, Limestone Creek, New Guinea Ridge and some other small areas in East Gippsland.

Research over the past 20 years shows that many of the caves in areas such as Buchan are extremely old, and places such as the Potholes have been subjected to inversion of relief, i.e. what is now on the top of a main ridge,

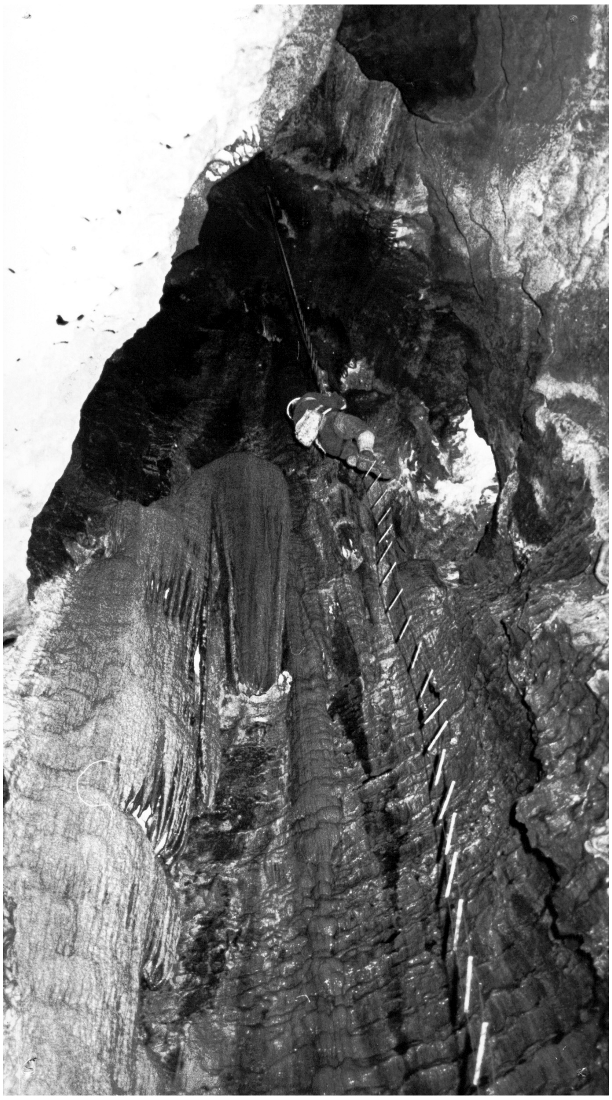

Figure 4: *Vertical pothole Jam Pot (M48) (Photo: R. Frank)*

200 m above the present river valleys, was the valley bottom (Finlayson et al. 1992). The caves were therefore formed below the water table before the landscape was lowered by erosion.

2. Cainozoic limestones

There are large areas of Cainozoic limestone in Western Victoria and South-Eastern South Australia, but variety in density of cave development in this province (Fig. 5). There are some areas with intense karst development, and yet other areas, sometimes not far away, where there is little development at all. The reasons for this are not very well understood, but appear to be at least partly related to the purity of the limestone. There is certainly sufficient rainfall. Compared with the caves in Palaeozoic limestones, there is more variation in the limestones, lower relief and very few joints.

Examples of Cainozoic limestone cave areas include Glenelg, Bats Ridge, Codrington, Timboon, Warrnambool, and Naracoorte. These caves tend to be horizontal, have collapse features, and are often multientrance. The quantity of calcite decoration is highly variable, the most common is moonmilk. The presence of solution pipes is a prominent feature in many areas (Fig. 6).

Some Quaternary dune limestones show syngenetic karst development where prominent features include a cemented (calcreted) cap-rock near the surface, vertical solution pipes and low wide horizontal maze caves either just beneath the cap rock or at the level of the surrounding plains. The poorly consolidated nature of the rock means that collapse plays a very important role.

In all of the Cainozoic limestone areas solutional, subsidence and collapse dolines are important, and there is a large doline field in the Peterborough area that is largely undescribed.

3. Basalt

The Western District lava plains extend from Melbourne to about 50 km west of Hamilton, with an isolated flow at Mt. Gambier. They were formed during periods of volcanic activity in the late Tertiary and early Quaternary. Fluid lava erupted from fissures and shield cones and spread across large areas. One theory is that as the top layer of lava cooled, the still liquid lava below drained away, leaving lava tubes and caves. They vary from simple tubes to complex branching and multi-level tubes and other forms as well, e.g. Mt. Eccles (Fig. 7), Byaduk. Other spectacular volcanic features are also present such as volcanic cones, tumuli and stony rises (Fig. 8).

4. Acid igneous rocks

These have never been thought to be very important for caves, but are now known to be more common and extensive. The main rocks are granite and granite-like rocks and examples of caves are found at Labertouche, near Warburton, Tynong, and Neerim South (Fig. 9). Other igneous rocks also show cavities similar to this. A small cave on Mt. Bogong is an example. Very interesting, small and rare opaline decoration is found in some.

There is a variety of forms from rockfall type to enlargement of joints in solid granitic rock. These areas

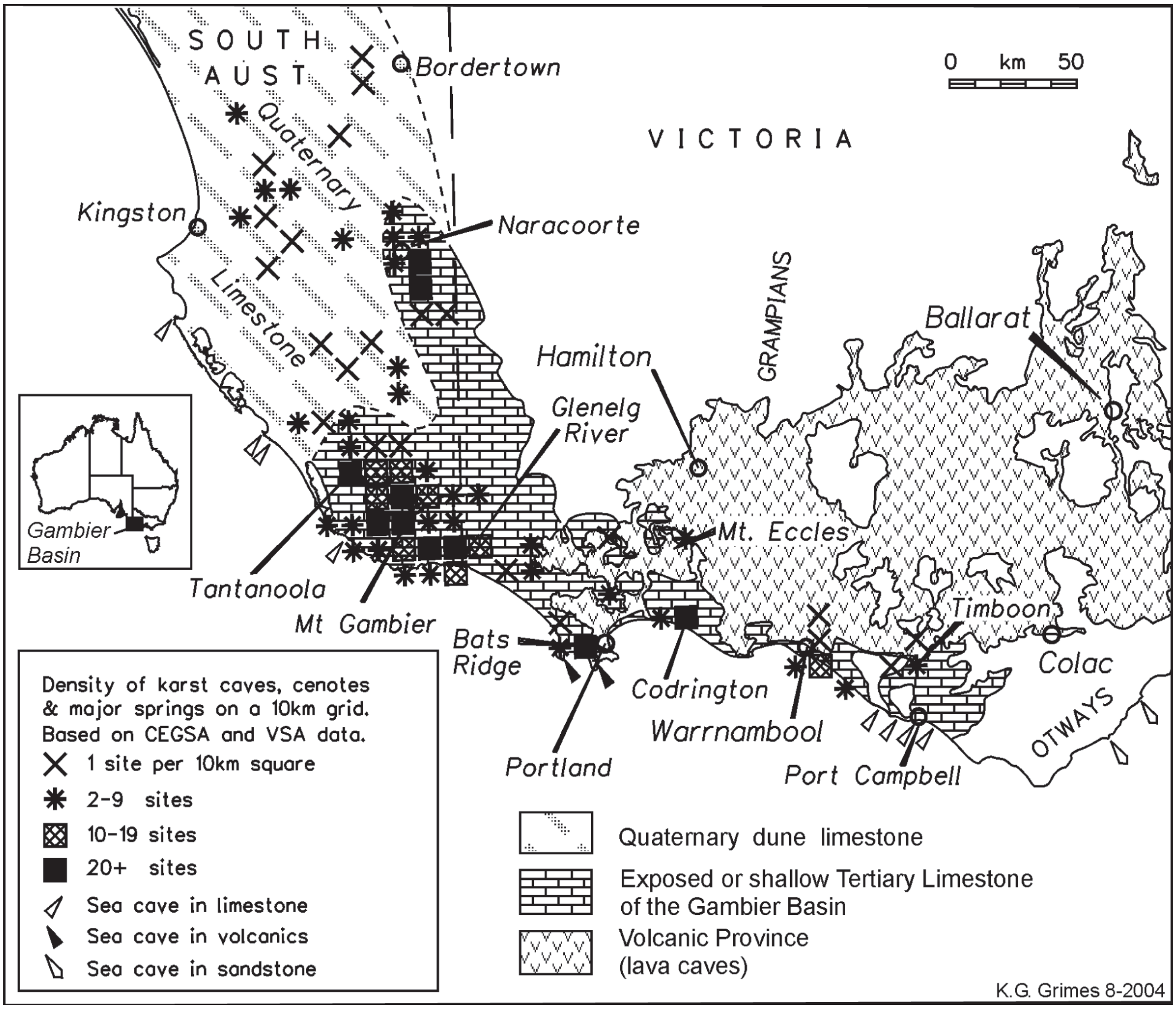

***Figure 5:** Density of cave and karst features in western Victoria and southeastern SA (K.G. Grimes 2004).*

are not described in detail in this field guide. The cave areas in this rock type are generally in eastern Victoria, but there are features similar in the Black Range granites in the Grampians area and Melville's Caves near Inglewood.

Finlayson (1986) describes three different types of caves in granite; boulder caves, open joint caves and closed joint caves. The boulder cave type includes two sub types; caves in boulder piles, such as Melville's Caves and caves in boulder filled channels, such as Labertouche Cave. In both cases the more weathered material around the boulder cores (grus) is removed. Open joint caves are formed by weathered material being removed from an open joint and roofed by boulders dislodged during the excavation of the joint. The best known example of this is River Cave, Girraween, in southern Queensland. Closed joint caves are formed by erosion along a joint. The only known example is Goebel's Cave at Girraween, Queensland.

Granite boulder caves are not uncommon in Victoria. The best-known and particularly well developed example is located in the headwaters of Labertouche Creek about 100 km east of Melbourne (Fig 9.). The bedrock is a Late Devonian granite known as the Tynong Granite.

***Figure 6:** Solution pipe G-10 Glenelg River (Photo R. Frank).*

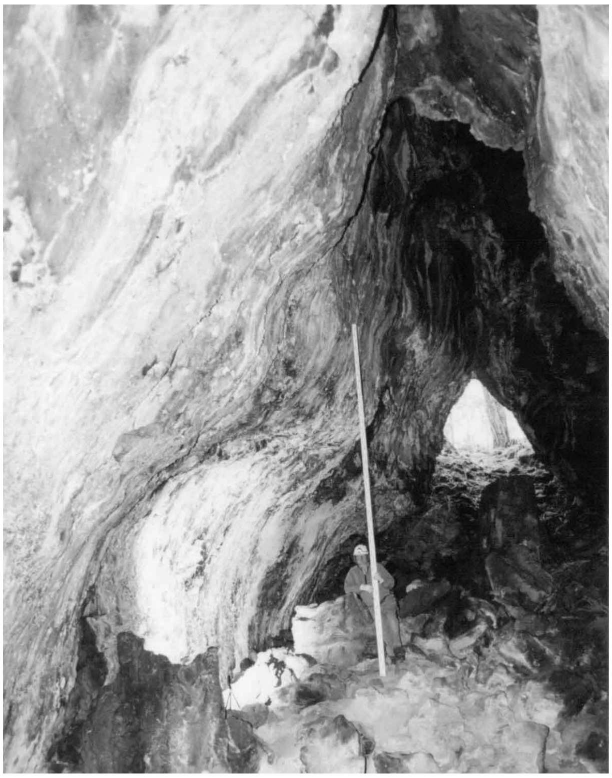

Figure 7: *The ceiling of Natural Bridge (3H-10), Mt. Eccles, has a "Gothic" shape that suggests it formed by levee overgrowth. (Photo K. Grimes).*

Figure 8: *Stony rises near Lake Condah, on a 30,000 year old lava flow from Mt. Eccles. (Photo K. Grimes).*

The cave is formed in a blind valley with the crest of the col terminating the valley about 25 m above the stream level. The 175 m of cave passage is comprised of spaces between the boulders.

5. Miscellaneous

These include sea caves in basalt (Cape Bridgewater), sometimes with limestone overlying the basalt (Fig. 10); mudstones (Cape Liptrap), sandstones (Cape Patton, Cape Otway area, Cape Paterson, San Remo, Mt. Speculation), basalt (Cape Bridgewater) and caves behind waterfalls such as Den of Nargun in Mitchell River National Park. Included with this group is the extensive series of overhangs in the Grampians which are still undescribed in cave or karst terms, but which have important art features on their walls.

In most of these cases, erosion of weathered material has occurred along planes of weakness or by abrasion from high-energy waves or streams. The arkosic sandstones and mudstones of the Otway Group and Strezlecki Group sediments in southern Victoria have significant joint enlargement caves at or just above sea level and at the coast.

Summary

Caves in Victoria have been known and used by man for a long time. Aboriginal Victorians have left evidence of using caves as habitation sites (Cloggs Cave, East Buchan) (Flood, 1980) and as art sites (Grampians and New Guinea Ridge). European interest in caves in the Buchan area is reasonably well documented since the visits by geologists such as Howitt and Stirling in the 1880s.

Nineteenth century interest in the caves of western Victoria is less well known. James Bonwick, a school inspector who travelled around south-western Victoria published descriptions of caves and karst in 1858 (Bonwick, 1878). Many detailed descriptions of the unusual mineralogy in Skipton Lava Cave were published in the 1870s and 1880s. The volcanic caves have been described in detail over the past century but less was

Figure 9: *Top entrance Labertouche granite boulder cave (Photo N.White).*

done on the karst areas of the Cainozoic limestones. Some descriptions are available but they are often hidden among other geological material.

The perception that Buchan is the only cave and karst area of interest in Victoria is no longer valid. The impression that one has about Victorian caves and karst areas is that there is immense variety of types and forms. There are many areas with small but very interesting caves in host rocks which are unusual, and new caves and new areas continue to be discovered.

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Figure: 10 *Sea cave in basalt; tufa and aeolianite overlying the basalt, Cape Bridgewater (Photo E. Hamilton-Smith).*

Karstcare - Cavers Looking after Caves and Karst: an update

David Wools-Cobb [1,2,3]
[1]Mole Creek Karstcare, [2]Northern Caverneers Inc., [3]Savage River Caving Club Inc.

Introduction

Karstcare is a group of active cavers in Northern Tasmania who are interested in contributing to the management of caves in the Mole Creek Karst National Park. Each Karstcare participant is a member of Wildcare, which is the largest incorporated environmental group in Tasmania. Wildcare has existed since 1998 and is a community partner organization with the Tasmanian Conservation, Parks and Wildlife Service. Wildcare members work alongside staff of the Service.

Wildcare has its own insurance, regretfully an important necessity in current times. The insurance premium is paid by Wildcare to cover members who are undertaking any Wildcare-approved work. Working bees are either proposed by Parks staff themselves, or our own group may propose a project, subject to Parks approval. We work directly under the Parks Office at Mole Creek. Our structure is somewhat casual, with a President, who I prefer to call a coordinator, and various volunteers from caving clubs and cavers not aligned with a club. We have contributed about 1500 hours of "hands-on" work in the past 8 years.

The President's role is, in effect, the link between Parks and volunteers. This role is as a liaison with Parks staff to discuss projects, coordinate volunteers and equipment. The President also arranges all administration with Wildcare, such as working bee call-ups and activity notification and ensures proper registration of each volunteer for each activity, to ensure insurance cover. One of the most difficult tasks for the President is the raising of funding for projects. This can be from within the Wildcare organization itself, from various Government-based environmental bodies, or even from corporate bodies. Although most of our work is labour-based, funds are required for such things as cleaning equipment, ropes for access, track markers, and protective matting. Parks sometimes assists with some equipment but often volunteers provide their own.

Achievements to 2008

Kubla Khan Cave

Kubla is one of Australia's premier caves and is considered by many to be of world class standard. It is approximately 4.6km long, with outstanding speleothems and involves considerable vertical skills. Access is extremely restricted, involving a permit and supervision by an accredited leader.

Cavers' contribution to Kubla Khan's management started in the early 1990s with a proposal from Northern Caverneers Inc. Any caver who has visited this cave will have seen a great deal of evidence of our members' contributions. Initially sandbagging and boot washing stations were introduced to minimize mud tracking and erosion. Assistance was also given to Parks staff with gating and since then a huge amount of cleaning the main route has been on-going.

Just prior to the ASF conference in Tasmania in 2005, fixed rig points were installed and water was stored in a large children's swimming pool in preparation for a major cleaning project carried out by conference attendees, in return for the opportunity to do a 'through trip' of this magnificent cave. To date a total of 883 hours of work have been contributed to this cave since 2001.

Boot-washing stations are positioned throughout Kubla Khan Cave. If used properly, they are an effective method of limiting further mud tracking onto previously cleaned areas. These stations need periodic maintenance to remove accumulated mud and to replenish the water (sometimes from several hundred metres away). Some sections of the route have recently been re-marked to keep cavers to the cleaned areas, further limiting mud tracking.

Just recently the cleaning of the rock fall down to the huge stalagmite known as 'The Khan' (18 m high) was completed. We used an innovative method for this; instead of carting water in 20kg loads in backpack sprayers, and getting aching muscles from scrubbing and spraying, we rigged up a siphon hose of 120 m with a spray head. This resulted in much less impact on the cave and cavers, and enabled this project to be completed in about one-half of the estimated time.

Tailender Cave

We have carried out a line survey, instituted track marking and placed some advisory signage and string-lines on 'no-go' areas. We are also currently undertaking extensive cleaning and have installed two boot washing stations. This time, instead of siphoning we have installed a pump to get water up to the work site, as it would have been almost impossible to manhandle backpack sprayers from the water to the work site. We have also installed p-hanger-bolts on the pitch to enable safe climbing and we are gradually laying down tube matting over the cleaned surfaces. This has proved to be our most difficult project, as to get to the worksite, usually with a big load of matting and cleaning gear requires about 400m of crawling. Often our volunteers are semi-exhausted before they even start the work!

Assistance with water-tracing

Our group was able to assist with local knowledge in a National Heritage Trust (NHT) project involving the hydrology of the Mole Creek area, including the placement of charcoal collection bags to determine stream flows in a particular valley.

Weed reduction: Mersey Hill & Wet Cave Block

The Mersey Hill area was purchased by Parks some years ago and has ongoing problems with the weed Spanish Heath. As the land is just above the Mersey River, it was considered that there was a risk that this weed would spread to adjacent areas and downstream.

The Wet Cave Block also has problems with holly and sycamores. So far three working bees have contributed to the weed eradication on these blocks. The Wet Cave Block project is the first time we have been involved in cutting hundreds of trees down in a National Park. Painting poison on plants seems an unusual activity for cavers but we have managed to contribute a total of 186 hours to these surface projects.

Croesus Cave

Croesus is probably the second most spectacular cave in the Mole Creek area, with a spectacular flowstone feature named "Golden Stairs". On the top of these stairs is a big muddy pool, making it difficult not to track mud onto sections of the stairs. To improve this situation we built a rock walkway from surrounding rocks to prevent picking up mud and tracking it further. We also cleaned this area and a further 100 m upstream.

We have also worked on a little known upper-section of Croesus; string-lining, cleaning the route and carrying out a delicate job of cleaning a major speleothem that may have been used as target practice with mud balls some years ago. A minor job was also carried out protecting some calcareous sand formations near the entrance of Croesus.

Marakoopa Tourist Cave and Beyond

Some time ago we spent a day removing all 'non-cave' material possible from the tourist sections of Marakoopa Cave. Apart from minor public litter, many old electrical installations were still lying around, plus other old construction materials. In total, four large garbage bags were filled with rubbish. The most interesting find was a very old 'Milo-type' tin with candles and a few old-style light globes. Countless broken light globes were also removed. We have also installed some string-lines in the 'Fireplace section' and matting to limit floor damage.

More recently we had a visiting interstate group keen to do some Karstcare work, so we arranged for a challenging vertical job of removing ivy from the cliff-face entrance to Marakoopa Tourist Cave.

Off-reserve Projects

Opportunities exist outside Parks controlled areas to contribute to karst environments.

Our group spent 16 hours cleaning rubbish from the entrance to Harry Creek Cave in the Dogs Head Hill area; it seems caves and other holes in the ground are great places to dump rubbish!

In July 2008 we were approached to be involved in the re-wiring and re-lighting project of Gunns Plains Tourist cave. We were given a tight deadline to have the cave 'cleaned up' before the re-opening ceremony. This involved removal of old wiring, from sometimes quite 'hairy' places, cleaning up any tourist rubbish and ensuring the pathway was clean. The contractor was so impressed with our efforts that we received a substantial donation. Members have also been involved in the non-tourist section of Gunns Plains cave with cleaning and matting and on-going maintenance.

Baldocks Cave

Just recently we installed a second fauna sanctuary near an entrance that is no longer used. This involved string-lines, tape and advisory signage.

Plans For The Future

Some of our current projects like Tailender Cave will be on-going for some time. My personal plan for Kubla Khan is to have as much of the route through this cave cleaned as is possible, thereby assisting in the management of this cave for long term human impact. Boot washing stations always require maintenance and previously cleaned areas often need minor re-cleaning.

Shortly we propose to commence a project in Lynds Cave and Cyclops Cave and only just recently Parks have acquired several additional blocks of land within the Mole Creek area that contain significant caves which will require careful management. We expect Karstcare to be involved in this management at the earliest opportunity.

Many of our tasks in the future will involve assisting Parks staff in the more difficult areas. Our guiding principle is to undo previous damage done by cave visitors and assist in managing caves to minimize future damage. Much of our work is tough! It sometimes involves standing in water of 2ºC while scrubbing flowstone with a brush! Many of our sites are difficult to access, but then who better to work in a cave than those who 'naturally' feel comfortable in such an environment? Over the time that Karstcare has been in existence, over 1500 hours have been contributed to cave and karst management in our area. We believe that we have gained tremendous respect from Parks staff for both our expertise and determination to contribute to caves in an extremely positive way.

Lessons Learned

Designing, negotiating and funding underground environmental projects is a tremendous amount of work but is particularly rewarding. For every 10 hours spent on carrying out a project, about 2 hours are taken to 'make it happen'. Without a great band of volunteers, and our determination to contribute in a positive way, our local Parks staff could not possibly complete such environmental projects. Frankly it gives us a different reason to go caving. We'd like to think that the caves that we work in are always better off for having us be there!

We've learned things such as:

1. Natural rock is easier to clean than most flowstone.
2. Not all mud is from cavers.
3. Gravity can be your friend if you can harness it (siphoning).
4. Batteries and pumps can minimize impact on caves and cavers.
5. Collapsible backpack sprayers wear badly but are easier to transport.
6. Children's swimming pools make great water storage tanks.
7. Only stainless steel pegs can be used as string-line supports (not aluminum).
8. Laminated signage is best on waterproof paper, waterproof markers and a good surrounding sealed area.
9. Some work sites are harder to get to than the work required when you're there.

10. Even the most skeptical caver is surprised by what can be achieved with a scrubbing brush and a sprayer. Visiting cavers are usually quite willing to put in a few hours work in return for a great caving experience.

11. If you keep plugging away, Parks staff will eventually be positive about what cavers can contribute.

12. Cavers can influence management with regard to caves.

What Can You Do in Your Area?

It is important to involve speleologists/cavers in cave and karst management especially as they are often the people who have found the caves, surveyed and documented them. I feel we should not judge either past practices of cavers or cave managers using today's values. By using the expertise of cavers, managers can undo some past damage and institute management principles (such as track marking, boot washing stations) to limit future damage to caves. By cavers developing relationships with cave managers in a particular caving area, managers can make use of the cavers' local knowledge and expertise. Cavers usually welcome the opportunity to have an input into management decisions. We all care about caves, so with cavers and managers forming a partnership we can work together for the good of caves and karst.

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Wildcare - Notes for Presidents <http://www.wildcaretas.org.au/>

Karstaway Konference Participants
Photo D. Carr

Workshops

A number of workshops were run at Karstaway Konference. Where abstracts were sumitted they are included here and a limited number of more detailed papers written up by the convenors of the workshops. However several workshops did not submit more than a couple of lines of abstract and have not submitted papers from the discussions. The workshops run were on the following topics: Action Figurative Art for Cavers and Non-cavers (June MacLucas), GIS for Cavers (Bob Kershaw), Publishing: a means to give a wider understanding of caves and karst to the community (Susan White), Out of Harm's Way: Best Practice for Risk Management in Caves (Caroline Forrest), Cave and Karst Conservation Forum (Nicholas White) and Documentation and the Karst Index Database (KID) Forum. Out ot the KID and documentation forums came the article by Bob Kershaw.

Armchair caving in the 21st Century or 'GIS for Cavers'

Bob Kershaw
Gregory Karst Research SIG Mapping Coordinator

Introduction

This article is a summary of an impromptu workshop given at the recent ASF conference in Sale and is not an article of a technical nature. The article explores the possible use of a Geographical Information System (GIS) in cave mapping and documentation by cavers in Australia.

Many cavers want to be able to take their GPS waypoints of caves they have located, and with their surveys of those caves, superimpose this information over an aerial photograph. A GIS will allow you to do this task. The *Compass* survey program will allow you to complete this task but with the survey plot line only, not the drawn walls. Numerous cavers use *Adobe Illustrator* to draw maps after importing the plot lines for features such as walls, from other survey software. However, this is not a Geographical Information System! Basically, a GIS is a computer software program that links all the geographic information collected about a place and displays it in map form.

This article briefly outlines the following topics related to GIS and caving: how I became involved in GIS, hardware that may be required, costs associated with this system, time needed to use the system and the minimum programs that you will need to use a GIS.

I became involved in GIS when I tried to do what I mentioned above, that is, overlay cave surveys on an aerial photo and also to digitise and draw maps of the 100 plus kms of the Bullita cave systems that kept changing each year. Historically, Don Glasgo in 1994 placed all the Bullita survey information into the Compass cave survey program. This data was then converted into ESRI shapefile[1] data to draw the plot lines and survey stations in Arcview (the ESRI GIS software). I have now been using the Compass program for 12 years and the ESRI GIS system for 6 years and easily update cave maps and GPS data as new information is added each year.

Hardware

You will need a reasonably good system to run the GIS software. The computer I use is a stand-alone PC with 4Gb of RAM, 2 disks; one is used as a backup. The computer runs a duo core processor and I do not connect it to the internet for the reason of security breaches and possibly crashing. I use a good quality A3 printer to print off the maps produced each each year which are copied and used in the field. Data is distributed to various cavers each year as an offsite backup.

Costs

The costs involved are what you want to spend, but a minimum a club should spend is approx $50 for Compass, $50 for a GPS program, such as GPSU or OziExplorer. If you go to the ESRI Australia web site and download a form for a grant under their Conservation Program, Arcview, that will cost approximatley $275. The alternative to ESRI is MapInfo but I don't think you can get it with a grant, and most government departments use ArcView and other add ons so there is always someone around to assist you. There are free GIS programs but stick to the 2 mentioned as there is a lot of support for beginners.

You may also need to purchase Adobe Photoshop or use the free GIMP, to enhance aerial photos. I also use Adobe Acrobat to produce print quality PDF's of the maps to send around Australia. But you could use free software to achieve similar results. You should build your GPS waypoint databases using Microsoft Access and this data is easily integrated to the GIS program. You can link cave entrance photos to the GIS as well. The purchase of aerial photographs is extra depending on which state you live in.

Time

The time you will put into learning this process and how to complete the tasks is enormous, but once learnt, and after you write yourself a 'How to' manual showing how all the software integrates to produce the plotlines, draw the cave maps etc- the process is easy. (Ed: Contact Bob for one).

Once you have the programs, convert your GPS waypoints to a database and import them to the GIS. Using Compass, export your survey stations, plot lines and wall shapes (this comes from your LRUDs) into shapefiles and load into the GIS. Register your aerial photographs and incorporate into the GIS. You can now draw your cave plans and every cave is located correctly (plus or minus 3-5m) so you can see how your cave system relates to the geography of the area.

Unfortunately, the whole process could become a one person operation but, if some members do the field work, others the inputing of survey data and others input the information into the GIS, someone else could do the map drawing. Alternatively, various members could look after certain areas of their state.

Conclusion

GIS has the potential to revolutionise cave surveying and data collection for large areas, but if you draw maps of single caves, *Adobe Illustrator* may be the way to go. If you have several caves with surveys and you want them geographically oriented to overlay an aerial photograph, and you also want to include creek lines, contours and data about cave animals or bat specimens found, then a GIS system is the way to integrate your data.

If you explore the countryside with a GPS and take a waypoint reference of caves you find and then undertake cave surveys and use a software program to reduce your data, and later you draw cave maps using software you are three-quarters the way to using a GIS system. So, why aren't you using GIS to do the complete task?

If you want information on Mapinfo contact Susan White or John Webb. The author can be contacted at rkershaw@ozemail.com.au

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*[1] **ESRI** is the abbreviation for Environmental System Research Institute..Shapefiles are a term used by ESRI and other GIS for points, lines and shapes.*

Out of Harm's Way: Best Practice for Risk Management in Caves

Caroline Forrest [1,2]

[1] ASF Leadership, Safety & Risk Management Commission, [2] NHVSS

Abstract

What do the ASF members want from the Safety, Leadership and Risk Management Committee? I would like to workshop the issue of new members and what would be reasonably expected from an ASF member who "puts themselves out there" as a leader. Risk management should be seen as an opportunity that any true leader would welcome as a challenge.

For effective risk management, the rewards are to be found in the events that do not happen. It is a fact that good risk management results from constant risk assessment, evaluation and monitoring. The lack of risk management can be seen in incident reports and relatives' faces. What can we say when the judge asks "what else could the defendant have done to minimize the harm?" How do you respond when your comrades say "if only we had... done something differently, thought this through, done another cave, stayed at home."

Come to the SLARM workshop to begin the ongoing commitment of ASF to be leaders. Agenda items are as follows:

- What is a leader and what is expected?
- What is Duty of Care?
- When is a beginner not a beginner?
- Risk Perception
- Environmental Risk
- Formal Training and qualifications
- What's the law got to say?
- What do you want from the SLARM Committee?

Workshop: Action Figurative Art for Cavers and Non Cavers

June MacLucas
Cave Eexploration Group (SA)

Abstract

Life Drawing: You don't have to be a caver.

Learn to capture on the spot cavers in action in or out of caves. This could assist in drawing figures at any time; in any situation.

Introduction

The Australian Speleological Federation Conference of 2007 witnessed the last of the Australian Speleo Art Exhibitions. It had been running consecutively at each Conference since 1999 and although the main work was always new and the exhibitions were always greeted with much interest resulting in substantial sales, it was suggested that it was time for a change. This time for the 2009 ASF Conference I was asked to present something different as there was no space for an exhibition, would I therefore be interested in presenting an Art Workshop.

I hesitated at first but eventually agreed, as there is so much work involved in arranging and presenting an Art exhibition and when I thought about the prospects of giving an Art Workshop it gave me a chance to present a workshop that perhaps would be of interest to both cavers and non cavers. In Australia there are very few cavers confident enough to try their hand at sketching what they see before them in caves. Here was my chance to encourage this aspect by teaching the simple techniques of elementary figurative drawing while using charcoal, pencil or some other easily applied medium to create an image. Just a little knowledge of learning to sketch what you actually see and transporting that onto paper by extending the use of various art materials to portray that image, can be very uplifting when used for the first time. Hopefully those who attended the workshop have used and achieved a greater interest in their own artwork to portray what they see, whether it be figures in caves, landscape, portraits, or whatever.

Action Figurative Art - Some quick and effective materials to use

After pencil, charcoal is one of the oldest and most basic drawing mediums available. It is easily erasable on most papers, allowing changes to be made at any point and enabling the drawing to be kept fluid and free. Large charcoal sticks can be used on their side to cover large areas of the paper with dense tones, while sharpening the ends of the charcoal are used to portray detail.

Red chalk or conte is another great and interesting way to create an image quickly. Used by important artists, such as Raphael (1483-1520) and Da Vinci (1452-1519) who both exploited its qualities for their precise figurative work by using the red warmth of the conte to enhance the fleshy qualities of their drawings.

Pastels are another quick and useful addition to the artist's arsenal. They can be used dry without oils or solvents. With only a dozen colours you have the scope to make paint-like studies of your model or cave.

Pens produce flowing drawings as seen in Figure 1, but there is not much scope for hesitation or change of mind, pens need a quick and steady hand. I feel it is not as useful and adventurous as the above media if you are not accustomed to it. There is a certain amount of confidence needed with using pens before venturing into this medium.

Figure 1: *Ceris Jones UK – Pen & Wash*

Papers

Dry media, such as pencils, charcoal, conte and pastels work well with textured papers. Wet media, such as ink and watercolours work better with harder papers. Please don't use thin paper or lined paper. If you intend to do some art work take the time to purchase a better quality paper from an art shop.

We have a model - Let's get started - Using tone

Tonal values are the gradations from light to dark seen on any solid object under the play of light. Observing tonal relationships between objects or parts of an object is a way of conveying a sense of structure. It is a traditional method that works well. To get started, half close your eyes so that the colour effects are diminished and tonal values are made simpler to read. Rendering tonal values requires materials that can produce a wide range of gradations from dark to light and back again. Charcoal fits the bill, especially compressed charcoal with its wide tonal range (Figs 2 & 3). Conte and graphite offer some flexibility but are not as quick and as affective as charcoal.

Let's look at the use of high-contrast or light and shadow to give form and shape to your subject

Light sources are a strong influence on your ability to see the form of your model. Light and shadow are important indicators of form and harnessing them allows you to create the effects of three dimensions on the flat surface of the paper. The use of a dramatic light source may also give the drawing impact, adding a sense of excitement to the drawing. While working in a cave, the light source from the cave entrance can give a sense of excitement to a figure set against a very dark background. Another way is by placing a lamp on the ground near the figure either to lighten the figure or lighten the background; this will add drama to your work. The best way to create form in your figurative work is to use light on the figure itself. Light gives shape and form; it rounds the figure giving it strength in its shadows of darkness, while giving life and form in the lighter areas. Harnessing the essence of light and shade is the secret of dramatic figurative work. Another way is cover the page with charcoal smearing it all over the paper smearing it with the side of your hand, then lightly trace in your figure. After establishing some proportions, begin lifting out the lights with the corner of a rubber while continuing to strengthen and clarify the shadowy areas giving strength and character to your work. This way of 'pushing' charcoal can be very exciting while bringing to life the image you wish to portray.

Figure 2: *Ceris Jones UK - Charcoal*

Figure 3: *Robin Gray UK - "Abseiling" Charcoal*

Hard and soft edges

Hard and soft edges are usually what give a drawing its two-dimensional quality. Too many hard edges usually flatten your drawing. By hard edges, I mean the actual outline of the drawing. Soft edges or just gentle shading, by comparison, creates a stronger sense of reality. These soft and hard edges are usually carried out by shading and lifting out using a rubber and can be used on both the inside and outside edges of a figure.

Measurement

Measurement is important, especially if you wish to use the figure to indicate the size of a cave or landscape. You may find this a bit daunting at first, but it soon becomes second nature and will be seen as a useful tool. The tool most commonly used, is to take continual measurements using your pencil and thumb as a guide. You can use these measurements in two ways: sight-sizing and comparative measurement. To measure the distance between two points extend your arm fully and hold the pencil vertically. With one eye closed align the tip of the pencil with the upper point and tip of your thumb with the lower one. Take a measurement from your model i.e. the size of their head and in this way you can measure how many heads fill the length or width of the body. For example: is it four or five heads down and one or two heads wide. This method is quick and easy and really works. It also works when measuring the figure in its surroundings, by taking the height of a full figure you can use this as a guide as to how large or how small an area you are placing the figure in that you wish to portray.

A demonstrations of this is shown by Elery Hamilton-Smith when he states Burke in his 1757 essay, (Hamilton-Smith, 1997:8) from *The Sublime and Beautiful*, that things which frighten us by their scale or mystery become transformed in our mind into something sublime and beautiful. This meant that landscapes were often reconstructed as much bigger and more grandiose than they are in reality by making the figures appear small and tiny compared to their surroundings. Hence using the figure to distort reality.

Balance – changes in tension of the muscles

No matter which position the model is in, it is important to develop an awareness of where the centre of balance of the body lies in order to make your drawing convincing. To establish the equilibrium of a figure in any pose, be it standing upright, sitting, hanging from a rope or whatever, you will need to determine the line of balance that travels down the centre of the body. This is done by looking where the centre of the clavicle (collarbone) is and drawing a line down the centre of the figure while looking to see where the weight is distributed in regards to this imaginary line. This is an important observation and one that can give the drawing a quick likeness and a sense of strength as to the positioning of the figure. Whether the figure is the front or back view, twisted, or leaning against a support, always check the weight and balance against a straight line down the centre of the figure.

Capturing the Essence of Movement

When studying movement, the essence is more important than detail. It is about the bigger picture; don't become bogged down in facial features and fingers. You can look at that later. Moving figures are not easy to draw; you need to be quick and simple in order to form a basis upon which to build. By focusing on the bigger issues and keeping them simple, you can make the freezing of action more convincing. If the pose is particularly difficult you can ask the model to rest and then repeat the pose several times as in Figures 4 and 5, or you can take a photograph and freeze the action so it is realistic. This can be seen in Figures 6 and 7. Degas (1834-1917) employed photography to capture his models in ballet movements. However, don't rely entirely on photography as sometimes the form is lost and figures can look weightless with no sense of balance.

***Figure 4:** June MacLucas – "Peter Ackroyd laddering down Thampanna Cave, 6N206 Nullarbor". Charcoal, graphite pencil and water colour pencil.*

Proportions of the head.

Although this workshop was never meant to be a portrait class here are some guidelines about the proportion of the head. Artists throughout history have noted that the proportions of the head are almost identical for every person regardless of gender or ethnic origin. As you learn the parts of the head and how they relate to each other, you will notice how age and gender change these relationships. For instants, in a male figure, the jaw line and the area between the eyebrows are more angular and pronounced. A woman's face is softer and oval while a child's face is rounder with eyes proportionally large for the rest of the face. Of course there are always some variations but mostly these guidelines are rules you can work from.

Barrett (2008:80) gives an excellent study of the proportions of the head when he states that the eyes are set at a halfway point between the top of the head and chin. The tip of the ears are set at the same level as the eyebrows and the base of the ears at the same level as the base of the nose. I have drawn many portraits and this rule is correct in every aspect of portraiture and no matter which way the face is turned up or down or sideways, if you draw a line across these areas and look at your model you will see that it works, it is correct and an easy guide to the proportions of the head.

The body as landscape

Finally, dealing with the complexities of the human form can be daunting. Rowlands (2005:126) claims a useful exercise is to regard the body as a landscape whether you are working on a figure set up in a cave, at home drawing your friends or you actually do have

***Figure 5:** June MacLucas – "Ray Gibbons abseiling down Thampanna Cave, 6N206 Nullarbor".Charcoal, graphite pencil and water colour pencil*

Figure 6: *June MacLucas – "Frank Hankinson abseiling down Murra-el-Elevyn 6N47 Nullarbor". Charcoal, graphite pencil and water colour pencil.*

Figure 7: *June MacLucas – "Frank Hankinson prusiking out of Murra-el-Elevyn 6N47 Nullarbor". Charcoal, graphite pencil and water colour pencil.*

someone set in the landscape. Think about what we have talked about, light illuminates the body while the shadows help to reveal the form. Don't worry too much about drawing detail. Concentrate on where the figure is in that so-called landscape. In a cave the landscape is as important as the figure. Try to capture that essence and let the work flow freely. Don't worry too much about detail; it's more of a feeling of presence that you are after. Even if you work quickly, remember that your model cannot stay too long in one pose; change the pose and start a new drawing. Take your camera and take shots while you are drawing, this way you will have a great source of material to work from.

We have a model, so let's get started on our drawing.

Many thanks to Sue Bateman of Sydney who kindly volunteered to be our model for this workshop and who wore the complete caving outfit, helmet and headlight. All participants at the workshop completed two drawings of Sue in different poses of which Sue on completion of the workshop gladly collected as a reminder of the event.

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June & George MacLucas Photo B. Downes.

Publishing: a Means to give a Wider Understanding of Caves and Karst to the Community

Susan White
ASF Publications and Helictite Commissions

Abstract

Publishing material about caves and karst is a major way of disseminating information and publicizing messages of good karst management. There are several forms of publication that can be used to get our messages across to cavers, the general public and to participate in scientific discussion. This workshop will explore the different modes of publication and what their advantages and disadvantages are and how the relevant ASF commissions can be used. The various publications of ASF will be used as the framework.

Introduction

Why should we publish our findings? Where do we fit in the scheme of things as amateurs in what is increasingly a workplace situation? It is important to discuss these issues as they occur all the time. Do we need information from the various scientists and what do they need from us?

Reasons for publication

The reasons for cavers to publish information is basically that we need to show that we are experts on caves and karst. If we do not do this in a professional (rather than Professional i.e. paid for) manner we are doing ourselves a disservice. We cannot then claim to be 'experts' because we do not subject our ideas and findings to others to be reviewed and subject to positive criticism. We are also abdicating from a responsibility to present material in a way that can lead to the protection/conservation of caves and karst.

Publication can be in the forms of reporting trips for exploration details, social reporting, publishing cave descriptions, cave documentation, scientific descriptions and conservation issues. It can be in any or all of these: Club Newsletters, Club Journals, Caving Journals, Speleological Scientific Journals (some refereed and some not), Speleological Monographs, Unpublished Reports, Conference Preceedings/Proceedings, refereed Scientific Journals, Books, Monographs or just about any other media. All of these are important in getting information out there to the caving and general public.

When publishing material it is important that material is accurate. Misinterpretation and inaccuracy are usually due to the following problems:

a) Failure to absorb and use new ideas and interpretations of new ideas and data. In this case the major issues in ASF and clubs is the regurgitation of out-dated ideas. Just because an eminent scientist said something 20, 30, 40 or even 5 years ago, is it necessarily true today? Or was it ever true? New information, updated interpretation occurs all the time and we need to keep up with it. We should not automatically accept an eminent persons' statement when we can see it does not fit the data before our eyes!

We also need however to make sure we do not make improbable statements, e.g. the cause of the feature at place A is due to processes A, B, and C. They will not necessarily be the same causes in place B or C unless the same or similar conditions apply. This is particularly the case with new ideas in areas we are unfamiliar with.

b) Failure of communication. We are all guilty of this and we need to make sure we try to describe things carefully and clearly. Equally we need to listen to what is actually said rather than what we think was said.

c) Tendency to blame lack of resources This is an old issue and although we can make it clear we cannot do everything immediately, we can keep working on it. Equally we need to give people time to get things done.

d) The retention of out of date material long after it is past its 'use by' date. This is related to the issues discussed in point a)

e) Myth and misinformation creep. This is where information becomes confused. The best example I heard was in a tourist cave where the cave was a small stream cave that was a tributary to a larger river; stream became **a** river, **a** river became **the** river, and the cave was described as having the main river having flowed through it in the past and formed the passage. Most unlikely!

f) Scientific education problems. These are not going to go away and the level of understanding of geological processes and geological time alone is an issue.

Some Questions?

There are many issues that arise out of the questions of what and how to publish. What are the advantages and disadvantages of each type of publication listed above? What sort of articles are the best to publish in each? How should we regard and use the articles? What is refereeing? What role do editors play?

When material is edited **please** do not take this as gratuitous interference. It is **impossible** to edit your own work; you just cannot see the problems. You see what you think you wrote. *Caves Australia* is edited i.e. the editor goes through submitted work and corrects grammatical and spelling mistakes, points out repetition, inconsistencies, citation of other people's work and poorly expressed sections and will usually make suggestions as to how to fix any problems. The people we really like are those whose material is well written, interesting and who can take the suggestions in the spirit they are given i.e. to make the article better! There will often be a few things to discuss. Sometimes material is forwarded to someone who knows the topic to check it. We try really hard to make sure that previous work is appropriately acknowledged. None of us likes seeing things we have done go unacknowledged in publications. That it is a small club journal does not mean you cannot be rigorous and fair about this.

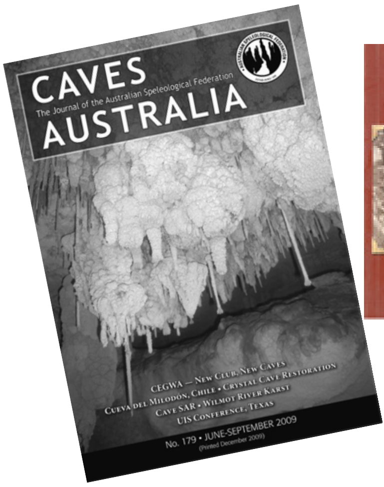
Refereeing (or reviewing) is a more detailed and rigorous version of this, where the article or book is referred to someone for an opinion on its quality and for suggestions on how to improve it. This is normal for scientific/academic papers, e.g. for Helictite and for monographs and books. This all takes time to do, especially as referees are not paid to do it (even for very prestigious journals). The article in question is returned and then altered to meet the requirements requested. If there is something the referee and the author disagree about, this can be discussed and usually a compromise of some kind is worked out or the work is withdrawn. All of this takes time and it often takes over 12 months for the process to work its way to final editing stage. Certainly monographs, books and *Helictite* will not be published under the ASF logo without this happening.

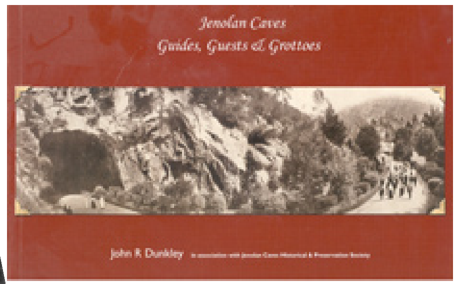
What does ASF publishing do?

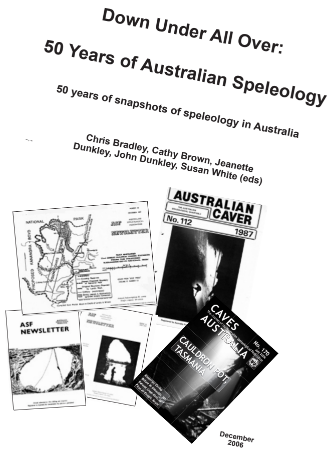
The ASF Publications Commission is responsible for the editing, production, publication and distribution of hard copy items and publication of electronic material produced by ASF. This includes quarterly magazines such as *Caves Australia* or member newsletters such as *ESpeleo*, but does not include the publication of *Helictite* which is the responsibility of the ASF Helictite Commission. The Commission members oversee issues to do with copyright and potential issues of offensive material. Fortunately we have had very little problem with this last issue. The main tasks revolve around collecting material and editing it to a suitable standard and getting appropriate graphics, again of suitable standard for printing, and then getting material ready for publication. This involves layout and proofreading. Finally then sending it out to members or organising distribution and/or sales. The main time consuming matters are to do with editing and proofreading, both of which take time, and rushing tends to result in mistakes.

Why is *Helictite* not part of the Publications Commission and has its own separate commission? Isn't this just duplication? This does look like duplication but when ASF received *Helictite* from the Speleological Research Council Inc, it was agreed that it would have a separate commission. People were concerned that it might just disappear and the money be 'frittered away'. In reality we struggle to keep the journal going, however we are managing to do so 'just'! Having the two commissions run in tandem rather than merged has minimised duplication.

This workshop finished with some discussion on how people can get involved and what tasks are needed to be done.







Examples of ASF publication

Cave and Karst Conservation Forum

Abstract

This forum is to provide an avenue to air problems and look towards solutions. The following questions are just some to prompt a contribution to the forum.

What is the state of play in your patch?

Are you in control?

Are the caves being trashed and is it us or them?

Does the Minimum Impact Caving Code need reviewing?

Could the caves be better managed by your local management agencies?

How should ASF support local karst conservation initiatives?

No findings or discussion were written up and submitted but the discussions were important for the Conservation Commission's work.

Other Activities

The Great Karstaway Trivia Quiz

The Trivia Quiz was conducted in teams and included some activities e.g. knots, as well as questions. The questions are listed below and the answers are in italics.

Rules

- Teams of 2 to 4 people
- Complete all sections on the sheets
- Judges decision is **FINAL**
- Answers will be posted at the end of the night and your team's answers will be marked by another team. This includes the knots and activities.
- The time permitted will be announced.
- **Have fun**

Questions and Answers

1. The book 'One Thousand Metres Down' written by Jean Cadoux and others in the 1950s is about the exploration of which famous French Cave? *Gouffre Berger (or the Berger)*

2. Who is regarded by many as the first 'professional caver' and made the first descent of England's Gaping Gill Cave? *Edouard Martel*

3. Who wrote the book 'Caves of Adventure' about the early exploration of Pierre St Martin? *Haroun Tazieff*

4. Name of doyen of Australian Speleology and author of 'Karst' in the series 'An Introduction to Systematic Geomorphology'? *Joe Jennings*

5. Name a previous Australian president of the IUS? *Julia James*

6. Where is the next IUS going to be held and when? *Texas July 2009*

7. UIS/IUS. What does this acronym mean and why are there 2 versions? *Union Internationale de Speleologique (French) International Union of Speleology (English)*

8. What are the individual groups in the National Speleological Society in the USA called? *Grottos*

9. Which Australian capital city hosted the first ASF Biennial Conference and when? *Adelaide, Jan. 1957*

10. Who was ASF's first president? *Brian O'Brien*

11. Name 3 past presidents of ASF since 1990? *Any 3 of: Jay Anderson, John Dunkley, Peter Berrill, Miles Pierce, Lloyd Robinson, Brendan Ferrari*

12. Give three names for previous conferences and where those conferences where held? *Any 3 of: Nibicon Sydney Dec 1972; Cavconact Canberra Dec 1976; WACCON Perth Jan 1979; CaveConvict Melbourne Dec 1980; SpeleoVision Adelaide Jan 1983; Speleomania Hobart Jan 1985; Speleotec Sydney Jan 1987; Tropicon Tinanroo Falls Dec 1988; Cave Leeuwin Margaret River Dec 1990 - Jan 1991; TasTrog Launceston Jan 1993; Vulcon Hamilton Vic Jan 1995; Cave Queensland Yeppoon Jan 1999; A Cave Odyssey Bathurst Dec 2000- Jan 2011; UnderWAy Bunbury Jan 2003; Cave Mania Dover Jan 2005; Caves Craters & Crtitters Mt Gambier Jan 2007. All other conferences did not have names.*

13. What ASF Commission evolved into ACKMA? *Cave Tourism and Management Commission*

14. What do the initials ACKMA stand for? *Australasian Cave & Karst Management Association*

15. In what year was the first edition of the ASF Speleo Handbook published? *1968*

16. Name of the current editor of Caves Australia? *Brooke Grant*

17. Who first drafted the Code of Minimal Impact Caving? *Rauleigh Webb*

18. What ASF survey grade number applies to a cave survey where distances between deliberately chosen survey stations are measured to within 0.1m and compass bearing and inclinometer angles to within 2 degrees? *Grade 4*

19. In the ASF standard cave mapping guide the symbol "x" represents what material? *Guano*

20. If the elevation angle between two survey points is 60 degrees and the straight line distance between the points is 10 meters what is the corresponding horizontal distance? *5 meters*

21. Name one of the recipients of the ASF Edie Smith award announced at the Mount Gambier Conference in 2007? *Grace Matts, Ian Houshold*

22. To whom was the newly created ASF Award of Distinction made in 1993 and in connection with what long

running cave and karst conservation campaign? *Norm and Doreen Pershouse, Mount Etna Campaign*

23. Nomenclature purists rail against this eight word cave name and where is it? *The-cave-with-the-thing-that-went-thump, Mount Etna, Qld*

24. What respiratory fungal disease can be contracted from bat guano, particularly if it is dry and dusty? *Histoplasmosis*

25. What gas is produced in a carbide lamp and burnt as a light source? *Acetylene*

26. Which cave currently claims the record as the world's deepest cave? *Voronja (Voronya) Cave*

27. Name the longest surveyed cave in Australia and in which state or territory? *Bullita System NT*

28. Name the deepest cave in Australia and in which state? *Tachycardia, Tasmania*

29. Queensland volcanic region with extensive lava tubes, some used for tourism? *Undara*

30. What is the French word for abseil? *Rappel*

31. The word speleology has its etymological roots from which classic language? *Greek*

32. What is the generic word pertaining to the construction of static rope such as Blue Water rope? *Kernmantel*

33. What is the common name of the bat *Rhinolophus Megaphyllis*? *Eastern Horseshoe bat*

34. Name three descending devices as used in SRT? *Whaletail, Figure of Eight, Rack, Petzl Stop.....*

35. What type of knot is a prussik knot? *Slip knot*

36. Approximately how long ago is the mid Devonian era? *about 400 million years ago*

37. Rocks are classified initially according to the way they are formed. One type is formed when various substances are deposited and cemented together. Another type is formed when hot liquid rock material solidifies and the third type is formed by the effect of heat and pressure on rocks. Name the three types of rocks in order of descriptions above? *Sedimentary, igneous and metamorphic*

38. What is the name given to the huge slabs of slowly moving rock that form the Earth's crust? *Tectonic Plates*

39. Name the two main types of doline? *Collapse and solution*

40. What is the key difference between Dolorite and Dolomite? Dolerite is an *igneous rock similar to basalt and Dolomite is a sedimentary rock (magnesium calcium carbonate). Dolomite is also the name of the mineral.*

41. What are the main chemical constituents of Dolomite? *Calcium/Magnesium Carbonate (Ca/MgCO3)*

42. Name an Australian cave area in Dolomite? *Bullita, Pungalina, Tantanoola but there are several others*

43. What is the common name for the mineral responsible for the massive crystals in the 'Cave of Crystals' discovered by miners in Mexico in 2000? *Gypsum*

44. What is its chemical name? *Calcium Sulphate (or more strictly, hydrated Calcium Sulphate)*

45. What is the chemical formula for calcite? $Ca\ CO_3$

46. What is the collective name for Stalactites, Stalagmites, Shawls, Straws, Flowstone, etc? *Speleothems*

47. What is the technical term for cave passage development dominated by solution in flooded cavities? *Phreatic*

48. What is the word to describe the cave passage development dominated by free flowing water? *Vadose*

49. Name a relatively common cave type not formed by solution? *Volcanic / lava tubes, coastal sea caves*

50. What is the name of the process by which plants use the energy of sunlight to produce oxygen gas and sugars for energy? *Photosynthesis*

51. What element is the main component of all of Australia's silver coins? *Copper*

52. What do you call the point about which a lever pivots? *Fulcrum*

53. Animals on Earth come in all sizes. What is the largest living species of mammal? *Blue whale*

54. Some animals eat only plants. Some eat only other animals. What is the word to describe an animal that eats plants and animals? *Omnivore*

55. List the planets in our solar system from closest to the sun to furthest away? *Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune*

56. How many times does the moon revolve around our sun in one year? *Once*

57. Around what planet does the moon Titan orbit? *Saturn*

58. Who was the first woman to win a seat in the House of Representatives in the Australian parliament? *Enid Lyons (Tas) in 1943 (Dorothy Tangey was elected to the Senate the same year from WA).*

59. In what year did regular TV broadcasting start in Australia, and in what year was colour TV introduced? *1956, 1975*

60. Australia Day is celebrated on January 26 each year. Why was this day chosen as the country's national day? *Commemorates the day in 1788 that the Union Jack was raised in Sydney and foundation of NSW colony declared*

61. Using the word CAVERN create as many 4 or more letter words. Do not use plurals or proper nouns or acronyms. Using the word Speleological create as many 4 or more letter words. Do not use plurals or proper nouns or acronyms. *Answers to these questions are not provided here. The list is too long!*

62. Like all living organisms on Earth humans can be classified based on the Linnaean classification system. Classify humans according to

Kingdom *Animalia* ***Phylum*** *Chordata* ***Class*** *Mammalia* ***Order*** *Primates*

Family *Hominidae* ***Genus*** *Homo* ***Species*** *sapien*

63. Using the supplied cord tie the following knots :- Fishermans knot, Bowline, Figure of eight.

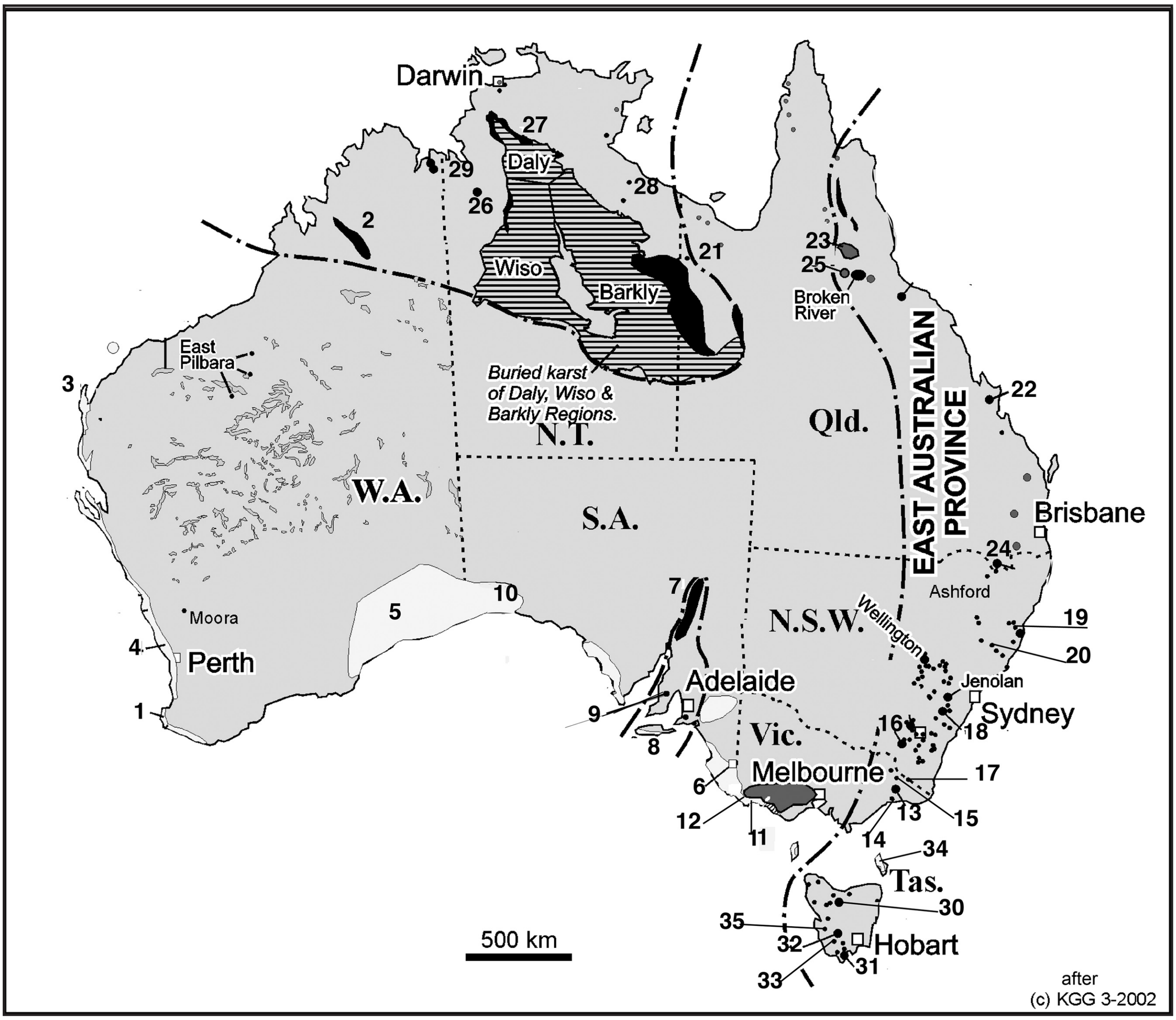
64. Fill in the table from the information on the map. Be careful, as some information is not obvious. A couple of clues are given to assist. The map is Figure 1.

Number	**Caving area name (some clues are given)**	**Full Area Code**
1	Margaret River	6 MR
2	Kimberley	6 KN, KG, KH, KL, KO, KP
3	Cape Range	6 C
4	Yanchep	6 YN
5	WA Nullarbor	6N (now 5N)
6	Naracoorte	5 U
7	Flinders Ranges	5 F
8	Kangaroo Island	5 K
9	Yorke Peninsula	5 Y
10	Nullarbor SA	5 N
11	Bats Ridge	3 BR
12	Drik Drik	3 DD
13	Murrindal	3 M
14	Nowa Nowa	3 NN
15	Limestone Creek	3LC
16	Yarrangobilly	2 Y
17	Indi	2 I
18	Wombeyan	2 W
19	Yessabah	2 YE
20	Timor	2 TR
21	Camoweal	4 C
22	Mt Etna	4 E
23	Chillagoe	4 CH
24	Texas/ Border Rivers Karst	4 BRK

25	Undara	4 U
26	Bullita	8 BAA
27	Katherine	8 K
28	Pungalina	8 PUN, SEL
29	Keep River	???
30	Mole Creek	7 MC
31	Ida Bay	7 IB
32	Junee Florentine	7 JF
33	Mt Anne	7 MA
34	Ranga	7 RA
35	Lower Gordon	7 LG

Keep River area code will be related to the 1:100000 maps sheet.

Figure 1: *Cave and karst areas of Australia (after Grimes 2002)*



Photographic Prints Display and People's Choice Voting

Miles Pierce

Conference registrants were invited to submit mounted A4 size photographic prints of cave or karst related subjects for display at the Conference. It was decided, after taking into account experience at recent previous ASF Conferences, not to arrange for external judging but rather to focus on the display aspect, together with a 'people's choice' competition wherein conference delegates could vote for their preferred print in each category.

Four categories were proposed in the invitation notice, viz: Surface Karst & Cave Entrances; Underground Action; Cave Passages & Pitches; Speleothems. Two further categories 'Scientific' and 'Humorous' were suggested by interested submitters in December '08, however it was by then considered too late to revise the invitation in fairness to others who may have already arranged their prints for submission. Instead, an advice was issued that an 'Unclassified' section would be included for the display, but that prints in this section would not be included in the 'people's choice' voting.

Seventy-two submitted prints were displayed on panels in the Conference common room from Monday to Thursday in the respective categories plus 'unclassified' prints. Some submitters offered their prints for sale and in this case the asking price (inclusive of a 10% conference commission) was placed beside or under the respective prints. For voting purposes, each print in the four nominated categories was assigned a serial number. A single ballot paper was included in each registrant's 'showbag' with spaces to write in the number of the preferred print in each category. A total of 53 ballot papers had been placed in the ballot box by the close of voting on Thursday.

The accompanying table lists the photographic prints submitted for each category and the number of votes (out of 53) accorded to the respective prints by the 'people's choice' voting. The winning print in each category is printed in blue type. The actual number of votes received for individual prints is included particularly for the interest of the submitters. At least one of the photographers was surprised by the relative preferences as reflected in the numbers of votes for particular prints.

Prints offered for sale in the display ranged in price from $19 to $29. Out of a total of 46 prints offered for sale, 27 were sold at the conference.

Table of Submitted Photographic Prints and Voting

*The winning print in each category is printed in bold **colour type. ie blue**

*Submitter initials:

DW-C	David Wools-Cobb
GS	Garry Smith
IMcC	Iain McCulloch
IN	Ida Newton
NP	Norman Poulter
RZ	Reto Zollinger
YI	Yvonne Ingeme

Number	Title / Description	Submitted by*	Votes
Category:	*Surface Karst & Cave Entrances*		
1	Bunda Cliffs	NP	1
2	Nullarbor Cave	NP	3
3	Tree Moulds	DW-C	1
4	Stromatolite	DW-C	2
5	Thampana Cave	IN	10
6	Timor Karst	GS	1
7	Lava Tube – South Korea	DW-C	2
8	Abrakurrie	IN	1
9	Yarrangobilly Karst	GS	4
10	Bullita Karst	DW-C	5
11	Xeres Cave	GS	10
12	**Loch Ard Gorge Cave**	**GS**	**13**
Category:	*Underground Action*		
1	Squeeze	NP	
2	Handholds?	GS	4
3	**Walking in Mud**	**GS**	**15**
4	Cockroach (2 prints)	IN	1
5	Climbing in Passage	GS	8
6	Dave Butler in Brown Snake Cave (SA)	GS	5
7	Midnight Hole	GS	9
8	Crawl	DW-C	2

9	Soft Caving – Lava Tube	DW-C	
10	Linda	DW-C	8
11	Glow worm threads	DW-C	1
12	Gunns Plains Cave	DW-C	

Category:	***Cave Passages & Pitches***		
1	The Panthenon (Nullarbor)	NP	2
2	Christmas Extension	NP	1
3	Main Cave Timor	GS	7
4	Abrakurrie Cave	IN	2
5	Serpentine Cave meanders	GS	8
6	**Croesus Cave**	**GS**	**26**
7	Not used		
8	Quarry Cave	GS	4
9	Bullita Tree Roots	DW-C	1
10	Gunns Plains Cave	DW-C	
11	Croesus Cave	DW-C	
12	Bullita	DW-C	2
13	Croesus	DW-C	

Category:	***Speleothems***		
1	Halite spaghetti	NP	1
2	Crystalline Halite	NP	
3	Fossil Lake – Prostrate Pit	NP	
4	Prostrate Pit	IN	3
5	The Hook – Prostrate Pit	NP	
6	Speleothems – Prostrate Pit	IN	1
7	**Spirit Cave**	**RZ**	**11**
8	'The Hook' straw	NP	6
9	Matilda Cave	IN	
10	Quarry Cave	YI	2
11	Quarry Cave	YI	
12	Speleothems – Prostrate Pit	IN	
13	Sentinel Cave	IN	1
14	Crystal	IMcC	3
15	'Fried Egg'	GS	2
16	Tick Cave	YI	4
17	Tick Cave	YI	
18	Murder Cave	GS	1
19	Forbidden City – Kubla Khan Cave	DW-C	
20	Helictite Profusion - Cliefden	GS	1
21	Calcified Tree Roots – Monbulla	GS	7
22	Not used		
23	Jaws of Pleasure – Glass Cave Jenolan	GS	3
24	'The Ball' – Croesus Cave	DW-C	
25	Lava Column - Korea	DW-C	
26	Rimstone Dams – Glass Cave	GS	1
27	Bullita Balls	DW-C	6
28	Jessica – Quarry Cave	DW-C	

Unclassified	***(not included in voting)***		
	Face in Hole	GS	
	The Loop	DW-C	
	Lava Chocolate	DW-C	
	Bat	GS	
	Skull	GS	
	Weta	GS	
	Bone Yard	DW-C	
	Underground Pottery	DW-C	
	Moth	GS	

ASF Awards

Various awards were announced and some presented at the Dinner. A number of past recipients of various awards were presented with plaques or badges to further acknowledge their earlier awards.

The awards announced at Karstaway Konference were:

Edie Smith Award	Ken Grimes	(VSA, CEGSA)
	Mike Lake	(SUSS)
Award of Distinction for exploration	Jodie Rutledge	(NHVSS)
Award of Distinction for exploration	Alan Jackson	(STC)
Award of Distinction for Conservation	Stephen Comino AM	
Award of Distinction for Conservation	Maria Comino	
Certificates of Merit	June MacLucas (CEGSA)	
	Tony Watson (VSA, Vic Scout Caving Team)	
	Gary Smith (NHVSS)	
	Peter Robertson (VSA)	
	John McCabe (CQSS)	

Jodie Rutledge receiving the Award fof Distinction for exploration from President Stan Flavel. Photo: B. Downes.

Grace Matts & Nicholas White receiving plaques for awards announced at previous conferences. Photos: B. Downes

A Photographic Record of Some Conference Activites

From top left: Abseil Races set up (DC); Ken Boland in SpeleoSports (DC); Browsing the KFC silent auction (BD); The Buchaneers SpeleoSports Team (DC); Joe Sydney negotiating an obstacle in SpeleoSports (DC) Photos: D. Carr & B. Downes

Karstaway Konference - 27th Biennial Conference of
Australian Speleological Federation Inc, 4-9 January 2009, Sale, Victoria


Australian Speleological Federation Inc
Certificate of Merit
Tony Watson
his involvement in the development and leadership of the Victorian Scout Caving Team, the organization of ASF conferences and assistance with the development of ASF Codes.