Proceedings Of
UNDER **WA**Y 2003

2nd – 8th January 2003
Bunbury, Western Australia



24th Biennial Conference of the
Australian Speleological Federation
Incorporating
3rd Australian Cave History Seminar
6th Australian Karst Studies Seminar

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Bunbury Cathedral Grammar School, Western Australia

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We had wonderful support from all of our sponsors – we couldn't have done it without you.
We thank in particular, our principal sponsors:

- MainPeak – John Mustard
- CaveWorks – Robyn McBeath
- Ngilgi Cave – Liam Kinsella
- CALM – Anne Wood
- Devils Lair Winery – Manny Loucas

Additional thanks to all other sponsors, supporters and contributors.

For those who helped with or/at the conference, we wish to thank, in order of appearance:

- Wayne Jefferies for his assistance posting our website information.
- Michael Whitworth for helping us set up at the school.
- June MacLucas, Chris and Ray Gibbons for the art show set-up and handling.
- Greg Thomas for speleosports logistics and lots of other help.
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- Dennis Sarson for his input in co-judging the photographic competition.
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- Bob Kershaw for his rapid data entry of the Survey Stakes data.
- Paddy Morris for lending us, bringing (and working on) the climbing wall for the speleosports.
- Arthur Clarke for his photographic expertise.

Finally we wish to express our appreciation to the management and staff of Bunbury Cathedral Grammar School, for all their help in running the conference.



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Photos Around the Conference









Clockwise from top left: *Welcome BBQ; Auditorium crowd; Bus trip participants; Discussion outside Ngilgi Cave; Lunch in the dining room; ASF meeting; Display of poster presentations.*

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***Submission not received for this presenter, the abstract has been inserted in its place.*

[#]*Unable to reproduce poster submission, the abstract has been inserted in its place.*

Photos supplied by Jay & Ross Anderson, Arthur Clarke, Ian Collette, Chris Gillard, Fran Head, Ida Newton, Rebecca Newton and Noelene Taylor.

We have endeavoured to publish the presentations as the authors intended, we apologise for any oversights.

Conference Timetable

Thursday 2nd January 2003

Time	Activity
2 – 5pm	Registration
6pm	Welcome BBQ

Friday 3rd January 2003

Time	KARST STUDIES and GENERAL PRESENTATIONS
9am	OFFICIAL OPENING with **Dr Brian O'Brien**
9.30am	A Little Plane, a Big Plain and Very Many Feet: The Finding of *Thylacoleo* (K) **Ken Boland**
10am	Documentation and Ground Exploration of Nullarbor Karst (K) **Paul Devine**
	MORNING TEA in Mainpeak Auditorium
11am	New Discoveries of Articulated Well-Preserved Megafauna from Nullarbor caves (K) **Dr John Long**
12noon	Troglobitic Spiders of the Nullarbor Plain (K) **Norman Poulter OAM**
12.30pm	Underwater Helictites from the Nullarbor (K) **Jill Rowling**
	LUNCH in Devil's Lair Dining Room
2 – 3pm	ASF COUNCIL MEETING - PART 1
	AFTERNOON TEA in Mainpeak Auditorium
4 – 5.30pm	ASF COUNCIL MEETING - PART 1
6pm	DINNER in Devil's Lair Dining Room
7 – 8pm	IMAGES FROM BELOW - Art Show Opening
8.30pm	Inside Karst - slide show (G) **Andrew Eavis**

Saturday 4th January 2003

Time	CAVE HISTORY and GENERAL PRESENTATIONS
9am	Where is Australia's First Identifiable, Recorded Cave Discovery? (H) **John Dunkley** Risk management workshop (G) **Jodie Rutledge**
9.30am	Augusta's Jewel Cave from a Caving Perspective (H) **Lloyd Robinson**
10am	Who was Australia's First Speleologist? (H) **John Dunkley**
	MORNING TEA in Mainpeak Auditorium
11am	A Short History of the Yanchep Cave Area (H) **Lex Bastian** Risk management workshop continued **Jodie Rutledge**
11.30am	Some Little-known Early Cave Visitors (H) **John Dunkley**
12noon	A Thumbnail Sketch of the Leeuwin Ridge and Caves History since European settlement (H) **Brian Combley**
12.30pm	The Ideal Health and Holiday Resort: An Investigation into the Development of the Caves Area at Yallingup, Western Australia as a tourist destination Caves House, Yallingup (H) **Lise Summers** Protecting the Intellectual Property in Cave Site Locations (G) **Sandy Boulter**
	LUNCH in Devil's Lair Dining Room
2pm	Acetylene Illumination of Early Tasmanian Show Caves (read by Grace Matts) (H) **Stephen McCabe** Arthropod Ecology of Bat Cave, Naracoorte, SA (K) **Timothy Moulds**

2.30pm	Abridged Oral History Interview with Mr Peter Smith (H) **Busselton Historical Society** Karst Features in Pleistocene Dune Limestones, San Salvador and New Providence Islands, the Bahamas (K) **Susan White** and **Nicholas White**
3pm	The New Caves of South Mole Creek, in Northern Tasmania (H) **Arthur Clarke** Carbon Dioxide and Climate in Jewel Cave (K) **Stefan Eberhard** and **Neville Michie**
	AFTERNOON TEA in Mainpeak Auditorium
4pm	Cave Photography – Getting Started (G) **David Wools-Cobb** Caving for "Pink Puffers" and "Blue Bloaters" (G) **Garry K Smith**
4.30pm	Where are the Cave Conservation Projects in Australia? (G) Karst Abuse in Western Australia (G) **Rauleigh Webb**
5pm	Cave Photography – Getting Good Photos (G) **David Wools-Cobb** Cave Fauna and Cave Ecosystems in Southern China (K) **Arthur Clarke**
6 – 7pm	DINNER in Devil's Lair Dining Room
7.30pm	PRUSSIK CHALLENGE - GYMNASIUM
7.30pm	Official Judging Photography Competition

Sunday 5th January 2003

Time	BUS TRIP – Sponsored by CaveWorks, the Department of Conservation and Land Management and Ngilgi Cave
8am	Leave on the bus
9.30 – 11am	Ngilgi Cave/morning tea
11am	Bus in transit to Wharncliffe
12noon	Labyrinth Cave Survey (G) **Michael Bradley**
12.30pm	Managing Caves and People in the Leeuwin-Naturaliste National Park, WA (G) **Anne Wood**
1pm	LUNCH Walkway Technology (G) **Neil Taylor**
2.30pm	Bus in transit to Calgardup/Mammoth or Lake/Giants caves
3pm	Lake Cave – Caveworks display
4 - 6pm	Visit Calgardup/Mammoth or Lake/Giants caves
6.30pm approx	Head back to the school for dinner
8pm	DINNER

Monday 6th January 2003

Time	KARST STUDIES and GENERAL PRESENTATIONS
9am	Karst Hydrogeology and Speleogenesis in the Leeuwin-Naturaliste Ridge (K) **Stefan Eberhard**
9.30am	Dune Subsystems of the Swan Coastal Plain (K) **Lex Bastian**
10am	Recent Advances in Radiogenic Isotope Mass Spectrometry : Implications for Reduced Environmental Impact of Speleothem Paleoenvironmental Studies (K) **Dr John Hellstrom**
	MORNING TEA in Mainpeak Auditorium
11am	Hydrogeology and Speleogenesis Update, the Yanchep Cave Area, WA (K) **Lex Bastian**
11.30am	Anchialine Systems in Australia – Why are they so Interesting? (K) **Dr Bill Humphreys**

Conference Timetable

12noon	Environmental Hydrology and Stygofauna in the Jewel Cave Karst System (K) **Stefan Eberhard**
12.30pm	Caves under your House (K) **Paul Tholen** Pilchers Mountain Caves (G) **Garry K Smith**
	LUNCH in Devil's Lair Dining Room
2pm	Troglobitic Spiders of Research Cave 6N-327 (K) **Norman Poulter OAM**
2.30pm	Surface Tufa Deposits of the Leeuwin-Naturaliste Ridge (K) **Jane Scott** The ASF's Web-based Karst Index Database – A Brief Update (G) **Mike Lake**
3pm	Cave Rights Revisited (G) **Norman Poulter OAM** Cave Diving Exploration in Western Australia (G) **Paul Hosie**
3.30pm	AFTERNOON TEA in Mainpeak Auditorium
4pm	Water Loss in Caves of the Yanchep Region (K) **Lex Bastian** Cave Diving Exploration of Australia's Top End (G) **Paul Hosie**
4.30pm	Cave Aragonites of New South Wales (K) **Jill Rowling** An Eclectic Review of Subterranean Biology in Australian Waters (K) **Dr Bill Humphreys**
5pm	New Troglobitic Cave Fauna Species in Tasmania, including Apparent Species Varieties of the Southern Cave Harvestman: *Hickmanoxyomma cavaticum* (K) **Arthur Clarke** Solution Pipes and How to Make Them (G) Syngenetic Karst in Australia: A Review (G) **Ken Grimes**
6 – 7pm	DINNER in Devil's Lair Dining Room
7.30pm	PHOTOGRAPHY COMPETITION SLIDE SHOW

Tuesday 7th January 2003

TIME	Activity
9 – 10.30am	ASF COUNCIL MEETING - PART 2 Gear, lights and gadgetry (G) **MainPeak**
	MORNING TEA in Mainpeak Auditorium
11 – 1pm	ASF COUNCIL MEETING - PART 2
	LUNCH in Devil's Lair Dining Room
2 - 3.30pm	SPELEOSPORTS in Junior playground
	AFTERNOON TEA in Mainpeak Auditorium
4 – 5.30pm	SPELEOSPORTS in Junior playground
6.30pm	CAVER'S DINNER - Awards and prize presentation in Devil's Lair Dining Room

Wednesday 8th January 2003

TIME	Activity
10am	Leave accommodation and head out for post conference caving

Profiles of Presenters

Please note: Presenters without profiles are listed at the bottom of this section.

Jay Anderson

ASF Conservation Co-convenor / WASG

Jay is a speleologist and an active outdoor leader. As a member of ACKMA the ASF and the two Speleological Groups in WA, Jay is interested in all aspects of caves and their management - with particular interests in karst management and cave conservation, cave rescue training, vertical ropework skills, cave fauna, ecology, geomorphology and hydrology.

Jay is the WASG conservation officer and one of the ASF Conservation Co-Convenors for WA. She is the chair of the WA Speleology Conservation Committee" which co-ordinates and facilitates active discussion, participation and research by members into karst conservation issues and develops and implements cave conservation projects in WA. Jay is involved in writing regular submissions on environmental assessment documents & management plans and letters to Government & land managers/proponents. It was Jay's participation in the ASF VS Finesky (Cape Range Court case in the Mining Warden's court (1999-2002)) that has led to her enrolment in postgraduate studies in Karst Management. Jay also has a 4 year Psychology degree and currently works fulltime as a Senior Child Protection Officer with the State Government, often performing counselling or social work services.

Lex V Bastian

Western Australian Speleological Group Inc.

A virtual "living legend" in Western Australia, Lex has been caving since he discovered Yanchep during his teenage years.

After graduating in geology from The University of WA in 1961 he spent six years with the Bureau of Mineral Resources in Canberra before returning to spend the next 23 years as a mineralogist at the Western Australian Chemistry Centre until his retirement in 1994. This retirement presented him with more time to go caving in the Yanchep/Wanneroo region in order to pass on his knowledge to current generations of cavers.

A founding member of the Western Australian Speleological Group in 1958, Lex has been a guiding force ever since and has been honoured by WASG with Life Membership.

Ken Boland

Victorian Speleological Association Inc.

Originally from Melbourne, Ken began caving in 1983 with the Western Australian Speleological Group Sub-Group (WASGSG), now known as CLINC. He has 29 years flying experience, is chief flying instructor of a gliding club and an Instructor of the National Gliding School.

Ken led the survey of 6N-206, and with more than 9km of passageway, is the longest and most complex cave of the Mundrabilla region. He is also a Catholic priest with an interest in natural history, particularly the development of life: "how the Creator has most cleverly created".

Ken's appearance here at Under WAy is sponsored by: Order of St. Francis Church (Vic.), Members of CLINC, June and George McLucas, Norman Poulter OAM, Members of WASG, Ida Newton, Rob Foulds and Frances Loveday.

Sandra Boulter

Environmental Defender's Office

Sandra is the Coast Law project Solicitor for the Environmental Defender's Office (WA). Sandra completed her training as a nurse and midwife, and worked as an intensive care nurse specialist at Royal Perth Hospital between 1972-76. Sandra studied law while raising her family of 5 children.

Sandra obtained her law degree from The University of Western Australia in 1997. She worked as a volunteer at the EDO while studying at UWA, and served on the Management Committee of the EDO for 3 years. Working as the "Bushlawyer" since January 2000, Sandra has travelled throughout Western Australia providing public environmental law legal advice and community legal education to rural and remote communities.

Arthur Clarke

Southern Tasmanian Caverneers Inc.

Arthur has been caving since the mid-1960's and actively involved in the documentation of caves (and their contents) and karst areas in Tasmania since the early 1970's. For over two decades, Arthur's voluntary efforts have included various aspects of the management of caves and karst in Tasmania including recording of caves as the Australian Speleological Federation (ASF) State Area coordinator for Tasmania since 1984, active engagement in the conservation of caves (as a past co-convenor of the ASF Conservation Commission) with a particular dedication to the Ida Bay karst in southern Tasmania, the Exit Cave system and closure of Benders Quarry, plus a more recent involvement in the Mt. Cripps karst area of NW Tasmania.

His other speleological endevours include the photography of caves and cave animals, plus studies of cavernicoles (particularly invertebrates) and cave ecosystems. He is presently completing post-graduate studies of the invertebrate biodiversity of cave ecosystems in southern Tasmania with a comparative chapter related to the ecology of caves in SW China. (He has been involved with studies of caves and karst in Guangxi Province of SW China on three occasions, including twice as an invited member of separate expeditions in NW Guangxi during 2000 and 2002).

Arthur is the Immediate Past-President of the former Tasmanian Cave and Karst Research Foundation and was Foundation President of Southern Tasmanian Caverneers when it formed in 1996. He was a vice-president of the ASF Executive for five years including a period serving as Executive Secretary and also held a position as ASF the Liaison Officer on the Committee of the Australian Cave and Karst Management Association (ACKMA).

Arthur has been actively involved in several international organisations including the British Cave Research Association, International Society of Biospeleology and the Biospeleology section of the International Union of Speleology (IUS) and is currently one of five Australian abstractors for the IUS Bibliography Commission.

In 1993, he was awarded the ASF Certificate of Merit and appointed a Fellow of ACKMA in 2002. He has had three troglobitic invertebrates named after him: two from Tasmania and one from SW China. Arthur is presently acting as Convenor for the next (25th.) biennial conference of ASF, being held in southern Tasmania in January 2005.

Andrew Eavis BSc

United Kingdom

Andrew has had a varied career in the coal mining industry before becoming a joint owner of the Thompson Plastics Group (Windcrown Ltd.) in 1979.

A Fellow of the Royal Geographical Society, council member of the British Cave Research Association and National Caving Association as well senior vice-president of the World Caving Association, Andrew's caving achievements are nothing short of spectacular over the last 31 years - being involved with the discovery of the world's first, second and third largest chambers in Mulu (Malaysia) and China and exploring the largest cave passage and cave in the world as well as twice being to the bottom of the world's deepest cave.

An expedition or project leader on many occasions, Andrew has explored caves in numerous climatic regions from Scandinavia, Europe, Asia, South-East Asia to Central and South America. From a photographic collection of over 25,000 slides, Andrew has won many photographic awards and includes 3D photography amongst his underground research interests.

Profiles of Presenters

Dr John Hellstrom

ARC Postdoctoral Fellow
School of Earth Sciences, University of Melbourne
Caving Club Victoria Inc.

I am originally from New Zealand, where I became heavily involved in caving at about the time I started my BSc at Victoria University of Wellington. After completing my BSc with honours in Geology I successfully applied for a PhD scholarship at the Australian National University in Canberra, working on a project that combined my interests in caving and paleoclimate reconstruction by investigating the geochemistry of speleothems from the deep and climatically stable cave systems of New Zealand's South Island.

I afterwards moved to the United Kingdom, where I worked as a post-doc at Royal Holloway, University of London, assisting with the development of analytical protocols for a new multi-collector inductively-coupled plasma mass spectrometer (MC-ICP-MS) with emphasis on uranium-thorium dating of carbonates.

Returning to Australia I worked for a year at Monash University on a project assessing the viability of the rhenium-osmium isotopic system as a mineral exploration tool, while successfully applying for an Australian Research Council post-doctoral fellowship at the University of Melbourne starting in 2002. This current project aims to apply the Melbourne University MC-ICP-MS to the U-Th dating of very small samples, producing long continuous paleo-environmental records from Australasian speleothems.

Stephen J McCabe

Highland Caving Group Inc.

A member of the Sydney Speleological Society for almost twenty years, Stephen is currently a member of the Highland Caving Group. An electrician by trade, he current works for the casino at Pyrmont.

Brian O'Brien

FTSE

Dr Brian O'Brien began his professional life as an Antarctic research physicist (1958-9), and later, as Professor of Space Science at Rice University in Houston (1963-8), was Principal Investigator for 6 experiments on the moon. Brian became Foundation Director and Chairman of the EPA in Perth (1971-77), started Greening Australia (WA), and has been extensively involved in environmental review and management work. He holds the NASA Medal for Exceptional Scientific Research and in 1993 was elected Fellow of the Australian Academy of Applied Sciences and Technological Engineering. Brian was the inaugural President of the ASF in 1956 and is a Life Member of SUSS.

Norman Poulter OAM

Speleological Research Group Western Australia Inc.

Commenced caving in 1965 with the Highland Caving Group, serving at least one term as president. Drafted to become Newsletter Manager of the ASF Newsletter during the course of the 1968 Goolwa ASF Conference and joined the Sydney University Speleological Society before leaving NSW on a working holiday at the end of 1970.

Following attendance at the 8th ASF Conference in Hobart, he spent 7 months working and touring Tasmania before travelling to and spending 5 months in South Australia. While in Tasmania he was amongst the last to attempt to "bottom" the then deepest cave (7JF-4-5) using ladders, although never setting foot at the deepest point. During his stay in South Australia, he was awarded one of CEGSA's (1971) "Leather Medals" for being the first person to suffer a broken bone in Sellicks Hill Cave - a feat that could have proved fatal for both he and Grant Gartrell.

He first set foot on the Nullarbor Plain as part of Ian Lewis's first CEGSA cave diving expedition (1971-72) and became fascinated with the region, a fascination that still persists. On arrival in Perth he became employed at The University of Western Australia and later became a foundation member of SRGWA.

Norman has travelled to varied overseas cave destinations and is very interested in speleo-photography, troglobitic fauna and their protection, cave conservation and management issues. He has visited numerous Karst areas of Australia although centres on the Leeuwin-Naturaliste Ridge and Nullarbor regions of Western Australia.

During 1993 he received an ASF Certificate of Merit followed by a special SRGWA/WASG/CALM citation in 1996. In 1999 he was honoured to receive the ASF "Edie Smith Award" and Medal of the Order of Australia (OAM) for his services to speleology and conservation.

Lloyd N Robinson

Illawarra Speleological Society

Lloyd became interested in caves of Bungonia at the tender age of 9 when his family moved to the nearby town of Marulan. Since then he has been caving in all states of Australia, and is still actively involved whenever he has the opportunity, most recently on the Nullarbor Plain and Northern Territory.

He first visited Western Australia in 1957 and spent some time in the Leeuwin-Naturaliste Ridge, where he was involved in locating a number of caves including what is now the Augusta Jewel Cave.

He has been a member of Sydney Speleological Society, Western Australian Speleological Group, Speleological Research Group Western Australia and is a life member of the Illawarra Speleological Society.

In 1982 he was awarded the ASF Certificate of Merit and in 1995 a Fellow of the ASF.

Jill Rowling

Jill is enrolled at the University of Sydney, School of Geosciences, and is studying part time for her MSc on “Cave Aragonites of NSW”.

Jane Scott BSc

Cavers Leeuwin Inc

Jane has an Honours Degree in Geography (BSc) from University College, London (1970), and qualifications in teaching and librarianship. She has lived for 20 years in the Margaret River area of Western Australia bringing up a family, walking, caving and checking out the wildflowers.

She has recently published several books on the local area: "Walking the Capes", "The Cape to Cape Track Guidebook" and "The Fieldguide to Wildflowers of Australia's South West".

Garry K Smith

Newcastle and Hunter Valley Speleological Society

First went caving as a cub scout around the age of 10. This sparked my interest in caving, a passion which I still pursue with great enthusiasm today. I went on many caving trips through Scouting and went on to become a caving instructor in the movement. In addition to the Scout caving, I joined the Newcastle and Hunter Valley Speleological Society in 1988.

Member of the Australian Speleological Federation (from 1988 to present, 15 years.), member of the Newcastle and Hunter Valley Speleological SocietyÊ (1988 to present, 15 years.) and have

held positions of President, Vice president, Secretary, Librarian and Magazine editor, Equipment officer, Training officer.

Member of ACKMA Australasian Cave and Karst Management Association (6 years). Within the Scouting Movement, I presently hold the position of Regional Activity Leader and have been an active leader for the past 26 years. Other qualifications include, Scouting Instructor in:- Caving, White Water Canoeing, Abseiling, Canyoning, Bush Walking and Cross-country Skiing. Appointed by the Scout Association as a Nationally accredited Assessor in these disciplines.

Lise Summers

State Records Office of Western Australia

Lise Summers is an Archivist at the State Records Office of Western Australia, where she has worked for the past four years. Her work at SROWA includes reference and research work, presentation of seminars and training sessions, and development of the annual preservation program for State archives. Lise is also a post-graduate student in history at Edith Cowan University, where she is currently researching the history of Perth's public parks and gardens.

Neil Taylor

Department of Conservation and Land Management and Cavers Leeuwin Inc.

Norm: ”Neil, any chance of getting your biography by the closing date, which was yesterday?”

Neil: “P#@% Off Norm”.

Ida: “Neil any chance of getting your biography by tomorrow, which is the conference start?”

Neil: “P#@% Off Ida, Gail and I are going to bed now!, you write something about me!”

Written by Ida Newton with apologies to NT and GT…

Anne Wood BSc. Dip.Ed.

Caves Manager, Department of Conservation and Land Management

Started her working life as a high school biology/ science teacher before moving to the Margaret River region about 20 years ago, working in the dairy industry with her husband, spending their spare time searching for caves. She joined Cavers Leeuwin (CLINC) around 1990 and spent 6 years working for the Augusta-Margaret River Tourism Association.

Divesting themselves from dairying, the family moved into viticulture before she became the inaugural Caves Manager of the Department of Conservation and Land Management in 1999.

Anne has just completed the Certificate in Karst Management offered by Charles Sturt University and highly recommends it to speleologists.

David Wools-Cobb

Northern Caverneers Inc.

David is a Tasmanian caver of 33 year's experience, having explored caves in many Australian states and overseas. Apart for his passion for going "where no man has been before", his major interest is in cave photography. He finds that sharing his photographs with others, particularly those unlikely to visit such environments particularly rewarding.

David has won several awards for his cave photography, and has entertained many people with his photographic shows, but considers the challenge of getting "that great shot" in such a difficult environment to be the greatest attraction.

Profiles of Presenters

List of Presenters without profiles:

Kyle Armstrong
Biota Environmental Sciences

Peter Armstrong
WASG

Michael Bradley
SRGWA

Ric Brown
SRGWA

Brian Combley
Cavers Leeuwin Inc.

Paul Devine
CEGSA / SRGWA

John Dunkley
ASF President

Stefan Eberhard
CaveWorks, Western Australia

Ken Grimes
Regolith Mapping

Paul Hosie
WASG / Trimix Divers

Dr Bill Humphreys
Western Australian Museum

Mike Lake
Caver, Linux enthusiast and interested in anything technical

John Long
Western Australian Museum

Timothy Moulds
University of Adelaide

Paul Tholen
Nature Conservation Ranger – Yanchep National Park

John Webb
Department of Earth Sciences, Latrobe University Bundoora, Victoria

Rauleigh Webb
WASG

Susan White
Victorian Speleological Association

Nicholas White
Victorian Speleological Association

Official Opening

Caving: Risk Management: Dreams and Visions

Brian O'Brien FTSE

SUMMARY

In 1956 I had the honour in Adelaide to be elected the first President of the Australian Speleological Federation (ASF). Today I have the honour and delight of opening the 24th Biennial Conference of the ASF.

The theme title of this conference is "Under WAy", and how right it is. The program is of staggering and wonderful variety, the mixture that speleology should be, of science and exploration, of delight and joy.

The title of my opening address is deliberatively provocative –"Caving: Risk Management: Dreams and Visions". I take the liberty of that franchise of Presidency loaned to me in 1956 to suggest a few thoughts you might bear in mind later in this Conference.

I will also take the opportunity to correct some of the many errors in the literature about me being lost for 3 days in the East Deep Creek Cave at Yarrangobilly in 1953.

I went into the cave with my long-time caving mate, Fred Stewart, about 2pm Monday, 14th December, 1953 for a brief reconnaissance, just as we had done in the West Deep Creek Cave shortly beforehand. We wanted to choose one cave and plan full exploration for the next day.

We quickly separated, as we usually did to double our speed of probing such unknown, 3-dimensional mazes of rock, where the roof had fallen in again and again over millennia. Fred came out again after about half an hour, having found only more rocks. But I found a fabulous, wondrous white and glittering cavern below the maze of rocks. Entranced, I explored it a little, but then could not find the right slots in the maze to rejoin Fred. I did not even know if Fred had got out. So I had to try to find my own way out, listening for the underground creek and perhaps even a yell from Fred. For all but about 8 hours of the next three days, I was exploring in the dark, and I will describe my techniques and feelings. I emerged with one of the half dozen search parties at 5.30 pm on Thursday, 17th December.

The Yarrangobilly incident made headlines in the Eastern States for a few days, and may have inspired more general Australian interest in speleology. I went back to the East Deep Creek Cave twice more, and it has now been more extensively explored.

One of the later sessions is on risk management. Many of my scientific discoveries during my half century of science occurred because I was politically incorrect. I challenged "accepted" views. In fact, almost any "discovery" must challenge accepted views. There is a vital lesson here for cave explorers dealing with risk management. Fred and I pioneered chasing "foul air" in caves, and with Dennis Bourke and Ben Nurse, pioneered in very, very primitive high-risk underwater exploration. Many of the most exciting discoveries, provided one survives, involve political incorrectness, serendipity, and both dreams and visions, as in Apollo work.

I revisit that old Biblical forecast about old men dreaming dreams, and young men seeing visions. I urge you all, no matter what age or sex, to be as young men and see visions as the most vital need of all speleologists. So I have great delight in opening this 24th Biennial Conference by urging you to get "Under WAy", and turn more visions into dreams, so that in turn you can continue to inspire new and original visions amongst those who follow over the next 50 years.

THE GENERATION GAPS

I started caving in 1951 in my first year at the University of Sydney, and ended really active caving in 1958, when I went to the Antarctic. So for this audience of active cavers, I first have to convince you that I know that times have changed, and that there are generation gaps.

For example, Fred Stewart and I were very poor and students, without a car for our first 4 years of caving. So it was hitch-hiking plus walking to find a cave. This meant that food, camping and caving supplies were limited to what you could carry, say, 30 kilometres or so through the bush. Not for us your modern 4-wheel drive, air-conditioned Range Rovers.

So in the midst of scarcity of resources, we developed our own code of ethics, unwritten. These days some United Nations group would have hundreds of conferences costing billions of dollars and call it all "sustainability. Indeed, the word "development" is now so politically incorrect that one cannot speak of "sustainable development", the catch phrase of the Rio Earth Summit only 10 years ago.

Take care that caving bodies do not over-regulate. Our code of ethics was commonsense.

For example, one day we would have only one hard-boiled egg to share for lunch. The fellow who cut the egg then put one piece in each hand behind his back. The other fellow chose "which hand?". If the cutter had not cut exactly in half, he might get more or he might get less. If he got more, his mate got less. So obviously we automatically cut the egg in half. The "hands behind the back" routine was our only self-regulated control mechanism, much more efficient than having salaried inspectors and legislated regulations. And no-one could ever cut a hard-boiled egg EXACTLY in half, depending on which end the yellow bit had slid to.

In our day, this was a logical way of risk management. Commonsense is now out of date, the victim of the "me" generation, Dr Spock outputs, and decades of plenty. Australia and private organisations seem overfond of regulatory controls. But intellectually, if folk are sensitive enough, you can detect or make a simple bridge over generation gaps that makes sense, can provide the best of both "sides", old and new, and offers a new possible hope for the future.

My favourite example of this kind of generation gap spans from my grandmother Nana Hoban to my granddaughter Steffie. Obviously, I am in the middle.

One night in 1957 I wheeled Grandma Hoban out to the backyard of our home in Sydney and tried to show her weary eyes and mind the magic, man-made star called Sputnik 1 that whizzed on schedule across the star-pricked velvet night she had seen unchanged for 87 years. Nana grew up in Tamworth, read by the light of one candle, and left school aged 12 to become immediately a country teacher, until she married a bossy farmer at 18 or so. Despite my exultation at Sputnik 1, she just shook her head and said "It's not right. It's not right."

About 40 years later, I was carrying my half-asleep eldest grandchild, Steffie, aged 5, out to her mother's car after a family dinner. It was the usual clear Perth night. The full moon was low on the horizon, so full and bright you felt you could reach out and touch it. We said our usual "Hello, Mister Moon", as I had indoctrinated first our children then their children.

It is always good, I told them all, to have a friend in the sky, on whom you could rely when the rest of society was behaving irrationally. The first word one grandbaby could say was "moon", pointing a chubby arm up, one daughter assured me once.

This night I was feeling nostalgic and whispered to little Steffie, all warm and snug in my arms:

"You know, Steffie, Grandpa has six experiments up there on Old Man Moon."

My eldest grandchild merely said softly and sleepily:

"That's nice, Grandpa",

and, becoming alert, slid out of my arms to play with Algernon, the cat.

DREAMS AND VISIONS

For several years, I felt hurt and sorry for myself for such a "put-down" response from my granddaughter Steffie to my wonderful achievements - 6 experiments on the moon. I wanted continued congratulations, not playing with the bloody cat.

Then one night a few years ago I gave an after-dinner talk to a Melbourne annual conference of about 300 engineers. Chatting to young and old as we wandered around before dinner, I realised that Steffie was correct. She did not mind me having dreams of past achievements. She thought that was "nice", using the word lovingly.

In Joel, chapter 3, verse 14, is one of my favourite quotations, which has very deep significance and which, unfortunately, is too often ignored by Australians, young and old and in-between like me.

> *Your old men shall dream dreams,*
> *Your young men shall see visions.*

The same verse begins

> *Your sons and your daughters shall prophesy*

but with the present quality of the media plus political correctness in Australia only the frightening prophesies - the "bad news" - will be published, while the prophesies of joy, other than sexual delights, are ignored. So I will focus here only on dreams and visions, not prophesies.

With the wonderful clarity and uncluttered purity of a young child's mind, Steffie had instinctively known that what she wanted and was most interested in was her ***Future, not the Past***. I had done only what grandparents are expected to do, prepare for the future. She wanted new visions before her. She wanted to come to know how to create HER visions and to fulfill them so that she and other grandchildren could have their own dreams. She wanted, instinctively but unvoiced, to then add her dreams to my old ones and pass them all one to her own grandchildren, to help them see new visions and enjoy them with their own grandchildren.

Old engineers in my Melbourne audience spoke mostly about the past, the bridges they had built, the roads, and machines which are now part of our present reality. They wanted thanks and praise, but only old engineers praise old engineers. Many of them had leading roles in the Snowy Mountain Scheme, whose 50th anniversary we had celebrated a few weeks earlier. The Snowy Scheme transformed Australian demography and built our multicultural nation. It was built largely by "Displaced Persons", men who had been shooting and bombing each other only a few years earlier in Europe and Russia. Would the Snowy Scheme be approved now? I think not.

Many of the old engineers at this dinner were forgetting the youthful vigour and often political incorrectness with which they had turned their old Visions into realities, now become dreams. Many had no new vision at all, in the true sense. Many were suspicious of new visions, and wary of new ways of solving old problems.

On the other side of the generation gap, the young engineers might have some visions. But many had little experience or lateral thinking as to how to turn those visions into reality, which in turn could become their own fulfilled dreams in the future.

So what each of us and Australia as a whole needs so desperately is a multi-generational synergy, a combination of dreams and visions, a sympathetic understanding that bridges across all generation gaps.

Speleology is an ideal opportunity to achieve such synergies, as you will hear in later presentations.

It is a staggering achievement that a conference of such quality will be held nearly half a century after a few of us gathered in Adelaide in 1956 for the first big Nullarbor trip and the creation of the ASF.

Since Joe Jennings lay on his back in a Nullarbor cave in 1956 and gazed for hours at the roof, the ASF has bridged over 30,000 years of Australian history and pre-history. Since Henry Fairlie-Cunningham set fire to his flame-throwing flashlight to create bright, blinding mushroom clouds of magnesium oxide, the real Diprotodon has revealed more real bones that walked and lived and loved maybe 10,000 Diprotodon-generations ago.

I congratulate heartily the organisers and contributors, and indeed the whole assembly. CONGRATULATIONS to those who know they deserve them.

RISK MANAGEMENT

I notice the special full session on risk management. I plead with ASF organisations not to become as overly zealous and regulatory as governments are, even though I recognise the problems of insurance and litigation. Way back in the less-litigious days of the early 1950s, I investigated getting insurance cover for speleos. The best policy I could get was at a premium of 1 pound ($2) per person per weekend, for a recoup of $100 per death per person. I did not investigate the rates for broken arms. We never took out caving insurance, but simply accepted responsibility for ourselves. There was one particular SUSS character, however, overly fond of gelignite for "clearing" squeezeholds, and if he was going to Jenolan, I went to Bungonia.

Risk management, such as the national policy of the "precautionary principle" foolishly but currently applied by Federal and State legislation is a killer disease, an enervation of epidemic proportions, which is politically correct. Only a very few dare speak about it in a commonsense or even technically accurate manner, drawing attention to the economic caveat on its application placed on it by the United Nations Framework Convention on Climate Change, but omitted in Australian laws and policies. I try, but get little support. Younger scientists, seeking to become established, know that the bulk of government grants are given only to true believers, politically correct, so that rigorous and vigorous scientific debates are not encouraged.

Quite separately, there are today many and varied scandals about failures in risk management. There are issues of corporate governance, which is also risk management for massive billions of dollars in events like Enron, HIH and many others. On a smaller scale, lifetime smokers sue tobacco companies. There is a Sydney surfer who found that the naughty sea had moved a sand bar so that when he dived in, he broke his neck. Unable to sue the sea, he sued the local council. There is even a movie about the man who sued God.

A tourist is taken by a crocodile in the Kimberley, and the Canberra-based Minister promises to erect a warning sign everywhere in Australia where a crocodile is or might be. Obviously he did not consult Treasury. Even so, recently, a crocodile who could not read killed a tourist who also could not read and walked past such an official warning sign into the water.

Who has a "duty of care" when you enter an unexplored cave these days? I'm glad that my caving was done when such a question was never even thought about.

The most magnificent example of risk management I ever encountered was with Apollo 13. I had two experiments on Apollo 13 to be placed on the moon, but they burned up over the Pacific when the landing on the moon was aborted. I was in Mission Control in Houston at the time. The moon was at full light, and as I walked through the clear but humid night back to my rented apartment, I knew that somewhere between me and the moon were three desperate but skilful explorers.

The three days of frantic and desperate actions at Mission Control and in the spacecraft inevitably brought recollections of my three days lost in the dark at Yarrangobilly. One stark contrast was that almost everybody in the world knew the position of the Apollo 13 astronauts, and the Mission Control group and support groups worldwide were desperately but knowledgeably working for their rescue. In my case at Yarrangobilly, I did not know if Fred had got out of the cave. If he had not, nobody would be searching for us for many many days, if ever, so I had to assume that nobody knew I was lost, and therefore I had to try to get out by myself.

I assure you, there is an immense difference between being lost yet knowing that people are trying to help, and being lost not knowing if anybody is looking for you.

If you want to understand risk management then I recommend you see the movie of Apollo 13. It could not hope to cover all the contingencies, but it does show the improvisation which went far beyond any of the vast and complex risk management plans that already existed. It is the only movie that remains a thriller even though you already know how it ends.

Risk management, and people who sue anybody they can for injuries resulting from their own actions, taken under their own free will, must recognise that accidents can happen, and nature is unpredictably variable. The Tourism Minister who wanted signs warning against crocodiles did not realise there would be a crocodile who could not read or a tourist or tourist guide who would not read. There are many other more substantial reasons requiring a review and overhaul of insurance and damages litigation. Accidents happen. Accidents happen most often in the home. But a risk-free world would be a sad and dreary place.

I can only hope that the threatened species known as commonsense is a powerful voice for change. But my hope is not strong, even in this wondrous country where once self-sufficiency was routine, bolstered by unfettered mateship being the unwritten law.

For example, it pains me to see ant-like lines of people, linked together and dressed in uniforms just as if they were convicts, paying to climb the Sydney Harbour Bridge. Their ears are bombarded by a spruiking overseer, their eyes directed on command, they cannot take photos, their forced march moves to a clock-driven turnstyle, and they move when given the command to move. All in the name of risk management and risks of litigation. When Fred Stewart and I climbed to the top of the Harbour Bridge up to the red light back in the 1950s, we did so at midnight and it was great fun. Nobody bothered our free spirits at all.

So we stood there in the wind and wonder of the night, not talking but immersed deep inside ourselves at one with the wonders of the sky, the city and the harbour, while the busy cars and trains and ferries did their own things far below, in a different universe.

THE YARRANGOBILLY INCIDENT

Some may wonder how I can speak about risk management after myself getting lost in a cave for 3 days, alone and ill-equipped. I will leave you to judge.

But my main reason for discussing “The Yarrangobilly Incident” (O’Brien 1955, 1958), is that only recently after I began collecting material for an autobiography did I realise how much incorrect and nonsensical writing had been published on the subject by others in the caving literature. Most was hearsay third-hand or worse. I have received some apologies, but I heard yet another myth in mid-December to the effect that the ASF was established mainly to “prevent” such incidents. That is absolute nonsense.

Indeed, this is one of the more dangerous bits of nonsense for caving in Australia, because it could lead to over-regulation zealotry. The ASF was created for reasons of sharing information, talents and comradeship, not regulations. Our care for the environment was innate and an essential and automatic instinct. There were a few exceptions, but not many, and they tended to leave the scene quite quickly.

The Yarrangobilly incident did excite nationwide interest amongst the media, but as I recall, we only started the idea of a national organisation a year or two later, when more groups we had not known about wrote to SUSS.

“The Yarrangobilly incident” was simply that I got lost in the previously unexplored and wild East Deep Creek Cave at Yarrangobilly, near the Snowy Mountains, for about 3 days, without light except for the first 8 or perhaps 10 hours. Estimates of the numbers of people in the half dozen search parties in the cave and bush varied between about 35 and 50, with up to about 5 groups in the cave.



Fred Stewart during the Yarrangobilly incident

My long-time good mate Fred Stewart and I had often explored Yarrangobilly on many trips, discovering and exploring many caves previously unknown. We mapped a few large ones and made some fluorescein tests of the Eagles' Nest Creek. We had to hitch-hike from Sydney and walk in, so supplies were always critical. It could get very cold, but we were young and fit.

On our trip in December, 1953, over the first day or so we had completed our mapping of one of the Eagles' Nest Caves, down near the tourist Caves House. Then we moved camp up to the plateau where little or nothing had been explored, although Trickett had mapped and named a few cave entrances.

We left most of our gear at the new camp, but wanted to make a quick reconnoitre of both the West and the East Deep Creek Caves, to see which one was worth doing a proper exploration the next day. Neither had ever been explored.

We were travelling lightly. Normally each of us carried two lights, a carbide hand-lamp to give a wide hemisphere of diffuse light and a helmet torch to provide a searchlight beam of stronger, more concentrated light but covering much less area. But for quick reconnoitres, we were as usual anxious to conserve our supplies. So that afternoon I wore a black beret and carried only a carbide lamp. Fred wore his helmet and its torch, but carried no carbide lamp. We wore no watches, and rarely did in caves, because they were too expensive to risk, scrambling in rocks and water.

We spent about half an hour in a quick look in the West Deep Creek Cave. Then we walked through the lovely but rugged Yarrangobilly bush to East Deep Creek, where it splashed steeply and scrambled among the boulders to disappear underground. We separated to explore, as we often did, to cover twice the volume of tumbled rocks.

We used a prismatic compass while mapping caves, but one would obviously be useless in the tumbled rock mazes of either Deep Creek cave.

Some people seem to find it strange that Fred and I were separating and rejoining, again and again, but that is the way we explored in a maze of rocks, searching for a break through to a cavern. Besides, even in a cave with caverns and tunnels and not merely a 3-dimensional maze of rocks, you have to get lost to be an explorer. It is getting unlost that is the real trick. Rather like science.

In the East Deep Creek, down through the maze of fallen rocks that made an entrance, I found a way into a great big new and lovely cavern. I was entranced at the pure white crystals glittering in my lamp light, but when I climbed back up into the maze of cold, muddy rocks, I could not find the critically small entry way out again. I was lost, quite thoroughly.

Fred got out first after about half an hour, after finding only more of the maze of rocks, and no cavern. He went back to look for me briefly before going a few kilometres to Caves House for help, leaving me a note which I still have. My gratitude for his actions then and later have (literally) my undying gratitude.

I emerged about 75 hours later with one of the five or so search parties at 5.30 pm on Thursday, 17 December. For all but the first 8 hours or so, I tried to find my way out in the dark, listening for the East Deep Creek or any running water. The problem was that I did not know if Fred had got out. Hence I did not know if anyone was looking for me.

Official Opening

There is an infinite difference between being lost yet being comforted by knowing for certain that people are searching for you, and being lost not knowing.

In the first you can have hope in others. You are not really lost, just temporarily misplaced.

In the second, you have only yourself and what you are.

You have only yourself and your memories. Fortunately, I knew a fair amount of poetry, and books I had already read, whose fragments in memory saved my sanity. I also knew a moderate amount of "good" music, which helped. I neither spoke the poetry nor sang the melodies, because I quickly found that any such noise only emphasised and exaggerated my being alone.

In the cave the essential truth I found was that ultimately each individual is absolutely alone. I was as alone as is possible to be on this planet because I did not know if anyone was searching for me.

When I accepted that I was lost and my yelling produced no response from Fred, I turned the carbide lamp very low. I decided it was better to have a dim light for a longer time than a bright light for a short time. There is no right or wrong general answer as to whether this was sensible.

So I was lost in the vast underground jungle of rocks, caverns and twisting passages, and glorious sparkling limestone formations of what we called the East Deep Creek Cave. The name of the unexplored cave and the location of its entrance were all that was known as that day began. Nobody had ever reported going into the Cave.

My older brother Terry has never been in a wild cave, yet 40 years later he gave the most vivid and evocative description of the wilderness of the East Deep Creek cave.

> *There were half a dozen search parties and about 35 to 40 men searching the bloody place for almost 3 days, and they could never even find each other except at the bloody entrance.*


THE SUN

STUDENT MAY BE IN HOLE 200 FEET DEEP

Torch hunt in huge cave for youth

I spent three days alone in that cold place where there is no day or night but only eternal darkness. My carbide lamp light lasted for the first six or eight hours, or maybe ten. I turned its water flow down until there was a mere bubble of light. I walked slowly over and around big rocks. I came to a sheer drop, and hooked the lamp in the roof while I climbed down. Even with two hands free for climbing, I lost my grip and fell about 10 feet, on my bum.

I could not climb back or reach my lamp again, so I took off my boilersuit to swing it by a trouser leg and knock the lamp down. When I hit the lamp, the bubble of light burst but the lamp stayed in place, in the dark, where it hangs to this day, despite my later trips to find it.

I was in total darkness. I knew there was a 10-foot cliff on one side. Was there another 10-foot drop nearby, or perhaps even 30-foot, unseeable?

Earlier and deeper down I had discovered beautiful white crystal caverns and pure, still pools so clear you did not know they existed until you stepped in them. No human had seen these beauties before. That lower part of the cave had some order and structure.

Where I was really lost it had become a wild cave. In many parts it was totally disordered.

Over thousands of years the roof had fallen again and again, producing many tilted mezzanines of boulders and rocks of all sizes. The cave was a multi-story three-dimensional maze of rocks. If you went around one side of a big rock, you were likely to reach a different location than if you went around the other side, or over the top, or wriggled underneath if there was room.

I had no food and no companion. I did not know whether Fred had managed to get out so that somebody else might know I was lost and they might come searching. I yelled out from time to time, but no answer came. My calls were deadened as they thudded into the tangled rocks and muddy cavern. There were no echoes in that cave, only sullen rocks and mud.

I listened for the whisper of the underground creek that might lead me to the surface and the lovely bright-lit sky.

I held my breath from time to time, so that its noise would not prevent me hearing the waters of that creek, or even perhaps a faint call from Fred, that very precious “Coo-eee” of the Aussie bush. It is a bit tricky holding your breath while your entire body is shivering violently. The temperature was in the low 40's Fahrenheit, although it was a brisk Snowy Mountains summer outside in the sun, and frosty at night. Shivering was a whole-of-body experience, draining my energy even while I rested, and the muddy rock was an eternity of chilling cold.

I heard my heart beat. How I wished my heartbeat was not so loud. It doesn’t go “pitter pat” as I had read in books. My heart went “whoosp whoosp”, an unwanted background noise as I listened in the tomb-like silence of that cave.

When I sat to listen after I had given a couple of yells, I would first hold my breath, then hold my boilersuit out free of my chest, to reduce the effect of my heart pulsing the fabric. My sight was useless, but I still had hearing.

In the eternal dark and eternal stillness, I was alone with the Bogeyman, and he certainly was no help. When my breath was still, and there was no sound but my beating heart, the Bogeyman came near, on every side. He came closer after I had finished calling out.

In my older years, I often read that youth of 19 years of age, as I was, commonly feel that they are invulnerable, with eternal life. I assure you that was certainly not the case for me. I had to try to find my own way out. Cave exploration the hard way, in total, absolute darkness and isolation.

I had to move, a non-trivial problem in that jungle of rocks, tumbled together in three-dimensional chaos. There were big holes of empty air between big boulders, and falling in the dark is not funny. Falling in the light, as I had just done, was not funny either.

So moving had to be done while sitting down and sliding. Many years later I called the technique “sitz-bumming” , when I helped my wife or little children come down a steep rock face using 4 or 5-point contact with solid earth, 2 hands, 2 feet and the bum.

At Yarrangobilly I chose sitz-bumming, because there was no floor but a lattice of rocks and nasty holes between rocks, sometimes very deep holes. If I stood up and walked in the dark, and one foot went down a drop, the rest would likely follow. So I did not stand up too often.

Instead, I sat and reached around me to find a loose rock. When I could feel one small enough to hold, I would throw it in a direction of choice. My only compass in the total darkness was where my legs were pointing. If it took a few seconds before I heard the rock hit the ground, I would not be going in that empty direction. I would feel around for yet another rock and then try yet another direction.

After all, I knew my physics and the equation for calculating how deep a hole was by counting the number of seconds it took a falling rock to hit the ground. In the first second a rock falls 16 feet, about 5 metres, a nasty enough fall. Two seconds would mean a fall of about 64 feet, or 20 metres, a seriously nasty, crippling or fatal fall onto rocks, unless I bounced a few times on the way down. Definitely not nice.

The sounds I really did not like at all were a series of sounds, like a rock bouncing down from one boulder through a new hole on to another boulder.

Thrown rocks are very insensitive substitutes for eyes. Imagination makes holes in the darkness.

Progress was slow. Progress was also not measurable because in the darkness a pair of hands was not sufficient to identify a landmark, or even find it again. I sitz-bummed on, feet always first, with my clinkered boots searching preferably for horizontal, or an upwards slope, room to advance.

For one long time, after perhaps 24 hours, maybe twice that, I sitz-bummed myself in the total darkness slowly into a sloping tunnel, where the roof got lower and lower, and the sides closer and closer. My light had gone out long before. I had also used up the few matches I had kept dry under my beret. With the last match I had set alight the tassel of my cap, and it flared most wondrously but so bright it blinded me from seeing anything useful. Now I was in eternal darkness.

Finally the roof came so low that I had to lie flat on my back, feet first on a moderate downward slope that went I knew not where. I was now stuck in a tunnel, sloping down. I wanted to go up, not down.

In that tunnel was the only time in about 74 hours when despair captured me totally, because I grew to feel it was my tomb. Lying on my back, I could reach by touch the walls to the left, to the right and overhead. The clinkered heels of my boots were dug in, scratching at the slope to stop me sliding further down into the black unknown. I shivered noisily, desperately cold, with no kind of warmth except shivering.

I had no way to learn how far that tunnelled tomb stretched down beyond my boots, because I had no room to sit up or even twist and throw a stone beyond them.

So when I did manage to find a small loose rock I did not throw it. Instead I scratched a very short last will and testament in the muddy rock roof in easy reach just a few inches above my face. It was my first last will, and the shortest.

Writing with a rock in the dark focussed my mind to construct a will with as few letters as possible. The powerful and beautiful brevity of the King James Bible or Shakespeare's plays and sonnets will never be achieved again, since megaherz word processors replaced the quill and papyrus, or a rock on a muddy cave roof.

How long I stayed in that tube I cannot know, my whole body shivering almost rattling in pain from the cold. But then I decided that I would not die just there and then. I wriggled back upwards, using elbows and heels of boots. I had more black space for my body, and more unspoken poetry and unsung music to refresh my mind.

More sitzbumming. An occasional call out into the darkness, just in case someone was searching. An occasional pause to hold my breath and listen for that blessed creek, just in case no-one was searching.

Scratching a will was also quite silly of course. It might even be considered black humour.

Even if my body had been found, nobody would have thought to look above it, even after my body had been dragged out of whatever sort of tunnel I was in. Nor would anyone think to decipher crude and ragged scratches of each letter in the rock and the mud, written in total blackness without the power to make any corrections or connections.

But I suppose it was the thought of love that counted, as it does so often. I also suspect that it was the physical action of facing the finality of that last will and testament which caused me to say when I finished scratching, "Bugger it, I'm not staying here, and I won't die yet."

So I kept moving and then stopping, moving and stopping. I stopped to listen for that nice little creek that leads up to that bloody sunlight. I moved to listen from a fresh spot.


DAILY MIRROR

NO SIGN YET STUDENT

Searchers explore

Mouth of unknown cave mouth, where The Daily Mirror reported I was lost

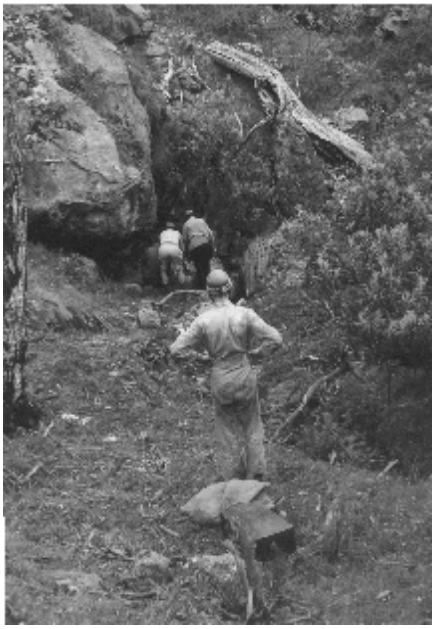
The only humour I found in the cave was in my mind. It was in the poetry that saved my sanity, my beloved Belloc, Keats, T.S.Eliot and Macavity the Cat, (long before "Cats" became a fashionable musical), even Ogden Nash and his tree. Other times I conjured up companions from Shakespeare and Chesterton and all those like Winnie the Pooh who have problems. "A Bear likes honey. Buzz, buzz, buzz. I wonder why he does." Beauty helped. Images of the Aussie bush just outside, of campfire smoke floating up to the starry roof of the cathedral of tall night time trees in moonlight.

I wanted the Southern Cross, and the two Centauri. Even Omar Khayyam and "Awake, for Morning in the Bowl of Night has flung the Stone that Put the Stars to Flight" - not bloody likely here.

My eyes had nothing to see. My ears heard only my own life elements. My physical senses were useless or dulled by the freezing cold. But my mind was intensely active. Alone, I was not lonely. Thank God for memory. My eyes had once read books and poetry. My ears had once heard wondrous melodies. Now my memory read and listened again, and again. But I did not speak or sing aloud.

Mixed with the awkward sitzbumming, I also knew throughout that, down somewhere below me, free of the jumbled rocks, was a magical mix of purest white cascading crystals and pools of still water so clear you could not see it unless you stepped in it with muddy boots. And I had discovered it all. I, just Me.

So, in the dark, I slid further on my bum, picking up and throwing a rock in the direction my legs were pointing as my only compass.



Mouth of the real East Deep Creek Cave

If there was silence for a second or two, I swivelled my legs to a new direction, and threw another rock, and so on. It made for slow progress, with no landmarks to mark real progress. No tunnels, no formations, and no features recognisable by touch alone.

A real compass would have been useless in the top 3-dimensional maze of rocks where the roof had fallen in over previous millennia. Fred, Laurie Bishop and I went back later to try to find my lamp. We took 400 feet (about 130 metres) of string to about where I thought the lamp might be. After scrambling and wriggling through and up and down the rocks, we had laid out all the 400 feet of string. So I left Laurie at the end of the string and explored further within earshot, with no success. Returning to Laurie, we then spent about an hour looking for the string, because Laurie had wandered just a few metres. It was a real wild cave in that area, with rocks of all sizes jumbled in a 3-dimensional maze, with plenty of gaps of unknown depth between many of them.



Daily Telegra

LOST CAVE EXPL

FOUND

3-days ordeal

YARRANGOBILLY, Thurs.— Searchers today found university student Brian O'Brien, safe and well, in the Yarrangobilly Caves.

THE QUEEN IN FIJI

Media interest switched underground away from the Queen's tour!
(Photo by courtesy of the Sydney Daily Telegraph)



The successful rescue party

The search party of five that found me consisted of my old mate Peter MacGregor of SUSS, Mr Finney of the NSW Tourism Bureau, and three members of the Canberra Alpine Club, Jack Leslie, Dick Pickering and Jim Webb.

They had laid a paper trail "to stop ourselves getting lost", but we all got lost again on the way out. We did not stay lost. The difference this time was that we all had lights, and we stayed together. We were not exploring, simply getting out. I helped Mr Finney over the occasional awkward bit.



Brian with one of the Snowy Mountain horsemen who helped in the search

I was found about 900 feet into the cave. We took well over an hour to cover those 900 feet, that being the nature of the East Deep Creek Cave.

I apologised for being a nuisance, because about 70 people had been searching. But the Snowy bushmen were used to accidents.

One very fine bloke gave me a big chunk of his wife's fruit cake, lovely and sticky and very heavy. He poured me an enamelled tin mug of black tea thick with sugar.

Then he gave me a ride on the back of his horse to get up to the road and a car to Caves House and my family. I had not realised how weak I was until I could not swing my leg over the horse's back. I could get my foot into a stirrup, but not swing my leg over. Wordlessly, we shook hands, he gave me a hoist, and I rejoined the world.

I've been back to the East Deep Creek Cave a few times, once to show my then-fiancé Avril the crystal cavern. Since she has now been my wife for 43 years or so, I guess there was no long-term damage. My lamp is still there, so far as I know.

Reverting to the issue of risk management in a brief analysis of the Yarrangobilly incident, clearly we were equipped for what we intended, but were tired at the end of the university exam period and our previous caving and walking.

Fred was bigger and stronger than me, but there is little point to such personal comparisons. The rocks were rocks and various distances apart, but all was fairly straight-forward scrabbling.

We had caved as a pair for 3 or 4 years before and a few years afterwards until university absorbed us totally. The fact that I had the wide-angle but weak carbide lamp rather than Fred's strong, directional head lamp may have helped him. It certainly hindered me in looking for a way out of the top, muddy-walled cavern that met into the crystal chamber. Being effectively one handed did not help me, but there is no real "excuse" for what happened. Nor do I intend to try to offer "excuses", although I am happy at trying to analyse useful lessons.

A real fact is that we should have had a routine agreement for the first one out of any cave where we got separated to leave a note at the entrance. Fred had left one, which I still treasure. But after the first two days of searching the cave, the police and the bushmen were fairly convinced that I had got out of the cave before Fred, and got lost in the bush or fallen down another hole. The speleos and Fred knew how well I knew the Yarrangobilly plateau, and concentrated the search on the cave itself. But the intensity of their search was necessarily weakened. There was an understandable desire also, for the police and bushmen to search familiar, daylit environments.

The press delighted in the nearby limestone formation nick-named "The Tombs". Over their beers at Caves House, they speculated seriously whether Fred had murdered me and left my body in The Tombs. Fred was a quiet young man, always taciturn and with few words, which is one of the reasons we were such good mates. But he was under enormous strain, and the police were responding to the press gossip. Only my Dad's intervention prevented the speculation being given some official status. Although Dad had never met Fred before, he knew the man-boy quickly.

The press coverage was mostly atrocious, as if each reporter collected any anecdote he or she could. In fact, many articles, even headline front-page stories, read as if they were written at the bar by somebody who had not been near the correct cave. I gave no interviews, so any quotations in the press were inventions or third-hand at best.

If anyone wishes to study the facts, the first thing to do is a suggestion similar to that made by Shakespeare's Dick the Butcher: "*The first thing to do is kill all the reporters*".

CONCLUDING COMMENTS ABOUT YARRANGOBILLY

Some months after "The Incident", a perceptive (female) speleo asked me whether I was glad that I was alone or would I have preferred to have companions while I was so lost.

I immediately, and subsequently, confirmed that I was glad I had been alone, apart from the issue of having a brighter torch to try to get out.

In the dark, no matter how close the Bogeyman came, I was able to focus on my mental and physical state alone. That would have been difficult with another person or two, no matter how closely bonded and how much I trusted someone like Fred. I could not have resolved the writing of my will except through being alone. The poetry and music and my recollections had to be allowed freedom to dance and skip through my mind without necessarily verbal utterance to someone who necessarily would paint the words on a different canvas of different backgrounds and different memories. Throwing exploratory rocks in the darkness would have introduced a different dimension of danger.

If Fred and I had stayed together, we could have explored only half the volume or less. We may never have discovered the crystal palace, to draw others back.

More important for me personally, I may never have experienced such an epiphany elsewhere.

I continue to be grateful to my peers who subsequently elected me the first President of the ASF.

But I don't think I would recommend to any one a repeat performance, particularly not knowing if anyone was searching. Three days of exploring a wild cave in darkness is a trifle long.

To my caving mates, including the new ones I found when they found me, and to the police and local bushmen, I can never repay them for the simple gift of life.

One unexpected bonus gift was a lifelong one. Having faced an unseen Death, alone, I have never feared him since. Instead, and conversely, every new minute of life, even now 44 years later, is a bonus. Not earned, but much valued. And the world and its people are amazing and wondrous to behold. I pity those scientists who plod along in life, not finding magic and joy in their discoveries. I hope that teachers share such magic and joy with their charges.

FOUL AIR

I don't want to end on a note implying that the Yarrangobilly incident was the only magical experience or epiphany that cave exploration brought me, when I was so young and still stretching the envelope of my invincibility. So I'll conclude just with brief comments about foul air and underwater exploration in those primitive early days in the 1950s.

As you know, in some caves you can get ephemeral pockets of foul air, of excess carbon dioxide. In the fifties, most cavers who encountered foul air in a cave, and found their carbide lamps flickering out or matches refusing to light, while their own breathing became painful panting, simply turned and went somewhere else. Nothing was known in any of the Australian or international reports or books we could find. People just regarded foul air as a hazard, and left.

For Fred and me, him a medical student and me a physics student, turning from the unknown was simply not a thing we did.

Somehow, through Dennis Bourke, a much more senior medical student and SUSS member, we learned that Professor Cotton was interested in foul air. I think he was researching men's breathing gear for high-altitude balloons. Since he was famous for inventing the G-suit, or "anti-gravity" suit, that helped fast-turning Spitfire pilots in the Battle of Britain, he was a big wig at the University of Sydney.

More important, he would give Dennis who would then give us small, half-pint or so glass bottles with ground-glass stoppers. He would fill them with salt water, tightly stoppered. We would find foul air, empty out the water with a ceremonial flourish, swirl the now-empty bottles around most scientifically to fill them with foul air, put the ground glass stoppers back, and eventually give a bundle of them to Dennis, safely back at the University of Sydney. He presumably gave them to the Professor, whom I never met, and after a week or two Fred and I would get a typed out analysis of the percentages of oxygen, nitrogen and carbon dioxide.

Before we started all this, both Dennis and the Professor via Dennis, told us that laboratory experiments had proved that humans could survive concentrations of carbon dioxide of up to 30 per cent. We were even shown the medical textbook of the day with this claim.

What the learned ones failed to tell us, or perhaps did not know, was that such laboratory experiments were in a laboratory tank "atmosphere" where the other 70 per cent was pure oxygen.

What nobody at first appreciated was that, in a cave, where there is increased carbon dioxide there is a corresponding decreased concentration of oxygen. So you do not get only carbon dioxide poisoning, you simultaneously suffered from oxygen starvation, which is why a match will not burn. Not for us a 70 per cent rich oxygen supply, like the humans in laboratories.

So it was that we disappointed Professor Cotton at first, because we found it very tough finding carbon dioxide concentrations much above 6 per cent, and living to tell about it. When questioned, we responded with undergraduate Aussie bluntness "If he wants 30 per cent bloody carbon dioxide, he can find it himself."

But we developed a methodology of exploring foul air, first of proceeding until carbide lamps went out if you moved them, and matches would not light, while our breathing rate increased. Then we would switch our electrical head lamps on, and proceed very swiftly as far as we could, suffering sharp headaches and gasping for breath, breathing very fast.

We would generally separate by this stage, drawing a shortened match to see who would take the really, really final sample that day. One also tends to lose short-term memory, and all in all, it could get a little risky by about 6 per cent. Actually, we only turned back once, along an extension of the Drum Cave at Bungonia, which had a 140-foot (45 metres) initial tube-like drop at the start, and a waterfall, great for foul air. We got to the end of a passage at the bottom, and came to about a 10-foot (3-metre) drop, which we knew well and normally could scramble up.

We were sensible and drew short match to decide who would go over the drop for what we knew in our hearts had to be the last sample that day. Fred went over, did his thing with the bottle and then tried to get back. He could not, and I was so affected by the foul air by then that at first I frankly was not interested in Fred's problems. We both had splitting headaches. Finally I thought of taking off my boilersuit, and holding one leg while Fred grabbed an arm, and I pulled. We got back okay, but later decided that 6.5 per cent or so of carbon dioxide was enough.

However, we achieved, so we were told, world leadership in the field of foul air. I understand that later generations from ASF have gone even further into larger concentrations.

UNDERWATER DIVING IN CAVES

We also pioneered underwater diving in Australia, using one of the tourist caves at Jenolan. Our first effort was with a garden hose and a giant bellows somebody had "borrowed" from the Medical School. Dennis Bourke was involved again, and because Fred and I were still feeling a bit angry that the text books were wrong about foul air, we democratically agreed that Dennis would go in first.

I, the physicist, had "invented" a copper wire signalling system for Dennis. Something like "one ring" means give me more air, "two rings" mean you can stop pumping, and the like. But I was not a chemist, and my bare copper wires simply short-circuited in the underground Jenolan River, ringing the bell all the time, so we removed the signal from Dennis because of the noise.

Ben Nurse and I went "point", as they say on military expeditions, paying out the garden hose to Dennis as he went upstream and underwater into the blackness. We were the smallest and lightest in the team, and the larger fellows like Fred and Jim Tasker pumped the bellows as hard as they could when I called out instructions or Ben Nurse did.

Then the hose stopped going forward as smoothly as we thought it should, so I decided we had better pull Dennis back. It was as well we did, because by then he was a little blue - the hose had kinked and no air was getting through.

The next trip we used a bloody great and very heavy electric pump, and an improved garden hose. But it wasn't very successful either, so we decided there were other fun things to do.

Later on, they had invented scuba diving gear, much too expensive for us at university. Ben Nurse got together with the Sydney Underwater Explorer Club, but that is Ben's story to tell.

CONCLUSION

We also carried out other experiments, including direction-finding with VHF radio in co-operation with the amateur Radio Society of Sydney. That was great fun, but when they triangulated on me as being poised about 100 feet (30 metres) above the middle of the Blue Lake, well outside any caves, we realised there were some real problems to fix before it could be reliably used in Search and Rescue. Quite apart from a speleo having to lug around a great big "walkie-talkie" in those days, the signals were obviously being greatly distorted by the wet, cavernous and cracked limestone.

I studied the chemical composition causing after-glow of helictites, the lingering glow in some after a flash bulb was used. And we explored various other parts of the sciences of speleology, while others improved the caving gear. They developed new tools and instruments and flash guns like Henry Fairlie-Cunningham's flamethrower called the Diprotodon. It threw powdered magnesium measured by the pound (half kilogram) past a lighted flame, and was a very awesome device indeed.

But mostly we discovered new caves, and explored. We wandered through the bush and countryside. We camped. Through long and beauteous nights, in rain, snow or open starlight, we solved the problems of the universe across campfires and through innocent mugs of tea, when nobody had to speak and nobody chattered simply to make noise or hear his own voice.

The fifties were the days of innocence, before Flower Power and other, wilder, often sadder times of the sixties. Student demonstrators rarely threw anything, perhaps a small bag of flour or water, or a rose, and then mostly in good humour. We felt many things passionately, but respected each other. The worst thing a policeman could do was to take off his badge, so you could not take his number. They were the days before the mobile phone, oh rapturous days.

They were the days when you could hitch hike anywhere in perfect safety, apart from the occasional drunk with poor brakes on his truck. You could meet the wondrous range of people all around Australia, when the truckies were all great and friendly friends, being taxed into poverty by government rail subsidies and road taxes. You changed truck tyres, and a mob of trucks would stop to first check their trucky mate was okay. Then these giants of men would offer laughing advice, sometimes lewd, while drinking straight from large bottles of beer, and enjoy in a friendly way the inefficiency and weaknesses of university students. But among them, you could find more practical wisdom, thoughtfulness and friendship than you rarely found from begowned aloof Professors on campus.

You could get a ride in Victoria with the Benalla undertaker who had "buried the last of the Kelly's", and in New South Wales with the Tumut pastor driving a Holden up the winding dirt road through the Snowy Mountains faster and more dangerously than Jack Brabham in his heyday.

The pastor told Fred and me, as he raised clouds of dust and drifted in that tilt the first Holdens had round one sharp corner, "Don't be so scared. I have a private arrangement with God. If He wants the people to pray to Him in Tumut at 9 am sharp every bloody Sunday, and in Kiandra at 11 am sharp, then He can bloody well concentrate on me in between."

With a short prayer before entering a cave, and one of thanks on coming out, that would be enough for a pretty good risk management programme for speleologists.

I wish you all such happiest of days, and declare this conference open.

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Contact details
12 Caithness Road, Floreat Park WA 6014

Dune Subsystems of the Swan Coastal Plain

Lex V Bastian

INTRODUCTION

A feature of the Swan Coastal Plain not generally recognised is the existence of distinct ridges running more or less parallel to the presentday coastline. In the Perth region itself for example, it is relatively easy to trace a strip of near-coastal high ground through suburbs such as Karrinyup, and note its separation from a similarly high ridge running through the suburb of Yokine seven kilometres to the east. The eastern flanks of these ridges are generally more pronounced than their western flanks, and there are many spots where it is possible to stand upon an elevation and see that there is an extended north-south hillslope, with a vista to the east, usually as far as the Darling Range. Sandwiched between these two there is a third moderately distinct ridge line - but generally of slightly lower elevation - running through the suburb of Balcatta.

These ridges consist for the most part of surface yellow sands overlying dune limestone, with variable amounts of limestone caprock cropping out in areas nearer the coast. Their origin as coastal dune systems has been understood for some time, and collectively they go under the name Spearwood Dunes (McArthur and Bettenay, 1960). The limestone beneath the sands is referred to in geological terms as the Tamala Limestone (Playford et al 1976), and it is within the Tamala Limestone that the caves and other karstic phenomena of the region occur.

MINERALOGY

The limestone itself is an aeolian calcarenite, with variable and often considerable amounts of siliceous sand. In the Perth region the calcarenite typically contains around 30-40 percent quartz, rarely as little as 20 percent, and sometimes as much as 60 to 70 percent. Such material even when consolidated yields a very friable "stone". The yellow sand over the limestone is residual sand left over from limestone dissolution, as the dunes have degraded. A hypothesis that the yellow sand is inland desert sand that has been blown over the dunes during times of severe aridity has been disproven on mineralogical grounds (Bastian, 1996).

Mineralogically the Tamala Limestone does not reveal any trends that can be used to differentiate the ridges: the general composition is variable and the limestone beneath any ridge may find its match in any other. However, the yellow sands developed over the ridges vary in age, the more eastern sands having more mature profiles, and becoming progressively younger in the western direction. The author, working on the assumption that the eastern ridges would be older, has from 1984-on analysed the mineralogy of the residual sands during work at the Chemistry Centre WA., with particular attention to their heavy mineral content. The results up until 1994 were published in the paper cited, and additonal work continues part-time with a special funding.

A "Maturity Index" was devised to compare ilmenite and its alteration product leucoxene, with several unstable minerals that tend to weather away in the soil environment. These are garnet, amphibole and epidote. The results revealed a very pronounced maturation trend, which enabled the major dune ridges to be confidently distinguished.

DUNE SUBDIVISION

While the plural name Spearwood Dunes implies a multiplicity of dune events, it has not been possible to distinguish each individual event because of the proximity and often considerable overlap of the ridges. However, since as a general principle growth of the coastal plain will have occurred in the western direction, a partial subdivision of the Spearwood Dunes has been made, based on those ridge lines with intervening swales which can be clearly distinguished.

(i) The more inland ridge has been named the Yokine Dunes. Northwards the ridge lies to the east of a chain of freshwater lakes extending between Lake Goollelal (south of Wanneroo) to Loch McNess at Yanchep. It is broad and has a complex topography, suggestive of a number of major dune events overlapping.

(ii) The ridge to the west of the lake chain, usually somewhat lower, has been named the Balcatta Dunes. Its topography is for the most part simpler than the Yokine, but in the central Perth area at least two major dune events appear to be represented.

(iii) The higher ridge near the coast has been named the Karrinyup Dunes. There is generally an intervening valley between the Balcatta and Karrinyup, which however usually does not contain lakes. The Mitchell Freeway runs mostly along this valley.

In the region northwards from Perth to as far as Yanchep the three major ridges abovementioned are not difficult to recognise. However, vegetated Holocene dunes (the Quindalup Dunes of McArthur and Bettenay) overlap the Karrinyup Dunes in many places, an overlap which tends to increase northwards, and covers much of the Karrinyup in the Yanchep region.

Besides these three, a lesser ridge west of the Balcatta Dunes, which in some places is distinct but in others almost merging topographically with the latter, has been named the Gwelup Dunes. However the ridge cannot be distinguished in the Yanchep area. A coastal or near-coastal ridge, which in places forms low but rugged coastal cliffs wherever it has not been covered by the Holocene dunes, has been named the Trigg Dunes. In the Yanchep region it is almost completely covered by the Holocene, except for isolated offshore rock stacks. To the east of the Yokine a further ridge which appears quite distinctly in some places - but elsewhere overlapped by the Yokine - has been named the Gnangara Dunes. Thus from west to east the full sequence so far identified consists of the Trigg Dunes, Karrinyup Dunes, Gwelup Dunes, Balcatta Dunes, Yokine Dunes, and Gnangara Dunes (Bastian, op.cit.).

Ridges as published in the 1996 paper covering the Yanchep to Peel Inlet region are shown in Figure 1.

It is important to note that these six ridges do not by any means exhaust the number of dune ridges on the coastal plain. Their considerable overlap tends to camouflage ridges: there are numerous spots where elements of a separate dune ridge will appear for perhaps one or two kilometres, then disappear beneath its neighbour again. In the Yanchep area itself, a more substantial dune ridge emerges immediately east of Loch McNess, with a narrow and in places swampy valley separating it from the Yokine complex. The trend, which is herein named the Yanchep Dunes, can be traced with a few gaps for fifteen kilometres southwards as far as Lake Neerabup, and the author considers that remnants of it can even be seen farther to the south. The ridge is relatively small and narrow compared to its neighbours, and the main chain of lakes/swamps may be impounded either immediately east or immediately west of it. The ridges identified in the Yanchep area, including the added Yanchep Dune trend, are shown in Figure 2.

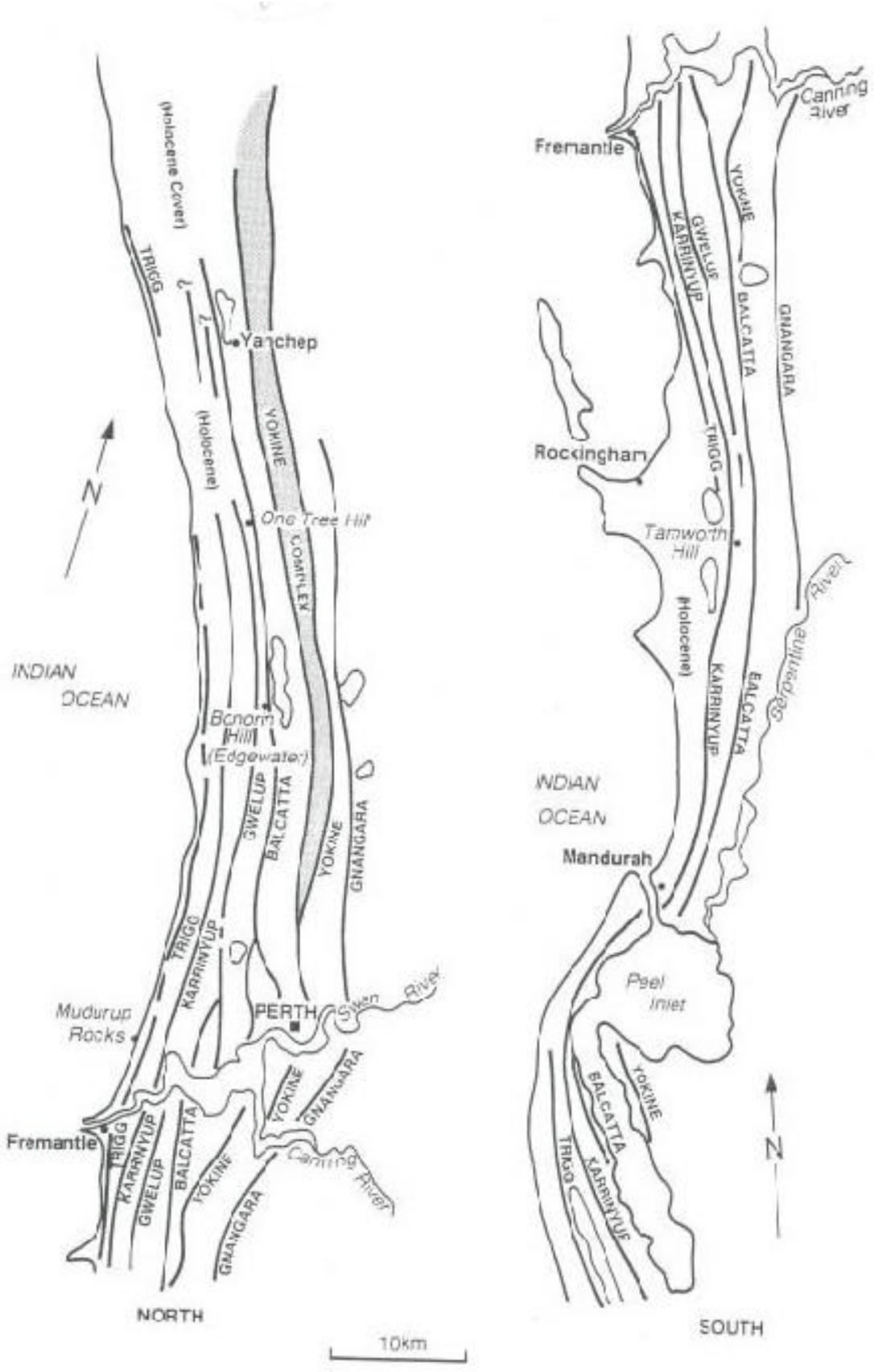


Figure 1 - Dune trend lines in the Yanchep to Peel Inlet region (from Bastian, 1996)

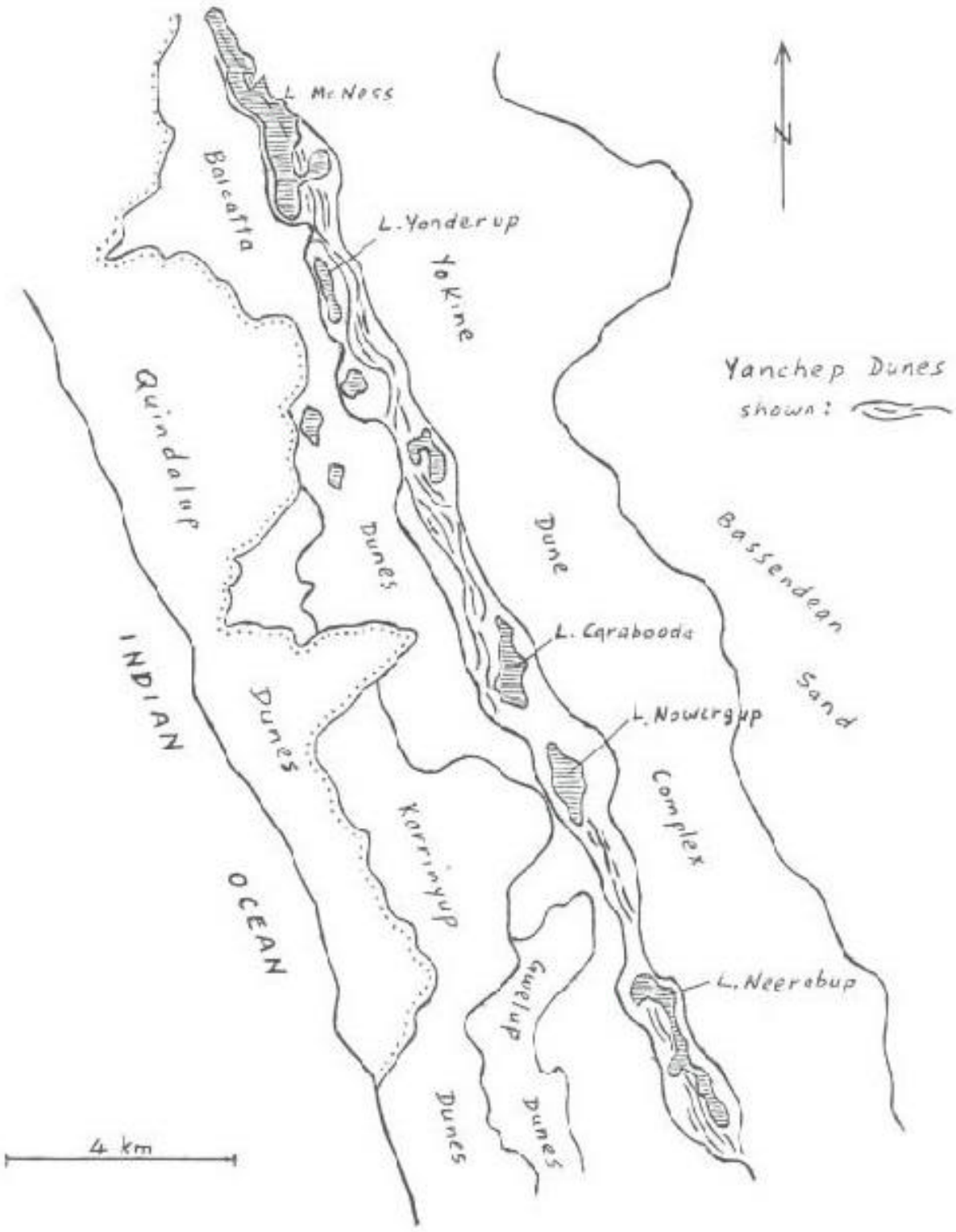


Figure 2 - Dune systems in the Yanchep-Neerabup region

It is concluded that the west coast dune trend lines broadly correspond with those identified as Ranges in southeast South Australia, and that probably every coastal dune belt seen South Australia had its counterpart along the west coast. However, because this coastline was not emergent they abutted or overlapped each other too closely for most of the individual lines to be recognised. In addition to these onshore elements there are offshore at least three reef lines of submerged dune belts, showing that rising sealevels were capable of reoccupying older dune belts, which had probably occurred with the named features. For example, the topographic complexity of the Yokine may well be the result of several repeated incursions of the ocean at different times. This means that those named cannot be equated with any specific Range, and that most if not all the ridges so far identified must be a composite of two or perhaps more dune belts.

At this point it is necessary to correct a persistent tendency among writers to compress the whole Tamala Limestone complex into too narrow a time-frame, with various authors limiting its maximum age to 120,000 years B.P. (eg. Maxlow, 1994). The present author's studies have indicated much older ages for the more inland elements of the Tamala complex, which have recently been confirmed by speleothem datings from caves on the Naturalise/Leeeuwin ridge. It is now considered that the oldest Tamala is in excess - probably well in excess - of 500,000 years.

On the basis of ridge size, topographic complexity, and distance inland the Yokine Dunes are suggested to be the possible equivalent to the Naracoorte Range. Recognising that in this region there has been submergence of the westernmost ridges, then the outer island chain of Rottnest-Garden Island is possibly equivalent to the Woakwine. Those between would at this stage be very difficult to correlate without extensive dating, and no attempt will here be made to do so.

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Hydrogeology and Speleogenesis Update, the Yanchep Cave Area, Western Australia

Lex V Bastian

INTRODUCTION

This article updates and modifies a paper of similar title (Bastian, 1991), introducing significant changes in terminology, with the reasons behind them.

The Yanchep cave area is situated approximately 50 kilometres north of Perth, and from 4 to 8 kilometres from the coast. The area is highly cavernous, and several hundred caves are known to exist within a relatively small area, much of which is incorporated within the boundary of the Yanchep National Park. The linear stream cave systems seen in the Leeuwin-Naturaliste block are controlled by the buried topography of a Precambrian basement (Bastian, 1964), however this factor is not present at Yanchep, where the underlying strata are unconsolidated sediments. There are peculiarities of the cave distribution at Yanchep, in particular the existence of a large tract of limestone country in the eastern part of the Park which is devoid of caves altogether.

REGIONAL GEOLOGY AND HYDROLOGY

The surface formation at Yanchep is a friable dune limestone (aeolian calcarenite or aeolianite) of Pleistocene age, the Tamala Limestone (Playford, Cockbain and Low, 1976). This is the same formation as that seen in the Leeuwin-Naturaliste belt, and is also an approximate equivalent to the Bridgewater Formation (Boutakoff, 1963) of southeast South Australia. A similar type of Pleistocene karst has been described from Bats Ridges in western Victoria (White, 1989).

The Tamala Limestone consists of a series of calcareous coastal dune ridges formed during successive interglacial high sea levels. In terms of geomorphic structure the ridges have been named collectively the Spearwood Dune System (McArthur and Bettenay, 1960), and at least five individual ridges have been recognised in the Perth region (Bastian, 1996). In contrast to the picture in southeast South Australia the ridges in most cases abut each other closely, with the younger ridge partially overlapping its older inland neighbour. However, there is one major interdune corridor in the Yanchep area, which is occupied by a chain of lakes, those within the National Park being Wilgarup and Yonderup Lakes, and Loch McNess. The younger ridge west of the lake chain is correlated by Bastian with the Balcatta Dunes of the Perth area, while the large limestone ridge to the east of the lake corridor correlates with the Yokine dunes.

In this part of the Perth Basin The Tamala Limestone abuts and overlies an extensive formation of sand, known as the Bassendean Sand (Playford and Low, 1972). This relationship contrasts markedly with most of the Leeuwin-Naturaliste area, where the unit generally rests upon impervious Archean metamorphic rocks, although the latter area does have pockets of pre-Pleistocene sands which have been buried beneath dune systems. The Tamala dune systems extend to about halfway across the Swan Coastal Plain; from thence to the Darling Scarp the surface formation is the Bassendean Sand.

The carbonate content in the aeolian calcarenite which makes up the Tamala Limestone has enabled solution and lithification to proceed rapidly, despite its geological youth, whereas the absence of carbonate from the underlying sand formation has left it in an entirely unconsolidated state. As a result the limestone rests upon loose porous sand. Also the contact between the two is not horizontal, but slopes westwards from relatively high levels at the eastern extremities of the limestone formation, to be well below sea level at the coast.

A large fresh unconfined groundwater resource has been identified in the region, known as the Gnangara Mound (Allen, 1981). This is a shallow body of groundwater with a mounded shape, which rises to over 60 metres above sea level between the Swan River and Gingin Brook, 70 kilometres to the north. Davidson (1995) dealt with the structure and hydrology of the Mound in the context of a general study on the groundwater resources of the Perth region.

Figure 1 is modified from the 1991 paper, showing the generalised surface geology of the area, including the Gnangara Mound.

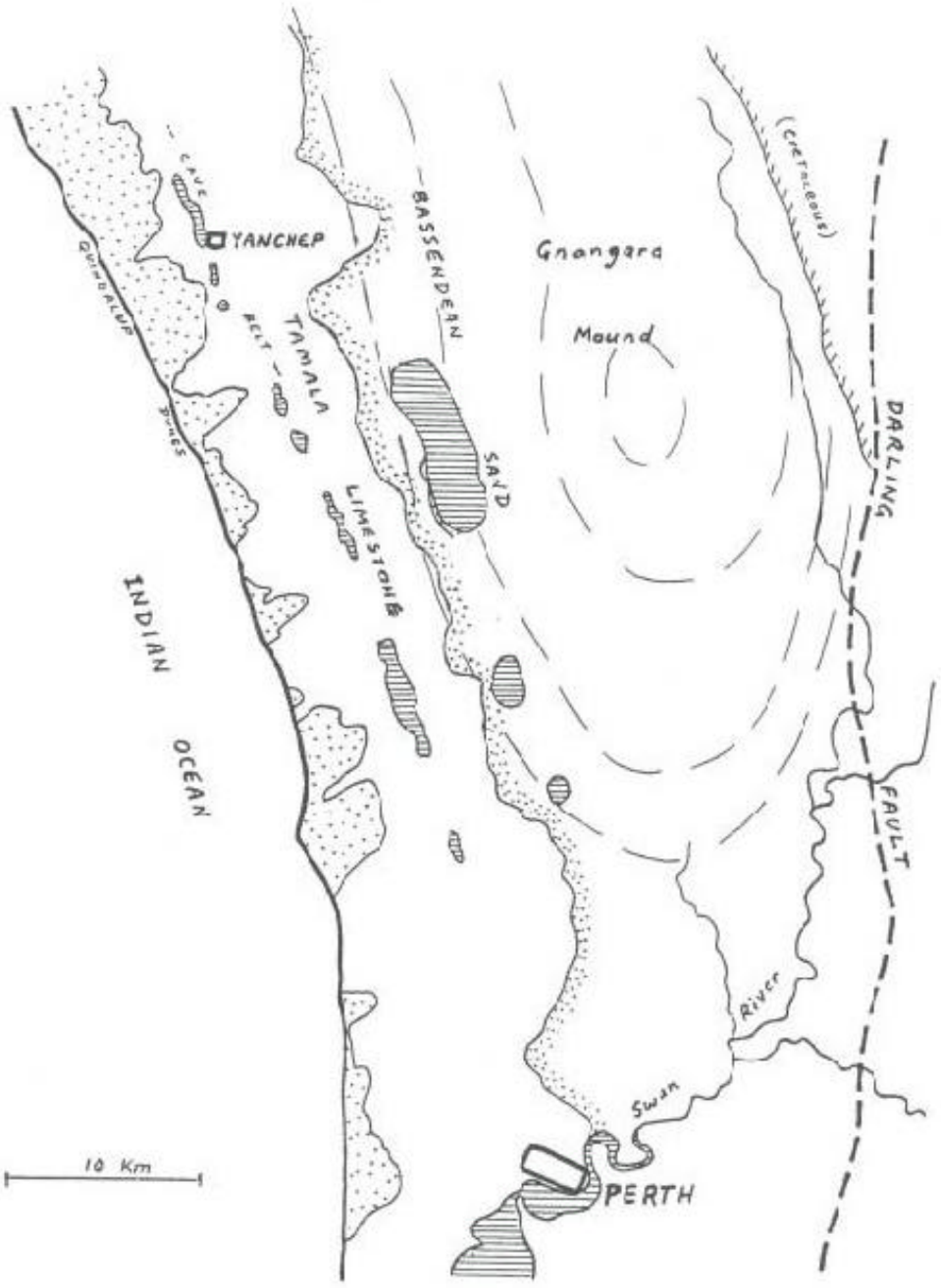


Figure 1 - Locality Plan
Watertable contours on the Gnangara Mound are shown schematically

The highest levels occur in an area east and southeast of Yanchep, resulting in radial groundwater movement from the Gnangara mound southwards towards the Swan River, and westwards towards the coast. The west-flowing sector takes the water into the Tamala Limestone, prior to discharge of the groundwater into the Indian Ocean. This process, operating in conjunction with the geological makeup of the region, leads to a unique hydrogeology, with several distinctive north-south zones.

SPELEOGENESIS

Cave development at Yanchep falls within the scheme described as syngenetic karst (Jennings, 1968), a sequence first proposed by the author (Bastian, 1964) from studies of caves in the southwest region. In this process cave development proceeds contemporaneously with the lithification of the dunes, and may already be well advanced by the time the material has become a reasonably firm limestone.

The groundwater relationships with respect to the limestone formation fall into five distinct zones aligned roughly parallel to the coastline. From east to west these are:

(i) Dry Substrate Zone
(ii) Cave Source Zone
(iii) Paraphreatic Cave Zone
(iv) Interdune Lake Chain
(v) Phreatic Cave Zone

Figure 2 shows a cross-section of the zones as modified from the 1991 paper.

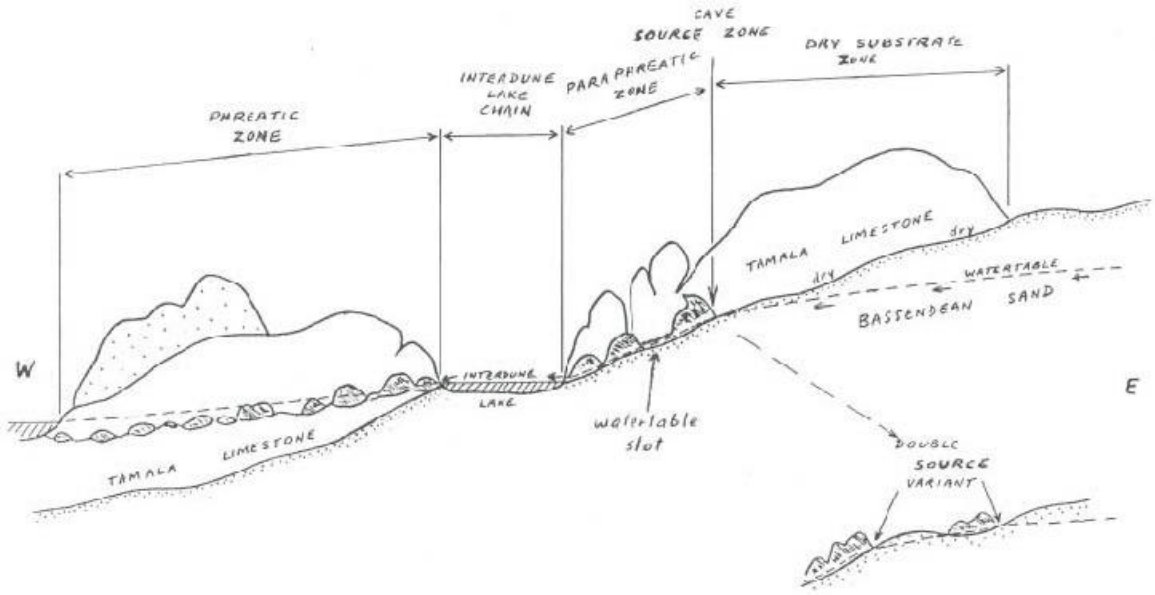


Figure 2 - Schematic east-west cross-section

(i) Dry Substrate Zone

This replaces "Subjacent watertable zone" as used in the former article, with a term that focusses more clearly on the reason for the absence of caves. In the zone, extensive tracts of the dune limestone lie as a relatively shallow veneer over the non-calcareous sand substrate, with the water table being located in the sand, generally well below the base of the limestone. For example, Drillhole NE72, located approximately 3 kilometres ENE of the Yanchep Park office, passed through 40 metres of limestone followed by 14 metres of dry sand below the base of the limestone, before intersecting the water table (Gozzard, 1982). It is debatable as to how much of the rain falling directly upon this zone reaches the water table: it is the opinion of the author that much of it remains perched in closed off solution pipes.

Even at the springtime maximum the water table does not rise sufficiently to reach the base of the limestone. Since there is no contact of groundwater with the limestone, solution at the base of the limestone is virtually nil and there is no cave formation. The zone is devoid of surface cave indications, and the dominant vegetation is heath. Karstification is limited to surface phenomena only, such as solution pipes and pinnacles; the pipes characteristically close off with depth.

(ii) Cave Source Zone

As outlined in the section on geology, the base of the Tamala Limestone descends westwards to be below sea level at the coast. This basal surface is steeper than the natural gradient of the water table, which cannot go below sea level. Hence the water table intersects the base of the limestone. Being virtually free of dissolved carbonate, the groundwater can dissolve the limestone vigorously, hence this line is marked by a sharp onset of solutional activity.

I had for some time been attempting to give a suitable title for the zone along which the groundwater makes its first contact with the limestone. In the 1991 paper I used the term: "Cave Threshold", but subsequently realised that this expression was already in regular use for the entrance area of a cave, where partial light penetrates. Due to seasonal fluctuations of the water table the actual point of groundwater contact fluctuates within a rather narrow zone, which therefore has been redefined as the "Cave Source Zone" (Bastian, 1996a). As a result of this activity a semi-continuous belt of caves is developed, manifested by the appearance of collapses, dolines, and fissures, with numerous enterable caves. A profound vegetation change is also seen, in the appearance of tuart (*Eucalyptus gomphocephala*), which thrives in broken limestone ground with access to the water table, and the understorey as a whole becomes denser in response to the increased accessibility of water.

Since the solutional attack must commence along the whole line of groundwater contact, it results in a loosely integrated cave system, with a distinct north-south elongation in plan. Continuity is however interrupted by breakdown features, somewhat analogous to a lava tunnel which has been broken by collapse into numerous segments. Chamber sizes tend on the whole to be larger than in other parts of area, because of the powerful solutional attack of the groundwater at the point of first contact with the limestone. Caves within this zone include Yanchep Cave (YN16), Catacombs Cave (YN8), and the eastern end of Crystal Cave (YN1), while the eastern (north-south) arm of Boomerang Gorge is an excellent example of a collapse feature developed along this trend.

Primary solution features are rarely seen, as the pervasive collapsing which occurs in the friable limestone means that most of the accessible caves are above the primary speleogenetic level. The most frequent cave form is the "inclined fissure" (Bastian, 1964), but open arched chambers are also common, due to complete dissolution of collapsed ceiling rock.

(iii) Paraphreatic Cave Zone

Westwards from the Cave Source Zone the base of the Tamala Limestone continues to maintain a gradient which on the whole is slightly steeper than the natural gradient of the water table. The strong solutional activity which now occurs at the base of the limestone creates extensive cave systems, into which the groundwater discharges as a network of subterranean seepages, being fed into the streambeds from a slight excess of hydrostatic pressure.

Open streams fed from these seepages are able to transport the discharging groundwater much faster than it can percolate through the sand formation, thus the typical stream is in effect a sheet of fast moving groundwater. When functioning normally, the streams accommodate seasonal variations in the water table, by simply increasing or decreasing their rate of flow through relatively slight rises or falls in stream depths, respectively. Thus, instead of the pronounced annual fluctuations of the water table seen in central parts of the Gnangara Mound, water tables in this zone maintain an almost constant level[1].

Loss of hydrostatic pressure in the stream seepages means the water table is unable to penetrate the limestone, but instead follows down the sloping contact between the two formations until it has descended to not far above sea level. The relative gradient of the water table depends upon the slope of this contact plane.

Caves in this zone are not formed within the epiphreatic level (which by definition is the level of *intermittent* saturation, in which caves are subject to seasonal inundation). However, they do not fit a standard vadose model either, because vadose streams flow in conduits at levels above the zone of water saturated rock. These Yanchep cave streams are, by contrast, genetically linked to the water table within the underlying sand. In the 1991 paper the term "exophreatic" was proposed, but this is now regarded as an inaccurate term to cover the situation, as the water doing the

dissolving is not outside (*exo-*) the phreas but remains at all times an integral part of the phreas. Instead, the term *paraphreatic*[2] has been substituted to reflect more accurately the locus of solution activity (*para* = from, alongside). *Paraphreatic* is defined as the condition in which the base of a limestone formation is in contact with a saturated non-calcareous aquifer, with a slight excess of hydrostatic pressure. It is essential to the paraphreatic condition that the intake area of the aquifer be relatively low, as any marked excess of pressure, such as in subartesian conditions, would cause the water table to invade the limestone, leading to the development of normal phreatic caves.

Also in the earlier paper the zone was described as a "Groundwater Escarpment", to highlight an apparent oversteepening of the water table in this zone. However, water table contours in the Yanchep area, derived from Water Corporation monitoring bores, confirm that the steepening is only slight and is not consistent, depending as it does upon undulations of the limestone/sand interface. The term has been dropped.

Although most caves in the region display the inclined fissure structure (Bastian, 1964) or complex variants thereof, the primary form in paraphreatic caves is a broad *watertable slot* with a horizontal ceiling. These slots typically have only a few centimetres space for the streams to run between their limestone ceiling and sandy bottom. As cave systems develop, the streams then continue to dissolve any limestone which may have collapsed into the water. Due to the friability of the limestone this eventually becomes the main means of cave enlargement: a typical ceiling in caves of the Paraphreatic Zone has no solution carved features, the only solution features being those at the base level, where a stream may be seen issuing from its slot. Since the stream beds are actually on the underlying sand formation, they are invariably shallow with a bottom of clean washed sand. Rotational Collapse of fallen roof blocks in the stream beds, as described by Caffyn (1973) can be seen in a number of places.

Caprock (kunkar) is well developed throughout the area, and plays a modifying role in terms of the cave morphology. Upwards stoping generally stops at the base of the caprock level, resulting either in extensive fissure complexes below the caprock or, less commonly, open chambers with subhorizontal ceilings. These complexes may virtually honeycomb a hill which has outwardly few or small entrances giving access to the system beneath.

(iv) Interdune Lake Chain

After the water table has descended by about 6-7 metres down the limestone/sand contact, the cave streams efflux onto the main lake chain. These are of the groundwater throughflow type (Davidson, *op.cit.*), and with a mean level of around 7 metres above sea level, afford a natural boundary between the water table regime east of the lakes and that to the west.

The lake chain interposes a significant modification to the hydrological system. In the winter peak period (June - August) the peat-clogged lakes are generally not able to discharge the amount of water entering them from the numerous effluxes along their eastern side. This in most cases results in a distinct winter rise in lake level which exceeds the rise in the streams feeding them, during which period the lakes in effect function as natural dams.

In the limestone hill barriers between the lakes, where dune lobes of younger western dunes have bridged across to the older dune system, there are several cave streams which traverse the barriers from east to west, thereby skirting the lakes. Thus, water dye tracing (Bridge 1969) failed to show a water connection between the lakes, although the water from the Loch Overflow (YN13) was detected in Mambibby Cave (YN12) about a thirdway across the gap.

The lake water exits via several natural cave spillways (Allen, 1981). These are cave systems which are exceptionally well developed and relatively free of organic matter, enabling them to take strong winter streams when the lake level rises. These disperse into cave labyrinths in which water movement is almost stagnant, and which are typically floored by thick deposits of peat. Caves of this type have been found along the western shores of Yonderup and Wilgarup Lakes and between Loch McNess and Yonderup Lake. This sluggish dispersed movement then makes its way to the coast, to emerge eventually as submarine seepages.

Figure 3 shows the main effluxes and inflow points found along the lake margins. Note that these are very incomplete, due to dense swamp vegetation and snake hazards: the number recorded along the northern flank of Loch McNess is due to a severe bushfire in 1991 which temporarily afforded easy movement and visibility.

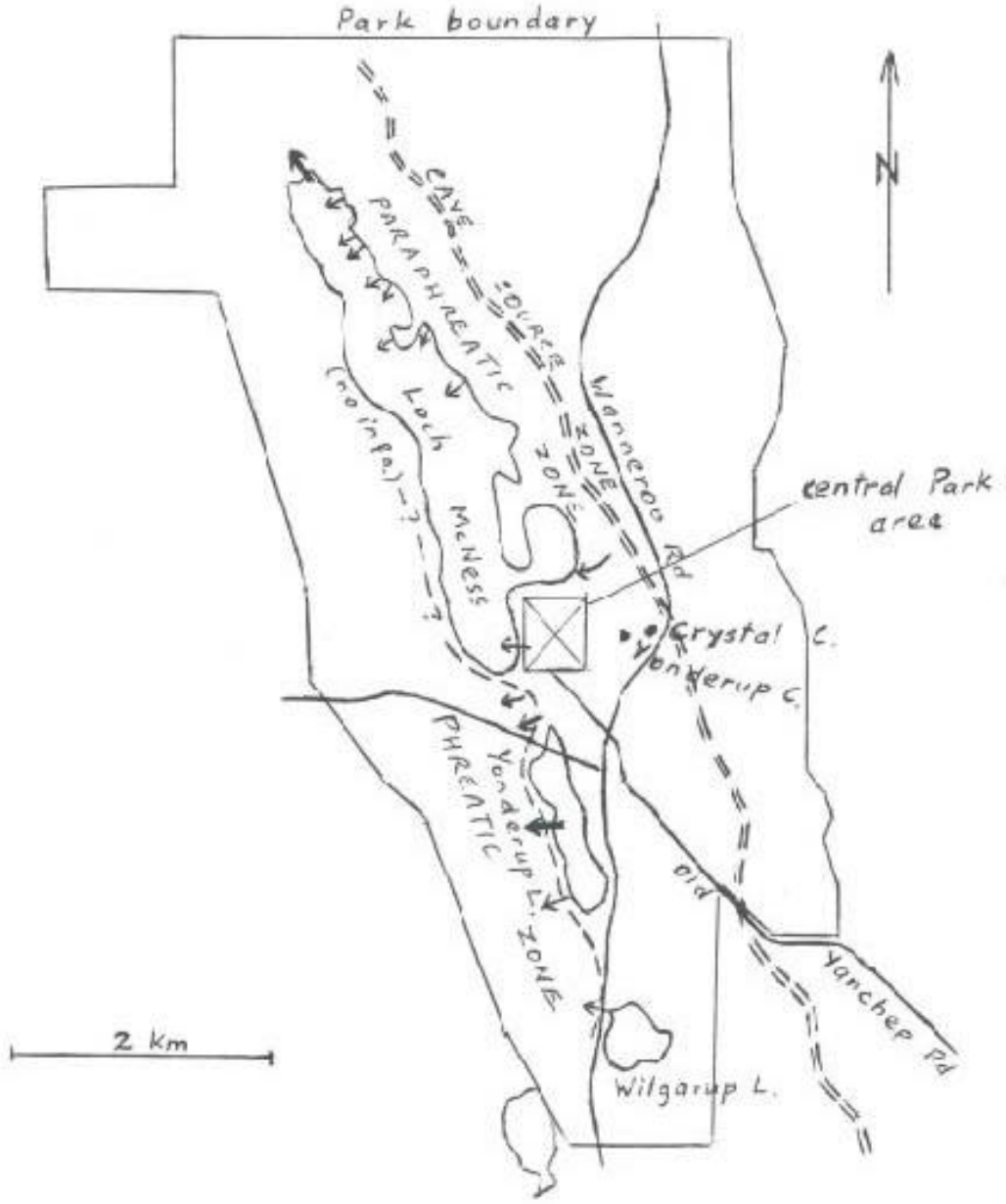


Figure 3 - Cave zones, effluxes and inflows in the Yanchep National Park area

The main cave spillway of Loch McNess is at the northern end of the lake, taking a vigorous winter stream which runs northwestwards to bypass the mainly blocked western shore of the lake. That this lake drains northwards was a feature observed by one of the early settlers in the district, Henry White (Milligan, 1903). The cave labyrinth named Loch Overflow (YN13) at the southern end of the lake does not actually draw surplus water from the lake as its name would imply, but is fed directly by a sheet of seepages from the east. The water in the lake is slightly alkaline; a set of pH readings taken at various points in the lake ranged from 7.6 to 8.1 (McComb and McComb, 1967).

At Yonderup Lake two major spillways have developed, one about halfway along the western shore of the lake, and another at the southern end. The spillway system on the western shore takes such a strong flow that a clear sandy floored channel crosses the lake to the inflow point, making it virtually a river within the lake. These two spillways have become so effective in draining the lake that it has an almost constant level summer and winter, which at 6.0 metres is a full metre lower than Loch McNess. Wilgarup Lake has a single inflow point at its northwestern corner, which appears to have silted up, and is not draining the lake very effectively: with the result that the lake level is higher than either of the others.

(v) Phreatic Cave Zone

A younger component of the Tamala Limestone - the Balcatta Dunes - forms the main lake frontage on the western side of the lake chain. The base of the limestone formation continues to descend, and eventually goes below sea level nearer the coast. The groundwater therefore must invade the formation, resulting in a radical change in the type of flow in the cave systems. Thus, instead of shallow streams flowing down the contact plane between the limestone and sand, the water movement changes to normal phreatic conditions.

Apart from the actual spillway points, where water levels reflect the fluctuations in lake level, the water table in this zone shows only a small annual variation, until the area subject to tidal effects is reached. A radial pattern can be identified originating from the various spillway points along the western shores of the lakes (Bastian, 1989). This pattern is soon lost as the water disperses throughout the zone in its movement towards the coast. A progressive lessening in subsurface karst phenomena can be observed toward the west, evidently due to increasing carbonate saturation of the cave waters. Cave distribution becomes more sparse and cave dimensions likewise tend to gradually diminish, with fewer or smaller collapses managing to break through to the surface. No caves have been accessed within several kilometres of the coast.

In this zone true phreatic solution features make their appearance, in which solution profiles can be observed, not just dissolved ceiling rock. An excellent example is the tunnel labyrinths of Concinna Cave (YN166) in the southern part of the Park. Instead of shallow streams these caves have ponded lakes, complex tunnel labyrinths, broad flat ceilings with roof pendants, and concave solution pockets. Caves fed from the lakes typically have heavy peat deposition in the tunnels.

A distinctive feature is the presence of a pronounced high water mark on the cave walls. This is particularly well seen in Loch Overflow Cave (YN13) and several others, in the form of a solution carved ceiling with numerous roof pendants, generally around one metre above present day levels. Deep notches on cave walls and on the pendants directly below these ceilings show that the level was maintained for some time. Broad flat-roofed chambers similar to the "Flat Roofed Lake" in the Augusta Jewel Cave are widespread in Loch Overflow Cave.

It is suggested that the high water level was brought about by an interglacial high sea level, which forced water tables near the coast to rise. The most probable time for this to have occurred would have been the major interglacial high sea level at about 120,000 years before present. Support for the antiquity of the high water level is afforded by the presence of old corroded cave decorations, with younger decoration superimposed on it.

The widespread nature of this phenomenon is evidenced by its presence in the Augusta cave area, having all the features mentioned above, including old corroded decoration and superimposed younger decoration. It is noteworthy that the high water level at Augusta is clearly higher than in any Yanchep cave. The probable reason for this is that the Augusta caves would have been particularly close to the coast at times of high sea level, resulting in a rise of the water table to match that of the ocean. Bermuda, virtually antipodeal to this region, reveals the same sequence of events in its caves. Harmon et al (1983) report the imprint on speleothems of the interglacial high sea level in the period 125,000 to 120,000 years B.P., and suggest a sea level rise of approximately 5 metres occurred at that time.

Paraphreatic/Phreatic Transitions

Because the limestone base is undulating there is no sharp demarcation between the two. Inaccessible watertable slots having vertical openings of only a few centimetres, in which the only solution carved rock will be the ceiling of the slot, grade into accessible mud tunnels having small roof pendants. Slightly deeper penetration of the limestone by the groundwater gives rise to scolloped ledges, larger pendants, and alcoves with a corrosion profile, but still lacking a rock floor to the main tunnels. The tunnel labyrinths of Loch Overflow Cave (YN13) are almost wholly of this type. As the base of the limestone deepens, the profile likewise deepens, resulting in full solution carved chambers floored by solid rock.

Again, the undulating substrate of the limestone formation causes variations in detail of the zonation. Depressions in the sand substrate which had become filled in with the calcareous dunes, result in hollows where the groundwater has invaded the limestone to produce an isolated pocket of phreatic caves, surrounded by caves with shallow paraphreatic streams. Of particular note is a group of phreatic caves in the limestone tract between Loch McNess and Yonderup Lake, which have developed within the swale that formerly occupied this strip prior to dunes advancing across it and separating the lakes. The most well known of these is Water Cave (YN11) near the south end of Loch McNess.

Mass Subsidence

There is one aspect of speleogenesis at Yanchep which deserves special mention. The limestone formation in this area is thin: the total thickness of Tamala above the sand substrate may range from around 50 metres to as little as 10 metres or even less. The pervasive groundwater contact with the base of the limestone can undermine it so extensively that there may be a complete loss of integrity of the limestone, from bottom to top of the formation. This effect can spread laterally to encompass a wide area. Once this happens, the rock as a whole begins to settle *en masse* as it is being dissolved from beneath. Such areas may be described as undergoing *mass subsidence*.

This phenomenon begins to manifest itself in an *early stage*, in which caves will have lost the "inclined fissure" form, consisting instead of fortuitous spaces amongst massive breakdown blocks. Pendant decoration in such caves frequently reveals extensive areas of leaning ceiling, showing that essential loss of integrity has occurred *above* the cave. A common feature seen on the surface is groups of vertical or near-vertical rifts, resembling the crevasses of a glacier, showing that the ground is effectively in a broken condition. There is a large rift (YN115) high on the hillside west of Yonderup Lake, showing that the eastern half of the ridge - which superficially appears intact - is actually already beginning to tilt towards the lake.

This is followed by an *advanced stage*, in which the rock is breaking down into smaller and smaller blocks, until finally no enterable caves can be found in the mass of subsiding limestone. Boomerang Gorge is a relic of a former cave whose collapsed ceiling rock has been almost wholly dissolved away, leaving only tumbled blocks of caprock along its flanks. The surface also becomes increasingly bare, due to the loss of soil down the multitude of cracks, and instead of the usual terrain of caprock pinnacles projecting through the soil what is revealed is a surface of disoriented blocks and boulders.

Eventually the limestone is reduced to isolated hummocks, either surrounded by swamp or by extensive tracts of residual yellow sand, and ultimately the limestone will disappear altogether. A considerable volume of residual sand is released from the dissolving limestone, and accumulates as aprons round the remnant hills. There is evidence that this has already occurred along much of the eastern side of Loch McNess, in the occurrence of extensive tracts of residual sand. Most of the effluxes along this side of the lake have eroded short stream channels through these sand tracts en route to the open water, which is mainly to be found along the western side of the lake. As a result of this process the lakes at Yanchep have been enlarged peripherally, so as to become much larger than their original sizes.

FOOTNOTES

1. N.B.: Due to a severe and progressive fall in the water table from local human causes since the early 1990's, water table data have become increasingly anomalous, and at present (2002) do not represent the normal situation for the locality. Many streams with a history of reliable flow are now drying out in the summer, while others have dried out altogether.
2. Ken Grimes (*pers.comm.*) has pointed out that the term had been published by Tratman in the late 1950's, but has never come into use. The term is reinvented here because the prefix is the best that can be used to cover the situation described.

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Water Loss in Caves of the Yanchep Region

Lex V Bastian

INTRODUCTION

This paper does not pretend to be a comprehensive statement on the problem, as the author has to this point in time not by any means fully digested, nor indeed accessed, all relevant material; however it presents a line of thought that needs to be aired.

The author's own experience began as a youth exploring caves with a torch in 1949; at that period a stream in the cave now known as Gilgi Cave (YN27) was running, as it was again in 1954. In that period it was just the place to pop down and quench ones' thirst. Yet both those years had well below average rainfalls. In 1988 when the author's systematic documentation of the area began, all cave streams were running normally; in fact, since by that stage the water in Jewel Cave at Augusta had long gone, the contrast between this and what over forty years experience was seen to be the *total reliability* of Yanchep cave streams could not be missed.

The cave streams afford a habitat for a wide range of aquatic fauna, including watermites, aquatic worms, leeches, hydra, crayfish, midge larvae, snails, flatworms, rotifers and fish. Some species of Amphipoda and Isopoda yet to be named occur only in these caves, and some, including a crangonyctoid from Crystal cave, have ancestry dating back to Gondwanan times. Tuart (*Eucalyptus gomphocephala*) trees on the surface send taproots down into the streams, and these mats of fine rootlets provide shelter and food for the invertebrates. Of particular importance is the fact that significant species differences have been noted between various cave groups, indicating that populations have been isolated for a considerable time.

The Gnangara Mound - which supplies the karstic formations with their water - peaks southeast of Yanchep at over sixty metres above sealevel. An extensive area of planted pine forest lies along the western flank of the Mound, a large portion of it being directly up the groundwater gradient from Yanchep. Since the early 1990's there has been a progressive loss of water from the Mound, with by far the most serious effect being in the Yanchep karst. At the point of writing (2002) every stream cave in the region has dried out, and even the deeper phreatic caves such as Water Cave are at critically low levels.

CHANGES SINCE LATE 1980's

The first caves to be affected by the drop in water table were the easternmost caves: those in the Cave Source Zone, because these lost their hydrostatic head as soon as the Gnangara Mound began to drop. Crystal Cave, with a water table at 13 metres was one of these. In effect, the Cave Source Zone has been gradually shifting westwards, and the eastern caves are now in the Dry Substrate Zone. In these caves all solutional activity has ceased, the water is well below the stream beds, and the caves have effectively "died".

Caves farther west, such as those adjacent to Loch McNess, with water table around 7-8 metres, were not affected at first, because there was still a hydrostatic head available. However, the effect has now reached Loch McNess itself. The east-west zonation no longer functions, no caves are now operating under paraphreatic conditions, and the Cave Source Zone has shifted almost completely out of the main cave belt. The lake, which in living memory had never varied significantly through all climatic conditions, has now begun to fall markedly in the summer dry period. Water Cave, with its levels closely connected to the lake, is at its lowest level ever.

Of critical import is the loss of cave stream habitats. Fauna has been completely lost from drying out of the Gilgi Cave and Cabaret Cave streams: despite the development of artificial ponds in the latter, into which tuart root mats have been encouraged to grow, the creatures have not reappeared. In other caves such as Crystal Cave a small population of the endangered crangonyctoid has been maintained artifically.

Government authorities such as the Water Corporation and Water and Rivers Commission have attributed loss of water primarily on a recent period of lowered rainfalls, however it will be shown below that this is not the prime cause of the problem, and it is debatable whether it is even a significant secondary factor, for reasons which will be explained.

ANECDOTAL BACKGROUND

First references to streams in the caves date to 1838 and 1841, when both Grey and Roe encountered strongly flowing streams. Little is known about the level of water in the caves for the next sixty years, however rainfall records show that there was a dry spell in the 1890's to 1915 comparable to the present lean period. Despite this, during the early 1900's water levels in the streams were holding well. Comments made during that period include the following:

A letter to "The West Australian" by J.A. Grant, a local farmer who in early 1903 was the discoverer of Yanchep Cave. The letter appeared on page 10 on Saturday March 28th 1903. After general praise of the region and its attractions he went on to say:

> *"As there is one fairly large and several small underground streams going into the lake, and flowing from thence to the sea, there must be miles of subterranean galleries yet undiscovered."* He went on to add*: "this running water makes the lake a suitable place for several species of fish."*

The next one comes in a detailed description of the discovery of Mambibby Cave by Mr H.E.B.Gull of Guildford. This article appeared in "The West Australian" on page 7 on January 19th 1904. After describing the cave's main chamber he continued:

> *"In the far end of this chamber is a miniature lake, with a tiny island of rock in the middle. Turning from this chamber in a N.W. direction one comes to a running stream of spring water, and, after crossing this, there is a sandy beach, which leads to the beauty spot of the cave."* etc.

Finally, from the Yanchep "Visitors Book" which was kept by Henry White, (and now on display at the Gloucester Lodge Museum) there comes this entry dated March 28th 1905:

> *"The stream of running clear, fresh water, in the limestone cavern near Mr White's homestead is a real boon to visitors, and a charming sight for those who dwell on the Goldfields where the precious* fluid is so scarce." etc. (signed) John Kenny.

At a somewhat later (although uncertain) date, E.S. Simpson wrote the following about Yanchep:

> *"The coastal limestone hills immediately east and south east of Lake Yanchep contain a number of caves decorated by secondary growths of stalactite and stalagmite, and in some instances further beautified by underground streams of crystal clear water."* Published posthumously, the text was substantially written for his Doctoral thesis at the University of Western Australia in 1919, and doubtless indicates no noticeable changes to the streams had occurred in the previous low-rainfall years.

The author's own experience dates back to a childhood visit to Crystal Cave in1942, during which the bases of the "Elephants Feet" were seen to be just above the water. This group of suspended columns - planed off at the base where they are (or used to be) laved by the waters of the stream - has for many years been a faithful guide to the normal water level of the cave stream; which until the 1980's had never been seen to vary significantly.

By the late 1980's the author had arrived at the conclusion that any general lowering of water levels over the Gnangara Mound is automatically countered by slower drainage downslope, because the gradient has flattened off. This variation had been noticed in the small variations in stream depths that occurred seasonally: lower levels of late summer with their slow flow alternating with deeper and more swiftly flowing streams in winter and spring. The difference in stream depths had always

been in the order of centimetres. Hence the Mound may be said to be "self-buffering"; this is why there was no significant change in the caves' water in the earlier dry period. Doubtless the streams would have run slower, but they were never lost.

FACTORS AFFECTING WATER LEVELS

(i) Climate change

If we look at *climate* as a possible cause for the recent disastrous collapse of the cave streams, there has certainly been a marked drop in rainfalls within the past third of a century; commencing in1969. However, the actual recent performance of the water levels has not matched the climatic changes at all.

In the 1975-1990 period no significant drop in cave waters occurred. Yet a detailed examination of the records shows that the most serious rainfall deficit occurred in the first five years of this period (1975-1979), during which the rainfall for Perth averaged 697mm, as against the normal long-term mean of 869mm. (Rainfall over the Mound as a whole is less - probably in the order of 800mm, however the pattern is closely similar to that of Perth.) The major drop in the cave streams began in the 1990's: not only was this twenty years after the rainfall shortage began, but the drop actually commenced during two wet years 1991 and 1992. In fact, rainfall in Perth for the five years1988-1992 averaged 868mm, almost identical to the long-term mean; which - had natural factors alone been operating - should have ensured the water table would have stabilised in the karst systems. My own appraisal of the data suggests that by the conclusion of the 1992 season, water tables - had they been operating naturally - would have fully recovered to pre-1975 levels.

The actual drop experienced has been so rapid and unprecedented that only an extremely severe drought - far worse than that of the pre-1915 period - could have achieved it. The rainfalls from 1992-on cannot by any imagination be described in these terms, for the nine years 1993-2001 averaged 770mm, well above the 1975-1979 drought. Furthermore, the fact that the drop has continued during these modestly below-average years does not obscure the fact that it commenced in the very years where it could least have been expected, had climate been the prime factor.
It can be concluded that the drop in water tables has been mainly a result of human-caused influences. Yet authorities such as the Water and Rivers Commission continue to blame climate as the primary cause of the problem.

(ii) Pine plantations

There are 23000 hectares of pines in the region. These are situated in three main plantations:

(i) the Yanchep pines, north of the Park, which were planted in the 1950's and 1960's;

(ii) the Gnangara pines, much closer to Perth, which also were planted in the 1950's and 1960's; and

(iii) finally the Pinjar pines, immediately east and southeast of Yanchep, which were planted in the late 1970's and 1980's.

The approximate location of these pine plantations is shown in the accompanying figure.

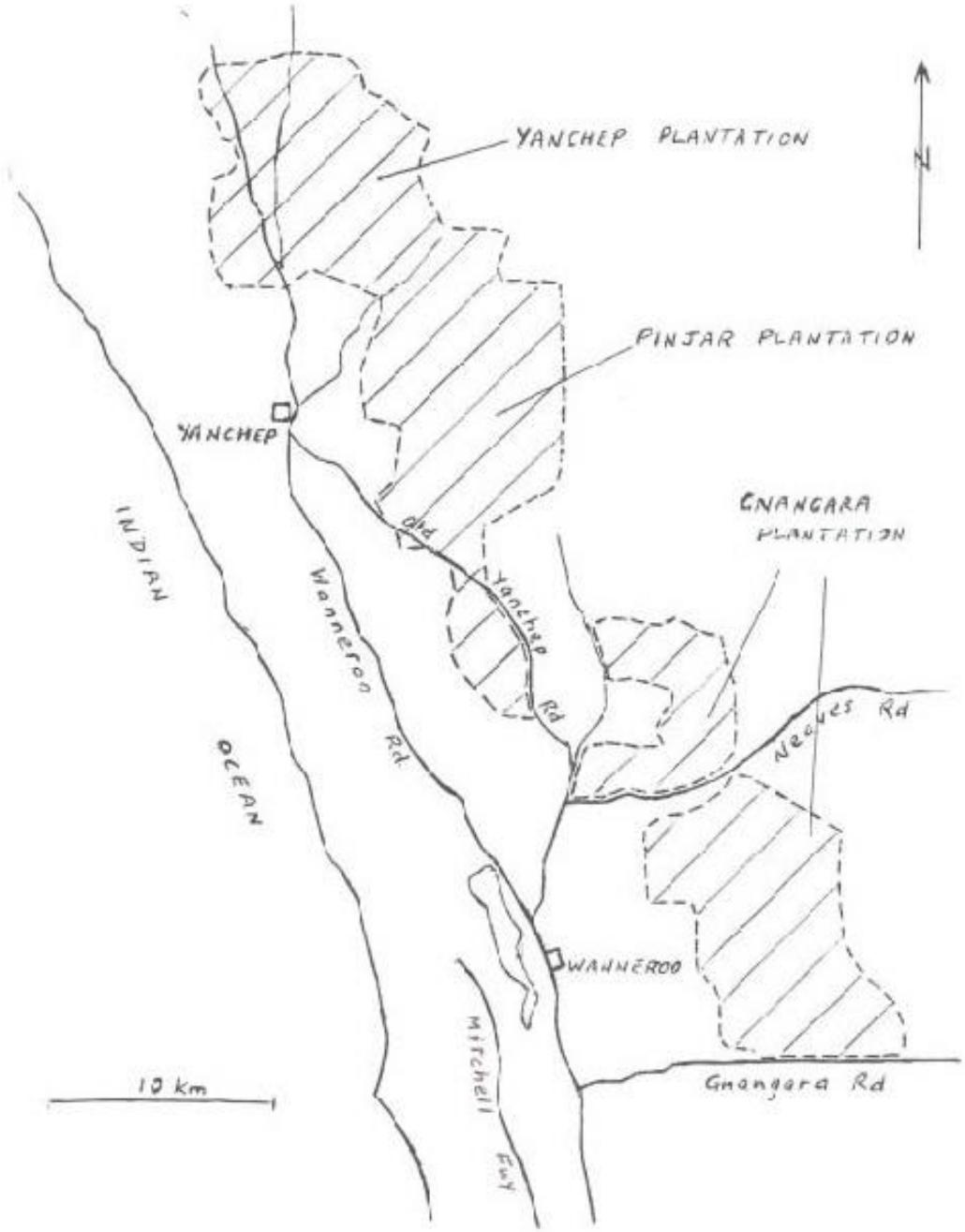


Figure 1 - Pine plantations in the region north of Perth

Monitoring bores in the region show that the most dramatic drop in water levels centres around the top (eastern) edge of the Pinjar plantation. This feature is so marked that it can not unfairly be described as a "hole" in the Mound, with drops as much a five metres. It is surely self-evident that climatic factors could not cause such a highly localised feature as this.

The pines have two effects: they draw more water than the natural vegetation, and they intercept large amounts of rain from reaching the ground. Past studies in other regions (eg. Holmes and Colville 1970, Allison and Hughes 1972) had shown virtually no recharge occurred to an aquifer beneath pine forest. If we bear in mind that most of Perth's winter rain comes in the form of showers, then the rain from each shower tends to evaporate off the pines prior to the next.

The pines meanwhile continue to draw water, hence they cause what is in effect a huge "cone of depression", which in this region happens to be mainly on the western flank of the Mound. The pines in effect may be said to have "turned off the tap" on the most critical part of the Mound. This has a repercussion further down the gradient: the downslope water levels in the karst belt have dropped, and are continuing to drop.

The Forest Products Commission is commencing harvesting of the oldest pine plantation, the Gnangara Pines. However this is well south of Yanchep, and the resultant recovery of water table will only have its impact on the southern end of the Mound: it will have no effect upon the Yanchep area. The Pinjar pines closest to Yanchep - and the ones doing all the damage - have not even reached the "first thinning" stage. They are not intended to be harvested until such time as their profit potential is maximised, whch will be some decades into the future. It is transparently clear that the forestry body have taken on board the view that the recent collapse of the water table is climatically caused, hence "not our problem". This can be no more than a whitewash, to deflect blame away from the pines, which are the real culprit. This poses a real potential for disastrous loss not only of the cave streams but of the whole wetland environment.

(iii) Public and Private Extraction

Supplementary factors in the drop in water levels that have been mooted are the effects of public and private extraction. However, although the Water Corporation is drawing large volumes of water from the Mound, its main borefields are farther south, and mostly well to the south; no currently producing bores are situated on the groundwater flow path upslope from Yanchep.

As for private extraction, water is taken regularly by private bores in the region, mainly for market gardens, turf farms and horticulture. However, none are located directly up the water table gradient from the central part of Yanchep where the main threatened-species habitats are located. A lateral effect from private extraction farther south has been mooted; the main usage being in the Carabooda area, a little to the south.

It needs be noted that these bores operate on cleared terrain. Thus there is an elevated input to the water table during the winter season, which will at least partly compensate for the summer period of heavy usage. Furthermore if this were a significant factor, then the "hole" should be centred round the area where there are most bores. This is not the case. Thus, although these bores take a significant amount of water, it is certainly far less than the effect of the pines.

THE CDFM

A method of rainfall analysis which has been widely accepted by Governmental agencies in WA has been the CDFM (Cumulative Deviation From Mean). Taking the mean rainfall of a site, the analysis compares this with the current year's rain to yield a plus/minusdeviation, which is then accumulated. The deviations for the period from 1969 on have now accumulated a considerable deficit. Using this as its pointer as to how the water table should perform naturally, the CDFM has led these agencies to the conclusion that it would have gone down parallel to the accumulated deficit, hence that falling water tables in recent times are mainly the result of natural climatic change. Inevitably this downplays the impact of the pines.

The main fallacy of the method lies in the fact that, as a strictly *linear* treatment of the rainfall data, it does not really simulate the performance of a mounded water table. In a typical mounded water table, the outflows are low-pressure seepages at the surface of the water table itself, having minimal hydrostatic pressure. Thus they are finely tuned to variations in the water table gradient, and are constantly adjusting to it. If rainfall is deficient for a period, the water table does not continuously subside to match the cumulative rain deficiency, but almost immediately will begin to compensate by reducing the rate of flow down the gradient. This compensating effect is then transmitted down to the seepage outflows. CDFM may only work if the outflow remains more or less constant; a scenario which may occur where there are springs discharging under pressure, such as does occur in major karst regions. In that case the rate of flow is controlled more by the size of the conduits, and thus can be more or less constant regardless of the variations in pressure.

The contrast can best be described in terms of a "leaking tank" versus an "overflowing weir". (Assume other variables such as evaporation and human exploitation are excluded.) In the first case the leak is well below the water level in the tank, hence is under high pressure, but the flow is restricted by the size of the leak. The critical point here is that if the water level subsides the leak will continue unabated. Hence a CDFM plot of the system may at least approximate the situation, as rainfall pulses top up the tank erratically from time to time, whilst the leak continues to drain it. On the other hand the overflow scenario has minimal pressure, and will fluctuate to match stream pulses. A strong influx raises the level over the top, the flow increases, then subsides again to the point where it is barely overflowing. The weir may then sit at top level even with no fresh inputs. A CDFM plot will not resemble the situation at all.

The "leaking tank" scenario is most likely to apply to the abovementioned large karst systems in thick limestone formations, because the water flows through interconnected phreatic complexes and exits via strong resurgences on the sides of gorges. These typically will be well below the top of the phreatic water level in the massif, and the strength of the resurgences will be determined by the size of the conduits feeding them. Outflow will continue unabated even if there is a drought situation in the hinterland. On the other hand, the Gnangara Mound clearly fits the "overflowing weir" scenario, because there is minimal hydrostatic pressure in the cave seepages, and outflow will cut back very quickly with any rainfall shortage.

Again, by using the long-term mean rainfall as its yardstick the CDFM is in effect giving equal weight to all past years' rainfalls. For example, the notable drought year of 1914 is supposedly still exercising its own significant influence upon the current water table performance, as do the wet years 1945/46. It is surely self-evident that the Perth region now has a new mean rainfall; and that the water tables should already have adjusted to it. The actual performance of a stable mounded water table must be a greatly subdued version of the rainfall variations, one which progressively reduces the impact of past rainfalls. If the rainfall drops off for some time - as it has done in this case - then it will in due course stabilise at a level appropriate to the altered rainfall regime.

- The water table is constantly adjusting (with a backlog) to increases or decreases in rainfall from the mean, and if those changes are reasonably consistent over a period of time then a new stable level will be the result. CDFM cannot simulate such a stabilising performance.
- Hence the real performance of the water table over extended periods such as the above, *will not be linear*: it will be in effect a curve which tends to flatten off exponentially, towards an asymptote which will be the stable water table for that altered pattern of rainfall.

If we are looking at rainfall as a guide to how the water table would perform without human influences, then for stable mounds such as the Gnangara Mound a realistic rainfall analysis plot must incorporate a "memory factor" that adjusts the rainfall year by year away from the (old) mean, thereby reproducing the above tendency for the water table to stabilise. Such a plot must yield a far closer approximation to the actual performance of the water table.

Not only does it show the stabilising outcome, but also will show that the water table is capable of restoring itself without having to have a rain surplus equalising out to the cumulative deficiency of the lean years. This is most important: even if rainfalls have been deficient for a considerable time, then since the Mound will have stabilised to the reduced rainfall it will need only a relatively short period of good rainfalls will "top it up". In the case of the region there were two above-average rainfall years in 1991/2, which - *had the Mound been running naturally* - should have been sufficient to restore it fully to pre-1969 levels.

The inability of CDFM to depict the way stable mounded water tables can not only stabilise but then quickly restore, was evident in a paper by Boehmer (1998). An accumulated rainfall deficit over three dry years (1984 to 1987) recorded over a small aquifer in Burkina Faso, did not reverse but only *levelled off* when the dry spell ended (because 1987 was a year of approximately average rainfall) whereas the actual water table performance in that year *raised* it fully to the1984 level. On the other hand, a plot for a site in the Colesberg region of South Africa reproduced in the above paper apparently followed a CDFM pattern. However the author did not notice the hydrological

contrast between this and the other site; notably in the highly erratic fluctuations of the water table, and a spring (not a seepage) only three kilometres from the observation bore, indicating that the Colesberg aquifer was not a stable mound, but was behaving more like a "leaking tank".

The proposed alternative treatment of the rainfall data was trialled by using a reduction factor of 55%, based on an arbitrary choice to reduce to minimal the impact beyond ten years antecedent to the current year. The actual factor must depend on how far back a realistic impact of a former year may be considered reasonable, and also may vary with different aquifers. Using rainfall data from Perth, a plot was obtained which indicated that the water table - were it to have operated entirely naturally, without human-caused changes - would not have dropped greatly within the past thirty years of reduced rainfalls.

CONCLUSION

In view of the fact that the authorites are at present laying the primary blame for the water loss on climatic factors, and have in effect sanitised the pine plantations, the prognosis is exceedingly bad for the Yanchep karstic belt. The challenge facing the speleological/environment fraternity is a double one: because the Government instrumentalities are not seeing the pines as the major culprits of the crisis, there is a pressing need to firstly enlighten them on this crucial point before one can expect to see any balanced appraisal of priorities coming from the decision-makers.
If this does not eventuate, and the threatened disaster runs its inevitable course, then blame for it can and should be placed not only on the pines but also on the public servants and politicians who kept them there for reasons of pure greed.

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A Little Plane, a Big Plain and Very Many Feet: The Finding Of Thylacoleo

Ken Boland

AN IDEA DEVELOPS

The finding of *Thylacoleo* was, in itself, an unexpected detail in a much longer process. For some ten years, a dedicated group of cavers from CEGSA, CLINC and VSA had spent many trips drawing together the main features of Thampanna Cave to which we had been introduced by earlier surveyors, notably Max Meth and Graham Pilkington. By 1999 new challenges were desired; and a new purpose, so that we could continue to justify enjoying what Rudi Frank has called "that unique state of mind": the Nullarbor.

An abiding inspiration has been a saying, attributed to the late Joe Jennings, that "Time spent in personal reconnaissance is seldom wasted." It had long been noted that large trackless areas had virtually no recorded features. It was often accepted that probably no features worth searching for existed.

One such area was chosen, some fifty kilometres square, and a solo three-day walk undertaken. Ten features were found; and of these, two were within eleven metres of each other, yet neither was visible from the other. One was a delightful small stand up cave with several salt domes and a little lake and geckos. Moreover, the best find of the walk was a small cave, barely a hundred metres from where the walk began, found at the end of the three days. Clearly, longer legs were needed. Ladders on vehicles, cameras on kites and even wilder ideas were entertained, but our needs were resolved when an ultralight aircraft was generously made available.

It is a low-cost, quite elderly, single-seat plane, with conventional three-axis controls, making it more suitable for modestly windy conditions. The two-cylinder, two-stroke, single-ignition engine is adequate for short take-offs, and easily handles a 100 km/hr cruise. The aircraft is of metal frame and fabric covering, light and sturdy, and is an old design with an excellent safety record. Most of all, it has a rocket-powered parachute to bring it to ground should some disaster occur.

So with an aircraft available, and with many years of flying experience, a seven-metre-long van was built to bring aircraft, pilot and Nullarbor together. Actually fitting the aircraft into the van took several days, much frustration and disappointment, and continued modifications to the van and fitting; but departure was possible by Easter 2000. The trip from Melbourne proceeded, albeit slowly, towed by our elderly but faithful two-litre Rodeo, never quite moving into fifth gear except down the long hill into Adelaide.

The aircraft was assembled on the airstrip at Mundrabilla, and a successful take-off proceeded. This remains the only occasion on which a "proper airstrip" has been used. We had planned as carefully as we could; however we were writing our own guidelines as we went. If we had covered all contingencies, then we simply never would have started at all. So with some cautious abandon, armchair caving became cockpit caving on Friday 28 April 2000.

PURPOSE AND METHOD

At the beginning our idea was quite simply to look for new caves. Fortunately there were none. Blowholes and other small things there certainly were, but nice big new caves we simply were not going to find. So we would have to record just what was available: anything at all!

The idea grew rapidly as we found what was workable, and what simply wasn't, dictated largely by the shape and confines of a small cockpit. Before long, we had settled on a few parameters:

- The aerial survey would be total, recording everything seen to be disturbing the surface.
- The area chosen would be coverable in a three-week period, allowing for wind and rain preventing flying on some days.
- About ten people on the ground seemed a good ratio for one aircraft.

- We would aim for minimum track-making.
- Equipment would be simple and undistracting in the cockpit: no radio or camera, but an EPIRB would be carried.
- This combination seems to yield the maximum number of finds, over a maximum area, at minimum cost, and with minimum aircraft time in the air.

It was during this period that Paul (Devine) arrived unannounced and totally unexpected in our camp, and arrived to stay. Paul, whom I had not previously met, had the temerity to take my precious GPS, feed it into his computer, and then HE showed ME where I'd been. It came as a shock to find a friendly gremlin in my GPS had been noting everything I did, and without telling me! Since then our little group has consisted of CEGSA, CLINC, SRGWA and VSA.

There are some factors that need to be kept in mind during the process of searching for features, and recording them:

- All entrances are fortuitous, having little or no relationship to the formation of a cave.
- All caves are phreatic, followed by internal collapse, but totally lacking vadose development.
- Entrances are either collapse events, or tubes formed upwards or downwards by the preferential action of moisture and salt wedging.
- The ratio of caves with entrances to caves without is unknown, and an absence of obvious entrances does not indicate an absence of caves.
- All large entrances are known.

With these factors in mind, we aim to record all rockholes, blowholes, dolines, notable areas of caprock, collapse entrances, notable ridge and donga lines, some tracks, and all villages. A "village" is a waterhole area with a multiplicity of animal tracks radiating like spokes from it.

OUTCOME

Our first year of this project, 1999, was the year of the solo three-day walk. Just ten features were found, mainly blowholes, some with small caves. By contrast, in 2000 (the project's second year, when the aircraft was first used), 480 features were yielded. Ground parties were unable to visit all features in the three weeks, particularly as many air features would lead to another one or two features being found by the ground party, either obscured from the air or simply not spotted or recognised. Of these 480 features, ongoing visiting and documentation is occurring, some as recently as last October.

It was also found that (due to an absence of any features such as hills, lakes or roads) it is easy on overcast days to fly in the opposite direction from that intended, with embarrassing results if the heading is maintained for very long. And on the last landing of the last day, the undercarriage collapsed on touchdown due to a welding flaw. To add to the challenge, this occurred many kilometres from the nearest track, and the aircraft was no longer able to take off.

Recovery was achieved by the generosity of the whole group, who pitched in to help with food, clothing, cartage, equipment, time and endurance. These combined simply with lots of concern and care after what could have been a serious accident, with potentially serious consequences including fire, in a very remote and difficult area to access. In fact we liked the site so much that we chose it as our base for the following year. I would also like to note the generosity of the staff of the metal analysis laboratory of the late Ansett Airlines, who provided both expertise and their facility, all at no cost.

Our efforts during our third year, 2001, appeared to be somewhat disappointing. Only some two hundred features were noted, and it became apparent that our work was moving into an area virtually devoid of features, certainly nothing like the results of the previous area. However, one new cave of considerable size was found, providing some boost to our hopes.

Nevertheless, our disappointments were accentuated when one member sustained broken ribs in a vertical shaft: our first serious injury over very many years. During one flight, the GPS failed completely at the outermost limit of search, requiring a return to base largely by estimation and guesswork of prevailing wind direction. The compass was unreachable at the time. And to cap it all, this was the year I ensured everyone had the coordinates to move to a new camp, then took off in strong wind and some rain only to find I did not have them myself.

The fourth year was 2002. Paul found the first Thylacoleo skull in a cave he spotted while *en route* to an aerial feature; and soon afterwards a small nondescript "doline" (for so it seemed from the air) yielded the now well known complete skeleton.

SUMMARY THOUGHTS

- At our current rate of progress, we shall complete an initial survey of the Nullarbor in just 120 years. However, we are happy to leave some for others, either now or next generation.
- We would like to make a small plea to resist the urge to drive right up to a Nullarbor cave feature; and where a vehicle is necessary for a safe belay only one vehicle. A look at the aerial photographs of Carlisle, Thampanna, Old Homestead and Spidersink entrances shows just how beautiful and unique each is when devoid of human intrusion marks. More importantly, it is hoped to take very seriously our own ASF code of ethics on minimal impact, realising we do not know how much we, and others, may yet learn from these unique places.
- It needs to be said that chance has not been a large factor; and that very much hard, consistent and detailed work has been done. In 2000 alone, when 480 features were found (which is the greatest density recorded), there was still less than one feature for every three square kilometres examined, and not one of the 480 would be of much interest to the average tourist caver. The ground visitation of these features is not complete yet, though there has been continued ongoing documentation from ground-gathered data, some even very recently, by a small and dedicated party of just two.
- What has been achieved to date is the work of around a dozen people, whose willingness to work together (notwithstanding differences in abilities, purposes and methods) has been crucial to both current achievements and to mutual enrichment within the group.
- Complete visiting by ground parties cannot be overstressed, for we have learned that the apparent value of any feature recorded from the air can be at great variance from the reality found on the ground. In a recent example, a feature recorded from the air in 2000, and quite "obviously a long-disused airstrip" in a very odd place, was left in the "don't bother with it" basket until recently, when a ground party found it was actually a very long, narrow, shallow dam. The aerial assessment of the "doline" which led to the complete Thylacoleo was given our very lowest category of importance, but fortunately the small ground party had time to check the "don't bother" one that time. Usually aerial assessment is completed in several seconds at around 100 k/h.
- Our searching has been widespread and general, not limited to caves only, or bones, or any particular detail. Tempting though it may be to focus on one area when surprised by discovery, we nevertheless want to continue with a very broad outlook, calling in those with suitable expertise when appropriate. We have been pleased with finding bones from a distant and lost past, but we wonder about, for example, uncontaminated and unique bacteria for the future.
- Finally, for those of us of British ancestry, it is worth reflecting upon our history of finding, collecting, keeping and owning. "Finders keepers." Effort and cost easily creates a desire to own. Our costs have been met from our own pockets, so certainly we do claim discoveries made as our own, and the information gained as our own. But the objects found remain just that: "the objects found". They belong to a rich past. They do not belong to our group, not to any body, organisation or government. They are held in trust, and our desire is simply to provide any objects found with the best possible custodians, so that this land's unique archives may be better appreciated tomorrow.

Contact details
St. Francis' Church, 326 Lonsdale Street, Melbourne VIC 3000.

Cave Fauna and Cave Ecosystems in Southern China

Arthur Clarke

ABSTRACT

China has an area of carbonate rocks covering approximately 3.5 million km^2 (almost equal in area to half the size of Australia). Dating from the Pre-Cambrian to Quaternary, the carbonate rock (limestone and dolomite) sequences in China extended to 3000 metres thick, giving potential for some deep cave systems. During recent cave exploration in Chonqing, cavers descended to -920m in Qikeng Dong and expect to break the one kilometre depth mark later in 2002 or early 2003. Although some carbonate rocks areas are still inaccessible, caves have been recorded from almost every province in China and at least a third of the known carbonate rock areas in China contain confirmed karst, situated within a range of climatic zones with abundant annual precipitation. Tectonic activity has resulted in the formation of numerous structurally separated blocks of limestone with locally or regionally defined independent karst drainage patterns, resulting in extensive but ecologically separated and isolated subterranean hydrological systems. Karst is a prominent landform in at least six provinces of southern China, where there are a range of varied structural or solutional forms present. The southern lowland plains of China are dominated by tower karst; cone karst and associated tiankeng collapses are found in the more mountainous areas further north; and "stone-forest" type pinnacles form in the dissected plateau karst of more elevated areas. The most intensely karstified region is situated in three adjoining provinces (of SW China): Guangxi, Guizhou and Yunnan, where the varied subterranean systems comprise large multi-level chambers and passages, active streamways and abandoned upper fossil levels providing hypogean environments and habitats for numerous cavernicolous species.

Combined with the high nutrient inputs in cave ecosystems of southern China, the presence of vast amounts of perennial throughflow water and percolation fed standing waters have promoted the evolution of a diverse hypogean aquatic fauna including a rich troglobitic ichthyofauna (comprising 31 cave-limited fish species), numerous crustacean species (particularly copepods and decapods), aquatic beetles and amphipods. The troglobitic terrestrial fauna of Chinese caves is mainly composed of diplopoda, collembola and coleoptera (dominated by 40 trechine carabid species), plus a few cave adapted spiders, crickets and isopods. Some of the troglobites found during recent caving expeditions in China, are from animal groups new to science, including species of a possible new family of decapod shrimps and two new genera of beetles: *Guizhaphaenops* (*Guiaphaenops*) *lingyunensis* and *Giraffaphaenops clarkei*. Apart from the troglobitic invertebrates and the true cavefish, the ecosystems of Chinese caves include an abundance of epigean species (often washed in by floodwaters), plus vertebrate trogloxenes such as bats and birds. There is increasing evidence to show that many cave ecosystems are now being impacted by regional developmental pressures such as dam construction and associated works including diversion tunnels and a number of both vertebrate and invertebrate species appear to be diminishing from cave sites, due to the foraging habits or culinary preferences of local Chinese villagers.

New Troglobitic Cave Fauna Species in Tasmania, including Apparent Species Varieties of the Southern Cave Harvestman: Hickmanoxyomma cavaticum

Arthur Clarke

ABSTRACT

There are now more than 4,000 caves in the known karst (and non-karst) areas of Tasmania. New caves are still being regularly discovered in known cave areas and several new areas. Most of the karst caves are found in limestone or dolomite. The non-karst caves in Tasmania mainly occur in dolerite, granite and sandstone. The majority of karst and non-karst caves in Tasmania are found in forested regions where the sheltering effect of tree canopies and understorey plants helps maintain a moist or humid envelope around underlying rock surfaces and the caves therein. Over the last two decades, the collections of invertebrate cavernicoles in Tasmania by cave biologists Eberhard and Clarke have lead to the discovery of many new aquatic and terrestrial invertebrate species. A number of these new cavernicoles are obligate species (confined to caves). Defined as troglobites, these obligates show varying degrees of "troglomorpy" and amongst these there are several microphthalmic or anophthalmic species. More than 85% of the new cave species have not been identified and it will be many years (or decades) before most new species are described. The general lack of taxonomic resolution amongst our Tasmanian cavernicoles means that our species list includes new "undescribed" species, "undetermined" or "indeterminate" species. Notable amongst the new troglobitic cave species there are crustaceans (with apparent speciation amongst anaspidacean syncarids), hydrobiid (aquatic) snails, carabid beetles, collembola and many arachnid species, including spiders, mites, pseudoscorpions and harvestmen.

Harvestmen are one of the most abundant groups of arachnid species types found in caves in Tasmania and a number of the cave-dwelling forms were described by the late Dr Glenn Hunt. In his 1990 description of the genus *Hickmanoxyomma*, Hunt included the results of some preliminary allozyme studies conducted on some of the cave dwelling species being described. One of seven new *Hickmanoxyomma* species described, the southern cave harvestman (*H. cavaticum*) is recorded from three distinctly separate, but neighbouring karst areas of southern Tasmania: Hastings, Ida Bay and North Lune. Based on the allozyme studies, Hunt suggests the Hastings and North Lune populations of *H. cavaticum* may be considered as genetically isolated populations. In private discussion with the writer, Hunt gave permission for the southern cave harvestman to be considered as three variety types (corresponding to the three separate karst areas): *H. cavaticum* (variety 1) from the Ida Bay karst, *H. cavaticum* (variety 2) from Hastings and *H. cavaticum* (variety 3) from North Lune.

Documentation and Ground Exploration of Nullarbor Karst

Paul Devine

In 1998 when I first became involved with Karst documentation on the Nullarbor, one of the first questions which came to mind was, how many features and caves will I find?

Initially I found that if you travel 100 km and given an average effective view for spotting features of 40 m either side, you can find an average of around 4 features. This was based on random travel on a motorbike across country and works out to be 1 feature in an area of 2 km^2. This equates to a lot of traveling if you are only finding the 1 feature for every 25 km traveled. On a bike that's 5 features per refill of fuel, or 4 to 5 hours riding, and if traveling cross-country by vehicle and you manage to only have one flat tyre every 200 km, (that would be pretty good in places) that's one flat per 8 features.

On a conservative estimate of 50,000 features on the Nullarbor, that starts adding up to pretty hard yakka. Now it stands to reason that if you are looking at these sorts of figures. Then the last thing you want to do, is have to travel back to half of these features, to get more information, when you are getting a pattern emerging and you happen to be missing data. So recording as much data as possible in a consistent format, at the time I first visited a feature, soon became my priority. Not just the location and "does it go".

The past history of the Plain along with the number of features which can be found all seemed to indicate the number of features documented is very small, but also indicated a high number of features which have been located in the past but never recorded.

Ground based exploration of the Nullarbor has been an ongoing process which dates back to the late 19th century has involved a large number of people. Documentation has also spanned this time frame, but it has been a lot more limited. Early exploration faced far more difficulties than faced with today. Any mishaps were far more costly, (Stevens G P 1938). Even today given modern technology and equipment we must remind ourselves of the realities of the physical environment we are searching, and maintain safety as a priority. Early exploration was limited and mainly concerned with opening up the plain for pastoral use, but there are a number of karst features found during this time which have been mentioned in records. The thing which stands out through the past history is the number of features which have been encountered and then lost in the memories of those who found them. This is mainly due to the problem of defining positions on the Nullarbor.

Post European settlement a group of people who have spent a large amount of time on the Nullarbor is the Rabbiters (most notably the Carlisle family). Rabbiters would have undoubtedly located a large number of features. The sheer number of meteorites they located indicates their powers of observation (Bevan 1992, De Laeter 1983). But unfortunately they never had either the means nor motivation to record features, yet they have in recent times along with pastoralists had the greatest knowledge of the Nullarbor Karst. Only a few of the features they found have ever been transcribed.

Limiting factors of previous documentation:

- Needs for documentation: Early documentation focused more on survival, ie. rockhole location or caves containing water, (such as that by Turner in the 1880's), and suitability of the Plain for Pastoral purposes, (Jones 1880, Gair 1933, 1888)
- Difficulties of remoteness, past and present traveling on the Nullarbor has always been a case of being totally self-sufficient even for pastoralists etc.
- Physical nature of the plain: by and large the surface is treeless, featureless, rock-strewn, and for most of the year hot and waterless. To anyone who has spent a great deal of time on the treeless plain or "Plain Proper", "Strewn with Rocks and Bluebush" are the words which paint the scene the most appropriately.
- Difficulties in giving features any form of accurate location. Without an accurate location there was and still is, very little chance of relocating the same feature.

Features which have been logged previously include those by Keith Quatermaine and Harry Wheeler who as a team achieved the highest visitation/documentation in pre GPS days by recording over 600 features. Some of these features have accurate locations, while others further off the beaten track do not. In a worst case scenario they could be over 10 km's out. Even for people who know the plain intimately recalling positions away from tracks is still a case of error of 1 + km. The fact that almost all features (>95%) recorded in pre GPS days lie close to established tracks should be no real surprise. And again even with the Quatermaine/Wheeler features 90% are close to tracks. The only real exceptions to this were the Jennings data. (Lowry 1967), and then post GPS with the Plane Caving finds in the 1990's.

Simply the lack of definable location due to the physical nature of the plain and the chance of redefining and relocating the same feature has been the greatest limiting factor in past documentation. The advent of the GPS and subsequent ability of computer processing has made the task of relocating and redefining features, a lot more accurate and quicker.

In early 2000 whilst in the middle of an extended Nullarbor trip I found myself with the time, having the luck of no immediate pressure to return to work; and the resources, namely a fairly up to date laptop (set up with the Nullarbor Database in lieu of the, at the time, missing-in-action Max Meth) and GPS for crosschecking features found. I then had the good fortune to be invited to be a part of Ken Boland's team. Being part of Ken Boland's team enabled me to help,laongside Peter Ackroyd and the rest of the crew, in the enormous and at times, daunting task of documentation and ground Exploration on Ken's trips. Both Peter Ackroyd and myself have been involved with the processing the large quantities of data which Ken has produced.

DATA COLLATION OBJECTIVES

- Maintain a consistent data format, which is easy and effective to use.
  It also has to be maintained to ASF and Nullarbor Database standards.
- Crosschecking with previously known features.
  This has been achieved by two methods - manual transcription/plotting of features on maps and computerised logging and plotting.

Both methods have drawbacks and both are labour intensive. Computerisation offers a quicker and more versatile tool, from communication with GPS's to cross linking to the Nullarbor Database. But it is by far the most vulnerable system and failure could be drastic. Hence a need for manual reference material. Manual transcription is the most labour intensive, as each point must be hand recorded and then plotted manually onto maps. In 2001 and 2002 Peter has spent copious amounts of time to ensure hard copies are maintained for reference and storage.

EXPLORATION AND DOCUMENTATION

Ground exploration and documentation is still extremely time consuming. Through efforts of all involved, this has led to a 33% (540+) increase in documented karst features on the Nullarbor. The basic aims are to visit, document and explore as many features as possible. This can involve traversing large distances. Hence field time on the trips is split between traveling, checking, and documenting Ken's features, and whatever else is found along the way. On most trips the team splits up into groups of 3 to 5 people who visit separate areas thus enabling a greater number of features to be explored and documented.

With Ken's flying patterns he locates a fairly even distribution of features. Whereas ground exploration is far more sporadic, turning up features localised in the areas of travel and visitation. Background research, route planning and increasing visibility, ie. scaling pole, along with increasing the amount of time spent looking, are probably the only methods of increasing finds on the ground.

Whilst searching on the ground extra features rarely turn up more than a hundred metres from the path of travel. The majority of new features turn up in local proximity to the features Ken has seen from the air. People in the ground team who are not needed in documenting, explore the area in the immediate vicinity, and then often find the next feature to document. Only on average of 3 or 4

of Ken's features are visited each day per ground team. Generally for each feature Ken has seen from the air a further 1 or 2 are located on the ground. Using a quick, effective and consistent data collection routine for features visited on the ground is necessary to be able to record all features encountered and complete your planned trip for the day.

A quick overview:

- Due to the possible errors associated with previous feature locations, a constant broad crosschecking with previously known features is required to establish each feature as being either known or new.
- All information gathered is documented to ASF Standards.
- This includes feature position data and location descriptions.
- All surface details, ie. doline and entrance measurements and descriptions.
- The horizontal and vertical extent below the surface, future prospects or leads, along with tagging and photography details.

WHAT YOU FIND

The average density of features appears to be greater than previously calculated at around 1 per 1.3 km^2. In general the karst features found still fit into the Thompson (1950), Jennings (1962) assertions as to shallow and deep caves, the only real difference to the past trends is the lack of deep caves and the relatively high proportion of solution shaft "BH" (Blowhole) karst features being noted. There are very few exceptions to this. The most under-recorded feature is by far the shallow dolines, ones <10m in diameter with no visible leads. These are almost as numerous as BH's.

Blowhole development is by and large shallow, (area dependent) ranging in depth from 3 to 5m, avg. 3.5m depth. Few BH's extend beneath this. Most penetrate the Nullarbor limestone capping only to diffuse into the underlying porous and intense small scale phreatic tubing (5-10 cm), or simply end in choked flood squeezes. In the few caves which do exist we find that they are mostly horizontal and consist of small networks of tight passage. In general they contain only small chambers which rarely exceed a few metres.

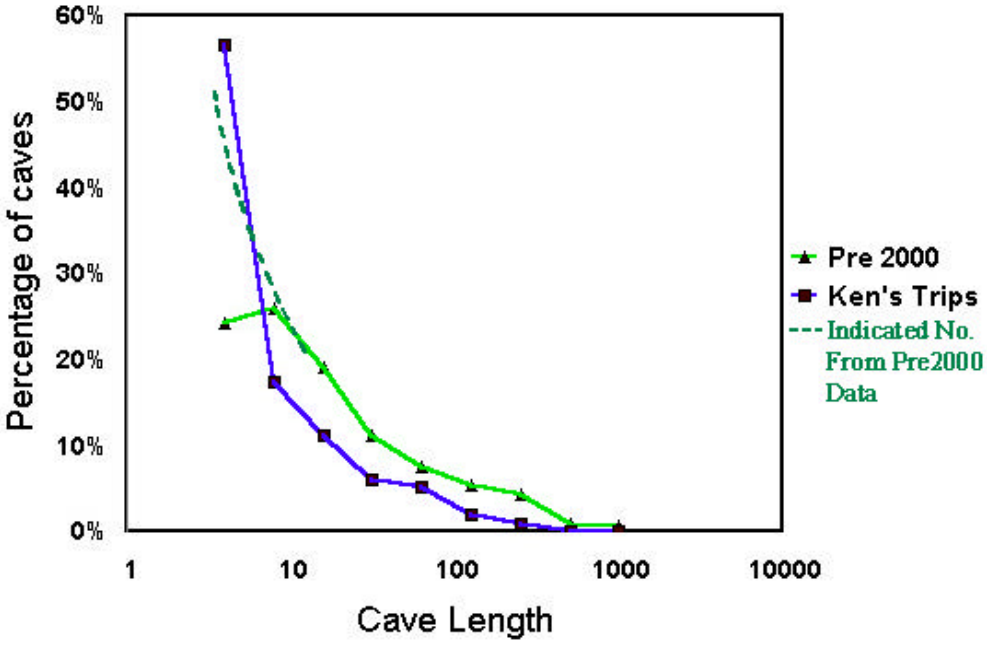
By and large most of these caves are features which have been exposed to the elements for long periods of time, such as the effects of dissipation of rainfall runoff. The most important things noted in these shallow caves are localised fauna populations consisting mainly of cave crickets *Pallidotettix nullarborensis* and *Tartarus* sp. spiders. These caves often contain recent fauna remains, which on a rare occasion date back to pre European times; examples of these are the lesser sticknest rats *Leporillus aspicalis*, and western quoll *Dasyurus geoffroii*. But apart from this, these caves as a rule contain very few noteworthy aspects.

As previous systematic searching has begun to suggest, enterable large caves shallow or deep, are not the norm, rather they are exceptions too. They are more sparse and make up a smaller proportion of Nullarbor Karst features than previously thought.

Some of the reasons for why you find what you do, could be equated to:

- Our recording techniques, emphasis by the whole group to record all karst features and all details.
- In the past recording has trended towards being focused on features which "do go" ie. ones with more substantial caves. Minor features were a lot more likely, to be left unrecorded.
- Previous records (pre GPS) have been dominated by features which have been easier to find and relocate eg. ones near populated areas, areas of easier traveling, or near tracks. There was also a bias, towards larger features, in other words ones which are easier to spot from the ground and air. This is opposed to BH's, small dolines and other Karst features which are harder to see and find, even though there are a lot more of them.
- Areas searched after the advent of GPS , had resulted in a more representative sample being gathered. There was still some bias toward features with bigger caves. This was still partially due to the trend of documenting only features which "go". It is also due to some of the areas searched by Plane Caving which turned up large numbers of shallow but long caves.

- Have all larger features and entrances been found???? Apart from exceptions, undoubtedly the vast majority of collapse dolines, are in records. As these features were more likely to have direct access to deeper caves they have caused a bias in previous data.



Graph showing the number of Caves vs their Length
The number of caves is expressed as a percentage of 1650 features for pre 2000, and 540 for Ken's trips. The regular trend shown in pre 2000 caves between 10m and 250m in length, indicates that there should be a much higher number of small caves/features which are not shown in earlier records.

The dedication for meticulous recording of all features by the teams on Ken's trips can be shown by a more representative sample of Nullarbor caves. These have a high proportion of minor features and features which don't go. The features recorded as a result of Ken's trips, 18.5% have caves; of these caves ones with lengths between 4m and 8m make up 56%, and caves which are >50m make up just 10% of the total. Pre 2000 29% of all feature records had caves, caves with lengths between 4m and 8m made up only 24% and caves which were >50m made up 26.5% of all caves. In the future the percentage of minor karst features will continue to climb, and hopefully a continuing representative sample will result. The future benefits of this are the ability to spot trends, patterns and predict which minor features are likely to "go" when pushed.

It is not always the big features which will access caves and turn out to be significant or important. Thanks must go to all those involved whose hard work and efforts produced the data and ultimately the finds of 2002.

FOOTNOTE

A cave in this instance is determined as a feature which has >=4m horizontal extent or a combined total of >=8m for depth and horizontal extent.

Teams for 2000 included:

- (VSA) Ken Boland, Peter Ackroyd, Daryl Carr, Margaret James, Rudy Frank, Jose Curras, (VCC) Greg Leeder, (CLINC) Rob Klok & Dawn Graves, (CEGSA) The Author.

Teams for 2001 included:

- (VSA) Ken Boland, Peter Ackroyd, Daryl Carr, Margaret James, Nick White, Hank Coppus, Rodger Taylor, Lyn & Brendon.
- (CEGSA) Aaron, June & George MacLucas, Ray & Chris Gibbons, Graham Pilkington, Max Meth, The Author, (CLINC) Rob Klok & Dawn Graves.

Teams for 2002 included

- (VSA) Ken Boland, Peter Ackroyd, Daryl Carr, Margaret James, Nick White, Tom Porritt, (NSS) Jake Turin, (CEGSA) Ray & Chris Gibbons, The Author & (SRGWA) Eve Taylor.

Apologies to anyone who is missing from this list.

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Anchialine Systems in Australia – Why are they so Interesting?

Dr Bill Humphreys

ABSTRACT

Anchialine habitats are groundwater estuaries, being inland mixohaline groundwaters affected by marine tides, usually with a reduced subaerial exposure. They occur mostly in arid coastal areas in tropical and subtropical latitudes around the globe. The water column characteristically has a stable hydrological stratification with a marked density cline, with the salinity increasing and oxygen decreasing with depth. The systems may show complex microbiological assemblages associated with a nitrogen species cascade and bands of hydrogen sulphide.

Anchialine ecosystems often support diverse crustacean assemblages and from which at least 12 new families and a new class of crustacean has been described recently. Anchialine ecosystems-especially in the oligoxic reaches of the water column-support macroinvertebrate communities the structure of which is highly predictable, mostly comprising biogeographic and/or phylogenetic relicts. Those assemblages occurring in continental or epicontinental waters are remiped-type, while those on remote oceanic islands (mid-ocean ridge islands and sea-mounts) are of the procarid-type. Australia has anchialine systems of both the remiped-type (in the northwest) and the procarid-type (Christmas Island, Indian Ocean) and a synopsis of these Australian anchialine systems is presented.

As found in the amphi-Atlantic sites, the Australian remiped-type anchialine system is composed of atyid shrimps, thermosbaenaceans, hadziid amphipods, cirolanid isopods, remipeds, thaumatocypridid ostracods, and an array of copepods, including epacteriscid and psedocyclopiid calanoids, halicyclopine cyclopoids, speleophriid misophrioids. So far ridgewayiid calanoids and superornatiremid harpacticoids have not been reported from the Australian anchialine system although they may be expected as they are characteristic in the Northern Hemisphere systems.

The procarid-type anchialine system of Christmas Island is the only one known from the Indian Ocean. All described procaridids are sympatric with one or more species of atyid shrimps. The occurrence of procaridid, alpheid, hippolytid and atyid shrimps in the same anchialine system on Christmas Island mirrors that found on Bermuda. As well as Christmas Island (Indian Ocean), the genus *Procaris* is known from Hawaii, Fiji (Pacific), Ascension Island, Bermuda and Cozumel Island, Quintana Roo, Mexico (Atlantic/Caribbean).

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Contact details
Western Australian Museum, Francis Street, Perth WA 6000.

An Eclectic Review of Subterranean Biology in Australian Waters

Dr Bill Humphreys

ABSTRACT

The last decade has seen a major shift in understanding of subterranean biodiversity in Australia. Two decades ago Australia was considered to be depauperate in subterranean fauna (cf Howarth 1988), a decade ago it was firmly established that the eastern seaboard, both tropical and temperate zones, had a rich subterranean fauna (Howarth 1988; Eberhard and Spate 1995; Eberhard et al 1995). It is now recognised that the arid zone and the "shield" regions of Australia also contain rich subterranean faunas, in both tradition (karst) and novel habitats.

Remarkable widely disjunct faunas inhabit salinity stratified near coastal aquifers (anchialine ecosystems) at Cape Range (Humphreys, 2000) and Christmas Island (Humphreys and Eberhard 2001), although the faunas themselves are quite distinct. The former-remiped community-has close affinities with anchialine habitats on either side of the North Atlantic while the latter-*Procaris* community-has affinities with the anchialine fauna of sea mounts (Bermuda, Ascension Island, Fiji, Hawaii).

Numerous subterranean communities comprising short-range endemic species are now known also from the "shield" regions (Pilbara, Yilgarn and Arunta Block) in arid Australia. However, these are found in areas not the traditional focus of biospeleological research in hyporheic (below river) groundwater and in groundwater calcretes in the palaeodrainage channels. The chains of salt lakes (playas) that form such a conspicuous component of the landscape of arid Australia are the surface expression of groundwater flows within the alluvial infill of ancient palaeochannels. Rainfall recharges the groundwater which flows towards the base level represented by the playa surface. The groundwater flowpath gradually comes closer to the ground surface and through which evaporation occurs. The resulting salinity gradient leads to CaCO3 precipitation (<3000mg L-1 TDS) near the groundwater surface and subsequently to gypsum deposition closer to the saltlake fringe. On a landscape scale this results in a series of isolated masses of limestone (calcrete) in the landscape immediately upflow of the playa (Humphreys 1999).

Groundwater calcretes are especially important in the Australian context as they form in arid climates (annual rainfall <200mm) with high potential evaporation (>3000mm per year), where rainfall is episodic and resulting in fluctuating groundwater levels. Thus groundwater calcretes are found throughout arid Australia and in Western Australian alone there are more than 200 major deposits (Humphreys 2001). These calcretes are widely referred to as karstic and the general models have them expanding, contracting and coalescing with changing climatic conditions.

Groundwater calcretes are the focus of considerable stygobite (obligate groundwater inhabitants) biodiversity and they have become a hot topic in the scientific and resource development area. Claims of a very speciose amphipod fauna in the Pilbara iron ore region (Bradbury 2000) are being disputed on the basis of allozyme data (Finston et al in press) in the same areas that new genera of ostracods are being described, each of which is known from only a single calcrete area. The calcrete fauna undoubtedly is best known in the Yilgarn where almost every discrete calcrete area examined have proven-based on both morphological and molecular evidence-to have a unique fauna (Cooper et al 2002). For example, these calcretes were invaded by numerous lineages of diving beetles at about the same time-molecular evidence indicates that this occurred in the middle Miocene-and within which subsequent speciation appears to have occurred (Leys et al 2002). There is a real need to obtain independent estimates of the age of groundwater calcretes but this seems to be an intractable problem.

Together, these faunas provide evidence for the past connections of Australia with Pangaea, Gondwana and Tethys and for the onset of aridity (Humphreys in press), and they make a major contribution to the biodiversity of Australia. They include a number of higher order taxa variously new to science (undescribed family of flabelliferan Isopoda), new to the southern hemisphere (Thermosbaenacea; Remipedia; Epacteriscidae; *Danielopolina* Thaumatocyprididae: Ostracoda), or new to Australia (Spelaeogriphacea; *Stygocyclopia*: Pseudocyclopiidae). In addition numerous new

genera and species of Amphipoda, Ostracoda, Copepoda and Coleoptera are being described by numerous researchers-particularly John Bradbury, Ivana Karanovic, Tom Karanovic, Chris Watts respectively-in an active process of investigation of these new and exciting stygal worlds.

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Contact details

Western Australian Museum, Francis Street, Perth WA 6000.

Karst Hydrogeology and Speleogenesis in the Leeuwin-Naturaliste Ridge

Stefan Eberhard

ABSTRACT

Southwestern Australia holds extensive karst developed in coastal Quaternary dune limestones. Thermoluminescence dating and altitudinal correlation with palaeo shorelines suggest an early Pleistocene or Late Pliocene age for the oldest dune units. Syngenetic karst development has proceeded with lithification of the dune ridges. In the Leeuwin-Naturaliste Ridge, the dune limestones are underlain by an impermeable granite basement which has strongly influenced the karst hydrology and speleogenesis. A diversity of karst drainage systems and associated cave patterns are represented, including: (1) Exsurgences or stream caves dominated by diffuse autogenic recharge; (2) Directed conduit caves fed by allogenic winter-flowing streams sinking at the inland margin of the dune ridge and which drain rapidly beneath the ridge to resurge on the coast; (3) Watertable maze caves developed by mixing corrosion processes and involving allogenic swamp waters in a flank margin setting. The geomorphic history of these swamp margin caves involved multiple cycles of fluctuating watertable levels linked with climate change and extreme flood events over the last > 600, 000 years, whilst marine waters may also have influenced speleogenesis during sea level highstands.

Environmental Hydrology and Stygofauna in the Jewel Cave Karst System

Stefan Eberhard

ABSTRACT

The Jewel Cave karst system comprises extensive watertable maze caves developed within a shallow aquifer in coastal Quaternary dune limestone, southwestern Australia. The groundwater ecosystem includes communities of freshwater invertebrates associated with submerged tree roots. These aquatic root mat communities are listed as critically endangered due to declining groundwater levels, which have dropped > 1 m during the previous 22 years. Southwestern Australia is a region notable for a prolonged and significant decrease (21 %) in winter rainfall over the period since 1968, although rainfall in the study area decreased only 1 % over the same period. Groundwater pumping and tree plantations have not contributed to the watertable decline as earlier implied. Mean groundwater recharge rates decreased 29 % after 1979-80, corresponding with a significant change in fire regime within the karst catchment. Fire frequency decreased from an average 4.3 fires per decade to less than 0.5 fires per decade. The virtual absence of fire during the previous 25 years has allowed a dense growth of understorey vegetation and accumulation of ground litter, which through interception and evapotranspiration of rainfall, is hypothesised to be a major contributing factor to the watertable decline. A prescribed burn will be undertaken and the effects of fire treatment on groundwater recharge will be investigated with Before-After-Control-Impact (BACI) monitoring of rainfall, leaf area index, ground fuel load, soil moisture, infiltration rates and watertable response. The ecological requirements and conservation status of the groundwater communities are reviewed, and management strategies suggested.

Carbon Dioxide and Climate in Jewel Cave

[1]**Stefan Eberhard,** [2]**Neville Michie,** [1]**Robyn McBeath,** [1]**Peter Bell**
[1] CaveWorks, Western Australia
[2] Michie Research & Design P/L, Sydney

ABSTRACT

Elevated concentrations of carbon dioxide (CO_2) in Jewel Cave present a challenge for the maintenance of safe working conditions for cave guides. To characterise and manage the problem, 12 months intensive monitoring and targeted investigations of carbon dioxide and cave climate were undertaken.

Carbon dioxide was present year round in concentrations ranging between 0.5 – 2.8 %, including short-term fluctuations (day - week intervals) of +/- 1 %. There is a distinct seasonal cycle in CO_2 which is influenced by the annual temperature cycle on the surface. Carbon dioxide levels build up through spring-summer when the surface temperature has been consistently higher than the cave temperature, then decline through winter-spring when surface temperature has been consistently lower than the cave temperature. To remain within national safe work exposure limits, the duration underground for cave guides is limited to 1.6 hours per day during the peak summer season.

The atmosphere in the main chamber of Jewel Cave is extremely stable, due to thermal stratification in the air column and the CO_2 gradient, which inhibits mixing between upper and lower air masses. During winter when the external temperature is consistently 1.5 to 2 degrees cooler than the cave temperature, then deep ventilation displaces CO_2 laden air in the bottom of the cave. This winter flushing effect may also occur to some extent on cool nights during summer, especially when assisted by a barometric pressure gradient.

The cave climate model for Jewel Cave system invokes gravity-driven air flows, barometric pumping, stability in the entrance chamber, and winter flushing effect on CO_2. The natural ventilation rate of Jewel Cave is likely to have been reduced by the modification and blocking of some entrances. The climate model predicts that increasing passive ventilation in the entrance chamber may help to lower CO_2 levels by a 'trickle -down effect' to deeper parts of the cave. An experiment is being undertaken in an attempt to improve passive ventilation and lower CO_2 levels within the tourist sections of Jewel Cave, by removing the air-lock door and restoring some entrances to their previous natural condition.

Recent Advances in Radiogenic Isotope Mass Spectrometry: Implications for Reduced Environmental Impact of Speleothem Paleoenvironmental Studies

Dr John Hellstrom

ABSTRACT

Records reconstructed from measured geochemical parameters within speleothems are playing an increasingly important role in the reconstruction and understanding of past climates and environments. The first significant records of this type were published over thirty years ago, since when improvements in analytical technology have on one hand reduced sample size demands and on the other hand increased the number of analyses undertaken. Because all geochemical analyses are essentially destructive techniques, conflict can arise regarding the relative importance of speleothems' intrinsic values within caves versus their scientific value once removed.

Most published speleothem paleoenvironmental records to date have been based on the analysis of whole stalagmites, partly because of their generally high suitability for stable isotope analysis and partly because they are the most straightforward means of recovering a continuous interval of speleothem deposition from a cave. A few researchers have instead targeted core samples of flowstones, hoping to obtain longer more continuous records, but also because the visual impact of such sampling on the cave environment is hopefully lower. Unfortunately the sample size demands required for uranium-thorium dating have been such that recovery of core samples large enough to be useful has been very difficult.

Many of the parameters of interest such as stable isotope ratios (particularly oxygen and carbon) and trace element contents (eg. magnesium, strontium, uranium) can now be measured on samples as small as a few hundred micrograms or indeed even by laser ablation or other micro-beam techniques. This has reflected a slow but steady improvement in the capabilities of available analytical technologies, but leaves the actual dating of speleothems as the last common analysis type requiring significant amounts of sample. For a speleothem paleoenvironmental record to have any significance it must be placed against time, which almost always requires the use of a radiometric dating technique such as uranium-thorium.

Uranium-thorium disequilibrium dating was first undertaken using alpha-spectrometry, a technique which in most cases required hundreds of grams of speleothem for a single date. Since the late 1980's alpha-spectrometry has given way to thermal ionization mass spectrometry, which produces more precise ages from typically two to five grams of sample. It is this advance which has made flowstone coring viable as a sampling technique, but only where long, large diameter cores can be taken. Here I will review and report progress in adapting the relatively new technique of multi-collector inductively-coupled plasma mass spectrometry (MC-ICP-MS) to the uranium-thorium dating of very small speleothem samples.

MC-ICP-MS U-Th dates at the University of Melbourne are giving good precision on samples containing less than ten nanograms of uranium, which in practice means that only a few hundredths of a gram of speleothem are required to date most samples. This advance means that time-resolved paleoenvironmental records can be reconstructed from flowstone core samples of as little as 10mm in diameter even where the speleothem growth rate is of only a few millimetres per thousand years. A case study from a 22mm flowstone core sample from New Zealand spanning the last 150,000 years will be presented and contrasted with an earlier study from the same location requiring one metre of 50mm core sample. Details of a new portable electric drilling system for recovering 10mm and 22mm core samples will also be presented with discussion of drill site impact and rehabilitation techniques.

New Discoveries of Articulated Well-Preserved Megafauna from Nullarbor Caves

Dr John Long

- Gavin Prideaux (Flinders University, Adelaide)
- Ken Boland (Victorian Speleological Association)
- Ray Gibbons (Cave Exploration Group South Australia)
- Peter Ackroyd (Victorian Speleological Association)
- Paul Devine (Cave Exploration Group South Australia)

ABSTRACT

In May 2002, cavers from CEGSA and VSA using ultralight aircraft discovered a number of new karst features on the western Nullarbor. Some of these caves contained articulated skeletons of extinct mammals. The cavers notified museum specialists in Victoria and South Australia, who then in turn notified paleontologists at the WA. Museum as the caves occur on WA crown land. A recovery expedition took place in July 2002, resulting in the finding of several complete skeletons of the marsupial lion, *Thylacoleo*; skeletons of three species of sthenurine kangaroo, the giant wombat *Phascolonus gigas*, the giant kangaroo *Procoptodon goliah*, extinct species of *Wallabia* and remains of an unidentified macropodine kangaroo.

The Nullarbor discoveries are extremely important in providing the first complete, articulated skeletons of megafauna from the Pleistocene epoch from anywhere in Australia. Samples are currently being tested for ancient DNA, and for dating the age of the fossils using OSL (optical stimulation luminescence) and ESR (electron spin resonance) techniques. It is likely that the unique preservation of the fossil material was the result of a long period of constant dry conditions in the caves, which we believe may have been sealed off in some cases shortly after the animals accidentally fell in.

The series of events that took place from time of first discovery to recovery of the specimens is a crucial time to preserve valuable scientific information. Correct procedures were followed here enabling uncontaminated skeletal specimens to be sampled for ancient DNA. On first discovering a skeleton in a cave, cavers should stay clear and take photographs which can then be sent to appropriate museum authorities. If, as in this case, the material proves to be of great scientific value, then an expedition can always be arranged to retrieve the fossils. In any event it is better to leave bones in caves and send photographs than to touch or remove specimens from their in-situ positions.

Research on the prehistoric animals discovered from the Nullarbor caves is sponsored by the Rio Tinto Futures Fund.

Contact details
Head, Department Of Earth And Planetary Sciences 2003 & Currator of Vetebrate Palaeontology
Western Australian Museum, James Street, Perth WA 6000

Arthropod Ecology of Bat Cave, Naracoorte, SA

Timothy Moulds

INTRODUCTION

Bat Cave, situated in the Naracoorte Caves World Heritage Area, South Australia (Figure 1), is one of only two maternal sites for the large bent-wing bat, *Miniopterus schreibersii bassanii*, in Australia's southeast. The invertebrates inhabiting the extensive guano deposits in the maternal chamber are believed to have suffered a catastrophic decline over the last several years (Hamilton-Smith 2000). The current study follows an honours project (Bellati 2001) that investigated the diversity, distribution and abundance of the guanophilic arthropod assemblage in Bat Cave. Bellati (2001) identified the abundance and diversity of arthropods in three zones of varying light intensity; the entrance zone, flyway and maternal chamber of Bat Cave and compared these with the diversity of arthropods in the entrance and dark zone of Cathedral Cave, Naracoorte, which contain very little guano deposition. The arthropods in the maternal chamber consist of guanivores, fungivores, predators, parasites and parasitoids. The Bat Cave contains several endemic species including, *Tomogenius ?ripicola* (Coleoptera: Histeridae), *Ptinus exulans* (Coleoptera: Anobiidae), *Derolathrus* sp. (Coleoptera: Jacobsoniidae) and *Monopsis crocicapitella* (Lepidoptera: Tineidae) (Bellati 2001).

Bat Cave is primarily occupied from October to March by the large bent-wing bat where the maternal chamber is used for giving birth and rearing young. The maternal chamber houses approximately 36,000-50,000 bats during this time (Reardon, 2002, pers. com.) and there is a corresponding increase in guano deposition during these months. Over the winter months all bats vacate the maternal chamber, hence there is no guano deposition during that time. Temperatures in the maternal chamber remain nearly constant, ranging between 19°-21°C (Sanderson and Bourne 2002). The maternal chamber also shows a vertical temperature gradient with temperatures of 30°C recorded from bat roosts in the chamber roof (Baudinette et al 1994).

This study seeks to expand upon the arthropod diversity study of Bellati (2001) by conducting a longer-term investigation in the hope of elucidating and explaining temporal and spatial patterns of arthropod diversity and abundance in the maternal chamber. A range of environmental factors including pH, moisture content and guano deposition rates are being examined to evaluate their micro- and meso-scale affects on arthropod populations. The affect of varying guano deposition rates, both spatially and temporally, should aid in determining how and why the arthropod populations change.

METHODOLOGY

The study commenced in July 2002, and is planned to include two years fieldwork in Bat Cave incorporating two consecutive seasons, 2002/2003 and 2003/2004. The cave will be accessed bimonthly from October 2002 until August 2004. The first sampling period was conducted from 10th - 12th October 2002. Target species selected from data compiled by Bellati (2001) show both high abundance and potential important roles in the food web of the maternal chamber. They include predators; *Tomogenius ?ripicola* (Coleoptera: Histeridae), *Speotarus lucifugus* (Coleoptera: Carabidae) and *Protochelifer naracoortensis* (Arachnida: Pseudoscorpionida) and also fungivores/guanivores such as *Monopsis crocicapitella* adults and larvae (Lepidoptera: Tineidae), Acarina spp. (Arachnida), *Ptinus exulans* (Coleoptera: Anobiidae) and *Derolathrus* sp. (Coleoptera: Jacobsoniidae).

Pitfall traps are being used in this study because it was found by Bellati (2001) that target species were most easily captured using this method. Sticky traps were found to collect considerably fewer individuals, and lower species diversity (*Monopsis crocicapitella* adults and Phoridae sp. composed 92% of total abundance), compared to pitfall traps in the maternal chamber (Bellati 2001). Sampling consists of 36 pitfall traps, 55 mm in diameter and 70 mm deep positioned in a systematic pattern throughout the maternal chamber (Figure 2). The pitfall traps are placed in pairs at the top and bottom of 18 separate guano piles. The piles were selected for both their position within the chamber as well as showing signs of guano deposition within the past two years. During sampling periods pitfall traps are held within sections of plastic pipe permanently positioned in the

guano to a depth of approximately 10 cm and which remain *in situ* for the duration of the study. This consistency will ensure pitfall traps remain in the same location throughout the study to enable the temporal analysis of data. Between sampling periods the pipes are capped. Displaced guano from pitfall sites has been placed in the immediate vicinity of pitfall traps to keep arthropod populations in their respective microhabitats. The pitfall traps, containing salt water and a small amount of detergent, are open for approximately 48 hours each sampling period and are set and retrieved at night, coinciding with minimum bat numbers in the cave to ensure disturbance of the maternal chamber is kept to an absolute minimum.

Relative rates of guano deposition have been calculated from samples collected from all pitfall trap locations throughout the maternal chamber. During sampling periods, fresh guano has been collected in large high sided containers (approximately 0.8 m^2) covering pitfall sites. These samples have subsequently been measured for weight and moisture content. The fresh guano samples allow an accurate measurement of the differing guano deposition throughout the maternal chamber. Guano will not be collected between sampling periods to allow the buildup of fresh guano that provides habitat for taxa such as Jacobsoniidae and other fungus-feeding guanophilic arthropods. The moisture content and pH of guano surrounding the pitfall trap sites has also be measured by random sampling within 20 cm of the sites. The measurement of moisture content of both falling (freshly deposited) and *in situ* guano will enable a correlation analysis between taxa and guano moisture content.

All samples are sorted to species, and their abundance recorded. Samples containing greater than 1000 individuals will be estimated to avoid excessive sorting time. Such samples are placed on a 10x5 cm grid with 5 mm squares, with 10 randomly selected squares, counted and averaged to provide an estimation of total numbers.

PRELIMINARY RESULTS AND DISCUSSION

The most abundant species collected (Table 1) were Oribatidae sp. (Acarina, 16,952 individuals), *Protochelifer naracoortensis* (Acarina: Pseudoscorpionida, 291), *Tomogenius ?ripicola* (Coleoptera: Histeridae, 263), *Ptinus exulans* (Coleoptera: Anobiidae, 112), Phoridae sp. (Diptera, 61), *Monopsis crocicapitella* adults (Lepidoptera: Tineidae, 28), *Speotarus lucifugus* (Coleoptera: Carabidae, 26), *Apanteles ?carpatus* (Hymenoptera: Braconidae, 21) and Nycteribiidae sp. (Diptera, 8).

Total species abundance was greatest in the central area of the maternal chamber (Figure 2) with over 95% of total individuals, followed by the rear and front areas with approximately 2% of total individuals each. Individual taxa including Oribatidae sp., *Apanteles ?carpatus* and Nycteribiidae sp. show this overall abundance pattern with greatest numbers found in the central area. *Protochelifer naracoortensis*, *Ptinus exulans* and *Speotarus lucifugus* show decreasing abundance with increasing distance from the cave entrance. The abundance of Phoridae sp. was greatest in the rear area of the maternal chamber, although due to an extreme concentration of individuals (56) on a single guano pile this pattern may not be indicative of actual distribution within the chamber. The abundance of *Monopsis crocicapitella* adults is greatest in the middle and rear areas of the maternal chamber.

Preliminary data show a generally clear distinction in arthropod diversities and abundances between the top and bottom of guano piles. Several taxa show clear preferences for these micro-habitats, with the most obvious trend concerning *Tomogenius ?ripicola*, which was collected at up to nearly 25 times greater numbers at the tops of piles than at the bottom of the same pile. Only two guano piles (8 and 10, Figure 2) showed greater numbers at the bottom and in each of these cases the total number of individuals was five or fewer. The adults of *Monopsis crocicapitella* appear to exhibit this trend to a lesser extent, but further collecting will be required before any clear trend can be established. The abundance of *Protochelifer naracoortensis* also follows this trend, and individuals were collected more often from tops of piles than the bottoms. The opposite trend is believed to be exhibited by *Ptinus exulans* which was collected predominately from the bottom of guano piles. The low numbers of individuals collected in some taxa, such as *Apanteles ?carpatus* preclude any speculation concerning preference for the top or bottom of piles. The low numbers of individuals of *Speotarus lucifugus* collected from any one pile, combined with the weak association for either the top or bottom of guano piles suggests a widely distributed, generalist predator within the maternal chamber.

Environmental factors measured at each sample location are the amount and moisture content of falling guano and the pH and moisture content of *in situ* guano within 20 cm of each pitfall trap. Harris (1973) stated that guano becomes more basic with increasing age. Preliminary results from this study indicate that tops of guano piles in the front area of the maternal chamber are generally slightly less acidic or the same as the bottoms of the piles. Guano piles in the rear area of the chamber showed similar trends but tops of piles ranged from extremely basic to slightly acidic. The central area of the maternal chamber showed the greatest variation with tops of piles ranging from highly basic to mildly acidic with bottoms of piles showing respective inverse pH levels.

The central area of the chamber showed the highest deposition rate of fresh guano and urine in the first sample period (Figure 3). The greatest deposition was recorded on the top of Pile 11 with approximately 88 g/m^2, containing 83% H_2O by weight. The average guano deposited in this area was 57.46 g on pile tops and 11.16 g on pile bottoms. These values contrast sharply with guano deposition rates in the front and rear areas of the chamber where average deposition rates were considerably lower, recording 0.07 g/m^2 at tops of piles. The water content of guano piles in the front and rear areas was also lower than that recorded from the central area with values as low as 23% H_2O by weight on pile tops.

FUTURE RESEARCH

Bat Cave and especially the maternal chamber provides numerous opportunities for further research projects in many diverse areas. Following this preliminary research in Bat Cave, I plan to use the microhabitat and temporal data collected from throughout the maternal chamber to explain the population dynamics and community ecology. A food web for the predominant species present in the maternal chamber is also being constructed as data are collected from ongoing trips into the cave and from observations using the infrared cameras throughout the cave. This will incorporate the diet, feeding habits and life cycles of target species. This information is known only in a broad sense and this project seeks to further elucidate aspects of their diet and habits in the maternal chamber ecosystem. The genetic relationship between the species inhabiting Bat Cave will also be compared with similar caves in the south east of South Australia and western Victoria. Other research projects in the maternal chamber should encompass several different aspects including fungal and microbial diversity and conservation and management practices.

ACKNOWLEDGEMENTS

I would like to thank Department of Environment and Heritage, South Australia and The University of Adelaide for funding this project. Andy Austin and John Jennings for comments and proof reading the manuscript and all the staff and students from the Insect Evolution and Ecology Lab, University of Adelaide for extensive discussions and insightful comments. Steve Bourne, Alice Shields and Judy Bellati provided field assistance. I would also like to thank the extremely friendly, interested and helpful staff from the Naracoorte Caves, World Heritage Area, South Australia.

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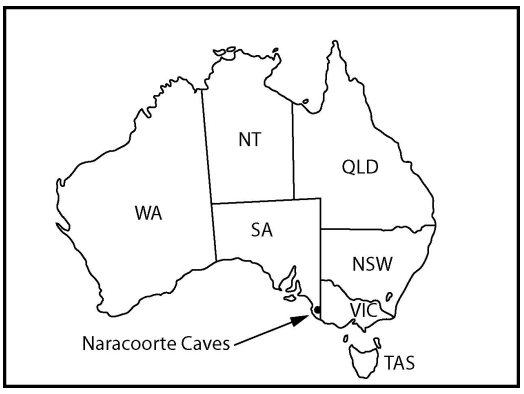


Figure 1 - Naracoorte Caves, World Heritage Area, South Australia

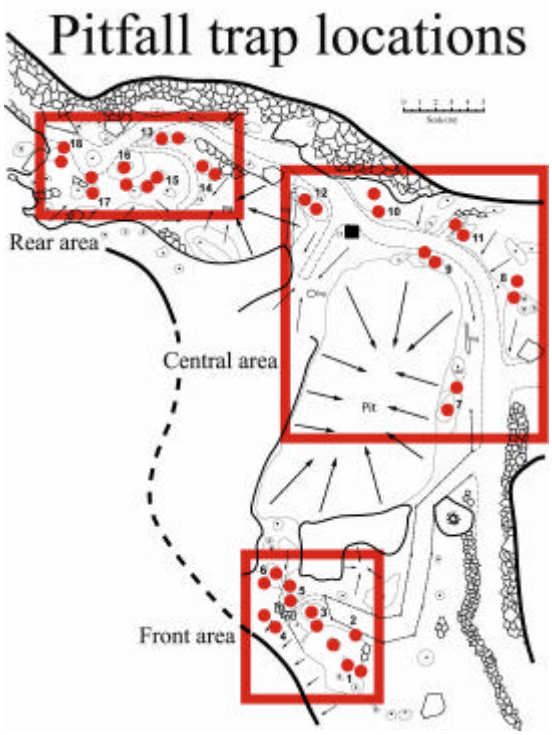


Figure 2 - Pitfall trap locations, maternal chamber, Bat Cave, Naracoorte Caves

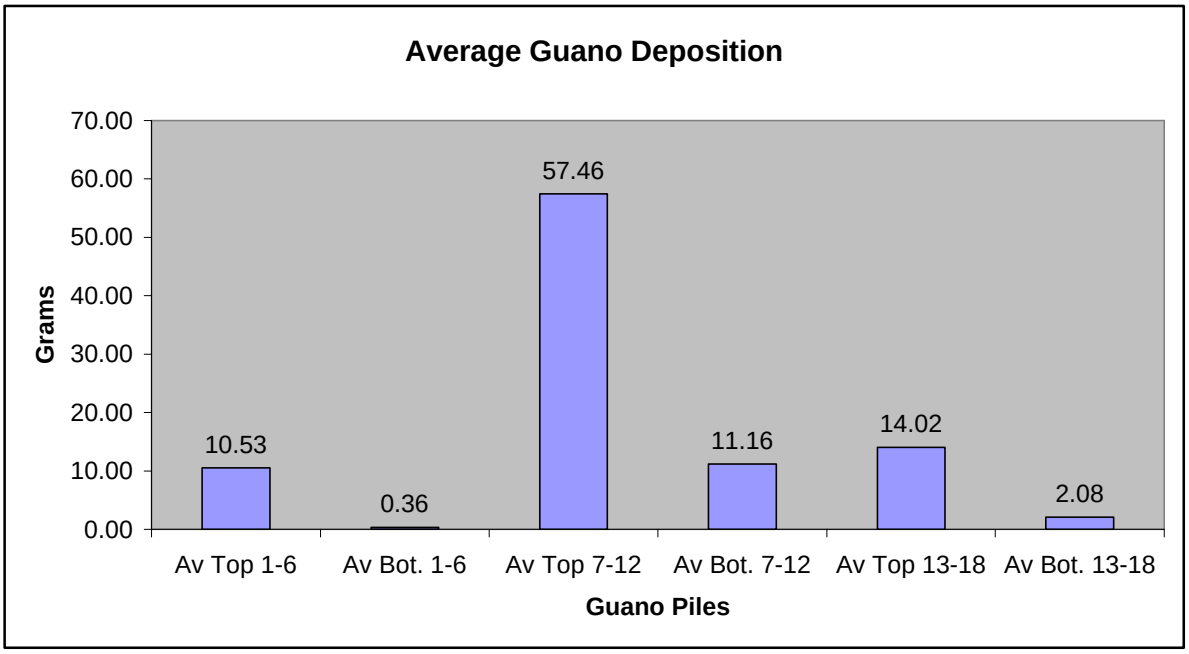


Figure 3 - Fresh guano deposition, maternal chamber 10-12 October 2002

Guano Pile	Sample	Histeridae	Anobiidae	Carabidae	Braconidae: *Aparteles ?carpatus*	*Monopsis*	Pseudoscorpionida	Oribatidae	Phoridae	Nycteribiidae	pH	Fresh Guano Wet Weight	Moisture Content %
1	Bottom	0	0	0	0	0	6	0	0	0	5.5	0.05	17.60
1	Top	1	0	1	0	0	9	2	0	0	9.0	5.90	76.95
2	Bottom	0	5	1	0	0	8	0	0	0	6.0	0.04	14.00
2	Top	7	0	2	0	1	18	0	0	0	6.5	2.19	72.60
3	Bottom	0	3	3	0	0	11	0	0	0	6.0	0.15	33.33
3	Top	18	16	3	1	0	50	5	0	1	7.5	0.10	23.60
4	Bottom	1	30	1	0	0	13	0	0	0	5.5	0.31	45.16
4	Top	6	1	0	1	1	23	98	0	0	5.5	29.73	80.83
5	Bottom	0	1	0	0	1	2	0	0	0	6.5	0.94	67.02
5	Top	0	0	0	0	1	8	0	0	0	8.5	18.43	83.72
6	Bottom	0	11	2	0	0	4	0	1	0	5.0	0.65	55.38
6	Top	3	0	1	0	2	18	3	0	0	5.5	6.84	76.75
7	Bottom	3	0	0	2	0	0	0	0	0	6.5	19.70	76.04
7	Top	22	9	1	8	0	25	0	0	3	7.0	10.17	78.17
8	Bottom	4	2	3	0	0	13	0	0	0	5.5	18.66	84.57
8	Top	0	0	0	2	0	10	6	0	0	5.0	0.44	54.55
9	Bottom	27	16	2	2	0	7	2218	0	0	6.0	11.99	67.47
9	Top	39	0	0	1	1	1	3020	0	0	7.0	119.03	83.73
10	Bottom	4	7	1	1	1	2	0	0	0	4.5	0.98	47.96
10	Top	1	0	0	1	1	9	693	0	0	6.5	26.89	82.67
11	Bottom	2	3	0	0	0	2	8	0	0	5.5	1.58	46.84
11	Top	49	3	0	0	7	0	10640	2	3	7.5	141.85	83.67
12	Bottom	1	0	0	0	0	7	0	0	0	5.5	14.04	68.23
12	Top	9	0	0	0	1	7	27	0	1	5.5	46.37	85.18
13	Bottom	1	0	2	0	1	1	0	0	0	5.5	3.58	70.11
13	Top	9	0	0	0	0	6	228	0	0	5.5	17.92	45.48
14	Bottom	3	1	1	1	2	0	0	1	0	6.5	4.65	51.61
14	Top	25	2	1	0	0	11	0	1	0	5.0	32.84	82.58
15	Bottom	2	1	0	1	1	0	0	0	0	6.0	0.15	6.67
15	Top	5	0	0	0	1	3	0	0	0	5.5	1.56	44.23
16	Bottom	2	0	0	0	1	3	0	0	0	6.0	1.82	56.04
16	Top	18	0	0	0	2	2	0	56	0	5.0	17.87	71.63
17	Bottom	0	0	0	0	0	1	1	0	0	6.5	0.53	54.72
17	Top	1	0	0	0	0	1	0	0	0	10.5	0.11	27.27
18	Bottom	0	1	1	0	3	8	0	0	0	8.5	1.75	67.43
18	Top	0	0	0	0	0	2	3	0	0	5.0	13.84	60.48

Table 1 - Diversity and abundance of dominant species collected in the maternal chamber

Contact details
University of Adelaide, Department of Environmental Biology
North Terrace, Adelaide SA 5005

Troglobitic Spiders of the Nullarbor Plain

Norman Poulter OAM

INTRODUCTION

The first discovery of troglobitic spiders on the Nullarbor Plain occurred during 1966 when Jackie and David Lowry discovered the remains of a large mygalomorph spider, *Troglodiplura lowryi*, in Roaches Rest Cave (6N-58) and later in the same year an araneomorph troglobite, *Janusia muiri*, in Weebubbie Cave (6N-2).

The famed *Tartarus mullamullangensis*, was discovered in 1969, but it was to be 18 years before another species was discovered.

More recently another web building species at present attributed to the genus Icona was discovered in Nurina Cave (6N-46). It belongs to the “comb-footed spiders” (*Theridiidae*) and has troglophilic relatives in caves across southern Australia (Gray 1974 - then listed as "near Steatoda sp.")

During the intervening 36 years, the known range of most of the spiders has been vastly increased while knowledge of their life cycles and environmental needs has remained static. Living populations of the *T. lowryi* have been found in South Australia as well as Western Australia.

Spiders seem to be the dominant predators in the Nullarbor cave's food chain. This paper documents the ranges of the four known troglobitic spider species, where they seemingly overlap while speculating where new populations could be found.

TROGLODIPLURA LOWRYI MAIN 1969 (DIPLURIDAE)
NULLARBOR CAVE TRAPDOOR SPIDER

In August 1966 David Lowry, then working for the WA Geological Survey, in company with his wife Jackie, discovered body parts of an undescribed troglobitic spider in Roaches Rest Cave (6N-58) which lies some 43km NE of Madura Roadhouse. The body parts were described by Dr Barbara York-Main of the University of WA's Dept. of Zoology and named *Troglodiplura lowryi* (Main 1969). Several body parts of the same spider species were collected from Old Homestead Cave (6N-83) by Graham Pilkington in 1986 and the Col area of Mullamullang Cave (6N-37) by Norman Poulter in 1992 (Poulter 1993).

In 1982 however, Adrian Davey observed and photographed the first live examples of *T. lowryi* in the cave 5N-253, NE of Nullarbor Roadhouse and permission was granted (the area being under the control of SANPWS) during 1991 to Dr Mike Gray of the Australian Museum for some specimens to be collected for study. The cave 5N-253 is some 350km east of the initial Roaches Rest (6N-58) discovery site. An outcome of the 1991 trip was the preparation of a National Estate listing proposal for Cave 5N-253 because of its association with the only living population of *T. lowryi*. This resulted in its listing upon the Register of the National Estate in 1994. *T. lowryi* is listed as a threatened species under the *Nature Conservation Act 1980*, "Fauna which is rare or likely to become extinct".

Live examples of *Troglodiplura* spiders were not seen in Western Australia until Michael Bradley (SRGWA) observed one walking across a damp intermittent streamway in the research cave 6N-327 on Mundrabilla Station during 1998 although they are now also suspected to be residing in nearby 6N-1384.

Following entry to the (now) research cave 6N-1327 on the Roe Plain section of Madura Plains Station in mid-1997, numerous body parts of *Troglodiplura* specimens were also found leading to speculation that it too, harboured live examples. This was confirmed when Stefan Eberhard visited the cave at the beginning of 2001 (Eberhard 2001). The cave 6N-1327 is the only cave that reaches the water table where *Troglodiplura* has been found - all other caves depend on surface seepage and runoff for moisture.

The few live specimens of *Troglodiplura* seen were simply observed wandering across the cave floors and no associated web or burrow has ever been found. While this suggests that these spiders are vagrant predators, far too little is known about their biology to make any definitive comments. The taxonomic status of the various and widespread populations of *Troglodiplura* remain uncertain although currently all are attributed to one species, *T. lowryi*. There remains some taxonomic uncertainty about the family placement of *Troglodiplura*. Main (1993) concluded that its affinities are with the family Dipluridae or curtain web spiders of eastern and south-western Australia.

JANUSIA MUIRI GRAY 1973 (CTENIDAE)

Again during 1966, the team of Jackie and David Lowry discovered another troglobitic spider, this time in Weebubbie Cave (6N-2) and a living species. The spider was also discovered some 240km away in Pannikin Plain Cave (6N-49) during 1972 by Mike Gray and Nick White of VSA. Both collections apparently took place close to the cave's entrance "near the junction of twilight and dark zones" (Gray 1973) although subsequent encounters have taken place well into the dark zones of caves. Norman Poulter collected a mature *J. muiri* from the far end of the Weebubbie lake in 1985.

Since then, examples of the nomadic *J. muiri* have been found in three other widely spaced and environmentally different caves, namely 6N-206, 6N-1327 and 6N-1536. The muiri spiders noted by Norman Poulter in the research cave 6N-1327 and 6N-206 appear to be much smaller than that found in Weebubbie Cave, being similar in size to those found by Paul Devine in 6N-1536 on Balgair Station near the Trans Australian Railway. The Weebubbie species could be 'ecologically' larger due to the abundance of food opportunistically provided by the external feeding habits of the resident population of (twilight nesting) birds and bat species (dark zone).

However, these smaller spiders could simply represent younger growth stages. The paucity of mature specimens and the absence of males makes assessment of the taxonomic status of these populations and of generic relationships extremely difficult. Gray and Thompson (2001) suggested that *Janusia* may be related to *Bengalla bertmaini*, a troglobitic species of Northwest Cape Peninsula.

THE GENUS _TARTARUS_

The species that was to become the most famous Nullarbor spider was found in the Dome chamber of Mullamullang Cave (6N-37) by Peter Hawkes in 1969. Initially it received scant coverage, merely "CEGSA found an unidentified live spider in the Dome, Mullamullang," as reported in the Down Under All Over section of issue 43 of the *ASF Newsletter* (Anon 1969). A description written by Alan Hill and a drawing of the spider appeared in the following issue (#44) although Hill made no mention of spiders when his paper "Caves of Australia #4, Mullamullang Cave" was published in the ASF Newsletter #52 in June 1971. The spider was ultimately named *Tartarus mullamullangensis* after the cave and its peculiar "lampshade" web was described (Gray, 1973). The spider's only food source appeared to be the blind cockroaches (*Trogloblattella nullarborensis*) observed in the Dome chamber. For almost 16 years this was the only residential address the spider had, and there was even speculation from the early 1980's that the spider may already be extinct, the last known sighting in the Dome being the mid-1970's.

1985 saw a minor explosion of *Tartarus* spider findings begin when members of the Murdoch University Outdoor Group, led by Wayne Tyson, found examples of the spiders to the north of Mullamullang in Murdoch Sink (6N-330) and Phyllistine Flattener (6N-194). At the same time, the Group voiced the first concern that the spider may be extinct in Mullamullang. Several months later, Norman Poulter, leading a trip of SRGWA members on behalf of UWA researcher Dr Brenton Knott, found a colony of *Tartarus* spiders in a newly discovered section of Nurina Cave (6N-46) while a single female was found in Thampanna Cave (6N-206) several days later by other SRGWA members. Subsequent research conducted by Dr Mike Gray revealed significantly different body variations in the respective spiders, enough to create three new species: *Tartarus murdochensis*, *T. nurinensis* and *T. thampannensis* (Gray, 1992).

The important point about this work was that it showed that these spiders, including *T. mullamullangensis*, are highly localized, with species distributions perhaps confined to single cave systems. This contrasts markedly with the tendency to assume wide Nullarbor cave distributions for other troglobitic species like the blind diplurid, *Troglodiplura lowryi*.

But it didn't stop there! *Tartarus* spiders now began to be found over an ever-widening range, seemingly spearheaded by members of CEGSA and SRGWA. Colonies were subsequently found in 6N-36 (CEGSA), 6N-53 (SRGWA), 6N-149 (WASG), 6N-206 (SRGWA) 6N-326 (?), 6N-327 (SRGWA), 6N-645 (CEGSA), 6N-707 (only remains found), 6N-747, 6N-1327 (SRGWA) and 6N-1384 (CEGSA). These caves are all in reasonable proximity to the Eyre Highway.

However, SRGWA member Paul Devine, operating from Kalgoorlie, began prospecting for caves along the Trans Australian Railway and during the late 1990's made some exciting discoveries of *Tartarus* spiders at 6N-1612, 6N-1556, 6N-1536 and 6N-1593 on Balgair Station near Rawlinna in addition to 6N-1759, 6N-1764, 6N-1773, 6N-1789 and 6N-1789 in the vicinity of Old Homestead Cave (6N-83) near Forrest. He found one enormous colony of 45-50 in 6N-1536 which was only recently topped by the 90 counted in the research cave 6N-327 on Mundrabilla Station during January 2002 (Poulter 2002).

There appears to be significant differences between the *Tartarus* spiders found close to the Eyre Highway and those in the vicinity of the Trans Australian Railway. Those found close to the Trans Australian Railway are smaller than their southern relatives and spin totally different webs. Reaction to prey also appears to be markedly different.

The typical female web made by southern Nullarbor species, like *T. mullamullangensis* and *T. nurinensis* is a gently widening cylinder (lampshade-shaped), established on horizontal or sloping roof, wall or boulder surfaces. The spider sits at the cylinder's base with legs spread out to touch the web's side wall from which it senses prey movement. The web in turn, due to its airborne structure, can, with it support lines, occupy several cubic metres of space. Apart from the capture silk, the web structure is virtually impossible to see with direct lighting and is highly susceptible to air turbulence. When prey encounter the web, there is instant reaction from the spider who lifts a portion of web and throws it over the prey while moving in for the kill. The females spin this web seemingly from birth, young spiders with a legspan that would barely cover a 1¢ piece have been seen in webs scaled to their size.

On the other hand, the northern *Tartarus* spin a flat, rectangular web (about 500 x 700mm) that hangs from the roof or steeply angled walls or rocks. To all intents, the spider sits underneath the web towards one corner and from observations so far, appears disinterested when prey become entangled in the web. Indeed, when on two occasions, cave wetas were guided into a web in 6N-1536, the spider showed no reaction at all, which allowed the weta in question to escape - twice. Another weta was not so lucky, thoroughly caught, it was consumed overnight, although again, the spider seemed disinterested with the initial ensnarement. Spiders utilising this web have been seen as far south as 6N-36, a short distance to the west of 6N-37.

Male *Tartarus* spiders, from limited observations in southern caves, appear to be nomadic. As they navigate in search of females they lay a silken thread across the ceiling rock between webs. Again, from limited observations, courtship appears to be a long, drawn-out affair with some indications that the female may have cannibalistic tendencies if the male doesn't perform to her liking. During courtship, the female's web can suffer considerable damage. Observation also suggests that when the female spider moves her web site, she may re-ingest the majority of her web as a possible energy-saving measure. Small suspended egg sacs, resembling Grecian urns have been found in the research caves 6N-327 and 6N-1327 that are suspected to be related to the *Tartarus* genus.

The *Tartarus* spider became a protected species under the *Wildlife Conservation Act 1950* as "Fauna which is rare or likely to become extinct" in 1994.

THE GENUS *ICONA* (FAMILY THERIDIIDAE)

A blind species of *Icona*, as yet undescribed, is the smallest of the Nullarbor troglobitic spiders with the most limited range, currently known from only two caves approximately 9km apart on the Roe Plain, Nurina Cave (6N-46) and the research cave 6N-1327. These spider belong to the "comb-footed spiders" (*Theridiidae*) and have relatives in caves across southern Australia, all of which are temporarily placed in *Icona*, but according to Mike Gray they will require a new genus.

The spider's body length is approximately 5mm with the legs extending about the same distance. It was first discovered in the Fauna Chamber of Nurina Cave in May 1987 (Poulter 1987) and 6N-1327 almost eleven years later (Poulter 1998). The spider builds a small complex horizontal suspended platform web and hangs underneath. The platform would be approximately 40 x 20 x 5mm which in turn is suspended a short distance from the rock ceiling or projection and has numerous support lines. Nothing is known of its prey preferences.

DISCUSSION

The Nullarbor Plain is a vast karst region of some 200,000km^2 whose troglobitic fauna have received scant scientific attention in either the more frequently visited forested southern sector or the more arid interior. The term "forested" is purely figurative, the correct term being closer to "woodland". However, the majority of discoveries have been made by members of speleological societies on a more-or-less opportunistic basis. Based on what has been found over the last fifteen years, the potential for further discoveries, especially microscopic or aquatic, would have to be rated high.

As shown by the accompanying simplistic diagrams, the ranges of three of the genera of troglobitic spiders and their prey species is quite large. The ranges were derived from drawing arbitrary boundary lines between the outermost caves in which the various spiders were discovered. These ranges indicate that if environmental conditions are right, a troglobitic faunal regime could exist in any cave within those boundaries - being careful not to exclude the possibility of finding more faunal caves beyond the existing boundaries. Quite obviously, speleological exploration in these regions need to be conducted with upmost care - particularly where a new cave is opened by excavation.

However, it will be noted that in several instances, boundaries overlap - where two or more spider species coexist in the same cave, do they occupy convenient, non-competitive food niches, or actively prey on each other? Only further long-term observation will yield an answer to that and other behavioral questions.

ACKNOWLEDGEMENTS

I would like to thank Dr Mike Gray, Australian Museum, for his comments and contributions to this paper.

FOOTNOTE

Since the presentation of this paper during January 2003, two spider discoveries of note have taken place. In cave 6N-2203, which lies within the area predicted where both the spiders *T. lowryi* and *Tartarus* genus could be found if conditions were suitable, a small co-existing colony was found by SRGWA members Paul Devine and Eve Taylor. The member of the *Tartarus* colony was of the sheet-web variety. Of greater significance however, was the discovery a short time later of the one sheet-web building *Tartarus* spider in 6N-2455, a small cave to the north of the Trans Australian Railroad in the vicinity of Loonganna – thus greatly increasing the range of this species of troglobitic spider, see updated maps.

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Contact details

PO Box 120, Nedlands WA 6909.

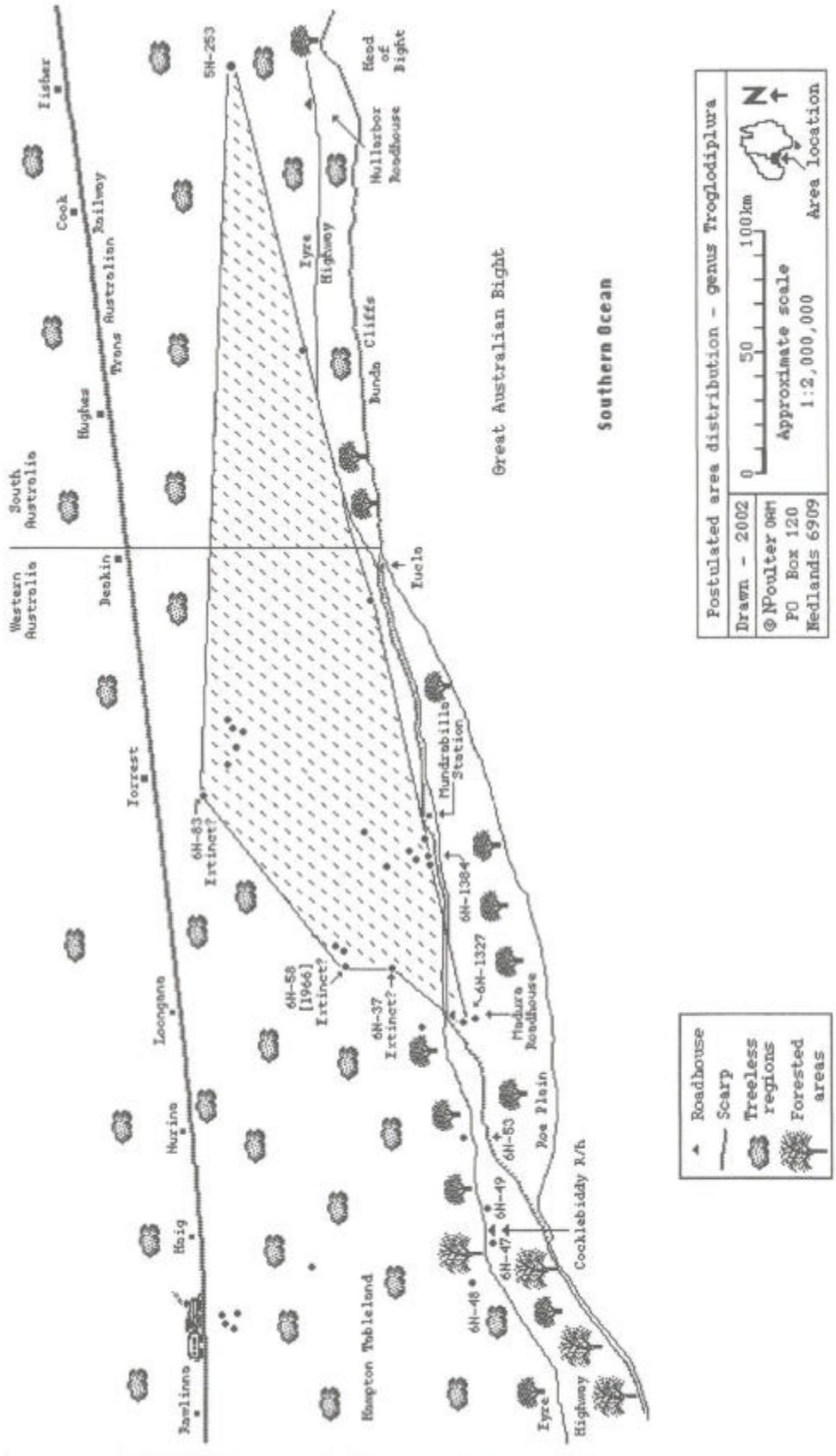


Figure 1 – Postulated Area Distribution – genus Troglodiplura

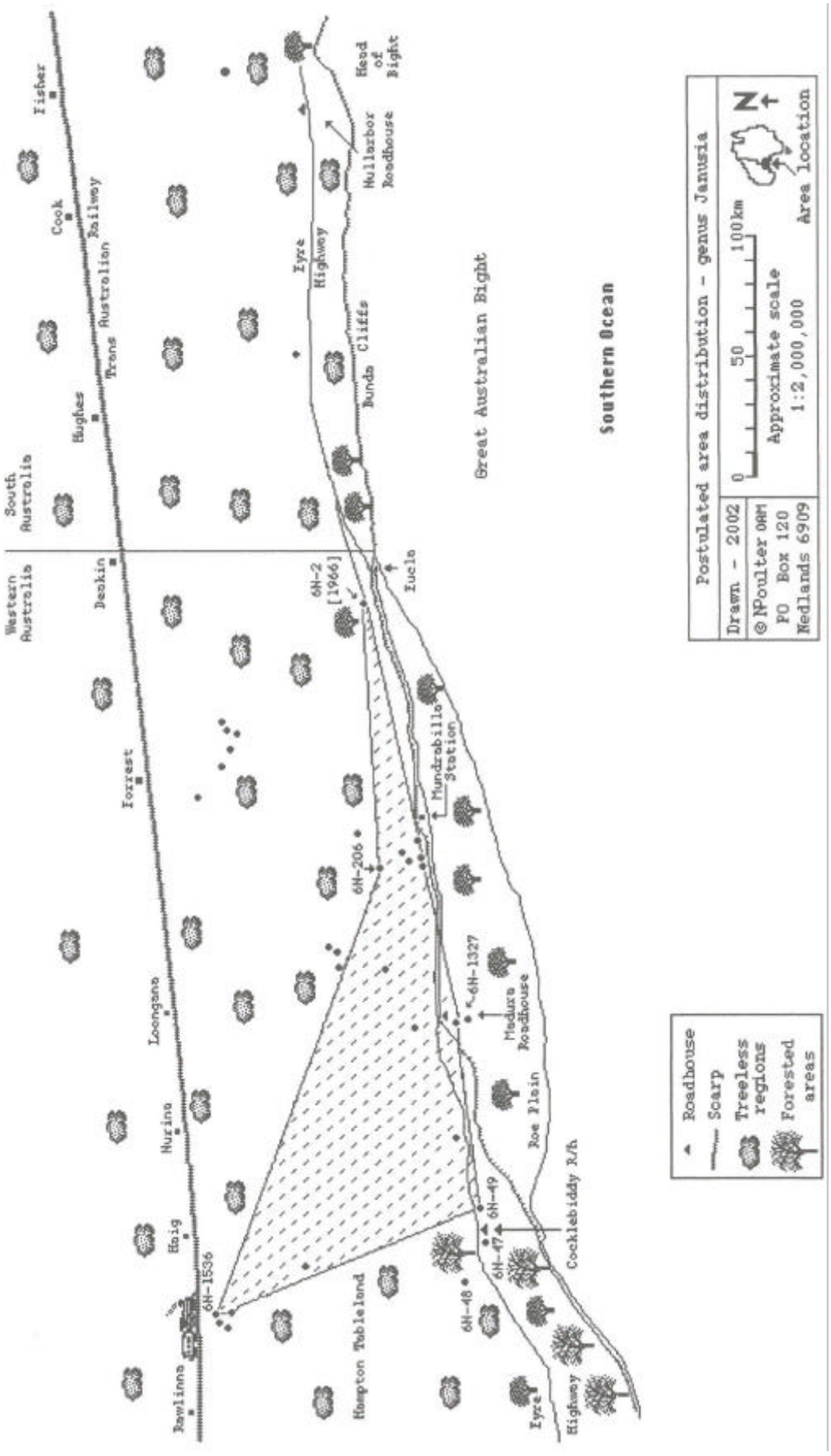


Figure 2 – Postulated Area Distribution – genus Janusia

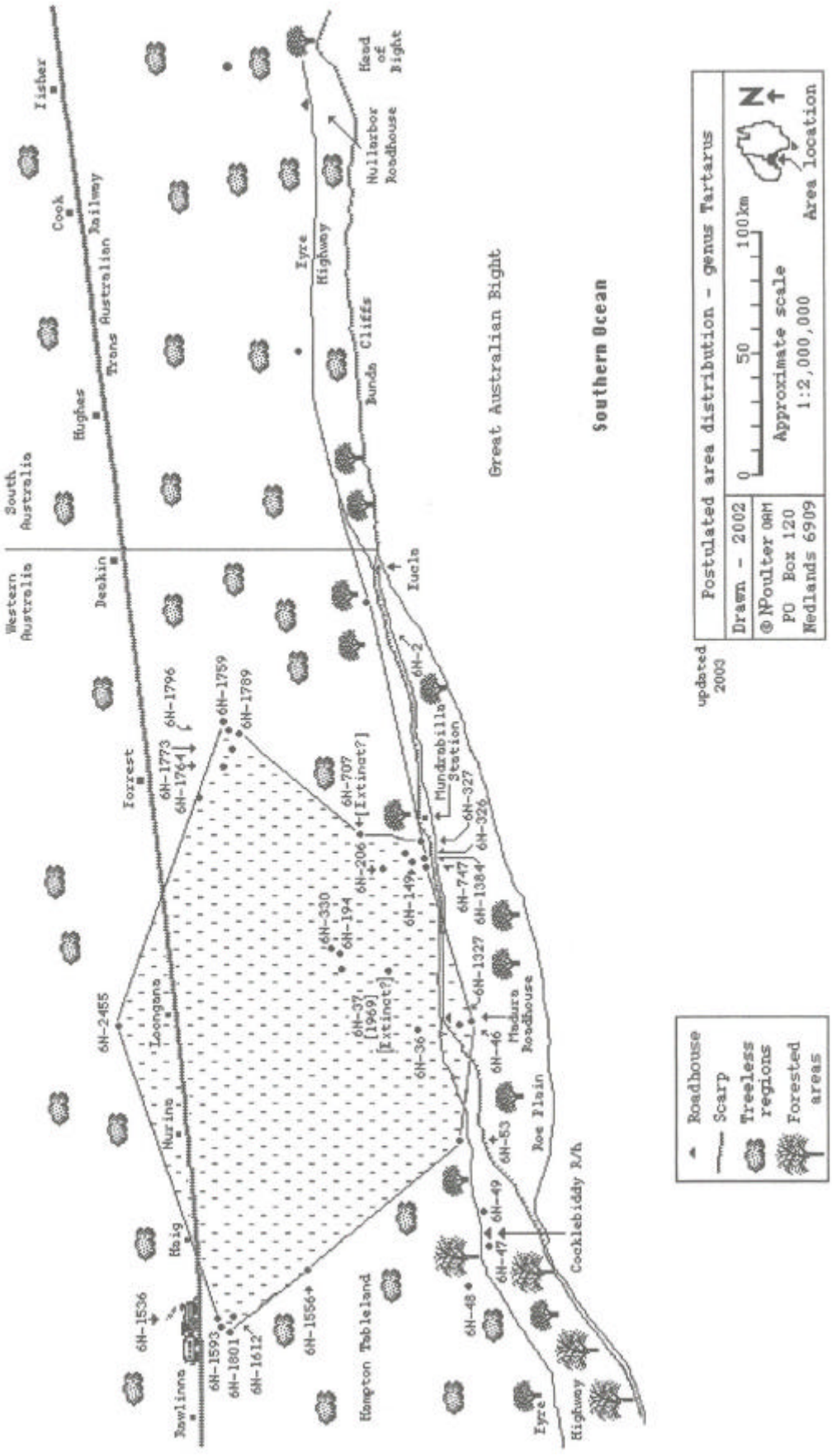


Figure 3 – Postulated Area Distribution – genus Tartarus

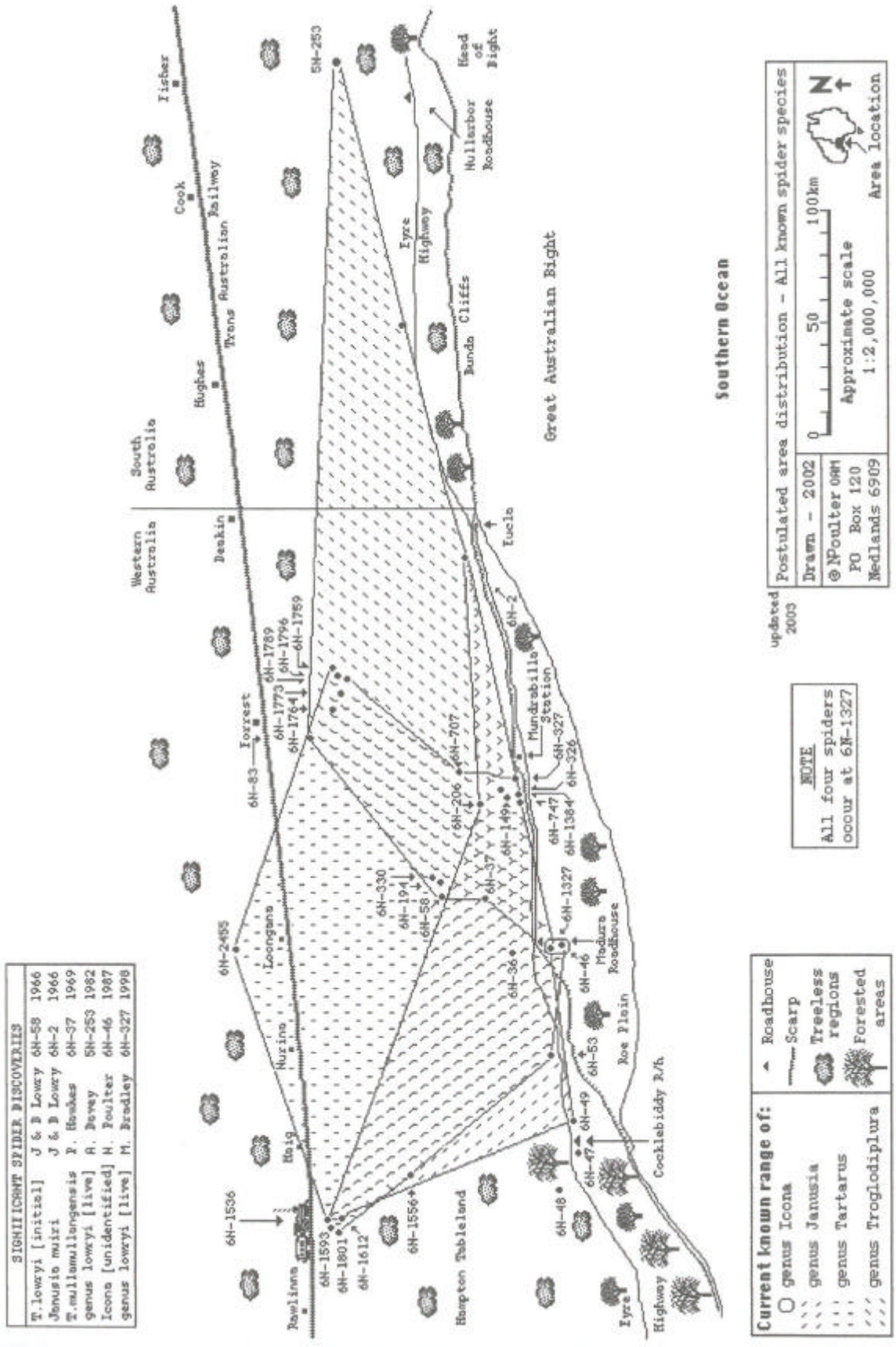


Figure 4 – Postulated Area Distribution – All known spider species

Troglobitic Spiders of Research Cave 6N-327

Norman Poulter OAM
Speleological Research Group Western Australia Inc.

During the SRGWA Nullarbor Expedition of 1992-93, Max Meth (CEGSA) took me to one of several karst features on the Hampton Tableland of Mundrabilla Station for the purpose of attaching identification numbers. The feature 6N-327 was a shallow cliffline adjacent to a small rock pavement amongst scattered trees approximately 1.5km north of the scarp. While I was preparing the number and attaching it to a suitable location, Max, in his own inimitable style, was conducting a preliminary dig, armed in his usual way with a shovel (mine), crowbar and bucket. Within a few minutes, a small 30mm hole suddenly appeared with air rushing out. Max almost seemed disappointed as he laconically stated that the feature was now another cave. A few minutes later, we placed a small rock over the hole and left to number other features.

During another SRGWA expedition, on January 1, 1997, with the numbers, attitude and implements, we were back for a dig. The day was not really conducive for digging, it quickly became hot and cloudless. Digging was enthusiastic as it was the coolest place to be, the only downside being the dust-laden gale howling out from the depths. Sweaty arms, faces and necks quickly became darkened due to successive layers of adhering dust - which at least gave some protection from sunburn. After about 3 hours digging, and at the bottom of a 2 x 1m trench, a hole big enough for most people to crawl through appeared, we had our cave. We cleaned the dust from our eyes, washed our hands, and immediately retreated to the shade of a nearby tree for lunch.

Max was the first to succumb to curiosity, finished eating, strode across to the trench and crawled headfirst through the hole, which was still blowing a gale. Everyone else entered feet first to be confronted by one of our greatest surprises - a seemingly sealed eco-system! The first *Tartarus* spider was encountered less than 10m into the cave. It did not take long to conclude that we had a major biological discovery on our hands that needed protection. Over the next two days when the two main arms of the cave were partially explored and route-marked during the course of a “stick survey” more than 24 spiders were encountered of all age groups and both sexes. This was the highest population of spiders discovered to date - even egg sacs were found, presumably associated with the *Tartarus* spider. Negotiations immediately commenced with the Station owners, Lucy and Bob Eglinton, to declare the cave a research site and restrict entry. One year later, with financial support from the Speleological Research Group Western Australia (SRGWA) and Australian Geographic Society, the cave entrance was covered by an environmental gate. The partially pre-fabricated gate was assembled and cemented into place by members of the Canberra Speleological Society and SRGWA.

During the year from the time the cave was opened to when the gate was fitted, the spiders had retreated from the entrance region possibly due to a combination of air turbulence and surface predators even though every effort had been made to re-seal the entrance. Data loggers (obtained with the aid of a Gordon Reid Foundation grant) placed in the entrance zone and deeper into the cave during the gate construction period showed a dramatic climatic effect as soon as the gate was closed (Figure 1) and observation has since shown that the spiders soon re-colonized the entrance region.

One major outcome of the initial discovery was being able to witness for the first time what appeared to be the preliminaries of the *Tartarus* courtship ritual which gave every indication of being a long drawn-out affair. Since that time it has been discovered that the cave's troglobitic ecosystem also includes the spider *Troglodiplura lowryi* (the first recorded live sighting in WA), cockroach, isopod, beetle, mites associated with root material and a suspected flying insect. Micro-karst connections to the surface allow the inflow of water, tree roots, water with vegetable debris and intrusion of surface fauna which has included a small rodent-like creature suspected of being a dunnart (Poulter 2002).

A major survey of the cave began at the beginning of 2002, revealing that the entrance rockfall region is more extensive than first thought. The cave is essentially two chambers with at least two side extensions although the lower, major chamber is divided into “multiple chambers” by either the

ceiling or extensive ceiling (calcite) decoration dipping down to meet the sediment floor. In this way, almost one kilometre of “passage” has been mapped with more visible. Surveying has been conducted so as to cause the minimum of disturbance to the soil floors and web structures - movement through the cave is deliberately slow as spiders periodically change location and once unobstructed pathways can become blocked by web support lines. One essential survey tool is an 8m retractable builder's tape which allows side distances to walls and other features to be plotted without leaving an established track. Ultrasonic or laser distance measuring instruments may also be used in forthcoming work. Once mapping is completed in most regions, redundant trails are blocked off and rehabilitated while preferred trails are more substantially track-marked where possible. When spider webs are located close to a main trail, their position is marked so as to avoid future web damage should the spider remain “on station”.

At the close of surveying in 2002, some 90 *Tartarus* spiders of all age groups and sexes had been plotted. This is the highest population density ever recorded in a single cave. There has been only one confirmed sighting of a live *Troglodiplura lowryi* (1998) although a fungus-covered body was recovered and an unconfirmed live sighting made in 2002. Observation indicates that when the female *Tartarus* spider moves her web site, she may re-ingest the majority of her web as an energy-saving measure.

The lower chamber is further divided into two distinct sectors with the conveniently and centrally located Main Drag acting as a border. The region to the west is drier and slightly elevated, contains the majority of the calcite decoration (mostly dead) and it is possible to stand up most of the time which is particularly welcome. Some of the floor deposit could include intermixed “coffee and cream” material fretted from the ceiling. Few female spiders were found in this area, although in 1997, many spiders were discovered in the vicinity of Logger Junction (Stn. 37a). By stark contrast, the sparsely explored and surveyed eastern sector is mainly sedimentary floodplain, largely devoid of decoration but with a high population of spiders which has made movement slow and extremely difficult to avoid damaging inter-woven web structures. Sitting up in this region is a luxury to be relished. There are also occasional though extensive deposits of exudated shards.

A north-easterly extension with extensive dry and broken calcite decoration found to contain spiders, tree roots and egg sacs has been entered twice, but as yet, only received a rudimentary survey. A suspected dunnart has been seen in this area too, possibly entering via a micro-karst passage.

Tree roots that penetrate the cave appear to obtain nutrients from two sources, either directly from the cave's humid atmosphere in which case it is not uncommon to encounter large tufts of fragile, dark coloured rootlet clusters along fault lines or, consolidated taproots and associated rootlets penetrating the cave's floor soil and rock structures. Tree roots in turn, provide nutrients for the cave's troglobitic fauna. Cockroaches of all age groups can be seen foraging amongst the rootlets either cropping the roots themselves or possibly feeding on the microscopic mites and fungi. Newly hatched female *Tartarus* spiders have also been found to set their webs close to some root systems.

The female *Tartarus* spiders can be found living a solitary existence or in moderately scattered social groups although this could also indicate abundance or lack of food. In the case of the male *Tartarus* spider, some credence must be given to the possibility of territorial range. Encountering more than one mature male in close proximity to a cluster of females is rare. The mature male spider is nomadic, searching out prey and suitable females with which to mate. Males have been seen moving towards females either following or laying a single silken thread. Careful examination of cave ceilings reveal a small network of these silken highways.

Credence also needs to be given to the possibility that the female may also be cannibalistic in relation to courting males, borne out by the drawn-out and hesitant behaviour exhibited by the male during the only mating ritual observed in 1997 and web-entangled husks periodically encountered in this and other fauna-rich caves. Admittedly, web-entanglement of husks that has been seen may have occurred during a spider's moulting maneuvers. Cannibalism is exhibited by other spider groups, eg. the female redback spider will eat her much smaller mate if he does not perform to her liking. In a presumably nutrient-poor cave environment, cannibalism of the numerically smaller population of male spiders seems on the one hand, unlikely - while on the other, advantageous to the continued survival of the species. Only long-term and detailed observation in the remarkable underground laboratories provided by 6N-327 and its companion 6N-1327 will yield answers to this and other questions about the unique spiders of the Nullarbor caves.

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Contact details

PO Box 120, Nedlands WA 6909.

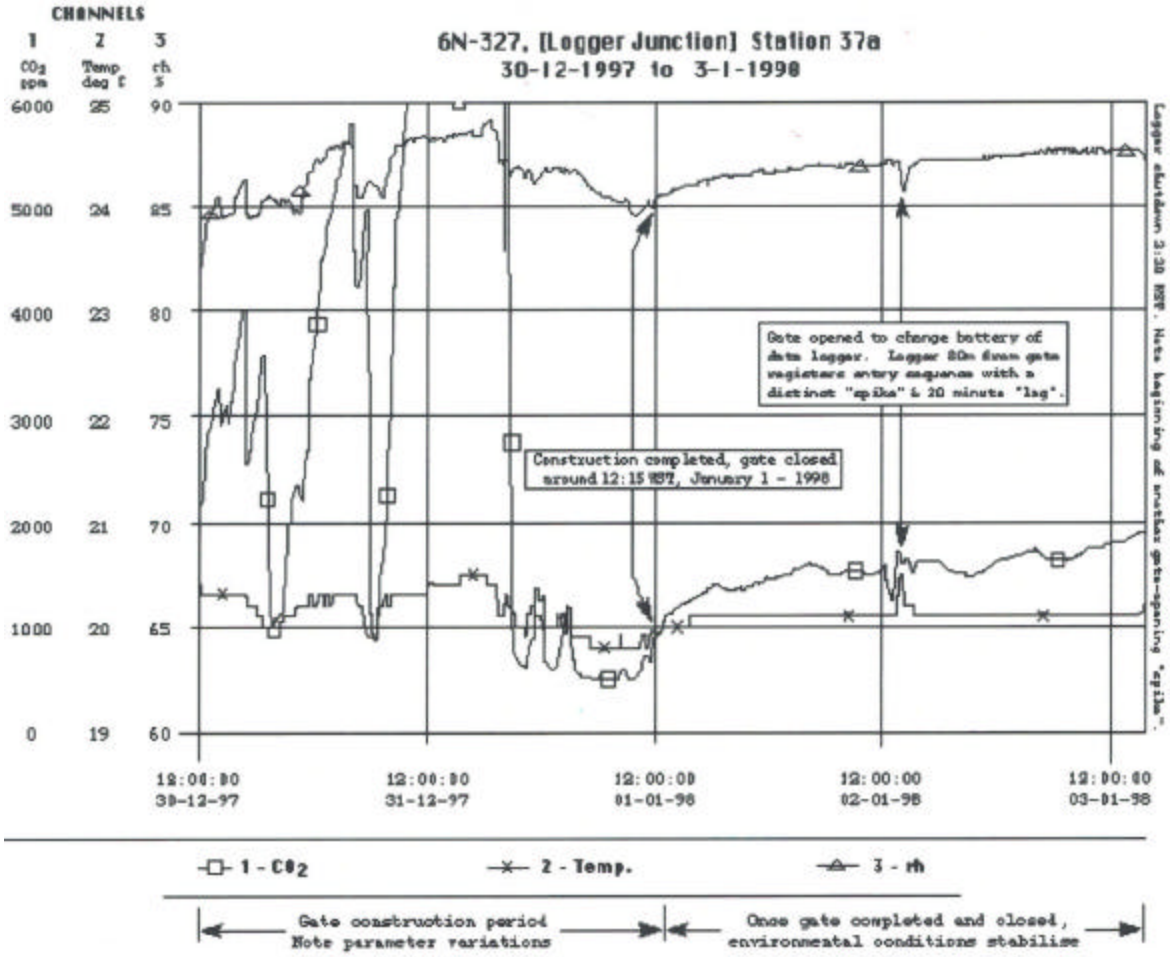


Figure 1 – 6N-327 (Logger Junction) Station 37a

Underwater Helictites from the Nullarbor

Jill Rowling

INTRODUCTION

In January 2001, Paul Hosie, a member of Trimix Divers (Hosie 2001, 2002), announced on the internet mail list "Ozcavers" that their team had discovered a number of peculiar underwater helictites present in lakes in Mullamullang Cave, one of the caves of the Nullarbor. Members of the Trimix Divers club are investigating the underwater sections of Mullamullang Cave and record their findings of unusual speleothems. These include a thick wall-deposit and at least eight different kinds of helictites.

In order to identify the helictites, Paul Hosie sent a number of digital pictures to interested people. Samples of two different varieties of helictites were posted to Jill Rowling for identification. Preliminary descriptions and classifications were passed onto Paul. Classification was based on the present scheme devised by Hill & Forti (1997), however a more comprehensive analysis was required (as Paul says) "to do justice to" these peculiar speleothems.

This paper covers the analysis and description of two of the helictites. The helictites examined are of two forms: one which is a cylindrical shape ("pool fingers") and the other which has an almost triangular symmetry and flattened structure ("sh'bulatites").

The helictites have a rather unconventional layered structure. Minerals present include high and low magnesium calcite, aragonite, hydromagnesite, huntite and others (see Tables 2 and 3). The substrate appears to be a reddish deposit with large limestone blocks apparently collapsed into it. The helictites develop vertically from the blocks (so perhaps they should be called heligmites).

Mullamullang Cave is on private property. Trimix Divers obtained all permissions for diving and sampling with the property manager.

HISTORY OF DISCOVERY OF SUBAQUEOUS HELICTITES

January 2001:	Announcement on the internet by Paul Hosie regarding the discovery of unusual helictites during a recent dive in the lakes of Mullamullang Cave, Nullarbor Plains. Includes photos from the dives and a request for identification of the speleothems.
29th January 2001:	Paul Hosie mentions on the internet that disc shapes are part of some helictite structures.
5th February 2001:	Rowling receives helictite samples and begins analysis.
12th December 2001:	Further internet discussions regarding helictite classification.
16th April 2002:	XRD results discussed via internet.
19th April 2002:	Paul Hosie develops project plan to record the subaqueous helictites of Mullamullang.

LAKES WITH SUBAQUEOUS HELICTITES

Mullamullang Cave has several lakes. According to the divers, some of them have subaqueous helictites. Table 1 lists the lakes and the type of speleothems recorded to date (data and names are from Trimix Divers). There are at least eight different helictite forms estimated (P. Hosie, pers. comm.).

Photos of some of these speleothems may be seen on the Trimix Divers website, http://www.trimixdivers.com in the section on Mullamullang Cave.

Lake	Distance From Entrance	Speleothem
White Lake	2.5 km	Fine coral branches Pool fingers Fat fingers
Easter Lake		Crystal coating
Lake Sh'Bula	5.2 km	Crystal matting Robust coral branches (“sh'bulatites")
X Lake		Passage floor needles Stacked branches Roof fingers Boulder coatings Crystal floor plates Chalky wall deposits
Helictite Lake		Crystal matting
Grotto Lake		Not studied yet
Lake Cigalere		Not studied yet
S Lake		Not studied yet
Keyhole Lake		Not studied yet
Gurgle Lake		Not studied yet

Table 1 - Mullamullang Lakes and Speleothems (after Hosie)

ANALYSIS OF WHITE LAKE POOL FINGER HELICTITES

The samples forwarded for analysis consisted of three "fingers": One was loose and the other two joined together. They are approximately 45 mm long and 7 mm diameter with cylindrical symmetry. The tip is hemispherical. To the naked eye they are white and chalky on the outside, with patches of yellow, and inside they are hard and crystalline.

Under the microscope, the outside coating has a porous appearance. The whole surface is coated in triangular crystal outgrowths with a clear yellow outer coating. The surface has fine black speckles resembling soot. One of the specimens had an empty shell of a small crustacean adhering to the surface, possibly a syncarid. At the tip of the helictite the thin surface layers of white crystalline material can be seen. The inner crystalline part of the helictite appears to be made of concentric layers.

One of the helictites was sectioned and viewed with the microscope on both reflected and transmitted light. The innermost area appears to comprise several hollow capillary tubes surrounded by a wider area of radial needle crystals. Some needles appear to be in bunches and flattened. Also in the inner layer is some more yellowish material. In the sampled section, there is a hard inner layer which forms a triangular pattern.

Some layers are white and chalky. They reflect white light but transmit light poorly: this is a property of powdery minerals such as hydromagnesite or huntite. Other layers are more transparent and fairly hard.

A small part of the helictite was powdered, mounted on a glass slide using double sided tape and scanned with a Siemens D5000 Xray diffractometer using a copper target. The Xray spectrum was analysed using Bruckner Diffrakt-Plus software. The results of the analysis are given in Table 2 and its Xray spectrum is shown in Figure 1. The main peaks seen were calcite and magnesian calcite, with aragonite, hydromagnesite, gypsum, celestite, graphite and some halite present.

One assumes the halite, and the strontium in the celestite are from wind-blown sea water and deposited in the cave as part of the ground water.

Using the speleothem classification system of Hill & Forti (1997), possibly they could be classified as Type: Helictite; Subtype: Subaqueous; Variety: Heligmite.

Mineral Class	Mineral	Cat. No
Native Elements	Carbon (Graphite)	01-0640
Halides	Halite	02-0818
Carbonates	Aragonite	41-1475
	Calcite	03-0612
	Hydromagnesite	03-0093
	Magnesian Calcite	43-0697
Sulphates	Celestite	01-0885
	Gypsum	33-0311

Table 2 - XRD results for Pool Finger helictite

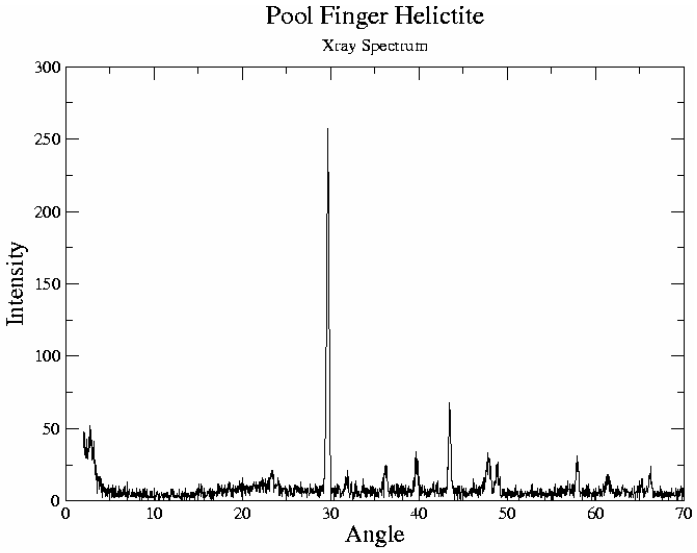


Figure 1 - Xray spectrum of Pool Finger helictite. Vertical scale: counts; horizontal scale: 2θ



Figure 2 - Pool Finger helictite samples



Figure 3 - Pool Finger helictite - tip detail

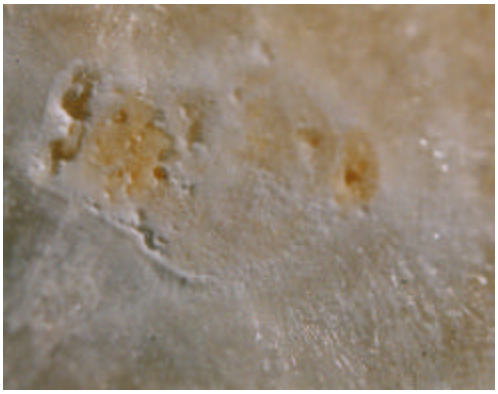


Figure 4 - Pool Finger helictite - cross section detail in reflected light
Note the multiple central canals

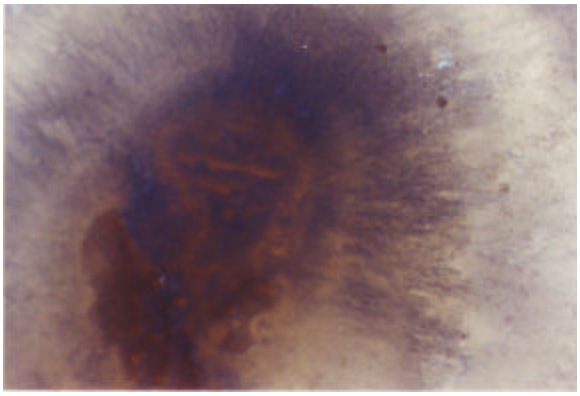


Figure 5 - Pool Finger helictite - cross section detail in transmitted plain polarised light
Note the triangular central area and the radial aragonite region.

ANALYSIS OF LAKE SH'BULA HELICTITES

The specimen is a white and yellowish aggregation of roughly square plates forming a rough-surfaced triangular prism. At first glance it resembles cave coral rather than a helictite, however it has a number of flattened capillary tubes which mean it is classified as a helictite. The specimen is about 40 mm long and about 30 mm diameter at its base and forms a rough triangular pyramid. A broken section exhibits ray-fan crystals presumably of aragonite.

Under the microscope, the surface appears to be chalky with small dark specks. The plates on the surface are squared, possibly by crystal twinning. Near the center of the helictite, some of the plates resemble gypsum swallowtail twins. On the surface there appear to be the remains of microbial veils. Development may be by twinning near the surface. The white powdery matrix appears to be porous, and the needle core is definitely porous.

The interior is similar to the Pool Finger sample except that the central canals are extremely elongated. The insides of the flat plates are hollow, and lined with needle crystals with alternate layers of clear and opaque white minerals.

Its cross section is rather similar to the Pool Finger sample but with a tendency to form flat plates instead of cylinders. At first, it was thought that these plates may be sunken and overcoated calcite rafts, however the divers recorded them from all sorts of places in the lake where it is extremely unlikely that rafts would form. P. Hosie describes other raft-like structures in similar helictites as being about 5 mm thick and 25 mm diameter.

One interesting feature of these helictites is they appear to have macroscopic triangular symmetry, with the outer "petals" of the helictites developing along the edges of a regular triangular prism.

A small part of the helictite was powdered, mounted on a glass slide using double sided tape and scanned with a Siemens D5000 Xray diffractometer using a copper target. The Xray spectrum was analysed using Bruckner Diffrakt-Plus software. The results of the analysis are given in Table 3 and Figure 6. The main peaks seen were calcite, aragonite and magnesian calcite, with huntite, hydromagnesite, cristobalite, gypsum, graphite and some halite present. Specimen grinding was surprisingly difficult but could have been because of the presence of cristobalite.

Mineral Class	Mineral	Cat. No
Native Elements	Carbon (Graphite)	41-1487
Halides	Halite	01-0993
Carbonates	Aragonite	01-0628
	Calcite	02-0629
	Hydromagnesite	08-0179
	Huntite	14-0409
	Magnesian Calcite	43-0697
Silicates	Cristobalite	39-1425
Sulphates	Gypsum	33-0311

Table 3 - XRD results for Lake Sh'bula helictite

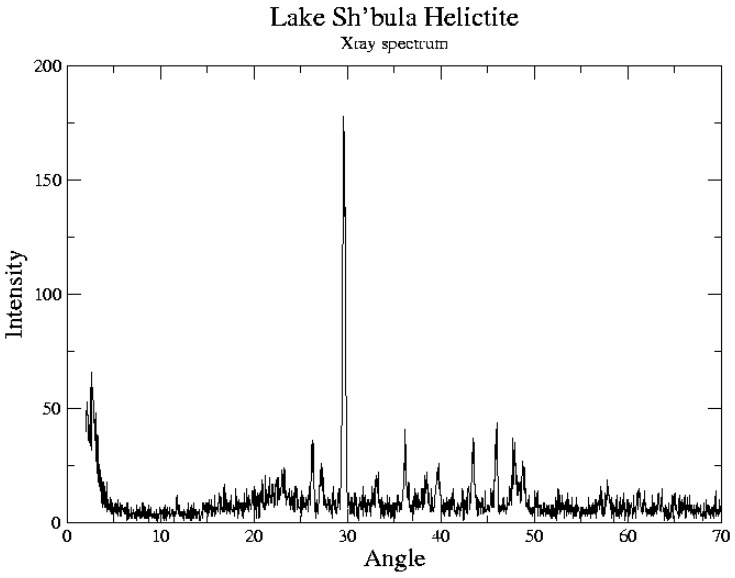


Figure 6 - Xray spectrum of Lake Sh'bula helictite
Vertical scale: counts; horizontal scale: 2q



Figure 7 - Lake Sh'bula helictite sample

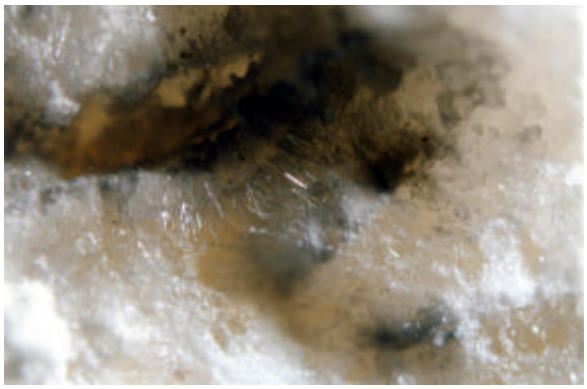


Figure 8 - Lake Sh'bula helictite - cut section detail in plain polarised light
Note the elongated central area and the radial aragonite region

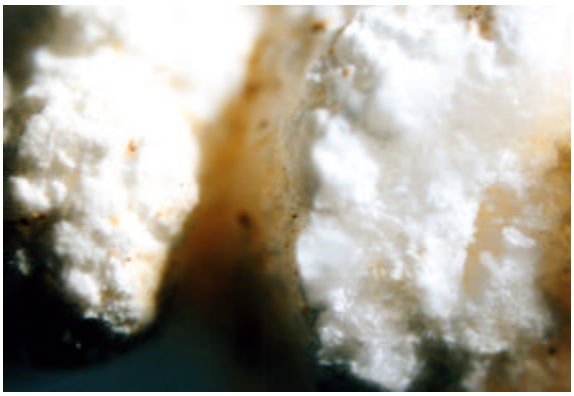


Figure 9 - Lake Sh'bula helictite - cut section near the end of the helictite

Using the speleothem classification system of Hill & Forti (1997), possibly they could be classified as Type: Helictite; Subtype: Subaqueous; Variety: Heligmite. However this is problematical as the rather elongated central canals of these helictites should be distinctive. Possibly they are part way to being a cave shield, as the elongated central canals are similar to the conventional cave shield in many respects. The central canals appear to form a twin plane, so whatever develops on one side of a plate also develops on the other side. The overall triangular symmetry may also be due to twinning.

An interesting discussion of a small aragonite cave shield may be found in Hill & Forti (1997) in the special section on the Blue Cave of France (page 314).

OTHER HELICTITES AT MULLAMULLANG

There are a number of other helictite types reported by the Trimix Divers from lakes at Mullamullang Cave. Some of these are recorded as digital images by Paul Hosie as follows:

Lake Sh'bula helictites: Some of these are developed on cave shields or the upper edge of a stegamite. Others appear to be developed on tepee structures or rock surfaces. Some helictites are spheroidal or cylindrical, others have a triangular shape. There are yellow platey helictites which resemble overgrown sunken cave rafts but form the upper edge of a stegamite.

White Lake helictites: Fine white helictites take on a branching form. All tips go upwards. About a dozen tips per "shrub". "Shrubs" about 200 mm height and diameter, wider at the top than at the bottom forming a cone shape. They apparently develop on top of rocks in the lake. Small discs are apparently embedded in some of these helictites (P. Hosie, pers. comm.) which could be similar to the "sh'bulatite" variety, only smaller.

Crystal matting: This is a wall surface coating which superficially resembles Cave Clouds (Hill & Forti 1997). Closer, the surface appears to be made of spheroids. Without seeing more of it, it may be still a variety of Cave Clouds. According to the divers, it occurs in areas where microbial veils have been recorded. Where it occurs, the boulders are completely coated in this "crystal matting".

Fat fingers: Paul said there were not many of these. Close up photos show some standing, some naturally toppled helictites. The substrate appeared to be pink silt and reddish (rock or sediment). A yellowish coating appears on some helictites.

Some of Paul's pictures are included as an appendix to this paper.

CONCLUSIONS AND ACKNOWLEDGEMENTS

Subaqueous helictites have not often been recorded, and this discovery from the Nullarbor shows that there must be something special about the cave chemistry to cause helictites to occur in these lakes.

The association between the "sh'bulatites" and stegamites or vertical cave shields would be worth investigating further. The above-water cave analogy to this association would be the regular vermiform helictites that develop along the edges of cave shields.

In contrast, the pool finger helictites appear to develop on bedrock blocks.

In summary, the subaqueous helictites of Mullamullang Cave have only started to be analysed. Discovery was only possible by cave diving. It is hoped that the divers will discover more of these interesting speleothems. The study of these fascinating helictites has been an interesting exercise in remote analysis. The author has never been to the Nullarbor (yet) but the ease of corresponding by internet for the exchange of photos and ideas has been invaluable. All field work was done by members of the Trimix Divers group, assisted at times by various (dry) cavers such as members of WASG and SUSS. Photographs of the Mullamullang helictites *in situ* were done by Paul Hosie.

All sample preparation, XRD work and spectral analysis was done by the author using equipment at the Electron Microscope Unit at the University of Sydney. All optical microscopy and specimen photography was done by the author using optical equipment at home and at the School of Geosciences, the University of Sydney.

Specimen photo scanning was done by Dr Phil Maynard at the Forensics Dept., the University of Technology, Sydney.

This paper has benefited from constructive criticism by Paul Hosie.

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HOSIE, P. (2001, 2002). Trimix Divers website, Internet: http://www.trimixdivers.com.

Contact details
2 Derribong Place, Thornleigh NSW 2120.

APPENDIX - PHOTOS BY PAUL HOSIE



Figure 10 - Coral Fingers
Original photo copyright 2001 Paul Hosie



Figure 11 - Crystal Matting
Original photo copyright 2001 Paul Hosie



Figure 12 - Fat Fingers
Original photo copyright 2001 Paul Hosie



Figure 13 - Sh'bulatites, variation
Original photo copyright 2001 Paul Hosie

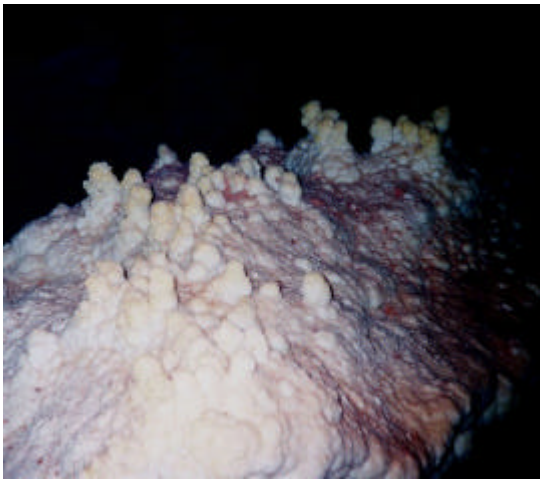


Figure 14 - Sh'bulatites, variation
Original photo copyright 2001 Paul Hosie

Cave Aragonites of New South Wales

Jill Rowling

INTRODUCTION

Although cavers and cave managers have reported aragonite from a number of NSW caves, there is surprisingly little literature in the scientific community regarding its occurrence in NSW caves. The aims of this project are to:

- Investigate caves reported to contain aragonite
- Verify that the material either is or is not aragonite
- Analyse the substrate on which the aragonite is depositing
- Determine what factors lead to the deposition of aragonite in NSW caves.

INVESTIGATING REPORTS OF ARAGONITE IN NSW CAVES

Walli
C.S. Wilkinson, NSW Government Geologist, visited caves near the Belubula River near Orange and Canowindra in about 1870 (Wilkinson 1892). He visited three caves: the small Bone Cave, the "Long Cave" and a "Deep Cave" (believed to be Deep Hole, WA17, also known as Deep Cave). His investigations of the "Deep Cave" were limited to the bottom of the first pitch as the party had insufficient rope to see the rest of the cave. He reported aragonite deposits in "Long Cave" although he did not report about the substrate on which it was depositing, nor is there any record of either the analysis or the sampled material. The cave which most resembles Wilkinson's description and map is Piano Cave (WA12) at Walli on the "Bingera" farm property.

These caves are not open to the public, however permission to visit may be obtained through the Sydney Speleological Society (SSS) who manage the caves. The specific sites at Piano Cave that may have been sampled by Wilkinson are damaged to some extent however this is not unusual to expect in a cave which has been well visited for over a hundred years.

In both Piano Cave and Deep Hole, aragonite occurs as a surface coating mixed with gypsum and barite. In Deep Hole, aragonite also occurs as small anthodites associated with seams and joints.The Walli Limestone is a tough dark (foetid) limestone of Ordovician age containing numerous chert nodules. In the chert nodules there are dolomite (or de-dolomite) rhombs and pyrite cubes / goethite pseudomorphs. Barite occurs throughout the limestone and also in the nearby Walli Andesite. An abandoned barite mine at Walli is developed in the Andesite (Anon. various years' reports).

Piano Cave and Deep Hole have been selected as study sites for this project because they contain aragonite and are the earliest reference to aragonite in NSW caves.

Wyanbene
In 1978, Webb and Brush analysed aragonite collected from the ground near an anthodite at Frustration Lake in Wyanbene Cave and found that the material was a mixture of calcite and aragonite (Webb & Brush 1978). The substrate on which it was depositing was not analysed.

The author has reported what appear to be aragonite deposits in the form of *flos ferri* “flowers of iron” helictites at Wyanbene (Rowling 1995, Osborne 1996). Aragonite appears to be present in several forms: as surface coatings, stalactites, helictites, anthodites, columns and possibly a coralloid. Some of these speleothems are coloured blue or green. The substrate appears to be a type of gossan.

A report on the rock chip geochemistry of the Wyanbene deposit was done by Richardson (May 1981). Analysis by the Dept. Mineral Resources shows that the deposit contains quantities of ironstones as either gossans or hydrothermally deposited minerals which include heavy metals and sulphides.

The limestone has steeply-dipping joints filled with this material. It also has some dolomitised areas. In Wyanbene Cave, aragonite is mostly associated with areas of the cave which expose these joints, as reported by Rowling (Rowling 1995). Gypsum occurs in parts of the cave, often as fine needles on sediment banks.

The chemical influences on aragonite development at Wyanbene cave appear to be heavy metals: gold, lead, zinc, nickel, cobalt, cadmium, with sulphate and magnesium.

Jenolan
Welch (1976) and Dunkley & Anderson (1978) have produced guidebooks to the caves at Jenolan. There are reports and photographs of aragonite in some of the caves at Jenolan but the authors did not confirm that the material was actually aragonite. There is aragonite in the tourist caves and at least five other caves. Two caves (Contact Cave and Wiburds Lake Cave) have been selected as study sites for the cave aragonite project.

The Jenolan limestone deposit is mostly a fairly pure Silurian limestone. It also has some impure and dolomitised areas, especially towards the eastern and western edges of the deposit. Other parts of the deposit have been intruded by igneous dykes. This is most pronounced in Wiburds Lake Cave.

Despite the long period of time that some of the aragonite speleothems at Jenolan have been known, there has been little in print about it. One of the earliest references to aragonite deposits in the tourist caves at Jenolan is Osborne (1993). The earliest printed reference to aragonite anywhere at Jenolan is Welch (1976) and concerns the undeveloped caves. There are, however, over a hundred years' worth of tourist guidebooks and photographs of speleothems now known to be aragonite (such as the Lyrebirds Nest, the Arabesque and the Furze Bushes).

- ***Wiburds Lake Cave***
  Members of Sydney University Speleological Society, I. Cooper, Dr P. Maynard and others have reported (pers. comm.) over the last ten years on aragonite deposits in Wiburds Lake Cave. Some of these deposits are difficult to get to, but at the sites I have visited, aragonite takes the form of beaded helictites, anthodites and a spathite. Areas visited include "Neddys Knock" area and "The Maze". Thin sections and XRD (Xray diffraction) of material from "Neddys Knock" shows that the aragonite is deposited in a matrix of what appears to be de-dolomite, weathered pyrite and fine sediment, giving the appearance of a gossan. Chemical influences on the deposition of aragonite in Wiburds Lake Cave appear to be magnesium (as hydromagnesite) from de-dolomitisation of brecciated dolomitic bedrock with manganese(as braunite, todorokite and others) associated with a devonian mafic dyke; sulphate (as gypsum) from oxidation of pyrite in both the bedrock and the dyke, and phosphate (from bat guano).

- ***Contact Cave***
  Aragonite in the small Contact Cave takes the form of anthodites, helictites and surface coatings, mainly on the low, flat ceiling. The speleothems are liberally coated in white pasty hydromagnesite and huntite, with rhodochrosite and dolomite as sands and other coatings on the speleothems. There are also dark manganese minerals present such as todorokite and pyrolusite. There are also phosphates (from bat guano). Contact Cave is very close to the limestone / shale contact. Here, the bedrock is dolomitised and corroded in places; there are also goethite cubes (pseudomorphed after pyrite) in the dolomitised areas.

  Contact Cave also has a "popcorn line" below which aragonite is deposited. This may infer that air humidity may be an influence on the type of speleothems deposited, and whether supersaturation may be achieved with respect to calcium carbonate.

  The main chemical influences on aragonite at Contact Cave appear to be magnesium and manganese, and possibly phosphate.

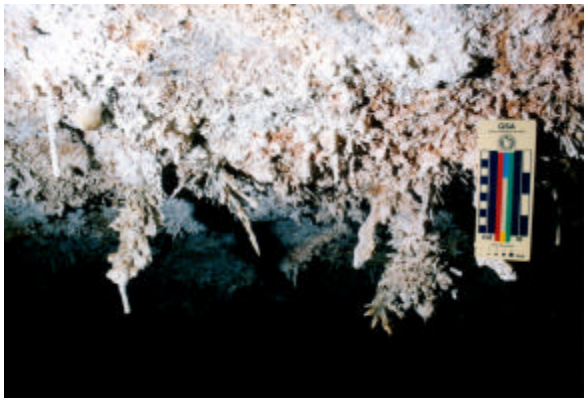


Figure 1 - Scene from Contact Cave showing various coated aragonite speleothems

- ***Mammoth Cave***
  Cavers' reports from Jenolan include M. Vizjak on Mammoth Cave's World of Mud Extension. This recently-discovered area of Mammoth Cave was still being explored and mapped by members of the Sydney Speleological Society up till the end of 2001 (Vizjak 1998b, Vizjak 1998a). Photographs of the site indicate that it contains fairly extensive deposits of what appears to be aragonite in the form ofanthodites and wall coatings. Some blue and green aragonite is present. During a visit to "The World of Mud" I saw what appeared to be aragonite anthodites, helictites and coatings. The areas visited were "Toms Kitchen" and part of the rockpile heading upwards from that area. Other cavers have reported gypsum ramshorns from higher in the deposit.

  Interestingly, aragonite also occurs in the lower rockpile of this large chamber, as a coating on large boulders. There is also a slightly blue flowstone ("the Blue Lady") and some unusual orange cave pearls in a side chamber. These are also possibly aragonite.

  The mud is unusually dark in some areas and appears to contain manganese oxides. In other areas it is almost red. Like Contact Cave, this part of Mammoth Cave is very close to the steeply-dipping limestone / shale contact and appears to be developed along the boundary.

  The bedrock appears to be highly corroded in places. As the shale contains a lot of manganese oxides, this is assumed to be the source of it in the mud; the corrosion may be from weathering pyrite. Some of the large helictites are almost black, presumably because of manganese oxides. Many have white efflorescences (assumed to be huntite and / or hydromagnesite). One such large helictite mass has about half a dozen branches, each about 400 mm long but only about 5 mm diameter. They are very dark brown. In this same area, aragonite "stars" protrude from red ochrous sediment at the ends of bedrock blocks.

  Another smaller dark helictite mass resembles a sea urchin. The spines are about 100 mm long and about 3 mm diameter. The tips are white with blobs of hydromagnesite, and each has a small growth ofaragonite at the tip, angled back towards the wall. This shows that the mass of helictites form part of a single speleothem with a common hydrological influence.

  One characteristic of aragonite is it is slightly harder than calcite. This may enable speleothems such as helictites to reach a greater length than is normally achieved with calcite.

  As the entrance to this part of the cave was dug out, it is unlikely that phosphates from bat guano would be present, however none of the "World of Mud" has been sampled so this cannot be confirmed.

  It would appear that chemical influences on the deposition of aragonite in this area are magnesium, sulphate and manganese.

- ***Other Caves at Jenolan***
  Although not analysed, there are speleothems in Spider Cave which appear to be aragonite. These occur in Helictite Chamber, as beaded helictites, anthodites and thickened straw stalactites. The substrates in this case appear to be rusty-coloured ochreous deposits. They occur in a relatively dry section of the cave.

  I have also visited Glass Cave (Jenolan) and described the aragonite anthodites therein (Rowling 1999). These are deposited on a rusty red and black coloured, porous substrate which looks superficially the same as that which can be seen in the tourist caves, in particular "The Jungle" area of Orient Cave. A grain from the floor, and moonmilk recovered from clothing, have been tested. XRD has confirmed the presence of aragonite, gypsum, phosphates and hydromagnesite.

  Osborne, Pogson and Colchester have been investigating minerals in the Jenolan Tourist caves. They reported aragonite from Ribbon Cave, the Mud Tunnels and other sites (Osborne, Pogson & Colchester 2002). The substrate is also being investigated. Their work is ongoing.

Cliefden
In a geological description of the caves at Cliefden, Osborne reported calcite which may have inverted from aragonite (Osborne 1978). The article also includes a description of the sample of a blue aragonite speleothem from Boonderoo Cave which is held by the Australian Museum. This was analysed and found to be blue aragonite coating a white calcite core. There is no description of the substrate from which it was taken. I have not visited this cave; access is not presently permitted.

In Turner (2002), Australian Museum samples of this material were analysed to find out what caused the blue colour. Metals detected in the blue material (apart from calcium) were copper, chromium, nickel, iron, zinc, strontium, barium, with small amounts of magnesium, lead and uranium.

Barite occurs both in the limestone and in the local andesite. There is an abandoned barite mine at Cliefden, about 500 m to the south of Boonderoo Cave, in the andesite.

Also at Cliefden, aragonite has been reported from Taplow Maze (cave) and from Murder Cave in the form of blue stalactites.

Colong
A deposit of what appears to be aragonite has been reported near the dyke in Colong Cave (R.A. Osborne, A. Pryke pers. comm.). Xray diffraction work by the author shows that this material is mainly calcite and clays, with minor aragonite, calcium silicates, phosphates and manganese. The spiky nature of the material was mainly due to needle-form calcite.

Bungonia
J. Bauer & P. Bauer reported aragonite in a cave at Bungonia, "The B4-5 Extension", but the specific site was not sampled so there is no confirmation that the material is actually aragonite (Bauer & Bauer 1998). R. A. Osborne has also reported (pers. comm.) *flos ferri* from Flying Fortress Cave (B17) at Bungonia. J. Bauer reports that the material in Flying Fortress Cave is aragonite, determined by XRD (J. Bauer, pers. comm.). I have visited the sites in Flying Fortress Cave, and it appears that the aragonite is associated with steeply-dipping, weathered dolomitic beds. This is in the fossiliferous Lookdown limestone, identified by J. Bauer. The forms taken by the aragonite include helictites (*flos ferri*), stalactites and spathites. The colour ranges from white to orange-brown and may be a mixture of calcite and aragonite.

A sample from near the dyke has been analysed using Raman spectroscopy and appears to be aragonite with a calcite coating, and hydromagnesite.

Jaunter
M. Scott (pers. comm. approx. 1989) has shown the author "Crystal Cave" with what appeared to be extensive deposits of aragonite in the form of large anthodites. This is in the Silurian Jaunter limestone at "Tarakuanna" (previously known as "Iona") in the Jaunter region to the west of Jenolan Caves. In this case, the aragonite was deposited below a porous, rusty coloured substrate, resembling a gossan. The property owner no longer allows access to this cave,

however there are plenty of photographs showing the range of anthodites present. The chemical influence on aragonite deposition in this cave appears to be magnesium, judging by the white material deposited on the ends of many of the anthodites.

Another cave in the same area, Tugellella Cave, is also said to contain aragonite but the aragonite is apparently nowhere near as extensive as in the "Crystal Cave".

Wombeyan
Cavers around the world have often mentioned hollow spheroids - "cave turnips", which often occur near cave entrances. They are briefly described in Hill & Forti (1997). At Wombeyan Caves, they are often found naturally broken. A Swiss caver has reported via the internet that the material inside these balls is aragonite but has not confirmed this.

I have visited sites with these spheroids at Wombeyan Caves (Sigma Cave and Cow Pit) (Rowling 1998b). These sites also appear to have aragonite deposits in the form of surface coatings. The surface coatings in Sigma Cave have been confirmed as being aragonite (by XRD) but the spheroids in Cow Pit are calcite. Under the microscope the material resembles aragonite. Some of the material from the "turnips" appears to have been influenced by biological activity. Either the deposit was originally aragonite and has reverted to calcite, or it was originally deposited as needle-form calcite. As the insides of these "turnips" appears to be mud with occasional white hydromagnesite and / or huntite one can guess that in some cases, aragonite may be deposited. Clearly more work needs to be done on these speleothems before an accurate assessment can be made.

- **Wollondilly Cave**
  Aragonite has been reported at Wollondilly Cave. There are four places of interest: an anthodite in "the Cathedral", spiky stalactite tips near "Star Chamber", fluffy and crusty coatings in "the Loft" and a spiky pool crystal deposit at the base of "Jacobs Ladder".

  The lower "Cathedral" anthodite is high on a ceiling and thus out of reach, however access is possible to the area about 15 m directly above the apparent aragonite deposit. This is called "The Loft". In "The Loft", there is a perched deposit of allogenic gravel and cobbles. Older speleothems have been corroded by bat guano. The grey crusty coatings here have been analysed with XRD; they contain calcite, aragonite, vaterite and various phosphates. Also in this area is a white fluffy material which is mostly needle-form calcite but also contains aragonite, phosphates, calcium silicates and hydromagnesite.

  The nearby "Star Chamber" spiky coatings are mainly calcite with huntite and hydromagnesite. The calcite grains appear to be recrystallised from aragonite. They are more brittle than normal calcite crystals.

  Although the spiky pool crystal at the base of "Jacobs Ladder" XRDs as calcite, it appears to be recrystallised from aragonite. There is hydromagnesite in the nearby clays, determined by XRD. Possibly in this pool, calcium carbonate can deposit either as calcite or aragonite depending on the amount of magnesium ions present in the pool solution.

  Another white deposit that looked like aragonite was sampled; this turned out to be calcite also. The chemical influences allowing aragonite to precipitate at Wollondilly Cave appear to be phosphate and magnesium.

- **Sigma Cave**
  Also at Wombeyan Caves, Sigma Cave is located towards the southern end of the marble deposit. A trip to Sigma was organised in 2002 to examine the aragonite in one part of the cave. Some material was sampled, including bedrock veins, pieces of anthodite, wall coatings and stalactite pieces. Much of the material sampled was from the floor, that is, it was taken from material already broken. Some small pieces of material were taken from the walls. The samples were analysed wth XRD, with interesting results. The aragonite samples taken from the wall were almost pure aragonite with traces of huntite and hydromagnesite. Their surfaces were spiky with good aragonite crystal form.

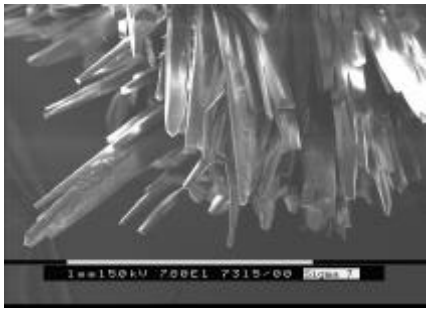


Figure 2 - SEM image of a number of aragonite crystals from the wall of Aragonite Canyon, Sigma Cave

The samples that had lain on the floor in the mud were a mixture of calcite, aragonite and calcium silicates (scawtite). The surface of these samples appeared to have been recrystallised. A fallen stalactite was sampled; it consists of layers of chalky phosphates, hydromagnesite, with crystalline aragonite and calcite. Most likely the phosphates are derived from bat guano. An interesting spathite (also broken) was examined. This comprised a hollow tube of aragonite, surrounded by twisted needles of aragonite. Longer needles (also aragonite) projected from the main shaft of the stalactite giving it a bottle-brush appearance.

It is suggested that the samples obtained by Webb and Brush at Wyanbene may have been altered to aragonite after they fell from the original anthodite, and this suggests that there is something special about the anthodite that keeps calcium carbonate precipitating as aragonite rather than calcite. In the case of Wyanbene, this is most likely to be magnesium-based chemicals such as hydromagnesite and copper-based chemicals such as copper carbonate which will poison a calcite crystal's development. In the case of Sigma Cave the chemical poisoning appears to be from phosphates and manganese, as well as from magnesium.

PRESENT KNOWLEDGE ON ARAGONITE OCCURRENCE IN CAVES

Association with Ochres and Gossans

In Slovakia there are extensive aragonite deposits in show caves. Some of these deposits are associated with "ochres" containing Fe, Mn and Mg eg. Cilek, Bosak, Melka, Zak, Langrova & Osborne (1998). Some of these deposits were ascribed to microorganism activity, especially the manganese-based compounds.

Another type of aragonite occurrence overseas is in conjunction with iron mines. In particular, the Styrian (Austria) iron deposits had world-renowned occurrences of aragonite in the form of tangled masses of helictites known as *flos ferri* (flowers of iron). There is a sample of this material in the Australian Museum, and it is aragonite as tested using XRD, according to the Minerals Curator, Ross Pogson (pers. comm.).

As there are examples of *flos ferri* in NSW caves the association of this form of aragonite with iron oxides and aragonite occurrence was investigated at Wyanbene (Rowling 1995) and the "Lyrebirds Nest" at Jenolan (Osborne et al 2002). Although it is tempting to say that iron may influence the precipitation of aragonite, it is more likely that the aragonite is precipitated under the influence of other materials such as magnesium, cobalt or manganese. Iron is not a recognised calcite inhibitor (Morse 1983). Iron is an extremely common element in cave sediments yet aragonite is not. The iron-rich sediments associated with aragonite are hard, yet porous, and it may be these physical qualities that make it possible for other chemical influences (eg. magnesium or sulphate) to dictate the form taken by precipitating calcium carbonate. In Rowling (1998a), SEM/EDX work performed by Maynard showed that ribbon helictites from Jubilee Cave, Jenolan, contained iron, however they were calcite, not aragonite.

There are several goethite deposits at Jenolan Caves. They occur either as massive deposits or as concretions. In-cave massive deposits include the western areas of Glass Cave where the aragonite deposits occur, Orient Cave and Ribbon Cave (also associated with aragonite). Concretionary

deposits in caves include the roof near the Diamond Mines area of Imperial Cave. Outside the caves, goethite occurs as nodules and concretions at Lucas Rocks, on the tourist track along the western margin of the limestone and as both concretions and massive deposits behind two of the houses on Burma Road. The latter deposit is associated with apparently weathered de-dolomite.

A similar but much smaller deposit occurs near Contact Cave on the eastern margin of the limestone. Thin sections show that the iron is associated with de-dolomitisation; basically as ferroan dolomite weathers, the magnesium seems to be released first, and this may be the local source of hydromagnesite at Contact Cave. What is left in the bedrock is porous iron oxides, forming diamond-shaped patterns after the original dolomitic texture. Different iron oxidation states colour the material variously from yellows and browns through to reds and black. The black areas also contain significant quantities of manganese oxides. Weathering is presumably enhanced by sulphuric acid from oxidising pyrite: also a good source of sulphate, eg. gypsum. At Contact Cave the de-dolomite contains small cubes of goethite pseudomorphed after pyrite.

Association with Magnesium
According to Morse (1983), magnesium is a significant poisoner of calcite crystal growth so it is not surprising to find aragonite being deposited at the expense of calcite in caves with significant amounts of magnesium.

In France, there are a number of outstanding caves with aragonite. In most cases, the aragonite is associated with areas of metamorphosed dolostone. Some of these French deposits are associated with gypsum and sulphur, and some with hydromagnesite. The aragonite was often associated with clays. Where there was no clay, there was no aragonite (D.W. Gill, pers. comm.). An unpublished report concerning these caves (Cabrol, Gill & Gunn 2001) has been circulated to interested members of the International Union of Speleology.

In South Australia, aragonite occurs in caves associated with dolostone (G. Gartrell, pers. comm.).

The relationship between aragonite and hydromagnesite has been described by others eg. Hill (1987) and it has been confirmed by XRD that in several caves at Jenolan, this relationship exists (Contact Cave, Glass Cave, Wiburds Lake Cave). Huntite in the tourist caves is also associated with aragonite (Osborne et al 2002). Other caves at Jenolan appear to contain magnesium minerals but they have not been analysed. Normally, dolomite and dolostone is more resistant to weathering than limestone however magnesium compunds can be released if the dolomite is subjected to strong acids such as sulphuric acid (from the weathering of pyrite), nitric and phosphoric acid (present in fresh bat guano). Both pyrite and bat guano occur at Jenolan, Walli, Bungonia and Wombeyan Caves.

Blue Speleothems
Aragonite in the form of blue speleothems occurs eg. the Blue Cave, France, (Hill & Forti 1997) in conjunction with deposits of heavy metals (eg. copper). This appears also to be the case with blue aragonite speleothems in some NSW caves such as at Cliefden and Wyanbene. The copper ion can form a solid solution in the aragonite crystal structure but not in calcite, where it precipitates instead as malachite or azurite separately from the calcite structure. Turner (2002) describes how copper is most likely the main heavy metal colouring in blue aragonite speleothems at Cliefden.

Influence by Sulphates
The author has visited several well-decorated caves at Mole Creek, Tasmania which contain aragonite deposits in the form of rock coatings, "donkey tail" stalactites, anthodites and helictites. These are in Gordon Limestone which contains magnesium carbonates and pyrite (I. Cooper, pers. comm.). These caves also contain deposits of gypsum.

Carlsbad Caverns and Lechuguilla Cave (Carlsbad National Park) contain extensive deposits of aragonite. This has been discussed in Hill (1987), Thrailkill (1971), Hill & Forti (1997) and well illustrated in Speleo Projects (1998). In these cases, evaporation is said to be the primary cause of aragonite deposition.

The caves at Carlsbad also contain significant deposits of gypsum and sulphur. There are two effects of gypsum in solution. One is the common ion effect, which causes calcium carbonate to deposit first in a mixture of calcium carbonate and calcium sulphate. The second effect is the crystal poisoning effect, where the sulphate molecule adheres to the growth points of the calcite crystal. This prevents calcite from depositing. Instead, calcium carbonate deposits as aragonite which is not affected by crystal growth poisoning by sulphate.

Independence to Biological Activity?
In the marine environment, aragonite is commonly produced as the result of biological activity (eg. sea shells) whereas in the spelean environment, biological activity has been implicated in calcium carbonate deposition as moonmilk (needle form calcite) and other calcite deposits rather than aragonite. It could be worthwhile comparing the microbial activity on aragonite speleothems compared with calcite ones in the vicinity. Biogenic calcite in the caves of the Nullarbor as described by Contos (2000) implies organic acids in the alteration of the crystal shape of calcite, but XRD indicates the mineral is calcite not aragonite.

The only examples of possible biogenic deposits seen by the author at Jenolan are some pasty "moonmilk" or hydromagnesite deposits. Where aragonite is associated with these deposits (eg. in Glass Cave, Jenolan), it appears to be secondary to the pasty deposit. That is, the aragonite appears to be deposited instead of conventional calcite as a result of the chemical influence of the pasty material.

Temperature Independence?
There are caves in Hungary which are hydrothermal and are reported to contain aragonite deposits eg. Leel-Ossy (1997). Temperature is said to aid the formation of aragonite however this is disputed by other researchers eg. Morse (1983).

In Australia, aragonite occurs in caves in South Australia, Western Australia, Tasmania and NSW, with average cave temperatures ranging from 8°C (Mole Creek, Tasmania) to 19°C (Cliefden and Walli, NSW). In NSW at least, temperature does not seem to be a factor in aragonite deposition.

Humidity and Air Movement
Cave climate (temperature and relative humidity) was measured at the study sites, however there was no strong correlation between these measurements and the presence or absence of aragonite.

At Jenolan, Wombeyan and Wyanbene, aragonite appeared to be concentrated in areas where a breeze can occur due to air movement in the cave, or where humidity could potentially be lowered due to the position of the site with respect to the entrance of the cave. It also occurred in areas where there is no air movement.

When the humidity was measured, it was usually over 98% however one site (The Loft) had relatively low humidity. Possibly if a high reading instrument were available, more meaningful results could be gained.

It should be noted that in each case where there was aragonite, there were chemicals present (eg. hydromagnesite) which would contribute to the development of aragonite.

The area of the cave with the lowest humidity and highest air movement is the entrance area, however aragonite was not detected there except in one case (Cow Pit), where it was a minor constituent of cave fill. Generally, calcium carbonate deposits near the entrance were as calcite, sometimes as needle-form calcite.

Effect Of CO_2
CO_2 concentration was measured at each study site using Draeger tubes. Some sites would be classified as "fresh air" whereas other sites visited measured 0.5%. There was no correlation between the CO_2 concentration and the presence or abscence of aragonite.

METHODOLOGY

The methodology being used to investigate aragonite is as follows:

- Literature search
- Visit field sites
- Obtain permission from site owners to sample
- Select field study sites
- Analyse samples
- Determine what factors lead to the deposition of aragonite in NSW caves.

Literature Search

A literature search was started in 1999 for all references to cave aragonite in NSW. There was not a great deal written on the subject.

Other sources of NSW material included cavers' trip reports. Personal observations from cave guides, other researchers and sport cavers were investigated. This led to the realisation that aragonite may be more common than originally thought in caves, especially at Jenolan.

The literature was examined on cave aragonites, and aragonite formation in general. There has been a lot of work done on the chemistry of aragonite in the marine setting eg. Bathurst (1974), also Tucker & Wright (1990) however for the spelean environment, a very good summary of references is Hill & Forti (1997). The best reference so far on aragonite chemistry kinetics is Morse (1983).

A list has been compiled of caves (based on trip reports etc.) which are reported as having aragonite.

Field Study Sites

From the list of caves said to contain aragonite, a short list was compiled of caves which would be relevant to this study.

Many of these cave sites have been visited to determine the extent of the deposit. Some of these sites have already been visited over the past 10 years.

Reported sightings of aragonite in caves have been checked, as some cavers report anything spiky as aragonite (could be gypsum, calcite, etc.). The only sites which were not checked were those which were considered to be either insignificant or extremely difficult to visit, either because of physical difficulty or landowner policy.

Three cave areas were identified as being worthy of further investigation to become case studies (i.e. they form the majority of the study work). These sites were identified as being relatively accessible both physically and with permission of the owner.

Study sites were chosen on the following basis:

- Ease of access to site
- Significance of aragonite at the site
- Preferably each of the sites is in different limestone deposits so that comparisons can be made of them.

Caves chosen are Wiburds Lake Cave and Contact Cave at Jenolan, Sigma Cave and Wollondilly Cave at Wombeyan, and Piano Cave and Deep Hole at Walli.

In some cases, there are samples of cave aragonite already held in museum collections so further sampling of aragonite at the original site was not necessary however sampling of the substrate and the speleothem water (if possible) was required. One of the problems the author has encountered is that the aragonite speleothems are often fairly dry. Museum samples have been located in the Australian Museum and inspected. There was little data associated with the samples apart from the general collection information (date, collector, region).

For each sampling site, small samples were obtained of aragonite material from the caves. Also samples have been taken of the substrate and the bedrock. The following investigations are being made of the aragonite in the field:

- What is the form taken by the speleothem, classified as per Hill & Forti (1997)?
- What is the CO_2 level at the site?
- What is the temperature at the site?
- What is the humidity at the site. Is there a boundary layer?

The following investigations are being made of the substrate:

- What is the physical relationship between the aragonite and the substrate?
- What is its structure (eg. sediment, dyke, speleothem, etc.)?
- Description of the material (eg. gossan, bedrock, etc.)

The following investigations are being made of the bedrock:

- What is its structure (eg. dip, strike, relationship to aragonite deposits, etc.)?
- Description of the material (eg. limestone, dolostone, etc.)

Field Work

Where museum or other samples were not available, field samples were obtained of:

- The substrate material (mud, rock etc.) on which the aragonite is depositing
- The host rock
- The aragonite (only a very small quantity is required).

Caves are non-renewable, fragile environments and it is important that sampling be done carefully without destroying the visual appearance of the site.

Photos and descriptions of the speleothems and their environment were made in the caves. In-situ measurements have been made of temperature, and CO_2 levels. Relative humidity was checked in the caves using a whirling hygrometer. If possible, samples were to be made of water from actively wet aragonite speleothems however during the course of this project none have been found in a wet state as NSW was in drought.

Cave maps were required. In some cases, very good ones were already available and just needed to be annotated however in other cases, the author made her own.

The geological setting of each study site is being described (where it hasn't already been done).

I also looked at paleokarst fills and prepared geological descriptions of the sites. In many cases it appeared that the best aragonite was to be found associated with these fills.

Sample Analysis

Thin sections and polished slabs of selected host rock material were examined using optical microscopy.

Most samples were analysed using XRD, using a Siemens D5000 diffractometer. Some soft specimens and wall deposits were examined using a Philips SEM505 scanning electron microscope. The substrate was checked for carbonate content by simple test with HCl. Substrate composition was determined by XRD.

For the aragonite specimens, the overall appearance was described and the material was determined to be aragonite (or not) using XRD.

WHAT THIS PROJECT WILL CONTRIBUTE TO KNOWLEDGE IN THIS FIELD

- A list will be compiled of caves in NSW which contain aragonite.
- Reported sightings of aragonite in caves will be checked and verified as to whether or not the material is aragonite.
- More information will be known about the type and composition of the substrates at these sites.
- The cave environment at each site will be described. (eg. temperature, humidity, chemical, physical and geological factors).
- Common factors leading to the deposition of aragonite will be discussed.
- Ideally, the extent and mode of formation of NSW cave aragonites will be determined.

APPENDIX - LIST OF CAVES REPORTED AS CONTAINING ARAGONITE IN NSW

(*cfm*): confirmed by XRD.

- Bungonia: B4-5 Extension; Flying Fortress Cave (*cfm*).
- Cliefden: Murder Cave; Boonderoo Cave (*cfm*); Taplow Maze.
- Colong: Colong Caves (*cfm*).
- Jaunter Limestone: "Tarakuanna", Crystal Cave.
- Jenolan: Ribbon Cave (*cfm*), mud tunnels (*cfm*), Orient Cave; Mammoth Cave; Glass Cave (*cfm*); Hennings Cave; Wiburds Lake Cave (*cfm*); Contact Cave (*cfm*); Spider Cave; Dwyers Cave.
- Timor: Hill Cave.
- Walli: Piano Cave (*cfm*); Deep Hole (*cfm*).
- Wee Jasper: Careys Cave; Nice Cave; Dip Cave.
- Wombeyan: Sigma Cave (*cfm*); Cow Pit (*cfm*); Guineacor Cave; Wollondilly Cave (*cfm*); Kooringa Cave; Blackberry Hole/Dutchmans Cave; Lantern Cave, Bullio Cave.
- Wyanbene: Wyanbene Main Cave (*cfm*).
- Yarrangobilly: North Glory Hole; Eagles Nest.

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Contact details
2 Derribong Place, Thornleigh NSW 2120.

Surface Tufa Deposits of the Leeuwin-Naturaliste Ridge

Jane Scott

The Leeuwin-Naturaliste Ridge in the far south-west of Western Australia is made up of very young, wind-blown (aeolian) limestone less than 2 million years old, which rests unconformably on a basement of hard, resistant, Precambrian granite-gneiss and other metamorphic rocks. While the processes of solution and deposition occurring here are essentially the same as in any limestone rock, the region features some unique karst which results from the young age and aeolian nature of the limestone, combined with the topography of the Ridge.

As the limestone was deposited in the form of huge sand-dunes which gradually consolidated, the pre-existing east-west drainage was generally maintained, and streams continued to flow through to the coast. However, the flow of water was impeded in many places, backing up into swamps from which water gradually seeped westwards through the base of the limestone. This water was (and still is) aggressive due to its high content of carbon dioxide from the air and from soil acids, and it has carved out many cave systems en route to the ocean.

Tufa is the common name given to calcium carbonate which is re-deposited from solution in water saturated with carbon dioxide. As water, containing dissolved carbon dioxide from the air, and from plant respiration and decay in the soil, travels through limestone strata, calcium carbonate is dissolved and held in solution as calcium bicarbonate. When this water emerges again into the open air, either in caves or as surface springs, changes in environmental conditions can cause the carbonate to be re-deposited.

As cavers, we are familiar with stalactites, stalagmites and other calcium carbonate deposits in caves, but are maybe not so aware of the tufa deposits that occur at surface springs. These springs and seepages emerge along the Capes coast at the junction of limestone and the impervious granite-gneiss rock beneath. The tufa deposits which form around them vary from a thin veneer, to massive cliff features, such as those at Quarry Bay and Meekadarabee.

Thin sheets of tufa coat the granite in many places, and form cement around water-worn boulders, for instance on the boulder beach north of Gracetown. Tufa covers the sloping granite rocks at the southern end of Foul Bay, and at Cosy Corner. Some of it is still active in winter, while a large area has not been replenished for a long time. At a larger spring near Kilcarnup, a long, thick raft of tufa has built up over the sand where the water trickles down to the sea. Adjacent deposits, which are now dry, show how the stream has changed course over the years.

The most spectacular tufa outcrops occur where the spring water falls over a vertical drop. At Quarry Bay, near Augusta, and at Meekadarabee Falls, near Ellensbrook, substantial deposits have built up from spring water trickling over a cliff face, allowing carbonate to accumulate gradually. At Meekadarabee, the whole of the cave has developed in a huge tufa deposit, formed over thousands of years from the spring which emerges from the north side of the valley.

The incorporation of vegetative material helps provide a framework on which the mineral can be laid down. The part played by mosses, twigs, roots and leaves can clearly be seen if you look closely at the cliff sites, where complex, overhanging, bell-like shapes have slowly built up as water trickles over the vegetation. Various types of algae are found growing in the lime-rich spring water where tufa forms over beaches and rocks, and these also become incorporated into the deposits. Photosynthesis by aquatic plants, which extracts carbon dioxide from the water, may accelerate the deposition of calcium carbonate.

The role of microorganisms in the formation of carbonate deposits is complex. In several localities, eg. north of Quarry Bay, south of Conto's Beach and below the spring north of Canal Rocks, superb rimstone pools have formed. These pools become very special minature eco-systems, which contain a host of algal and bacterial species, unique because of the high carbonate content of their environment, and high salinity due to their proximity to the sea. A fascinating feature of these pools, is the growth in them of tiny stromatolites. These rock-like structures are built up by a combination of

the growth of cyanobacteria (formerly known as blue-green algae), and the precipitation of calcium carbonate from the water. They appear as small nodular concretions in the pools.

Stromatolites belong to a group of organisms known as microbialites, and are among the oldest lifeforms on our planet. They are complicated beasties, despite their formation by simple organisms, and they grow in a variety of ways. Those found at Lake Clifton, which are known as thrombolites, for instance, have quite different structures to the stromatolites found at Shark Bay. Those found along the Capes coast are particularly significant, because their intricate, finely-layered structure is similar to that of fossil forms, which grew millions of years ago in the Precambrian period, when stromatolites were the dominant life-form on earth. This type is apparently very rare amongst living stromatolites today.

I hope that this short introduction will generate interest in the unique tufa deposits that occur along the coastline of the Leeuwin-Naturaliste Ridge. If we become more aware of these fascinating and unusual formations, and learn more about them, we will hopefully look after them, and treat them with the respect they deserve.

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Contact details
C/o Post Office Witchcliffe WA 6286.

Caves under your House

Paul Tholen

The difficulty in managing caves within the metropolitan area is that people generally only know about what they see. To most, the natural environment encompasses trees and other plants, birds and the occasional lizard. In Yanchep National Park, there are also kangaroos, koalas and a beautiful golf course, with the caves, Crystal and Cabaret (as mentioned on the map), isolated natural features. This is actually quite comforting for most because the thought of snakes in the backyard, birds of prey in the neighbour's tree or caves underfoot is a thought that many would not be too keen on.

Caves in the backyard would make many people worry if the reality of the situation became known. The northern creeping arm of the Perth metropolitan area now extends into karst areas within Quinns, Emerald Valley and Sea Trees, all areas that also contain karst features. When we look at a map of Western Australia, it is evident that as a band of limestone extends into the southwest along the coast, so it is here that Western Australia's population will extend because people have a great desire to live by the ocean. With people now building in karst areas, a cycle of events has turned full circle in that the original human inhabitants (the Nyungar aboriginal tribes) were quite wary of dark places containing caves in the Yanchep area.

When looking into the pulling of resources from caves in Yanchep and Wanneroo, we find that the process actually began several decades ago with the mining of guano and limestone. More recently, the abstraction of water for timber, vegetables, drinking water and gardens has also had an impact which, coupled with lower than average rainfall, has led to a decline in the waters within the Yanchep caves.

These single events, added together over time, are having such an impact upon the karst systems of the Perth metropolitan area, that animal species as well as caves have the potential to be lost to future generations.

In looking at building in karst areas, corporate developers put together concept plans containing a summarised brief on the karst systems within an area, which are initially produced by local speleologists. Presented for comment to the EPA (Environmental Protection Agency), CALM (the Department of Conservation and Land Management), the Water and Rivers Commission, Local Government and the public, Local Government generally approves the plans with additional guidelines outlining areas of interest and the project proceeds. Where the development borders CALM land, and where there is a possibility of biodiversity being compromised, CALM can have more of a bearing on proceedings. CALM has the option of adding further constraints, and/or will consider land acquisitions as an extreme measure. Lot 51 (Wanneroo/Perth) is one such development that is currently under such consideration. The block of land is relatively small and the potential impact on surrounding karst and remnant vegetation is high. A very good submission was made for rural development, which has scope for sectioning off a reserve, but further investigation is necessary before the full impact can be assessed.

Without such a described threat, the resulting effect on a karst system may be very different. From the complete destruction of a cave through filling with concrete or collapsing with heavy machinery to substantial and partial deterioration with rubbish dumping and the taking of souvenirs, to good caving practices by segregating and fencing, the destiny of a karst system in a developing area is great and varied. When it comes down to the individual making his or her claim on a block containing caves, I have found that many of those lucky enough to obtain such a feature have taken a strong stand in saving their cave for future generations. Fears of collapse and instability sometimes play a part in sectioning off the karst area, but many are finding that through a little investigation and research by entering the caves of the Yanchep National Park, these fears are diluted. Upon seeing formations that have been growing for periods ten times longer than the pyramids have stood, or a thousand times longer than the longest standing building in their area, people realise that cave are not the unstable, dangerous places they once thought they were.

Putting these educational messages to the public is the result of a great deal of research by past rangers and students. With Dr Edyta Jasinska, Dr Brenton Knott, Dr Andrew Storey, Mr Rob Foulds, Mr Lex Bastian and Mr John Wheeler to name a select few of those continuing to research the geological, hydrological and biological elements of the Yanchep karst systems, discoveries including historical changes and new species identifications are being achieved. These people on the ground believe there is more life yet to be discovered in the caves of Yanchep and that the importance of keeping the ecosystems alive for further study is of the utmost importance. One such important factor recently discovered is that root mats from the tuart trees above (*Eucalyptus gomphocephala*) are being produced in the shallow caves to support a mycorrhizal fungus, which acts as a food source and habitat for entire communities of aquatic invertebrates.

With a loss of groundwater in this area now having these animals under threat, a joint effort between CALM, the Water and Rivers Commission and the Water Corporation has been progressing to reinstitute water into several important cave systems. Trials have been continuing since late 1999, with a recovery team guiding emergency action within the isolated caves of Twilight, Carpark, Cabaret, Boomerang and Crystal and more robust trials within Crystal and the Ornamental Ponds.

The emergency actions have seen solar panels and enclosed 12-volt car batteries providing power to pumps in localised soak-wells. These pumps send water to lined areas containing root material within which survive these unique communities. Investigations throughout the world have indicated that the primary food source of the roots, the mycorrhizal association within and the groundwater streams flowing through the caves are vital to produce both the large numbers and great variety of species being seen. A need to develop groundwater resources for public use whilst maintaining species richness has led to the three government bodies becoming involved together and determining responsibility for collecting information and sharing resources to develop strategies for the long-term conservation of the caves.

Attempts have been undertaken to directly recharge Crystal Cave with appropriate waters as indicated through biological, physical and chemical parameters. Following on from this is the current project for re-flooding the Ornamental Ponds in the vicinity of Cabaret and Boomerang Gorge stream caves to aid in the recovery of streams in these root mat caves and others in the area. By placing water into an area downstream of the caves, a mound is developed and water banks up. In this manner, streams can be created throughout an entire area rather than in single caves.

There are several reasons being suggested for the lack of water in the Yanchep caves and none are as simple as the natural reduction in rainfall Western Australia is currently experiencing. Because higher rainfall relates directly to higher groundwater levels, it would be convenient to disregard the influences of pine trees, abstraction for market gardens and abstraction for Perth's drinking water supply. Although individuals may query the extent to which each factor is having an influence, the major governing bodies continue to work together to research historical levels, develop models and put in place infrastructure to resolve the issue of continuing degradation of caves, be they natural or not.

Karst Features in Pleistocene Dune Limestones, San Salvador and New Providence Islands, the Bahamas

Susan White and Nicholas White

INTRODUCTION

The Pleistocene karst islands of the Bahamas have many similarities with the Pleistocene dune karst areas of Australia. This article describes these features and their similarities and differences.

In 2001 we were able visit a limited number of the karst islands of the Caribbean and the western Atlantic. The observations in this paper are based on fieldwork in the Bahamian islands of San Salvador and New Providence and the extensive literature published through the San Salvador Field Station.

REGIONAL SETTING

The Bahama Islands are part of a long archipelago of carbonate islands and shallow banks extending to the south east from just off the coast of Florida parallel to the main islands of the Caribbean, Cuba and Hispaniola in the Western Atlantic Ocean (Figure 1). The northwestern Bahamas Islands are the landmasses isolated above sea level, of the large carbonate platforms, Little Bahama Bank and Great Bahama Bank. The carbonate banks are at least 10m deep. Southeast of these, the Bahamian islands such as San Salvador are small isolated platforms capped by islands (Carew et al 1996). There are 29 carbonate islands and 66 cays. The islands are predominantly low lying, up to 30m ASL with topography dominated by aeolianite dune ridges.

The origin of the Bahama platforms has been the subject of many debates in the scientific literature and has evolved into two main theories. The "graben" hypothesis explains the present pattern of banks, troughs and basins as inherited from the rifting associated with the plate tectonics of the western Atlantic since the Mesozoic (eg Mullins and Lynts, 1977). The competing "megabank" hypothesis (eg Ladd and Sheridan, 1987) maintains that the area is a segmented remnant of a much larger Mesozoic carbonate platform. Later work by Mullins and Hine (1989, 1990) indicated that the Bahama banks are undergoing both depositional progradation and erosional segmentation. Despite previous tectonic activity, they are currently stable and subsiding very slowly ie at 1-2m. per 100ka or less (Carew and Mylroie, 1995b). Most of the published geological work is related to the carbonate banks and related deep-water environments and the subaerial geology of the islands is less studied. The work associated with the Bahamian Field Station, San Salvador, the regular symposia on Bahamian Geology, and the work of Mylroie and Carew and their students has at least partially rectified this. The Bahama banks (Great Bahama and Little Bahama Banks) are used extensively as modern analogues of ancient carbonate deposition models (Enos, 1983).

The basement geology underlying the present islands is either composed of tilted fault blocks of mid Jurassic volcaniclastics or oceanic crust. This is overlain by a Late Jurassic carbonate “mega bank” and Late Cretaceous shallow water carbonates. Post Cretaceous faulting of these is due to interaction between the Caribbean and North American Plate. Periods of Tertiary aggradation and progradation occurred in response to sealevel change and sediment production and there is evidence of sediment type transition from the Pliocene (Beach & Ginsburg, 1980).

The area is subject to a subtropical temperate to semi arid climate with an average temperature range of ~ 18° C (Jan) to 28° C (July) and an average annual rainfall in the northern islands, of ~ 1300mm. The area becomes more arid in the southern islands. Hurricanes are common in summer.

The islands were previously heavily vegetated with a mixed tropical broadleaf coppice. Pine barrens with palmetto now largely covers the Northern Islands eg New Providence. The dune ridges common on many islands are covered with thick scrub.

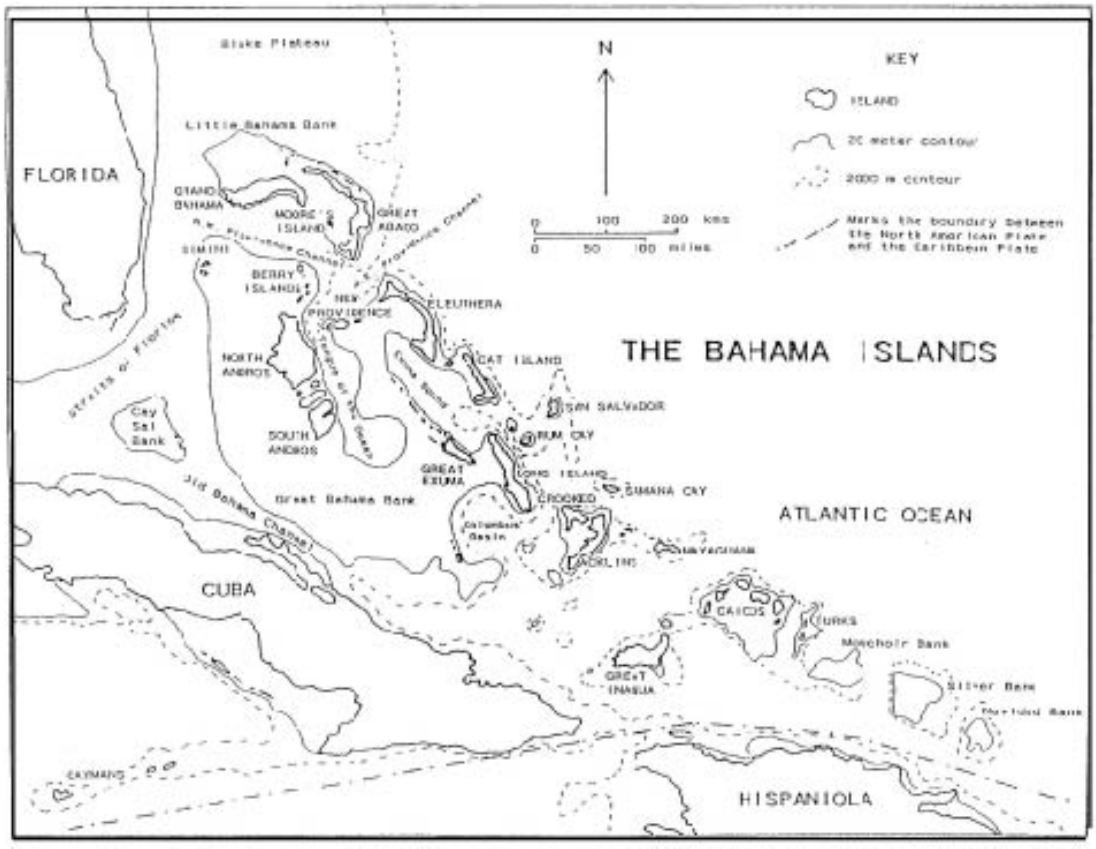


Figure 1 - Map of the Bahama Islands and surrounding areas, detailing islands, banks, and deep-water troughs (Carew et al 1996)

PLEISTOCENE GEOLOGY

The surficial rocks of the Bahamas are Late Pleistocene and Holocene oolitic and aeolianite carbonates. The sea-level fluctuations of the Pleistocene alternately flooded and exposed the carbonate platforms and subjected them to cycles of carbonate deposition and dissolution (Carew et al 1996). The sequences of carbonate sediments can be regarded as individual packages deposited at each sea-level highstand and separated by erosional unconformities, usually marked by palaeosols, from the sealevel low stands (Carew & Mylroie, 1995a). The present sea level is sufficiently high that the only marine deposits exposed on land now are those associated with the highstand of oxygen isotope substage 5e (c. 125 ka), which was about 6m higher than present sea-level (Carew et al 1996). Earlier highstand deposits were either not high or extensive enough, or occurred too long ago to be preserved. The aeolianites (dune limestones) however, show evidence from several past sealevel highstands.

The most complete sequence of deposits is preserved from the highstand substage 5e. A general model for the deposition and stratigraphy was developed by Carew and Mylroie in the 1980s, using San Salvador, but it has been applied successfully to other islands eg Carew and Mylroie (1989°), Wilbur (1987, 1991), Kindler (1991, 1995). Carew and Mylroie, with others, have modified this model as new data has become available eg 1989b, 1994a, 1995a, 1996, 1997. An example based on this model is shown in Figure 2.

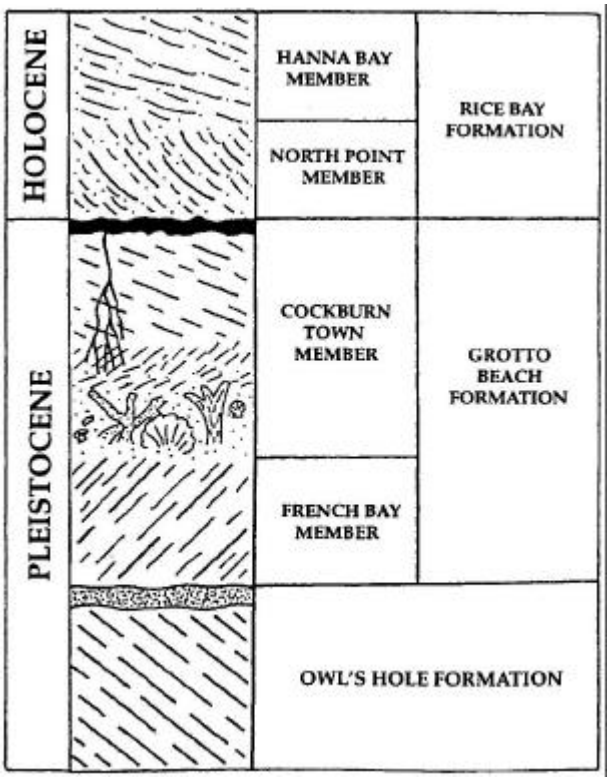


Figure 2 - Stratigraphic column for the Bahamas, illustrating the temporal relationships between units. Actual field relationships are rarely vertically stacked and are usually laterally adjacent (Carew and Mylroie 1995a)

The Pleistocene aeolianite dune ridges formed during all phases of the sea level highstands dominate the surface geology. They are up to 30m above present sea level and are composed of crossbedded fine dune sands (Figure 3). Calcrete often forms on the surface. Terra rossa palaeosols are evident between the dune sequences.



Figure 3 - Pleistocene aeolianite ridge with thick scrub vegetation and saline lakes, San Salvador

Aeolianite features include impressive dune cross stratification and older solution and infill features (Figure 4). Excellent exposures of crossbedded dunes can be found on both San Salvador and New Providence islands, often in road cuttings (Figure 5).



Figure 4 - Solution and infill features, coastal cliff, New Providence Island

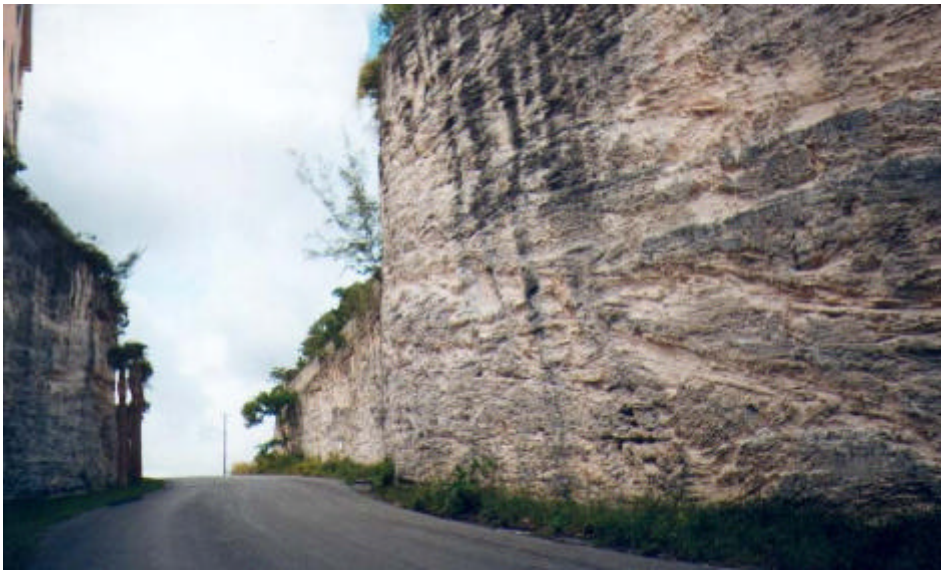


Figure 5 - Dune cross bedding, road cutting, New Providence Island

The Holocene lowland areas of the islands are composed of marine and terrestrial sediments. Sometimes these are currently below present sealevel. Most distinctively, they have no calcrete or terra rossa soil. Interdune swales, shallow lakes and swamps are common. Many of the lakes and swamps are hypersaline (Figure 6).



Figure 6 - Hypersaline Storrs Lake, San Salvador. Note the saline tolerant vegetation in foreground

KARST FEATURES

Dissolution is the predominant process influencing post depositional change on the islands. Karst features include a variety of caves and pits (or solution pipes), blue holes, notches and minor solutional features. Review papers on Bahamian karst can be found in Mylroie and Carew (1995a), Carew et al (1996), and Panuska et al (2002).

The major cave type is a Flank Margin Cave, which formed in the freshwater lens under the aeolianite ridge. The fresh water lens floats on the denser seawater that permeates the subsurface. Dissolution occurs where fresh and salt water mixes. Variations in lithology means that the ideal lens shape rarely if ever occurs, but the model (Mylroie et al 1995, Figure 7) is a functional approximation of the relationship between fresh and salt water in an island setting. Mylroie and Carew have developed the flank margin cave model over many years and a detailed discussion of the model and its use in describing the island dune karst can be found in Carew et al (1996) and Mylroie et al (1995).

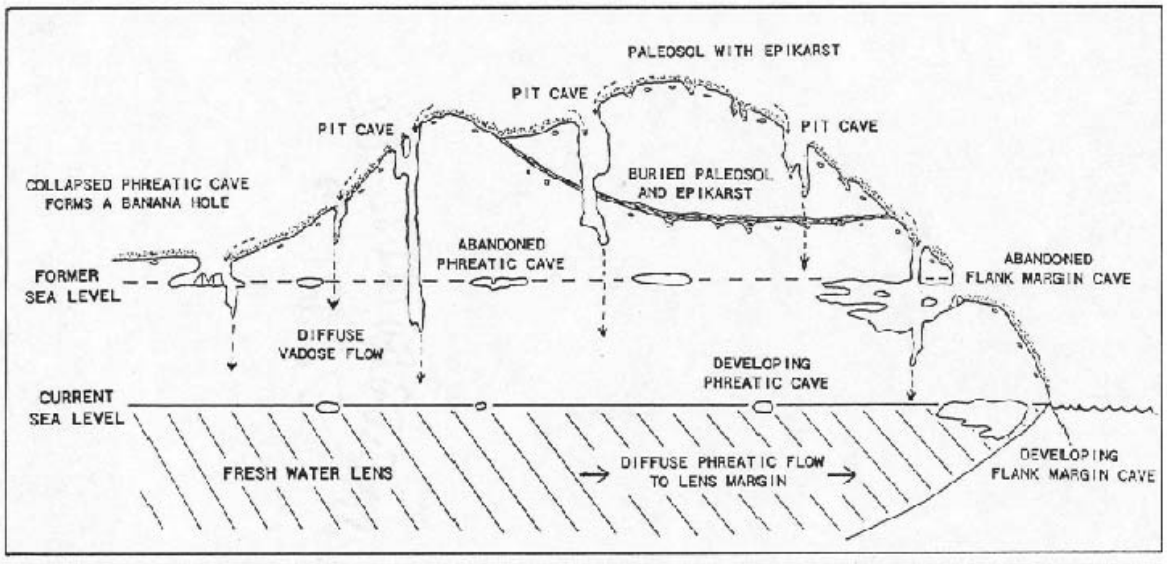


Figure 7 - Diagrammatic representation of the freshwater lens within a typical Bahamian island, showing the epikarst, pitcaves, banana holes and flank margin caves
The last interglacial sealevel highstand versus current sealevel position, and various karst features produced, are shown (from Mylroie et al 1995).

During the Pleistocene, when sea levels were at higher or lower levels than at present, the freshwater lens would have also been related to sealevel. Solution occurred at those levels and is represented now by either stranded or flooded older cave systems. The stranded caves have been described as "dry phreatic caves" (Carew et al 1996) as they formed below the water table but are now dry and well above current water table. The flooded systems are caves that are flooded by modern sealevel and are often accessed via Blue Holes (Mylroie et al 1995). A few are undergoing dissolution at current sealevel conditions eg Lighthouse Cave, San Salvador (Figure 8).



Figure 8 - Lighthouse Cave, San Salvador

Blue Holes are pits extending below sea level for most of their depth and are flooded karst features of polygenetic origin. There are two types:

- ocean holes in open ocean or tidally influenced lagoon containing marine water; and
- inland holes with surface water from fresh to marine and which often change chemistry at depth.

The blue holes are the result of several different processes. These include the flooding of vadose shafts or pit caves, collapse to the surface from deep phreatic cave and fractures produced by bank margin collapse (Carew et al. 1996). Watling's Blue Hole, San Salvador (Figure 9) is an example of the pit cave flooding process.



Figure 9 - Watlings Blue Hole, San Salvador

Pit caves and solution pipes are common and particular areas have concentrations of such features. A spectacular concentration of pit caves is found at the southern end of San Salvador where a large variety of solution pipe features are found (Figure 10). These are very analogous to the solution pipe features in the Australian aeolianite karst areas.



Figure 10 – Pits, San Salvador

The open shallow hollows or banana holes often contain a notch and sometimes a small overhang cave. The name banana hole comes from their use as banana growing sites. The banana holes appear to be the result of several processes. In some cases they are the result of solutional modification of the interdune swales and in other cases the consequence of collapse of the roof of a very shallow cave such as Garden Cave (Figure 11). The limestone is extremely pure, unlike Australian equivalents, which have a substantial silica component. The banana holes are therefore one of the few areas where soil has developed on the dune limestone as the aerial deposits of fine silt from the other side of the Atlantic combine with organic matter.



Figure 11 - Garden Cave near the San Salvador Field Station

As well as the major caves and karst features there are many minor solutional features. These include notches (Figure 12) and karren of various types. Usually aeolianite does not develop karren type features well but coastal phytokarst can be found in many areas eg Grotto Beach (Figure 13).



Figure 12 - Grotto Beach



Figure 13 – Phytokarst, Grotto Beach

SPELEOGENESIS

Karst development on the Bahamian islands can be seen in the model outlined in Figure 7, which shows diagrammatically the main aspects of speleogenesis. The freshwater lens floats on denser salt water and this freshwater lens follows sea level in position. During past high sea levels the freshwater lens was as high or higher than today. Solution occurs in the phreatic zone of fresh water due to the mixing corrosion process during mixing of salt and fresh water. As sea level fell the caves are abandoned and dry. Blue Holes lead to flooded caves formed at lower sea levels.

Abundant carbonate sediments are deposited during high sea levels and landforms are dependent on sea level position. Banana Holes, flank margin caves and lake drains develop in the freshwater lens and Banana Holes and flank margin caves that are now dry, were formed c.125,000 years ago when sealevel was about 6m higher than at present. The purity of the limestone has serious implications for absolute dating of the dunes, as the luminescence methods that rely on the quartz fraction are inappropriate. Much of the dating as a result remains controversial especially dates involving the use of the amino acid racemisation dating method (see Panuska et al 2002). Pits, karren and epikarst form on subaerially exposed limestones.

The Flank Margin Caves show some features of syngenetic karst whereby after an initial lithification of the dune, cave and karst development occurs simultaneously with continued diagenesis and lithification of the sediments. In general the karst of the Bahamas is not as old as similar karst in southern Australia eg. Otway Basin and Southwest WA.

DISCUSSION AND CONCLUSIONS

Similarities occur between the Bahamian Late Pleistocene karst and the Pleistocene dune karst of Australia. The forms and shape of karst features especially caves are similar; there are few speleothems; collapse is common and solution pipes (pit caves) and features such as soil pipes are common in specific areas. The overall landscape is very similar in appearance despite the subtropical climate.

However three major fundamental differences in the setting are important:

- The limestone has almost no non-carbonate fraction. In comparison to the southern Australian aeolianites where the quartz fraction can be as high as 60%, and is almost never below 5%, the very pure marine oolitic limestone source rocks have resulted in almost pure carbonate dunes. This has made the lithology in the Bahamas difficult to date, as the usual luminescence methods are inappropriate. The major source of quartz is fine windblown dust from the Sahara many thousands of kilometres to the east.

- The age of the current limestones has been generally determined as much younger and is estimated as being about 125,000 years old. The extensive older aeolianites, such as the well-dated series in the Otway Basin are not present.
- Finally, the tectonic setting is greatly different. The Bahamas are an island setting and not a continental margin like the southern Australian equivalents. Although southern Australia is not as tectonically active an area as New Zealand, gradual and measurable uplift of the continental margin has occurred during the Pleistocene which complicates the sealevel story in southern Australia.

These give important variation to karst formation in young and relatively soft limestones. The understanding of speleogenesis in aeolianites can tell us a great deal about the overall processes.

Finally, the Bahamas are a fascinating place to look at karst development and have interesting parallels with similarly young Australian karst.

ACKNOWLEDGEMENTS

We would like to thank the staff of the Bahamian Field Station, San Salvador. Special thanks are due to the Director Vince Voegeli who made our stay on San Salvador enjoyable. Neil Sealey Nassau is thanked for his generosity and extensive knowledge of the Bahamas, which he shared with us. Thanks to John and Joan Mylroie, Mississippi State University gave us a wonderful welcome to Mississippi and shared their enthusiasm for aeolianite karst. We hope that one day we can show them all the dune karst of Australia.

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Contact details
123 Manningham Street, Parkville VIC 3052.

Presenter Photographs











Clockwise from top left: *Jane Scott; Jill Rowling; Lex Bastian; Susan White; Ken Boland.*

*Protecting the Intellectual Property in Cave Site Locations**

Sandra Boulter

INTRODUCTION

From the little I know (EDO WA Cape Range litigation on behalf of the ASF) it appears that Western Australia is a speleologist's paradise. I understand that many cave site locations are not publicly disseminated because of the risks posed to fragile cave ecosystems by vandals, thieves or well intentioned but uninformed amateurs. The question is then raised:

How can cave site locations be secured against unwarranted inexpert invasion?

My paper today provides a brief overview of two protective mechanisms - copyright and confidential information - and follows with a management strategy to forestall unwanted requests for cave site information. (I note in passing that there is no Privacy Act in Western Australia and the *Privacy Act 1988 (Cth)* applies in WA only to corporations.) (I also note in passing that any proposal to enter a cave that might cause significant harm to the cave or its environs can be referred by any person to the EPA for environmental impact assessment[1].)

What is intellectual property law?

Intellectual property law is a group of legislative[2] and common law[3] rights affording protection to creative and intellectual effort. It includes laws on copyright, confidential information, design, patent, circuit layouts, plant varieties, trade mark and business reputation[4]. On general intellectual property principles the holder of cave site locality knowledge would own that factual information but having disclosed the information to a caving group such as WASG, the information would belong to both parties. However, the knowledge itself is neither real nor personal property which can be protected at law[5]. What can be protected is the dissemination of knowledge by the reproduction of works that record knowledge or protection of knowledge that is imparted confidentially. The ownership of a record of factual information and the issue of confidentiality are two separate legal issues.

COPYRIGHT

Copyright is one facet of intellectual property law. Copyright protects the expression of ideas but not the idea itself. Copyright is thereby a protection of the form of expression of an idea[6]. Copyright is personal intangible property which allows the copyright owner (or those authorised by the copyright owner) the exclusive right to prohibit or do certain acts.

In Australia copyright is governed by the *Copyright Act 1968 (Cth)*[7]. Material is protected if there is a connecting factor between it and the *Copyright Act 1968 (Cth)* (the Act). There is no requirement for registration or notice of copyright, for copyright to subsist in a work. Copyright protection is automatic from the moment the subject matter is embodied in a material form. Copyright may subsist in original unpublished or published *literary works*[8] . A literary work is a type of work which is intended to convey information or instruction, or which is intended to afford literary enjoyment[9]. A literary work for the purpose of the Act does not require literary merit[10]. A written record or map of cave site locations can be a literary work for the purpose of copyright protection under the Act[11].

How is a map or record made by a caving association protected by copyright?

If a caving group through an exercise of intellectual skill, professional knowledge or opinion makes a composite record (such as a map) of cave sites identified by its individual members, the caving group would own that composite record[12]. Ingenuity in the compilation of the cave site record may be another factor contributing to it obtaining copyright protection[13]. Incorporated associations can own property[14]. As owner of the copyright in the record, the caving group would have the exclusive right to reproduce the information in any material form[15]. It is the copying of the record or map which would be an infringement of copyright under the Act.

The legitimate use of such records should be identified in the constitutions of caving groups along with what will and will not constitute a breach of copyright. Furthermore, records and map should be marked that they are copyright and in whom the copyright subsists.

CONFIDENTIAL INFORMATION

Confidential information can be an intellectual property right which is protected by common law principles. Confidential information is made up of facts or knowledge that is not in the public domain. Information in the public domain cannot be confidential but a combination which draws together separate pieces of information in the public domain[16], resulting in something different may be protected[17]. The range of information which has been protected by actions for breach of confidence is very broad. Information may be simple or of little commercial value but nonetheless constitute confidential information[18]. Confidential information may be disclosed by oral communication and this may be sufficient to impose an obligation of confidence[19].

> *"…information which on its own is public knowledge may be confidential between the two parties where the information is associated with a particular context and the confidant knows or should know that the association of the information with the context is a matter if special significance, peculiar sensitivity or confidentiality…"* [20].

Furthermore, possessors of confidential information are often subject to fiduciary duties which prevent them from misusing the information for their own advantage[21]. A fiduciary relationship is a relationship of trust and confidence[22]. The critical feature of the fiduciary relationship is that the fiduciary agrees to act on behalf of another person in the exercise of a power or discretion which will affect the interests of that other person in a legal or practical sense[23]. Clearly, associated caving groups are in a fiduciary relationship with their members[24].

> *"…In the vast majority of cases…the duty of confidence will arise from a transaction or a relationship between the parties…it is well settled that a duty of confidence may arise in equity…"* [25]

Thus equitable remedies to restrain or for damages for the unauthorised dissemination of confidential information may be available to caving associations or their individual members.

An action will lie in certain circumstances to prevent a breach of confidence or to compensate the creator of the confidential information for the consequences of unauthorised use or disclosure of confidential information[26]. To establish a cause of action against a breach or proposed breach of confidence, a complainant must show:

- that the information has the necessary quality of confidence; and
- the defendant owed a duty of confidence to the complainant.
- furthermore, it is likely that it will be necessary to show that some prejudice to the complainant's interests must or will occur as a result of the breach of confidence[27].

There are a number of defences to excuse conduct that is a breach of confidence and one of these is disclosure in the public interest[28]. Even when disclosure of confidential information is required for example, by a statute or court order, an action may lie if the information is used by the recipient for some other purpose[29].

Are cave site locations confidential information that is protected by the common law?

When confidential cave site information is disclosed by individual members of a caving association to that association which in turn reduces that information into a record or map held by the association, the member who provides that information should expressly state that the information is confidential and how the information might be used.

Equally the recipient association should disclose to the member providing confidential information how the information will be treated and under what circumstances it will be disseminated. Clearly it is important that the constitution of each caving body outlines how confidential cave site information will be treated and disseminated.

MANAGEMENT STRATEGIES

WA Caving Associations

In Western Australia I understand that there is the:

Speleological Research Group Western Australia Inc. (SRGWA) which is incorporated under and has a Constitution and Rules of the Association[30]. An incorporated association under the Act means that the affairs of the group are regulated by the Act and its constitution and rules (and any changes thereto) must be approved by the Commissioner for Consumer Affairs[31]. Through its Rules the SRGWA has adopted the Code of Ethics and Minimal Impact Caving Code produced by the Australian Speleological Federation Inc. (ASF). There is no specific affiliation of the SRGWA with other caving groups identified in its constitution or rules but I am informed that it is a member of the ASF.

Western Australian Speleological Group Inc. (founded in 1958) (WASG Inc) is also incorporated[32]. The objects and rules of WASG are outlined in the Constitution and By-laws of the Group. WASG Inc.'s identified as a Full Council Member of the ASF.

Cavers Leeuwin Inc. (CLINC) is a subgroup of WASG, its members are WASG members but it is separately incorporated[33] with its own formal constitution which identifies CLINC as an affiliate of WASG.

The three associations each include as one of their objects *"…to foster preservation…"* of WA caves. WASG Inc qualifies this object by saying that it will be in cooperation with other interested organisations. It is arguable that the object to foster cave preservation would support a decision to suppress a cave site location ensure its preservation and accordingly, suppression of the information would be consistent with the objectives of each of the organisations.

One of WASG Inc.'s objects is to publish results of its investigations if suitable: By-law 10.4. The Constitution is silent as to the meaning of *"…if suitable…"*. Any member of WASG Inc is entitled to inspect the WASG Inc records: Constitution, at clause 18. The Constitution is silent as to what purpose such inspection can be for. The WASG constitution requires the State Cave Recorder appointed by WASG Inc to publish cave area lists: By-law 10.4. *Publish* is not defined and the By-law is silent as to whom the information should be published. Accordingly, it is likely that the ordinary meaning – to make public – would apply. The WASG Inc By-law 11.0 pertains to copyright in information obtained on field trips and provides that copyright to this information does not subsist in the WASG Inc. However, it does not identify in whom the copyright (of WASG Inc.'s information) subsists. Furthermore, By-law 11.0 does not identify what information is held by WASG Inc in which copyright in favour of WASG Inc.

The WASG Inc Map Curator and SRGWA librarian are responsible the maps held by their organisations. The WASG Inc Map Curator may sell copies of or lend maps at his discretion. The SRGWA librarian may only divulge confidential information with the approval of the SRGWA committee. The SRGWA constitution is silent as to whom or under what circumstances the committee may authorise the release of confidential mapping information or in whom copyright subsists in respect of cave site records.

CLINC's mapping curator is responsible for the group's maps but their constitution is silent as to whom or under what circumstances map information may be divulged.

All of the constitutions are silent as to the consequences for breach of copyright or confidential information by members, ex-members, officers or the committee. The Three associations each include as one of their objects *"…to foster preservation…"* of WA caves. It is arguable that this object would support a decision to suppress a cave site location to foster its preservation. However, other objectives of the various groups might be said to be inconsistent with this approach[34]. For example, the WASG Inc. constitution has as an objective *"…promote and encourage speleology in all its aspects…"* Furthermore, the WASG Inc Constitution, objective at clause 2.1 requires publication of suitable information and By-law 10.4 requires the State Cave

Recorder to publish and update cave lists. Accordingly, in determining to suppress cave site information each of the objectives must be addressed and meshed to a cohesive strategy to ensure a committee's actions are consistent with all of the objectives of its organisation.

The Constitutions

Clearly, the constitution of each organisation could, in respect of cave site locations, identify:
- in whom reposes the copyright;
- the criteria to establish what information is confidential and why;
- the circumstances under which information can be released;
- to whom information can be released;
- remedies available to the groups in respect of unauthorised release of map information;
- appropriate security for confidential maps; and
- identification of opportunities to educate the community about the reasons for protecting certain cave site locations.

Constitutional amendments take time and the process is described under the constitution and the *Associations Incorporation Act 1987 (WA)* of which the secretary of each group should have a copy. Changes to the WASG Inc By-laws however can be made by the Committee from time to time. By-laws could expand on the meaning of clauses of the Constitution provided that they are not inconsistent with the Constitution.

Requests for information

When asked for confidential information in respect of cave sites a caving group committee should:
- Ensure the request is in writing and that the written request identifies the person or organisation making the request, under what law, regulation, order or power the request for information is made, for what purpose the information is needed and how the information - if given - will be kept confidential;
- Consider the *Associations Incorporation Act 1987 (WA)*, the group's obligations to be found in its constitution and its rules or by-laws;
- Formally refer the request to the group's committee for its consideration;
- Enter the request into the minutes and record any decisions made in respect of the request;
- Speak to the person who provided the group with the sought after information in the first place as to his or her attitude to the request;
- Consult with the owner, occupier and/or manager of the land under which the material cave sites are located; and
- Identify any known risks of or features that require special care associated with a particular cave and make these known to the person to whom the information is divulged, the site of which is divulged.

CONCLUSION

Can a caving group be compelled to divulge confidential cave site locations?

There is little doubt that a caving group cannot be compelled to provide confidential cave site locations without a requirement under their constitution to do so, statutory authority or a court order supporting such a demand. Nonetheless, a group's reputation will be enhanced by acting co-operatively with the reasonable request from government agencies or authorities. This could be achieved while at the same time preserving confidentiality in cave site locations. A policy to guide such co-operative ventures would be of benefit to all and mark a beginning in development of a comprehensive strategy to manage this increasingly vexed issue for speleologists.

NOTES AND REFERENCES

* The intellectual property issues addressed in this paper are based on general principles and are not intended to constitute specific legal advice on any particular issue.

1. *Environmental Protection Act 1986 (WA)*, section 38.
2. See for example the *Copyright Act 1986 (Cth).*
3. See for example the protection of confidential information.
4. Butterworths Concise Australian Legal Dictionary, 1997, page 210.
5. Butterworth's, Halsbury's Laws of Australia (240-505).
6. *Pacific Film Laboratories Pty Ltd v FCT* (1970) 121 CLR 154; *Autodisk Inc. v Dyason (No 1)* (1992) 173 CLR 330; 22 IPR 163.
7. Butterworths Concise Australian Legal Dictionary, 1997, page 91.
8. *Copyright Act 1968 (Cth)*(the Act), section 32.
9. Butterworths Concise Australian Legal Dictionary, 1997, page 246; *Computer Edge Pty Ltd v Apple Computer Inc* (1986)161 CLR 171; 6 IPR 1; 65 ALR 33; *Kalamazoo (Aust) Pty Ltd v Compact Business Systems Pty Ltd* (1985) 84 FCR 101; 5 IPR 213 at 232.
10. The Act, section 10(1); Butterworths Concise Australian Legal Dictionary, 1997, page 246; and *Computer Edge Pty Ltd v Apple Computer Inc* (1986)161 CLR 171; 6 IPR 1; 65 ALR 33.
11. The Act, section 10.
12. *Saltman Engineering Co Ltd v Campbell Engineering Co Ltd* (1963) 3 All ER 413; and *Coco v A N Clark (Engineers) Ltd* (1968) FSR 415; and *Breen v Williams* (1996) 186 CLR 71.
13. *TR Flanagan Smash Repairs Pty Ltd v Jones* (2000) FCA 625.
14. *Associations Incorporation Act 1987 (WA)*, sub-section 11(1).
15. The Act, sections 13 & 36, and sub-section 31(1)(a)(i).
16. Butterworths Concise Australian Legal Dictionary, 1997, page 246; *Coco v A N Clark (Engineers) Ltd* (1968) FSR 415; (1969) RPC 41.
17. Butterworths Halsbury's Laws of Australia (240-570); and *Coco v A N Clark (Engineers) Ltd* (1968) FSR 415; (1969) RPC 41 at 47, per Megarry, J.
18. Butterworth's, Halsbury's Laws of Australia (240-560); *Nichrotherm Electrical Co Ltd v Percy* (1956) RPC 272; and (1957) RPC 207, CA
19. Butterworth's, Halsbury's Laws of Australia (240-570).
20. Gurry F Breach of Confidence Clarendon Press 1904 cited in Butterworth's, Halsbury's Laws of Australia (240-560) at footnote 8.
21. *Seager v Copydex Ltd* (1967) 1 WLR 923; Butterworths Concise Australian Legal Dictionary, 1997, page 81.
22. *Boardman v Phipps* (1967) 2 AC 46; (1966) 3 All ER 721; Butterworths Concise Australian Legal Dictionary, 1997, page 157.
23. Butterworths Concise Australian Legal Dictionary, 1997, page 157; and *Hospital Products Ltd v United States Surgical Corp* (1984) 156 CLR 41; 55 ALR 417.
24. *Associations Incorporation Act 1987 (WA)*, section 13(2).
25. *Attorney-General v Observer Ltd* (1990) 1 AC 109 at 281 sub nom *Attorney-General v Guardian Newspaper Ltd (No 2)* (1988) 3 All ER 545, per Lord Goff, HL.
26. Butterworth's, Halsbury's Laws of Australia (240-500).
27. Butterworth's, Halsbury's Laws of Australia (240-630).
28. Butterworth's, Halsbury's Laws of Australia (240-990) (240-1025).
29. Butterworth's, Halsbury's Laws of Australia (240- 650).
30. *Associations Incorporation Act 1987 (WA)*.
31. *Consumer Affairs Act 1971(WA)*: *Associations Incorporation Act 1987 (WA)*, section 9.
32. *Associations Incorporation Act 1987 (WA).*
33. *Associations Incorporation Act 1987 (WA).*
34. I am grateful to EDO solicitor Lee McIntosh who first raised this point with me.

Labyrinth Cave Survey

Michael Bradley

Labyrinth cave, which is located in the Augusta region is, as the name suggests, an extensive phreatic maze stretching out to about three kilometers. Labyrinth was first surveyed in 1962 by Lex Bastian and Alex Saar when the watertable was much higher, which is now virtually non-existent. This has allowed more of the cave to be explored and surveyed.

I was fortunate enough to be taught how to survey caves by one of our most experienced and respected surveyors, Barry Loveday. I had been surveying with Barry for about four years when he told me of his plans to update the survey of Labyrinth. However because of personal commitments and changing circumstances he told me he would not be able to do it himself and so he asked me if I would like to survey Labyrinth instead. I eagerly accepted and applied to the department of Conservation and Land Management (CALM), through it's Cave Management Advisory Committee (CMAC) for permission.

Ian Collette from WASG also expressed an interest in helping out, and because of the huge job ahead of us, it was decided a joint venture would be the best way to go. Ian would lead the team from WASG to tackle the Southwest section and the Sump extension, whereas I would survey the Northeast and Northwest sections with SRGWA. We were also given a great deal of support by members from CLINC.

Apart from the usual compass, clino and opened reel tape, we also used an eight metre steel retractable builders tape. This tape was not only useful for measuring the ups & downs, lefts & rights, but was also good for extending into low areas where it was too awkward to crawl. We were also using the blue aluminium reflective discs for survey stations.

Our first survey trip was on the 21 April 2000. A seventeen metre pitch brings you down to the top of a rockpile, after climbing down we came to a flat sandy floored chamber. Following this chamber to the left for about ten metres takes you into the Lunchroom, which is a convenient eating and meeting place. After we had surveyed up to the Lunchroom from the entrance we began to survey into the Northeast Passage for a short distance before we came to a dry sump section, which led into a large heavily decorated chamber.

Continuing on into the Northeast section we surveyed through a series of low chambers and passageways until we came to a Y-junction. First we surveyed the right side of the junction. This led into a maze of tunnels which took two weekends to complete. Then we surveyed the left side which led us around in a loop heading back towards the entrance, where we came into the Artistic Chamber. This is a heavily decorated, high ceiling chamber which is another Y-junction. The left side takes you back to the entrance, whereas the right side leads into the Northwest section.

While we were surveying in the Artistic Chamber I noticed a small hole in the floor about a metre wide. Climbing down, I discovered it led into a cramped lower level that seemed to go back a long way. Unfortunately it was too difficult to survey, however I did see an unusual group of brown and white stalactites. One side of the stalactites was a pure crystal white colour, whereas the calcite on the other side was a dark brown colour. I have no idea how the two colours were formed, but they looked most unusual.

On our next trip we started surveying from the Artistic Chamber and headed up into the Northwest section. After going through a crawl the passage opened up again, where we came across a huge triangular suspension table five metres across that went back about six metres. A short distance past the table, the passage led into another large decorated chamber, which is also a Y- junction. We first followed the passage that went to the right which led into the Bastian Network. This is a series of connecting chambers which loops back into the Artistic Chamber. While we were surveying in this loop, I found a small extension where we had to crawl into a low muddy section. This is where I discovered a pool of water, which is the only part of the natural watertable still in existence in the whole cave. After we had finished surveying the Bastian Network, we went back to the junction which continued on into the Northwest section.

Going through another short crawl we came into Piccadilly. Piccadilly is a chamber about twenty metres long with a maze of connecting tunnels branching out from the right side of the chamber. Someone had long ago, also gone to the trouble of dragging in a large timber sign which reads, “beware of the trains”. The characteristic maze of tunnels continued on for about fifty metres, which meant it was very time consuming to survey.

Pushing on further we came to yet another Y-junction. Now this is a major junction. The left side takes you around a large loop that eventually circles back into the right side of the junction, before it branches off into the Lighthouse. We started to survey from the left side and when we were about half way around the loop, we came across a high rockpile off to one side of the main passage that appeared to choke off at the ceiling. Surveying up to the top of the rockpile, I discovered a three metre horizontal section before it choked off at the ceiling. This flat section continued to the left for about ten metres before terminating. We quickly finished surveying this section as I was eager to get back down to finish surveying the loop back to the junction. But then I noticed a small opening in the far corner of the chamber. Fully expecting this to choke off, I crawled through only to discover a very large chamber on the other side of the rockpile. While I was taking a quick look around I came across a vertical drop. Because I was on my own, I decided not to go down, so I made my way back to the others. This appeared to be a large extension, so we would have to come back another day to survey it. For now we made our way back down the rockpile and finished surveying the loop back to the junction.

Needless to say, on our next trip, we went straight back to the top of that rockpile and surveyed the extension. That vertical drop I had found was quite interesting. It went down about ten metres and was well decorated with flowstone, shawls and crystals on the way down, and ended in a small chamber at the bottom. This extension was not as big as I had hoped. It was mainly a very large chamber that went parallel to the main passage for about fifty metres. Something that caught my eye were some very unusual tree roots. They came from a single stem about twenty centimetres thick and were in a tight twisted spiral from the top to the bottom.

The next day, we surveyed from the loop over to the Lighthouse. This is a chamber with a hollow clump of limestone hanging down from the ceiling, with decoration inside. According to the old map, the Lighthouse marks the end of the cave, where it chokes off at a large soilcone. However when we had finished surveying the Lighthouse chamber up to the soilcone, I noticed a small opening off to the left. Crawling through I discovered a wide spacious chamber with a bewildering number of leads branching out in all directions. Little did I realize I had just opened up Pandoras Box of surveying, because it would take me another ten months to finish the map, with what lay ahead.

Looking around this wide chamber I decided to tackle it systematically. I located a central point near the middle of the chamber where it branched out in different directions. One by one each lead was dwindled down, each time we came back to our central starting point, until all the leads were finished. Then all we had to do was to finish surveying around the circumference of this large central chamber, and our work was done. But just when I thought I had almost finished we came across another one of those small openings in the wall which I had overlooked.

We crawled through into yet another large chamber that extended out into two main directions. We established another central starting point, where we could survey in both directions. First we went to the left through a maze of chambers for a short distance until we came to another crawl. After we had all squeezed through we came into a high central dome chamber with a large rockpile that was reminiscent of a typical entrance collapse. Working our way up to the top of the rockpile and down the other side, I found the cave just kept on going until, to my surprise, the passage led right back to the Lighthouse in a huge loop. It’s also interesting to note that all through this whole section, we found old survey markers from the Bastian survey, so we were not the first ones to discover these sections, although for some reason it was never drawn up on the original Bastian map.

When we had finished surveying what we had just found, we went back to our central starting point to survey the right side of that chamber. That’s where we planned to start surveying on our next trip,, but not everything would work out according to plan. There were times when something would go wrong. For instance, as you can imagine by now it would take us well over an hour to reach the far end of the cave, just to start surveying. On this occasion Andy Lambert and Chris

Cummings (CLINC) were with me. We had just travelled up to the far end of the cave at a brisk rate, which took us about an hour and a quarter. As usual, by the time we had reached our destination, we were tired and sweaty. After resting for a while, I began to get my survey gear out of my bag to start surveying the right side of this chamber, when I realised I had left my compass and clino in another bag back at the entrance.

This presented a problem of course. It was understandable that Chris and Andy would not feel inclined to come back with me. It was my fault anyway, so I decided to take a punt and make a dash for the entrance on my own. A potentially risky situation, but all went well. In fact, I knew the cave so well I actually made it to the entrance and back again in just forty minutes. You can imagine how I felt when I got back to the others, but my determination was stronger than my aching muscles.

Anyway, we finally started surveying the right side of that chamber. The characteristic maze of passageways continued for some distance until we came to a small hole in the wall. This led into a tight passage which terminated in a small chamber, with an interesting solution pipe going up into the ceiling.

When we were making our way back to our central starting point, we found another passage leading off from the main chamber. We followed this passage for about twenty metres around a few corners until it terminated at a small circular chamber. Now, this appeared to be all there was left to do. However because it was too late in the day to survey this section, we decided to come back for one last trip to finish off the whole survey.

At the next general meeting, on the 25 July 2001, I boldly announced that this would be the last survey trip for Labyrinth. Norm Poulter, Vicki Bresnan and Michael Whitworth were with me on this trip. After travelling up to the far end of the cave, we started surveying into the passage we had found, then on into that small circular chamber. We had almost finished when I noticed Norm was pocking around a tiny hole near the ceiling and pulling out rocks. I remember thinking to myself, “you’re wasting your time Norm, I’ve already checked this chamber out, let’s get it finished so we can go home early”. But before I could turn around again, Norm had climbed through the hole he had made and disappeared out of sight. Twenty minutes later he came back to proudly announce that he had found, what appeared to be a huge extension that had never been discovered before.

When I got over the shock of having my work load considerably increased, we pushed on into Norm’s Extension, as it became known. One chamber lead into another through a maze of connecting passages. By the end of the day we had surveyed about fifty metres with no end in sight. As we made the long jouney back to the entrance, I began to speculate on just how long it would take to finish the survey, that’s if we ever could find the end to Labryinth Cave.

Andy Lambert, Michael Longman (CLINC) and my son Steven joined me on our next trip. After making the even longer jouney to the far end and on into Norm’s Extension, we started surveying from where we had finished off last time. Andy found a small skeleton which was almost completely calcified. This proves there may have been another entrance of some kind in the past. As we were surveying I noticed what appeared to be a sizeable lead off to our left, but we would have to come back to that later. For now we kept surveying along the main passage which was wide and spacious with good head room. When we had surveyed about a hundred metres into the extension with still no end in sight, we decided to call it a day and head back. By now it was taking us three hours to make the return trip, to get into and out of the cave, which meant we were spending ten to twelve hour days to make it worthwhile.

On our next trip we planned to have one long day’s surveying to see if we could finally finish off the entire survey. I was so determined this time, I was even brave enough to announce that this would definitely be the last survey trip. Could this really be true, after all there was still that lead I hadn’t even looked at yet. Time would tell.

Ida Newton, Norm Poulter and Vicki Bresnan (SRGWA) were with me this time. When we had finally arrived at our destination, I showed Norm the small skeleton that Andy had found the trip before. He was able to collect a jawbone for identification at the museum. Continuing on from where we last finished, we pushed on deeper into Norm’s Extension. Eventually we came to a low lying muddy

section which we had to crawl into, and when we came up on the other side, I found something I had been looking for, for months. And there it was dead ahead. There could be no mistake this time, I had found it at long last. It was the END OF THE CAVE. This is the furthest point from the entrance to the end of the Northwest section, which is the longest part of the cave.

We finished surveying a few pockets that were near the end, then we made our way back to begin surveying that lead I had noticed earlier. This turned out to be a long parallel passage which eventually joined up with the main passage towards the end of the extension.

Norm's Extension came to a total length of two hundred metres, which was a very significant find. It extended the cave far beyond its outer limits. And yes, it was true, for after nearly two years and over six hundred survey stations, the Labyrinth survey finally came to a end.

Although the cave will be trackmarked in appropriate areas, the original survey markers from the Bastian survey will be upgraded and left in place. These have proven to be a valuable navigational aid. Certain discoveries have also been tied in to these points.

The Labyrinth survey proved to be a huge success, not only in producing a quality map, but it also produced a good spirit of cooperation and support between the three clubs. I would like to take this opportunity to thank all those who helped us out.

Contact details
37 Salter Street, Pinjarra WA 6208

Inside Karst

Andrew Eavis

ABSTRACT

A highly illustrated lecture on caves around the world including many of the largest passages, chambers and cave systems. The lecture will be an overview of caves and cave formation using photographic examples taken from British Expeditions over the last 30 years. Spectacular photographs of gigantic caves will be used from many areas around the world. These include Brazil, Mexico and USA in the Americas, Ursbekistan and China in Asia, Malaysia, Indonesia, Papua New Guinea, Australia and New Zealand in Australasia, not to mention pictures from all over Europe.

Solution Pipes and How to Make Them

Ken Grimes

INTRODUCTION

The "Petrified Forest" at Cape Duquesne, west of Bridgewater Bay, is a particularly good example of the many exposures of vertical pipes in calcareous dune sands which are seen in coastal areas of western Victoria, South Australia and Western Australia (Figure 1). Similar features also occur in other parts of the world (eg. Southern Africa, the Caribbean and Bermuda - see reference list) where the host sand is known as calcarenite or aeolianite.

Typically the pipes in the Gambier–Portland region are 0.3 to 1.0 m across and the exposed part is 1-3 m high (with the top removed by erosion and the base hidden below the surface). In a few places we see them up to 20 m deep. They can occur as isolated individuals, widely spaced sets (eg. 5-10 m spacing) or in dense fields (as at the "Petrified Forest") with spacings as close as 1 metre (Figure 2). They form smooth vertical cylinders which may narrow towards a rounded base ("cigar shaped" is a common description) or terminate abruptly in a hemisphere (Figure 3). They commonly, but not always, have a calcareous cemented rim around them that is a few centimetres thick. These rims may have concentric layers, and some have traces of thin calcareous root structures (rhizomorphs) and calcareous veins embedded in them (as does the surrounding sand). The exposed pipes tend to be empty, or are filled with a red or pale brown soil (silty sand). The pipes are commonly, but not always, associated with an old soil horizon - either descending from it (Figure 4), or cutting through a calcified band that could be a sub-soil hard-pan. Occasionally, as noted by Boutakoff, the pipes may bottom in a paleosoil.

Rhizomorphs are hard calcified root structures. They are common in the calcareous dunes of the region and have an obvious branching root structure. These form from carbonate that has been precipitated around the root, and are thus much thicker than the original root - which may be identifiable as a thin hollow core if that has not been infilled by younger cement.

A PETRIFIED FOREST?

In 1963, N. Boutakoff interpreted the pipes in the Portland region as having formed where an advancing dune had engulfed a forest of trees. Boutakoff argued that after the sand had been cemented into a soft rock, and the trunks had rotted away, the pipes were left as open holes which were locally filled by later soil that developed on the surface of the engulfing dune. He rejected the alternative hypothesis that these were solution pipes (which had been argued by Woods (1862) and others); but he did allow that occasional deeper solution pipes occurred as solutional modifications of the tree molds. Calcified traces of what are recognisably old roots (rhizomorphs) occur together with the pipes and were cited in support of his hypothesis. Boutakoff claimed to have seen "unmistakable rooted tree stumps" and bark, logs and other "woody structures". He illustrated his argument with an imaginative diagram (his figure 17, which is reproduced here as Figure 5); that unfortunately shows large roots spreading out from the base of the "trunks", that do not appear in the real outcrop!

Boutakoff has overstated his case: these features are either capable of alternative interpretations or cannot now be found in the area.

Boutakoff's interpretation is attractive at first sight, and his diagram is deceptively beguiling. It has been cited on numerous occasions in the local literature and appears on newly erected interpretative signs in the area. However, his 1963 interpretation was rapidly challenged. Blackburn & others (1965, p.39ff), described numerous areas of pipes just across the border, in South Australia, and referred to Boutakoff's site (and others) as having "indisputable solution pipes". Jennings (1968) favoured solution as the main process, and commented that "secretion round the roots of vegetation growing down into the sand" seemed more likely than burial of a forest. Coetzee (1975) also argued against Boutakoff's concept from a study of similar features in Africa. There was initially some support from workers in Bermuda, where the pipes were regarded as molds of palmetto stumps; but recent work has discredited this (Herwitz, 1993). Palm trunks have a rounded basal form more akin to the shape of the pipes than other trees, but no native palms are found in the Portland region.

The "tree mold" hypothesis has a number of problems, which I will expand on below:

- The spacing of the pipes (less than 1 metre in places) is too dense for a typical forest with trunks the size of these pipes.
- Where seen, the base of the pipes is a rounded hemisphere - nowhere are there thick-rooted tree structures such as those shown in Boutakoff's figure.
- Boutakoff claimed his pipes were based ("rooted") in a paleosoil layer and extended upward from it. This is unusual, usually the pipes are seen descending to varying depths below an old soil or unconformity.
- The forset cross-bedding of the dune sand shows no disruption where it passes the "trunks".
- Some pipes are up to 20 m deep (or high!), and are all unbranched vertical cylinders.
- The pipes are not restricted to dunes, they also occur in beach and marine sands.

Size and spacing

At the "Petrified Forest" site, and elsewhere, the spacing of the pipes (less than 1 metre) is too close for a typical forest with trunks the size of these pipes. In addition, Lundberg & Taggart (1995) report overlapping pipes in Puerto Rico, where younger pipes intersect older ones - though there are no good examples of this in our area. McNamara (1995) argued that the pinnacles at Nambung, WA, were remnant areas left between coalescing solution pipes.

The close spacing seen in the "Petrified Forest" could only occur with small trees such as paperbarks or ti-trees. Boutakoff recognised this problem, and argued for the development of a series of calcareous layerings around smaller trunks which makes them seem bigger. None-the-less, the hollow centre within the cemented rim is still larger than is compatible with the density of the "trunks". Also, if one accepts Boutakoff's suggestion of massive "thickening" of the original trunk size by cement rims, then one must consider also Jennings' (1968) suggestion that calcification around tap roots growing down into the sediment is a more likely explanation of the pipes than burial of a forest - though Jennings favoured solution as the primary process.

Lack of solid basal roots

The bases of the pipes are seldom seen at the "Petrified forest", but where we do see them (there and elsewhere) they end in a rounded hemisphere (figure 3). Nowhere have we found thick-rooted tree structures such as those shown in Boutakoff's figure 17. His photographs (his plates XIV-3 & 6) of a supposed stump with roots show small rhizomorphs running away from a pipe, but even without allowing for the exaggerated thickness of such calcareous overgrowths, these are too small to support a trunk of that size. Small calcified roots (rhizomorphs) do occur, but at all depths, not just at the base of the pipe.

Downward or upward development?

Boutakoff claimed his pipes were based ("rooted") in a paleosoil layer and extended upward from it. When observing the surface outcrops, as distinct from the cliff cross-sections, one frequently gets the impression that the pipes are ending just below the surface. This is because of the concave layered filling of partly cemented red soil and is misleading. Where seen in a good cross section (cliff or quarry) the pipes descend to variable depths, but have a uniform upper termination at the present surface or at an old unconformity surface which may have an associated paleosoil (Figure 4). Where pipes are seen to bottom uniformly in a basal soil (as in some parts of the "Petrified Forest"), that could be explained by reduced permeability and solubility of the soil material inhibiting further downward solution.

Lack of disruption to the dune bedding

The forset cross-bedding of the dune sand shows no disruption where it passes the "trunks" - there are no eddies or hollows on the lee side. This is not a strong argument, as Boutakoff argued that his calcareous growth layers extended out into the dune bedding and so would have destroyed any such distortions.

Some very deep pipes occur

The pipes at Cape Duquesne are only short (1– 3 m), but similar pipes elsewhere in the region can be up to 20m deep (and some give access to caves, Figure 6). These deep pipes are simple vertical unbranched cylinders - not tree-like. Boutakoff regarded these isolated long pipes as "secondary" solution pipes formed by modification of his tree molds.

Host sands are not all dunes
The pipes are a characteristic feature of dune limestones, but are not restricted to dunes. Similar pipes occur in beach sands associated with the dunes, and in the mid Tertiary marine Gambier Limestone - though the latter do not occur in the dense fields described by Boutakoff and so one cannot be sure that the genesis is identical. An example of solution pipes in marine limestone is seen in Brown Snake Cave (5U-14) at Naracoorte. This cave, in soft, sandy, Tertiary marine limestone, is entered via a 15m deep solution pipe that opens into the ceiling of a large chamber. This vertical pipe is perfectly cylindrical and about 60cm wide (apart from a constriction where it passes through a better-cemented band just above the ceiling of the chamber). Within the cave chamber there are 10 other blocked pipes in an area about 60m long; each with a conical soil cone below it indicating a connection with the surface.

OR SOLUTION PIPES?

A recent review of solution pipes is given by Lundberg & Taggart (1995) - who advocate "dissolution pipe" as being a more correct term. They note that dissolution by focussed downward vertical flow of under-saturated rain or soil water through the porous sediment can explain all the features of the pipes: the uniform, vertical cylindrical form, the dense clustering in places, and the cemented rims (where dissolved material is re-precipitated at the edges of the pipe). The associated rhizomorphs are simply formed around rootlets that have penetrated the sands from above, possibly following the soil-filled pipes by preference and radiating out from them. As the pipes are developing downward from the surface or from a soil cover the infilling material will progressively fill them as they deepen.

But why is the downward water flow focussed into the pipes rather than travelling evenly throughout the uniformly porous sand? In hard limestone, pipes usually form where flow is concentrated along the intersections of joints or steeply-dipping bedding planes. But in soft sandy limestone there are no vertical joints, and the initial inter-granular porosity is uniform apart from occasional horizontal hard-bands - the dune cross-bedding seems to have little effect on flow directions. Three methods of concentrating the flow have been suggested by Lundberg & Taggart (1995, drawing on earlier authors): surface hollows, roots and stem-flow; to those I will add a fourth: patches of higher porosity in the developing soil hard pan (Figure 7).

In passing, it is worth noting that similar vertical pipes occur in the giant podsols that develop on the quartz sand dunes of the Queensland coast (Thompson & Bowman, 1984, p.282). These have a deep leached A2 horizon over a humic-rich B horizon, with pipes of the leached A2 from a few centimetres to nearly half a metre wide penetrating several metres down into the enriched B horizon. I have also seen analogous, soil-filled, pipes formed in ferruginous duricrusts associated with deep-weathering profiles in tropical Australia. In both cases, focussing of downward water flow seems to be involved.

Stem-flow is the process whereby the leaves of a tree intersect rain, and direct it down the branches so that it is concentrated at the base of the trunk. The concentrated inflow would cause localised solution and pipe development (Figure 7-a). Herwitz (1993) measured stem flow under a variety of trees in Bermuda and showed that it could generate significant concentrations of water and noted that multiple generations of trees could produce the dense spacing of pipes which is observed in places.

The influence of **tree roots** was suggested by Jennings (1968) and later by Bird (1970). Roots generate organic acids and raised CO_2 levels that enhance solution in their vicinity (Figure 7-b). A vertical tap root could therefor form an initial thin pipe which would enhance water flow and enlarge with time. This is a self-perpetuating process as a pipe, with soil fill, would be a preferred place for continuing root growth and organic activity.

Surface hollows were suggested by Coetzee (1975) and others (Fig 7-c). If hollows exist (on a partly indurated surface, or on the top of the soil hard-pan) then water will accumulate in these and the base of the hollows will be lowered by solution at a faster rate than the surrounding higher areas - the process becomes self-perpetuating.

A possible fourth process involves **uneven cementation of the hard-pan**. Rain dissolves carbonate grains as it penetrates the soil, and some of this is re-precipitated lower down to form a hard pan or calcrete band near the base of the soil. In the initial stages this band would not develop evenly (Figure 7-d). The early-cemented areas would tend to deflect flow laterally to places which retained more of their original porosity and concentrated inflow would occur there, inhibiting further cementation, and allowing solution pipes to form below.

In all four cases, once the inflow is concentrated at a point, solution will progressively deepen a vertical pipe beneath the focal point. Lateral movement of saturated water out of the pipe would form the cemented rim (Figure 8).

DISCUSSION

Boutakoff himself admitted that some of the pipes were solutional in origin, but argued that most were tree molds. I argue the opposite: most are solutional and while it is possible that a forest could be buried and rot away to leave molds resembling the pipes, this would probably be a rare event and there is no unambiguous evidence for it at the "petrified forest".

The focussed solution process seems a better hypothesis for general interpretation of both isolated pipes, and the dense fields of pipes which are a distinctive feature of dune limestones throughout the world.

Rhizomorphs are common in dune sands and form around small roots growing through the sand. Such roots would preferentially follow the organic-rich soils that fill the solution pipes and branch out from them. Thus, rhizomorphs could be called petrified roots, but the pipes are not petrified trunks.

So, while "Petrified Forest" provides a picturesque name for the features at Cape Duquesne, the name should be kept in quotes, and not confused with the real process by which these features were formed. The recently erected interpretation signs are incorrect.

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Contact details
Regolith Mapping, PO Box 362, Hamilton VIC 3300

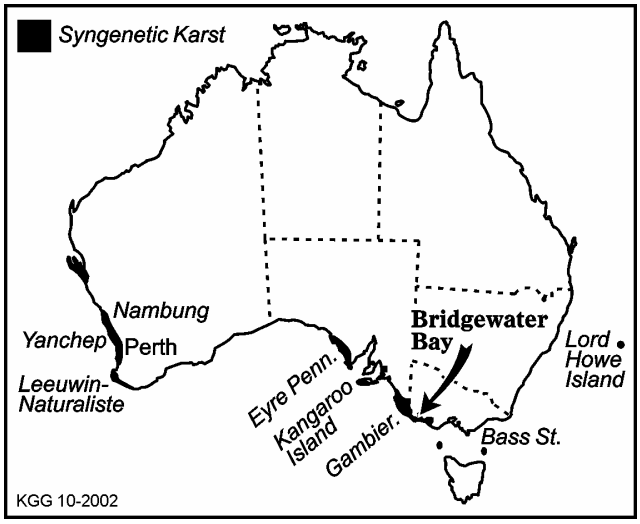


Figure 1 - Dune limestone areas in Australia

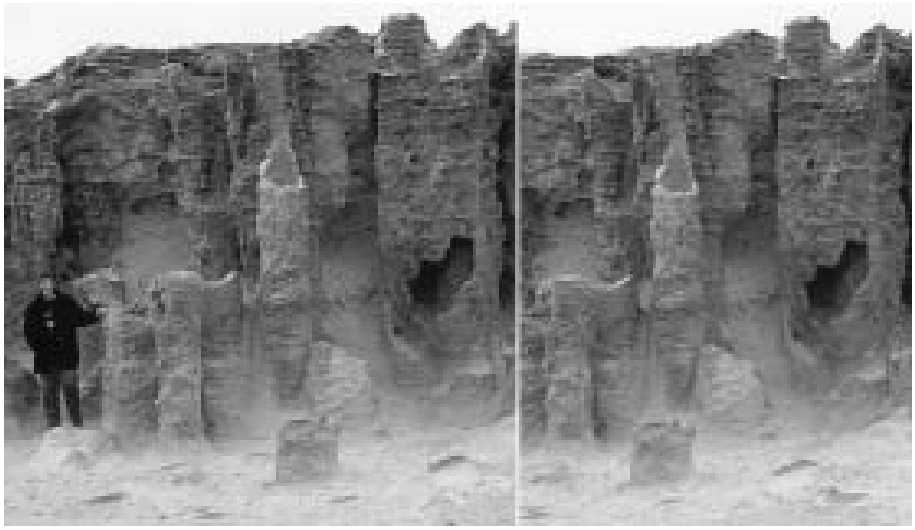


Figure 2 - Stereopair of the main cluster of pipes at "The Petrified Forest", Victoria



Figure 3 - Stereopair of a pipe with rounded base at "The Petrified Forest", about 30 m west of the main group shown in Figure 2. Scale-bar is 10 cm.



Figure 4 - Red paleosoil and soil-filled pipes beneath a younger sand dune exposed in a cliff at Canunda National Park, South Australia

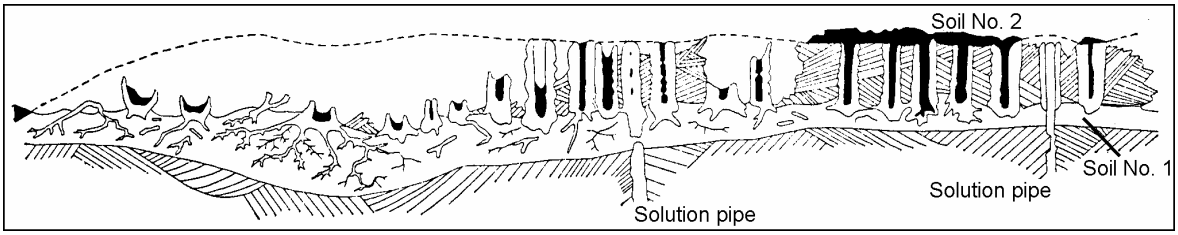


Figure 5 - Boutakoff's figure 17 shows many features of the "Petrified Forest" correctly but grossly exaggerates the thickness and extent of root development at the base of the pipes. Black is soil fillings.



Figure 6 - A deep, open, solution pipe that forms a cave entrance Ladder rungs are spaced 30 cm (Photo by R.K. Frank)

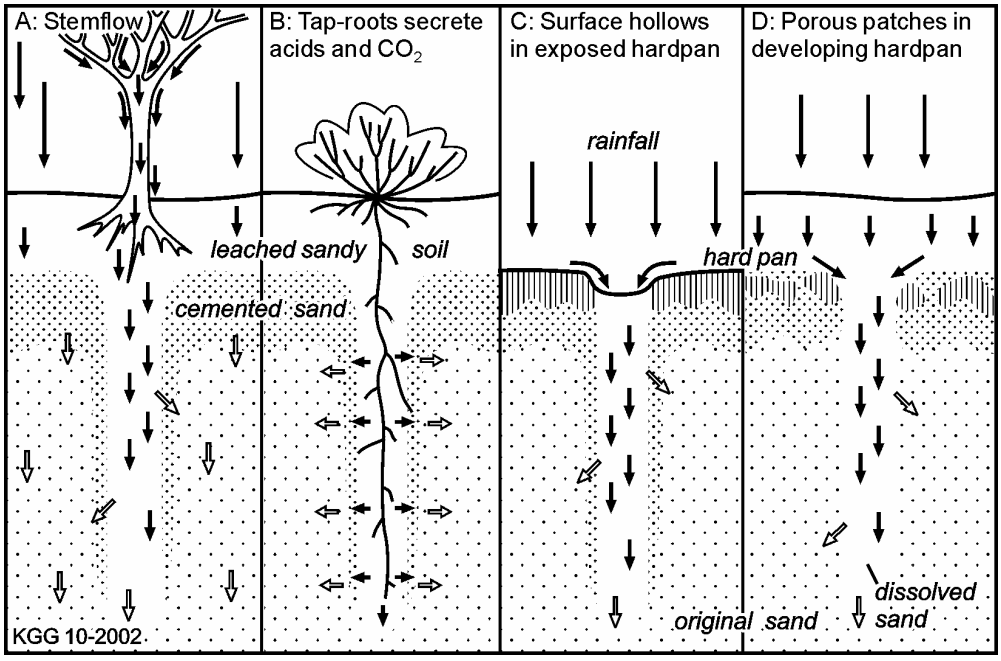


Figure 7 - Alternative ways to focus downward flow and generate solution pipes
Note: the alternatives are not mutually exclusive, they could all contribute in different settings.

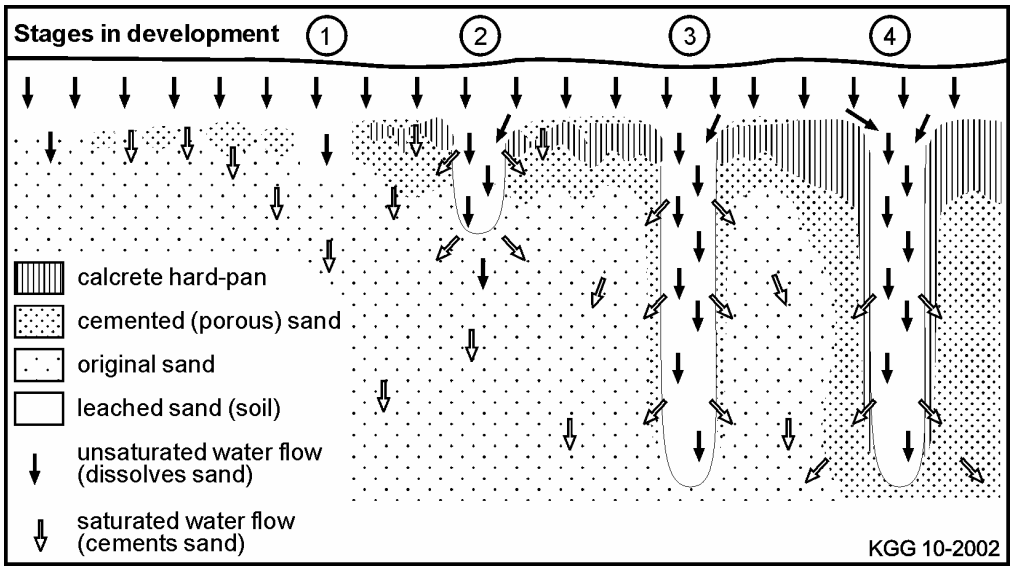


Figure 8 - How a solution pipe deepens and develops a rim

Syngenetic Karst in Australia: A Review

Ken Grimes

INTRODUCTION AND TERMINOLOGY

Syngenetic karst is a term coined by Jennings (1968) for karst features, including caves, that form within a soft, porous, soluble sediment at the same time as it is being cemented into a rock. Speleogenesis and lithogenesis are concurrent. Jennings based his discussion partly on prior observations reported in Bastian (1964) for Western Australia and Hill (1984) for South Australia (Hill's paper was written in 1957, but published posthumously).

Jennings was describing the active karst geomorphology of the Quaternary dune calcarenites of Australia. Concurrent studies by sedimentologists of paleokarst horizons at unconformities in the stratigraphic record used the related concept of **eogenetic diagenesis**: processes that affect a newly-formed carbonate or evaporite sediment when it is exposed to subaerial weathering and meteoric waters (Choquette & Pray, 1970). The resulting eogenetic karst (or "soft-rock karst") is distinguished from telogenetic ("hard-rock") karst that has developed on hard indurated limestones that have been re-exposed after a deep burial stage.

Choquette & Pray (1970) defined three major stages in diagenesis of limestones (Figure 1). **Eogenetic diagenesis** refers to processes affecting recently deposited sediments prior to deep burial . The processes include cementation and solution (with brecciation) by meteoric waters and solution of aragonite or its replacement by calcite. **Mesogenetic diagenesis** starts after the sediment is buried; and for limestones involves further cementation, re crystallisation and pressure solution (eg. styolites). **Telogenetic diagenesis** occurs after uplift and erosion returns the limestone to the surface where meteoric waters can dissolve the (now well-cemented) limestone to form "classic"(hard rock) karst.

Early diagenetic effects can be preserved within later diagenetic textures. These include paleokarst cavities, infills and breccias. Dissolutional porosity generated during the eogenetic stage of paleokarsts can direct water flow and further dissolution during the later mesogenetic and telogenetic stages, and also host ore minerals or hydrocarbons. Large solutional cavities (i.e. caves) can form in all three diagenetic stages, but are most common in the eogenetic and telogenetic stages. Those formed in the mesogenetic burial stage are generated from deep hot waters, or from acidic waters derived from oxidation of hydrogen sulphide or pyrite. Repeated cycles of uplift, exposure and reburial can form multiple ages of telogenetic paleokarst features (eg. Osbourne, 2002).

With reference to karst, the terms "syngenetic" and "eogenetic" overlap but involve different viewpoints. The former is best used for geomorphological studies of modern soft-rock karsts; whereas the latter is best retained for diagenetic studies of paleokarst porosities, where the sequence of dissolution and cementation events is much more complex. Some, but not all, paleokarst is eogenetic (Figure 1): the separation of eogenetic, mesogenetic, and telogenetic features requires a detailed study of cement morphology, mineralogy, chemistry, and related dissolutional and brecciation features; at both the microscopic and macroscopic scale (Moore, 1989,2001). Recently some authors have applied the term "eogenetic karst" to modern syngenetic karst features (eg. Mylroie et al 2001) – I recommend retaining "syngenetic" for that setting.

Soft rock Karst is a more general concept that includes both early and late syngenesis (see below), and also more mature sediments that have not been deeply buried and indurated, but in which the early, weak, cementation is essentially complete. In addition to the dune limestones, examples of soft rock karst include the mid Tertiary marine calcarenites of Australia (Lowry & Jennings, 1974, Gillieson & Spate, 1998, Grimes, 1994, Grimes et al 1999), as well as some of the limestones of the Yucatan (Lesser & Weidie, 1988) and Florida (Miller, 1990). The Cretaceous chalk of Europe is a special case of a moderately consolidated limestone that has both a very fine-grained matrix porosity and well-developed fractures - forming linear caves (Rodet, 1991; Gunn et al 1998).

Quaternary dune calcarenites, or aeolianites, show the best development of syngenetic karst. Examples include those of Australia (eg. Bastian, 1964, 1991, 1996; Hill, 1984; Jennings, 1968, White, 1994, 2000; Grimes & others, 1999, Grimes, 2002), South Africa (Marker, 1995), Bermuda (Mylroie et al 1995) the Caribbean (eg. Mylroie et al 1995, Lundberg & Taggart, 1995), and parts of the Mediterranean (eg. Ginés, 2000). However, other porous calcarenites, such as beach and shallow marine sands, can also develop distinctive syngenetic features; in particular solution pipes, calcreted cap-rocks and extensive collapse modification. Examples include the mid Tertiary Gambier and Nullarbor limestones in Australia cited in the previous paragraph. For less porous facies, such as micritic lagoonal limestones of oceanic islands, cementation is stronger and there is greater joint control so the syngenetic karst is more akin to the classical hard-rock karsts (Mylroie et al 2001, Grimes 2001). Other soluble sediments (gypsum, halite) can also develop syngenetic karst when exposed to subaerial conditions shortly after their deposition (eg. Sando, 1987) but these will not be discussed here.

In the following discussion Australian dune calcarenites in a "Mediterranean" climate are used as an example (Figure 2).

THE DEVELOPMENT OF SYNGENETIC KARST

In calcareous dunes, percolating rain water gradually converts the unconsolidated sand to limestone by dissolution and redeposition of calcium carbonate. Initial solution at the surface forms a terra rossa or similar soil depleted in carbonate but enriched in the insoluble grains (eg. quartz). At the base of the soil precipitation of carbonate forms a cemented and locally brecciated calcrete layer or hard-pan, also known as cap-rock. Below this the downward percolating water becomes focussed to dissolve characteristic vertical "solution pipes, and simultaneously cements the surrounding sand. Early cementation tends to be localized about roots to form distinctive rhizomorphs or rhizocretions. Cementation can progressively occlude the primary inter-granular porosity, but simultaneously, dissolution can generate localized secondary porosity of a moldic, vuggy or cavernous character.

Mixing corrosion occurs where percolation water meets the water table, which is commonly controlled by the level of a nearby swampy plain that also provides acidic water. In coastal areas, water levels fluctuate with changing sea levels and further complexity results from a fresh-water lens floating above sea water which results in two mixing zones, above and below the thin lens (Mylroie & Carew, 2000, Mylroie et al 2001; Figure 3). Solution is strongest at the coast where the lens thins so that firstly the two zones overlap (within the fluctuating zone of the sea level) and secondly the thinning of the lens causes stronger flow rates which also promotes solution. Tidal pumping may also assist. The result is a "flank margin cave" (Mylroie et al 2001) that has an irregular form of interconnected "mixing chambers" (Figure 4). The name refers to the tendency for these caves to cluster at the island margin. Similar clustering can occur along the edge of dune ridges adjacent to swamps that provide aggressive water.

In the early stages of dissolution (**Early Syngenesis**, Figure 5a) the loose sand subsides at once into any incipient cavities, possibly forming soft-sediment deformation structures. Subsidence dolines may form without caves (as described in South Africa by Marker, 1995). An exception is that beneath the cap-rock, which appears to form quite early, some shallow caves may form. Once the bulk of the rock is sufficiently hardened to support a roof (**Late Syngenesis**, Figure 5b), caves can develop. The presence of buried cap-rocks (and associated paleosoils) may also assist in cave development. The uniform matrix porosity, slow moving groundwater, and lack of joint control means that directed linear conduits seldom form. Instead, horizontal cave systems of low, wide, irregular, interconnected chambers and passages (Figure 4) form either in the zone of maximum solution at the water table, or by subsidence of loose material from beneath stable cap-rock layers. Flat cave ceilings are common: either marking the limit of solution at the top of the water table, or where collapse has reached the base of an indurated (cap-rock) zone. Bastian (1999) coined the term "watertable slot" for broad horizontal slots, too thin for humans to enter, that form at the top of the watertable at Yanchep, Western Australia. Where a shallow impermeable basement occurs, as in southwest Western Australia, its topography may concentrate water flow along buried valleys to form linear stream caves (Figure 6). Strong flows, in areas of steep gradients, can also concentrate flow into linear paths and form stream caves, as at Yanchep (Bastian, 1996).

Collapse is ubiquitous in these soft rocks and large collapse domes commonly obscure much of the original solutional caves. Breccia structures are common in paleokarst exposures, and are also sometimes seen in the walls of modern syngenetic caves or in the calcrete cap-rocks.
Sizable syngenetic caves can form in less than 100 thousand years (Mylroie & Carew, 2000).

Surface dissolutional sculpturing is rare, as there is little solid rock for it to act upon. However, some sculpturing can occur on exposed calcrete layers.

Variations on the above-described styles can occur in different climates, hydrological settings and host sediments. For example, calcrete is supposedly best developed in semi-arid climates, whereas dissolution and brecciation are thought to be more abundant in wet climates (Esteban & Klappa, 1983).

SOME FEATURES OF SYNGENETIC KARST

Syngenetic karst has several distinctive features as well as many that are shared with classical (hardrock) karst.

Solution pipes (or, more strictly, dissolution pipes) are distinctive features of syngenetic karst on porous host rocks (Lundberg & Taggart, 1995, Grimes, 2003). They are vertical cylindrical tubes with or without cemented walls, typically 0.3 to 1.0 m in diameter, which can penetrate down from the surface as far as 20 m into the soft limestone. The top is the present surface, or a buried paleosoil. The bottom, where seen, is generally abrupt and hemispherical. The pipes may contain soil and calcified roots (and root growth may have occurred hand-in-hand with dissolution of the pipe). They occur as isolated features, or in clusters with spacings that can be closer than a metre. In the Bahamas they have been referred to as Pit Caves, but that term also includes larger and more complex features (Mylroie & Carew, 2000). The pipes form by focussed vertical vadose flow through the porous sediment. The focussing may be spontaneous and associated with partial cementation of the hard-pan of the soil, or it may be guided by other factors such as concentrated stem flow beneath trees, or along tap roots (Grimes, 2003).

The influence of an impermeable basement: In the southwest of Western Australia, the dune limestone lies on a basement of impermeable gneiss. This has an irregular topography of old valleys and rises which channels the groundwater flow at the base of the limestone - forming linear stream caves (Williamson, 1980). Figure 6 shows an example taken from Williamson & others (1976).

Water from below: At Yanchep, Western Australia, dune limestone overlies a quartz sand aquifer and aggressive water enters from below to dissolve caves at the base of the limestone (Bastian, 1991,1996, 2003). A belt of caves forms along the eastern threshold where the water first rises into the limestone. Bastian used the term "paraphreatic" for this type of cave. The increased transmissivity of the caves captures diffuse flow from the adjoining calcarenite as well as from the quartz sand below and forms local cave streams which follow the base of the limestone. This high conduit transmissivity maintains the water table at the dipping contact.

Dune swales: Where the watertable is at or above the surface in the swales between dune ridges, swamps or lakes will form. The aggressive swamp waters can undercut the edges of the dunes to form small cliffs, and "sharpen up" the topography to form a steep sided, flat floored depression not unlike a polje (eg. at Codrington, Victoria; Berryman & White, 1995). The analogy to a polje is further emphasised in some places, eg. Yanchep, where springs feed into the hollow from the inland side, while the swamp water sinks into ponors on the coastal side of the same depression.

Collapse modifications: The subsidence of partly-consolidated material can form a variety of breccias and sag structures; these can be further cemented as diagenesis continues. Mantling breccias can occur as part of the surface soil. Within the caves breakdown of the soft rock is extensive. In many cases the original solutional cave system at the water table is largely replaced by rubble-filled collapse domes (Figure 7). Where the base of the rubble lies within aggressive groundwater the broken material can be dissolved and removed as it falls so that a large open dome will result. If not removed, the growing rubble pile rises faster than does the roof above and

eventually meets it. Collapse will stop at this point but narrow spaces may be left over and around the sides of the domes. These have been called "inclined fissures" in Western Australia (Bastian 1964), and similar narrow collapse domes and fissures have been described in South Australia (Hill, 1984) and elsewhere (eg. Ginés, 2000). Subsidence may reach to the surface to form dolines; a special type referred to as a "banana hole" in the Bahamas results from the collapse of the near surface calcrete band above a shallow cave to form a shallow overhanging doline. In paleokarst exposures these collapse areas appear as both discordant and concordant (intrastratal) breccias. In extreme cases mass subsidence of broad areas can generate a chaotic surface of tumbled blocks and fissures (Bastian, 1995).

Multi-level systems: Fluctuating water tables, possibly controlled by sea level or climatic changes, can result in stacked sets of horizontal cave systems. Rising watertables can flood and partly redissolve speleothems then re-expose them when the watertable drops (examples occur at Codrington, Victoria.

SYNGENETIC KARST IN AUSTRALIA

In Australia, syngenetic karst and softrock karst is restricted to a coastal belt running from Barrow Island down the western coast of Western Australia, and then along the southern coasts of Australia into Bass Strait (Figure 2). There is an isolated occurrence on Lord Howe Island, off the New South Wales coast.

Some of the Western Australian areas will be described in detail by others in this symposium – I will provide only a broad summary here. Starting in the north, the Barrow Island caves are in a marine Tertiary softrock limestone, though a small area of dune limestone is present. Cape Range is also in Tertiary limestone, but south from there we find a long belt of dune limestones that continues all the way to Perth. Within this the most interesting karst areas are probably the Nambung Pinnacles (McNamara, 1995) and the Yanchep area (Bastian, 1996 etc) which has the special hydrological setting mentioned in the main text above. South from Perth there are a few caves and springs on the Swan and other rivers. In the Leeuwin-Naturaliste region a belt of dune limestone up to 6 km wide contains numerous caves (Bastian, 1964, Williamson, 1980, Williamson & Bell, 1980). The caves are best developed in the older dunes and are of three types: linear caves formed by cave streams (eg. Figure 6), the inclined fissure type, which includes other breakdown forms (eg. Figure 7), and the horizontal maze caves of the Augusta area - which are relatively rare in Western Australia. The allogenic streams to the east of the dune barrier have mostly been dammed by the dunes and sink into the limestone to feed the stream caves, however some of the larger streams have managed to keep their channels open and flow through gorges of construction (Jennings, 1968). Some springs are known on the coast, but much of the underground water flow seems to be lost offshore. Water tracing experiments are being done (eg. Eberhard, 2001).

In South Australia the karst of the discontinuous dune limestones of the Eyre Peninsula is not well documented. Kangaroo Island was the base for Hill's (1984) work, which parallelled that of the West Australians. Most of the caves there are large collapse domes, but Hill also documented the influence of allogenic water derived from the swampy flats on the inland side of the dunes. The Gambier Karst Region is best developed in South Australia, but extends eastward into Victoria (Grimes, 1994, Grimes & others, 1999). Here we find both calcareous dune limestone, and the older Tertiary softrock limestone. Caves occur in both types and some caves have their entrances in the dune limestone but their main horizontal development is in the underlying Tertiary limestone. In South Australia the dune limestones form a broad series of discrete ridges separated by extensive swampy plains that extends up to 100 km inland. However, to the east in Victoria the dune ridges become confined to a narrow belt close to the coast with only thin swampy swales between them. In some of the older ridges minor joint control becomes apparent. Many syngenetic caves in the Gambier region are dominated by collapse but where the original solutional parts are preserved the typical form is a horizontal maze. This differs from SW Western Australia where linear stream caves are considered typical and mazes are the exception.

In the Victorian part of the Gambier Karst, Bats Ridge and Codrington are two particularly densely cavernous areas (White, 1995, 2000). Caves also occur in the Tertiary limestones. Some of the islands in Bass Strait have dune limestone, but there are only a few small caves (Kiernan, 1992).

On Lord Howe Island, off the New South Wales coast an isolated area of dune limestone hosts a few small caves (Standard, 1963 and H.Shannon, pers. comm.)

CONCLUSIONS

Syngenetic karst shows a number of distinctive forms as a consequence of its formation from soft sediments that are being consolidated and cemented at the same time as karst cavities are forming within them. These include: solution pipes, shallow cap-rock caves, brecciated zones, irregular horizontal mazes, "flank-margin caves" in coastal situations, caves that are dominated by collapse domes and "inclined fissures" - with little or none of the original solutional passage remaining.

Syngenetic karst is quite different to classical "hard-rock", telogenetic karst. The related term "Eogenetic karst" is best kept for diagenetic studies of paleokarsts. Recently some authors have applied the term "eogenetic karst" to modern syngenetic karst features (eg. Mylroie et al 2001) - I recommend retaining "syngenetic" for that setting.

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Contact details
Regolith Mapping, PO Box 362, Hamilton VIC 3300

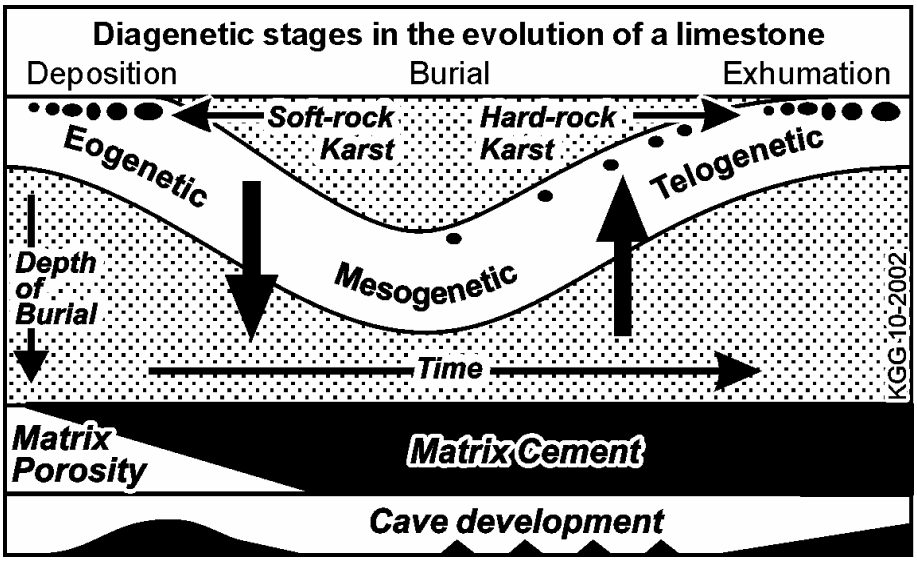


Figure 1 - Diagenetic stages in the evolution of a limestone, and of its karst Black dots indicate possible cave formation

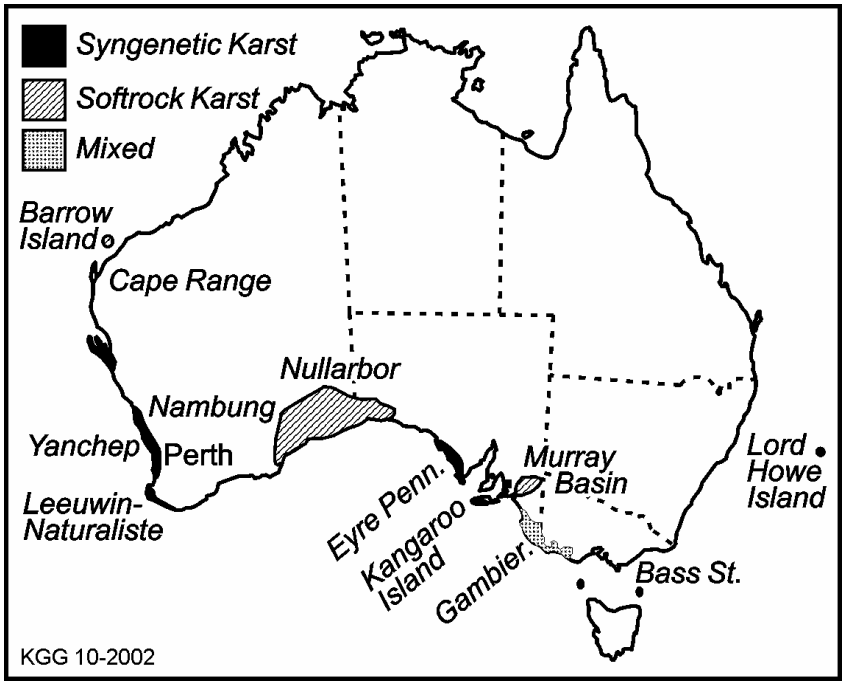


Figure 2 - Areas of Syngenetic and Softrock Karst in Australia

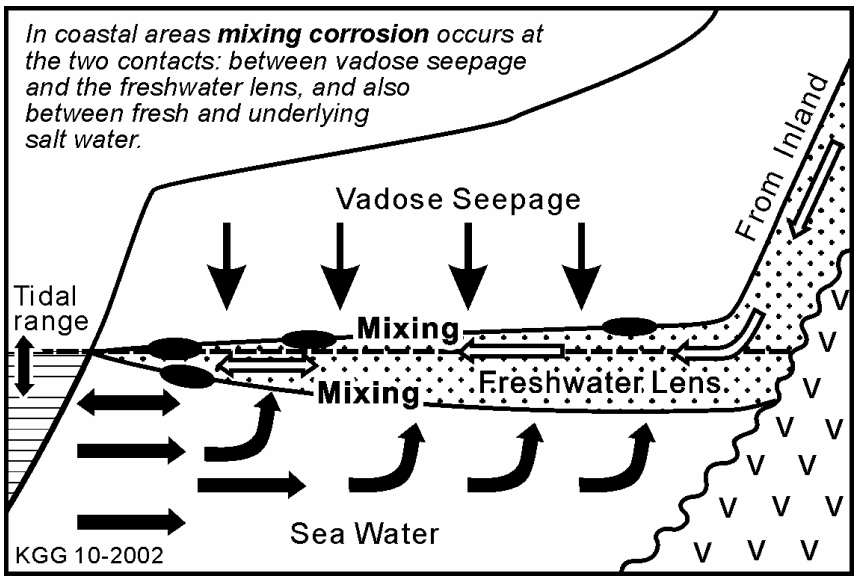


Figure 3 - The coastal freshwater lens, and its mixing zones
Note that the vertical scale is strongly exaggerated in all diagrams of this type. The lens is thin and the slopes are not as steep as they appear.

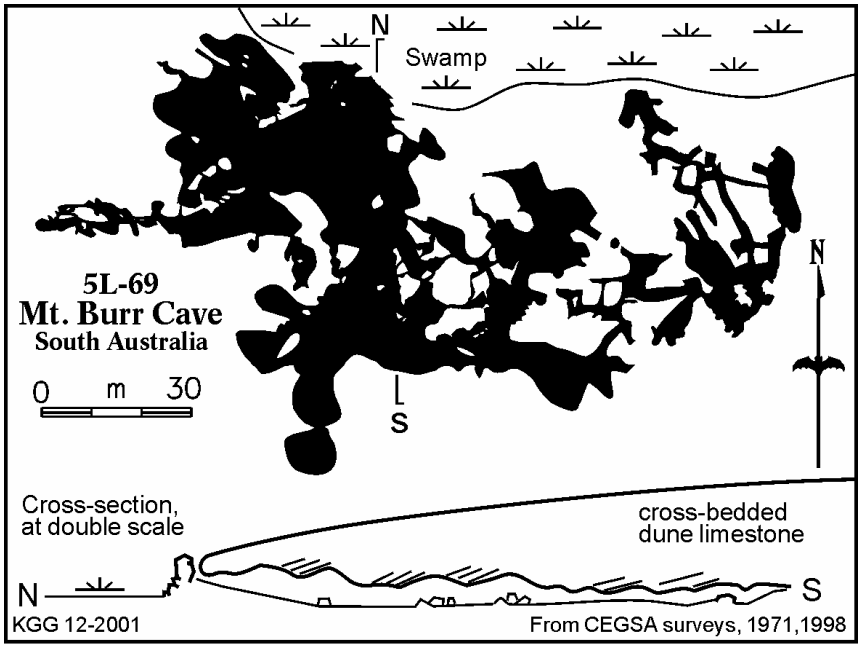


Figure 4 - A typical horizontal syngenetic maze cave in dune limestone adjacent to a swamp

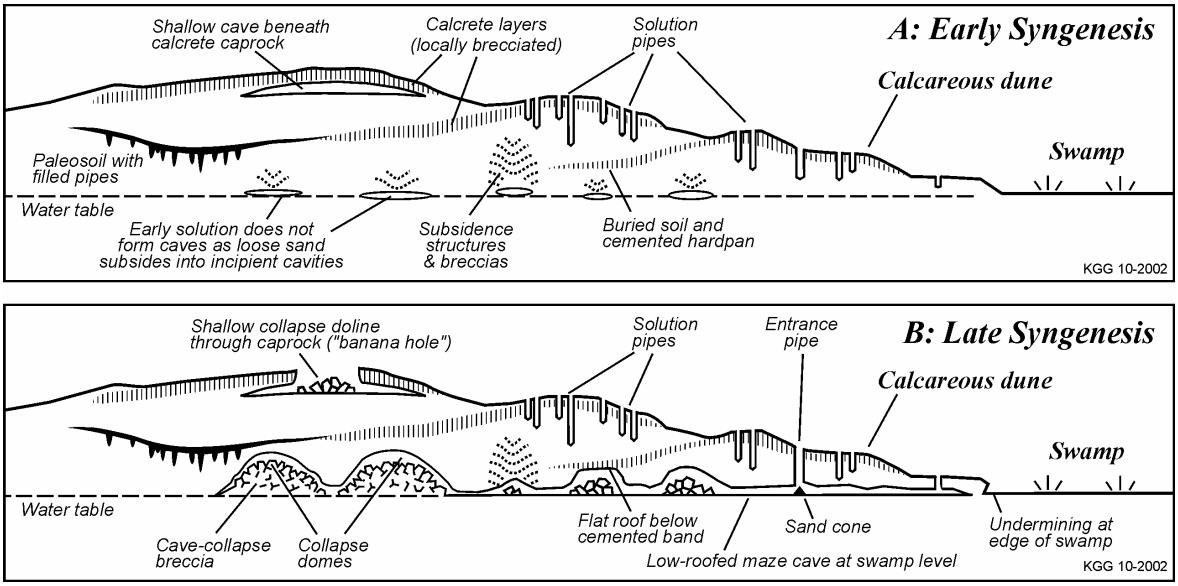


Figure 5 - Features of syngenetic karst developed on a calcareous dunefield adjacent to a swamp

Part A is Early Syngenesis – before the sand is sufficiently cemented to support a cave roof.
Part B is Late Syngenesis – the limestone is now strong enough to support a cave roof.

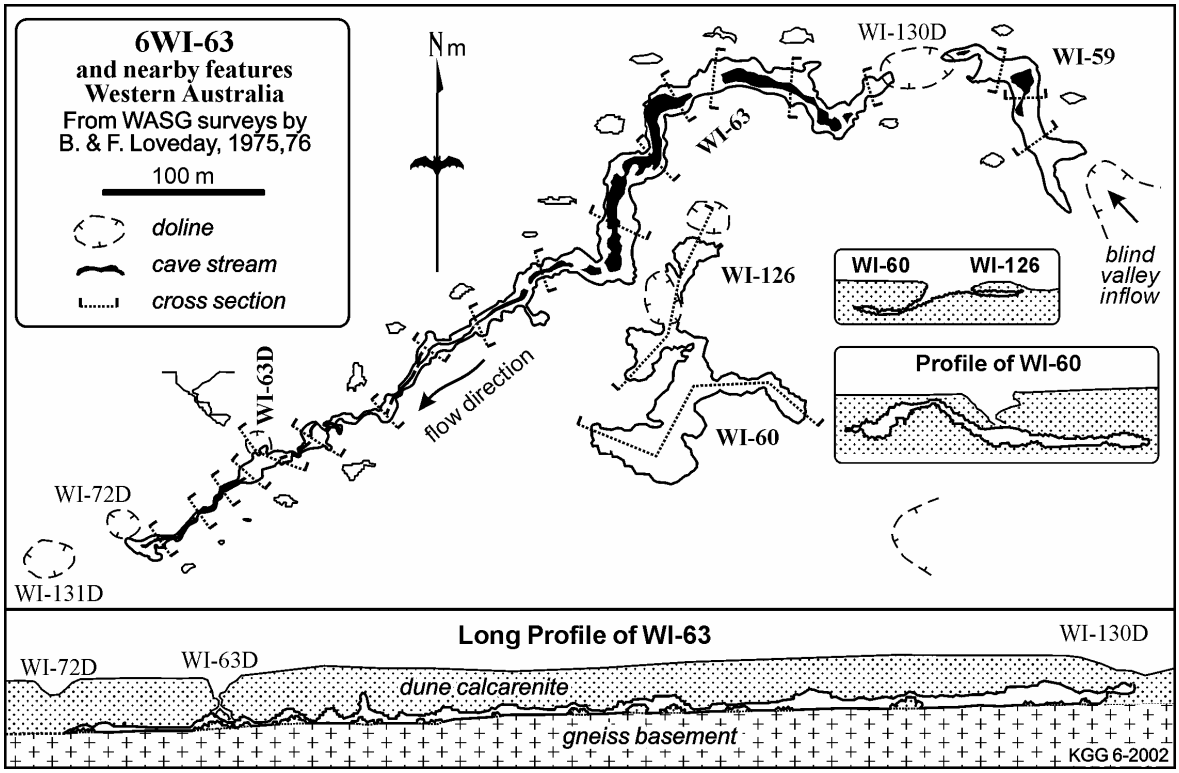


Figure 6 - 6Wi-63 is a linear stream cave that follows the basal contact between the dune limestone and impermeable gneiss

Note the downstream decrease in passage size, away from the source of aggressive water.

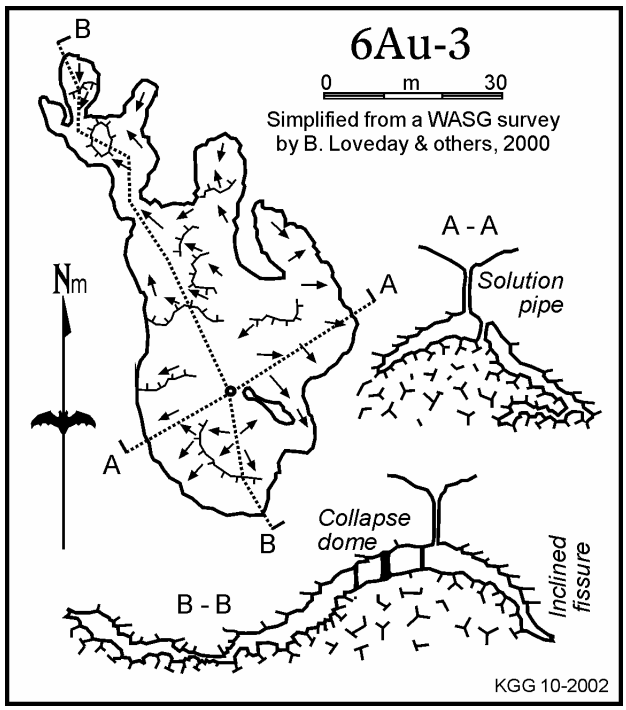


Figure 7 - An example of a small breakdown cave with a collapse dome inclined fissures at the edges, and a solution pipe entrance

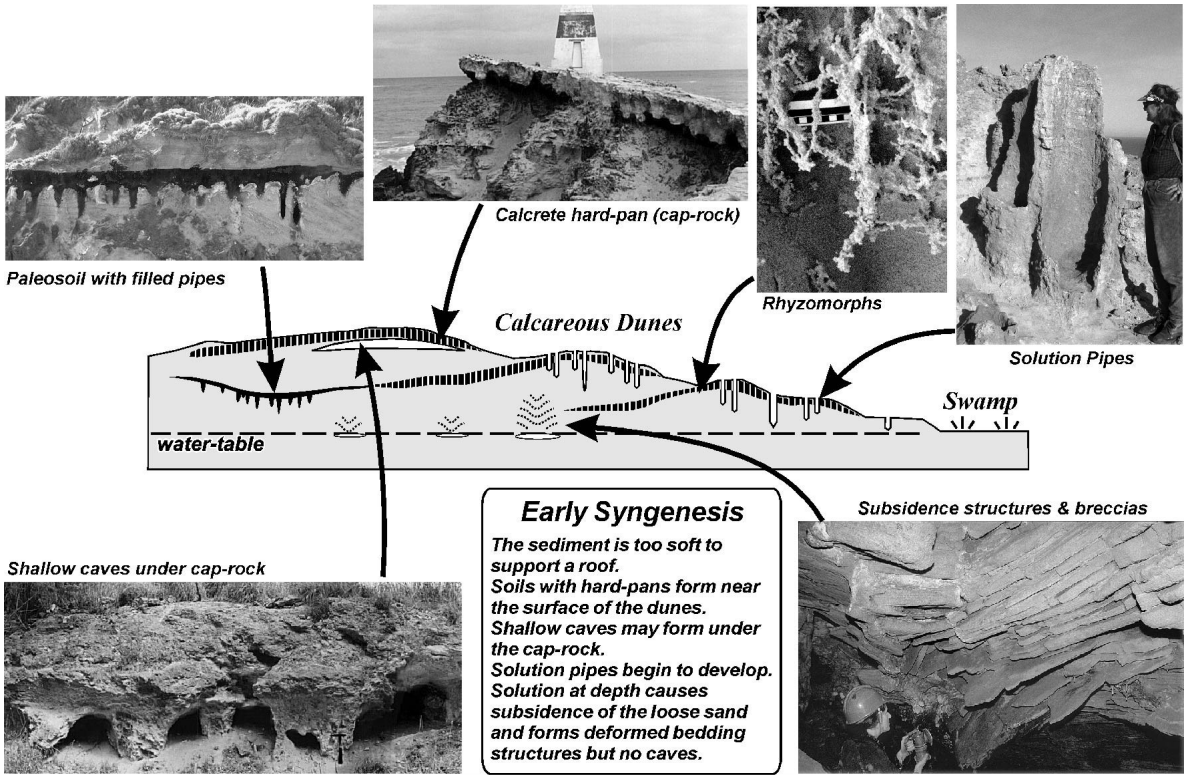


Figure 8 - Early Syngenesis

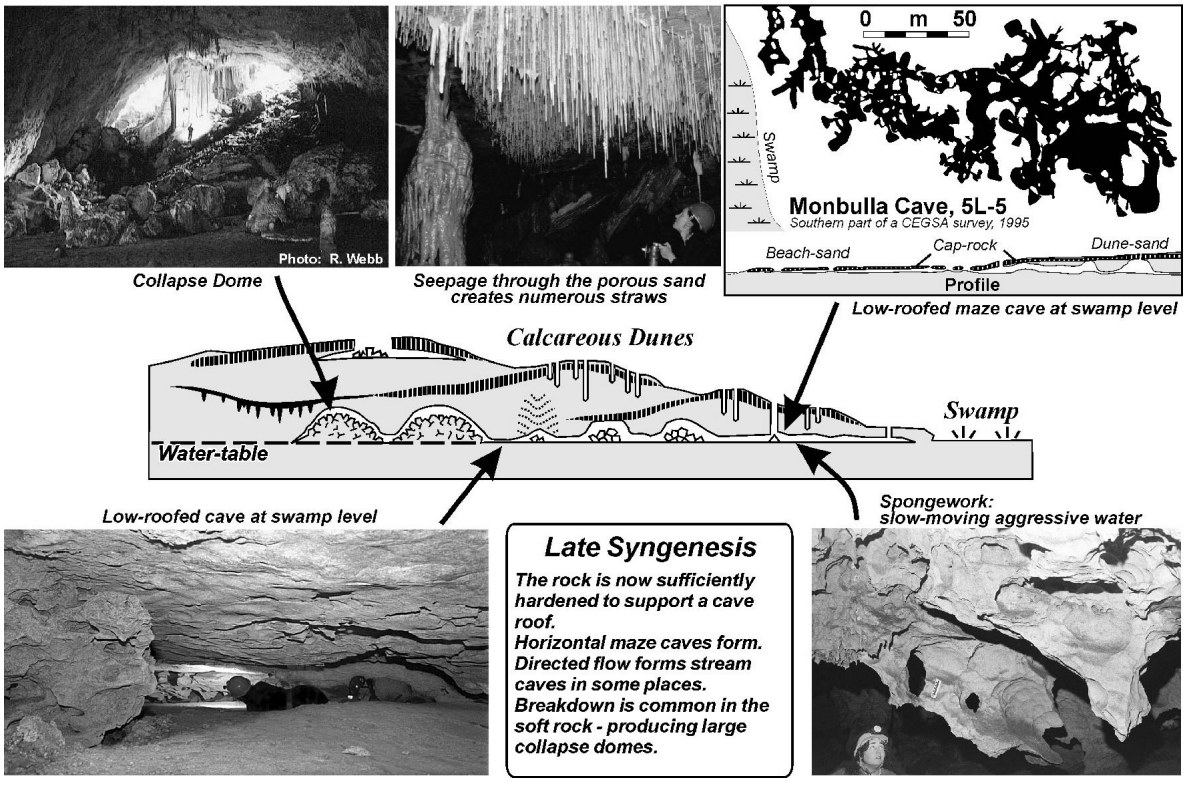


Figure 9 - Late Syngenesis

Cave Diving Exploration in Western Australia

Paul Hosie

(Accompanied by 2002 Nullarbor Cave Diving Video by Paul Boler)

INTRODUCTION

In the past two years or so there has been some concerted effort to explore and map some of the lesser known cave diving sites around Western Australia. This presentation will show you some of the remarkable discoveries we have made via Paul Boler's excellent video footage as well as maps and photos, most of which are available at our website: www.trimixdivers.com.

I was trained and qualified in cave diving on the Nullarbor Plain, which, after some four years and a dozen or so expeditions later, I now consider as my backyard !! Sadly, in my opinion, a very poor legacy that was left from the great era of Oz cave Diving in the 70s/80s, was the extremely poor quality maps for what are undoubtedly the country's most magnificent underwater caves (so far !). When we looked at the maps we realised that they had little representation of where we had just been ! It was this lack of quality cave maps that inspired us to get out there and start surveying. We soon learned that an unstated benefit of this tedious underwater work was the discovery of 'new' passages and leads. It also forced us to modify our techniques and dive almost exclusively with sidemount rigs. This took us from being goggle eyed cave divers to explorers.

On that note, let's have a look at what has been achieved in terms of exploration around WA over the past few years, beginning with the Nullarbor.

THE NULLARBOR

The Nullarbor Plain comprises the Nullarbor Plain proper (Northern area – arid), Hampton Tableland (heavily vegetated, southern region where most of the diveable caves are located) and the Roe Plain which is a younger limestone deposit next to the coast between Eucla and Twilight Cove. The water table is a mere 10m below the surface of the Roe Plain (bonus !!) and has the greatest likelihood for the discovery of many more extensive, diveable cave systems. Up until December 2001 only 12 caves on the Nullarbor were known to be diveable, now there are 13.

Warbla Cave
Despite having been dived for many years by many experienced divers, the cave had a poor map so we dived and mapped the cave in 2000 under a SUSS permit. The survey revealed a small roof step which led to over 200m of previously unexplored passages as well as the Lost Lake. Further leads are known of in the cave and more work is required. Being a multi level maze passage type system, the potential is good for additional passage discoveries using sidemount techniques, but access to the cave is limited. Refer to Figure 1.

Nurina Cave
First dived in the mid 90's by Steve Sturgeon and then Andrew Poole, some 90m of joint controlled passage was dived. Following our efforts between 1999 and 2002 using sidemount techniques, the passage length has been progressively increased to more than 400m. The tight and silty conditions within the cave make exploration challenging but there is without doubt much more passage yet to be dived. Refer to Figure 2.

Mullamullang Cave
Probably the cave with the most elusive (and difficult to access) diving sites. It is an enormous cave with about 6km of massive trunk passage. A number of km of multilevel maze passage systems are distributed along the length of the cave. There are more than 27 separate lakes in the cave, the closest to the entrance being at 1km and the furthest 5.5km. A number of cave divers have attempted dives in the lakes throughout the cave over the years with very limited success. Our efforts began in 1999 and since then 80% of the lakes in the cave have been dived, including Lake Gelato in the Easter extension (!!!). Three additional lakes were found that do not appear on

the cave map and early in January and April 2002, more than 750m of underwater passages were discovered, mapped & video'd by Paul Boler, David Apperley and myself. Some small leads remain to be pushed. The passages are in the stunning Easter Lake (150m) and X Lake (600m+).

Olwolgin Cave
Probably the most spectacular cave diving discovery on the Nullarbor in the past 10 years is Olwolgin Cave, south of Cocklebiddy. A number of dolines were spotted from the air and investigated by dry cavers from the ISS and WASG groups during Easter 2001. A couple of the caves went down to water but the dry cavers believed they had little potential for cave diving !!! In January this year I had the privilege of being the first cave diver to investigate these sites for underwater potential. From the very poor looking entrance lake, a small FH broke into a major submerged trunk passage with many side passages, over 400m of passage was dived and surveyed to start with. Refer to Figure 3.

I returned shortly after in February with buddy Andrew Nelson. After walking our 100cuft cylinders more than 1km through thick bush to the cave, we explored and mapped 1.3km of passage with several leads remaining. An attempt to return to the cave to survey and video it in April 2002 was thwarted by heavy rain in the area. Once this has been done, more information will be made available. The cave is named after a nearby bluff on the Nullarbor Escarpment.

OTHER WA CAVE DIVING SITES

Tombstones Cave, Cataby
Being only 200km north of Perth, this is our most accessible cave diving site although it is on private property. Prior to our diving the site last year, about 150m of diveable passage was known which terminated in a narrow, shallow vertical fissure. I could see a dark void beyond the gap and so encouraged, I pushed through this slice of rock and into the start of the rest of the cave! Over several visits during 2001, Craig, Karl & I extended the cave to over 1km of maze and fissure network passages. Future visits are required to complete surveying and video the passages. It is believed that most of the major passages in this cave have been explored, but we should never say never !! There are other known wet caves in the region requiring further investigation.

Cave C215, Exmouth
Located in the Cape Range near Exmouth, WA this cave is a very important site for rare troglobitic fauna. Formed along a controlling joint running NNE, the cave quickly sumps into a small underwater tunnel barely large enough for a single diver to pass through. The sculpted rock has many short sharp protrusions which grab & tear wetsuit material. In the late 90's, 20m of underwater passage was traversed by avid Perth cave diver Andrew Poole at which point a particularly tricky restriction is encountered which he did not pass.

In May 2001 I was able to carefully negotiate the restriction and continue along the shallow narrow passage for 90m at which point it drops through two large floor holes into a large conduit at 9m depth and another floor hole down to –18m.

Returning in June 2001 with cave diving buddies Karl Hall & Craig Challen, we pushed the deeper passage some 200m through keyhole shaped passages and a low flat restriction into a large terminal room with the continuation choked by a silted up floor.

The bottom of the –18m floor hole was choked with silt last year but a recent dive this July revealed that the heavy rains in the area in May have flushed the silt away to reveal a rock choked restriction leading to another low horizontal tunnel at a depth of –20m.

With the recently exposed 'deep tunnel', the end of the cave must also now be reviewed to see if it also now continues on. Other known wet caves in the area also require sump diving techniques applied to them.

The Blue Holes of Lake MacLeod
Jack's Vent is a sea water spring or vent in Lake MacLeod, an enormous salt lake near Carnarvon. Although known of and investigated in the late 90's by Perth cave divers, it was only recently re-

visited and some of the many other Blue Holes in the Lake were visited for the first time. Some were found to be heated artesian waters and others were fresh water springs coming from very small, barely passable tunnels and solution tubes in the lake's limestone substrate. The flow rate is quite high which makes this a somewhat more challenging diving proposition.

Further work with the land managers and CALM is hoped to lead to a systematic investigation of these and other blue holes in the region. Helping to reveal the secrets of the lake's complex hydrogeology will be a reasonable challenge in the years ahead.

Similar blue holes and springs along this part of the coast as well as extensive, unexplored karst areas offer very good potential for some interesting and unique cave diving sites. A recent visit with some friends from the WASG to this magnificent, but rugged part of our coast saw us discover a number of dry caves but none with deep lakes - yet !!

SUMMARY

What has been the key to our successful exploration of these WA cave diving sites?
Four reasons appear obvious to me:
1. Close relationship and communication with dry caving groups
2. Side mount/sump diving techniques.
3. Systematic, detailed surveying and mapping
4. Passion and Persistence

Our efforts have been sporadic, yet persistent over the past few years and it has shown that for those willing, the rewards are fantastic and the diving an absolute privilege.

My sincere thanks to Paul Boler for the use of his excellent video footage from our 2002 Nullarbor trip. More information (maps, photos, data) is available on our website at www.trimixdivers.com which has become a substantial database of Australasia's cave and wreck diving sites.

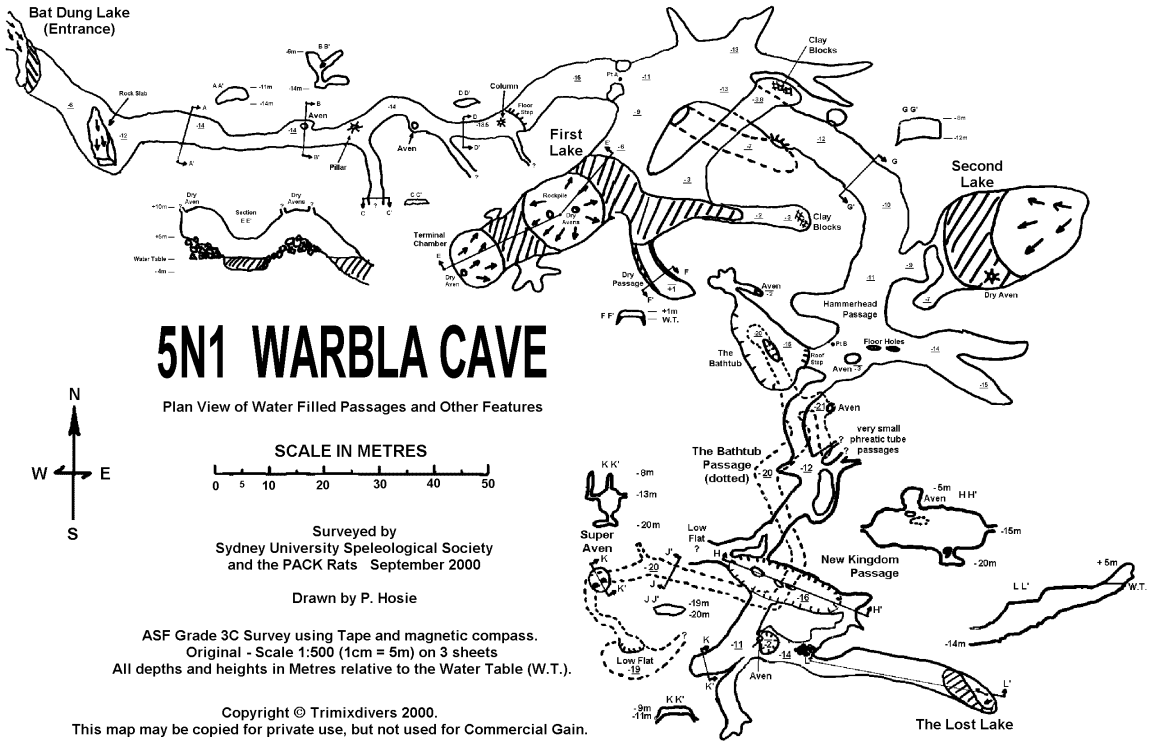


Figure 1 - Warbla Cave Map

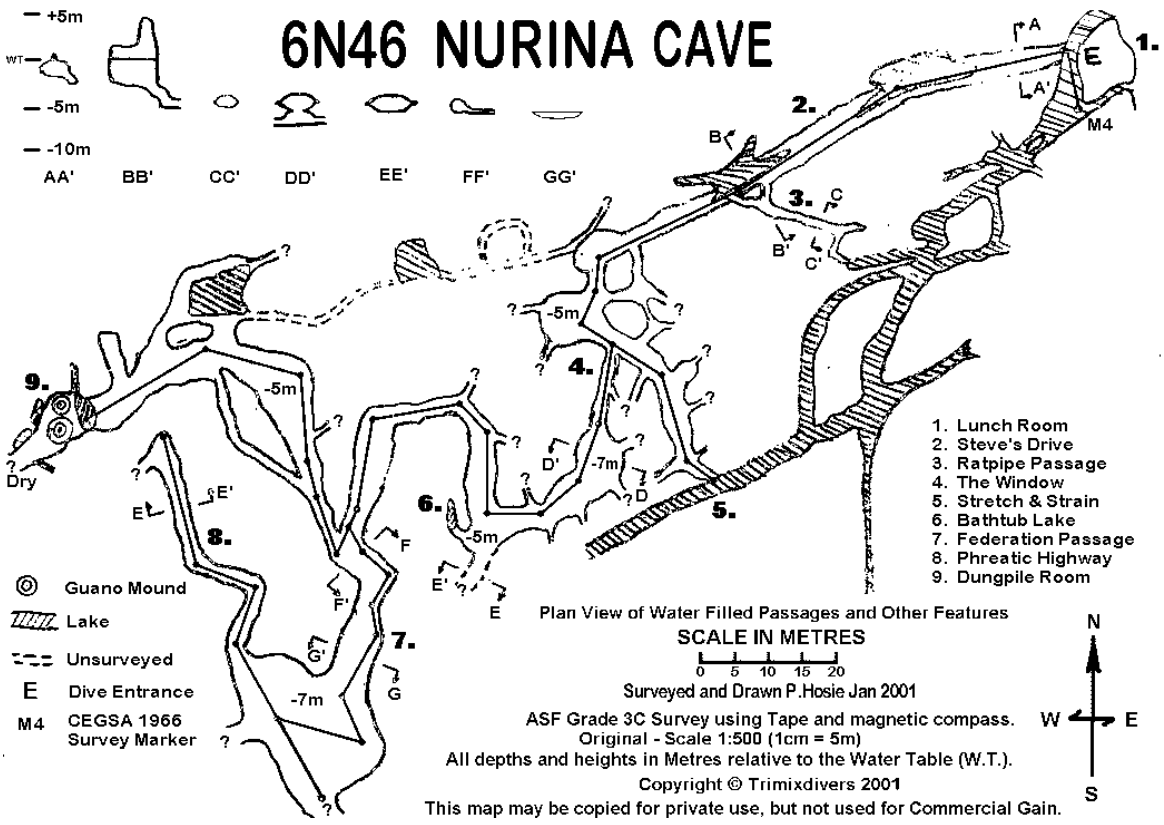


Figure 2 - Nurina Cave Map

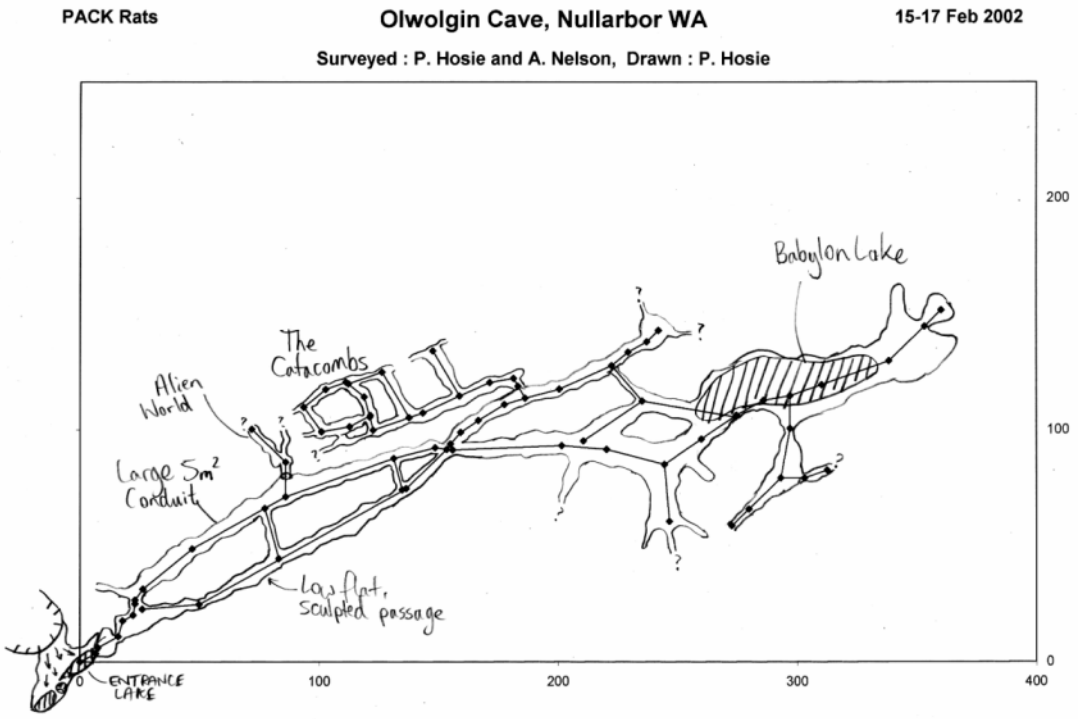


Figure 3 - Olwolgin Cave Sketch

Cave Diving Exploration of Australia's Top End

Paul Hosie

(Accompanied by 2002 KNI 19 Cave Diving Video by Paul Boler)

INTRODUCTION

It is only within the past twenty years that the karst of Australia's Top End has been looked at by speleologists with more than a cursory glance. It is only within the past five years that cave divers have ventured into these areas as well. Early indications are that although it is a far more challenging environment compared to down south, the cave and cave diving exploration potential far exceeds that of the South.

CAVE KNI 19 – NINGBING RANGES, THE KIMBERLEY

KNI19 is currently the most awesome cave dive in the Kimberley with 750m of diveable passage that gives no indication of ending. This is also one of the most spectacular cave dives in Australia as it has a 5m high, active crystal waterfall 160m into the dive. KNI 19 has proven to be one of the most challenging cave dives because above the crystal waterfall, 600m+ of passage so far dived has an average depth of 25m and maximum so far of 30m. Refer to Figure 1.

KNI 19 was discovered by following a heavily calcified outflow creek to it's source. The cave was first dived in the late 90s by Stefan Eberhard and line was left through to the stunning Crystal Waterfall. As no map of the underwater passages was available, this was the objective for our visit in 2002, as well as to explore the furthest extent of the cave. Cave divers Dr Jeff Swann & the author, both of the Western Australian Speleological Group (WASG), conducted the second ever dives into the cave over the weekend 19-21 July 2002. It would not have been possible without the assistance of local dry cavers, all of whom are also members of the WASG. Thanks go to John Cugley, Dave Woods, Paul Cornish, Leonie Turra and Clive Rippon for doing most of the dive gear lugging! Getting gear to the water is an awkward task due to the 100m+ of small, low-roofed, entrance tunnel. Banded Catsnakes and water monitors are regular inhabitants and they must be watched for.

Our first dive was with side mount 7 litre cylinders. From the entrance lake at the 'Tonsils' a small tunnel-like chamber sumps for 5m through to the first dome chamber and lake room. This can be duck-dived but the 130m of passage beyond it cannot. This dive passage has beautifully sculpted rock tunnels that connect several lake chambers together. The average depth is 10m and at 150m from the Tonsils, a low flat restriction is encountered that rises up into the fissure shaped Crystal Waterfall Room. Our first sight of this magnificent structure on breaking the water's surface, was truly breathtaking. The Crystal Waterfall is 7m wide and 5m high with sheets of water running down its surface in pulses.

Climbing above the waterfall, we found a 5m wide, 1.5m high canal passage and a suspended watertable held back by a number of gour pools. 20m from the waterfall, the gour pools end and the canal can be swum for 60m before it sumps again. Jeff & I decided to haul one set of gear up so that I could see whether it was worth returning with larger tanks. The passage continued shallow and straight to the NW, following a fault evident in the ceiling. After 50m the small tunnel I was in opened into a large water filled room – a room that had no floor !! The First Escalator Room dropped down to -17m and levelled for a short distance before opening into another large room – again with no floor! The Second Escalator Room took me down to –30m and at this point, with only relatively small tanks I was thinking; "I sure hope this doesn't keep on going down like Slug Lake at Jenolan (ie 90m+). If it does, it's going to be a pretty difficult dive!". Fortunately, the passage rose back up to -25m and pretty much stayed there as a $3m^2$ sculpted rock tunnel.

I was now 200m into the dive and approaching thirds (air turnaround point) when the passage did an abrupt right hand turn to the NE. The passage is shaped like a large keyhole, the rock smooth and bare. There is nothing to tie off to and I was getting a bit edgey – I needed to tie off my line, cut my reel free and get out of there. Pushing beyond thirds in this environment is tantamount to putting your life on the toss of a coin – because a failure of one of my air supplies means I won't have enough gas in the other to get out. 50m from the RH bend, the passage started rising up a steep sandy slope into a tall room and there, fortuitously, was a projecting rock that I tied off to. Jeff was waiting for me back at the canal and we celebrated the fact that this cave was still going in a big way. It was to be two months before we returned to get an idea of just how big.

KNI 19 – MOST RECENT PUSH

Paul Boler (NHVSS) and the author returned in September 2002 to push the cave limit and take underwater video of the passages and chambers. A sizeable population of leafnose bats had inhabited the cave since our July visit and disturbing them was kept to a minimum by doing all our gear lugging and diving at night, after the bats had left the cave to feed. Our push dive in September was conducted between 9pm and 2am plus an hour before and after to get gear in & out.

The dive above and beyond the Crystal Waterfall (which had by then stopped flowing) commenced with a pair of 100 cuft tanks each, filled with NITROX 36. The passage remained as a large conduit at a fairly constant depth of between -20 & -30m. The conduit is generally 4m wide and 2-3m high, though in some places it was a small vertical keyhole and in other places it is wide, oval shaped with finely scalloped walls. The floor generally has silt and sand piles but in narrower and smaller sections, the rock is bare, flushed clear by the massive wet season water flows. Large rooms occur regularly throughout the dive. Swimming through a low wide tunnel for 100m, the passage suddenly opens into a wide, tall room up to 30m long, 15m high and 10m wide.

The end was extended by 315m, bringing to total 600m of passage above the waterfall and 750m from dive start at the Tonsils. The overall trend of the cave takes the passage to the North to its water source(s). The passage showed no sign of ending, branching or diminishing in size. The depth of the conduit together with the surface topography, indicates the potential for several kilometres of diveable passage. This exciting and challenging cave will be dived again in 2003 with CCRs which will allow for a penetration of 4km or more. It is hoped of course, that no end will be found to this magnificent cave !!

FUTURE CAVE DIVING IN THE TOP END

The limited amount of effort made to date, the remoteness of the areas involved, dry season only, difficult access, cave resident snakes, high CO_2 and the largely unexplored nature of the karst offers the single greatest frontier for cave and cave diving exploration in this country. As an example, many caves were discovered in the vicinity of KNI 19 during 2002, several of them leading to sumps. KNI 64 has 85m of diveable passages and the potential to continue further into a perched watertable is similar to that of KNI 19. Refer to Figure 2.

Recent efforts in the Napier, Ningbing Ranges, the Tindall Springs and Camooweal clearly demonstrate the presence of extensive cave diving systems across the Top End. It is hoped that in the next few years there will be more concerted efforts to explore these remote karsts and reveal still more of this magnificent frontier.

Once again, my sincere thanks to Paul Boler for the use of his excellent video footage from his 1999 Camooweal trip with Rod Obrien and our 2002 Nullarbor trip with David Apperley. More information (maps, photos, data) is available on our website at www.trimixdivers.com which has become a substantial database of Australasia's cave and wreck diving sites.

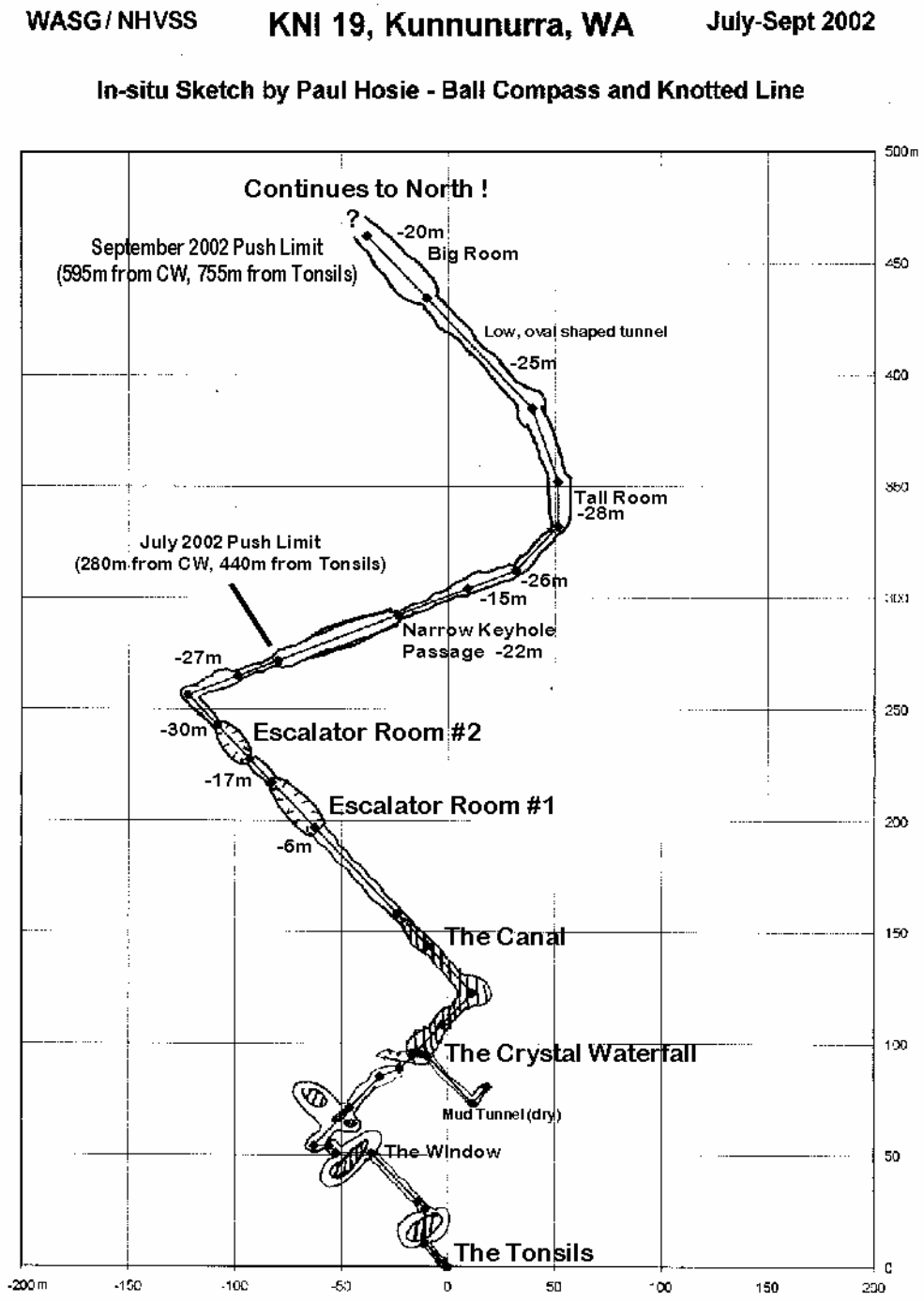


Figure 1 - KNI 19 Map

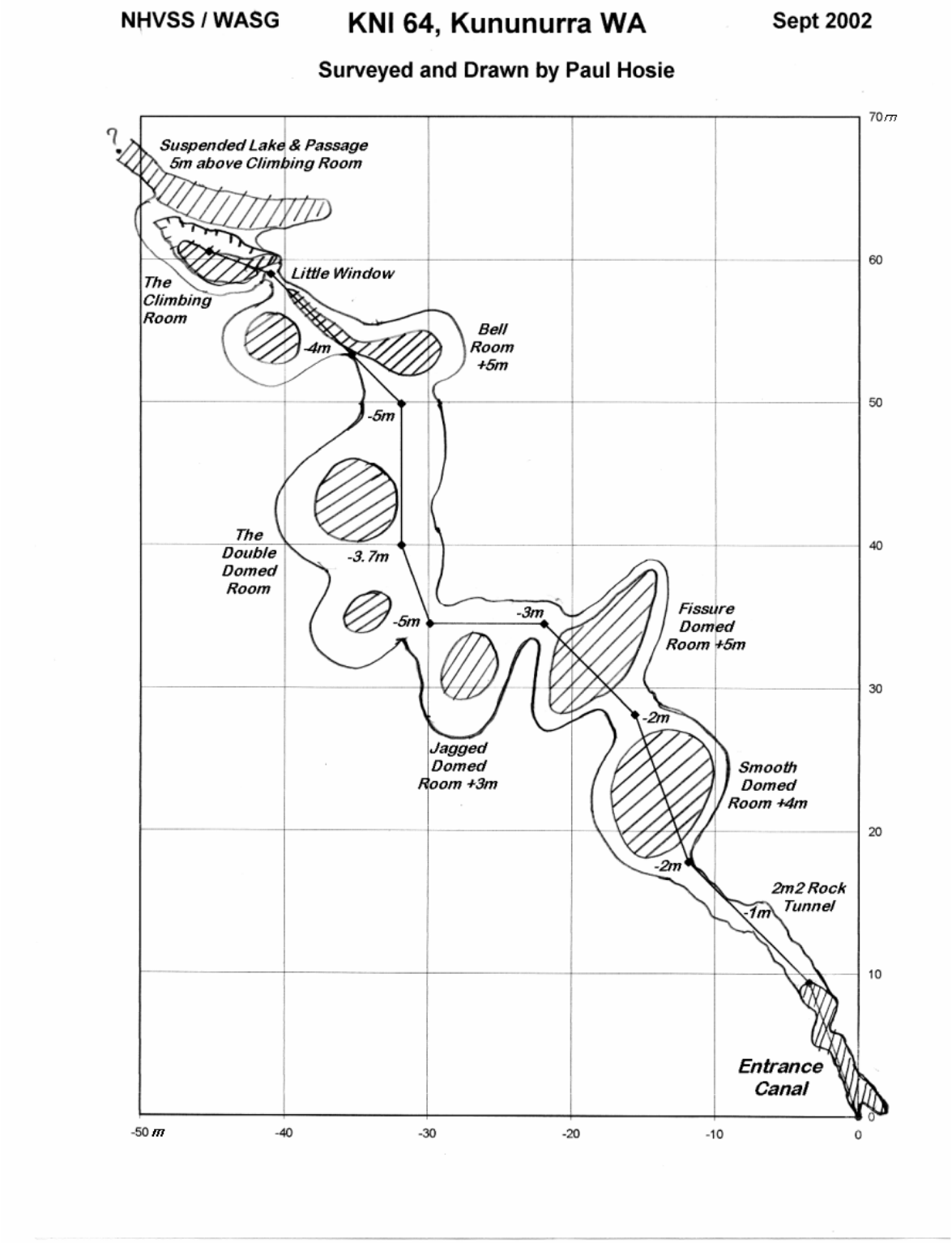


Figure 2 - KNI 64 Map

The ASF's Web-based Karst Index Database - A Brief Update

Mike Lake

INTRODUCTION

The Karst Index Database (KID) is a database of cave and karst features throughout Australia. The Web-based KID went online with most of the data available to anyone via a guest login in January 2001 in time for the ASF Conference at Bathurst. It is accessible on the WWW via any Web browser, including text-based browsers so users with vision impairment can access all functionality of the KID. You can find the KID at the ASF's Web site http://www.caves.org.au/

The data in the KID is a super-set of that published in the Australian Karst Index 1985 (1) but contains no information more recent than that. The current KID contains information on 6,692 caves with references to 925 articles, 192 organisations, 1,308 persons and 2,400 cave maps and covers 355 caving areas in Australia. The database itself consists of approximately 270 fields structured into 45 tables.

CONTEXT OF THE ASF's KID

The Union International de Speleologie Informatics Commission (UISIC) facilitates local and international exchange of data related to caves and karst by developing and publishing information standards related to cave and karst. The UISIC is a Commission of the Union Internationale de Speleologie (UIS) and is chaired by Peter Matthews. (see http://rubens.its.unimelb.edu.au/~pgm/uisic/)

Standards include definitions for cave and karst fields and suggested table structures for cave databases. The ASF's Web-based KID is the first Web-based database to implement these standards.

There are at least two other Web-based cave databases; a United Kingdom cave database (2) and a Czech cave database (3). The UK database appears to have a few dozen fields and about two thousand caves, the Czech database contains 479 caves and about a dozen fields per cave.

CURRENT STATUS

The KID has been working without any problems for two years. There have only been two brief periods of a few hours of downtime during this time; both caused by factors outside the ASF's control. Extra functionality has also been added by the original programmer and myself.

The KID has consistently been one of the most accessed sites within the caves.org.au domain, the "simple" and "standard" searches being the most used. Usage of both the ASF's Web site and the KID has been steadily increasing since both were launched. For the period of November 2002 a breakdown of KID accesses are given in the following table:

Location	**Accesses**
via ASF's Home page www.caves.org.au/	282
directly via www.caves.org.au/kid/	274
Simple Search	195
Standard Search	300
Longest & Deepest Search	28
The Top 10 Search	16
Advanced Search	105

A KID Access Group was set up in mid 2001 to provide assistance to ASF members, researchers, land managers, or government agencies who wish access to the few non-guest accessible fields in the KID and to decide if that access will be granted. This also separates the granting of access from the technical database administration side. This has worked very well. The members of this group are Ken Grimes, Andy Spate and Graeme Pilkington.

FUTURE PLANS

The present KID is a read-only system and over the next six months additional code will be added to the system to enable clubs to update present information and add new information via a Web-based interface. There will also be provision for uploading bulk data and for limited off-line data entry.

The following is the ASF's likely development schedule for 2003:

- February-April: Programming will start on the updatable KID. This is anticipated to take about three months. During this time testing of the code will be done and writing of user documentation for the updaters can commence.
- April-June: Writing final draft of documentation for the updaters. Three months is being allowed for this task however this will be ongoing for some time after that as we modify the documentation based on feedback from the first updaters. We will be using a test database to test the updating functionality and provide a safe environment for updaters to gain familiarity with the updating system where mistakes don't matter.
- June/July: Controlled entry of real data can begin.

By this time the ASF would like to have clubs ready with members keen to act as updaters. The ASF intends to provide documentation and training for club updaters.

The specification for the updatable KID includes requirements for:

- updating of caves from Cave Summary Forms;
- updating of areas from Area Summary Forms;
- updating of maps from Map Summary Forms;
- updating of persons and organisations;
- functionality for users to make queries about caves, maps, persons and organisations etc.;
- showing what changes have been made to the data so users and State Coordinators can easily identify what data has changed;
- output of filled-in Cave, Area and Map Summary Forms for checking, archiving and in-field use (I intend to do some of this aspect of the programming myself);
- import and export of CSV and possibly implementing KDI format for exchange of data;
- ability to enter and edit data off-line and later upload to the ASF KID;
- data attribution.

Data quality for fields is also recorded so that the accuracy of the entered data can be specified (eg. data quality for the ‘discovery date’ may be ‘probably correct’ while data quality for a cave's length may be ‘correct’). There are 27 available data quality fields varying from simple ranges such as correct to wrong to more complex statements about data accuracy.

The integrity of the data in the KID is of paramount importance and for this reason checking of all updates by independent checkers is part of the KID updating system so that the possibility introducing errors into KID is reduced. This also means that no single user is responsible for errors that get into the database. Errors can still make their way into any database so data history is recorded so that all changes can be traced back and mistakes corrected. This also extends to cover the data quality fields.

Data attribution will also be tracked so that newly entered or modified data is attributed to the organisation that produced that data.

DOCUMENTATION

Updaters will require documentation to assist them in understanding the overall KID system, the procedural aspects of field data collection, collation and updating and in understanding the many fields in the KID and their meaning. (for field definitions see UISIC document http://rubens.its.unimelb.edu.au/~pgm/uisic/exchange/atendefn.html)

A professional technical writer will be heading a small team of writers and users to write this documentation. Considerable skill and experience is required to write user manuals in an accurate and understandable way for users and we are fortunate to have a caver who normally works in this capacity who is prepared to put in their own time for this project.

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Contact details

2 Derribong Place, Thornleigh NSW 2120.

Cave Rights Revisited

Norman Poulter OAM
Speleological Research Group Western Australia Inc.

During a SRGWA fauna survey to the Nullarbor Plain in 1987 with Dr Mike Gray (arachnologist) of the Australian Museum, he made the suggestion that entry to the Dome chamber of Mullamullang Cave (6N-37) should be limited or banned in order to give the resident troglobitic fauna populations of the spider *Tartarus mullamullangensis* and cockroach *Trogloblattella nullarborensis* a chance to recover their numbers - if that was possible. He was of the opinion that their evident population decline in the Dome chamber could be due to habitat disturbance by cavers, given that this chamber was a major goal for most visiting caving groups. The spider had not been seen in the Dome since the early 1970's and its presumed food source, the cockroach, since the mid-1980's. It should be remembered that the Dome chamber was first entered during 1965 so that the decline in the Dome spider population since its discovery in 1969 could be reasonably correlated with the increasing visitation and disturbance over the subsequent decade. At that time *T. mullamullangensis* was the sole member of its genus and the Dome was its only known habitat - reason enough to be concerned about the future of this spider.

The reasons for such concern are many. Such relictual cave species are important biodiversity icons because of their unique morphology and behaviour, their role in fragile cave ecosystems, their limited distributions, and for the invaluable insights they give about evolution and biogeography in areas like the Nullarbor Plain. For example, research has shown that *T. mullamullangensis* has surface dwelling relatives in forest habitats in south western and south eastern Australia, indicating that similar ancestral surface species once lived in the Nullarbor region. It can be inferred that this occurred under milder, moister climatic conditions with more widespread eucalypt woodland than are seen today and that the surface populations probably contracted into cave doline or karst crevice refuges as the climate subsequently dried (Gray 1981, 1993).

Dr Gray's suggestion ultimately led to my paper entitled "Cave Rights for Troglobites" delivered at the 18th ASF Conference (Cave Leeuwin 1991) and resulted in a successful voluntary non-entry ban (to the Dome of Mullamullang) resolution from the ASF council meeting a day later (Poulter 1991a). Rather than centre solely on the plight of the fauna of Mullamullang, the paper was meant to draw attention to the broad spectrum of troglobitic fauna, their supporting food chains and speleologists' obligation to protect them and their habitats. This revision paper is no different.

Within a week of the Dome resolution being accepted as ASF policy, that determination was callously disregarded during the course of a post-conference recreational field trip, on the grounds that the resolution was "…absurd", based on "...bogus logic" and "...should be flaunted out of hand" (Bunton 1990). I believe that the quoted author, who attended neither the paper's presentation or the subsequent council discussions completely missed the point of the whole exercise. Given that we know next to nothing about the biology of any of these Nullarbor troglobites, the point was to raise awareness of the often fragile existence of troglobitic fauna in ALL caves, but using the plight of the Dome's fauna (and others) as a prime example, to emphasize the possible effect visitors have upon them, thus making them think before entering fauna regions, that their actions may degrade the habitat and put the fauna's continued survival at risk. To make them think that perhaps they should respect the rights of the fauna to exist and therefore conduct their activities elsewhere in any given cave.

Now, twelve years since the publication of the "Cave Rights for Troglobites" paper and adoption of the Dome resolution - what, if anything has changed? Has visitation to the Dome of Mullamullang been curtailed? Have the Dome's spider and cockroach populations recovered? Have the caving community's attitudes towards all cave fauna and habitats changed - for the better, worse, or remained much the same?

Overall, I believe that as a combined result of the "Cave Rights" paper, subsequent ASF resolution and signage within the cave, visitation to the Dome has declined but while there has been a recovery of the cockroach population with the last reported sighting in January 2002, there is no

evidence to suggest that the spider has made a similar recovery (Poulter 2002), leading to renewed speculation that the spider is indeed, at least locally, extinct. Should the voluntary non-entry resolution be therefore lifted and signage removed? I don't believe so. While it was long expected that the spider would be found in other parts of Mullamullang, and may yet be, the fact remains the Dome chamber population is the only one discovered in the cave. *Tartarus mullamullangensis* is now listed on the ANZECC list of threatened species and in Schedule 1: Protected Fish and Invertebrates under the Nature Conservation Act 1980. Despite the discovery of other species of the *Tartarus* genus in other caves from 1985 onwards, the Dome chamber in Mullamullang Cave remains the only known location for *T. mullamullangensis*. The hope is that this population will yet recover or that others will be found in Mullamullang. But the spider's endangered status and, more worryingly, continued absence in the cave give us an obligation to maintain protection of its Dome habitat by restricting visitation and/or by educating and trusting cavers to confine their visit to a well marked out path. If indeed the spider is extinct from its birthplace due to our intervention, it will be a sad indictment of a lack of caring, and one that should reinforce our resolve to better protect other cave species and habitats in future.

Has the general caver's attitude towards caves, cave fauna and habitats changed? Cavers once looked upon caves as their own personal playground where they could go anywhere and do anything they pleased without any consideration for the cave, let alone resident fauna. In some sectors of the caving community, this perception probably still exists today, although hopefully not nearly as much as it did say twenty or thirty years ago. It is the obligation - if not the duty - of the older generation of cavers to educate the middle order of caving club members (in addition to society at large) that caves are not playgrounds. It is not enough to merely say "don't touch or walk on decoration". Few caves are dead and even those that are may have special faunal or other significance that needs protection. For the most part, caves are dynamic living entities that can be quickly and easily disrupted or destroyed by ill-informed visitation.

Open areas of cave floors are especially vulnerable to indiscriminate, repetitive trampling which can degrade or destroy animal habitations such as webs or burrows and the open structure of moonmilk, guano (whether active or decaying) and litter or soil/clay sediments to form hard compact substrates in which nothing can live. It is in areas such as these where narrow trails (marked or otherwise) need to be carefully established so as to cause minimal disturbance within the region, even to the point of walking in previous visitors' footsteps.

Another point to consider is the case of modified caves. Caves that have had their entrances or passages enlarged to permit human access will, as a result, suddenly have their meteorological and habitat dynamics changed, which may be detrimental to any resident fauna. Where this has occurred in tourist areas, some managers have attempted restoration of the original environmental conditions by the installation of sealable doors - do speleological societies attempt comparable measures following their similar activities?

Of even greater concern however, is where an entire cave has been opened by digging, possibly exposing a previously sealed ecosystem to the whole range of surface intrusion (predators, competitors and displacing animals) as well as total disruption of the cave's meteorological parameters. While it can be argued that during a cave's geological lifespan, an entrance may open or close many times, and - over a surprisingly short period, when opened by caving activities, the diggers should have an obligation to protect the cave's fauna, habitats and atmospheric environment (all inter-related), even to the extent of re-sealing the cave between visits or, by the fitment of an environmental gate.

Land managers, both public and private, are today taking a more active role in their speleological responsibilities. This is to be encouraged, but there is also need for vigilance from the speleological community and improvement on both sides. Where once, citing ignorance or lack of expertise, land managers happily absolved themselves from karst management in favour of speleological societies, which encouraged the elitist and playground mentality amongst some clubs - today, those same land managers are appointing their own specialists/consultants or drawing up their own regulations and management plans for regions or specific caves. This is where the speleological community can be of assistance, to help prevent or minimise bureaucratic or ill-informed policies being enacted, especially in relation to fauna and habitat protection.

Another aspect of concern is where a cave has no apparent land manager protection whatsoever. Numerous faunal caves on the Western Australian side of the Nullarbor Plain occur on Vacant Crown Land (VCL) under the jurisdiction of the Department of Land Administration (DOLA) who openly admit that they are administrators, not managers. One such cave is 6N-46, with seven confirmed troglobite species ranging from aquatic amphipods to *Tartarus* spiders, and is arguably one of the most important and diverse faunal caves on the Nullarbor with probably the highest human (public and speleological) visitation due to its proximity to the Eyre Highway and nearby roadhouse, despite the fact that private leasehold property must be crossed in order to access the area containing the cave. Apart from the scenic attributes of its confining phreatic passages, the cave has numerous inter-connecting shallow lakes with a clarity similar to that of 6N-2 (another DOLA responsibility). It was with a certain amount of dismay in recent times to learn that the Cave Diving Association of Australia has been periodically promoting the idea of 6N-46 becoming a sporting dive site, such a promotion should be discouraged in the interests of both the cave and troglobitic (both terrestrial and aquatic) fauna protection. But with no active land manager, how can such activities be stopped? In addition and as has been reported elsewhere, diving equipment easily transports contaminating organisms from one water body to another. "We can only hope that cave divers develop a sufficient sense of environmental ethics that they will only dive such sites under very tightly controlled conditions equivalent to entering a sterile laboratory area" (Hamilton-Smith 2002). Dry cavers too, need to be mindful that their clothing can easily transport detrimental contaminates (particulates and organic) from one cave, or section of cave, to another.

As Australia's population steadily increases, spurred on by economic and political boosters in addition to various sectors of the general community, so too, has the upsurge in recreational or eco-tourism and in some regions, urban development encroaching on karst or karst watersheds. This has placed an additional burden on caves and troglobitic and associated fauna habitats, even in quite remote areas and sometimes outside the control or influence of some land managers, let alone speleological societies or the ASF. These pressures from increasing tourism and urban development need to be addressed by the speleological community via position statements to government at all levels and sympathetic politicians (Greens and Democrats for example).

This is why I maintain that it is important for the speleological community to embrace this issue as a matter of urgency and formulate and actively promote a population policy (Poulter 1999). Irrespective of medium to long-term economic hardships associated with such a policy, the Australian and world environment depends on lowering global population. Concentrating on local or specific environmental issues, although periodically successful in achieving short-term gains, is merely fiddling around the edges and ultimately doomed to failure unless the underlying cause, over-population, is tackled head-on and humanely solved.

As part of a submission in 1987, I formulated a quote, taken from several sources, that said "what we have now is less than we had yesterday". With the perceived extinction of the Dome's *Tartarus* spider - that is a creature we certainly HAD yesterday and we should work hard to prevent future extinctions.

To finish I shall repeat with a slight variation, the final paragraph from my original "Cave Rights for Troglobites" paper. Wherever there is a food source in a cave - it is possible there is also a faunal ecosystem. In times past we have argued the right of a cave to exist. It is about time we acknowledged that the fauna within a cave (no matter how much fear or contempt we may harbour for that fauna or its habitat), also has a right to exist - and that existence must be respected and protected.

ACKNOWLEDGEMENTS

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Contact details

PO Box 120, Nedlands WA 6909.

Caving for 'Pink Puffers' and 'Blue Bloaters'

Garry K Smith

INTRODUCTION

The terms "Pink Puffer" and "Blue Bloater," have been around for many years, but do we really know what they mean and how serious it can be for a person entering a cave containing the so called "foul air"? In the caving fraternity the terms are used colloquially to describe the physiological effect on a person exposed to foul air containing an elevated concentration of carbon dioxide (CO_2) and reduced oxygen (O_2). However, within the medical fraternity the terms are used to describe patients with medical conditions related to Chronic Obstructive Airways Disease (COAD). The meaning and use of these terms is examined in both a speleological and medical aspect. Also a possible link between smoking and the speleologist blue bloater is discussed.

WHAT IS FOUL AIR?

Foul air, sometimes called "Bad Air", is an atmosphere which has a noticeable abnormal physiological effect on humans. (Smith 1999a). In limestone caves, foul air can be described as containing greater than 0.5% carbon dioxide (CO_2) and/or lower than 18% oxygen (O_2) by volume. As a comparison, normal air contains approximately 0.03% CO_2 And 21% O_2 by volume (Smith 1999b). Foul air is only present in a small number of caves around Australia. When encountered, it generally occurs as an elevated concentration of CO_2 and a reduced concentration of O_2. Either elevated CO_2 or reduced O_2 or a combination of the two can be life threatening (Smith 1997c). A high CO_2 concentration is the most life threatening situation encountered underground while life threatening low O_2 concentration is rarely encountered (Smith 1999b).

There are three types of foul air as described by Halbert (1982):

- Type 1 foul air results from the introduction of CO_2 into the cave atmosphere and all other components mainly O_2 and nitrogen (N_2) are diluted - the source of the CO_2 is immaterial.
- Type 2 foul air is the result of O_2 being depleted and replaced with the CO_2 by-product of organic and micro-organism metabolism or respiration by fauna such as bats or humans. In this instance the O_2 concentration is reduced in proportion to the increase in CO_2. The N_2 concentration stays constant.
- Type 3 foul air occurs with the introduction of methane and nitrogen production and the non-respiratory uptake of O_2 as well as CO_2 stripping by water. Also falling into Halbert's third type is an atmosphere which results from a combination of Types 1 & 2 with addition of another mechanism, which alters the gas concentrations.

ORIGIN OF THE TERMS IN SPELEOLOGY

James and Dyson (1981) were probably the first to document the terms "pink puffer and blue bloater" in a speleological sense. They reported observing the responses of two types of individual exposed to foul air containing a high concentration of CO_2. Most cavers respond by hyperventilating and with some degree of blood vessel dilation near the skin, which results in a pinkish complexion. Dubbed the pink puffers, this description fits the overwhelming majority of cavers. A very small minority have a greatly reduced response to high CO_2. Because they do not hyperventilate their oxygen level in the lungs and blood is reduced, thus giving a slight bluish tinge to their skin. Dubbed the blue bloaters, these people have a greatly increased chance of passing out. Therefore "a known blue bloater should never enter a region of CO_2 without the warning companionship of a pink puffer" (James and Dyson 1981).

James and Dyson used these terms in the speleological arena because the outward physiological effect on cavers exposed to foul air often matched those of medical patients suffering COAD. The terms, pink puffer and blue bloater, were certainly in use by anaesthetists and respiratorists for some time prior to the publishing of James and Dyson's 1981 paper. For example, an article titled

"Blue Bloater: Pink Puffer" was published in the British Medical Journal in 1968 and refers to the terms first being used around 1958. (Anon 1968).

FOUL AIR EFFECTS ON HUMANS

To understand why cavers can be categorised as either a pink puffers or blue bloaters, one must look more closely at the physiological effects on a person exposed to foul air of varying CO_2 and O_2 concentrations. Indications are that a person's degree of reaction to foul air, is closely linked to the gas which is their primary regulator of breathing and heart rate. Bearing in mind that "a high CO_2 concentration is the most life threatening situation encountered underground while a life threatening low O_2 concentration is rarely encountered" (Smith, 1999b). Hence the warning by James and Dyson (1981), that a blue bloater should never enter a region of CO_2 without the warning companionship of a pink puffer needs to be reinforced.

Our respiratory system needs to work harder for us to cope with foul air. The red cell haemoglobin in our blood, transports O_2 and CO_2 between the lung and body cells by the blood circulation. The exchange of the two gases takes place in the lungs by diffusion across the walls of the air sacs (alveoli). Oxygen from inspired air diffuses across the lining of the air sacs and enters the blood, while CO_2 moves in the opposite direction. Diffusion occurs because a gas in high concentration will move to an area of relatively low concentration, until an equilibrium is reached. Breathing in foul air with an elevated CO_2, reduces the ability of the body to get rid of its waste CO_2 to the exhaled air. This causes an elevated CO_2 concentration in the blood, resulting in acidemia, in which the body tries to counteract by initiating a number of secondary mechanisms in an attempt to return the pH toward normal (Smith 1997a,b).

In simplified terms, if the inhaled foul air contains a relatively high concentration of CO_2 the haemoglobin is unable to get rid of the body's waste CO_2, thus the haemoglobin is not free to take on fresh O_2. Exposure to a high concentration of CO_2 can result in respiratory acidosis, coma, asphyxiation and death.

PINK PUFFERS FROM A SPELEO PERSPECTIVE

Most cavers react quickly by hyperventilating, when exposed to foul air containing an elevated CO_2 concentration. They also take on a pinkish complexion due to some degree of blood vessel dilation (cutaneous vasodilatation) near the skin. Other symptoms include headaches, clumsiness, fatigue, anxiety and loss of energy. Amongst the speleological fraternity these people are colloquially known as "pink puffers".

This reaction is considered "normal" amongst the human population and can be explained by a well known medical fact that most humans rely on CO_2 as their body's primary trigger to regulate breathing and heart rate. Nerve receptors in the aorta near the heart and in the carotid artery, which goes to the brain, monitor any rise in blood CO_2 and the brain's control centre reacts by accelerating the breathing and heart rates. In effect the body is trying to reduce the blood CO_2 and take in more O_2 through gas exchange in the lungs. Changes in blood O_2 are also monitored, but the receptors are not as sensitive to changes in O_2 as to CO_2. Hence the secondary trigger for regulating breathing and heart function is a lack of O_2 which is detected by sensors in the carotid arteries and aorta arch lining near the heart.

BLUE BLOATERS FROM A SPELEO'S PERSPECTIVE

Blue bloaters, on the other hand, do not respond to elevated concentrations of CO_2 as quickly as pink puffers. By not hyperventilating, the oxygen level in their lungs and blood is reduced. This causes cyanosis (reduced O_2 in blood), thus giving a slight bluish tinge to their skin. These people have a greatly increased chance of losing consciousness without warning.

It is medically recognised, that for a small percentage of the human population, their primary trigger for regulating breathing and heart rates, is reduced O_2 in the blood.

MEDICAL REFERENCES TO PINK PUFFER AND BLUE BLOATER

Doctors and scientists have written many research papers on the subject of Chronic Obstructive Airways Disease (COAD) which over time has been known by a number of other names, including Chronic Obstructive Pulmonary Disease (COPD), Chronic Airflow Limitation (CAL), Chronic Airways Disease (CAD) and Obstructive Airways Disease (OAD).

Medical patients with COAD clinically cover a wide spectrum and those extremes have become known as pink puffers and blue bloaters. Two components of COAD are emphysema[1] and chronic bronchitis[2]. When these diseases are examined in their relatively pure form, each has its own striking patient characteristics of body build, general appearance and underlying disordered physiologic condition. That is, pink puffers are emphysema patients and blue bloaters are chronic bronchitis patients (Mandavia and Dailey 1993). However, Voelkel (2000) stresses that "while COPD patients are viewed traditionally as being either blue bloaters or pink puffers, guidelines have made efforts to stress that many patients will fall into neither group".

Medical papers often quote significantly different figures as to the proportion of COAD sufferers in a given population. For example, Duffy (2000) quotes about 5% of the United States population are COAD sufferers, while Hunter et al (2001) quote approximately 20%. Mandavia and Dailey (1993) quote COPD as effecting more than 25% of all adults in the USA. These vastly different figures reflect the conflicts of definition between doctors and authorities.

PINK PUFFERS AND BLUE BLOATERS FROM A MEDICAL PERSPECTIVE

Pink puffers are patients with COPD where the pathology is widespread emphysema[1]. Their main symptom is breathlessness which is progressive, because their blood gases are relatively normal, their skin is of good colour and in the case of Caucasians, has a pink colour. They are of thin build and have evidence of airways obstruction with a reduced exhaling capacity - forced expired volume in one second (FEV_1). Their chests are over inflated (hyperinflated) due to air trapping and the diffusing capacity of the lungs for carbon monoxide (DL_{co})[3] is reduced. A disease of the heart (cor pulmonale)[4] is unusual and when it occurs is usually late in the disease. (West 1977, DeMarco et al 1981).

On the other hand, blue bloaters have mostly a severe bronchitis[2] with some emphysema[1]. They are overweight and have a chronic cough with sputum (sometimes purulent). They have an elevated carbon dioxide and low oxygen in the blood. There is severe airway obstruction with a reduced FEV_1. Lung volumes and DL_{co} may be normal. The patients have a plethoric[5] appearance due to polycythaemia (an increase in the number of red cells due to chronic hypoxia[6]), and are cyanosed (blue) because of low blood oxygen. Chronic hypoxia causes the pulmonary blood vessels in these patients to constrict so that the right side of the heart has to pump much harder. This is worsened by the thickening of the blood (polycythaemia) and leads to thickening of the muscle in the right side of the heart (cor pulmonale) with subsequent failure and fluid retention. These changes occur relatively early in the disease and give the blue bloater appearance. Patients usually respond very well to correcting the hypoxia with long term oxygen therapy (West 1977).





Figure 1 - Blue Bloater - chronic bronchitis





Figure 2 - Pink Puffer - emphysema

Figures 1 & 2 - Reproduced from a paper titled 'Chronic Obstructive Pulmonary Disease' by Mandavia and Dailey (1993)

VALIDITY OF THESE TERMS IN TODAY'S MEDICAL PROFESSION

The outward appearance of the patient is an interesting aspect to scrutinise. Certainly the subtle difference in skin colour (pink), may be true for persons of white Caucasian background, but would be less discernible for persons of dark coloured skin. If we just consider this aspect, one could speculate that the terms originated from within the Caucasian medical profession.

The "puffer" term certainly refers to the fact that the patient is hyperventilating. The "Bloater" term may be interpreted as being swollen or enlarged and is referring to the physical appearance (obesity) of the patient.

The medical profession has traditionally viewed patients with COAD as being either blue bloaters or pink puffers, however more recent guidelines stress that most patients will not fall into either category. The COAD medical condition now covers such a wide spectrum in relation to the traditional terms which only describes patients at the extremes of COAD.

Given that today's society is more attuned to acceptance of a mixed ethnic population and the use of a political correct vocabulary, the medical fraternity is moving away from these terms to categorise COAD patients.

WHAT EXACTLY IS COAD?

Howard (1990) gives the following definition:

> *Chronic irreversible obstructive airways disease is the end result of a number of disorders: airway damage from tobacco smoke, atmospheric pollution and occupational dust and fume, bronchiectasis, cystic fibrosis, bronchial asthma[7] and a number of congenital disorders of defective airway defence. The clinical features include sputum, wheezing, breathlessness and infective and noninfective airway inflammation[8]. The pathological consequences are airways obstruction, emphysema and respiratory failure.*

Duffy (2000) states:

> *In clinical practice most emergency physicians use the term more specifically for the conditions of emphysema and chronic bronchitis, tending to view patients with conditions such as asthma[7], bronchiectasis and cystic fibrosis as different entities, even though the clinical margins are often blurred and treatment options often overlap considerably.*

In general, medical authorities now use the term COAD to cover all chronic respiratory conditions in which a person has irreversible reduced expiratory airflow. Some medical references also include asthma in the definition of COAD, even though asthma is a reversible airway obstruction.

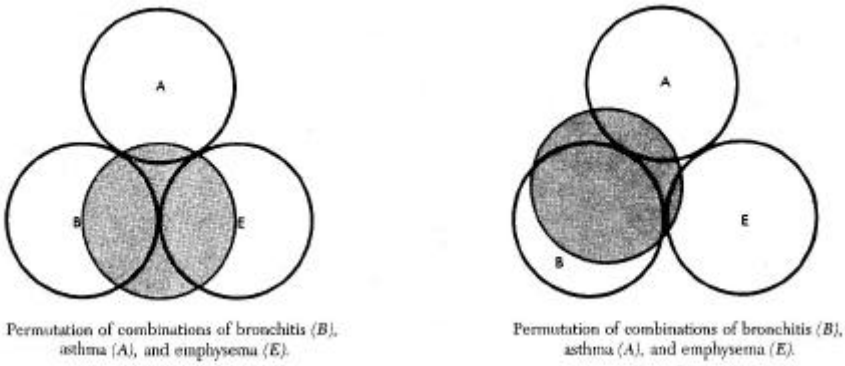


Diagram by Mandavia and Dailey (1993) which shows that a combination of several illnesses (of varying degrees) may contribute to a patients COAD condition
The shaded circle represents the individual patient

An exacerbation[9] can be diagnosed if an increase in breathlessness and/or an increase in sputum are experienced for two or more consecutive days. Other symptoms may include wheezing, sore throat, fever and cough (Thiadens et al 1998).

Voelkel (2000) says it is a commonly perceived myth that COPD is solely a self-inflicted disease of elderly smokers. He highlights that while smoking is a major risk factor for developing COPD, it is not the only cause and a sufferer may not be elderly.

A study undertaken by the Primary Healthcare Centre in the Netherlands (Thiadens et al 1998), cited years of smoking as the major contributor to COPD conditions. Their study of 192 patients aged 18-75 years, who presented themselves to their general practitioner with a cough persisting for at least 2 weeks, concluded:

> *About half ……. have asthma[7] or chronic obstructive pulmonary disease. With a simple formula based on three symptoms and prolonged expiration, pack years of smoking[10], and female sex, most patients may be identified correctly in general practice (Thiadens et al 1998).*

It is well established that cigarette smoking is the major risk factor with an estimated 10 to 30% developing COPD, however many smokers may not develop clinically significant airflow limitation. Owing to the large pulmonary function reserve, airflow obstructions can progress undetected for many years without the development of overt clinical symptoms of disease. Thus while many patients diagnosed with COPD are elderly, a decline in lung function often can be detected in smokers as young as 40 years of age. COPD is an indolent disease process that only produces symptoms when a considerable loss of the lung function has occurred (Voelkel 2000).

Mulloy et al (1996) studied 19 severe COPD patients and found that the majority desaturated during treadmill exercise, with a fall of greater than 5% saturation of arterial oxygen (SaO_2) and that the SaO_2 fell twice as much during sleep as during maximal exercise.

Thiadens et al (1998) studied 192 patients who presented to their general medical practice with a persistent cough over two weeks prior to the consultation. Of these 74 were diagnosed with asthma and 14 with COPD.

Breathlessness is of variable severity when the Forced Expiratory Volume (FEV_1) falls below 1.0 litre per second resulting in disability ranging from manageable to severe. (Howard 1990)

Breathlessness is a common feature of acute infective exacerbations, but breathlessness during normal every day activity develops insidiously over many years and most patients will have lost more than 50% of their predicted FEV_1 by the time that breathlessness becomes a problem. (Voelkel 2000)

COMPARING MEDICAL PINK PUFFERS WITH BLUE BLOATERS

Weight loss is common in patients with long standing disease with predominately emphysema (the Pink Puffer), although weight gain may also be a feature suggesting chronic hypoxemia[11] and the onset of cor pulmonale[4] (the Blue Bloater).

Johnson et al (1983) say that:

> *Pink and puffing patients (fighters) are frequently stated to maintain relatively normal blood gas tensions at the expense of breathlessness and are consequently severely disabled, whereas blue and bloated patients (non fighters) choose to be free of breathlessness and are less disabled, but at the expense of abnormal blood gas tensions and consequent right heart failure (right ventricle failure).*

They studied 26 patients (15 pink puffers and 11 blue bloaters) with chronic airflow limitation (with closely matched spirometric values[12]) to see if the fight to maintain normal blood gases had a noticeable cost in terms of increased disability. Measurements were made of the breathlessness,

exercise tolerance, and exercise physiology of the two groups. They found that blue bloaters "chose" to tolerate abnormal blood gas tensions, as they were able to improve the pressure of arterial oxygen (PaO_2) and pressure of arterial carbon dioxide ($PaCO_2$) considerably toward normal by voluntary hyperventilation. They failed to find any difference in breathlessness or exercise tolerance between the two groups despite a higher ventilatory response to exercise in the pink puffers. They conclude:

> *The misconception that the pink puffer patients are more breathless may have arisen from the increased ventilatory response to exercise, so that patients are seen to puff and thus look breathless. It may also reflect differences in way of life, with the pink puffer playing the hare, always rushing at life, in contrast with the tortoise blue bloater, who plods at one pace and never becomes breathless (Johnson et al 1983).*

A POSSIBLE LINK BETWEEN SMOKERS AND SPELEOLOGICAL BLUE BLOATERS

A few quotes are used here to outline COAD and its links with smoking.

Voelkel (2000) states: *"smoking is a major risk factor for developing COPD".*

Kerstjens (1999), states: *"Chronic obstructive pulmonary disease is largely preventable. The main cause is exposure to cigarette smoke. The disease is rare in lifetime non-smokers."*

Voelkel (2000) comments that: *"many smokers may not develop clinically significant airflow limitation……. Owing to the large pulmonary function reserve, airflow obstructions can progress undetected for many years without the development of overt clinical symptoms of disease."*

Thiadens et al (1998) highlights that: *"In the early stages of COPD, patients may only experience mild breathlessness when taking exercise, but older patients are often at the stage of their disease where they are unable to care for themselves because they are too short of breath."*

Bear in mind that, COAD sufferers could actually be chronic asthma or bronchitis sufferers, which may or may not be linked to smoking.

Over the past 30 years the author has been into many caves containing foul air and observed the reactions of fellow cavers. What particularly stood out were the reactions of smokers and non-smokers when foul air was first encountered. These informal observations indicated that a higher percentage of heavy smokers react slowly to elevated concentrations of CO_2 compared to non-smokers. At a cursory glance it would appear that many long term, heavy smokers could fit into the category of blue bloaters. Ex-smokers could be either pink puffers or blue bloaters. One could speculate that this may be due to a person's history of physiological conditions, which resulted in prolonged restriction of lung or respiratory function. Thus their body has become acclimatized to elevated CO_2 in the lungs and blood. This condition may have reverted their primary trigger to an O_2 deficiency and now uses the body's CO_2 sensors, as the secondary trigger to control breathing and heart rates.

DISCUSSION

Two possible scenarios are put forward for discussion.

1. Given that speleology is a physical sport and a reasonable degree of fitness is required to go caving, one could speculate that in speleological terms, a high proportion of blue bloaters may well be people with COAD at a stage, which is undiagnosed. Given that this disease progresses undetected for a long time before it impacts on the physical life of a person, it may have inverted the persons main trigger for their breathing function. Hence they may not respond as quickly to elevated CO_2, in a cave atmosphere as non-COAD cavers and as such have a greatly increased chance of losing consciousness without warning.

Lippmann (1992) appears to support this scenario by stating:

> *Some people have chronic obstructive airways disease, such as chronic bronchitis or emphysema which may cause excess carbon dioxide to be trapped in the airways. Certain sufferers become less sensitive to carbon dioxide to stimulate their breathing and rely more than normal on diminishing blood oxygen levels to cause them to breathe.*

Little evidence could be found amongst other medical literature to suggest that the onset of COAD may have reverted a person's primary trigger to an O_2 deficiency and use the body's CO_2 sensors, as the secondary trigger to control breathing and heart rates.

2. A more accepted view in the medical fraternity is that patients who are going to become pink puffers or blue bloaters, medically speaking, were probably destined to become one or the other at birth. The mechanism which determines this is not fully understood. Blue bloaters have a dulled respiratory centre and respond less to a rise in CO_2 concentration. Some 20% of the population have a pulmonary vascular bed which responds to hypoxia[6] by vasoconstriction[13] which causes hypertension[14] in the pulmonary circulation, overloads the right heart which hypertrophies[15] and subsequently fails causing swelling of the lower body. People with this basic physiological predisposition will probably develop blue bloater type COAD if they smoke heavily. Could it be that cavers who are speleological blue bloaters are probably destined to become medical blue bloaters later if they smoke heavily and develop COAD?

Certainly these two scenarios could form the basis of a research project for someone with access to equipment, capable of lung function measurements over a diverse range of individuals. Another consideration would be the large variation in levels of fitness amongst cavers – both smokers and non smokers.

CONCLUSION

The terms pink puffers and blue bloaters are used by speleologists in a colloquial sense to categorise how individuals react when breathing foul air in caves. Pink puffers hyperventilate and have good colour, while blue bloaters react slowly and look bluish because they are starved of oxygen. In foul air, a blue bloater runs the risk of losing consciousness without warning. James and Dyson's (1981) were quite within reason when they associated the medical term to describe the physiological effect of foul air on cavers. However, while the subtle difference in skin colour may be true for persons of white caucasian background, it is less discernible with persons of darker coloured skin.

Amongst the medical profession, patients with Chronic Obstructive Airways Disease (COAD) were traditionally viewed as being either "blue bloaters" or "pink puffers" because the terms described their outward appearance and reaction to breathing good air. More recent guidelines stress that most COAD patients won't fall into either group because the medical condition covers such a wide spectrum. The traditional terms pink puffer and blue bloater, were only describing patients at the extremes of COAD. The terms were used by the medical profession, to characterise the patient's general skin colour, body build and breathing habits in good air. Now the terms are rarely used by the medical fraternity, particularly with the awareness of the need for a politically correct vocabulary.

Over the past 30 years the author has observed the reactions of fellow cavers to foul air. At a cursory glance it would appear many long term, heavy smokers fit into the category of blue bloaters. Ex-smokers are either pink puffers or blue bloaters, and the majority of non smokers being pink puffers. Could this apparent high average of blue bloaters among smokers be due to their body becoming acclimatized to elevated CO_2 in the lungs and blood, thus reverting their primary trigger to an O_2 deficiency to control breathing and heart rates?

Two possible scenarios are put forward for discussion, which could link speleology blue bloaters, with smoking and the early stages of COAD.

1. Do long term smokers have an increased chance of being a speleological blue bloater because the early stages of COAD may have reverted their primary trigger to an O_2 deficiency and use the body's CO_2 sensors, as the secondary trigger to control breathing and heart rate?

2. Is a persons destiny as a speleological pink puffers or blue bloaters, determined at birth well before the influence of smoking or COAD? At birth approximately 20% of the population have a pulmonary vascular bed which responds to hypoxia by vasoconstriction[13]. People with this basic physiological predisposition are more likely to develop medical blue bloater type COAD if they smoke heavily. Is it an early sign that a speleological blue bloater will become a medical blue bloater if they smoke heavily and develop COAD?

These two scenarios could certainly form the basis of a research project for someone with access to equipment, capable of lung function measurements over a diverse range of individuals.

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FOOTNOTES

1. Emphysema is an abnormal permanent enlargement of the air spaces distal to the terminal bronchioles, accompanied by destruction of their walls and without obvious fibrosis (Kerstjens 1999). In emphysema the walls of the tiny air sacs (alveoli) within the lungs are gradually destroyed. The lungs lose elasticity and can no longer expand and contract easily to draw in and force out air. The disease develops so slowly that its victims are generally unaware that anything serious is wrong until much of the lung function in impaired (Howard and Lewis 1986).

2. Chronic bronchitis is defined as chronic cough, mucus production, or both, for at least three months for at least two successive years where other causes of chronic cough have been excluded (Kerstjens 1999). Bronchitis usually results from a viral infection, such as a cold, which spreads down into the bronchi and is followed by a bacterial infection.

3. A measurement of the diffusion capacity for carbon monoxide (DL_{co}) directly reflects the integrity of the alveolar capillary unit, and is useful for separating emphysema from the other forms of COPD, particularly in patients without substantial clinical signs. (Buist et al 1991)

4. Cor pulmonale: disease of the heart characterized by hypertrophy and dilatation of the right ventricle and secondary to disease of the lungs or their blood vessels.

5. Plethoric is a bodily condition characterized by an excess of blood and marked by turgescence (swollen or inflamed) and a reddish complexion.

6. Hypoxia is a deficiency of oxygen reaching the tissues of the body.

7. Chronic Asthma is a condition characterised by frequent bouts of breathlessness. In an asthma attack, the bronchi become narrow because their walls contract and cause partial obstruction of the airway, which makes breathing difficult. The mucous membrane lining may swell and be accompanied be secretion of thick sticky mucus. An attack may be brought on by an allergic reaction to airborne particles, such as:- pollen, mould spores, dust and animal fur (*The Family Medical Reference Book. 1987*). Some medical references also include asthma in the definition of COAD, even though asthma is a reversible airway obstruction.

8. Airway inflammation is an inflammation of the airway which restricts airflow to the lungs.

9. Exacerbation: to aggravate or make a medical condition more severe.

10. Pack years of smoking were calculated as the product of years of smoking and the mean number of cigarettes per day divided by 20.

11. Hypoxemia: deficient oxygenation of the blood; condition of having less than normal oxygen in the blood.

12. Spirometric values: are measurements made to determine the efficiency or the respiratory system. eg. **FEV_1**: Forced expired volume in one second.

13. Vasoconstriction: contraction of the muscular coat in the wall of arteries, which reduces the blood vessel bore and the amount of blood flow.

14. Hypertension: abnormally high blood pressure and especially arterial blood pressure.

15. Hypertrophies: Excessive development, morbid enlargement of an organ.

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Contact details
5 Fourth Street, Seahampton NSW 2286.

Pilchers Mountain Caves

Garry K Smith

LOCATION



The caves are located approximately six kilometres north of Wallarobba. This small settlement is centred around a railway station and road crossing approximately midway between Paterson and Dungog. The caves are currently within a Crown Reserve, which is surrounded by private property.

ACCESS

Access is through several private properties and permission is required from the land owners before entering the Crown Reserve. For further details on access conditions etc, contact the Newcastle and Hunter Valley Speleological Society.

DESCRIPTION

The Pilchers Mountain Crown Reserve was established to protect the caves and unique geomorphology of the surrounding area, comprising several sub-parallel offset chasms that host a picturesque pocket of dense subtropical rainforest, typical of many occupying small hillside gullies with a southerly aspect in this region.
The protected area lies in stark contrast to the surrounding grassy hills cleared of their original dry sclerophyll forest cover for grazing.



GRESFORD, 1:250000 Topographic Map CMA 9233-3-S

There are 5 disjointed main chasms, and a number of smaller ones running generally East West for approximately one kilometre, over a width of half a kilometre. The base and sides of the wider chasms are mostly strewn with massive angular sandstone blocks. The large depressions created a micro climate which aided growth of the present pocket of subtropical rainforest.

The chasms formed as a result of massive sandstone block separation along sub-parallel joint planes, aided by the dip of the sandstone layers towards the floor of the valley, and the presence of underlying shale bands which acted as slip planes when lubricated by groundwater (England, 1982). Many speculate that this event occurred gradually over millions of years, however Hunter (1991) suggests that the development process may well have been accelerated by the numerous earthquakes which occurred in the district over hundreds or even thousands of years.

The open chasms reach a depth of 90 metres and typically have vertical walls, with the gaps ranging from a metre or less to over 50 metres. In places where the walls are narrow, large blocks wedged between the two walls have created several large caves. (eg. Bat Cave and Rebel Cave). Smaller caves are located in piles of large angular boulders which have fallen into the wider chasms as the sandstone masses moved down-slope (Figure 1.).

The caves contain a wide variety of fauna. The Bat Cave (also known as Wallaringa, Pilchers or Main Cave) is the roosting site for a large colony of Common Bent-wing Bats (*Miniopterus schreibersii blepotis*) and a smaller population of Eastern Horseshoe Bats (*Rhinolophus megaphyllus*). There are also gecko lizards, frogs, weta, millipedes and various insect life in the caves.

The most northern gorge contains the Bat Cave, and Rebel Cave. Another contains the Lambton, Valentine, Diamond Mine and other caves. In all there are about 14 known caves. The largest chamber is found in Bat Cave, while the deepest known cave is Rebel Cave with a vertical depth of 46m. It contains a 6m pitch and another 27.5m free hang. The Bat and Rebel Caves generally follow the line of the northern gorge, while the others are more irregular as they occur in large rockpiles.

There are no reported cases of "foul air" being encountered at Pilchers Mountain caves. However, at some times of the year, the smell of decomposing bat guano in Bat Cave is overpowering to the uninitiated caver. The Rebel and Bat Cave tend to stay damp and humid even through the worst droughts. However the rockpile caves such as Valentine and Lambton Caves, tend to be dusty during extended periods without rain.



Northern most chasm at Pilchers Mountain Below this open chasm is Bat Cave

HISTORY

The gorge area and rainforest would have certainly been known by the aboriginals of the Worimi tribe (Tinbale, 1974), who inhabited the area prior to European occupation. However there is no evidence to suggest that they entered the caves or even knew of them.

Pilchers Mountain was named after Henry Incledon Pilcher who arrived in NSW during 1830 and was admitted to practice as an attorney and solicitor of the Supreme Court. He was granted a large estate called Wallaringa, near the mountain. Pilcher lived in Maitland where he practiced as a solicitor, while the estate was managed by an overseer who utilised a convict workforce (Hunter, 1991).

Around 1840, a group of notorious bushrangers called the 'The Jewboy Gang' terrorised the district, robbing travellers and homesteads of money, guns, ammunition, silverware, jewellery etc. This group of seven escaped convicts carried out robberies in many parts of the Hunter Valley and even up into the New England district. One of the convicts had escaped from the nearby Wallarobba Estate (within 5km of Pilchers Mountain). This estate, owned by Matthew Chapman, was thoroughly robbed as were many others in the area. It was believed by some that the overseer and convicts of the Wallaringa estate collaborated with the outlaws. One of the gangs' hiding places was known to be in the Wallarobba mountains and Hunter (1991) speculates that the Gang may have stowed their ill-gotten wealth in the boulderous caves at Pilchers Mountain. The gang's reign of terror came to an end on the 23rd December when they were captured at Doughboy Hollow over the range from Murrurrundi. The seven were taken to Sydney, tried, convicted and hanged in March of 1841 (Smith, 1994).

Certainly the gorges of Pilchers Mountain were known by the early 1880's, as a description dated 1886 refers to a fissure varying in depth from 100 to 300 feet (30 to 90 metres). The account also mentions large boulders, lush vegetation similar to a jungle with a tall tree canopy (Hunter, 1991).

During early European settlement and the clearing of land for grazing, it was inevitable that the early pioneers stumbled upon the gorges and lush rainforest, possibly even discovering the Bat Cave entrance, but no records have yet surfaced to indicate the exact time of its discovery.

Obviously the significance of these unique gorges, rainforest and caves was realised soon after their discovery, hence an area covering about 65 acres (26.3 hectares) was gazetted a Crown Reserve number 8894 on 18th April 1889 by the governor of the day (Government Gazette, 1889).

The earliest known map to indicate the existence of caves on the reserve is the NSW Crown Land Administrative Map from County DURHAM, Parish of DUNGOG, Edition 4, 1st January 1914.

The Dungog Shire Council (formerly Wallarooba Shire Council) was appointed as Trustee of the reserve on 18th February 1916. However this appeared to be just formalising the situation because under the local government act, Council had care and control of the reserve since its gazettal in 1889.



Peter Jackson ascends the 27.5m pitch in Rebel Caver

In the late 60's and early 70's the first caving groups began exploring the area. The cave now called "Bat Cave" was referred to as Wallaringa Cave (WC1) in the 'CAVE' official newsletter of the Newcastle University Speleological Society, May 1970. In this publication the editor states "Wallaringa Cave was run through with compass and tape early last year, but nothing further has arisen from this. The Cave is in sandstone, and has been formed by the collapse of a rock mass. It is the only reported cave of its type in Australia, so mapping it will be worthwhile, as would be a full scale study." It is interesting to note that the trip report in this magazine talks about five cavers entering (WC1) and exploring the main level but not the lower level. They then moved on to another previously unexplored hole at the top of the gorge (Jordan, 1970). From the description one could assume that they descended the small pitch into the first chamber of Rebel Cave. The name Wallaringa was taken from the name of the property at the junction of Spring Creek and Coxs Creek as shown on the early 1 inch to the mile maps of 1942. However on more recent maps the Coxs Creek was renamed Wallarobba Creek. The Wallaringa property is approximately 1.5km south of the caves.

In January 1988, the National Parks and Wildlife Service (NPWS) proposed to acquire Pilchers Mountain as a Nature Reserve. This led to a meeting on the 5th June 1992, where agreement was made between NPWS, Dungog Council and 'Department of Conservation and Land Management' (CALM) to dedicate the reserve for Environmental Protection and Recreation following land assessment action." NPWS agreed to withdraw from a Nature Reserve acquisition proposal on completion of a Plan of Management for the site (Wiseman, 1994).

In November 1995, the NSW Department of Land and Water Conservation, released for public inspection a 'Draft Assessment of Crown Land at Pilchers Mountain' as a requirement under the Crown Land act 1989, to seek public comment prior to changes in Reserve classification (George, 1995).

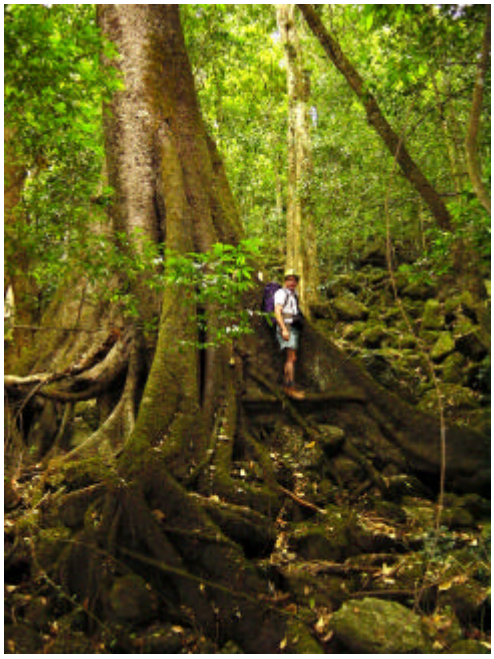
The reserve 8894 (Lot 338 DP No. 1009839) covering 30.07 hectares, was dedicated as an Environmental Protection Reserve on 15th December 2000, and the earlier classification of Crown Reserve for Public Recreation was revoked. (Government Gazette, 2000). The Dungog Shire Council was appointed to manage the affairs of the reserve trust (Aquilina, 2000).

In a letter to the Dungog Council, the Manager of Resource Access and Compliance for the Department of Land and Water Conservation, said the change in the reserve's status was "in recognition of the significance of the site." (Garboll, 2001).

Recently the Dungog Council applied for a Government grant to fund the preparation of a "Plan of Management" for the Pilchers Mountain reserve.



Bird's Nest Fern in rain forest among the boulders of the open gorges



Morton Bay Fig with a buttress in excess of 6m across

CAVING AT PILCHERS MOUNTAIN - PERSONAL EXPERIENCES

The first time I visited the gorge and Bat Cave was in 1969, as a young Senior Scout on a Unit outing. With a few Scouting friends, I revisited the area in early 1970 to once again explore the Bat Cave. After exiting, I searched a nearby pile of rocks and found a small opening beneath a jumble of logs. Wayne Jessup and I entered this 'new' cave (now known as Rebel Cave) while Tony Harris and Robert Patrick remained outside as a safety backup. In the floor of the first chamber, opposite the entrance pitch, there was a hole leading down into a small chamber which could fit several people. We scrambled down, and after finding no leads, began exiting this small rock pile chamber. When almost back into the spacious entrance chamber, a large boulder next to the squeeze began sliding on the soft sloping earth toward the hole. It took me a lot of effort to restrain the boulder until Wayne exited the dusty hole. When the boulder was let go, it quickly slid downward, resulting in a loud thud and cloud of dust, to completely block the hole which we had just exited. Wayne and I were noticeably shaken by this life threatening experience and left the cave without further exploration. The entrance was re-covered with logs and we vowed never to return to the cave. Several years later the Scout Association began running introductory abseiling and caving courses in the main gorge. Members of Kotara Venturer Scouts Unit rediscovered the cave and gave it the name Rebel Cave after the nickname of their Unit. They went on to discover a small passage off the entrance chamber, which led into a deeper section of cave containing the 27.5m pitch. After 1975, I did return to the cave and have been to the bottom on a number of occasions. Even today, visitors to this cave should be very wary of loose rocks as this cave can be very dangerous even to the experienced caver.

The caves most visited these days are the Bat (Main) Cave, Valentine Cave, Lambton Cave and Crawler Cave. Visitors should not enter the Bat Cave in winter when bats are hibernating.
A complete listing of known caves is given in Table 1.



Sonia Taylor in the Northern Gorge



View to the North from the top of Pilchers Mountain
Note: rolling hills and grazing land is dramatic contrast to subtropical rainforest in gorge, just 50 metres to the south of this spot

GEOLOGY

Pilchers Mountain consists of thickly bedded sandstone with lenses of conglomerate, part of the Carboniferous Age Wallaringa Formation. They are generally yellow-brown, grading to reddish at the top of the formation (beneath a bed of Volcanics). The beds are mostly massive and resistant to weathering and therefore are excellent cliff formers (England, unpublished).

Localized dissolution of minor calcite cement in the sediments has resulted in the formation of isolated poor quality calcite speleothems in parts of the Bat Cave.

Also of interest is the narrow seam of coal and shale exposed in Bat Cave. The coal seam reaches a maximum thickness of around 100mm and tapers down to just a few millimetres in other places.



Abseiling into the northern gorge



Sonia Taylor in the entrance passage of Bat Cave

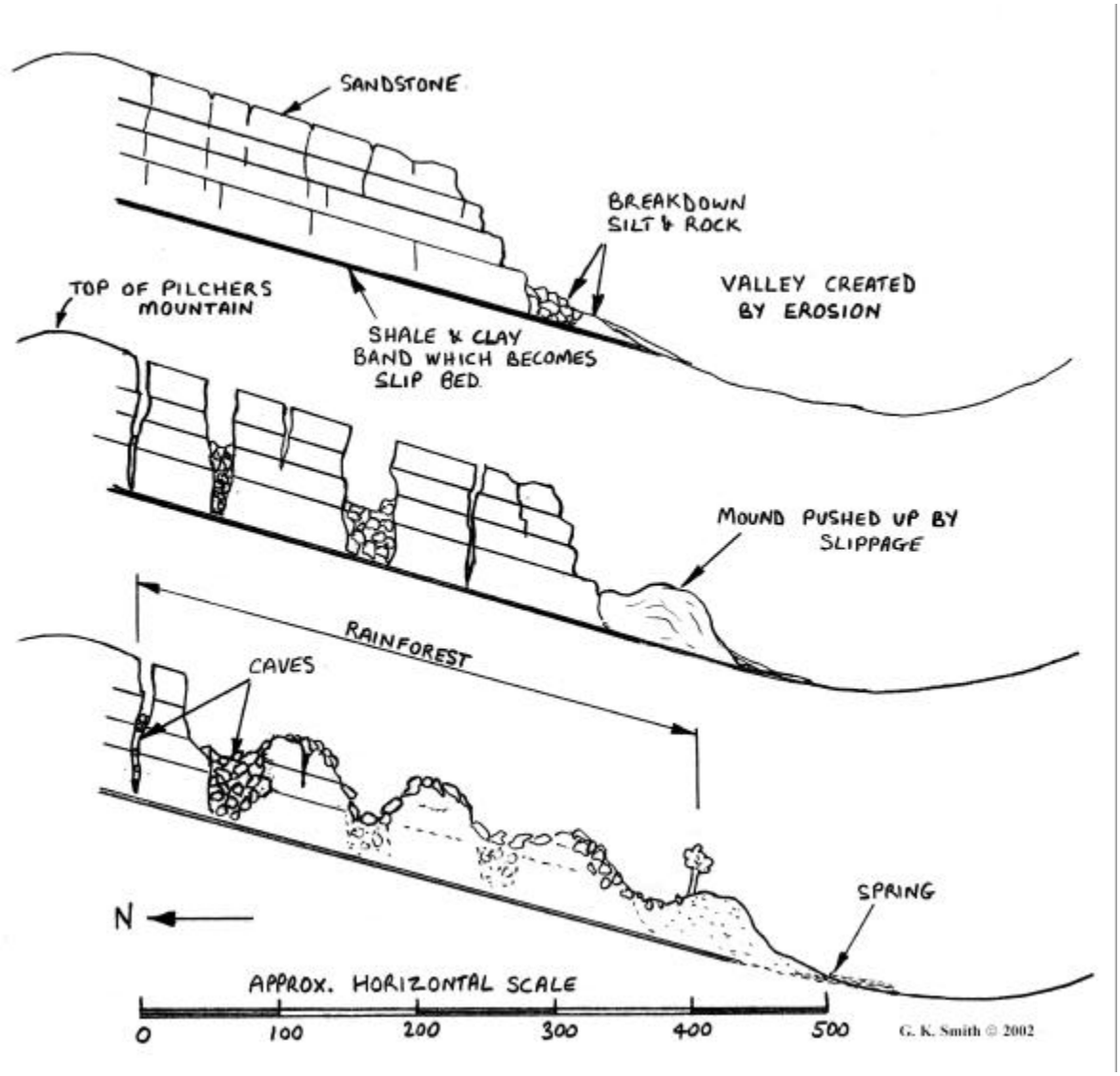


Figure 1 - Representative sketch of possible events which led to the development of chasms and caves at Pilchers mountain
North / South section through the Bat Cave

FLORA

The gorges within the reserve contain dense subtropical rainforest with an upper canopy in many places exceeding 50 metres. There are a number of varieties of tall trees, among them giant Morton Bay Fig, (*Ficus macrophylla*) with buttresses exceeding 6 metres. Some of the finest examples in Australia, of the Giant Stinging Tree (*Dendrocnide excelsa*), can be found in this rainforest. There are many good specimens of the Strangler Fig (*Ficus watkinsiana*), which have taken on the shape of their former host tree, before it died and rotted away from within the grasp of the fig. Other examples of the Strangler Figs' determination to survive are where they have actually grown over and around large boulders the size of small houses.

In the rainforest there are other tall trees, include the Flame Tree (*Brachychiton acerifolium*), Red Cedar (*Toona australis*), and Brown Beech (*Pennantia cunninghamii*).

The high canopy trees are hosts to huge vines, ferns, orchids and mosses. Among them are Elkhorn (*Platycerium bifurcatum*), Staghorn (*Platycerium superbum*), Bird's Nest Fern (*Asplenium australasicum*), Pink rock orchid (*Dendrobium kingianum*), King orchid (*Dendrobium speciosum*), and Maidenhair Fern (*Adiantum aethiopicum*). The vine Smooth Tender Grape (*Cayratia clematidea*) reaches its known southern limit here.

At the extremities of the rainforest and on parts of the surrounding land now used for grazing, one can see the occasional Grass Trees (*xanthorrhoea*), numerous varieties of Eucalyptus as well as Turpentines (*Syncarpia procera*) and Wattles belonging to the *Acacia* family.



Morton Bay fig growing on boulder



Strangler fig in gorge



Fig tree roots over boulders near Valentine Cave

FAUNA

The subtropical rainforest within the gorges supports a diverse range of wildlife including; possums, quolls, Brush-tailed Phascogale, koalas, bandicoots, wallabies, up to 50 species of birds and includes the nesting site of the rare Peregrine Falcon.

Fruit eating birds such as Top-knot, Wonga, White-head and Brown Pigeons have all been recorded in the area. Other birds include the Regent Bower Bird, Boobook Owl, and Wompoo Fruit Pigeon.

WATERSHED

There are two permanent springs which drain from the water table of the gorge area. The eastern spring drains into Spring Gully Creek and the other spring runs into an unnamed creek toward the western end of the gorges. Both these creeks merge and flow into Wallarobba Creek. Gresford, 1:25,000 Topographic Map CMA 9233-3-S.

ELEVATION RANGE

360 to 240 metres

ACKNOWLEDGEMENTS

I would like to especially thank Brian England for his critical review of this paper and the NSW Department of Land and Water Conservation for sourcing information on the gazetting of the reserve.

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Contact details

5 Fourth Street, Seahampton NSW 2286.

New Tag No.	Old Tag No.	Cave Name	Discovery	Mapped
		Main Chasm (Gorge)	Before 1889	Mapped 5-9-75
I6B15	PH-1	Bat Cave (Main Cave)	Before January 1970	Mapped by J. Smith, K. Rugg, G. McHugh & W. Brown, 29-8-75.
I6B16	PH-2	Cleft Cave	Before January 1976	Mapped by Steven Smith, 2-4-77, Grade 4 map
I6B17	PH-3	Diamond Mine	Before June 1975	Mapped by Peter Payne, David Carey & Wayne Smith, June-1975, Grade 4 map
I6B4 & 5	PH-4,5	Rebel Cave	Around 1970	Sketch map 22-2-86 by D. Armitage et.al.
I6B6	PH-6	Spider Hole	Before January 1976	No Map
I6B7	PH-7	Arch Cave	Before January 1976	No Map
I6B8	PH-8	Stalactite Cave	Before January 1976	No Map
I6B9	PH-9	Cathedral Cave	Before January 1976	No Map
I6B10	PH-10	Crawler Cave	Before January 1976	No Map
I6B11	PH-11	Valentine Cave	Discovered by members of Valentine Venturer Scout Unit prior to Jan. 1976	No Map
I6B12	PH-12	Pioneer Cave	Discovered prior to Jan. 1976 – links up to Valentine Cave I6B11	No Map
16B13	PH-13	Lambton Cave	Discovered by Garry K. Smith some time prior to January 1976, and named after Lambton Venturer Scout Unit	Mapped 27-2-93 by Garry K. Smith, Michael Smith, Pat Hyde & Katie Mottram
16B14	PH-14	Kotara Cave	Discovered by members of Kotara Venturer Scout Unit in 1992	No Map

Compiled from the following information by (Powell, 1976) (Smith, 1995).

Table 1 - Known Caves At Pilchers Mountain

Walkway Technology

Neil Taylor

ABSTRACT

This session will be informative and hands on. There will be a technical sheet handed out on the specific materials used in the walkway. The session is about the provision of a walkway into a cave with minimal impact on the cave. There will be a 3m section of walkway in kit form on site; participants can watch/assist as the kit is put together(and disassembled). The real value will be to see the materials used and be able to ask questions during the session. Participants wishing to see it put into Calgardup Cave will be able to do so if time permits. The materials used are 316 stainless steel and recycled plastic and the system could be adapted to accommodate varying path widths.

Contact details
Department of Conservation and Land Management, Busselton.

Karst Abuse in Western Australia

Rauleigh Webb

LIMESTONE MINING IN WESTERN AUSTRALIA

A review of the limestone resources of Western Australia was conducted by P.B. Abeysinghe, from the Department of Minerals and Petroleum Resources, in 1998 (Abeysinghe,1998). This review showed that by 1995 the state was consuming over 2.1 million tonnes of limestone per annum (See Figure 1).

Figure 1 also shows a graph of the uses of limestone for Western Australia. The major uses of limestone are our roads where limestone is used as roadbase to the tune of over 700,000 tonnes per annum (based on 1995 figures). The second biggest user of limestone is the cement industry at 500,000 tonnes per annum followed by the alumina industry consuming 300,000 tonnes per annum. These three uses are greater than 70% of our limestone consumption.

Year	Metro area	Loongana	Pilbara	Rest of State	Total
1992	1,967,651	112,281	69	3,845	**2,083,846**
1993	2,034,756	59,526	350	4,475	**2,099,107**
1994	2,154,060	62,021	420	6,410	**2,222,911**
1995	2,106,503	66,086	210	9,362	**2,182,161**

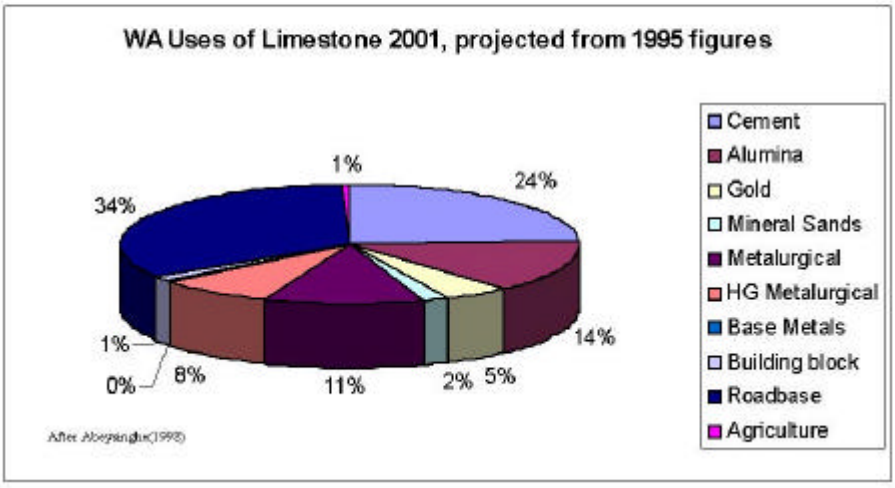


Figure 1 – WA Uses of Limestone 2001 – projected from 1995 figures

The majority, 96%, of this limestone is being mined in the Perth metropolitan area (See Figure 1). The next highest single area being mined is 3% being mined at Loongana on the Nullarbor. With the vast majority of the limestone currently being mined in the Perth region the impacts on caves is minimised as the Perth region has relatively few known caves in current mining areas. However the states "thirst" for limestone can only increase with population and mining companies with dwindling resources in the Perth region will look further a field for cheap limestone deposits.

Already that pressure is being applied to small limestone deposits just north of Perth in the Yanchep/Carrabooda and Moore River areas. If the Maud's landing development receives the green light then the development of a significant mine at Cape Range is very likely despite significant environmental and World Heritage Listing concerns.

Despite this the current situation is that mining of limestone in Western Australia is currently having a minimal impact on the cavernous karsts of Western Australia. However having said that the impacts of mining are low, the current usage of our precious limestone resources is at times frivolous.

The images shown in plates 1 through 6 show some of these uses. They range from blocks of limestone in train station car parks, to whole karst features being used as “ornaments” in road roundabouts, to children’s playthings in Kings Park, Perth, to the use of limestone as drainage rubble alongside roads.

This type of use of our precious limestone resource is unnecessary when alternatives are available.



Plate 1 - Limestone blocks at Beckenham Railway Station



Plate 2 - Limestone blocks at Cannington Railway Station



Plate 3 - Limestone block on footpath at the Royal Show Perth?



Plate 4 - A graffitied Karst Feature used as a Roundabout “centre piece”?



Plate 5



Plate 6 - Limestone used as drainage rubble Brand Highway North of Perth

WHAT OF THE FUTURE?

The review of Western Australia's limestone resources by Abeysinghe (1998) also contains an important discussion (Chapter 3) which indicates that the projected demand for high-grade limestone is expected to be 95 million tonnes over the next 20 years. This equates to 4.75 million tonnes per annum and hence a significant increase in limestone production.

Abeysinghe (1998) also predicts that the demand for low grade limestone for roadbase, construction, building blocks and agricultural use will also continue to grow. In his concluding remarks Abeysinghe also predicts that if "the large limestone deposits located at Cape Range and in the Eucla Basin are developed, not only to serve local but also foreign markets, then a major expansion o the industry could occur."

Given the significant size of the Nullarbor limestone deposit and the relatively sparse distribution of caves and karst features it is considered that the development of a "Mega Mine" on the Nullarbor would be preferable to the continued development of all of the smaller deposits in the South West of Western Australia. Such a mine, if large enough, could certainly provides all of Western Australia's limestone requirements as well as supporting a healthy export market. Such a mine would require very careful siting with easy access to both road and sea transportation while ensuring that the potential impacts on the overall karst are minimised.

DEVELOPMENT ON KARST

Another area of potential high impact on karst is human development. The sub-division of karst areas for housing development is one area that is having an effect on caves and karst features. As the Perth metropolitan area increases rapidly northward from Perth the karst areas at Carabooda, Yanchep and eventually Moore River are being developed for housing. Already one area at Carabooda, Emerald Valley & Alkimos Road, was found to contain a significant number of caves and karst features (23) but the development ignored the advise of speleologists and 8 of the caves or features were impacted by the loss of there entrance to roads or other infrastructure. (see http://www.wasg.iinet.net.au/asf_02.html)

This type of development is likely to continue and the conservation officers of the ASF must continue to lobby government departments to ensure that the impacts of development on karst is minimized.

Besides housing developments the placement of roads on karst also may have high impacts if cave entrances are covered or known caves have roads placed directly above them. In general the placement of new major roads requires an ERMP and companies preparing the ERMP generally contact speleological groups for information relating to caves in the vicinity of the proposed new road. Only roads on private developments have resulted in significant cave impacts in the last few years.

One of the major potential impacts on caves from development is the placement of infrastructure such as buildings, toilets, tracks/roads and car parks. Managers in karst areas must be made aware of the potential adverse impacts on caves by placing infrastructure adjacent to or worse still on top of known cave systems.

The developments at Calgardup and Giants cave in the South-West of Western Australia illustrate this point with buildings, water tanks, toilets and car parks placed too close to the cave systems they were trying to promote (See plates 7 and 8).

The placement of car parks for activities such as swimming and surfing adjacent to known caves is also to be avoided as this attracts the general public to visit caves when they may otherwise have not. Such a car park was placed within viewing distance of the entrance to Quinninup Lake Cave in the South-West of Western Australia. This can only result in unwanted uncontrolled extra visitation. Such decisions require cave managers to carefully consider the impacts of development on caves in karst areas and avoid such placements where at all possible.



Plate 7 - Building, water tank and toilet placed over known cave system



Plate 8 - Car park cleared adjacent to known cave system

CAVER IMPACTS

Cavers cause considerable impacts on caves just by visiting them. This level of impact can be minimized using now well documented techniques (http://www.caves.org.au/standards/minimal.htm). Despite cavers visiting a large number of caves the damage they cause is generally confined to features within caves. The impact of vandals on caves in Western Australia has been relatively small in the last 20 years. Generally, damage that has occurred with caves has been the result of uneducated visitors breaching gates on caves and then walking on sensitive features within the cave.

However, in some areas, such as the Nullarbor, the effects of driving the 4WD directly to cave entrances can have very long-term detrimental impacts. Once a single set of tyre marks (a track) is created to a cave entrance they can remain in place for years. They tend to encourage other vehicles to follow the "track" leading them directly to caves. As the Western Australian Nullarbor has no on-site management the visitation of caves by the general public is relatively common. By avoiding driving the last 2 to 3 hundred metres to a cave entrance the cave maintains its "wilderness" status and provides it with added protection from casual visitation.

CONCLUSION

In summary the greatest abuse of karst in Western Australia is inflicted by those "mining" limestone for a variety of uses. A second level of impact comes from managers of cave and karst while caver impact can generally be avoided if minimal impact techniques are applied to all caving trips.

Hence conservation efforts should be focused on minimizing the impacts of mining by encouraging the establishment of a "Mega Mine" near the Nullarbor coast. Efforts should also continue to educate local councils and cave managers about the impacts of development on karst systems.

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Where are the Cave Conservation Projects in Australia?

Rauleigh Webb

WHY CONSERVATION PROJECTS?

While examining the papers presented at the last Australian Speleological Federation (ASF) conference, it was clear there was a distinct absence of papers relating to cave conservation issues. The thrust of caving activity was clearly in some other direction. Did this mean there were less conservation issues in Australia?

Looking at the annual reports of ASF conservation commissioners, it is quite clear that the number of issues affecting caves and karst areas in general is on the increase. As development heads out from our major cities and as high grade limestone becomes a highly sort after commodity, the threats on our karst areas is escalating rapidly.

A great deal of voluntary work time is being consumed by vast quantities of paperwork, required to respond to Environmental Review and Management Programme (ERMP)'s, development proposals, mining proposals, and general requests for information from government bodies and consultants. This work is tedious but necessary to ensure that correct information about caves and karst regions is provided to appropriate authorities. See http://www.edo.org.au/edowa/fact5-EIA.html for information on ERMP's in Western Australia.

However it is vital that a significant amount of our efforts are directed at hands on, work that is required to ensure that caves are protected from visitors, managers, land owners or mining interests.

WHAT'S HAPPENING?

To determine what projects were happening around Australia I requested, via the internet, those cavers undertaking cave conservation projects to tell me a little of the projects they are conducting.

The responses are tabulated below.

Project/Group/Person	Description	Project Coordinator	State
Arthropod ecology in the maternal chamber of Bat Cave, Naracoorte.	Investigation of the seasonality in populations and correlations of arthropod diversity and abundance with guano deposition	Tim Moulds	SA
Pitch rebolting of the more popular vertical sporting Caves	To prevent ropes getting stuck in Midnight Hole, muddy ropes wearing away the bolts and even the rock below the anchor as well as the proliferation of spits in some caves.	STC	Tas
Deb Hunter	Working on a range of conservation issues and politics.	Deb Hunter	Tas
Graffiti project	Subject of paper at this Conference	Nicholas White	Vic
Friends of Buchan Caves and Friends of Mt eccles & Mt Napier Parks	Various projects relating to conservation, better interpretation and better management.	Friends Groups	Vic
The bats of Quinninup Lake Cave	A 12 month project to monitor the bat population fluctuations, predation, breeding and movements within the cave.	Ric Brown SRGWA	WA
Data-logger Project	To monitor cave visitation number in caves within the Leeuwin-Naturaliste National Park (LNNP)	WASG	WA

Project/Group/Person	Description	Project Coordinator	State
Data-logger Project	To monitor cave visitation number in caves within the Leeuwin-Naturaliste National Park (LNNP)	WASG	WA
Golgotha Cave Work – (LNNP)	To upgrade track and replace trackmarking. Flowstone protection and rehabilitation. Data logger monitoring of unauthorized trips.	CALM	WA
Carabooda Area	A number of issues relating to land development.	??????	WA
Karst Issues	A number of issues relating to land management/development.	??????	WA
Yanchep Rehabilitation project	Regular work trips to various caves to sample water, photomonitor selected sites, measure tree root mats, track mark and clean formations.	??????	WA
Drovers Cave Project	Attempting to reverse the vandalism inflicted on the cave's entrance.	??????	WA
Jurien/Lancelin Area	Changing of plan for areas of local development	??????	WA

WHAT DOES THIS SAY ABOUT CONSERVATION PROJECTS AROUND AUSTRALIA?

The outcomes from this minor exercise are as follows:
- The number of large projects is non-existent.
- The number of projects involving groups is small.
- The majority of projects are undertaken by a handful of individuals.

WHAT IS THE SITUATION IN THE USA?

The USA has ten times the number of cavers in their grottos (based on the 2002 NSS members manual) than the ASF has in its total membership. As a result you would expect a higher number of conservation projects in the USA. However they also have a structure which encourages the creation of Conservation Task Forces (CTF). In 2002 there are ten CTF's in the USA.

The CTF's are presently based on either individual cave conservation or regional karst conservation and management issues. The CTF is a group of NSS members who focus on major local-level cave conservation issues. As a CTF they enjoy a tax-deductible status that assists them in raising funds for their CTF. They may also apply for grants from the NSS for funding to assist them in their CTF work.

The creation and the ongoing financial requirements of NSS CTF's are described by Jo Schaper (pers. comm.), the NSS CTF coordinator from 1997-2002 as:

> "Creating an NSS CTF is done by contacting the CTF coordinator with a summary of the problem to be addressed, a proposed solution or plan of attack, a list of personnel, and an NSS contact person. This is often as informal as an email. Not all members have to be NSS members, but some (including the contact) must be. The CTF coordinator decides if this is a reasonable application, he or she passes it up to the Conservation Committee chairs for official approval, but this is often pro-forma; the CTF coordinator acts as the screener. If approved, the CTF may use the NSS name and non-profit umbrella. The NSS has a mechanism for startup loans (not grants) to CTFs, (never applied for in my 5 years) and the CTF can apply for NSS Conservation grants same as any other internal organization. In general, the CTF is expected to be financially self sufficient."

The size of CTF's vary from one person, to well organized groups of several dozen people. NSS CTF's are under the obligation to do quarterly and annual reports to maintain their status.

There are basically three time frames for CTFs-- crisis action teams, with a definite end-date; ongoing CTFs where the concerned cavers do not, and cannot own the land (eg. Oregon Caves CTF, which keeps an eye on the actions of a US federal karst national monument) and CTFs where there is a lease agreement with a private cave owner. The latter have been encouraged to become actual corporate conservancies called cave preserves, (NSS internal organizations which are also incorporated legal entities independent of their CTF status).

As of 2002 the NSS has ten Cave Preserves ranging from individual caves to karst areas containing multiple caves. Generally these Cave Preserves are donated to the NSS to ensure the protection of caves and, in some cases, cavers.

This level of structure provides a method of coordinating cavers to address conservation problems as a group rather than try and complete tasks single handed. The CTF's also receive state and federal recognition.

HOW CAN WE IMPROVE THE SITUATION IN AUSTRALIA?

The ASF now has a "Gift Fund" whose purpose is to "support the environmental objects/purposes of the Federation" (http://www.caves.org.au/administration/constitution.htm as at 30/12/2002). The "environmental objects/purposes" are not defined within the ASF constitution so it is not clear what the objects and/or purposes are.

However it is envisaged that the purpose of the fund is to provide assistance to ASF members and/or clubs who are attempting to ensure the protection/conservation of caves and/or karst areas.

In order to provide a structure for members to work within it would therefore be appropriate to create distinct "named conservation projects" to which funds can be directed.

The creation of distinct conservation projects will also force those individuals and groups involved in conservation work to carefully prioritise the needs of individual conservation projects. Volunteer groups such as the ASF and its member clubs have provided a large quantity of "free work" to cave and karst managers. The time available for direct contribution to cave and karst conservation projects by volunteers is very precious and a declining resource, as individuals are placed under greater pressures by work and home related activities.

Further value would be gained if the ASF built web pages describing each project and providing readers a simple method of donating monies directly to specific projects. These pages could also provide details of the plight of many caves and karst areas in Australia under threat or already in dire need of assistance.

At present, it is very difficult to impossible, to determine the conservation needs across Australia as there is no specific resource that details all of the current cave/karst conservation projects.

It is hoped that the ASF can appoint a Conservation Project Coordinator and establish the required structure to support Cave Conservation projects throughout Australia. At present it is clear that the non-coordinated approach does not ensure a focus on caves or karst areas that are in urgent need of attention.

WHERE IS THE MOST URGENT REQUIREMENT?

At present the most urgent requirement are the caves of the Western Australian section of the Nullarbor plain. This is one of the largest karst areas in the world but has no on-site management. Visitation to many of the sensitive caves of the Nullarbor can cause significant permanent damage. Caves in this area are receiving considerable visitation from cavers and the general public. With the South Australian portion of the Nullarbor requiring permits to visit caves, the Western Australian portion of the Nullarbor is receiving higher visitation from cavers throughout Australia.

A conservation project is required to hasten the establishment of sustainable on-site management for the caves of the Nullarbor karst.

Managing Caves and People in the Leeuwin-Naturaliste National Park, WA

Anne Wood
Department of Conservation and Land Management

BACKGROUND

The Leeuwin-Naturaliste Ridge in the extreme SW of Western Australia, is a band of aeolian calcarenite deposited over Precambrian granitic gneiss. The aeolian calcarenite is weakly consolidated limestone, which typically has a caprock layer at the surface. It is characterized by numerous solution pipes, which may intersect caves, extensive calcite speleothem development, and caves, which often show extensive collapse. (Jennings, 1968)

The south west of WA was heavily promoted as a holiday destination with caves as one of the main attractions over a hundred years ago. From 1901 to 1910 the Caves Board, a committee formed to protect and administer the caves was responsible for the installation of steps and gates in many caves including Yallingup, Lake, Mammoth, Golgotha, Calgardup, Giants, Brides and Blackboy Hollow. After the Caves Board disbanded in 1910, the caves suffered a long period of neglect under State Hotels.

In 1958 the local Tourist Bureaux were made responsible for the major tourist caves (Yallingup, Mammoth, Lake and Moondyne). Since 1959 caving clubs have been involved in management of caves. Caves considered by the clubs to be particularly significant were gated, with stringent controls developed for group sizes and number of visits.

From the 1960's on, there has been an increasing number of people exploring the caves of the Leeuwin-Naturaliste Ridge. Cavers, school groups, scouts, "Adventure" companies, surfers when there is no surf, and locals, have all added to the numbers. The Leeuwin-Naturaliste National Park is a three-hour drive from Perth, which makes it very accessible. The region is extremely popular for many reasons – for example beaches, surfing, walking, wineries, forest, fine food, and arts and crafts.

The most obvious visitor impacts are damage to speleothems; erosion around cave entrances and at cliff tops; erosion and sediment movement within caves; and damage to animal habitats. Erosion and breakdown of the limestone is a particularly severe problem in these caves due to the softness of the rock. Erosion of soil cones and sandy areas is also of concern. Between 1977 when Giants Cave was surveyed, and 1993 when a ladder was installed to bypass the rockpile, 53 cubic meters of soil had been removed from the rockpile – all by foot traffic! (Bell, P. & Wood, P. pers comm.)

LEEUWIN-NATURALISTE NATIONAL PARK MANAGEMENT PLAN 1989-1999

The Department of Conservation and Land Management (CALM) contributed very little to Caves Management until the development of the LNNP Management Plan in 1989. This management plan recognized caves as an area requiring management initiatives. Amongst the main recommendations were:

- "Action 6.1:
  Establish a Cave Management Committee jointly with CALM, Speleological Groups and other appropriate bodies to oversee cave management.
- Action 6.2:
  Implement a permit system for visitors to wild caves."

CMAC

The Caves Management Advisory Committee (CMAC) first met in October 1989 and continues to meet approximately six times per year. CMAC has been and continues to be a very successful and productive advisory group. CMAC has contributed to the development of the "Cave and Abseil Permit System", and the formation of the Cave Leadership Assessment Panel, as well as many other initiatives.

Initially CMAC was composed of representatives of Dept of CALM, Tourism Association and ASF affiliated caving groups. It was expanded to include representatives of the main user groups – Commercial operators, schools, scouts and the Defense Dept. This expansion of membership has provided a means of communication that has enhanced the understanding of cave conservation issues by many user groups.

PERMIT SYSTEM

Under the permit system, which was introduced in 1992, entry to any cave in Calm managed land in the Leeuwin-Naturaliste Ridge requires a permit (except for Calgardup and Giants Caves).

The objectives of the permit system are to:

- Improve cave conservation.
- Improve cave and abseiling safety.
- Educate cave users.
- Raise revenue on a user pays basis. (All revenue is deposited into trust accounts and is only to be used for the management of and conservation of caves/karst and abseil sites)
- Obtain information on people using caves.

Caves are classified into “Self Guide Caves” and “Restricted Access Caves”.

The majority of caves are in the “Restricted Access” category and are available only to ASF caving club members and researchers. Access to these caves is largely unchanged from the system developed by the speleological clubs. The maximum group size is between four and eight, and the maximum number of trips per year varies depending on the particular site.

The “Self Guide” caves are the caves available to commercial operators, school groups, scouts and others, as well as ASF members. This group is further divided into:

Class 1 : No permit required.
Class 2 : Horizontal entry.
Class 3 : Vertical entry requiring the use of a caving ladder or rope.

The caves chosen by the CMAC as self-guide caves were all accessible and already well known. However some well known sites were not included.

Caves or parts of caves can change classification. Since the permit system was introduced three caves have been changed from “Self- Guided” to “Restricted Access”. A cave may have more than one classification. For example Calgardup Cave has part of the cave open to the public, another section is classified as “Self- Guide 2”, and is available to groups of up to eight people including an accredited leader, and another section is “Restricted Access” and is only available to caving club groups with visitation restricted to groups of four people four times per year.

CALGARDUP AND GIANTS CAVES

Calgardup and Giants Caves were both operated as Tourist Caves early in the twentieth century. They have both remained well known and highly visited. As is often the case with ex show caves they have suffered greatly from inappropriately behaved visitors. These two caves are now locked and entry is available after payment of an entry fee. Staff ensure visitors are appropriately equipped and briefed prior to their entry into the cave. Helmets and lights are supplied. Infrastructure has been installed to protect the caves from further damage, and in some cases to provide safer access. Extensive rehabilitation has been carried out. Revenue collected is used exclusively for management of the caves.

Access to Calgardup and Giants Caves is also available to accredited leaders via the permit system.

TRACKMARKING, GATING, MONITORING

Nearly all of the self-guide caves have been trackmarked and many have been gated. Track marking follows the system developed by Poulter (1994). In some instances, the route is indicated with single reflectors up to 10m apart, whereas in more sensitive areas the track is defined with fishing line and reflectors on either side. Where a section of cave that was previously well visited has been closed off, a small sign is installed to indicate the reason for the closure. Eg. fauna habitat; dangerous. Trackmarking and gating have been carried out in conjunction with CMAC.

CALM staff monitor the more visited sites regularly for visitor impacts. The CMAC also carries out site visits to reassess issues such as group sizes, trackmarking and risk management.

LEADER ACCREDITATION

Due to concerns regarding continuing high levels of damage to the "Self-guide" caves, CMAC recommended that a more formal system of leader accreditation be developed to replace the self-accreditation scheme initially used for the "self-guide" caves. Initially, the only requirement to become registered as a cave leader in the "self-guide" caves was to complete a form. Over 400 leaders were registered via this self-assessment system. (Caving clubs have their own system of accreditation of "trip leaders" and this is recognized for the operation of club trips.)

The Cave Leadership Assessment Panel (CLAP) began regular meetings in 1998, when a course structure and manual were developed. This was followed by a pilot course in January 1999. Experienced leaders from the outdoor recreation industry and caving clubs attended the course and provided feedback. Extensive modifications were made as a result of this feedback and the first course was offered in May 1999.

CALM's Cave Leadership Assessment Panel is comprised of people with relevant technical expertise, training and teaching experience, and elected community members. It includes representatives from CALM, West Australian Speleological Group (WASG), Speleological Research Group of WA (SRGWA), Cavers Leeuwin (CLINC), Adventure Industry Association, Outdoor Education, and Community Groups.

The course is run over three days. The first day consists of theory and group exercises. This is followed by two days of caving. Assessment is by observation of the candidate during the course, a theory exam at the end of the three-day course, and a practical assessment, which involves observation of the candidate leading a caving trip. This is carried out at a later date by arrangement with an assessor.

Prerequisites:
- Current Senior First Aid Certificate.
- A minimum of six cave visits over the past year.
- Experience in leading groups in outdoor activities.
- A minimum age of 18 years.
- DSR Abseil Instructors Certificate or equivalent for vertical entry caves.

Course Outline:
Day One: (Theory)
- Geology, cave development, speleothems: Biology: Sediments, Paleontology and Archaeology.
- Cave Conservation.
- Cave and Abseil Permit System
- Leadership & Group Management.
- Risk Management.
- Emergency procedures.

Days two and three involve visits to four caves. The emphasis is on group management and cave conservation. The maximum group size for the cave visits is six people - five course participants and one instructor.

Cave Leader Accreditation has been a prerequisite for cave permits issued from January 2000. (excluding caving club trips) To maintain currency of the Cave Leader Accreditation, a leader is required to maintain currency of their First Aid Qualification and lead a minimum of six caving trips during a year.

CALM's Cave Leader Course covers units of competency from the Australian National Training Authority. It is likely that an increasing number of people will obtain accreditation from elsewhere. These people will be exempt from part of CALM's course, but would still be expected to complete areas concerning the operation of the permit system, trackmarking, and other information particularly relevant to the Leeuwin-Naturaliste Ridge.

RESULTS

- There has been a very large decrease in the number of accredited leaders. There were over 400 trip leaders registered prior to Jan 30th 2000. There are 82 leaders currently. These figures exclude caving club trip leaders.
- There has been a decrease in the number of visits to Self-guide 2 & 3 caves. See Table 1. There is also a decrease in the number using WI 16, for which Cave Leader Accreditation is not required.
- Reliable figures are not available for Calgardup and Giants Caves prior to 1997. Some estimates based on visitor books and visitor surveys have been produced for Giants Cave (Webb, 1989 & 1993). These are shown, together with recent permit system data in Table 2.
- There appears to be a high level of compliance to the track marking, as shown by a lack of footprints off the track, and regeneration of extensive tree roots in some areas.
- It has been suggested that a possible consequence of gating and controlling access to Calgardup and Giants Caves would be an increase in unauthorised cave entry at other sites. There does not appear to be evidence of any increase in "illegal" caving.
- Feedback forms completed by all Cave Leader Course participants are generally very positive, with the main criticism being that the course covers too much in too short a time.
- Informal feedback from Cave Leaders in regard to trackmarking indicates that although most can appreciate the benefit to the cave, there is some dissatisfaction with the lack of "adventure" or "wilderness" experience.
- It is difficult to draw conclusions regarding rescues due to the low frequency. There was a high number of rescues (average one/year) in Giants Cave in the early years of the Permit System. This is the period during which an estimated 35 000 people a year were visiting the cave. A permit was not required to visit Giants Cave at that time. There have been no rescues at Giants Cave since May 1997.

CONCLUSION

The last 12 years have seen an enormous change in cave management in the Leeuwin-Naturaliste National Park. Over 12 years ago, there were no controls on cave visitation apart from the self-imposed limitations implemented by caving clubs. In many cave areas this may not present a problem, due to relatively low numbers of cave visitors. However, in the southwest of WA, escalating visitor numbers to the "wild" caves were causing unacceptable impacts.

The permit system has been in place for over 12 years. Most "self-guide" caves have been trackmarked, and many have been gated. More recently, Leader Accreditation has been introduced. The emphasis has been on education. This has been an ongoing process, via the permit system, CMAC, newsletters, and more recently the Cave Leader Course.

ACKNOWLEDGEMENTS

Thanks to CMAC, CLAP and the many caving volunteers. Without the valuable contributions of volunteers (past and present) the caves of the Leeuwin-Naturaliste National Park would be far worse off than they are.

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Table 1 - Cave Visitation: Number of people

Self Guide 2 & 3 Caves and Abseil Sites *

	1993	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
WI 16	4560	4852	3120	3119	2655	3781	3402	2723	2449	1934
Brides Cave	4271	4191	2587	2579	2347	2748	2960	1831	1543	1734
Giants Pipe	3339	4395	2685	2750	1865	2370	1979	1270	1182	1360
Calgardup Pipe	closed	closed	26	400	647	766	1291	575	459	598
Nannup Cave	739	859	760	656	630	907	793	553	583	457
Golgotha Cave	977	1059	819	628	769	1221	997	571	1305	676
Dingo Cave	355	422	348	287	299	301	360	282	109	150
Mill Cave	558	597	468	298	460	529	323	368	488	255
Arumvale Pipe	232	150	127	259	219	168	126	66	96	94
Block Cave	96	113	60	72	101	141	61	71	30	37
Quinninup Lake	112	73	62	53	99	116	41	26	18	43
Mordang Dar	101	48	52	72	68	54	31	65	10	3
Blackboy Hollow	124	95	170	69	13	32	45	8	15	6
Total	**15464**	**16854**	**13449**	**13376**	**12397**	**15217**	**14438**	**10424**	**8287**	**7350**

** ASF Cavers and CALM accredited leaders.*

	1993	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
Restricted Access Caves **	927	834	523	377	537	477	507	538	394	494

***ASF Cavers only*

Table 2 - Giants Cave Visitation

Giants Cave	**1978**	**1988**	**1992**	**1998**	**1999**	**2000**	**2001**	**2002**
Abseil Permits				2,370	1,979	1,270	1,182	1,360
Cave Permits				1,776	2,269	1,420	1,305	1,199
Public Entry				NA	4,138	5,207	6,047	7,278
Total	**786**	**17,000**	**35,000**	**-**	**8,386**	**7,897**	**8,534**	**9,837**

Cave Photography - Getting Started

David Wools-Cobb

INTRODUCTION TO CAVE PHOTOGRAPHY

Many cavers I have spoken with over the years have shown an interest in cave photography, but seem to feel intimidated, or disappointed with their results. In this paper I will be outlining a fairly basic approach to getting started. I will be examining what is the best equipment to start out with. You certainly don't have to spend a lot of money to get into cave photography. In fact I will explain later that spending lots of money can be a big mistake.

Taking photos in a cave will influence just how you see a cave environment. Cavers go caving for all sorts of reasons; not the least is to record part of the incredible environment underground. It's a way of sharing some of the most magnificent wonders of nature with others that may never have the privilege of seeing.

THE CAVING ENVIRONMENT

Caving offers incredible challenges, both to cavers personally and more particularly, to their photographic equipment. Caves can be wet, muddy or dry & dusty. Gear can be ruined in just one trip if not protected. I will discuss packing for a trip in order to protect your gear later on.

What is special about the cave environment is that, apart from the proximity to entrances, it's totally dark. That means that YOU control all the light. How you light up a scene and how this light gets to your film will determine the final result. A cave photographer has incredible control. However, that doesn't make it easy. Focussing in low light is particularly difficult. Framing your shot so that it's horizontal or vertical is also difficult. Deciding how much of the scene to include and what position to take the shot from are often also difficult decisions. The most difficult issue is of course HOW to light a scene. Most of these more technical issues will be covered in my other paper: "Getting Good Photos".

THE CAMERA

This is where it all starts, but many cavers make the mistake of purchasing an extremely versatile, high tech. electronic unit capable of nearly anything. Caves can brutal to such gear. I believe it pays to use a simple, robust camera- best purchased second-hand. Then if ruined it doesn't hurt quite so much. The ideal camera is capable of operating without a battery- this is rare these days. It also would have a built in light metre; of no use in a cave, but good outside and around entrances.

The camera must be capable of a "BULB" setting, preferably with a lock. This means the shutter can be locked open for as long as the photographer decides. A flash hot shoe is also an advantage. I personally prefer single lens reflex cameras to the range-finder type, which are less expensive, but often not as versatile. My choices are some of the old Pentax series- K1000, MX, ME. Olympus OM series are also suitable.

Check out the second-hand camera stores, but ensure the camera comes with some guarantee. The disadvantages of a single lens reflex is their size; often bulky & heavy, however the variety of lenses available and the fact that you are looking at the scene you're photographing are definite advantages.

The modern "point & shoot" cameras with reasonable ability for the photographer to make some aperture adjustments and a zoom lens are much smaller, and if the user fully understands how to use them can provide good results.

Digital cameras are becoming very popular both above and below the surface. Currently I'm still learning what's possible and impossible with these. Digitals are certainly not as robust as SLR's, but are smaller and some models can be very versatile, enabling the photographer to set

apertures, etc. Many digitals seem to have difficult focussing, whilst others give superb results. Many digitals also don't seem to be able to handle additional flashes from an electronic flash, and others set off slave units with their infra-red focus beam and/or their "automatic" red-eye reduction. The quality and features of digitals seems to vary immensely, with features changing dramatically with the issue of the next model - not always for the better.

The advantage of digital of course is that you can SEE exactly what your photograph looks like, so if you don't like it, you can take it again. The disadvantage is that it can cost you a fortune to print your photos. Many digital photographers prefer to keep their photos in digital format, easy to put on to a television screen or to e-mail.

I believe our friend Arthur Clarke still holds the world record for the number of photos on a caving trip, averaging at 1/39.5 seconds!?

THE LENS

A rangefinder camera often has a fixed lens, which severely limits how a shot can be composed. Many also have a fixed aperture, which further limits the choices of the photographer. More modern ones often have a zoom lens, which is a great advantage to frame a shot.

Single lens reflexes offers a huge choice of lens, although my preference is to use a moderate zoom: say 35-80. With this you can frame the shot just as you wish. A great advantage is a "fast" lens- this means the lens can be opened up a long way, thus allowing more light in. Bearing in mind we're working in a dark environment, if you can open up the lens to a wide aperture, say f2 or better, then either less light is needed or the flash can be much further away from the subject.

THE FLASH

The vast majority of caver photographers use electronic flashes. Flash bulbs, which are great for caves are becoming rare. They generally give more light for their size, and a slower, softer light. Flash bulbs can give great results where water movement is involved. Electronic flashes are easy to use, give a fast flash, often between 1/10000 & 1/2000 of a second, recharging quickly ready for the next shot. Their light is harsher than a bulb flash and the flash beam is generally narrower.

A good flash should be simple to operate, with a manual firing button and in-built batteries. A hot shoe is an advantage, both for on-camera use and for flash-slave attachments. An ability to reduce the flash power is often an advantage.

Many flashes come with auto modes; this is not always an advantage, as I'll explain in my second paper. Some flash units are also dedicated to a particular camera. This is rarely an advantage, as often the flash unit is not mounted on the camera. Unfortunately almost all flash units currently on the market are dedicated to something- a feature you pay a lot for and may rarely use.

ACCESSORIES

The number one accessory one should consider is a flash slave. This is an electronic light sensor that sets the flash off when it detects a pulse of light. The quality of flash slaves on the market varies incredibly. I personally have found that most are not suitable for caving. Their electronics don't handle high humidity, and often they are not sensitive enough to work some distance from the main flash. The best I've found is the English "Fire-Fly 2". These are extremely reliable, built for caving and the manufacturer claims that they can detect a pulse of light at 500m. If setting up a big difficult shot, climbing over a rockfall, etc you need a slave that will ALWAYS work. Fire-Fly 2 is expensive, but so is the film and time you waste on an unreliable slave.

The next accessory to consider is a tripod. This enables you to set up the camera exactly how you want, with the shot framed. You can then lock the shutter open on bulb, knowing that the camera won't move, unless some idiot bumps it. A tripod also enables a photographer to work alone or with a minimal number of assistants. The ideal tripod is light, yet robust, folds down small to fit in your caving pack, and has a "ball head" which enable the camera to moved in both the horizontal

and vertical plain. This allows the photographer to set up the shot quickly. One can adapt other things for tripods: rock ledges, cave packs, or small beanbags. Unless you enjoy lying in mud, the very small tripods that are sometimes given away are of no use for a camera, but they can come in handy to mount a flash unit.

Another accessory is a diffuser for your flash unit. This lessens the harshness of the flash, often giving it a wider beam, but with the consequential loss of flash power.

A cable release is also a virtual necessity. This enables the photo to be taken without disturbing the camera set up, and more importantly, allows the shutter to be locked open. These come in a variety of lengths and qualities. 30cm is easily enough, and metal sleeved ones seem to last much longer.

PACKING FOR A TRIP

As mentioned before, a cave is often an unforgiving environment to delicate photographic gear. Water and/or dust proofing gear is essential. Good quality plastic bags, often with everything double-wrapped and sealed off with rubber bands is a cheap way of protecting your gear.
Dry bags are even better; these come in a variety of sizes and materials; some are as tough as caving packs. I find the softer ones best as the air in them is more easily expelled and they roll down tighter and take up less room in your pack.

Using long sleeve gloves and removing them before touching your photographic gear is essential in wet muddy caves. An old tea towel also often comes in handy for wiping hands and gear.

To protect gear from physical knocks is an area where many cavers differ in their opinion. I've seen some photographers take huge metal cases into caves, with all gear carefully placed in the foam within. This is unwieldy and much time is taken with unpacking & packing up. Smaller cases, often waterproof, can fit into the average cave pack, but these still leave little room for other gear. I personally prefer to pack my camera & lens in a well-padded soft camera case and the flash units and other accessories in good quality plastic lunch-box-type containers. In the containers each item is bubble wrapped. I have a variety of containers that are quite inexpensive and choose the size for the gear I wish to take. These are all placed in a dry bag. For most trips this still leaves room for vertical gear, lunch and the other necessities. This gives a good excuse as to why someone else should carry the ropes! My system isn't the toughest, and certainly wouldn't stand a pack drop from any hight, but so far the only damage suffered has been when I have all the gear out of its protection.

Another idea for gear protection are post office padded bags, but I find these don't last for too many trips.

FILM CHOICE

Some people like slides, some like prints; it's largely a matter of personal choice.

If showing your photography to large groups, then slides are certainly more versatile and offer better quality. Slide film is not as "forgiving" as print film, meaning there's less aperture tolerance. Print film will often handle up to 2 f-stops away from the ideal exposure and still give a good shot. Prints are generally cheaper, can be mounted in an album and easily shown around a small group of people. It’s often less expensive to have prints enlarged for wall decorations compared with slides.

Films vary in how quickly they take up light - this is called their speed. The slower the speed, the lower the Iso or ASA rating, the more fine detail in a shot with good textures. A faster film means that less light is required, which is good for caving, but with the resultant loss in fine detail - you get a grainier shot. Most cavers use between 100 and 400ASA. I have yet to be really impressed with film faster than this. "Professional" quality film does give better results if you're prepared to pay for it.

WHERE TO GET MORE INFORMATION / REFERENCES

Any basic photography text will give you a good grounding in photography but as stated earlier, cave photography has its own special challenges. A good understanding of light, exposure, and flash unit use is important to get good photos. Remember you control all the light, this can be a tremendous advantage. Keep this in mind when you're knee deep in snowmelt water in a Tasmania cave, getting that special shot.

- “The Photo” - a magazine series - good for a general understanding
- “Images Below”- Chris Howes - specific for cave photography, best text I've seen
- “Beyond Basic Photography” - H. Horenstein - generally good all-rounder

SUMMARY

Developing an interest in taking photos in caves can add a whole new aspect to your caving. You certainly don't need to spend a fortune to get set up, in fact I advocate buying a second-hand camera and being prepared to write it off and replace it rather than wrecking that good camera you use for everything else.

You should not rush out and buy up all the gear you think you MIGHT need, start gradually and only purchase gear that you feel will extend your photography. In this paper I have deliberately only covered the basics, not photographic technique.

In my second presentation I'll be discussing HOW to use your equipment effectively in order to get good photos.

Cave Photography - Getting Good Photos

David Wools-Cobb

In this discussion I will assume a basic understanding of photography - at least above ground. The advantage one has in a cave is that YOU control all the light (apart from entrance shots).

SINGLE FLASH

Most people start off with the basic single flash mounted on their camera. This is easy - the camera sets the flash off. Either the flash controls the amount of light, or the camera if it's a dedicated flash BUT this often gives a flat, boring shot.

FLASH AWAY FROM THE CAMERA

- Avoids lighting dust or condensation near the lens.
- May be remotely controlled from the camera by: cable, radio signal or slave unit.
- Can use BULB setting : Shutter opened, flash, shutter closed. This must be done quickly to avoid too much movement of the camera from the subject, but is quick & simple.
- Gives more depth to a shot, with shadows controlled by the flash angle: creates a more interesting shot.

TRIPOD USE

Advantages
- Can compose a shot and leave it set up.
- Can use multi-flashes.
- Can do all the work alone, or with minimal assistance.

Disadvantages
- Takes more time to set up.
- Someone invariably bumps tripod!
- More gear to carry.

Using A Tripod
- Once camera shutter is opened and locked on bulb in total darkness, only the light you provide reaches the film.
- Use a small spirit level to ensure shot is horizontal or vertical.
- Place a small, weak light underneath to assist you to relocate camera if moving away.
- If bracketing, no need to re-compose your shot, just change aperture.
- If multi-flashing, ensure subject remains perfectly still.
- Ensure head lamps of subjects are on low, or if multi-flashing: off.

USING A FLASH EFFECTIVELY

Flash power determines exposure - ie flash to subject distance NOT camera to subject distance.

Flash Synchronisation
Most electronic flashes fire at 1/1000 to 1/20000 of a second. The camera shutter must be fully open. Either use BULB setting or a slow speed of 1/60 sec or less

Guide Number
All flash units have a GUIDE NUMBER- indicates power based on using ISO 100 film. To calculate a new guide number for different film, multiply GN x1.4 for every doubling of film speed. I referred to the advantages & disadvantages of film speeds in my earlier presentation.

Eg GN 30 at 100 ASA = GN 42 at 200ASA = GN 59 at 400ASA

APERTURE = GN/DISTANCE or DISTANCE = GN/APERTURE

The Guide Number is important to determine the Flash to Subject distance & Aperture setting for the camera
Eg GN 30 for 100 ASA
= F4 @ 8metres, F5.6 @ 5metres

BUT a manufacturer's Guide Number is for an ideal situation (reflective walls, and a flash fired from the camera's position).

Caves are far from ideal conditions- minimally reflective surfaces (flash often away from camera's position) ie. often the manufacturer's GN is too high.

Human flesh tones are the easiest way to determine good exposure, so take a few photos in a typical cave situation, bracketing at various apertures and recording each shot. Choose which combination gives the most pleasing exposure of say, facial tones.

Remember GN= AP x Distance WRITE this new Guide Number on the side of your flash, plus a number of combinations for aperture & distance calculated from it: then you will be able to use your flash more accurately. ROUGHLY- in many shots opening your lens 1 or 2 F stops more will give a better shot, but much depends on the situation! FOR EXAMPLE: Lava Tubes have particularly non-reflective walls- they literally soak up light. To get good photos takes a lot of skill, F-Stop adjustment & frankly LUCK!

Flash Position
This has the greatest impact on the final photo.

- Flash must be shielded from the camera, even if not within the photo being taken.
- Caver in picture must NOT look directly at the camera ("red eye problems").
- Avoid other objects near the flash: a hand or cave pack can give a colour cast.
- Flashes from the side or well angled to the subject result in highlights, shadows & good texture.
- Flashes from behind a subject create a silhouette, if high humidity can result in an interesting halo effect.
- Side and back lighting add drama to a shot.
- Electronic flashes are relatively narrow and concentrated so avoid a flash too close to the subject.
- Position the flash for the most even lighting possible- keep flash same distance from each of the main subjects otherwise the closer ones will be overexposed.

Autoflash
A flash sensor assumes that all the surfaces in a shot reflect light evenly, but most scenes are not very even, especially if some distance from the camera, eg. a column with nothing close by may only occupy a small area within the photo, with most light going into the void beyond. The result will be a very underexposed shot.

To compensate, decide what proportion of the shot will reflect light. If 1/2 then 1/2 the Light is lost, So flash sensor detects less light is reflected, so quenches flash later giving an overexposed shot ANSWER - close aperture by 1 stop and so on.

Auto flash may also pick up the light from another flash unit, so unless it's a very even, straightforward shot, it's better to operate on manual.

COMPOSURE

- Look for scenes that look interesting, not just beautiful formations.
- Look at the scene from different angles.
- Decide how much of the scene to include: controlled by the camera position and how you frame it with a zoom lens.

- Decide how to light the scene, to test for shadow effects shine your headlamp from possible flash positions.
- Especially for large scenes- place a caver in photo for scale.

MORE POWER!!!! - MULTI-FLASH

To light up large areas a flash can be fired several times and/or repositioned to even-out how a scene is illuminated OR several flash units can be located around the scene.

Caution
- All flashes should be shielded from the camera.
- Take care with subjects close to the flash to avoid overexposure.
- Don't try to fit too much into the scene - the photo risks becoming too cluttered and uninteresting.

Set the lens aperture based on the main flash setting. Position other flashes at appropriate distances from each area to be illuminated based on their GN & determined aperture. Remember Dist= GN/AP. Best results come from using a number of small to medium powered flashes. Don't try to light the whole scene- allow some shadows to add to the effect. Avoid over-lap of flashed areas.

Cumulative Flashes
Used to increase the intensity of the light.
- Can improve depth of field (increased aperture).
- Can balance light in one area to compensate for a more powerful flash in another area.
- Often used if you can't get flash closer to the subject.
- Can use over a large area to "paint the scene" with just one narrow electronic flash.

Using Slaves
The term SLAVES does not refer to the assistant to the photographer. A slave unit is an attachment that sets off a flash unit if it detects a pulse of light. I use slaves on all but one of my flashes!!!!
- Enables all flashes to be synchronised, ie. one flash sets off all others.
- Camera can be hand-held, ie. no tripod.
- No need to communicate as long as flashes are fully charged.
- Can do all the work alone or with minimal people.

BEING ORGANISED

Cave photographers generally have a terrible reputation and are sometimes despised by non-photographers. Frankly they often deserve this scorn.

Be Prepared
- Know your equipment and how to use it.
- Decide how you're going to take the shot before you set up.
- If using assistants, ensure they know how to point, shield and fire a flash, and how to ensure it's recharged.
- Explain to them just what you wish to do.
- Let the team decide before-hand: is this a photographic trip, or a quick-few-shots trip or a non-photography trip.

If Working With Other Photographers
- Work as a team, or sub-teams.
- If wanted, all should set up tripods and discuss the shot.
- Get to understand how each other works or just don't bother as they'll continually stuff up your shots anyway.
- Generally best avoided!!!

IDEAS FOR SPECIAL EFFECTS

- Cavers in action - climbing, SRT, bridging.
- Water movement, waterfalls: strobed flashes.
- Weak fill-in flash with most flash behind or to side of subject.
- Large chambers: a special challenge.
- Macro or close-up lens work: crystals.

SUMMARY

- Challenging environment.
- Understand your gear & plan.
- YOU control the light.
- Effective flash use - correct setting, position, angle camera shielding.
- Multiflash & slaves.

Good cave photography can be affordable, only buy gear as you really have the need.

FINALLY

Don't be afraid to experiment - all caver photographers have made heaps of mistakes

Presenter Photographs













Clockwise from top left: *Bill Humphreys; John Long; Grace Matts; Andy Eavis & Norman Poulter; Jane Scott; Garry K Smith.*

A Short History of the Yanchep Cave Area

Lex V Bastian

EARLY EXPLORATIONS

George Grey 1838
First white man on the scene was the explorer, Lieutenant George Grey, who was later to become Governor of New Zealand. He made two explorations in the colony, neither of which achieved a great deal; the first to a small portion of the Kimberley region, the second a trip down the coast from the vicinity of Geraldton to Perth. The latter was to end in tragic circumstances, involving the death of the party's youngest member as they struggled through waterless country to reach Perth.

Grey's visit to the Yanchep area took place following his first journey of exploration in the Kimberley region, in the course of a minor foray that he made in December 1838, in which he advanced up the coast north of Perth to as far as the Moore River. It was during his return to Perth that he was shown to a cave in the area, and was also told about the existence of other caves nearby. His party camped at a spot north of a lake called Man-bee-bee, which was the stretch of open water at the southern end of Lake Yanchep, today's Loch McNess. His journal for December 6th (Grey, 1839, pp.308 & 309) then reads as follows:

> *"December 6th.- This morning, we started at daybreak, and breakfasted at Man-bee-bee, and immediately after breakfast resumed our route. I left the party with two natives, and travelled up a swampy valley, running nearly in the same line as the chain of lakes we had followed in going. The natives insisted on it, that these lakes were all one and the same water; and when, to prove to the contrary, I pointed to a hill running across the valley, they took me to a spot in it, called Yun-de-lup, where there was a limestone cave, on entering which I saw, about ten feet below the level of the bottom of the valley, a stream of water running strong from S. to N. in a channel worn through the limestone. There are several other remarkable caves about here, one of which was called the Doorda Mya, or the Dog's house. Probably, therefore, the drainage of this part of the country is affected by the chain of lakes, which must afterwards fall into the river I saw to the northward. We slept at Now-oor-goop."*

This is the sole reference to cave visitation on the part of Grey. Man-bee-bee was the earliest spelling of the aboriginal name for today's Loch McNess. This links it to the Yanchep area in general, but not specifically to any caves inside today's Yanchep National Park. The cave he was shown has been identified. After many attempts to match it with a cave inside the Park, it was eventually found to match a cave known as the Doogarch Cave (YN428), which is situated a few kilometres south of the National Park (Bastian, 1995). In retrospect this became obvious, as Grey's account shows he was travelling back towards Perth, and had evidently covered some miles from the lake at Yanchep before the above incident took place.

Septimus Roe 1841
John Septimus Roe, who was Surveyor General to the Swan River Colony, may be considered the first cave explorer as such in Western Australia (and this includes the aboriginal inhabitants, as the local people had a great fear of caves and would not attempt to enter any dark place: Doogarch Cave is an exception, as it faces north and allows much light into its main chamber). Whereas Grey's brief encounter with a cave was incidental to his trip, Roe set out in October 1841 with the specific goal of locating and exploring the other caves that Grey had been told about, but had not seen.

The primary objective was the cave which the local aborigines called "Doorda Mya", meaning the "Dog's house", because it was home to many of the wild dogs of the district. These were dingoes, but the local (Nyungah) name for them was "doorda" (or "dwerta", as used in more modern spellings). This proved to be a little to the east of the lake "Man-bee-bee", (or "Mambibby" as Roe preferred to spell it). Roe also recorded the name "Yancheep" for the swampy tract stretching northwards from the open water. In time the latter became the established name for the lake as

well as the district, although the other (with the spelling Mambibby) was not lost, as one of the caves today has this name.

Roe set out from Perth on 13th October 1841 with a small party, consisting of two soldiers and two aboriginal guides, to locate and explore the caves. Having made their camp at the southern end of the lake Mambibby, they were led to a hilly area approximately three-quarters of a mile eastward from that spot, in which they saw two small but rugged glens, to the larger of which he gave the name "Maidin Glen" (today's Boomerang Gorge). On the subsequent day they explored six caves. Roe wrote up a detailed account of his trip (Roe, 1841), which has facilitated the identification of most of these caves.

One of these, over which Roe was most enthused as to its decorations, has been positively identified with a cave in Boomerang Gorge (YN7), having many points of identity with his detailed description (Bastian, 1994). The largest of his caves is probably today's Cabaret Cave. Roe blazed a diamond upon an adjacent tree to mark the entrance. Unfortunately work on that cave in the 1930's to turn it into a Ballroom seems to have led to the removal of the tree, and also altered its internal topography drastically, involving the removal of much speleothem material, as well as filling in the original tortuous route - which included the crossing of a strongly-flowing stream - by which Roe accessed the cave's main chamber. The changes are so considerable that it can no longer be positively confirmed that this was the cave explored by him, however it is the "best fit".

As for "Maidin", this appears to be more correctly the name applied to the actual cave locality, as distinct from the nearby lake, and since this is the earliest name applied to the caves specifically, I have used it here as a matter of priority, even if it never comes back into use. A slightly later spelling put it as "Maiden" (Webb, 1847). (The story of the name changes does not end here, as Lake Yanchep was changed to Loch McNess in the 1930's, to honour a benefactor in the development of the Park.)

Roe's description of the trip had some major ambiguities, notably in the fact that only one of the two glens (Boomerang Gorge) was described. When a few months later George Webb made his own privately-organised expedition, he was apparently as confused by Roe's descriptions as the present author was 150 years later! Although he claimed to have found and explored the largest of Roe's caves, he did not mention encountering a stream, and his description actually matches more closely that of YN7.

TURN OF THE CENTURY

A major phase of exploration commenced in 1903. Information about this era is mainly to be found in newspaper articles held on microfilm in the Battye Library of Western Australian history, some also on Lands Department files held in the State archives.

The exploration was prompted by the recent discoveries in the Margaret River area, which were by then already being developed for tourism. A Perth man, Mr Milligan, knowing the existence of caves to the near-north of Perth, pushed the idea that perhaps these too had excellent tourist possibilities, which had merely been overlooked. One large cave (which appears to have been one of those seen by Roe, which later became the Silver Stocking or Cabaret Cave) was already fairly widely known. The first party to follow this suggestion up was put together by a newspaper of the time: "The Morning Herald". Consisting of four persons: a reporter L.Ramaciotti, photographer C.P.Conigrave, and two local men R.Cockman and H.Kent, this group went up to Yanchep in mid-February of that year, and after numerous frustrating explorations of small caves (of which there are an abundance at Yanchep!) that did not lead to anything of significance, they finally discovered and named Yonderup Cave (Ramaciotti, 1903). Highlight of this was the finding of a detached human skull in the farthest chamber of the cave, which was later identified as the skull of a white man.

Discovery of the skull deserves special mention because of what happened some thirty years later. Following its discovery a constable (Constable Cahill) was sent to the cave to search for more bones. With an aboriginal aide he dug the floor of the chamber for two days, but could find nothing. The only conclusion the police could come to was that the skull had fallen down the solution pipe (now blocked with a lrage rock) that is in the ceiling of the chamber, but that other bones from the

rest of the skeleton had not worked their way down. It was also positively identified as the skull of a white man. The final newspaper article does not go into details on this point, but since the finders had also readily observed it be a white man's skull, they possibly noticed gaps in the teeth or obvious fillings.

About the same time, a local farmer Mr J. A. (Jack) Grant, discovered a large cave a little farther north, which was subsequently named Yanchep Cave. Another local identity, Henry White, then was stimulated to begin his own cave searching, and the following month found Crystal Cave, which he at first called the "Crystal White Cave". Less than a month later he found another cave, which he named the "Clustered Coliflower Cave" (today's Cauliflower Cave), after its main decorative attraction. Both these discoveries were reported by him in letters to the Lands Department - however, he did not quote precise dates. Following upon these, a parcel of land was set aside as a Caves Reserve, and Henry White was appointed the first (Honorary) custodian of the Reserve. No actual tourist development took place however until the 1930's.

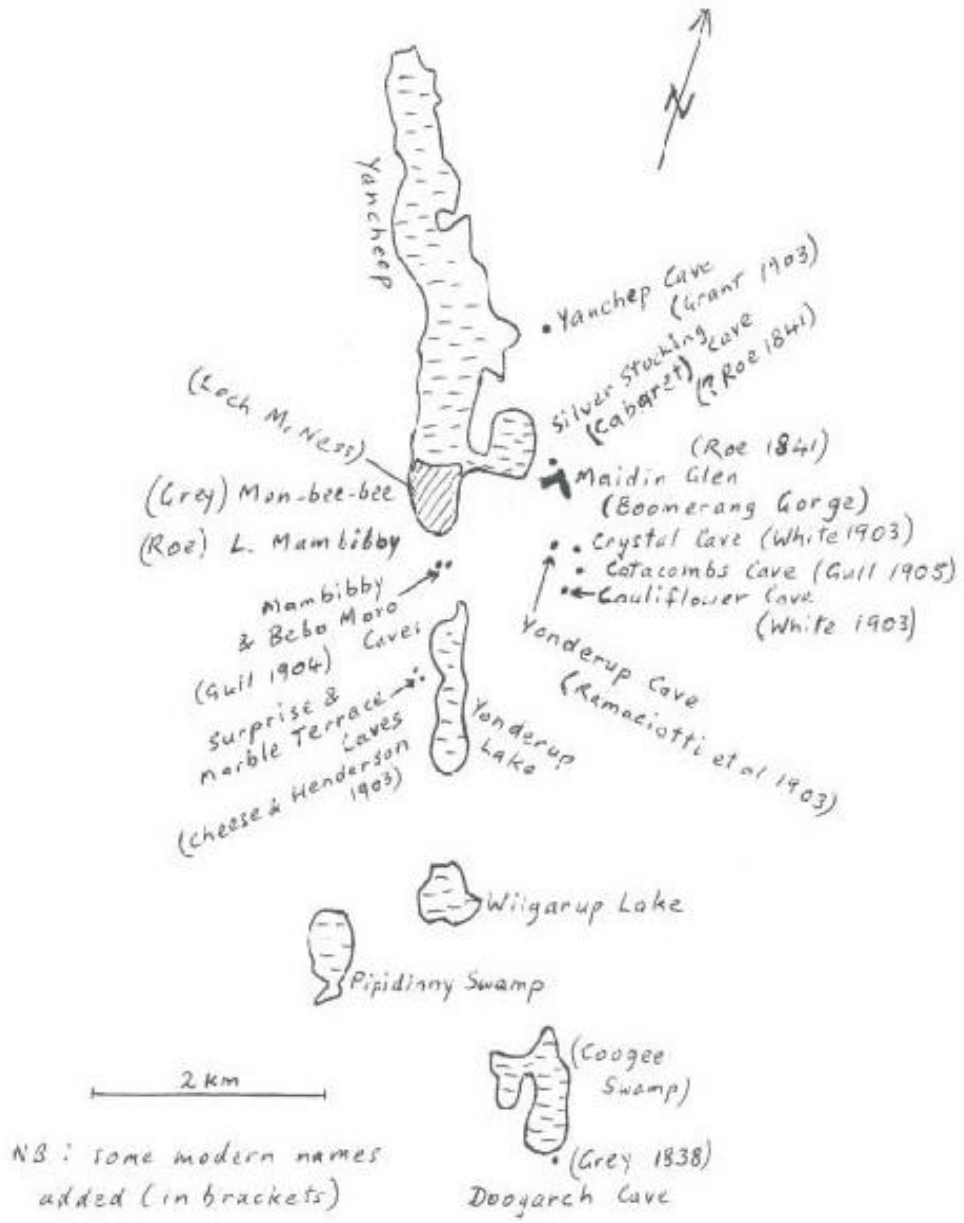


Figure 1 - Main events and dates at Yanchep 1838-1905

Henry White commenced a "Visitor's Book", which is today held in the Gloucester Lodge Museum at Yanchep, and this is a major source for information in the years immediately following. Two persons, Phillip Cheese and Edgar Henderson, explored Yanchep over the Easter period of 1903, finding numerous caves, including Surprise and Marble Terrace Cave, which are situated south of the Park centre. Two of their finds have never since been relocated, despite numerous attempts by the author. In March the following year they returned, discovering a large chamber near Crystal Cave, which they named Gilgar Cave, and another small but well decorated cave southwest of Surprise Cave, which they named the Amber Crystal Cave.

A Perth man Mr H.E.B.Gull, explored over Christmas/January 1904, finding two caves in close proximity, which he named Mambibby Cave and Bebo Moro Cave. He then returned the following summer, discovering an exceptionally beautiful decorated cave which he named the Catacombs. Both these were written up in detailed articles appearing in "The West Australian" newspaper (Gull, 1904, 1905). (Unfortunately when Wanneroo Road was extended past Yanchep in the 1960's the location of this cave had been forgotten, and the road was put right past the cave, which then came to be known as Road Cave; it also suffered considerable vandalism through its proximity to the road.)

THE RSV (REVISED STANDARD VERSION) OF YANCHEP

The Yanchep reserve came under the jurisdiction of the State Gardens Board. In the early 1930's this body, headed by Louis Shapcott, was given the task of developing the area for tourism. This included not only developing the caves, but also the building of several accommodation buildings. Top-rate accommodation was provided for in the Yanchep Inn, with Gloucester Lodge catering for middle-levels, and McNess Hostel being the equivalent of 'backpackers' lodgings. The main source of funding came from a gift made by a wealthy businessman, Charles McNess, and men who were out of work due to the Depression were employed on the development. The result of this development is testimony to the "Art Deco" era; with caves being "tizzied up" with pillars, walls and wishing wells, and where deemed necessary, the removal of whatever decorations stood in the way of a "nice" pathway through a cave. What was in the early 1900's considered to be the premier decoration in Crystal Cave, a shawl group known as "The Butterfly", seems to have disappeared about this time, evidently because it was in the way chosen for the pathway.

Shapcott - apart from having some very high-level contacts in the government of the time - had the "gift of the gab", and very quickly decided that in order to "sell" Yanchep, its story had to be made a great deal more colourful. He decided that the discovery of the main tourist caves had to be much older than a mere 30 years in the past (Shapcott, 1933). These caves were therefore "discovered" by George Grey, and this became the standard statement made by cave guides.

The original steep entrance fissure that Henry White had used to access Crystal Cave was greatly enlarged to change it into a set of easy steps, then the story was changed to that of Grey and his men swinging down by a rope through a hole in the ceiling of the cave in 1838. (I recall as a youngster looking up at that narrow hole and wondering how grown men had ever managed to fit through it!) The 1903 letter written by Henry White does not indicate that the first means of access was through the hole in the ceiling of the entrance chamber, as had been the guides' story for so long. Nor do any of the writings in the "Visitors Book" kept by him suggest that visitors to the cave had to endure the hardship of squirming down through a tight hole on a rope. (Ken Gibbs, whose father was the Reserve Caretaker in the late 1920's, has confirmed that the original access was via a ladder that Henry White had made, where the present entrance is situated.)

Yonderup Cave had an even bigger furphy woven into it, and for the background to this we have to note the skull that was found back in 1903. Development work proceeded with the objective of bringing parties in through one entrance and out by another route. To achieve this they located a small cave in a ravine nearby which seemed to come close to Yonderup Cave, and commenced to tunnel a connection. However funds seem to have run out, because the tunnel (still to be seen) terminates at a blank wall.

The tunnel was supposed to connect with the final chamber at the west end of Yonderup cave, however the series of tumbledown chambers going in that direction from the entrance had virtually nothing of interest in them. A great deal of tunnelling had already been done, but now it was going nowhere in particular, so in order to utilise it Shapcott hit on the idea of putting a large number of

bones into the west end chamber (the one that had the skull in it originally), and then made up a 'cock-and-bull' story about aboriginal men throwing their womenfolk down the solution pipe that opens in the ceiling of the chamber.

I remember the story - the bones were all females, there were sixteen of them, each skull had a hole in it, the women had been unfaithful, they had been punished by firstly being hit over the head and then thrown down, etc. Other discerning persons since then had observed that the main skeleton on display was actually a composite, that had been wired together. Where the bones came from we will never know, although I suspect they may have been in the museum, and that Shapcott who a great deal of "clout" simply demanded them, probably over the phone. The fiction he put together in a publication entitled "The Story of Yanchep" takes some beating, and shows the utter contempt with which aboriginals were held at the time! A full assessment of all the relevant material has been made, drawing very strong inference that the whole business was a hoax (Bastian, 2001).

Other work undertaken was the joining of Mambibby and Bebo Moro Caves, after which the latter name was dropped. Comparison with the description of the original discovery of Bebo Moro Cave, reveals that an immense amount of decoration was wiped out during the work (Bastian, 1993). Mambibby was wired for tourist visits, but the 1930's wiring was not good enough to stop current leakage as the cave is very moist, and the tours never got going. Cauliflower was likewise developed, but without electric light, and some tours are believed to have taken place. A big tunnel project was commenced in Loch Overflow Cave, with the objective of linking it onto Mambibby Cave, but stopped far short of its goal.

One unique piece of work was the conversion of Silver Stocking Cave (named from a curiously-shaped speleothem, which can still be seen) into a ballroom, with the name change to Cabaret Cave. This is a fairly astonishing cave in its own right, if only for its "Art Deco" work of arched pillars and concreted floors, and perhaps for once we may forgive the intrusion of man into nature, as anyone who visits it usually find themselves standing open-mouthed for a time.

POST WW-II

A major hiatus occurred in the management of Yanchep during WWII, when the Park was taken over for military purposes. As a consequence knowledge of the caves was set back considerably; for example Catacombs Cave was simply forgotten about. It was not until the formation of WASG in 1958 that sporadic attempts began to discover and/or rediscover caves in the area. Although a few old caves came to light, eg. Minnies Grotto in the north of the Park, it was not until the early 1980's that significant additions began to be made to the cave list. At that time numerous caves were located in an area north of the Park centre.

The author commenced a systematic documentation of the Yanchep caves in 1988, which was prompted by a conviction that there were many more caves than those appearing in the Karst Index. Over three hundred caves have been added to the list, as well as a large number outside the Park, which still come under the YN listing. During the course of the project many caves which revealed evidence of previous entry came to light, including old graffiti, spent torch batteries, etc. Catacombs Cave was positively identified, and found to be a cave which since the 1960's had been called "Road Cave" from its proximity to Wanneroo Road (Bastian, 1992). Melaleuca Cave was found to be not the cave shown on maps; the correct Melaleuca Cave was established by having the caver who originally named it come out and show it to the author.

Besides this numerous actual discoveries were made, many through enlarging small breathing holes. These include some rather special decorated caves such as YN151 (Serendip Cave) and YN438 - named Jackhammer Cave because the author was lent an electric jackhammer to open out the solution pipe - with extension leads run through the bush from a power point in the workshops! In the northern part of the Park YN256 (Orpheus Cave) was discovered after a bushfire in 1991. The most recent activity has involved considerable extensions to Mambibby Cave and Loch Overflow Cave, prompted by a hearsay that connection had been made between these two caves back in the 1930's. Connection was finally established in May 2002, however no sign of previous explorations have ever come to light, and the story appears to be yet another furphy of that era.

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APPENDIX

Excerpt from **"The Story of Yanchep"** by L E Shapcott. 1933.

> *"The Yonderup cave is . . . remarkable for its masses of piled rock and gloomy recesses, and its evident antiquity; while, buried away in the remote recesses of one long reach is a chamber suggestive of a heathen temple, with a crocodile's gaping jaws in one corner; in another, a yawning inferno from which spirits might emerge; and round about are piles of formation suggestive of the anatomy of animals butchered for votive offerings. At the extreme end of another corridor leading from the entrance is the aboriginal burying ground, from which five or six skeletons have been taken to enable a path past to be cleared, while the principle mound, doubtless containing scores of other skeletons, remains intact alongside. Truly, he who runs may read. Above the conical pyramid containing the ashes of the warriors and their women of bygone ages may be seen cut through the solid rock as though diamond-drilled - although doubtless fashioned by water - the cylindrical shaft down which the dead and dying were projected when their usefulness to their fellow natives had ceased. The aboriginal did not inhabit these recesses. If a member died or was so near death that his recovery was impossible, the body was thrown down the shaft. The survivors, unlike their American brothers and weak in their belief of happy hunting grounds, first removed his weapons for their own use in the future, threw him down a little food in the shape of the bodies of marsupials indigenous to the country, and went on their way to continue the battle of existence. In due time the hole was covered, either by design or by bush fires and falling rock, only to give up its secrets to the present-day visitor to Yanchep. From local knowledge it is clear that this burial ground could not have been used within the last seventy years. One skull found there is a most perfect example of an aboriginal, probably a woman of about forty years of age. Another complete skeleton appears to be that of a man at least ninety years of age. This historic link connects us with Yanchep before the white man roamed the mainland, when the savage held undisputed sway." !!!*

Abridged Oral History Interview with Mr Peter Smith

Busselton Historical Society Oral History Group

The Busselton Historical Society has recently re-commenced its oral history interview programme. On being notified of the Cave History Seminar at UnderWAy, they decided as one of their first projects to interview Mr Peter Smith, a former cave guide at Yallingup. The interview was conducted by Delys Forrest, who kindly provided a copy of the tape for playing at the conference.

My name is Delys Forrest, and I'm interviewing Peter Smith on the Ngilgi Caves at Yallingup. I'd now like to introduce Peter Smith, to give his account of what he remembers and knows of the caves.

Thank you. I'm Peter Smith from Dunsborough, and I was involved for 9 years from 1970 as a guide in Ngilgi's Cave at Yallingup. Now it was first discovered… the hole was first discovered by Amelia Curtis and a friend who were riding through to the beach in clear country in 1891, but it wasn't until 1900 that the cave was entered. And in those days they had to improvise with rope ladders and lanterns, blackboy tops which give a good light, and slowly they found more than one cavern to investigate. However, Caves House had to be built first before we could have visitors, and so until Caves House was built preparations were made for the entry of the cave. Uh…

DF: Tell me about what Mr Keenan did in 1960.

Oh, in 1960… Mr Keenan was the contractor to replace the steps leading into the cave. Quite a job he had, and I would like to read Ray Keenan's account of how he did it.

> Firstly work in the Yallingup Cave – it would have been 1959–60. The framework supporting the steps had to be completely renewed, so 8 x 8 inch sawn timber… sawn jarrah…was chosen as it was easier to work on the square, flat surfaces all round. If I remember right the timbers were 18 ft long and were straight off the saw. They were dumped in the car park, which in those days was not far from the cave; braces and girts had to be fitted in the scanty space in the cave. Every bolt-hole in both girts and braces had to be bored in all timbers, including the 8 x 8 uprights, so you'll understand that there wasn't much room for error.
>
> A fresh concrete pad had to be poured at the bottom of the hole for the pylons to rest on, and a metal strut set in the concrete to bolt the pylons to. I devised a method of getting the concrete down the hole by making a kibble, such as are used in the mines, from 12-gallon oil drums, a robust handle from half-inch mild steel being necessary. When on the farm we used to use an old Dreadnought tree-puller, and although it was rather prehistoric, I could see the possibility of using it for a winch to lower the kibble full of concrete. Once emptied, the kibble could be raised to the surface with the tree-puller in top gear. I had a wire rope that would easily reach to the bottom of the hole from where we anchored the tree-puller to a tree above the cave. The rope was taken through a block tied to the roof of the cubby-house that somebody had very conveniently built over the entrance to the cave. This enabled us to drop the kibble perpendicularly down the hole. We set the foundations out and boxed them in and the system worked like a bought one.
>
> Charles Ellis, who was on the tree-puller, had a brainwave about getting the loaded kibble down the hole quicker than by winding it down on the handle. He obtained a piece of 4 x 2 which he stuck into the shaft. He took the strain on the lever of the tree-puller, then releasing the pull, let the kibble down… blind down the hole, exerting what pressure was necessary to control the descent of the loaded kibble. Now likewise, timbers were lowered by using the gears on the tree-puller. We could easily manoeuvre the timbers into the required position. I congratulated myself that all the holes I had to bore in the timbers, they fitted exactly, with only one being a quarter-hole out. Further along the cave we had to renew some timbers under a walkway. This was tricky as the timbers had to be manoeuvred around a corner, but

for this persistence prevailed, and the job was completed to everyone's satisfaction. Incidentally, all the holes had to be hand-bored by brace and bit.

Now I was associated with the cave for 9 years, and that is a short time in 100 years of cave viewing. So I'll tell you what I know of those few years. Now Joy, my wife, happened to be the manageress of the committee, and she wanted extra guides as the population increased and extra tours per day came on. I assisted the first two years intermittently, until guides retired. After two years, full-time.

Fridays were closed before I started. They were guided tours in those days, and there were coloured lights in the cave also in those days, but they were changed after I became a guide. We didn't get much in the line of wages – we were paid peanuts compared with today – but we did our job. Eventually guides were stationed along the routes instead of taking groups along; they had their guide sheet with them, and numbered at various stages along the pathway. The best Easter I can remember was Saturday, Easter Saturday, 800-odd came through, and on the Sunday 1070 people came through, so you could see there were just lines of people everywhere.

Many changes took place about that time. We had walkie-talkies…. it didn't work above ground so telephones were installed and they were quite successful. And different lighting and rewiring of the cave took place. The whole of the old wiring had to be taken out in pieces – handfuls –because some of the passages are pretty narrow. Anyway the contractor, Turle, was quite successful in taking all that out and rewiring the whole cave with white lights, if I remember rightly. Now when I began there were only toilets on the area near the parking area, and there was much vandalism from the hippies in those days. I saw tearooms constructed during my 9 years, and that entailed having water tanks… rainwater tanks built, otherwise we may not have had enough water from Caves House.

Inside the caves there was also vandalism. Now when a boy I recall the Angel Wings as we entered the main cavern. They were beautiful stalactites. It is said a member of a school group got under the wire netting protecting them and grabbed a wing and it broke off, and it is said he lost a finger in that event. Another formation nearby was treated likewise by a schoolteacher who had to take several steps from the path to vandalise a large piece hanging by a small piece of formation.

DF: Did that have a name, Peter, that piece?

No, it did not, as far as I know. It was just a large stalactite hanging from a small neck. Now an overseas diplomatic tour smashed a good shawl within easy reach. This happened about when I started, but it was not known who smashed it because they were in a long line being guided. The guide was ahead, of course. There were once two tree roots in the main cavern, but over the time each died and fell, but new ones are showing at present.

Now, when a boy, everyone had to walk up to the caves, a kilometre or so. It was known as Lovers' Walk. There was a barrel to catch water off a small roof over the entrance, which was lower than the present entry by about a metre.

Various covers and gates were used. The largest roof was built in 1975. It was called a 'hyperbolic parabaloid', which looked impressive. Recent years it was removed to the nearby museum as it was considered obstructive to cave ventilation. The greatest change we noticed was the slow cessation of water drips throughout, until now it is virtually a dry cave.

Now torches came in when electricity was supplied to the cave in the early days, and before that they used magnesium flares and lanterns and the tops of blackboys, which gives a good light. Torches were carried always as there were blackouts, and that made removing a tour from the lower end of the cave a tedious job. It took anything up to a half-hour to get the people out. Now a set of emergency lights are used on the floor of the walkways.

Now my legs told me to retire eventually, and I wasn't sorry to cease. Now there's one or two places in the cave which is called a crawl, where you have to crawl, and Harney's Pinch which was a very tight passageway until it was blown back in the 1960s. It's a little bit better now. Further on in the main cavern you've got the Jewel Casket and the Arab's Tent; they are the major ones to be seen.

Now in conclusion I'd like to tell you a little story about Golgotha Cave at Forest Grove. Now in the early days of settlement a skeleton was found in that cave with a musket lying beside it. It was believed the skeleton would have laid there for about 30 years before white settlement. Now the musket was taken and sent back to Amsterdam where it was traced and that would be marked in the early… or in the 1600s, thereabouts. So that is the story of Golgotha. It is a large cavern which can be now entered, I understand, and it's just one of the many caves to be found in this area.

The New Caves of South Mole Creek, in Northern Tasmania

Arthur Clarke

ABSTRACT

The limestone and caves near Mole Creek have been known since the late 1820's when surveyors with the Van Diemens Land Company began their "westward" exploration. The first reports of cave exploration in the Mole Creek karst area date back to 1829 when caves were "discovered" in the Chudleigh area. The earliest descriptions of the "Chudleigh Caves": two neighbouring systems: Honeycomb Caverns and Wet Cave systems are recorded from 1833 and most of the cave descriptions in subsequent publications till 1878 relate to these two caves near Chudleigh. These "Chudleigh Caves" were known by several names during the course of their history. Some 40-50 years after being discovered by early settlers, the Chudleigh Caves became referred to as the "Old Caves" following the discovery of some new (initially unnamed) caves at South Mole Creek in the mid to late 1870's. This "new" area was described as being quite near to the Chudleigh district, but in actual fact the two cave areas were some distant apart and were thus considered separately as the "new caves" and the "old caves". In 1883, Higgins and Petterd described the Tasmanian Cave Spider (*Hickmania troglodytes*) from one of these unmanned "new" caves at South Mole Creek. In 1888, in his treatise on the Geology of Tasmania, R.M. Johnston describes the cave site with the recently described spider as one of the "New Caves in the Chudleigh neighbourhood" on the land of Mr Pickett. Although its location and name (if any) was a mystery, the cave was also known as a site recommended for further study because it contained a rich deposit of mammalian remains. In 1921, Baldocks Cave is identified as one of two caves in the Mole Creek district that was studied intensely, due to the presence of a rich deposit of mammalian remains. Literature sources and records from the Lands and Titles Office in Hobart indicate that the "New Caves" of the Chudleigh district were principally found in the Sassafras Creek area during the 1870'2 and 1880's, including Baldocks Cave that was opened for tourism privately, around 1890. Other caves known from this area - and believed to have been discovered during this time – are Sassafras, Glowworm and Cyclops Caves.

A Thumbnail Sketch of the Leeuwin Ridge and Caves History Since European Settlement

Brian Combley

Cape Leeuwin and Cape Naturaliste
- Named visited and recorded by the Dutch in 1622 and French in 1772.
- Mathew Flinders charted Cape Leeuwin and Cape Naturaliste in 1801.
- Augusta was the third settlement in W.A. in 1830 after Albany in 1826 & the Swan River Colony in 1829.

Port Augusta
- Used by whalers and sealers for fresh water before and after settlement.
- Some of the first residents
  - Captain John & Georgiana Molloy.
  - The Bussell brothers John & Alfred.
  - The Turner family.
  - The Allnutt family.

H. M. Ommanney reports cave 1840
- A surveyor based in the South West.
- On a trip from the new town of Busselton to the western edge of the Leeuwin Naturaliste Ridge, reported finding a cave (refer Appendix 1).
- It is assumed it was one of the Yallingup caves, possibly Northcote Grotto.

Deepdene Cliffs
- Deepdene Cliffs were adjacent to the Turner property and were known of at the time. Some small caves exist in the cliff face.
- Early mariners called in for fresh water near Deepdene as it was visible from the ocean and was on the lee side.



Figure 1 - Ducalup or Deepdene on Turner Brook

Cave discovered in Augusta 1848
- Mr G Turner found two caves about 12 kilometres north of Augusta.
  - Caves were Old Kudardup and AU 10
- Caves explored by Edward Hester and reported by him in the Inquirer of November 1848 (refer Appendix 2).
- The find was attributed to Turner in the article.

House Cave later called Wallcliffe

- Augusta found not to be suitable for farming.
- Bussells moved to Ellensbrook in 1857 and later to Wallcliffe about 1865.
- House Cave discovered about this time (Wallcliffe).
- Visitors were encouraged by the Bussells.
- Several reports are recorded in the West Australian newspaper of visits.
- Albert & Fanny Bussell's initials inscribed on the flow stone in Wallcliffe Cave.



Figure 2 - Albert and Fanny 1882

Warrawerrie or Blackboy Hollow

- Discovered by John Bussell in the late 1860's.
- Bussell encouraged visitors.
- Enlarged opening and installed a ladder of sorts.
- Visitors accommodated at his house.

Moondyne or Coronation Cave

- Discovered by Fred Grange in 1879.
- Used by Western Australia's only bush ranger "Moondyne Joe" or Joseph Bolitho Johns.
- Opened as a public cave on the coronation day of King George V.
- Was called Coronation Cave.

Lake Cave doline

- In 1867 Fanny reported to her family the existence of the Lake Cave doline found whilst searching for lost cattle.
- The family did not believe her as it could not be located again.

Mammoth Cave

- Reports of the cave in 1895.
- Tim Connelly credited with the first exploration.
- Mammoth was known as the "Dawn of Creation Cave".
- The name was possibly because of fossils found in the cave.
- The skeleton of a European was also found in this cave.



Figure 3 - Mammoth Cave Early 1900's



Figure 4 - Tim Connelly

Photograph's courtesy of Rauleigh Webb

Yallingup or Ngilgi Cave
- Discovered in 1899 by Edward Dawson when searching for lost horses.
- Explored by Dawson and two friends Seymore and Curtis.
- First tours conducted 1900.
- Edward (Ned) Dawson became the sole guide at Yallingup for the next 37 years.

Tim Connelly rediscovers Lake Cave doline 1897
- Tim Connelly, C. Price Conigrave and Wm. A. Nelson relocated the Lake Doline and found the Lake Cave entrance.
- They lowered themselves down into the doline to explore in November 1897, the cave was named "Queen of the Earth" by Connelly.

Connelly also explored other caves
- Museum, Calgardup, Bride's and Golgotha caves were probably first explored by Connelly.
- Connelly passed away in 1933.

Erskine May report commissioned 1900
- From the Chief Inspector of Lands
- To the Undersecretary of Lands
- Completed by Mr C. Erskine May
- Re the caves in the Margaret River Region.
- After pressure from a local resident Mr Brockman.
- Mr C. Erskine May prepared the report after visiting the caves of the region (refer Appendix 3).
- Reported that vandals were already at work defacing these marvellous and beautiful geological features.

Description of the report
- A report on the proposed management of the caves on the Leeuwin Ridge.
- It is interesting that conservation was recommended in 1900 due to damage being done to these caves.
- It is also interesting that even back in those days the solution proposed involved bringing more people to the caves.

How to save the caves
- Road from Busselton must be upgraded.
- A hospice for accommodation will be needed.
- Entrances ought to be guarded by iron gates.
- A caretaker should be appointed.

C. E. May specifically mentioned

- Wallcliffe.
- Blackboy Hollow.
- Calgadup (Calgardup).
- Boodjidup (Witchcliffe).
- Nindup (Giants).
- Deepdene.
- Crystal (recommended closing off).
- Historical photographs from the May report are shown below alongside current views (2002) of the same features.

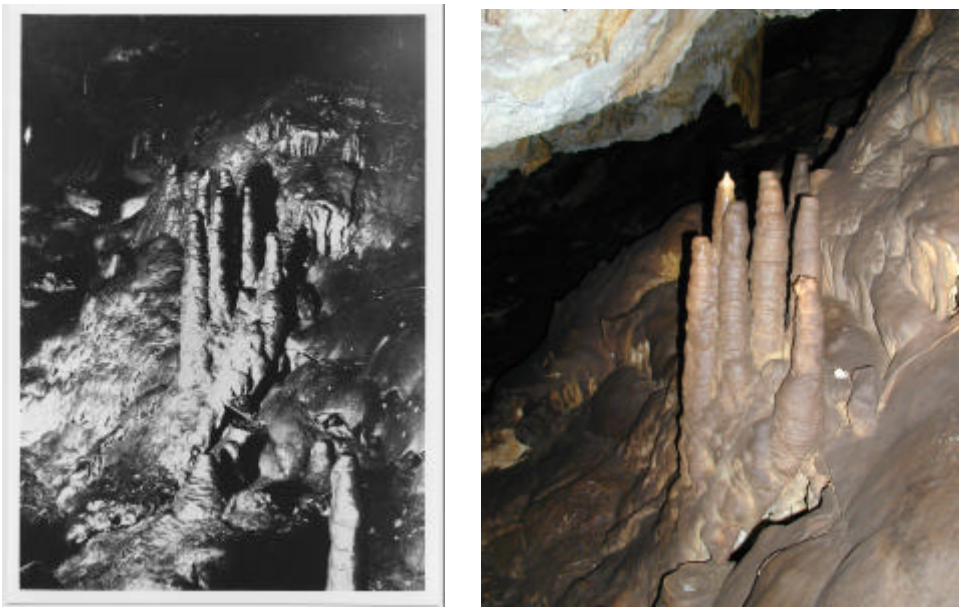


Figure 5 - The Devils Hand Wallcliffe Cave



Figure 6 - The Poultry Show Wallcliffe Cave



Figure 7 - Queens Crown Blackboy Hollow

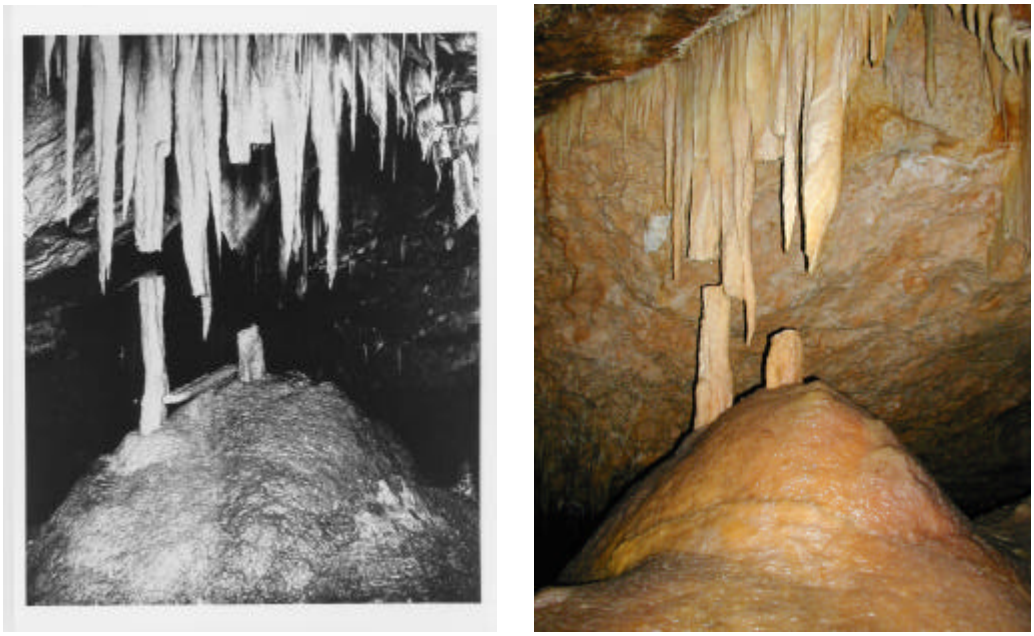


Figure 8 - Broken Column Blackboy Hollow



Figure 9 - Suspended Dome Calgardup



Figure 10 - Lots Wife

Connelly appointed as guide

- As a result of the C. E. May report Tim Connelly was appointed as a guide and caretaker on a salary of $100 (fifty pounds) per annum.
- Gates and locks were installed.
- Magnesium flares and blackboy torches were no longer used.
- Caves Board formed.

Strongs Cave

- Recorded by Marmaduke Terry in a survey in 1900.
- Many other caves in the area recorded around this time.
- Terry married Filumina Bussell on St Valentines Day 1900 about the time he was completing his survey.

Caves House

- Caves House, the accommodation recommended by May, was built in 1903.
- A fire destroyed it on 1930.
- The new Caves House opened in 1938.

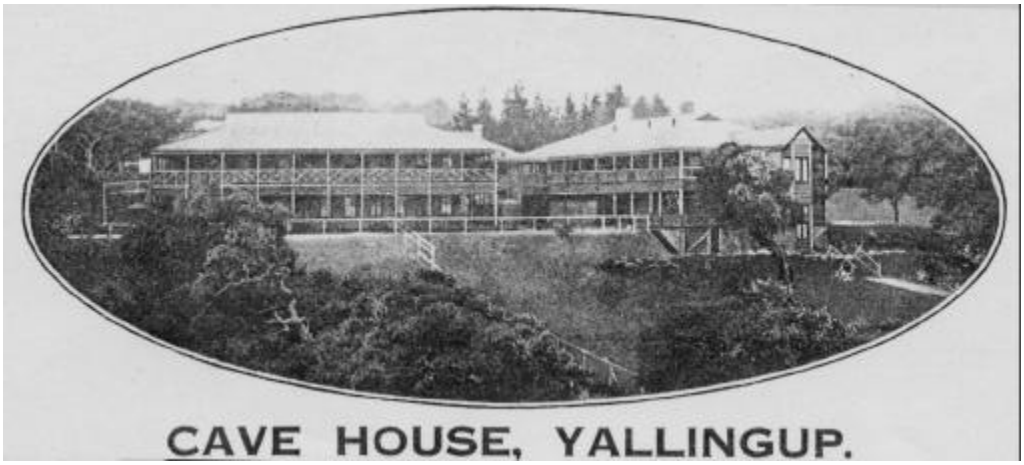


Figure 11 - The original Caves House



Figure 12 - Caves House reconstructed

Jewel Cave

- Solution pipe found by William Ellis in 1908 but not entered, called Windy Hole.
- Discovered by Cliff Spackman, Mr & Mrs Jack Burrows, Harley Webster and Tony Tapper in 1957.
- Jewel Cave will be covered in a specific presentation by Lloyd Robinson who first explored it in 1958 with Lex Bastian and Cliff Spackman.

The history from the 1950's on is well recorded in SRGWA and WASG documentation. Even today Witchcliffe Cave is not locked and is being used as a camp site. Many other caves still remain unlocked.

ACKNOWLEDGEMENTS

Thanks are due to:

- The Battye Library of Western Australian History, for permission to reprint historic photographs and documents.
- Tracey Bushell, for her expert assistance in locating items in the Battye Library.
- Jeff Murray of the Department of Land Administration, without whose help much of the material used would not have been found or confirmed to be accurate.

APPENDIX 1 - Exert from "An Excursion from Busselton to the Western Sea Coast by H. M. Ommanney - June 1840"

….At 10.15am we came to a sort of hole in the ground, its sides supported by limestone rock, some few points of which are just raised above the ground and drew our attention. We descended this with some difficulty for about 40 feet, and then advanced about 15 or 20 feet under an arch, the crown of which is about 15 feet high. Here it became dark, but it seemed to have one or two smaller passages leading from it. The floor of the cavern was of sand and appears to have a powerful stream of water running through it sometimes. The roof is limestone and had long pendants, stalactites, with stalagmites on the floor corresponding. I regretted that neither our time nor means permitted us to explore this interesting place further….

APPENDIX 2 - Discovery of Two Large Caves in the neighbourhood of Port Augusta.

We are indebted to a correspondent for the following particulars:
Though so many years have elapsed since the first settlement of Augusta, yet strange to say a most stupendous and wonderful production of nature was in the immediate neighborhood unnoticed and unknown. I allude to two caves of surprising beauty situated within eight miles of the north-ward of Augusta at the back of the sea hills. These caves were discovered accidentally by Mr G. Turner a few weeks since, but it is to Mr Edward Hester I am indebted for the following particulars, he having minutely inspected them during a late journey to Augusta.

On approaching the first cave there is nothing to indicate its proximity; the eye merely beholds a large limestone rock about 40 feet high. A more minute examination discovers two apertures in the eastern face of the rock separated from each other by a space of thirty feet, each large enough to admit the passage of a man in a creeping position. Upon entering either of these apertures Mr Hester had to descend an inclined plane at an angle of 45 degrees for a distance of 100 feet. The descent he describes as somewhat difficult from its steepness and ruggedness. This passage led to the floor of the cave and the scene which then presented itself fully repaid him for his trouble. He found himself in a lofty and spacious apartment of exquisite magnificence; it was thirty feet wide, one hundred feet in length and its extreme height one hundred feet. The roof was of circular form and the floor semi-circular, the inclined passage encroaching one one portion of the circle. The ceiling was in appearance a vast dome, hanging from which were splendid stalactites of every shape, form and size and in countless numbers, nor was the top of the cave the only portion thus adorned - around the sides the same glittering display was exhibited. The sizes of the stalactites varied, some being no thicker than a pipe stem, while others were from ten to fourteen feet in length and of a proportionate thickness. A short distance from the sides were pillars of the same material rising from the floor to the dome and of an equal circumference from top to bottom, the diameter of each pillar varying from eight feet to two inches. They were in every stage of their formation, some apparently just rising from the ground, others rather longer, while the post perfect had effected their junction with the roof. The masses of stalagmites assumed every form that can be imagined and from Mr Hester's description the appearance must not have been dissimilar to the ornamental screens seen in Cathedral Churches. The interior of the cavern as seen by torchlight must have formed a most striking 'coup d'oeil.

My narrator states it is impossible for him to attempt a description. Those who had seen it had exhausted their powers in this respect and yet one view was sufficient to convince him how far the reality exceeded the description.

The entrance to the next cave (about 200 yards from the one just mentioned) was an opening in a rock eight feet high by twenty feet broad, the passage having a general slope of about a hundred feet, led into a small cavern, the floor of which continued to slope towards another passage similar to the first, which likewise leads to a small cave- forming in fact a double cave. These, though inferior in size to that above described, presented the same splendid appearance, and were of the same beautiful form, save except that the roofs : were flat instead of domed. Their height was only twenty feet, length one hundred feet and breadth thirty feet. The floor of the larger and innermost of the double caves was perfectly flat and smooth and of a dark colour and yielding to the pressure of the feet. Mr Hester states its appearance to be that of a dark loam. In the centre of the former

were several pools of water, three feet in circumference and a few inches in depth, constantly supplied by droppings from the ceiling. This water was tasteless, limpid and ice-cold. here were also found the skeletons of three kangaroos.

Mr Hester on his return discussed two more of these natural apartments and has no doubt that there are many more. He had not time to institute a minute examination but states their appearance to be similar to the others from which they were distant one twelve and the other twenty-five miles North. The first had a rivulet running into it.

APPENDIX 3 - C Esrkine May Report

MARGARET RIVER CAVES

Pursuant to instructions, I have inspected the caves in the vicinity of the Margaret River, with a view to tendering "definite information as to what caves it will be advisable to protect, the means to be adopted, and the cost of the same". At the outset, I wish to emphasise that vandals have already been actively at work defacing these marvelous and beautiful geological features, which, in my judgement, excel in extent, picturesquences, and variety the Jenolan Caves of New South Wales, which the sister colony takes the greatest care of, and has at large expense made a favourite trysting place of travelers. The Margaret River Caves are so remarkable that if they were known they would become one of the famous tourist places of the Southern Hemisphere, if not in the world. But if nothing should be done to stop the wanton destruction that has been going on by curio collectors, the caves will, in a few years, be despoiled of much of their charm, and a national opportunity will have been lost of fostering health and recreation by founding on the Margaret River a sanatorium in a mild and bracing climate, fresh with the breezes from the ocean. To the goldfields people especially the Margaret River should be the Blue Mountains of New South Wales, the Derwent of Tasmania, or the Lakes of New Zealand, when they are making holiday.

How to Save the Caves
If the caves are to be visited as they deserve to be, the greater part of the road from Busselton, the nearest town, must be improved; a hospice for the accommodation of excursionists will be needed; entrances ought to be guarded by iron gates, and it is imperative that a caretaker must be put in charge, and, if necessary, a charge made to recoup his pay while he is acting as a guide. To leave things as they are would, I am convinced, be a reproach to the Department and the community. The spot is so isolated that, in the absence of an hostelry, the caves are practically inaccessible, except to bushmen, and there is no oversight to prevent the hacking off of the most exquisite and delicately-wrought specimens or the scrawling of names on the brilliant and fantastic handiwork of Nature. The New South Wales Government, recognizing in the Jenolan Caves a valuable heirloom of the Colony, have lavished money upon them, placing bridges to cross difficult places, and in many other ways devising that the pleasure of the sightseer shall be free from toil, alluring alike to the invalid or to the convalescent, as well as to the hale. While I do not counsel at present any prodigality, I am assured that the spending of a moderate sum will, even commercially speaking, be a most judicious step in adding to the fame of the Colony. The beauty spots of Western Australia are not so numerous that we can afford to leave them unknown or in ruthless hands.

Where the Caves are
The caves lie 35 miles South-Westerly from Busselton, the terminus of the South-Western Railway, and within a mile of the ocean, the total distance from Perth being 185 miles. They extend for about 25 miles Southerly from Wallcliffe (formerly the property of the late Mr Bussell, the pioneer of the district, but now owned by Mr Gale), towards Flinders Bay, where the M.C. Davies Karri and Jarrah Company do the loading of Jarrah. The caves are nearly all within a mile of the sea, in undulating limestone country, or a series of low hills. There are probably about 45 caves in all, but many of them have not yet been explored.

A Gem of a Holiday Place
The district possesses almost every desideratum for a perfect holiday to please diverse tastes. There is a trip by land and sea when a steamer is provided, as it would be at once if excursionists knew what they would enjoy in escaping the summer heats in the salubrious latitude. They could

go by way of Busselton, see the caves in a leisurely excursion down to Cape Leeuwin, thence driving or riding to the banks of the Blackwood River, at Augusta, to fish and shoot over Hardy's Inlet or stream, or sail to Flinders Bay, and follow the caves up to Boodidup Brook, to bask by the waters of the brook that is fed from a silver spring gushing from the side of Witchcliffe Cave. There is the Leeuwin Lighthouse to reach as a picnicking place from Augusta, with a broad, smooth beach for the children to paddle in, and a splendid cruising ground for the yachts of their elders. And when the caves are reached, there would always be the finding of something new to whet the zest of the explorer, and dispel the slightest sense of fatigue in rambling in and out of the huge and sparkling grottoes, each in a new garniture of cunning device and dazzling radiance.

The Trip as it is Today
The only route at present, when the caves are, I am sorry to say, a terra incognita to nearly everyone, is by railway to Busselton, a quiet and delightful rural retreat of itself, and thence by road to the hospitable homesteads of Mrs John Brockman, (Burnside), and of Mr Gale (Wallcliffe). The track, for it is little more, five miles beyond Busselton, winds in and out of an avenue of giant karri and jarrah, or of peppermints growing luxuriously; thence to the Margaret River, overlooking some fine reaches of which is the Wallcliffe residence, the broad bosom of the stream fully 100 yards wide, resembling a clear inland lake.

The Cunning Mouth of the Cave
No beaver ever more artfully concealed the entrance to his nest than is the lip of the Wallcliffe Cave. Part some peppermints, push aside the flowing fronds of ferns and bend low, almost on all fours, creep slowly for thirty feet, eyes bent to the ground, and then, what a transformation scene! The fairy grotto of a pantomime, the lustrous hair of the King of Jewels of Arabian Nights is, although this is an official report, the only simile that gives even a prosaic idea of it. A circular chamber, richly bedecked in gleaming white stalactites, with mammoth bunches of grapes (see Nos. 1 and 3), fleecy wefts apparently as soft as lambs wool, but solid as marble, and up springing from the floor of the chamber, as if greedy to clutch the fruit, yet frozen in making the grasp, is a monstrous hand several feet long (see No. 2). These are just hints of what we see. Why not spend a few pounds so that so singular and beautiful a place could be reached without having to do penance like Nebuchadnezzar when he was under sentence to eat grass?

The Blackboy Hollow
The Warrawerrie or Blackboy Hollow Cave is about two miles South of Wallcliffe, and is a mantrap for the unwary, for there is a 15ft. drop, if you fall in instead of using the ladder that the discoverer (Mr John Bussell) made in order to sound his find, and was thoughtful enough to leave behind him. This vertical hole will not take in anyone of very round proportions, so that Ministers or aldermen, for example, will be glad to hear of some simple enlarging work, which I recommend being done. So rough and high are the boulders on the floor of this cave, that we scrambled over, with the dim, flickering light of a candle, that we called it "Spion Kop". It was more than worth the scramble, however, for the flashlight by which we took some photographs revealed some superb pyrotechnic effects shining on the damp stalactites (see Nos. 4 and 5) like the glitter of a thousand diamonds. There is another chamber of this cave that has never been entered. A broken column (see No.s 6 and 7) apparently cut from Italian marble, as pure as alabaster, should make a noble monument for a patriot. There are also semi-transparent shields that look like snow-white tapestry from an Indian loom, and which only the touch shows to be hard as flint, formed by the dropping for ages of mineralized water, encrusted far down below the light of the sun. If this cave were lit with electric light and passes across chasms formed after the model of what has been done in the Jenolan Caves it would draw better than Millais.

The Pearl of the Diadem
While all the caves we saw are worth many times the journey, the crowning beauty is, in my opinion, the one known as Boodjijup, a mile South of Blackboy Hollow, and 100ft. above the slanderously entitled "Devil's Pool". (See No. 8) A lady could go through this cave without soiling her dress. You get into this lovely "bower" on the side of a high limestone ridge that gives from the commanding situation a pretty prospect of water and lea, with the shimmering streak of the Boodjijup Brook in the foreground. The access to the cave is rather steep and somewhat rugged,

but once the inlet is gained the labour is rewarded, and the visitor can move at ease and admire the terraces, the columns like the pipes of a cathedral organ, and the pendants that glow as the stars of night in the three chambers of this wondrous arcade. (See No. 9)

Calgadup Cave
Nearly three miles South there is a descent of about 100ft. first through an enormous pit like the excavation of a quarry, and then by the side of a limestone cliff, when the "door" of Calgadup Cave is disclosed. The floor of this cave is moist enough to show that it is the bed of a subterranean creek; it is about 70ft. across. The chamber sides are hung with many stalactites of myriad shapes and colour under the rays of our artificial light. What would be taken in a lady's boudoir for a very beautiful opera cloak of swansdown, thrown over the top of a low pillar, stands out in the foreground. This is a stalagmite "growing" upwards, while the stalactite is formed downwards like the tendrils of fruit of a vine. Here, too, in my opinion, is the gem of all caves – the suspended dome (see No. 10), the delicate tracery of whose splendid and fantastic fretwork hangs in mid-air, held by almost gossamer threads of crystalline.

Nindup Caves
The Giant's Cave (see No. 11) is the chief of the Nindup Caves, sixteen in number, which occupy a radius of two miles. Many of them, owing to the ugly approaches, are unexplored. Without the equipment of an Alpine climber, or of a cliff birdnester, it is not very inviting to attempt to clamber down the branches and boles of tall karri trees, that tower from the ground in front of the caves, up through huge "shafts" to the hillside, so that we, as well as all our predecessors, merely peered over the ledges and left these caves in their virgin solitude. The pits appear to have been due to the subsidence of what formerly were caves, but a more definite explanation I leave to the adventurous tourist who longs to set his foot on untrodden ground, and gaze on things that human eye has never seen.

The Giant's Cave.
The Giant's Cave has a false entrance (see No. 12) opposite to the real one, which we got down to, after a rather toilsome drop of about 80ft. The roof of the vault is so high that I could not throw a pebble to touch it. The floor is mainly strewn with great boulders, ornamented with magnificent ferns. The false entrance, of peculiar limestone formation, is 130ft. deep and 80ft. high, while the proper entrance is exactly opposite and almost 200ft. wide. The Giant's Cave is of bolder design in its interior decoration than some of the others to which I have alluded, just as a drop-scene is painted with a freer brush and less attention to minute details than a daguerreotype.

Nannup Caves
There is a very pretty approach to the Nannup Caves, which are a mile North of Boranup, and six miles South of the Giant's Cave. There are two chambers, separated by a "man-hole", which all but blocks up the noble frontal passage that is 200ft. long and nearly 30ft. high. The tunnel through which we crawl, or, in places, almost wriggle like an eel, is 30ft. long. The first hall is so full of the characteristics of Gothic ecclesiastical architecture that "The Cathedral Aisle" seems to be a most appropriate appellation for it. I am sorry to say that the walls preserve far too well the names of persons who scrawled them, in some cases 20 years ago, for such shoddy records in such a place look like sacrilege, and deserve the reprobation that Mark Twain so scathingly applied to the miscreant who tried with a spalling hammer to knock a memento off one of the pyramids of Egypt.

Crystal Cave
A running stream, which flows over the bed of Crystal Cave, half a mile South of Nannup Caves, gives it its name. This cave, of sandstone formation, is almost a ruin through the ravages of marauders and the falling of Karri timber overhead, which have wrought havoc among former grandeur. Ascending some 50ft. or 60ft. another vast chamber is entered; the dome-shaped roof that is set off by colonnades is cracked, and to all appearance unsafe. I beg to recommend that this cave be closed, so that it may, in the course of 20 or 30 years, restore itself from the hacking about it has received with a timber "jack" which I found in the cave.

Deepdene Caves
Deepdene Caves are six in number, within a radius of two miles, and are situated four miles South of Karridale. The one we visited, known as "Deepdene", is easy of access. It is very imposing in

the beauty of its stalactite work, and, further, it is embellished with a column of white crystal, 10ft. in diameter and 15ft. high. To the left of the column is a perfect arch, the roof of which scintillates with hundreds of pointed stalactites. A narrow passage takes us into a chamber of majestic height, from the dome of which hang graceful festoons of petrified tree roots, remindful for all time of the great karris of primeval days.

In my opinion, all the caves, except the Crystal Cave, are perfectly safe for the exploration of visitors. The air is beautifully fresh, showing that there are other openings from beyond the points that have been penetrated, a distance that is not more than one-eighth of a mile. How much further the passages extend remains to be discovered. I cannot too strongly urge that the caves shall be protected, and to this end I beg to make the following recommendations:

1. That iron gates, with locks, shall be placed at the entrances.
2. That Mr T. Connelly, a local resident, who is familiar with the caves, may be appointed caretaker at a salary of £50 per annum.
3. That visitors shall be admitted to the caves only under the superintendence of the caretaker.
4. That the use of proper lights that do not smoke shall be insisted upon.
5. That regulations be framed providing for the punishment of any person injuring the caves in any manner. To show the call there is for oversight, I need only mention that, in addition to the mutilation and defacement of some of the choicest specimens, the burning in the caves of blackboy rushes, and the smoking in of names on the walls with candles have caused discoloration and disfigurement.
6. It is further desirable that those caves that are not already located should be fixed by survey; also roads to the several caves should be marked.
7. That a house of accommodation should be built by the Department at Boodjijup and at Augusta, or that steps should be taken to draw the attention of private enterprise to the good opening there is in making this district the foremost pleasure resort of the Colony. Already this season (while there are no facilities for visiting the caves and for seaside) about 70 goldfields visitors have, at special expense, equipped themselves for the tour, which, I understand, they found highly beneficial, interesting, and enjoyable.

The Party's Work

The utility of the trip was much enhanced through the kind co-operation of the Surveyor General (Mr H.F. Johnston), thanks to whom I had the coadjutorship of Mr Morison, of the survey branch of the Department, in the taking of a series of views of the interior of the caves that have never to any extent been photographed before. Through the indefatigable efforts of Mr Morison, I am able to accompany this report with illustrations showing how much the Colony is losing by leaving these wonderful and beautiful phenomena unheard of and unexplored. Mr Thompson, inspector of lands for the South-Western District, also accompanied me and as guide Mr Connelly, whom I have in the foregoing recommended for the post of caretaker. The success of the magnesium light in heightening the loveliness of the caves was so marked that there is no doubt that they should be illuminated with electric light, as has been done in the Jenolan Caves by the New South Wales Government. It is noteworthy that the Margaret River caves are almost in the same parallel of latitude as those at Jenolan. It would be base ingratitude for me not to make acknowledgement on behalf of the party of the kindness with which we were treated by Mrs John Brockman, of Burnside; Mr Gale, of Wallcliffe; and Mr Herbert Davies, local managing director of the Karri and Jarrah Sawmilling Company. Mr Davies placed a special train at our disposal on the timber railway of the company, which runs through and opens up a considerable distance North and South of the cave country. In conclusion, I beg to state that it would probably cost from £150 to £200 to fence in the caves mentioned in this report. I recommend iron fencing, as I consider it to be cheaper in the long run.

C. ERSKINE MAY.
Chief Inspector of Lands.
Perth, 26th February, 1900.
Photographs were included.

Some Little-known Early Cave Visitors

John Dunkley

JOHN GALE: CAVING PIONEER

The practice of speleologists wandering Australia, or indeed the world, is something we take for granted these days. In the nineteenth century, however, there were surprising numbers of wanderers examining caves all over the country. They weren't speleologists but many wrote of their exploits. Some were well-known explorers (eg. Lawson, Mitchell) or adventurers and opportunists (John Henderson), some were naturalists (George Bennett) or gentlemen of leisure, others were not at all well off but somehow found the means to journey to remote places (James Backhouse, who founded Quakerism in Australia; Godfrey Mundy), and a few were painters seeking sublime subjects (Charles Conder). In some cases they traversed almost unexplored country to arrive at the caves.

In his account of Barbers Cave at Cooleman Plain, Joe Jennings (1968) mentioned in passing that the cave had been visited in 1875 by John Gale of Queanbeyan. However no reference was given and it appears to have escaped the notice of speleo-historians that this remarkable man not only journeyed to these remote caves but wrote a book on his exploits. Originally serialised in the Queanbeyan Age in 1875, the book was published in 1903.

The twelfth of thirteen children of Francis and Mary Gale, John Gale was born on 17 April, 1831 in Bodmin, Cornwall. After an apprenticeship as a printer in Monmouthshire, Wales, he was later ordained a Wesleyan minister. Posted to Australia in that capacity, he emigrated in May 1854, was sent to the Goulburn district, and eventually settled in Queanbeyan in 1857 after leaving the ministry. Here in September 1860 he founded the Queanbeyan Age, editing it for 43 years & continuing his journalistic and Wesleyan interests until his death in 1929. Freemason, head of a Temperance Movement and strong advocate for the eventual site of the national capital, he also acted as Coroner and was MLA for Murrumbidgee in 1887-89.

His only full-length book was *Canberra: History of and Legends relating to the Federal Capital Territory of the Commonwealth of Australia*, in which he recalls how, on Christmas Day 1855 he rode a horse to the top of Capital Hill, now the site of the Parliament of Australia. Of perhaps greater value are the two long booklets on his more adventurous exploits, *Six Days in the Mountains of Cowley, and An Alpine Excursion: Notes of a Trip to the Mountains, Rivers, Plains and Caves of the Australian Alps* (Fig. 1) The former appeared in 14 parts in the Queanbeyan Age between 6 March and 12 June 1875, the latter in ten parts in the Queanbeyan Observer between 3 February and 17 March 1903. Both were reissued as small books and are quite rare,

Although he conducted only two lengthy caving expeditions, and several minor ones, Gale was one of the first to write extensively of his exploits, albeit sometimes with journalistic licence. A Centenary of Federation project in 2001 saw the erection in Queanbeyan of a statue to this famous son.

Coolamon Caves 1875

In about 1872 a note appeared in the Queanbeyan Age and was copied widely in the colony's principal newspapers, alerting readers that:

"News was brought in from Brindabella … that a stupendous waterfall had been discovered on a tributary of the Cotter by two diggers whilst prospecting for gold … various descriptions were given by those who retailed the account of the discoverers, no two of them agreeing , either as to the exact locality or the topography of the region where this great sight was to be seen."

Gale set several dates for investigating this phenomenon, but for the same reasons which bedevil cave explorers today, *"Something invariably occurred to frustrate our design."* Several years then passed before he eventually determined to seize an opportunity to visit a friend, John McDonald at Uriarra Station, and to investigate *"not only the waterfall but the beautiful stalactite caves of Coolamon Plains".*

At last he set a departure date, and again *"Several Queanbeyan residents who formerly had been very enthusiastic volunteers for the trip, now found excuse for staying at home"*. Nevertheless, this time he departed on Monday 15 February, 1875. The original newspaper accounts identify his companions only by initials, but we now know that they included at various stages Sarah, daughter of John McDonald of Uriarra station, and her uncle Sandy McDonald. Breaking their journey at Yarralumla, Uriarra and at Brindabella Station, where they left Sarah, the men continued to Long Plain and on to the caves, basing themselves at the homestead for several days, where they were *"up to a late hour – such as the manufacturing of torches and candles, and collecting tools for operations in the caves…"*. Augmented by various local residents such as Albert McClung, Albert McCullam and Steve Grady, the party explored several caves, including what he called Haunted or Murderers Cave, in which he said two bodies had been found in about 1872. Hanging from a tree at what we now call Blue Waterhole they found a sardine can inscribed from 1860 with the names of W Fane de Salis and John White of Cuppacumbalong, and of P. O'Rourke of Currangorambla, dated 1868. He went on to describe the appearance of the Plain itself:

"The appearance of the place was that of the extinct crater of a volcano; or as I rather incline to believe, the funnel-shaped hollow of the roof of a collapsed cave."

While exploring the main passage of what is probably Murray Cave, they were *"enraptured with its wonderful objects, every individual or cluster of which presented some novelty or charm possessed by no others. This passage extends at least three-quarters of a mile, judging by the fact that it took twelve minutes of brisk walking to go from end to end*. *At one time this main passage extended much farther and was never thoroughly explored, owing to the presence of foul air"*.

Gale's journalistic embroidery shows in his account of cave exploration: a conspiracy of practical jokers from the homestead entered one cave in advance of the main party, 'planted' a ghost, and secreted themselves to make appropriate ghostly noises:

"It surely could be nothing else than a curious stalamite (sic) formation in human shape, the folds of whose snow-white raiment were formed of graceful foliated limestone. And yet there was the long, flowing, flaxen beard, with corresponding shaggy locks, the glaring eyes, the firmly set mouth, and the hands with clenched fingers resting on the breast.… the younger ones slunk behind; the boldest spirits amongst us stood their ground, it is true, but stood as if in breathless awe. A deep guttural moan uttered by the apparition extorted the cry from more than one…".

After a night with some shepherds they started for the legendary waterfall, across the Goodradigbee directly towards Mt Bimberi. Even today the Ginini Falls are difficult to reach. Although only 200 metres high, Gale compared them favourably with the greatest in the world. A few days later they were back home.

It is not clear from the account whether his six days included some travelling time, but in any event this was a remarkable journey for its time, and his account is a significant piece of pioneering literature.

Yarrangobilly 1903

Almost 28 years later, and now aged 71, Gale set out on another trip along much the same route in 1903, with the aim this time of:

"… eighteen days of mountain climbing, whipping the mountain streams for their very dashing trout, shooting game, brumby hunting, cave exploring, and whatever furnished excitement, contributed to exhilaration of the spirits, the invigorating of bodily health and afforded physical exercise."

Leaving Queanbeyan on 24 January, 1903, they idled (and idylled) at Gininderra and Wallaroo (near Hall) and then, at Uriarra, joined the festivities for Anniversary Day (ie. Australia Day, 26 January), which was even then a public holiday. By this time there was a surveyed road of sorts from Yass to Long Plain and Kiandra via Uriarra and Brindabella, and it seems the party grew as successive properties were reached: Gale, his grandson Alf Fallick, William McClung and his daughters May and Bertha of Murrumbateman, two McDonalds from Uriarra, George Harcourt from

Gininderra, and Barclay Haley, who held summer leases in the high country. We can picture this party of mostly young men and women, crossing the Brindabella Ranges and beyond to the relief of the high country at the height of summer, travelling by buggy, sulky, three on horseback and one on a bicycle, by a road which always was and still is rough, steep and narrow.

After a stay with the Franklins at Brindabella they climbed to the McDonald brothers' other property at Little Peppercorn, near the head of Long Plain, following a route now almost a memory for speleologists driving from Canberra to Coolemon, for it is now closed to the public. Soon after they reached Yarrangobilly and met caretaker Bradley. Here the party, now totalling twelve, was augmented by Lena Lampe and Linda Franklin, relations of the Brindabella Franklins, and other members of the Lampe family from Tumut and Talbingo. Over the next few days several caves occupied their attention and Gale's lengthy description covers Glory Hole, Castle Cave and Jersey Cave:

"This gentleman (Mr Bradley) is an enthusiast in caves and cave-lore. "Don't you find this daily guide-duty and reiteration of description becomes sometimes becomes stale, flat, and unproductive?" The question was a very natural one; but the answer revealed the enthusiast, the lover of Nature's sublime handiwork. "I find my work no drudgery. Every time I enter these caves, especially with visitors who appreciate what they see, I seem to love them more and more, and to discover richer beauties and loftier grandeur than before". These are not the exact words in which our plain-spoken guide expressed himself, but they correctly convey the sentiments he uttered.

Lake George and Mt Fairy Caves

The riddle of Lake George has made good newspaper copy for well over a century. But for some, when the mist hangs over the waters, imagination takes flight. Some locals believe the lake to be connected via underground caverns to another lake sited variously in the Nullarbor, or maybe New Zealand. When Lake George is full, so the story goes, its counterpart is empty.

John Gale added to the confusion, either taking a minimalist approach to research or determined not to let the facts ruin a good story. *"As for the lake itself, there can be no question of its having in bygone ages been an active volcano,"* he wrote in 1927. The water, he insisted, escaped through a fissure opened by *"some convulsion of nature"*. It flowed into a subterranean river coursing through limestone caves nearby. *"Nor can there be the least doubt that the water heard flowing beneath the floors of the Mount Fairy Caves is that escaping from Lake George,"* he wrote. The lake refilled, he said, after cattle trampled mud into the hole.

Considering his long local residence and the perspicacity of his other writings, it is strange that Gale did not notice the connection between precipitation and evaporation, and the filling and emptying of the lake.

Black Mountain, Canberra

In his 1927 book (p. 98) Gale mentions a cave with a legend on Black Mountain:

'...On the eastern side of Black Hill, Canberra, there is a cave, the shelter of several outlaws in the early days. Seventy- five years ago two of these unfortunates were arrested on Canberra Plain. They had escaped from the Queanbeyan lockup, and were half-starved at the time of their recapture; a third got away and was never after heard of. I believe, however, that the human remains found in that cave a few years ago are those of this unfortunate. This cave is of the size of an ordinary living room in a modern house. It has only one means of ingress and egress, and to enter it one has to go on all fours. Two friends of mine examined this cave in 1915. When it was first discovered, about sixty years ago, it contained some blankets and personal clothing, much decayed, and a few cooking utensils...'.

A cave is known on the east side of Black Mountain. Numbered I5P-1 in the Australian Karst Index and about 8m long, Limestone Plains cave is now drowned by Lake Burley Griffin. However Andy Spate thinks this may not be the site described by Gale; if that is the case, Gale's site is unknown.

Conclusion

Gale rode extensively over the land that is now Canberra, including to the top of Capital Hill in 1855, and was a passionate campaigner for the Limestone Plains site for our national capital. Though no geologist, John Gale (Fig. 2) on the whole shows a solid understanding of the processes of cave formation, without allowing his journalistic urges to overwhelm. He was an enthusiast about many things, founding newspapers not only in Queanbeyan but in Junee, Manly and elsewhere. Described as the father of trout-fishing in Australia, and publishing a small booklet on the subject, in a recent Federation Centenary memorial, he was further described as the father of Canberra. His prose reveals the enthusiasm, adventurousness and curiosity of a speleologist. Yet, compared with the turgid travelogues of some nineteenth century foreign visitors to our caves, Six days… and An Alpine Excursion … are unassuming, revealing much about life of pioneering communities in the district. John Gale adds light to the social history of cave exploration in Australia.

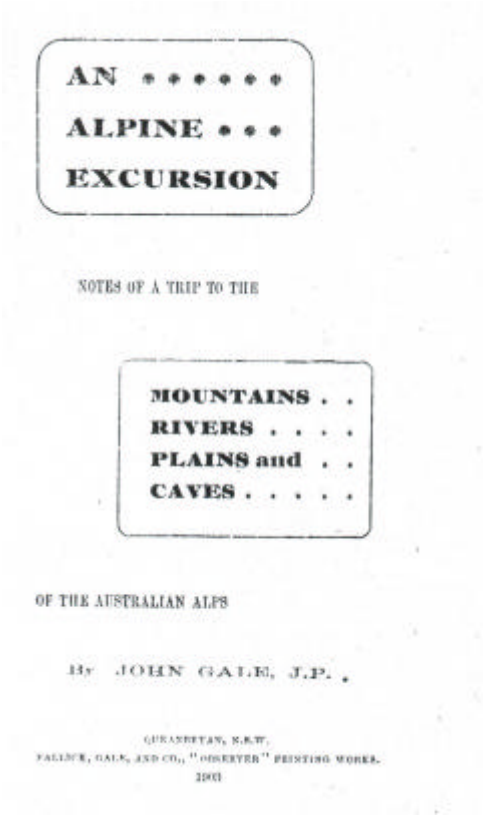
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AN ALPINE EXCURSION

NOTES OF A TRIP TO THE

MOUNTAINS . .
RIVERS . . . .
PLAINS and . .
CAVES . . . . .

OF THE AUSTRALIAN ALPS

By JOHN GALE, J.P.

Figure 1 - Title page of an Alpine Excursion



Figure 2 - John Gale

Where is Australia's First Identifiable, Recorded Cave Discovery?

John Dunkley

At our previous Conference in Bathurst I gave a talk on early cave visits in the Central West of NSW, later expanded to a more comprehensive account in the Proceedings (Dunkley, 2002).. The brief presentations today mostly cover material not known at the time of the previous Conference.

The association of Aboriginal Australians with caves has been summarised by Jennings (1979) and by archaeologists, but I am here concerned with the records of white settlement. The first colonists suffered from a shortage of lime for building, for many years relying on dwindling coastal shell middens, and expensive imports from Norfolk Island and Van Diemens Land. Very early supplies were obtained from sandstone shelters in Sydney Harbour, which were recorded as early as 1789 but we don't know the precise location of those described, like the one shown here (Fig. 1) from the early 19th century. All the early governors bemoaned this shortage, but the obvious answer of scouting the country beyond the limits of the settlement in Sydney was resisted for fear of unregulated settlement and absconding convicts if good land was discovered beyond the encircling sandstone.

Possibly to circumvent these restrictions, in 1802 Governor King appointed a visiting French Ensign, Francis Barrallier as his aide-de-camp, soon despatching him on several explorations of the country south-west of the colony, in the Burragorang Valley country west of Picton, bounded by the Nepean, Warragamba and Wollondilly Rivers. Of Barrallier's first trip, King himself said: *"The officer I sent to endeavour to pass the mountains has returned from his first trial with little hope of effecting it, or making any new discovery, except a very imperfect limestone and a better kind of iron ore than has yet been found"* (King to Hobart, 30 OCT 1802).

Like most explorers, Barrallier talked up his discoveries, because a month later, on 1 November a doubting George Caley wrote to Joseph Banks that *"I was informed that he had discovered a new river, limestone in great abundance, iron almost pure, and had been 50 miles or better in a western direction, but of all this I have doubts"*.

On his second trip, though, Barrallier sheltered in a cave. This passing reference has apparently escaped previous notice by speleo-historians. He recorded that on 25 November, 1802:

"At six o'clock in the evening I found myself at a distance of 2 miles from the western passage. I was here obliged to ascend a very steep hill on the summit of which I found a cave large enough to contain twenty men. I was then half a mile from the passage, and I sent two men in order to discover it, instructing them to ascend the mountain at the north of this passage. The rain compelled me to seek a shelter for myself and my men in the cave which, the natives assured me, was the home of wombats. I waited till 7 o'clock in the cave for my two men …".

Beyond this cave Barrallier passed through a gap, noting more sandstone caves: *"The width of this passage is about half a mile; its sides are perpendicular. The mountain is very steep and full of caves which are the homes of various wild beasts which go there in crossing the swamps near by."*

Now the big question is, where *is* this cave? For a century, various historians argued about the route taken by Barrallier, and most mentioned the cave (eg. Cambage 1910; Else-Mitchell 1938). But none had been to look for it. Not until a decade ago did realisation dawn that pinpointing the precise location of the cave was integral to the argument about how Barrallier crossed from the Tonalli to the Kowmung River. Some effort was then expended by competing historians in locating it. A CSS trip in 2002 followed, locating a roomy cave (Fig. 2) near Byrnes Gap, a few kilometres north of the ghost town of Yerranderie, and several smaller ones. This was definitely the one first reported by Andy McQueen (1993). From the entrance we took in a wonderful view almost unchanged since Barrallier saw it 200 years ago. It is in rugged, steep and heavily forested country, Yerranderie is almost indiscernible, and there is only a tiny glimpse of the water in Lake Burragorang. This, however, is almost certainly *not* Barralliers Cave, for in 1998 an experienced surveyor, Alan Andrews described a better prospect, 10 metres long and 3 metres deep,

commodious and comfortable enough for camping. Both caves are in sandstone, the more likely candidate in an eroded conglomeratic layer which we glimpsed at a distance from below, late in the day with no time left to reach, high on the south face of Gander Head and about 400 metres east of Byrnes Gap. Furthermore, between these sites and Byrnes Gap, we did pass several small sandstone shelters suitable for wombats and the like, as noted by Barrallier. Another trip is planned in 2003 to settle the question.

If Andrews' site *is* Barrallier's Cave, it adds strongly to the evidence that his route lay through Byrnes Gap to the Kowmung, and not via Church Creek, as some historians believed. Had he taken the latter route, he could not have missed remarking on the prominent limestone cliffs – that was, after all, one of the main reasons he was out there. Indeed, some speleo-historians (eg. Middleton 1969; anon. 1970; Battye 1984) have asserted that he *did* sight these cliffs, assumptions which have been repeated elsewhere. But there is no evidence of this in his writings, emphasising a lesson worth repeating: always check primary sources. He was unlucky. He missed the limestone, and by sheer misfortune he missed finding his way across the Blue Mountains.

We should keep in mind that until quite late in the nineteenth century, no significant distinction was drawn between what we would now refer to as karst caves in limestone, and artificial grottos, rockshelters and shallow sandstone caves. Both limestone and caves were regarded as significant more for their contents than for any consideration of genesis or aesthetics. From the earliest days of settlement there exist sketches of sandstone shelters in Sydney Harbour, but these are not unequivocally identifiable today. My conclusion is that Barrallier's account, just over 200 years ago, is of the first clearly identifiable cave recorded by the European newcomers to Australia.

POSTSCRIPT

In November 2003 another search at Yerranderie relocated the original Barralliers Cave on rugged slopes between the Tonalli River and Byrnes Gap. A report will appear in a future issue of Caves Australia, probably no. 164.

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Figure 1 - Caves, hunting and fishing of Aborigines of Port Jackson (early 19th century engraving by A Delvaux & J Devilliers)

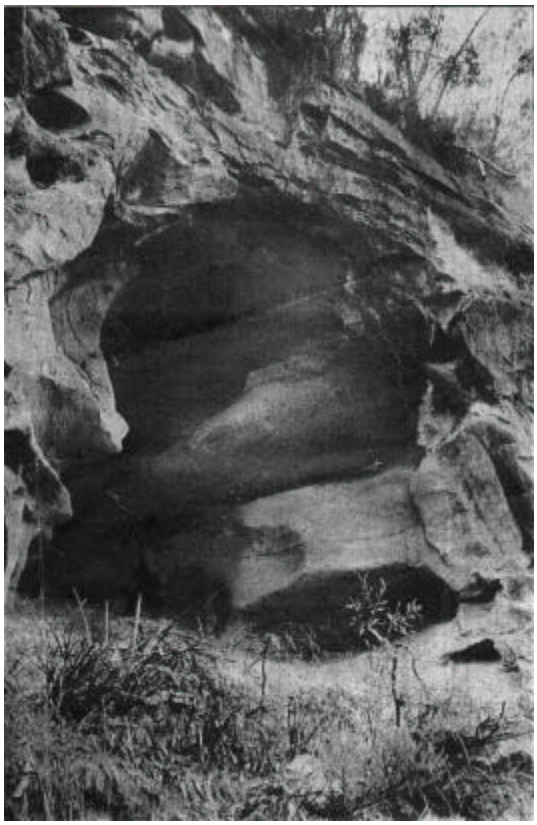


Figure 2 - Sandstone cave near Yerranderie, previously thought to be Barralliers Cave

Who was Australia's First Speleologist?

John Dunkley

In 1973 Ken Pickering drew attention to an account of a visit to a cave, probably Limekilns Cave near Bathurst, by Lieut. William Lawson (of Blaxland, Lawson and Wentworth fame) on the night of 9 November, 1821. Ken suggested that Lawson was Australia's first speleologist. Well, this is the earliest account so far located of a visit to a limestone cave by Europeans, but as pointed out elsewhere in these Proceedings in relation to Francis Barrallier's claims on cave history, no distinction at the time was drawn between caves in limestone and those in other hosts. In any event, a single brief visit scarcely qualifies Lawson as our first speleologist.

Two others can lay some claim to that title. First credit is often given to Surveyor-General Thomas Mitchell for his paleontological exploits, along with his wonderful surveys of caves at Wellington (Mitchell 1831, 1834, 1838).

However, a second contemporary figure has recently appeared in the Wellington saga. At the very time that Mitchell was at Wellington, in mid-1830, a certain Dr John Henderson appeared in what was then a tiny military outpost on the very frontier of white settlement in Australia. A surgeon in the Bengal Army, Henderson arrived in Hobart on furlough in 1829, where he founded the Van Diemens Land Society, Australia's first scientific society. A few months later he turned up in Sydney where he probably heard about the discovery of the bones at Wellington from the same source as Mitchell.

In a forthcoming paper I examine evidence that Henderson visited, described and produced sketch maps of Boree (Borenore) Caves before Mitchell's visit, that he reached Wellington probably before Mitchell but was there when Mitchell arrived, and that (partly at the behest of Governor Darling) he also collected bones at Wellington and produced an account of their origin. I will also argue that Mitchell and Henderson almost certainly were acquainted but definitely not on good terms with each other. Thereby obtaining credit for the first published maps of Australian caves, Henderson published sketches of Wellington caves six years before Mitchell, he was the first to describe karst topography, and first to write on the supposed effects of fire or heat on limestone. I have been unable to find what happened to Henderson's bones.

Except for a passing reference by Armstrong Osborne (1991), Henderson's very existence escaped the notice of all chronicles of the Wellington saga, including one written in 1986 for the first of this series of seminars on Australian cave history. But even Osborne missed one curiosity: why, despite their apparently simultaneous presence at Wellington engaged on the same mission, did neither Mitchell nor Henderson ever, anywhere in their writing, mention the existence of the other? It is now evident that it was because they were engaged in a pioneering example of intellectual rivalry, vanity, jealousy and possessiveness of a kind not unknown to later generations of scientists and speleologists. Henderson's writings were very critical of Mitchell's administration. They just didn't get along.

The protagonists were both well educated, literate men: Mitchell's writings are well recorded, while Henderson published a number of scientific papers catalogued by the Royal Society of London, and he founded Australia's first scientific society. However, neither was particularly qualified to write about the bones: both were opportunistic amateurs. Both were egotistical, vain and possessive. The difference was that Mitchell was the Surveyor-General. He had status and well-placed friends in the colony with connections in England. Henderson didn't: he left Van Diemens Land after getting offside with the Governor and others, and returned to India from New South Wales shortly after the Wellington saga.

Henderson was a strange character whose behaviour suggests someone who lingered too long in the tropics. After returning from Sydney he founded numerous enterprises in India, then he vanished, reappearing in Srinagar in November 1835. By then destitute, he had a remarkable tale to tell, having been one of the first half dozen or so Europeans to cross the Great Himalaya and

Karakorum Mountains, from which, alone and in disguise, he reached Yarkand in what is now Xinjiang. His health destroyed by these privations, he died in Ludhiana, between Delhi and Lucknow, on 12 March, 1836.

Mitchell, of course, went on to lead some of Australia's most successful journeys of discovery. On his instructions, his Assistant Surveyors recorded numerous limestone occurrences throughout NSW. His Wellington cave maps published in 1838 are models of surveying. He did eventually publish on the bones, whereas Henderson's were lost to posterity.

History, it's often said, belongs to the victors, or at least to the last man left standing. Mitchell survived Henderson and Governor Darling, both of whom were highly critical of his administration. Because he foresaw Darwinism, Mitchells' views on the bones prevailed over Henderson's outdated, antediluvian explanation of their origin. He was eventually knighted.

John Henderson deserves a place in the history of cave science, and indeed of science generally in Australia. But Major Mitchell was the greater explorer, he was closer to the truth on the bones, his writings attracted more influential attention, and he rose to greater honours. He was our first speleologist.

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Early Maps Of Tuglow Caves: The Bracewell Collection

John Dunkley

A manuscript collection of previously unrecorded maps of Tuglow Cave and other items has been located in the State Library of NSW, donated by Professor R N Bracewell. A more complete report will be presented at the next ASF Conference in January 2005.

Acetylene Illumination of Early Tasmanian Show Caves

Stephen J McCabe

INTRODUCTION

Tasmania, the apple isle, possesses some unique and interesting speleological features. One aspect of cave tourism in Tasmania, which has fascinated me since reading about a brief mention of it in the Journal of Sydney Speleological Society (Middleton 1988), is their illumination by means of an acetylene generator.

Acetylene illumination, although interesting and novel at the time, really damaged the cave environment. The noxious smoke and gas filled the cave, formations were stained, ceilings became covered in soot, and spent carbide was a problem to dispose of. (All this, plus the usual developmental damage the caves endured, but remain today as a time capsule or window into this fascinating period of cave tourism.)

This short article is a result of my studies into this little known and documented piece of Australian spelean history.

INVENTION OF CALCIUM CARBIDE

The English chemist, Edmund Davy, first documented calcium carbide in 1836. Ideas and improvements were made in 1862 when Frederic Woehler (nationality unknown) discovered that when calcium carbide came into contact with water, acetylene gas was given off. Davy had noted that a noxious gas was produced when combined with water but failed to see any significance with this reaction.

Easy commercial manufacture of calcium carbide only began after 1892 when Thomas L. Willson of Spray, North Carolina, discovered that passing a high ampere low voltage electromotive force through a finely powdered mixture of coke and lime produced calcium carbide. This method of manufacture became the standard for all carbide manufacturing plants worldwide.

COMMERCIALLY AVAILABLE CARBIDE IN AUSTRALIA

Tasmania with its hydro-electric potential had Australia's only commercial calcium carbide manufacturing plant at Electrona, south of Hobart. It seems unlikely that Tasmanian caves were illuminated by Tasmanian carbide, as this plant didn't come on-line until about 1924, after most, if not all the show caves finished using it as a method of illumination.

Carbide import companies such as Slade, C.H. & Co. of 304 Kent Street, Sydney, and the Federal Oil Co. Ltd. of 33 Rowe Street, Sydney, advertised in 1916/1917 (Anon 1916, 1917). Gillies Bros. of 74 Collins Street, Hobart, were importers of a wide range of related material and hardware. Similar companies or agents would have supplied the various caves with their carbide requirements.

WORLD SCENE

Gregg Clemmer (Clemmer 1987) notes several references to acetylene illuminated caves in the U.S.A. He records that in 1908 Mammoth Cave, Kentucky, was considering installing an acetylene generator outside the cave and piping the gas to burners positioned alongside the underground passageways (Anon 1908).

The La Jolla (pronounced La Holya) Sea Caves near San Diego, California, were being illuminated with acetylene as early as June, 1909 (Anon 1909). Wonder Cave near Monteagle, Tennessee, in 1909 had a large 100 burner system installed and this was later increased to 200 burners (Anon 1914). Additionally, Mount Tabor Cave, Ohio, was fitted with a similar system, using over 4,000 feet (1,300m) of piping (Anon 1911). Although these caves are all in the USA other cave areas worldwide would have experimented with acetylene.

THE TASMANIAN EXPERIENCE

Five individual caves in two different locations in Tasmania were at one point in time illuminated by acetylene gas generated in a stationary system with piping plumbed throughout the general visited area of the cave. These caves are as follows

- King Solomon Cave
- Marakoopa Cave
- Baldock's Cave
- Scott's Cave

All these four present and former tourist caves are located at Mole Creek near Deloraine. The Tasmanian Collection Pamphlet (Anon 19??a) says *There are four sets of caves, which compare favourably with any in Australia. They are lit with acetylene and can be visited either by day or night*. The other cave is at Gunn's plains near Ulverstone in Tasmania's north.

King Solomon Cave

A.D. and R.K. Skinner (Skinner 1978) state that King Solomon Cave was discovered in 1906 by a timber splitter named Poachin while hunting. He later opened the natural entrance to the floor. Somewhere between July 1908 to July 1909 King Solomon Cave was illuminated by acetylene (1909b). By 1913 (Anon 1913) a Mr E.C James was Proprietor of the Cave, which was still *lighted with acetylene*. Skinner notes that between the years of 1930 to 1933 Mr W. Marchant was the Cave Guide. In the previously undated guide book, "Deloraine, The Tourist's Paradise", mention is made of the recent cave *purchase by the Government Tourist Department* (Tasmanian Tourist Association) *and* (that they) *will be opened up at an early date; and lit up with electricity*. Although undated it is fortunate that an advertisement for the Racing Club of Deloraine advertising their Spring Meet Sat Dec. 9, 1922, and their Easter Tuesday, 1923, Meet was published in this guide. As this guide is of great importance to this article the author will refer to its date as 1922 (Anon 1922). Another presently undated information sheet by The R.A.C.T. Touring Service (Anon 19??b) states that, *the lighting with power provided by a stationary engine, is most effective and shows to advantage the many extraordinary formations which vary from slender and fragile pieces to one which weighs about three quarters of a ton and is held by a small neck*.

It would appear that when the change over to electricity happened in about 1922 or 1923 all the lead piping, burners and reflectors were removed. Fortunately the acetylene generator remained and is now a feature at the end of the modern day cave tour as at 1997.

Two oval legends with raised stamping soldered to the tank state that the unit was manufactured by a 'C. Davis, Furnishing Ironmonger' (McCabe 1997). This appears to be the same Charles Davis who in 1933 was granted a Registered Design for a Carbide Lamp (Anon 1933). At that time Charles Davis Limited was located at 64 Elizabeth Street, Hobart. This would indicate that the acetylene plant is of Tasmanian manufacture. Company research in this area may provide additional information.

Marakoopa Cave

Skinner (Skinner 1978) records that George and Harold Byard discovered Marakoopa Cave around 1910. The Byards obtained a lease covering the cave and opened it to tourists in 1912. The guide 'Deloraine, The Tourist's Paradise' (Anon 1922) as dated from the racing advertisement, records that Byard's (Marakoopa) Cave was owned at this time by the Tasmanian Tourist Association. No relics of the acetylene plant or piping is left in the cave other than former pipe anchors drilled and inserted into the cave wall.

Baldock's Cave

Baldock's Cave was one of the Government operated show caves in Mole Creek. By 1913, (Anon 1913) Baldock's Cave was under the control of The Northern Tourist Association (NTA) with its headquarters in Launceston. Acetylene illumination was in use by the middle of 1908 (Anon 1909a).

Twelve years earlier J.C. Wiburd of Jenolan Caves N.S.W. visited Mole Creek (Anon 1901). In a report to the NTA he encouraged gating the entrances to prevent access without the right authority, thus preventing the cave being *destroyed by sperm or other grease from candles, markings from*

names, but not least, destruction of the stalactites by breakage, which I am sorry to say almost every visitor seems to delight in. Candle composition varied between different brands, most contained sperm oil which was rendered down from sperm whale blubber, a major industry in Tasmania at the time.

It appears that the NTA over time developed the cave and are responsible for installing its lighting system. By July, 1917, the Tasmanian Tourist Association, which was founded in May, 1893 and was a rival to the NTA, took over its Launceston offices.

On 27th November, 1934, it was formally separated from the railways and became an agency in its own right (Archives Office of Tasmania 1997). Again in the guide 'Deloraine, The Tourist's Paradise' (Anon 1922) the writer describes a trip to Baldock's Cave. *After picking up the guide a span of half a mile lands you right at the entrance of the Caves These caves are owned by the Government, who have made a wonderful difference in easy access by enlarging narrow openings and making a footpath all the way through, so that the visitor may walk through in comfort, keeping quite clean and thus fully enjoy what one can only describe as "Aladdin's Wonderland"*. He also adds that *at present they are well lit up with a large acetylene gas plant, but which is shortly to be replaced with electric light*. It would seem that this never happened.

Baldock's Cave abounds in relics of this acetylene era. In the entry chamber the near complete (McCabe 1997) generator body and broken guide frame still stands in its original position. All the lead piping is long removed but a number of burners with reflectors and in-line gas cocks still exist as does remains of two wooden bridges. Wax still covers the burners from the cave guide illuminating each station as the tour progressed.

Scott's Cave

An article published in the Daily Telegraph (Anon 1909b) on Scott's Cave documents that *During the past twelve months rapid strides have been made in the development of the caves in Mole Creek district. "Baldock's", "the King Solomon", and "Scott's caves have all been illuminated with acetylene gas"* A.D. and R.K. Skinner (Skinner 1978) state that Scott's Cave was operated privately as a tourist cave for ten years from 1908 by family members. In the guide 'Deloraine, The Tourist's Paradise' (Anon 1922) the writer records visiting Scott's directly from Baldock's Cave. *Returning from Baldock's caves after the two mile span the road branches off to the right for Scott's caves. The guide and owner, Mr Scott, lives at the end of the road. Leaving the car here a walk of three-quarters of a mile brings you to the entrance. These caves are well lit up with acetylene and although the smallest of the Mole Creek series, one well worth a visit*. It becomes apparent that Scott's Cave was operated longer than ten years as previously thought, as the Archives Office of Tasmania possess a Visitors Book for Scott's Cave dated Jan. 1911 to June 1927 (Scott 1911). Written on the inside cover of the Visitors book is 'Gorden Scott, Proprietor, Mole Creek'. The only photograph known (to the author) of anything involving the illumination is the one in the Skinner book page 12 of Mr Anderson Scott standing next to what remains of their acetylene generator. Access to this cave could not be obtained when the author visited the area in 1997 (McCabe 1997).

Gunn's Plains Cave

As early as 1912, Ulverstone: The Tourist's Delight reads (Anon 1912) *the caves are quite dry and are well lit with acetylene gas*. In the Complete Guide to Tasmania issued by the Tasmanian Government Railway Department, 1913 (Anon 1913), we reads on page 85, *Gunns Plains Caves are about 18 miles from Ulverstone, and within 200 yards of the macadamised* (road surface made with successive layers of small broken stones rolled in with some binding material) *road. They are well let up by acetylene gas, which throws into relief some wonderful and beautiful shawl formations of the limestone within the caves. The drive to the caves passes through Gunn's Plains, and is one of the most beautiful in Tasmania*. According to Des Wing (Gates 1981) the caves were found in 1906 when a local by the name of Bill Woodhouse was shooting possums. He hit one and it fell out of the tree and into a cavern. In 1930 the Ulverstone Tourist and Progress Association installed electric lighting in the caves. Indeed by 1934, the caves at Gunn's Plain were electrically lit (Anon. 1934). Likewise, page 11 of "Tasmania the Wonderland" (Anon. 1936) states that *further inland, but within one hour or so motor drive, are to be seen wonder-inspiring sights of nature – the caves at Gunn's Plain, electrically lighted*.

Control later passed to the National Parks and Wildlife Service (NPWS). The state government spent £1,400 ($2,800) on new lighting in 1958. NPWS then spent $35,000 on lighting and handrails in 1980, and also cemented all the paths.

In 1981 Des Wing had been guide at the caves for the past 22 years having started in 1959. Family involvement began in 1916 when his grandfather, Ethram was guide. Then his uncle, Graham Maxwell took over and after 42 years handed the responsibility on to Des in 1974 (Gates 1981). The dates indicate that both Des and Graham's service overlap as Graham appears to have begun in 1932. Another reference indicates that Graham Maxwell began in 1929 (Anon 1961), so these dates cannot be considered too accurate.

The author does not know if anything remains of the former acetylene plant as this cave has never been visited.

PHOTOGRAPHIC DOCUMENTATION

Other than postcards very few photos remain from the early tourist caves of Tasmania. Although postcards exist of formation in the various caves, images of the lighting apparatus were apparently not documented or in some cases removed from the original photograph.

Note that the postcard of 'The Marble Pillar, King Solomon Cave' has a pipe running across the formation, a similar image can be seen on the postcard of 'The Shrine, Scott's Cave'. 'The Marble Hall, Baldock's Cave' Postcard No.464 by Spurling & Son, Launceston, is a particularly good example of a reflector / burner assembly which was rubbed out of the original photograph. Note: lower RHS circular mark to the right of the stalagmite. Further research is required in this area; photographic material in the Tasmanian Museum and Art Gallery as well as material in private local history libraries may provide more insight into this exciting period of gas lighting.

CONCLUSION

Although there is both physical and written evidence of generation of acetylene for illumination of tourist or show caves in Tasmania, very little substantive information appears to have been preserved in relation to its engineering or use. The author hopes that anyone with further information, references, or even photographs could make contact with him either directly or through the Sydney Speleological Society or The Highland Caving Group.

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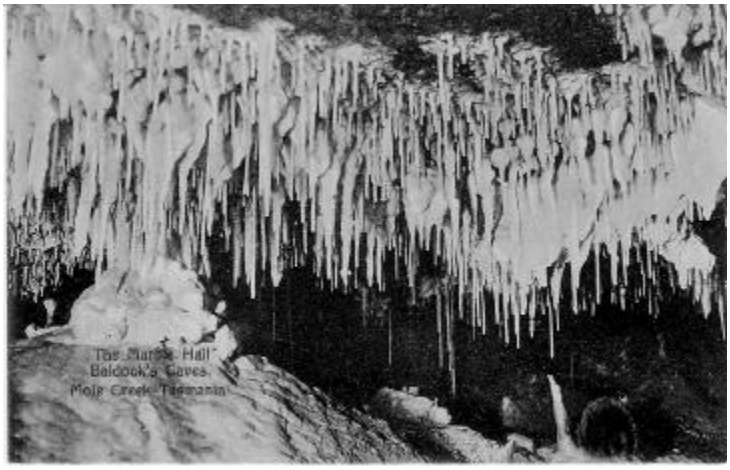
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Baldock's Cave Postcard



Baldock's Cave acetylene generator with Mole Creek caver in period costume
M Lichon photo



The author studying what remains of the Baldock's Cave generator



The author and Mole Creek Caving Club member, Cameron Hill studying and recording measurements of generator
Note: Water filling funnel at top, water cock and open carbide chamber
M Lichon photo



The author holding the water adjust cock which feeds water into the carbide chamber below (Bulk head cover missing)



The author next to the King Solomon Cave generator



One of the burners in good condition, note it is missing the screw in Bray burner



King Solomon Cave acetylene generator tank maker plate or legend - 80mm long

Augusta's Jewel Cave from a Caving Perspective

Lloyd N Robinson

The many inaccurate articles written about early history of the Jewel cave will add to difficulties future researchers of history will face in determining fact from fiction. It is not intended here to detail a history of the caves exploration, save to say, a factual account of the caves exploration can be found as the feature article in the June 1958 edition of 'Walkabout' magazine.

In caving terms, the Jewel Cave has to be classed as a major discovery. As caves go, it has had an unusually quick rise to prominence from its first known entrance in early 1957, to a fully operational tourist cave in December 1959. To compress time even further, the first exploration beyond its entrance pitch did not take place until February 1958.

The three explorers were an unconnected group, unknown to each other previously; comprising of a local 'man of all trades' working as a hairdresser, cave guide, to professional fishing; a young geology student with a keen interest in caves; and an unemployed wandering caving nobody from the East, with membership of an isolated caving club that had been shunned by the ASF. None of the three had any contact with ASF codes or practices written or unwritten.

Exploration was not difficult or haphazard, progress in a number of areas was confined to single file pathways, which remained that way for a number of years. Careful study of the cave floor, and time out to examine the myriads of formations slowed exploration. It was immediately obvious to the explorers that this cave needed care and protection, and that lake levels had been both higher and lower in past years.

For local political reasons, the explorers did not immediately reveal the find. When the find was announced, with State news in short supply the WA Newspapers Ltd. gave the cave the full treatment. News of the cave spread overseas. A tourist in England was surprised to see a photograph of one of the explorers in a London newspaper. A casual comment by an explorer to the media that 'this cave is in the class of Jenolan', intensified interest. At the time of publicity, only the three explorers had been in the cave; the level of public interest was surprising.

The explorers failed to name the cave, resulting in it being referred to as 'The New Cave', right up to near the entry of the first tourists. This caused confusion with other cave discoveries in the same area.

The result of all the publicity was swift action by the Augusta Margaret River Tourist Bureau. Their first action was to immediately take control of the cave, claiming the entrance came just within the boundary of the small Moondyne Cave Reserve, which was under the Bureau's control. A solid grill with a locked opening was installed over the entrance, and entry to the cave restricted.

There was no need of other than a few bearings to determine the cave extended beyond the boundary of the reserve. The Bureau considered it important that the reserve be extended to cover the cave's known and possible unknown extent. They took steps to bring this about. The cave being virtually hemmed in on three sides by low land, sand hills and Moondyne Cave, the reserve when eventually enlarged, mainly extended in the remaining direction. By chance, the increased reserve included the entrance to Easter Cave.

The Bureau president was considered by the locals as a 'blow in'. However, he had many contacts in state government of both persuasions, and with the help of continuing publicity, was able to gain government action.

The first visit of officials from Perth to see what all the interest was about, turned out to be a fizzer. They declined to enter the cave by the means available. Further the explorer with the means of gaining entry was not always in the district, and indicated a return to the east. The rare cable ladders stayed with him as they were in demand elsewhere.

To overcome these problems the Bureau engaged two of the explorers to find and prepare an alternative entry to the cave, that did not require the use of cable ladders. This long forgotten second entrance to the cave was completed in six days, and consisted of a ground level lock-up trap door, two fixed bush ladders and a fixed rope hand line used as an aid in negotiating a low height slope into the entrance cavern. Progress down and up this slope caused angst with some people. It now has a concrete plug to seal it off. As originally developed it had to be dug out. A number of people who entered the cave by this entrance have thought it to be the original entrance.

The Bureau was not in a position to fund any development of the cave for tourism. With no chance of funding from the local shire, a deputation from the Bureau, an explorer, and led by the local member of state parliament approached the Minister for Lands to seek aid from the state government. With the cave in a safe opposition electorate and a state election in the wind, the deputation left the meeting feeling dubious about any assistance.

The Minister immediately formed a committee of three to conduct a feasibility study of the cave for tourist purposes. Together with available explorers, the committee visited the cave to come to grips with the many intangibles that needed to be taken into account to enable tourist access to the caves features, and the all-important total cost involved. The committee relied on the explorers for much more than just finding the way around the cave. It was soon agreed that initially tours should be confined to the Entrance, Organ Pipe, Camel and Jewel Casket caverns and that the superb reflections in the Organ Pipe cavern lake should be shown off as one of the prime features of the cave.

The major discussion was the selection of a site for the tourist access tunnel. The least expensive method was enlarging the original entrance to accommodate lighthouse type spiral stairs, an option favoured by some members of the Bureau. All agreed it too risky to interfere with the entrance cavern roof in view of its large size.

Another option was to drive a tunnel into the far end of the No1 lead. This would have had the advantage of keeping the later built infrastructures away from above the cave. This was discarded as it would require walkways over the lake, detracting from one of the main features, the reflections.

It was decided that a tunnel be driven into a near surface cavern at one end of the entrance cavern, and to gain roof height on a slope into the said cavern. With many 'ifs' and 'buts' an all up cost was determined to cover the entire project involving a housed generating plant, tunnel, walkways, steps, viewing platforms, handrails, lighting and enlarging some access-limiting restrictions within the cave.

This completed the brief of the committee and for the next six months all went their various ways, the explorers keeping in touch with each other by mail. The Bureau was keen for the project to proceed and their president hoped the explorers would agree to become the principle contractors. Without funding they could do nothing except contact the minister and his department, and with the aid of the local explorer, taking anyone of influence through the cave. The WA Newspapers Ltd. maintained pressure on the government to develop the cave, going as far as an editorial in 'The West Australian' on the subject. Finally the government made a grant of two thirds of the cost of the project on condition the Bureau raise the remaining one third before any work could commence. In this the Bureau successfully raised a loan from the Rural and Industries bank with nine locals signing up as guarantors.

After lengthy discussions by phone and mail, two of the explorers agreed to develop the new cave, and operate the unlit Moondyne tourist cave on a reduced basis during the construction period. The third explorer wisely decided to continue with his studies.

Meetings were held with the re-formed committee in Perth, prior to work commencing in late December 1958, the start of the holiday season. The committee which now included the Bureau's president, could not visit the site until early February, a situation which left the contractors to themselves during this period.

Starting from ground level, a sloping trench, wide enough to allow entry of a landrover, was dug and at a length of fifty two feet and a depth of twenty four feet a good face was encountered to start tunnelling. Attention turned to inside the cave pending the arrival of drilling equipment.

Fortunately long timbers for platforms, stairs and raised walkways could be taken, with some difficulty, into the cave via the temporary entrance.

Augusta is a popular holiday venue for people working on the land. Men accustomed to hard physical work often became bored while holidaying, and welcomed the chance to assist in the construction of walkways, platforms and steps. In due course a number of walkways and viewing sites were completed within the entrance cavern. It was not long before word of these activities did the rounds, resulting in the Bureau placing a ban on anyone entering the cave, other than the explorers. The Bureau's concerns related to public liability which they viewed very much like we now experience today.

Cave access restrictions caused ill feeling between the contractors and visiting cavers with heated encounters. Many cavers of the day felt they had a right to enter any cave they wished. Being on site, the contractors became the first line of contact.

Some of the loan guarantors kept a close eye on progress reports as they could ill afford the bank to call up the guarantee if anything went amiss. One Bureau board member thought the tunnel was heading in the wrong direction; his concerns raised additional fears amongst the more anxious guarantors.

The government committee and contractors formed an excellent working relationship. The tunnel went through some unstable ground, which caused a drain on monies earmarked for lighting.

Three hundred and sixty seven days from commencement of work, the cave opened for tourism on Boxing Day of 1959. December in Augusta was the build- up to the 'three month wonder period' of tourism which many depended on for their survival. With thoughts on other things, the opening caught the Bureau short, as no surface items for ticket sale etc. were in place. The contractors came up with an old battered caravan to serve this purpose. Over the next six weeks the contractors turned guides, shepherded twelve thousand, six hundred visitors through the cave. Any worries guarantors had about the Bureau meeting the loan soon evaporated.

The cave was officially opened by the W.A. State Premier in May 1960.

Unfortunately television and documentary film crews played havoc with cave wiring over the first two years of the caves operation.

FOOTNOTE

This paper has been taken from a detailed account of the Jewel Cave exploration and development in preparation for the Western Australian Government Archives.

The Ideal Health and Holiday Resort: An Investigation into the Development of the Caves Area at Yallingup, Western Australia as a tourist destination

Lise Summers

The coastline of Western Australia is a relatively recent phenomenon, dating from around 6000 years ago. Previously the continent, part of the original Gondwana, included much of the land now under water and forming part of the Continental shelf. Long after the drowning of the coastline, it came to be occupied by plants, animals and eventually people.

The Archaeological evidence in limestone caves such as that at Devil's Lair, which lies in the same cave systems as the Yallingup and Mammoth Caves of Margaret River, indicates a long term aboriginal use of the South West area in particular and Australia in general[1]. Evidence from the Orchestra Shell Cave, adjacent to the Yanchep group of caves, confirms this occupation. However, not all caves were occupied and used as shelter by the natives. In the 1840s, when pastoralist Edward Landor stopped to water his horse at Yanchep, his aboriginal companion refused to enter the area, fearing a "chinga",or spirit being, from the nearby caves. From this and other examples it is clear that caves could, and did, become part of local aboriginal mythology and belief systems[2].

European explorers too wove caves into their story of exploration. French sailors in the *Gros Venture* with explorer St Allouarn in 1772 speculated that the presence of an obvious cave in the midst of the limestone cliffs along the South West coast might be the product of man's activities[3] but, following the settlement of the coast by British opportunists in 1829, little attention was paid to Western Australia's hidden landscapes until the middle of the nineteenth century.

Surveyor and explorer, Lt. George Grey, is reputed to have first discovered the caves at Yanchep, just to the north of Perth, although the first authenticated reference is by John Septimus Roe, Surveyor General, in 1841[4]. Roe lead a team of explorers, including the then Governor, Hutt, and wrote up an account of his exploits for the Western Australian newspaper, the *Inquirer*. In the South, Fanny Bussell, a member of the pioneering Bussell family of South Western Australia, is believed to have been the first European to discover the Lake Cave at Yallingup, while looking for strayed cattle. Caves in the Augusta region had been previously discovered in 1848 by local settler Edward Hester[5].

Despite these early discoveries, further exploration of both cave sites was delayed until closer to the turn of the century by the sheer necessities of life, proving climate, soils and crops, and creating towns and cities. Life in the South West was marginal at best, with many settlers leaving the southern Augusta area for wider, clearer land slightly further north. Around the settlements of Perth and Fremantle, settlers found the soil sandy and difficult to cultivate. So hard was the struggle that in the late 1840's, at a time when other colonies were eschewing convict labour, such labour was seen as the only solution, and in 1850 transportation of convicts to the Swan River colony became a reality. Transportation ceased in 1868, and the apparent stagnation of the colony would have continued had it not been for the growing market in beef and pastoral pursuits just to the north of Perth, and the sudden development of a timber export industry in the South West.

The jarrah and karri forests of the South West became one of the major resources of the Swan River Colony. Resistant to most forms of pest, and the dreaded marine teredo worm which bored through lesser timbers, Western Australian timbers were exported for use in ships, building and even as road material. The export of timber required the development of an extensive support system, including sawyers and loggers, timber mills and railways. Local hero and bushranger Moondyne Joe is reputed to have worked at a local mill. His legendary ability to escape from any confinement, predating Houdini's reputation, was apparently tested by pranksters who lowered him into one of the known caves in the Yallingup/ Margaret River area sometime in the 1880's[6]. It must be presumed he escaped without incident, to go on to other, better documented adventures.

As well as providing necessary infrastructure, timber entrepreneurs such as MC Davies endeavoured to be seen as progressive and humanitarian employers, utilising the necessary rail to provide a transport and access system to provide workers with holidays by the sea, and annual picnics where timber workers and their families could enjoy a day by the sea to bathe and sunbake. As early as 1910, there was a boarding house, catering for the holiday trade at Flinders Bay, in the far South West.

Further north, around Yanchep, land leases were made available for grazing purposes, and cattle and horses were fed and watered on their journeys to and from the markets and shipping in Fremantle and the pastoral regions from which they came. Several pastoralists apparently commented on the hollow sounds made by their horses hooves as they passed over the extensive, and mostly hidden, cave system[7]. Major landowners and pastoralists such as Edward Hammersley, entrepreneur and father of Margaret Forrest, wife of Sir John Forrest, bought land and developed large holiday homes in the barren coastal area between Yanchep and Perth[8]. Horse riding, bathing and exploring were the summertime leisure activities of Western Australia's landed gentry.

Cave development and exploration became a possibility around the turn of the century. During 1900 Colonel Ernest Le Souef, who holidayed in the Margaret River area when taking a break from developing a Zoo at South Perth, surveyed several caves in the Yallingup/Margaret River area with his close friend and local inhabitant, Tim Connolly[9]. Yallingup Cave itself is believed to have been discovered and explored by Edward Dawson, who later became the guide to the Cave, a post he held for over 30 years. Two years later A.W. Milligan, a lawyer from Perth, visited friends at Yanchep and was shown the caves there by Harold White, who owned property in the vicinity. Milligan made a recommendation for preservation of the Yanchep Caves, and the letter was duly passed to a newly formed Caves Board.

The Caves Board had been created under the powers of the Parks and Reserves Act of 1895, which set aside land "for the purposes of controlling and managing parks and reserves". Control of these parks and reserves were to be vested in the various Boards established for the purpose. The first such Board, established with the Act, had responsibility for Kings Park only. The Zoological Gardens Board was created three years later, and the Caves Board in 1901. Boards created under the Act were to "improve or ornament such parks or reserves and do all such things as are calculated to adapt such parks and reserves to the purposes of public recreation, health and enjoyment". Under the Act the use of the land for quarries, dams, timber cutting, grazing and even Zoos was all approved, as was, apparently, the construction of guest houses and hotels.

Work commenced on a guest house at Yallingup, under the auspices of the Caves Board in 1902. The hotel was placed near the Caves Reserves, declared in 1901, and within walking distance of a good beach. It was provided with a cow, chickens, pigs and a vegetable garden so that guests would have fresh food at all times. The main house was built of wood, using timber cut from the Busselton area, and was constructed on-site by local builder Robert Donald. The bricks for the chimney were made on the site, using local clay, and were apparently so porous that they were only passed by the Public Works Inspector after it was agreed to cover them in cement render[10].

A liquor licence was also suggested for the site, and met considerable opposition from a variety of sources. The biggest concern of all those against the licence was that the bar would attract men working in the various timber mills in the area.

> Permit the sale of intoxicating liquor in this isolated place, and the Cave-House will be run chiefly for the sale of it; spirits will be offered to cyclists and other so-called 'sports' as an inducement for them to make it a place of call on Sundays with the result that the Caves House will degenerate into a place of debauchery[11].

The rhetoric surrounding the establishment and construction of the Hotel concentrated on the healthy activities and environment which visitors could experience, " those who may be desirous of obtaining a quiet rest and beneficial change of air." It also stressed the family nature of such entertainment, and sought to place it beyond entertainment to an almost holy experience[12]. In his strongly worded personal argument against the licence Caves Board member Mr May referred to" ....the Caves Houses where fathers and husbands should be able to leave their wives and children in perfect peace and safety - as in a place of sanctity." Despite these arguments the licence was granted.

By the beginning of the Great War, Yallingup had become firmly entrenched as a a major tourist and holiday destination. Visitors could purchase coupons entitling them to a train journey to Busselton, accommodation at Cave House, Yallingup and entry to at least one cave, Yallingup Cave, during their stay. They were met by local transport entrepeneurs such as the Bignells and conveyed by car or cart to Cave House , which by 1913 consisted of:

> twenty two single bedrooms (which provide for eighty outside sleepers) three bathrooms, three slop-hopper rooms, two linen closets, nine WC's, over eleven hundred feet of verandah, one large smoking room, two drawing rooms, one dark room with water laid on (for photographers), two temporary store rooms, one large bar, one billiard room, one large kitchen, one servery, cellar for the kitchen, cellar for bar, cook's pantry, servants hall, boots room, and a creamery.

Servants quarters, a garage, farmlet, blacksmith's shop, petrol bowser and a laundry all combined to meet every visitors' needs and wishes. The coupons could be purchased through the newly formed State Tourist Bureau, which took over from the Caves Board in 1910, in line with the firmly held belief that the caves and tourism were synonomous. Indeed, a question was asked in Parliament as to why one of the contenders for the position of head of the Tourist Bureau, Mr Robertson, formerly of the Caves Board, had not been appointed.

The principal attraction and main reason for the development of Caves House were the caves. As early as 1903 they were being extolled in glowing terms by the Government Statistician, Malcolm Fraser[13], and in 1912 State Librarian James Sykes Battye described them as "the crowning glory of Western Australia... which those fitted by experience to speak upon the subject have pronounced the equal if not the superior of any known to exist"[14]. By the 1920's and 30's the caves at both Yallingup and Yanchep were touted to international and local holiday makers as Western Australia's premier holiday destination. The image of the 'Suspended Table', from Yallingup's Lake Cave, formed part of the letterhead for two government departments, while other cave formations were pictured in pride of place on a wide range of tourism brochures.

Visitors to the Yallingup caves sought a sense of well-being and a connection to nature. The proximity to the sea meant visitors in the summer months could enjoy the cooling breezes and the healthful benefits of immersion in seawater. A holiday at Yallingup promised refreshment for mind and body, so much so that holiday makers who, in the years before the Great War, visited for only one or two days, "now bring their families and stay weeks" [15].

During the first three decades of tourism at Yallingup, visiting the caves was the principal activity available to tourists. Holiday packages included at least one if not more caves in their itineraries. Access was by car, and for the first two decades, the importance of the scenery and the educational benefits to be derived from these excursions was paramount.. Early photographs show formally dressed Edwardian men and women in suits, long dresses and enormous hats, gathered at the side of a hole in the ground proposing to educate themselves about Western Australian geography and archaeology through access to the wonders below. They were guided in this experience by Edward Dawson, who seems to have been exclusively associated with the Yallingup Cave, and by Tim Connolly, who had responsibility for caves further afield. Between 1901 and 1910, thirteen caves were opened to the public, who accessed them through routes devised by the guides. As discoverers and guides there was obviously also a very personal sense of ownership to the caves, which probably created a more intimate experience for the visitor.

Early exploration was carried out using lantern light, but a magnesium wire was soon found to provide a better, clearer light, The magnesium wire was, in turn, replaced by an electric generator and Delco lights, after the system used in the New South Wales Jenolan Caves. Within the caves visitors were shown a variety of limestone formations, many of which had been given descriptive names by their discoverers. In the Yallingup cave, accessed by a small tunnel and over 200 steps, there are several chambers, such as the "Theatre", the "Cauliflower Chamber" and the "Shawl Shop", named after the shawl formations, "which admittedly has no equal anywhere" [16].
The archaeological importance of the caves was emphasised in 1914 when Louis Glauert of the Western Australian Museum undertook an extensive examination of the fossil record found in the caves, and located a Diprotodon in Mammoth cave. Glauert's expedition may have put Margaret River on the fossil map, but the manager of Caves House was less than impressed by Glauert's expeditionary skills. Glauert had descended on the House with his wife, three children and a maid, plus " a large quantity of luggage." It was suggested that, "In future should any more palaeontologists wish to visit the Margaret it would be better for Guide Connolly to meet them with a wagon at Busselton" [17].

By the 1930's, although the caves were still considered a central part of the Yallingup experience, it was less for educational purposes, than as part of a wide gamut of recreational activities. Photographs of the period show people wearing simple linen dresses, trousers and shirt (no tie) and even shorts. Swimming, hiking, tennis at Caves House, and even golf on the newly developed golf course vied with the caves as the recreational activity of choice.

With the Depression, facilities at Caves House, which had already become run down and overcrowded, continued to deteriorate. As early as 1922, complaints had been made about the facilities, a point which nearby Boarding Houses and hotels in Margaret River were quick to pick up on. Nevertheless, Caves House continued to operate as the premier tourist destination in Yallingup, until the fateful night of December 4, 1930.

Despite the proximity to the Christmas holidays, Caves House at that time was occupied only by one set of visitors, the aptly named Soothills, who were visiting during Mr Soothill's convalescence. During their first night in residence Mrs Soothill thought she smelt smoke, and on going out on to their balcony saw "flames everywhere" [18]. The fire alarm was rapidly raised and the fire brigade summoned from Busselton. Local car driver, Frank Bignell, who had so often taken passengers to Caves House and on excursions to the caves, was also a volunteer fire fighter. With five men on board, their fire fighting equipment, and three men hanging off the engine on either side, Frank drove the 28 miles through the dark in 20 minutes. Robert Donald, the builder of both the original and eventual replacement Caves House, is reputed to have said that they were inspired solely by thoughts of saving the Hotel Bar!

The State Hotels Department, which now managed Caves House developed plans for immediate repairs, which just as promptly lapsed. Minor repairs were carried out in 1931 and 1932, but state funding priorities meant that the House, and access to "the glories of our Caves heritage" were forced to limp along until 1937, when plans for a new Caves House were put in place. It was opened in 1938. When it once more returned to the public attention, after the Second World War, its isolation and bucolic charm saw it become one of the State's premier honeymoon locations, and caving became just one more activity on an evergrowing list.

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Presenter Photographs











Clockwise from top left: *Neil Taylor; Stefan Eberhard & Norman Poulter; Rauleigh Webb; Sandra Boulter; Paul Hosie.*

Mining Court Recognises Hidden Treasures in Northern WA

Jay Anderson

ABSTRACT

The Cape Range region of Western Australia is a place of world significance for many reasons. The karst system of the Peninsula is world renowned due to the subterranean fauna that reside there. The cave systems support troglobites, stygofauna, spiders, millipedes and mollusks. Despite the fragility and acknowledged importance of the karst and reef systems, the area is under pressure from tourism, oil and gas industries, mining and other human activities. Only a small part of this significant karst system lies within the National Park. During 1999, there was an application for a grant of 10 mining leases over 8,250 hectares of Cape Range, covering approximately 80% of the proposed "5 (h)" reserve area, and over which the company holds mining exploration licenses.

There were a number of objectors, on environmental grounds, to the grant of the mining leases. The Western Australian Speleological Group (WASG) and Speleological Research Group Western Australia (SRGWA) were the Objectors that were represented by the Australian Speleological Federation (Inc) (ASF). Representation of the Speleological Groups was made in court by the Environmental Defenders Office.

The ASF holds the view that Cape Range contains a karst area of considerable significance, which should be protected from mining. The ASF had information that the Cape Range karst contained features of considerable significance which should be protected from mining. The environmental attributes of the Cape Range Peninsula, and in particular the value of its subterranean fauna, were considered at a hearing in the Perth Mining Warden's Court. This hearing took place over 8 days during 1999 (August 12-11, 24-25, September 21-22). This poster follows the events that have occurred since 1999 regarding actions taken to protect the karst area at threat. Please contact the author for copies of several articles which detail the ASF vs Finesky legal proceedings.

*Seasonal Roost Site Selection by the Chocolate Wattled Bat Chalinolobus morio in Quininup Lake Cave, WA**

Peter Armstrong, Kyle Armstrong, Ric Brown

ABSTRACT

We are currently examining whether the chocolate wattled bat *Chalinolobus morio* changes roosting position within the Quininup Lake Cave, near Gracetown, according to season. Preliminary observations confirmed the presence of this bat species through an examination of echolocation calls collected at the cave entrance during nightly emergence. The ultimate purpose of this research is to be able to determine if current management practices can be augmented based on our observations. The cave has two main chambers, both of which appear to be used by the bats, although preliminary observations suggest that one is used more than the other. Track marking has already been undertaken in the cave, mainly with consideration to protection of geological features, however, we wish to establish whether this track is also suitable in terms of minimizing disturbance to bats at all times of the year. We are also considering whether current management practices are suitable for the troglophilic invertebrates that occupy bat guano beneath bat roosts. We plan to extend our experience in Quininup Lake Cave to other caves in the southwest, with the development of a proposed regional management plan for bats in caves.

***Winner of the Best Poster Award**
(Award for Best Poster supported by Fremantle Arts Centre Press and the Department of Conservation and Land Management)

Invertebrate Biodiversity in the Karst Bio-space of Tasmania

Arthur Clarke

ABSTRACT

Karst is a word used to describe the landforms (eg. caves) derived from the natural solution of carbonate rocks, such as limestone or dolomite. Karst bio-space is a convenient term to describe the total habitat space for the aquatic and terrestrial species living in carbonate rock karst areas. The karst bio-space is represented as the sum-total of the actual or potential habitats and micro-habitats of all living species in karst. This bio-space can be described in dimensional terms as micro-caverns (<1mm), meso-caverns (1 to 15-20mm) and macro-caverns (>15-20mm). Although most of our cave fauna records relate to species known or collected from caves (the macro-cavern component of the bio-space), in many karst areas, the meso-cavern size voids, tubes or cracks probably represent the major habitat component for invertebrate cavernicoles in the karst bio-space: either in the saturated zone below the water table), or in the unsaturated zone above the water table. The spatial component of these meso-cavern spaces includes the numerous interstitial voids in cave streambed or streamside substrates as well as the minutely small solution tubes, cracks and fissures that distribute waters through the carbonate rock, draining surface mantles, surface soils and forest litters or ground cover. There are about 4,000 known caves in Tasmania in 135 karst areas and additional non-karst areas. Cavernicolous invertebrates have been recorded from almost half of the cavernous areas of Tasmania. The cave fauna database for the 1997 Tasmanian Regional Forest Agreement (RFA) includes a list of 692 recorded invertebrate species and a map shows the location of the major karst areas where cave invertebrates have been collected or recorded. The cavernicolous invertebrate biodiversity in Tasmania includes a range of aquatic and terrestrial species from several ecological niches, with varying dependence on the cave environment, and the relationship between some of these species can be demonstrated with a food web, typically expressed in some of the stream caves in Tasmania.

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Graffiti at Loch Ard Gorge, Port Campbell National Park, Victoria

Nicholas White

ABSTRACT

Port Campbell National Park with its striking coastal scenery of rugged cliffs and stacks, The Twelve Apostles, is one of Victoria's icons. It is promoted in all tourist literature and Loch Ard Gorge is one of the featured attractions with a car park, developed walking tracks along the cliffs and a track with a timber stairway down to the beach in the Gorge. Loch Ard Gorge was the scene of the shipwreck of the Loch Ard in 1878 from which there were only 2 survivors. The two caves in the gorge are named Pearce Cave (3SW-2) and Carmichael Cave (3SW-3) after these survivors. Reputedly, they sheltered in the caves before being rescued.

Many people, however, do not realise that this is a karst landscape developed on Tertiary limestone. The gorge is now showing signs of wear and tear and graffiti is accumulating on accessible cliff areas and within the caves. Recently this was brought to the attention of Parks Victoria and steps are being taken to address the problems. More information will be available at the Conference.

Contact details
123 Manningham Street, Parkville VIC 3052.

Speleogenesis in Cainozoic Limestones, Western Otway Basin, Southeastern Australia

Susan White

ABSTRACT

Southeastern Australia has extensive areas of Cainozoic limestones. These include both Oligo-Miocene marine calcarenites and calcilutites and Pleistocene dune calcarenites. This talk will illustrate the factors involved in speleogenesis in these limestones and outline the relationships between speleogenesis, hydrogeology and lithology in relatively young limestones.

These limestones, whilst more extensive in area than the Palaeozoic impounded karsts of eastern Australia, are less well known especially for cave exploration. However they have both extensive and intensive cave systems including the flooded cenotes of the Mount Gambier area, large caves with important palaeontological deposits and maze-like systems in the Pleistocene dune ridges.

Speleogenesis in these lithologies is an interplay between the groundwater conditions and the lithification and diagenesis of the calcareous sediments. As such sediments are highly variable in their calcareous content, the solution/precipitation balance also varies from site to site. This variability is combined with both high primary porosity and permeability resulting in diverse surface and underground karst features.

The caves are dependent on the ability of the calcarenites to develop sufficient structural strength in the form of an indurated layer. This "caprock" is necessary for the development of many karst forms, especially caves, as it gives the relatively unconsolidated calcarenite structural strength. The caprock develops in both limestone sequences where conditions are favourable but somewhat better in the Pleistocene dunes.

The development of cave systems is also directly related to the groundwater conditions. Evidence of fluctuating groundwater conditions over time can be seen in the caves, especially the drowned cenotes of the lower southeast of South Australia. The inter-relationship of groundwater conditions and relatively horizontal lithologies, combined with the development of an indurated layer are the keys to understanding speleogenesis in these limestones.

Karstification in lithologies that have not been traditionally regarded as having high potential for caves can bring insight into the interplay of factors controlling speleogenesis. The variation in host lithology, hydrogeology and an ability to develop a structurally competent roof must be taken into account in the context of the time available for solution and speleogenesis.

Contact details
123 Manningham Street, Parkville VIC 3052.

Karst Development at Naracoorte, SA: Why There?

Susan White & John Webb
John Webb (Department of Earth Sciences, Latrobe University Bundoora, Victoria)

ABSTRACT

The Lower Southeast Region of South Australia and a substantial part of southwestern Victoria form a limestone province with discontinuous areas of intensive karst development such as Naracoorte, where the relatively high density of caves is atypical for the karst province as a whole. The Naracoorte caves have attracted a great deal of interest and research since the discovery of extensive Pleistocene vertebrate fossil deposits in 1969. The solution pipe entrances to some chambers acted as pit traps, and in Victoria Fossil Cave, large, now extinct animals like the thylacine, marsupial lion (Thylacoleo), giant kangaroos and diprotodontids fell into the cave, and are preserved in the extensive bone deposits. The fossils accumulated in several episodes during the Middle Pleistocene (100,000-400,000 years ago). The entrances to the Naracoorte caves are either vertical solution pipes less than 1m across and up to 20m deep or collapse windows. Both open into horizontal systems of collapse chambers floored by rubble cones and connected by low, wide, solutionally sculptured passages often partially filled with sediment. Sand from dunes on the surface sometimes falls into the caves through such solution pipes to form distinctive sand cones. The sand plugging the pipes may collapse from time to time to form a surface sinkhole. Phreatic passages, sometimes with spongework, are present, particularly in the lower levels near the water table, where they may be partially filled with clay. Caves that reach the water table have still, shallow pools with calcite rafts on the surface; the level of these lakes has fluctuated over time in response to changes in the regional water table. The longest cave, Victoria Fossil Cave, has over 3000m of an extensive rambling network of large collapse chambers and smaller connecting passages, some very well decorated. Naracoorte cave passages show a preferential northwest-southeast alignment, more or less parallel to the Kanawinka Fault which cuts through the host Gambier Limestone as a cliff-line formed originally by fault movement, but later modified by wave erosion. The fault has moved in the last few million years; the uplifted northeastern side is topographically higher.

Karstification at Naracoorte may have started when the sea retreated and first exposed the limestones to weathering around 15 million years ago. Cave formation probably slowed when the sea returned ~5 million years ago and covered the area for 2-3 million years. Around 900,000 years ago the sea advanced to the Naracoorte area for the last time, forming the sea cliff and sand dunes there. The caves may have been flooded by this sea level advance. Blanche and Alexandra Caves contain columns and flowstone (not yet dated) that have been extensively dissolved, exposing their internal layering, and suggesting that the caves were flooded after the speleothems had formed. The Naracoorte caves have remained dry since then. In Victoria Fossil Cave the oldest flowstones, growing directly on the floor of a chamber, are over 500,000 years old. Calcite deposition in the caves occurred during times when the climate was relatively wet, most recently about 20,000 years ago; there is only limited speleothem deposition at present.

It is uncertain why cave development at Naracoorte is so extensive, but it may be reflect a greater input of aggressive water at this location, perhaps from the nearby Mosquito Creek, and possibly accentuated by uplift along the Kanawinka Fault. Alternatively, there may be structural control of groundwater flow, so that it has been focussed by a greater concentration of joints and fractures in this area.

Contact details
123 Manningham Street, Parkville VIC 3052.

ASF Awards

ASF President, Mr John Dunkley, presented the awards to the following ASF members. The citations for WA members who received the Edie Smith Award was read by Jay Anderson (ASF Snr Vice President & WASG President)

Edie Smith Award

Lex Bastian OAM



John Dunkley and Lex (right)

Lex Bastian began his caving career in 1949, at the age of 12, when he took a torch and rode his bicycle on a 70-mile round trip to Yanchep, exploring the holes he found by the side of the road. Through the 1950s he continued to visit Yanchep, exploring every hole he could find, and very early on developed a disciplined habit of keeping field notes, sketching the caves, and locating them in relation to obvious landmarks and to each other. During this time he studied geology.

WA speleology's early beginnings were initiated and role-modelled by Lex, setting the scene for a very large and active speleological group in Western Australia.

Lex has remained a *very* active member of the group, participating in regular monthly meetings and training days, giving presentations to members and organising monthly caving trips to Yanchep.

The voluntary contribution made to speleology by Lex has been huge and outstanding, evidenced both by the number of research papers he has written on the hydrology, geomorphology and speleogenesis of the karst areas in south-west Western Australia, and the number of committees of which he remains an active member.

Summary of achievements

- Founder of the WA Speleological Group and father of organised speleology in Western Australia. The WA Speleological Group was started as a sub-group of the WA Naturalists, the first meeting being held in Lex's home on 17 July 1958. Lex was the first President of WASG and is an Honorary Life Member.
- Discoverer and re-discoverer, explorer, surveyor and recorder of numerous significant caves in the south-west of WA.
- Lifelong advocate of the importance of recording cave finds and scientific discoveries for posterity.
- Researcher of the caves of Yanchep and surrounding areas, with over 450 new records added to the Karst Index for the region over the period 1988-2001.
- Champion of the karst heritage of Yanchep and surrounding areas in the face of threats from urban expansion. As the universally recognised "Yanchep expert", Lex is an adviser to the national park, and is also frequently approached for advice by landowners, emergency services, local councils and Government Departments.
- Ongoing roles as trip organiser; trainer; motivator of cavers old and new; adviser to national parks, local authorities, Government Departments and landowners; popular speaker on geology; and conservation activist.
- Author of numerous articles on WA karst geology and cave history.

Lex is an individual with dreams and with insight; his level of fitness and activity, and his knowledge as a geologist and a speleologist, all contribute to a purpose-driven individual.

Postscript

Just three weeks after the ASF conferred on Lex the Edie Smith Award for achievements over a lifetime of caving, the Australia Day Honours List for 26 January 2003 contained the following citation:

> Order of Australia, Medal (OAM) in the General Division:
> Lennox Vernon Bastian, Beldon, WA, "for service to speleology in Western Australia as explorer and surveyor, and to the protection of caves".

We extend our heartiest congratulations to Lex, and our delight that the community recognises the contribution to Australia's social fabric of explorers and surveyors.

Edie Smith Award

Rauleigh Webb



Rauleigh's contribution to caving and conservation in WA cannot be calculated. He has been an "active" caver for a long time (over 25 years now), being involved in other aspects such as assisting in the organisation of WASG and of ASF as a Vice-President. Rauleigh started caving in 1976 and became a Trip Leader in 1978. He has, at all times, had the interest of the caves at heart. This is often in complete, selfless disregard for what other people would think of his actions or opinion.

Rauleigh has served on many committees including the ASF Executive, the WASG committee and CAC (Caves Access Committee), and has at all times been active in advocating the conservation of caves and karst. He joined ACKMA (Australasian Cave and Karst Management Association) years ago because he saw the need to get involved in management of caves and to educate landowners and cave managers. He has been a WASG representative on various committees involved in the management of caves such as the CMAC (Caves Management Advisory Committee) in Margaret River.

Rauleigh developed the Minimum Impact Caving Code when he saw a need for cavers to be aware of the impact that caving causes; it is a code that has achieved worldwide recognition and has been accepted by cave managers around Australia. He was the ASF Conservation Co-Convenor for WA for over 13 years. This involved coordination of a number of conservation projects and writing reports to the government and annual reports to the ASF.

He has been involved in numerous projects and has worked with many other bodies (other caving clubs, Scouts etc.) to help their members visit caves and learn how to cave in a careful and safe way. Rauleigh also helped, along with several other experienced Perth cavers, to develop a training system for cave leaders.

Rauleigh has been called a "cave surveyor extraordinaire". He has mapped many caves in Australia and overseas, thus contributing to the combined knowledge of caves in a variety of karst areas. He has been the WA coordinator for the Australian Karst Index, an ASF position involving liaison between the ASF and WA caving clubs with regard to cave information - a massive job in itself.

More recently, members would be aware of the Exmouth (Cape Range) court case (mining application by Learmonth Limestone) in which the ASF and WA caving clubs have been involved. Rauleigh was the primary organiser behind this important project. He spent countless hours of his time researching, meeting with lawyers and preparing the case for court, and then spent many days away from work and in court to support the case. As this case has not yet been completed, there is still more ongoing work being done that Rauleigh is involved in.

Rauleigh Webb has given outstanding service to the ASF over a long period of time, making specific contributions to a variety of roles within speleology - exploration, conservation and documentation of caves, leadership and administration. He continues to promote minimal impact caving practices through the development and refinement of policies and procedures. Rauleigh has made great personal sacrifices for ASF and its member clubs in WA over a long period of time.

Fellow of the Australian Speleological Federation Inc.

Peter Berrill

On a motion from the floor of the ASF Council meeting in January, Peter Berrill was unanimously elected Fellow of the ASF. Our equivalent of Honorary Life Member, the award of Fellow is given specifically for outstanding service to ASF itself, and accordingly is determined by the Council. In the 30 years since it was instituted, this is only the seventh time it has been awarded, a measure of the high esteem in which we hold recipients.

Peter was a member of the ASF Executive for 13 years, probably the longest continuous service ever, and President for five very difficult years until his resignation in 2002. Under his leadership in those five

years, as detailed in the ASF Annual Report for 2002, the ASF obtained registration as an Environmental Organisation, acquired the journal Helictite and other assets of the former Speleological Research Council Ltd, reformed the Karst Index Project, and undertook the highly acclaimed Natural Heritage Trust project in the Macquarie region of NSW.

Elsewhere, Peter's name has been most closely associated with the campaign to halt mining and to establish a national park at Mt Etna in central Queensland. This culminated in 1999 in the ground-breaking reconciliation which saw former adversaries surrender some leases and sponsor, jointly with Central Queensland Speleological Society and others, the incorporation of Cammoo Caves into Mt Etna National Park.

Certificates of Merit

ASF Certificates of Merit recognise specific contributions to speleology through exploration, scientific study, conservation or documentation, including roles of leadership, administration, publication and development of new techniques. Recipients for 2003 are:

Julie and Peter Bauer, NSW: for research, documentation and publication on Bungonia caves, particularly the book "Under Bungonia", and continuing active involvement in management advisory roles.

Fr Ken Boland, Vic: for innovative exploration (using ultralight aircraft), mapping and documentation of Nullarbor caves, especially Old Homestead and Thampanna Caves, and the discovery of major palaeontological and other sites of scientific significance.

Darren Brooks, WA: for systematic survey and recording of karst features of the Cape Range, WA, including assistance to WA Museum expeditions, thereby strengthening the case against mining in the area and for proper heritage protection; and for many years of editing The Western Caver (publication of WASG).

Daryl Carr, Vic: for exploration, discovery, mapping and documentation of numerous caves in the Buchan-Murrindal area, Victoria.

Peter Horne, SA: for documentation and publication of caves in south-eastern South Australia, and for long-term administrative support for Cave Exploration Group SA.

Athol Jackson, SA: for many years of service to Cave Exploration Group SA, including editing CEGSA News for many years, being President for over five years, and for assistance in organising several ASF Conferences in South Australia.

Tom Porritt, Qld: an active caver in several states, currently in north Queensland, described by a referee as "an Australian caver of note…a modest man whose achievements are not well publicised [and who] epitomises all that is best in Australian speleology".

Sue White, Vic: for exploration, research and publication on soft rock caves in general and western Victoria in particular; for editing of Helictite; and for leadership in introducing young people to caving.



Darren Brooks



Susan White



Father Ken Boland

NOTE: ASF Awards summaries by Lloyd Robinson, Jay Anderson and John Dunkley.

Images From Below - Speleo Art Exhibition

Artist	*Description*	*Meduim*
Bernadette Aitken	Silk Fabric – 2m	*Shibori and dye*
Bernadette Aitken	Silk Fabric – 2m	*Shibori and dye*
Bernadette Aitken	Silk Fabric – 2m	*Shibori and dye*
Bernadette Aitken	Silk Fabric – 2m	*Shibori and dye*
Bernadette Aitken	Silk Scarf	*Dyed and printed*
Bernadette Aitken	Silk Scarf	*Dyed and printed*
Bernadette Aitken	Silk Scarf	*Dyed and printed*
Bernadette Aitken	Silk Scarf	*Dyed and printed*
Bernadette Aitken	Silk Scarf	*Dyed and printed*
Pam Annesley	Jewel Formations	*Textile*
Wendy Binks	Carbide Emu	*Hand painted t-shirt as worn by Ian Collette*
Wendy Binks	Carbide Wombat	*Hand painted t-shirt as worn by Ian Collette*
Ian Ellis Chandler	Entrance Swildons Hole	*Acrylic on board*
Ian Ellis Chandler	Into the Brickyard	*Acrylic on board*
Ian Ellis Chandler	In Sight of Light (4 copies)	*Book*
Tanya Coxsedge	Two Headed Snake 1	*Small quilt embroidered with a variety of black threads & beads*
Frank	Murra-El-Elevyn, Nullarbor	*Print*
Robin Gray	Sketch Book Page (2 copies)	*Print*
Robin Gray	Formations in St Alectites Shaft. White Pit, Mendip.	*Print of oil pastel*
Robin Gray	Sketch Book Page - Descent (2 copies)	*Print*
Robin Gray	Formations, St Cuthbert's Swallet, Mendip (2 copies)	*Print of oil pastel*
Robin Gray	Big Shaft, Vercors, South France (3 copies)	*Print of oil pastel*
Robin Gray	Descent (2 copies)	*Print of oil pastel*
Robin Gray	Diggers	*Print of oil pastel*
Robin Gray	Aldo's Shaft, G. Berger, Vercors	*Print*
Robin Gray	Old Timer	*Original pencil drawing*
Robin Gray	Otter Hole, S Wales	*Original chalk*
Robin Gray	Abseil (2 copies)	*Print*
Robin Gray	Cavers in a Wet Passage (2 copies)	*Print*
Robin Gray	Kents Cavern, Devon	*Print*
Robin Gray	Cave Diver	*Print of oil pastel*
Robin Gray	Cavers in a Low Passage	*Print*
Robin Gray	Streamway	*Print*
Robin Gray	Reg Cartoon 1 Item, 3 pages from My Notebook. *Copyright free*	
Robin Gray	Cartoon	
Robin Gray	Descent	*Original Charcoal*
Dawn Klok	Cave Formation	*Leadlight*
Dawn Klok	Cave Formation	*Leadlight*
Dawn Klok	Cave Formation	*Leadlight*
Dawn Klok	Cave Formation	*Leadlight*
Dawn Klok	Cave Formation	*Leadlight*
Dawn Klok	Cave Formation	*Leadlight*
Dawn Klok	Ghost Bat (Upside down)	*Leadlight*
Dawn Klok	Ghost Bat (Wide)	*Leadlight*
Dawn Klok	Bat	*Leadlight*
Dawn Klok	Bat	*Leadlight*
Dawn Klok	Bat	*Leadlight*
Dawn Klok	Bat	*Leadlight*
Dawn Klok	Small Moon with Bat	*Leadlight*
Dawn Klok	Bat with Full Moon	*Leadlight*
Dawn Klok	Bat with Full Moon	*Leadlight*
Dawn Klok	Bat with Full Moon	*Leadlight*
Dawn Klok	Bat with Full Moon	*Leadlight*
Dawn Klok	Bat with Full Moon	*Leadlight*
Dawn Klok	Suspended Table, Lake Cave	*Leadlight*
Dawn Klok	Bat Circle	*Leadlight*
Dawn Klok	Cave Window	*Stained glass*
June MacLucas	Koonalda Cave, Nullarbor	*Pastel*
June MacLucas	Cabaret Cave No 1, Yanchep WA	*Pastel*
June MacLucas	Cabaret Cave No 2, Yanchep WA	*Pastel*
June MacLucas	Thylacoleo, Nullarbor No 1 *(Using Ken Boland Photos)*	*Pencil wash*
June MacLucas	Thylacoleo, Nullarbor No 2	*Pencil wash*
June MacLucas	Mimbi Cave, Kimberleys (2 copies)	*Print*
June MacLucas	Stagdemize Chamber, Thampanna	*Print*
June MacLucas	Organ Pipes, Chifley Cave, Jenolan (2 copies)	*Print*
June MacLucas	Castle Cave, Yarrangobilly NSW	*Print*
June MacLucas	Venus Pool, Jillabenan Cave, Yarrangobilly	*Print*

June MacLucas	Pleasure Dome, Kubla Khan	*Print*
June MacLucas	Recovery - Thylacoleo, Nullarbor 2002 No 3	*Pencil and wash*
June MacLucas	Cabaret Cave	*Pencil Sketches from Diary*
Angus Macoun	Cave Scene	*Glass plate*
Angus Macoun	Snow Cave, The Enchantments, Washington	*Photograph*
Angus Macoun	Snow Cave Entrance, The Enchantments, Washington	*Photograph*
Kath Powell	Miracles Of Mars	*Computer Generated Image*
Kath Powell	New Beginnings	*Computer Generated Image*
Kath Powell	Blue Grotto	*Computer Generated Image*
Steve Powell	Mocktree Cave	*Acrylic*
Steve Powell	Merlins Cave	*Pencil*
Steve Powell	Old Methusulahs Cave	*Pencil*
Di Redgement	Workers Down	*Watercolour*
Gerry Reilly	Helictite Vase	*Blown glass*
Susan Sowerby	Fruit Bats (Exhibited courtesy Dawn Klok)	*Mixed media sculpture*
Eve Taylor	Tartarus Spider	*Print of Acrylic paints on primed canvas art board*
Eve Taylor	Cavern Drawing	*Pastel drawing on paper*
Coral Thompson	Secret Grotto	*Watercolour painting*
Coral Thompson	Green Lake	*Encaustic wax*
Coral Thompson	Tower of Strength	*Encaustic wax*
Pamela Trigwell	Natures Grandeur	*Pastel*
Peter Uherek	Helictites at Labryinth Cave, WA	*Acrylic and watercolour*
Peter Uherek	Exploration of Tribal Cave, WA	*Watercolour*
Peter Uherek	Always Busy Lady J, WA	*Watercolour*
Peter Uherek	Nullarbor Mystery	*Wax colour and marker*
Peter Uherek	Stay A Little Bit Longer	*Wax colour and marker*
Tony Watson	Handline Into Staircase Cave	*Pastel and ink*
Tony Watson	Eagle Rock – Chimney Cave	*Pen and ink*
Tony Watson	Lava Arches – Imperial Cave 3H69	*Texta felt pens*
Tony Watson	New Lava – Maze Cave 3H71	*Texta felt pens*
Joyce Webster	Wonderment	*Oil*



John Dunkley (ASF President) speaking to the crowd at the opening



Art admirers: David & Jessica Wools-Cobb, Dennis Marsh, Jennifer Smyth, & Cathy Brown



Prospective purchasers: David Eavis, Noelene Taylor and Howard Richardson

Grotto Photographs











Clockwise from top left: David Wools-Cobb doing the 'cork chair' skill; Michael Ruttledge doing the 'cork on floor' skill; Greg Thomas fitting thru a coathanger; Greg Thomas doing the '360 around the bench' skill; Tim Moulds attempting the 'around the body batten' skill

.

Photographic Competition – Prints – First Prize



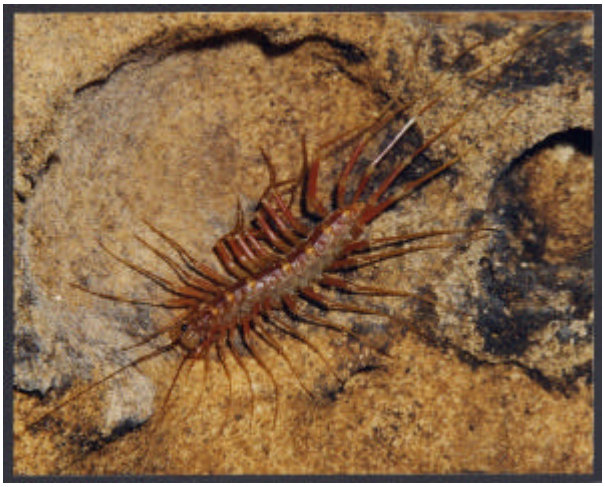
Chamber / Passage
Paul Devine



Entrance / Surface Feature
John & Glenda Wylie



Decoration
Ida Newton



Scientific
Fran Head

Photographic Competition - Prints

Sponsored by: Kodak Professional
Supported by: Epson Australia and the Department of Conservation and Land Management.

Judge: Dennis Sarson
Advisor: Norman Poulter OAM

Entrance / Surface Feature	First	John & Glenda Wylie
	Second	Fran Head
	Third	Leonie Turra
Chamber / Passage	First	Paul Devine
	Second	Paul Devine
	Third	Ida Newton
Decoration	First	Ida Newton
	Second	Ida Newton
	Third	Eve Taylor
Scientific	First	Fran Head
	Second	John & Glenda Wylie
	Third	Paul Devine
Cavers	First	John Wylie
	Second	Ida Newton
	Third	Ida Newton
People's Choice	First	Paul Devine
	Second	Ida Newton
	Third	Fran Head



Cavers
John Wylie



People's Choice
Paul Devine

Photographic Competition - Slides - First Prize



Entrance / Surface Feature
David Wools-Cobb



Chamber / Passage
Garry K Smith



Decoration
Ross Anderson

Photographic Competition - Slides

Sponsored by: Kodak Professional
Supported by: Epson Australia and the Department of Conservation and Land Management.

Judge: Dennis Sarson
Advisor: Norman Poulter OAM

Entrance / Surface Feature	First	David Wools-Cobb
	Second	Ian Collette
	Third	Ross Anderson
Chamber / Passage	First	Garry K Smith
	Second	David Wools-Cobb
	Third	Ross Anderson
Decoration	First	Ross Anderson
	Second	Garry K Smith
	Third	David Wools-Cobb
Scientific	First	Paul Devine
	Second	Arthur Clarke
	Third	Garry K Smith
Cavers	First	Garry K Smith
	Second	Garry K Smith
	Third	Garry K Smith



Scientific
Paul Devine



Cavers
Garry K Smith

Photographic Competition - Digital - First Prize



Entrance / Surface Feature
Arthur Clarke

Decoration
Stefan Eberhard





Scientific
Garry K Smith

Photographic Competition - Digital

Sponsored by: Kodak Professional
Supported by: Epson Australia and the Department of Conservation and Land Management.

Judge: Dennis Sarson
Advisor: Norman Poulter OAM

Entrance / Surface Feature	First	Arthur Clarke
	Second	Arthur Clarke
	Third	Arthur Clarke
Chamber / Passage	First	Brian Combley
	Second	Stefan Eberhard
	Third	Stefan Eberhard
Decoration	First	Stefan Eberhard
	Second	Brian Combley
	Third	Arthur Clarke
Scientific	First	Garry K Smith
	Second	Stefan Eberhard
	Third	Arthur Clarke
Cavers	First	Arthur Clarke
	Second	Stefan Eberhard
	Third	Stefan Eberhard



Chamber / Passage
Brian Combley



Cavers
Arthur Clarke

Prussik Challenge

Supported by: Vertical, Paddy Pallin, Jaycar Electronics and Snowgum.

The challenge was a timed ascent of a 30 metre length of rope using the 'frog' system.

In addition to first, second and third place in each Division, a men's and women's prize was also awarded in the Masters category (50 years and over).

MEN'S DIVISION

		Time
First	**Greg Thomas**	1 minute 39 seconds
Second	**Iain McCulloch**	1 minute 56 seconds
Third	**Darren Brooks**	2 minutes 9 seconds
Masters' Prize	**Ian Binnie**	3 minutes 18 seconds
	Stefan Eberhard	2:13
	Ross Anderson	2:18
	John Hellstrom	2:52
	Tim Moulds	3:24
	Rob Squibb	3:36
	Garry K Smith	3:51
	Ian Collette	3:56
	David Wools-Cobb	4:35
	Mike Bradley	4:46

WOMEN'S DIVISION

		Time
First	**Robin Weckert**	3 minutes 25 seconds
Second	**Ida Newton**	4 minutes 13 seconds
Third	**Kath Rowsell**	4 minutes 46 seconds
Masters' Prize	**Ida Newton**	4 minutes 13 seconds
	Jodie Rutledge	5:21
	Jessica Wools-Cobb	5:31
	Vicki Bresnan	5:38
	Noelene Taylor	6:50



Stefan and Darren in action

Conference Field Trip

Thanks to the generous sponsorship of the various cave managers, all conference attendees were able to visit a range of the major tourist caves on the Leeuwin-Naturaliste Ridge during the field trip.



In the morning, buses took the entire party first to Ngilgi Cave at Yallingup, where managers Liam and Jenny Kinsella showed us round and described the cave's history and some of their management initiatives. The group was particularly interested to see the moves to replace old, intrusive walkways and steps with more "cave-friendly", non-polluting recycled inert plastics. Another imaginative solution is the series of contoured plastic crawlways installed a short way inside the entrance, designed to offer families a "virtual caving experience" while protecting this section of the cave from the damaging exploration permitted in earlier generations. The Ngilgi visit was delightfully rounded off with a complimentary morning tea and scones taken in the pretty, peppermint-shaded picnic area.

For the middle part of the day we travelled south to Wharncliffe Mill at Margaret River, a former timber mill now run as a community recreation camp by the Department of Conservation and Land Management (CALM). Several presentations were given here, including two by CALM staff. Caves Manager Anne Wood explained the development of the permit system for in the Leeuwin-Naturaliste National Park, convincing some former unbelievers of the wisdom of restricted access in such fragile karst. Neil Taylor, Visitor Services Manager for the Blackwood District, presented CALM's own brand of new stainless steel walkway technology, firing everyone with his enthusiasm and roping in some "trades assistants" for a practical demonstration of the construction technique.

Following a picnic lunch, the tour continued southward to Forest Grove, where CaveWorks, the caves management and karst research branch of the Augusta-Margaret River Tourism Association, has its major interpretive centre at Lake Cave. Some chose to enjoy the excellent interpretive displays (or were they just picking out ASF members in the photographs?), while others were mainly interested in a speed challenge for the "virtual cave" crawlway (record now held by Rob Susac). Some found out the hard way about the virtual stalagmite….

We then split in half for the final cave visits, with each half able to visit one of the illuminated tourist caves run by CaveWorks, plus one of the unlit, normally self-guiding caves managed by CALM. CaveWorks offered either Lake Cave - where the vast doline is an event in itself before you even reach the cave with its beautiful formations reflected in the lake - or the equally beautiful Mammoth Cave, complete with video tour. (I should mention that each conference delegate also received a pass enabling them to visit any CaveWorks cave in the post-conference period.) The CALM caves were either Giants, a "through" trip combining vast chambers with some tight squeezes and climbs, or Calgardup, where the groups installed a little bit of that stainless steel walkway and heard about various other measures taken to rectify earlier tourist impacts.



While the Lake/Giants groups worked off some energy climbing stairs, the Mammoth/Calgardup groups enjoyed a short bushwalk between their two caves, with informative commentary on the local geography and flora from Jane Scott of Cavers Leeuwin and Anne Wood, kindly standing in for husband Peter who sadly missed the entire conference owing to injury. The day ended quite late, and we were grateful to all the cave managers and guides who stayed on to assist with the visits. The return bus trip to Bunbury was fairly subdued and it seemed everyone was worn out, but it's amazing what a little dinner and wine can achieve. The day concluded with a memorable night in the Grotto Bar, with hilarious games of physical contortion continuing until the small hours.

Speleosports



Arthur Clarke in the straws



Jay Anderson and the 'TuTu Fairies' doing their stuff in the tyres



Norm Poulter OAM dealing with tyres



The 'Exhibition Team'



Vicki Bresnan coming through the duck



The 'Also-Rans' team

Speleosports

Sponsored by: Mainpeak

The Speleosports obstacle course was set up around the pre-primary playground at the school. Teams were of four people and all participants had to do each section, unless noted otherwise. The course consisted of the following:

- **Crawl** through two wooden picnic tables with attached benches.
- **The Sump -** This involved diving through two packing crates full of 'simulated water' (empty plastic bottles) to locate and 'swim' through the sump (a short tube about 500mm in diameter connecting the two). On emerging from the bottles in the second crate, the first person had to reach through the timber bars of the crate to unlock a small padlock to release the 'gate'. A 5 second penalty accrued for each bottle not replaced when the team had finished.
- **Tyre squeeze -** Two team members only had to squeeze through a set of 6 tyres hanging about 600mm apart.
- Participants followed a path through the playground equipment negotiating flying fox, balances, slides, climbs and a snaking route through the monkey bars. The sand was screeded and at certain points participants had to place their feet in the leader's footprints (minimal impact caving). 15 second penalty for any steps outside the leader's.
- **The Duck -** Participants slid down a plastic tube into a bath full of water (cunningly roofed to ensure they got wet).
- **The Squeeze -** A short zigzag flattener squeeze between two sheets of plywood.
- **The Straw Passage -** This was a cardboard tube with lengths of spaghetti poked through holes in the top. Each broken straw incurred a 20 second penalty.
- **Climbing wall -** Once all team members were through the straw tube, one member had to climb to the top of a climbing wall and ring the bell to finish.

FIRST: **The Canberra Connection**
Iain McCulloch, John Hellstrom, Bob Kershaw, Chris Bradley.
Time: 7:01 No penalties incurred.

SECOND: **Also-Rans**
Dawn Klok, Garry K Smith, Lance Hoey, Brian Combley.
Time: 8:27 One rail touch, one foot fault and one straw penalty.

THIRD: **East Meets West**
Eve Taylor, Noelene Taylor, Robyn Weckert, Tim Moulds.
Time: 9:09 Three straw penalties.

Pro's And Amateurs
Judy Shaw, Norm Poulter OAM, Howard Richardson, Phil McGuigan.
Time: 10:53 One foot fault, one rail touch and five straw penalties.

RSS - As They Are
Evelyn Taylor, Jennifer Smyth, Chris Guillard, Alan Caton.
Time: 11:57 One bottle, one foot fault, one straw penalty.

Tutu Fairies
Ida Newton, Vicki Bresnan, Jay Anderson, Rebecca Newton
Time: 12:13 One foot fault and three straw penalties.

MainPeak
Jodie Rutledge, John Mustard, Barbara Wiesner, Nick White.
Time: 12:56 Five foot faults and one straw penalty.

Tassie Tigers
David Wools-Cobb, Jessica Wools-Cobb, Rob Squibb, Arthur Clarke.
Time: 13:00 Three straw penalties.

Victorian Specialists
Ken Boland, Miles Pierce, Faye Chapman, Kath Rowsell.
Time: 13:25 One foot fault and three straw penalties.

Exhibition Team
(not part of competition - included members of course set-up committee and others who had already competed)
Greg Thomas, Ross Anderson, Garry K Smith, David Wools-Cobb.
Time: 6:59 Two straw penalties.



Judy Shaw showing an innovative approach to the tyres



The 'Rovers' team



Streeeetched out in The Squeeeeze

Survey Stakes

Supported by: Mountain Designs, Bunbury and Cape Mentelle Vineyards.

The Survey Stakes consisted of a marked circular course of 20 stations through bushland. Surveyors used compass, clino and tape. Results were entered into a computer using the Compass (Larry Fish) program, and the closest to loop closure was the winner.

	Team	*Deviation*	*Distance out (metres)*
First	**Mike Bradley & Noelene Taylor**	0.29	0.63
Second	**John Hellstrom & Iain McCulloch**	0.38	0.81
Third	**Chris Bradley & Bob Kershaw**	0.45	0.98
	Julia James & Craig Barnes	0.63	1.35
	Darren Brooks & Ross Anderson	0.66	1.43
	Ian Collette & Greg Thomas	1.22	2.63
	Norm Poulter OAM & Vicki Bresnan	1.69	3.64
	Lloyd Robinson & Mike Lake*	3.30*	*6.64
	Jay Anderson & Rebecca Newton	4.34	9.34
	Howard Richardson & Ida Newton	6.27	12.41

* *It is noteworthy that the team of Lloyd Robinson and Mike Lake achieved their result entirely by estimation, without the use of instruments.*

Cavers' Dinner

Sponsored by: Devil's Lair

The Caver's Dinner was the climax of the conference calendar and the final celebration, where wining, dining and fraternising was interspersed between speeches, official awards and presentation of prizes for all of the competitions.

The Photography competition winners were announced and winning entries were displayed (prints) and shown (slides). Winners in the Speleosports, Prussik Challenge and Survey Stakes were congratulated and received their prizes. 'Images From Below' exhibits, which had been kindly donated, were auctioned and the 'Margaret River Made' raffle was drawn.

On behalf of the ASF, Dr Julia James gave a very warm hearted speech of appreciation to the organising committee, and John Dunkley announced the official ASF awards.

It was a great way to end the conference and we were all looking forward to packing up and heading off on post conference caving the next day.

Post Conference Caving

There were a number of caving options available to conference participants, and partners. The first caving trips were to start on Boxing Day (26th December 2002). Some very keen cavers had driven over the Nullarbor early and just wanted to get underground ASAP!! Several WA members met the first "crew" up at Yanchep. There were 6 people and we stayed two nights at the cottage (an old staff accommodation house in the National Park). A number of caves were visited over the two days, and the trips went well.

On the 28th of December, 4 of us drove further north to another karst area - booking into some excellent (but well priced) group accommodation at Jurien and heading into the bush again. We visited several caves in this area - notably the Stockyard Gully Caves. On the 29th December two more cavers joined us…….we visited more caves….and later two more cavers joined us (however they were doing more social/touristy events during the days….). On the 30th December the group visited caves in the Drover's Cave National Park and the Nambung National Park - returning to Perth the 31 December. This 5 day period was a success and the small group of cavers were looking forward to the conference…..

POST CONFERENCE TRIPS

It was a challenge arranging trips for a potential 30-40 cavers over a 5 day period. It was planned that there would be 5 days of trips in the south-west. The cavers were based at the two huts in the Boranup Forrest (WASG and SRGWA club huts). A number of trips occurred on a daily basis. Many of these trips were to restricted access and locked caves. It was great to see trips running smoothly, cavers in awe and the cave photographers in "their element". Keep an eye out for the next ASF photo competition - there's bound to be a good number of entry's involving trips to caves at this time. Aside from the main caving in the Leeuwin Naturaliste Ridge area (Margaret River region) a small number of cavers visited areas north of Perth. A few trips occurred in the Yanchep National Park and further north to the area visited by the pre-conference trips.

All of these trips are documented in more detail in publications by the WASG and SRGWA. For more information or a copy of particular trip reports please contact these speleological groups.

Interesting comment (from ISS 03/03 vol9, No. 1) "After caving at the Margaret River/Augusta area, I now appreciate the trouble that clubs in the west go to, to protect the caves and formation that exist in the caving regions of WA. It would be wonderful to go back 150 years in the east and start over, but unfortunately we cannot do this, so the caves in the east will in most cases continue to be abused by the uninformed". Something to think about……

Special thanks to the trip leaders who volunteered their time to take visiting cavers…. caving……. underWAy……





Golgotha Cave













Clockwise from top left: *WASG hut; Bob Kershaw; XXX; Nicholas White & Rob Foulds; SRGWA hut; Michael Ruttledge.*

Organising Committee

- **CONVENOR** Ida Newton
- **AGENDA** Norman Poulter OAM
- **ACCOUNTS** Vicki Bresnan
- **SPONSORSHIP** Fran Head
- **ACCOMMODATION** Howard Richardson & Vicki Bresnan
- **PRE-POST CONFERENCE CAVING** Jay & Ross Anderson
- **PUBLISHING** Rebecca Newton
- **SPELEOLOSPORTS/ACTIVITIES** Ian Collette
- **PHOTO COMPETITION** Ida Newton & Norman Poulter OAM
- **PARTNERS/CHILDREN/TOURIST INFO** Fran Head



Fran



Ian



Ross



Howard



Vicki, Ida, Rebecca & Jay



Norman

Augusta & Margaret River Caves and Region History



Brian Combley
CLINC
(Cavers Leeuwin Inc.)

Cape Leeuwin and Cape Naturaliste

- Named visited and recorded by the the Dutch in 1622 and French in 1772.
- Mathew Flinders charted Cape Leeuwin in 1801.
- Augusta was the third settlement in W.A. in 1830 after Albany in 1826 & the Swan River Colony in 1829.

Port Augusta

- Used by whalers and sealers for fresh water before and after settlement.
- Some of the first residents
  - Captain John & Georgiana Molloy.
  - The Bussell brothers John & Alfred.
  - The Turner family.
  - The Allnutt family.

H. M. Ommanney reports cave 1840

- A surveyor based in the South West.
- On a trip from the new town of Busselton to the western edge of the Leeuwin Naturaliste Ridge, reported finding a cave.
- It is assumed it was one of the Yallingup caves, possibly Northcote Grotto or the Seven Sisters.

Deepdene Cliff's

- Deepdene cliffs were adjacent to the Turner property and were known of at the time. Some small caves exist in the cliff face
- Early mariners called in for fresh water near Deepdene it was visible from the ocean.

Ducalup or Deepdene on Turner Brook



Cave Discovered in Augusta 1848

- Mr G Turner found two caves about 12 Kilometres North of Augusta.
- Caves were Old Kudardup and AU 10
- Caves explored by Edward Hester.

Caves Reported in the “Inquirer”

- **Reported in the Inquirer of November 1848 by Edward Hester.**
- **The find was attributed to Turner in the article.**

Cave Pearls Old Kudardup



20/01/2003

Pillars described in the newspaper article



20/01/2003

Bussell's Moved to Wallcliffe

- **Augusta found not to be suitable for farming.**
- **Bussell's moved to Ellensbrook in 1857 and later to Wallcliffe about 1865.**
- **House Cave discovered about this time (Wallcliffe).**

House Cave later called Wallcliffe

- Visitors were encouraged by the Bussell's.
- Several reports are recorded in the West Australian newspaper of visits.
- Albert & Fanny Bussell's initials inscribed on the flow stone in Wallcliffe Cave.

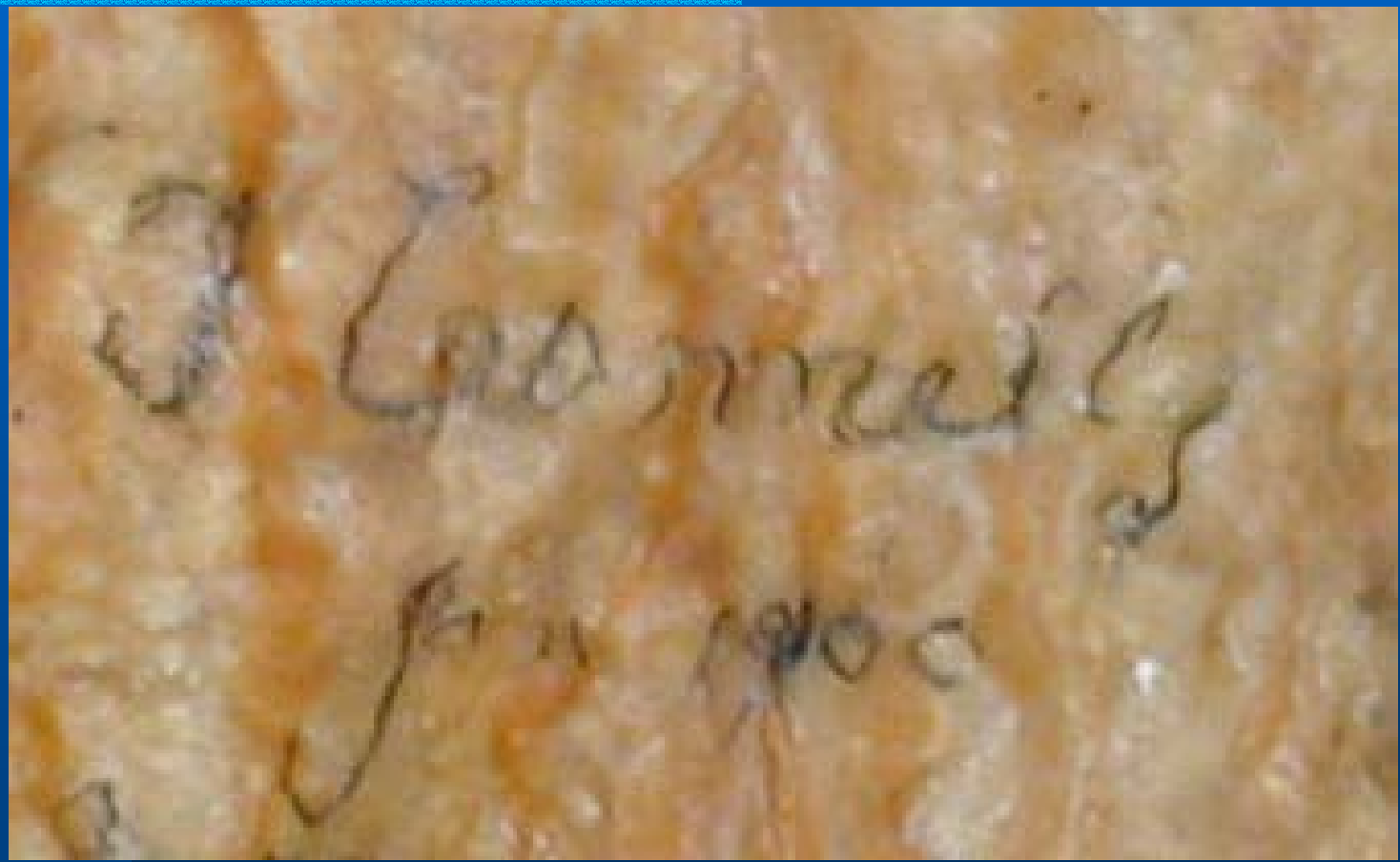
Early Graffiti

Albert and Fanny 1882





Tim Connelly



Warrawerrie or Blackboy Hollow

- Discovered by John Bussell in the late 1860's.
- Bussell encouraged visitors.
- Enlarged opening and installed a ladder of sorts.
- Visitors accommodated at his house.

Moondyne or Coronation Cave

- Discovered by Fred Grange in 1879.
- Used by Western Australia's only bush ranger "Moondyne Joe" or Joseph Bolitho Johns.
- Opened as a public cave on the coronation day of King George V.
- Was called Coronation Cave.

Lake Cave Doline

- In 1867 Fanny reported to her family the existence of the Lake Cave Doline found whilst searching for lost cattle.
- The family did not believe her as it could not be located again.

Mammoth Cave

- Reports of the cave in 1895.
- Tim Connelly credited with the first exploration.
- Mammoth was known as the "Dawn of Creation Cave".
- The name was possibly because of fossils found in the cave.

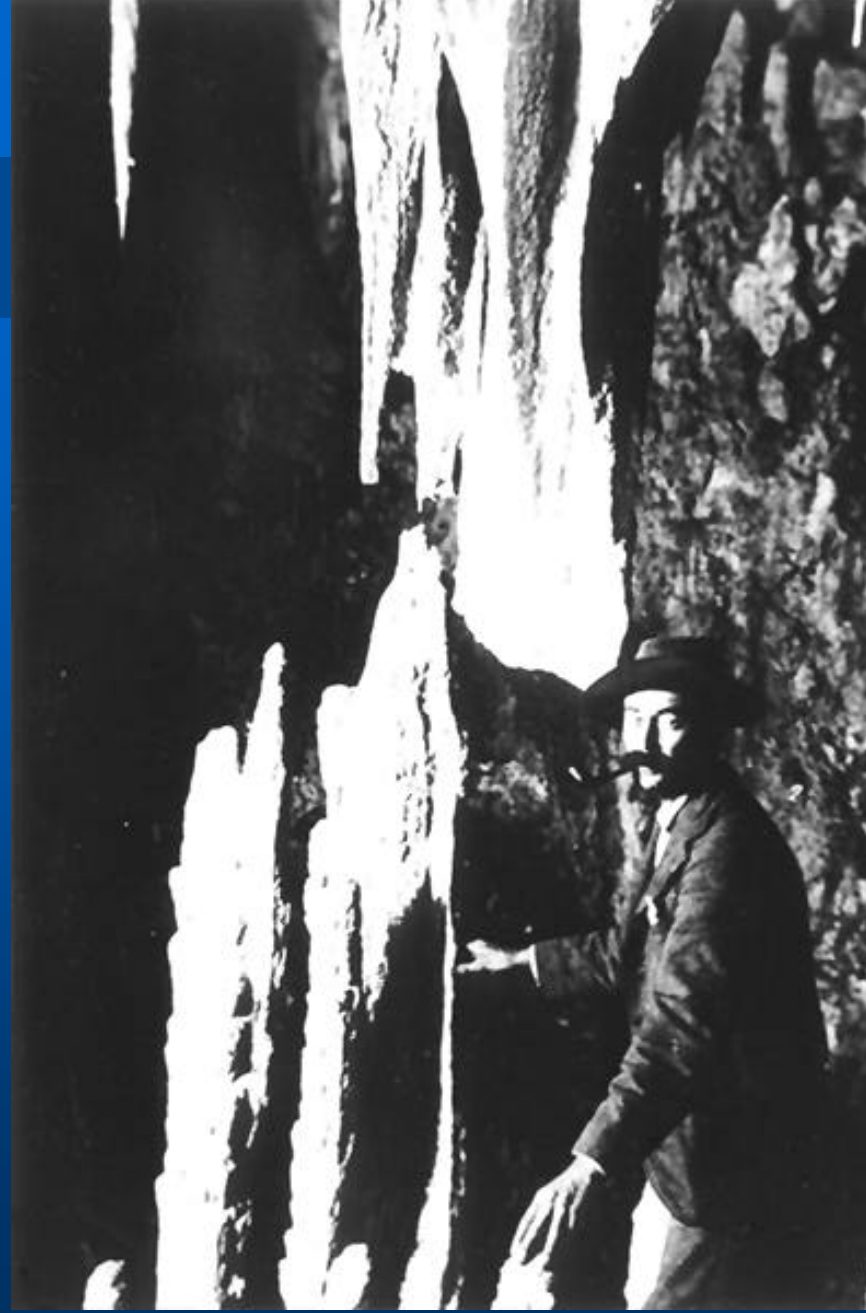
Mammoth Cave Early 1900's

Photo thanks to Rauleigh Webb



Tim Connelly

Photo thanks to
Rauleigh Webb



Yallingup Cave

- Discovered in 1899 by Edward Dawson when searching for lost horses.
- Explored by Dawson and two friends Seymore and Curtis.

Yallingup or Ngilgi Cave

- First tours conducted 1900.
- Edward (Ned) Dawson became the sole guide at Yallingup for the next 37 Years.

Tim Connelly rediscovers Lake Cave Doline

- **Tim Connelly, C. Price Conigrave and Wm. A. Nelson relocated the Lake Doline and found the Lake Cave entrance.**
- **They lowered themselves down into the doline to explore in November 1897, the cave was named "Queen of the Earth" by Connelly.**

Lake Cave Doline





Suspended Table Lake Cave





Connelly also explored other caves

- **Museum, Calgardup, Bride's and Golgotha caves were probably first explored by Connelly.**
- **Connelly passed away in 1933.**

Report Commissioned 1900

- From the Chief Inspector of Lands
- To the Undersecretary of Lands
- Completed by Mr C. Erskine May
- Re the caves in the Margaret River Region.
- After pressure from a local resident Mr Brockman.

Perth 26th of February 1900

Chief Inspector of Lands

- **Mr C Erskine May prepared the report after visiting the caves of the region.**
- **Reported that vandals were already at work defacing these marvellous and beautiful geological features.**

Description of the Report

- **A report on the proposed management of the caves on the Leeuwin Ridge.**

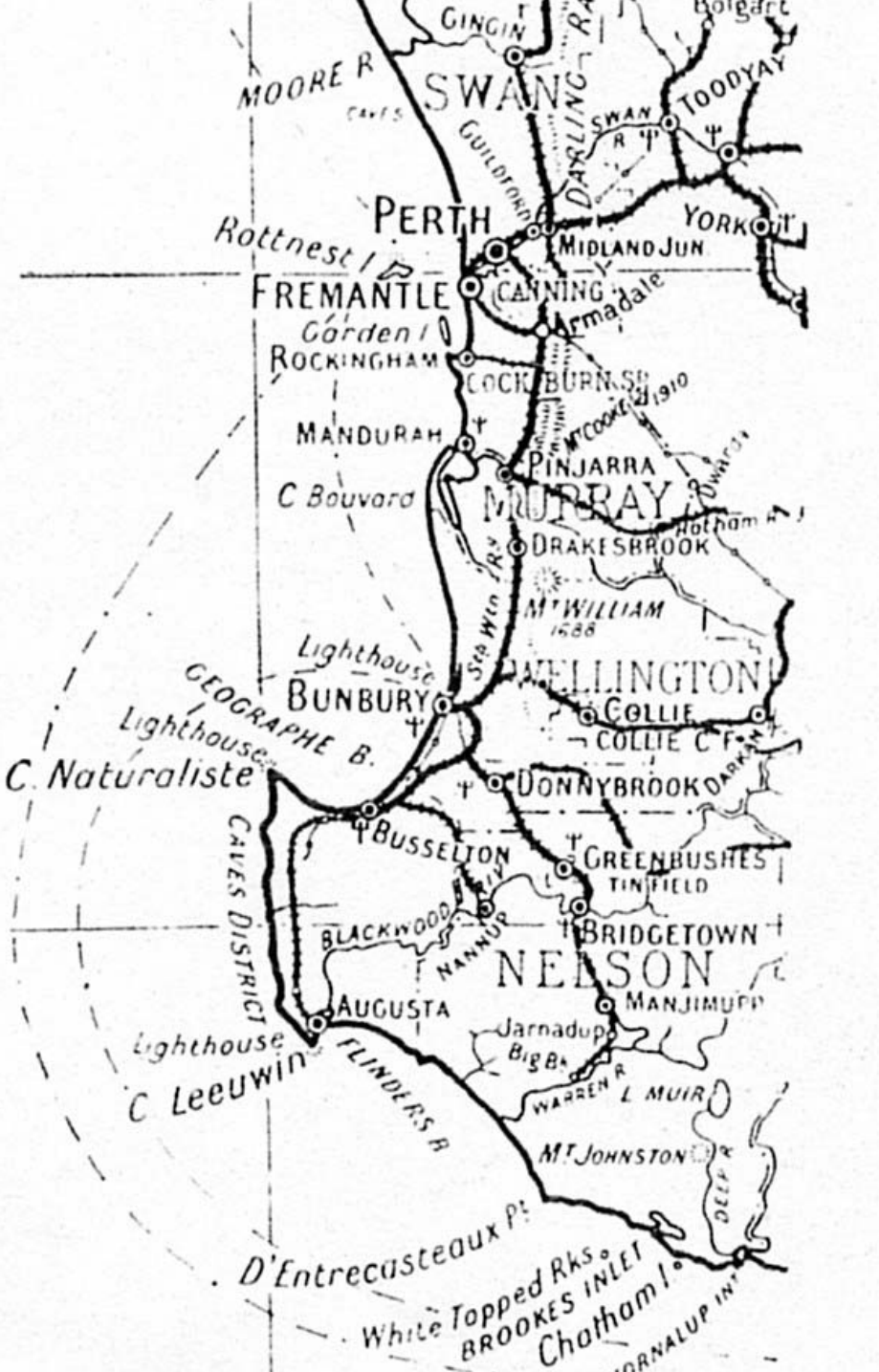
Some details of the report

- **It is interesting that conservation was recommended in 1900 due to damage being done to these caves.**
- **I will dwell on some of the detail of this report.**

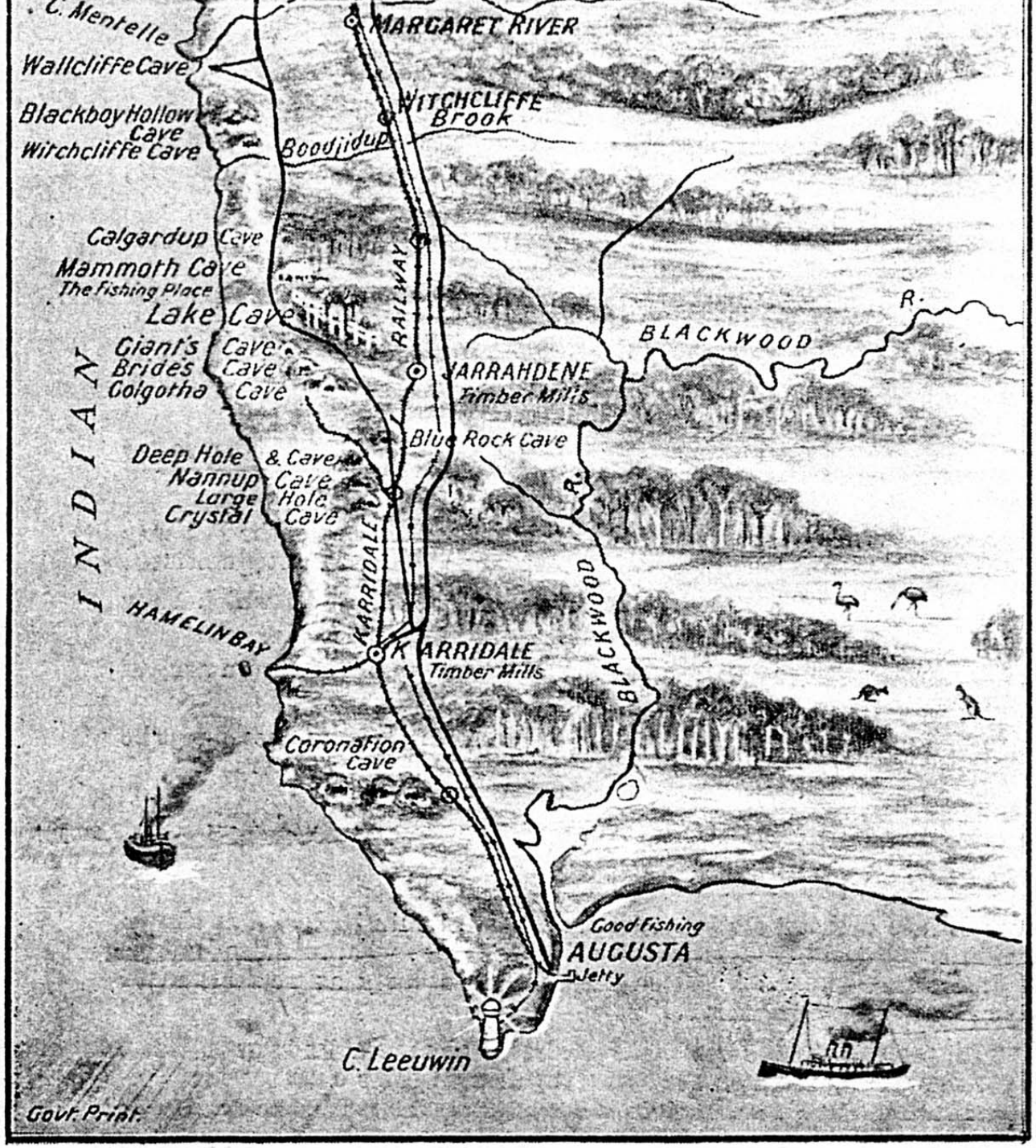
How to Save the Caves.

- Road from Busselton must be upgraded.
- A hospice for accommodation will be needed.
- Entrances ought to be guarded by iron gates.
- A caretaker should be appointed.

Where the Caves Are



Where the Caves Are



20/01/2003

C. Erskine May described the region as:

“A Gem of a Holiday Place”

A Gem of a Holiday Place

- Some of the features of the region.
- Cape Leeuwin.
- Hardy Inlet and the Blackwood River.
- Flinders Bay.
- Margaret River.
- Leeuwin Light House.

Cape Leeuwin



Blackwood River Hardy Inlet and Molloy Island



Flinders Bay



Mouth of the Margaret River



Leeuwin Light House & Historic Water Wheel



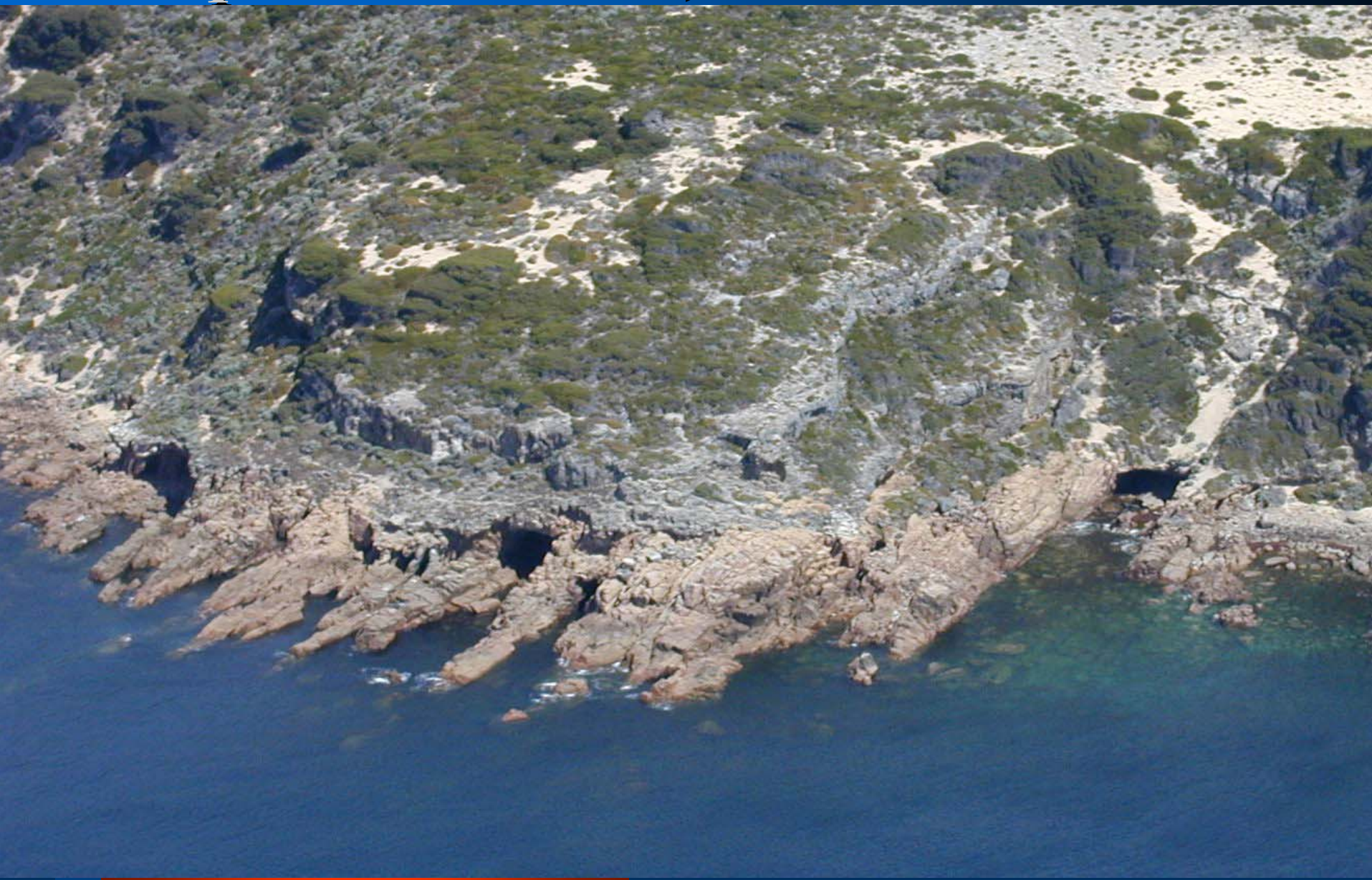
Other Features of the Ridge

- Cape Naturaliste.
- Bunkers Bay.
- Canal Rocks.
- Sugar Loaf Rock.

Cape Naturaliste, Bunkers Bay



Cape Naturaliste, Sea Caves



Canal Rocks



On with the History

Cave Discoveries

C. E. May specifically mentioned

- **Wallcliffe.**
- **Blackboy Hollow.**
- **Calgadup (Calgardup).**
- **Boodjidup (Witchcliffe).**
- **Nindup (Giants).**
- **Deepdene.**
- **Crystal (Recommended Closing Off).**

The Devils Hand Wallcliffe Cave from the May Report



20/01/2003

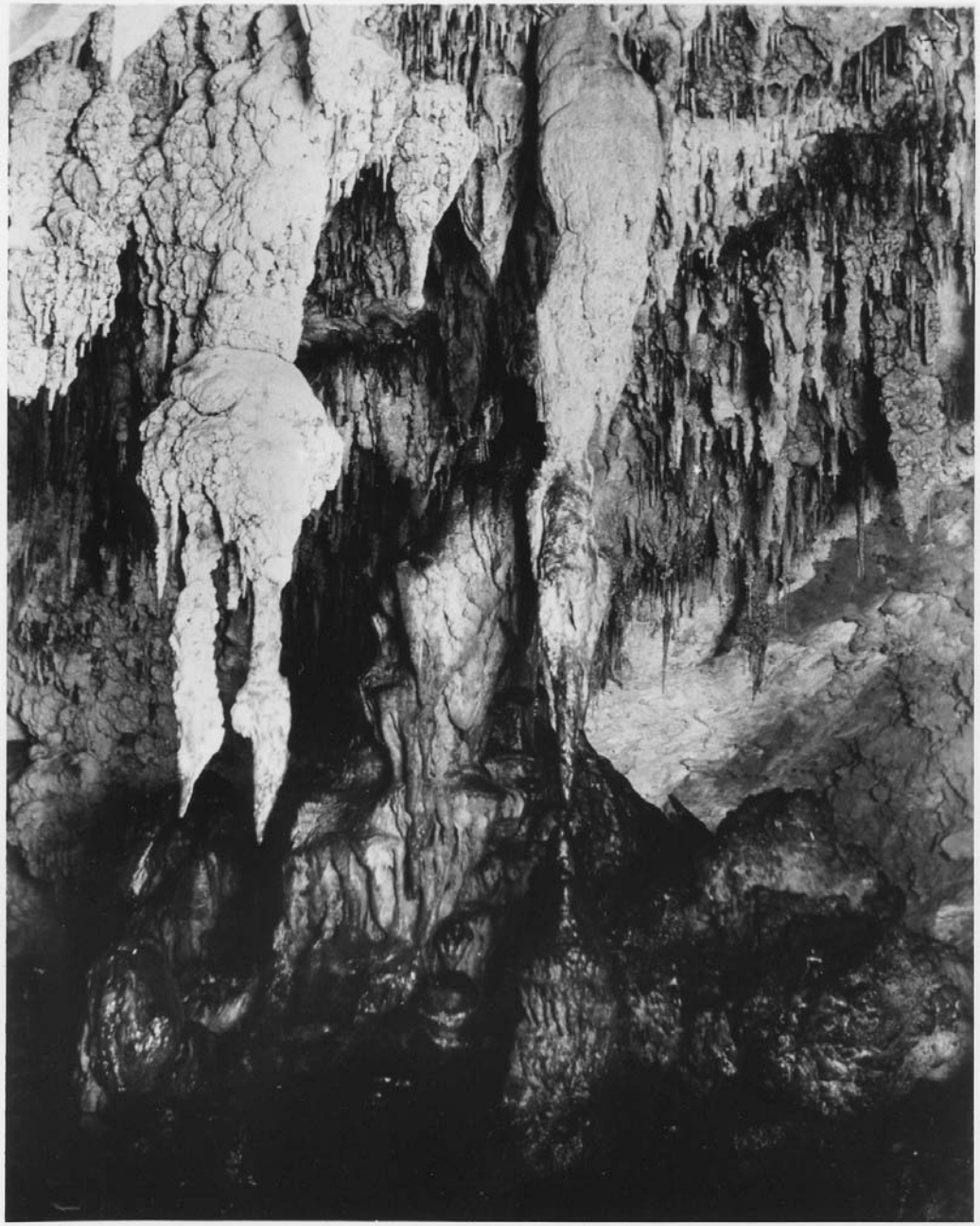
The Devils Hand Wallcliffe Cave



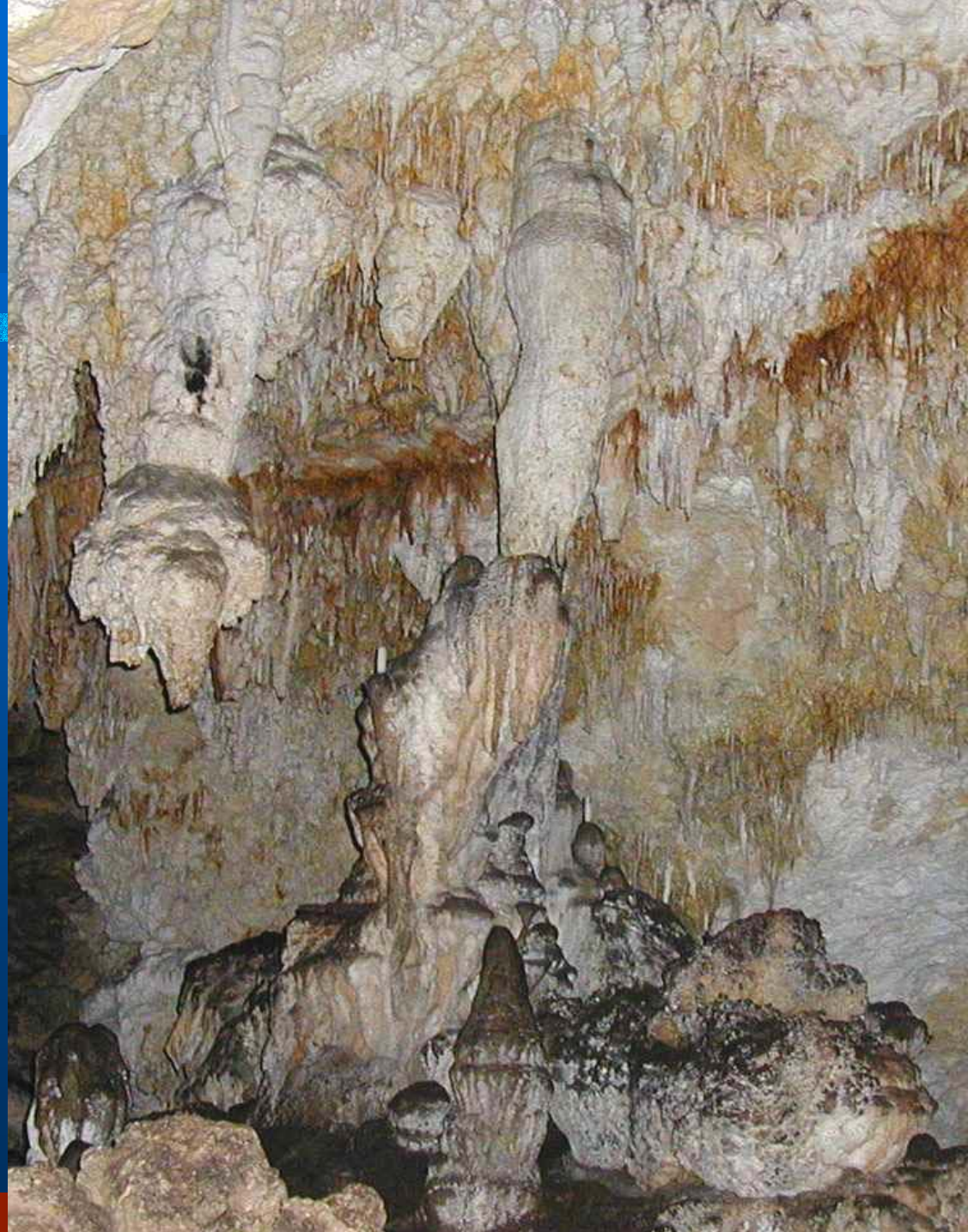
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The Poultry Show circa 1900 from the May Report

20/01/2003



The Poultry Show now



20/01/2003

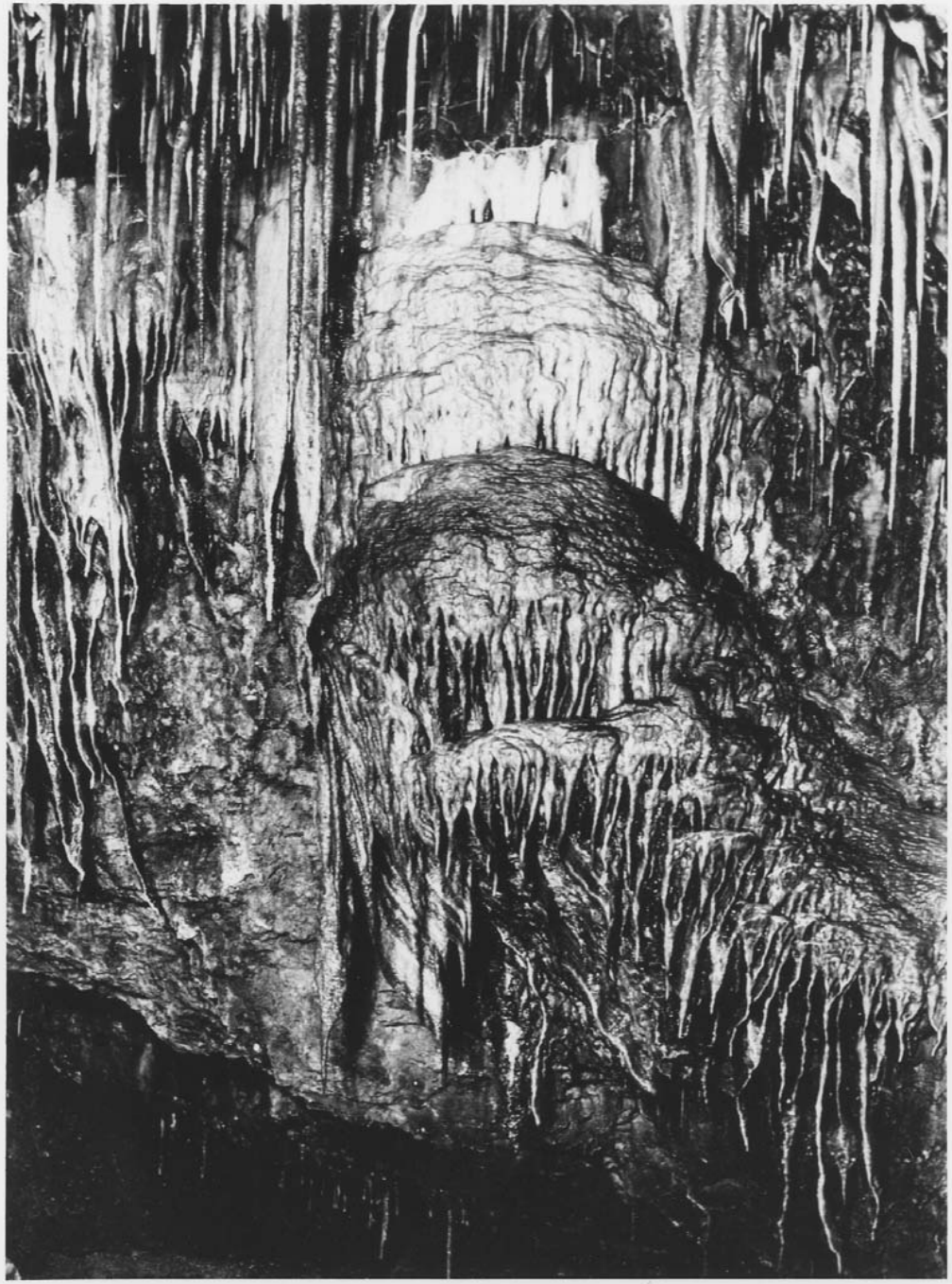




Warrawerrie or Blackboy Hollow

- Discovered by John Bussell 1880's.
- Bussell's installed a ladder and enlarged the opening.
- A comment was made in the report that this was done to allow the Aldermen to visit.

Queens Crown Blackboy Hollow from the May Report

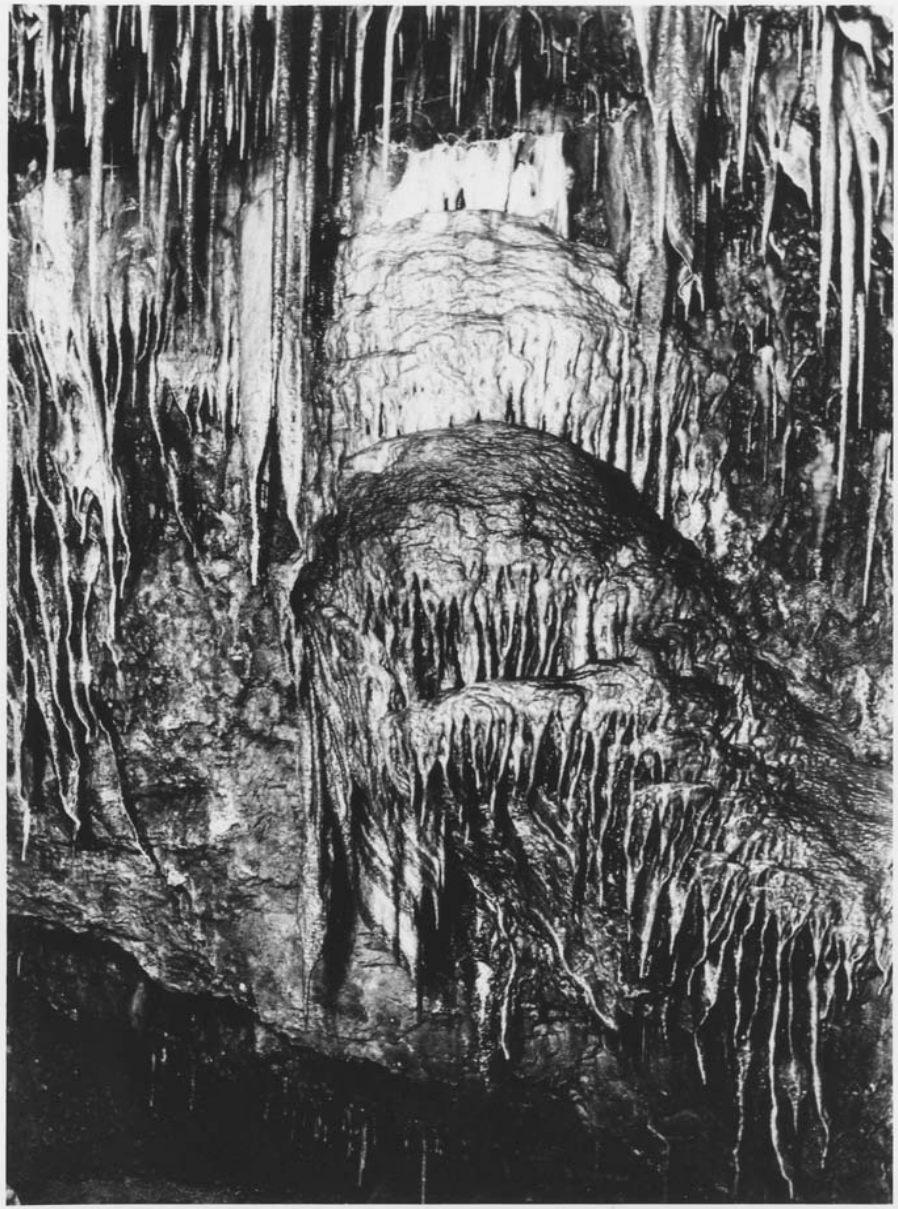


20/01/2003

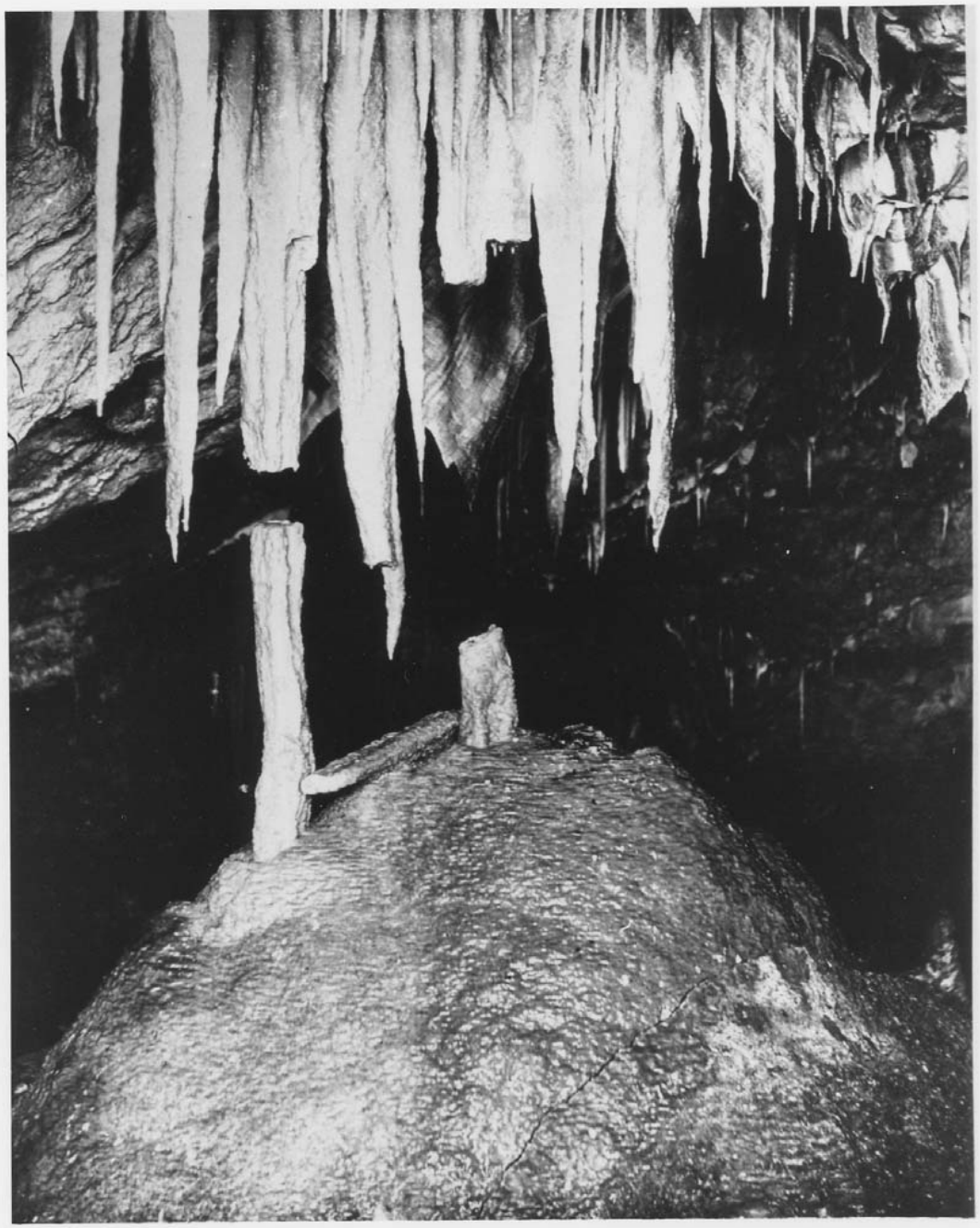
Queens Crown Blackboy Hollow





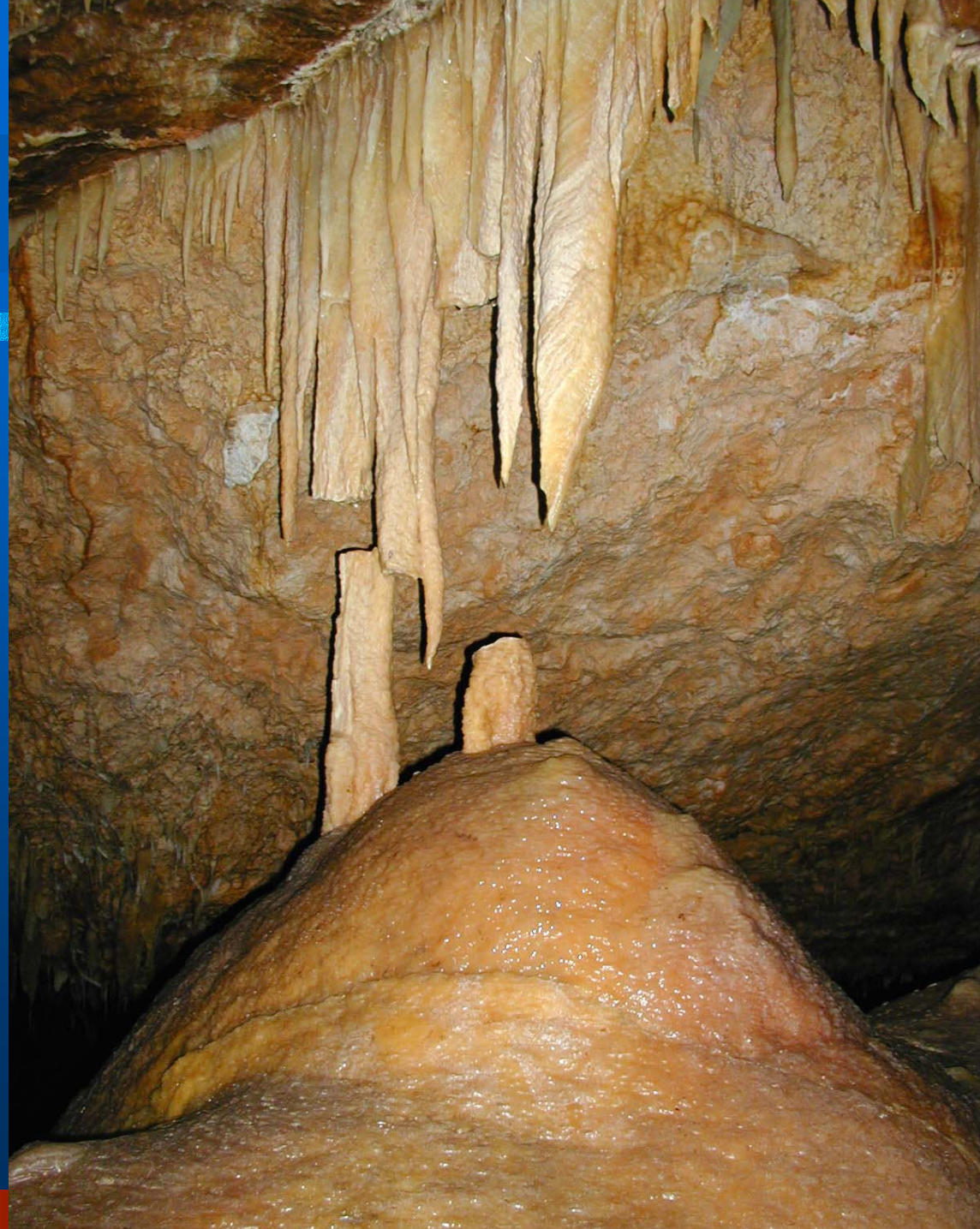


The Broken Column 1900



20/01/2003

The Broken Column

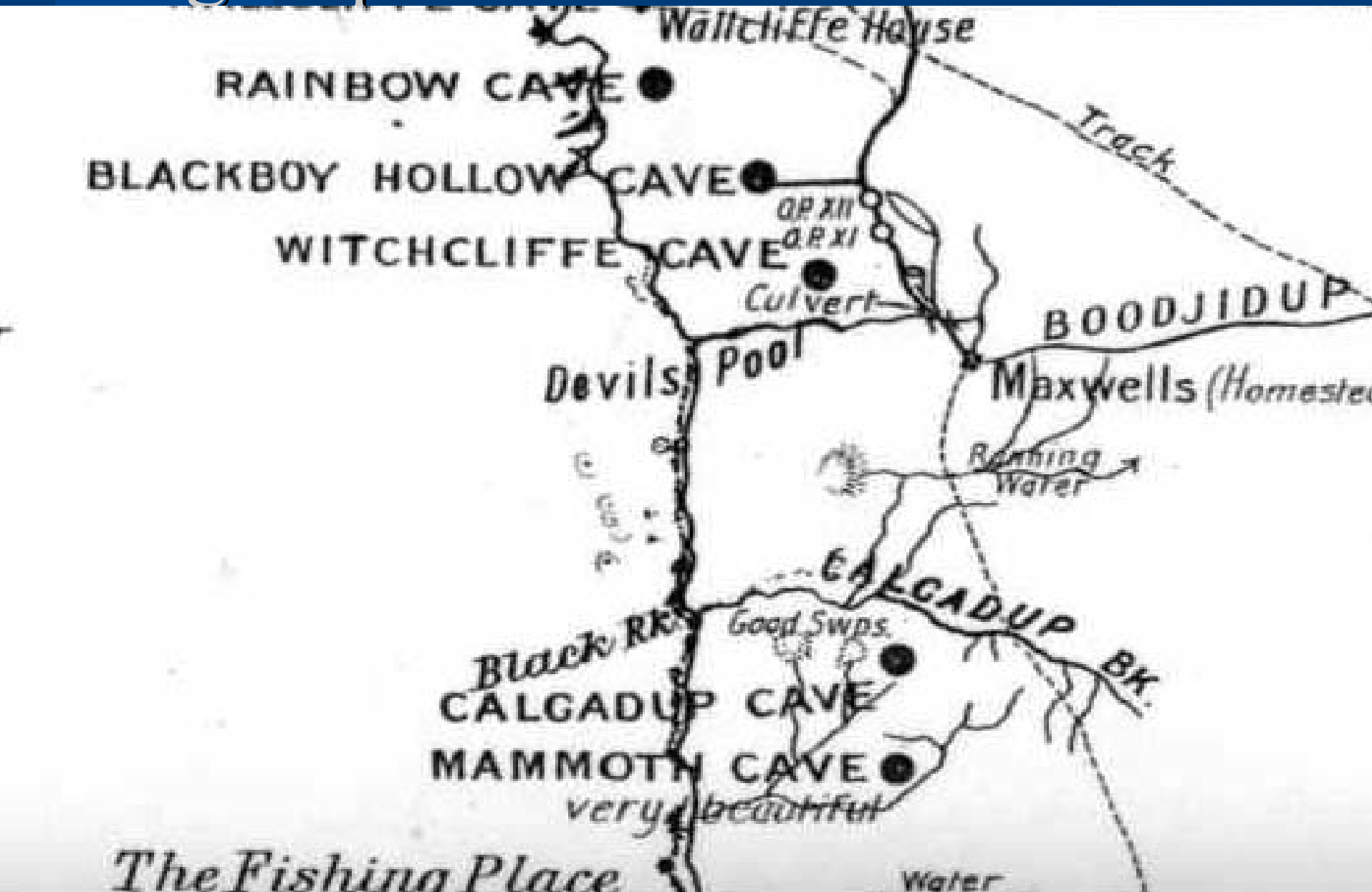


20/01/2003

Karri Tree Formation Blackboy Hollow



Calgadup Cave



Suspended Dome Calgardup



20/01/2003

Spear in the mud at Calgardup



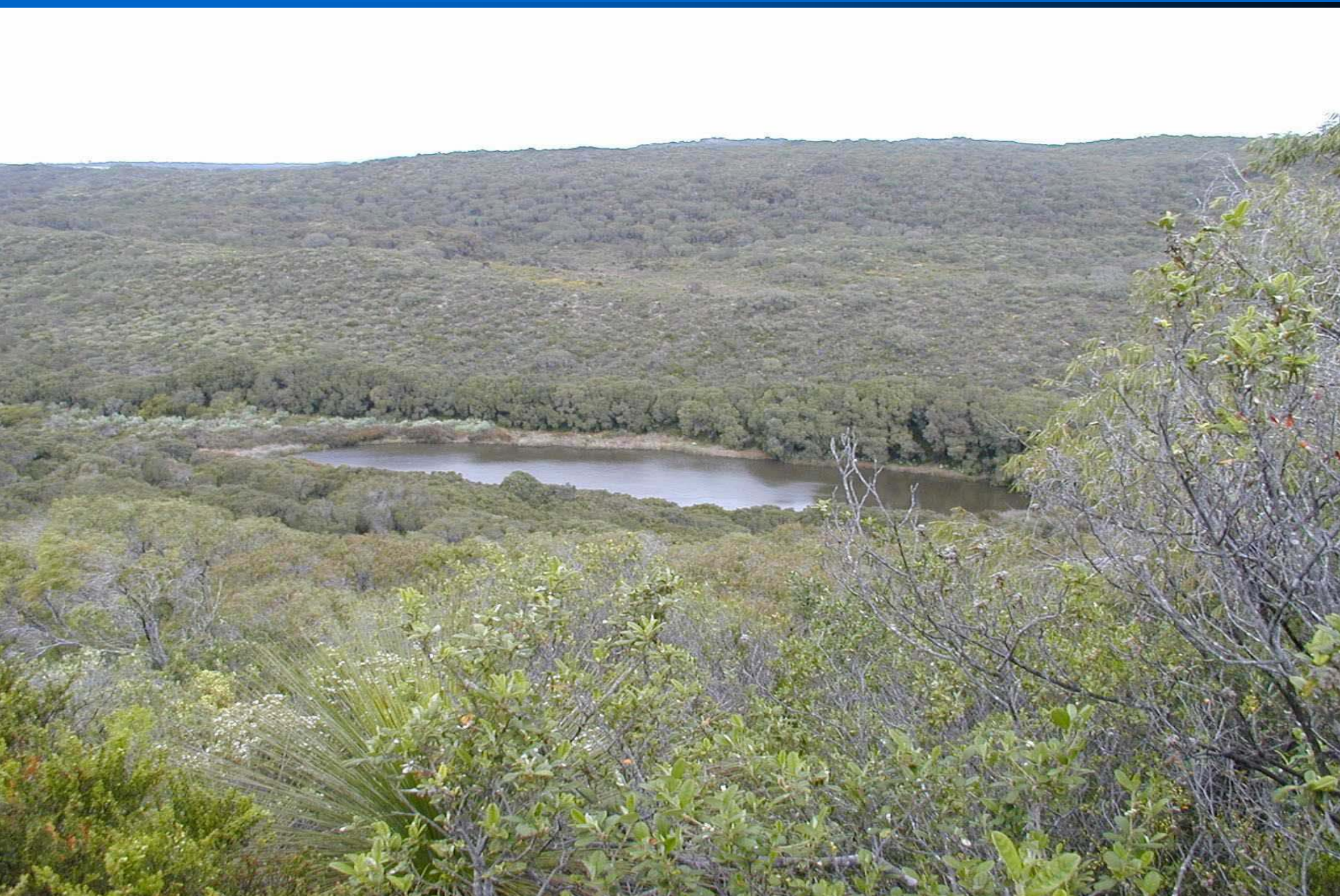
Devils Pool and Witchcliffe Cave

Devils Pool was a permanent source of water on the track up to Bunbury & Perth so it was not long before the Witchcliffe cave was discovered.

Devils Pool



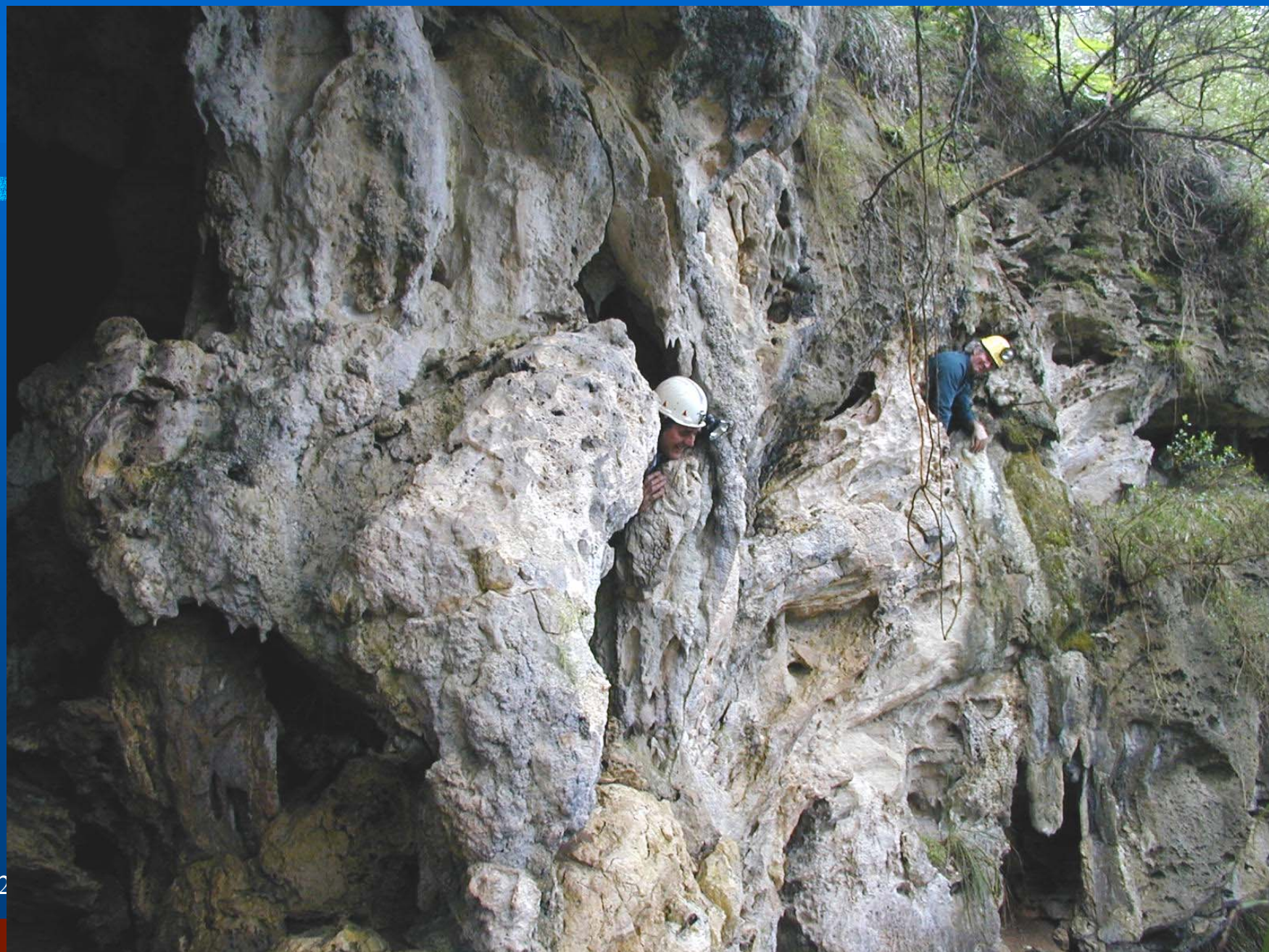
Devils Pool from Witchcliffe Cave



Witchcliffe Cave Entrance



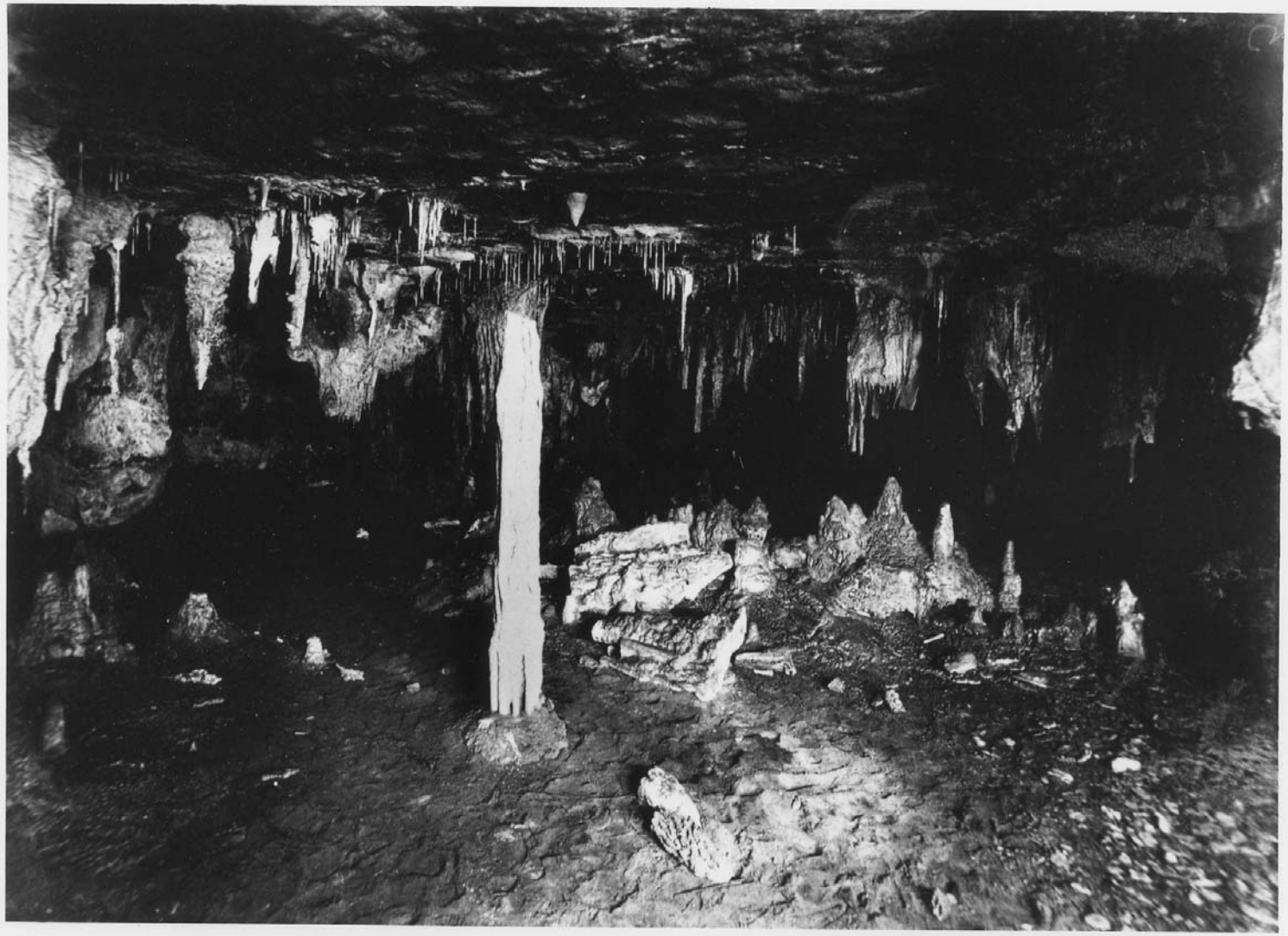
Witchcliffe Cave & CLINC



Star Chamber



Lots Wife



Lots Wife

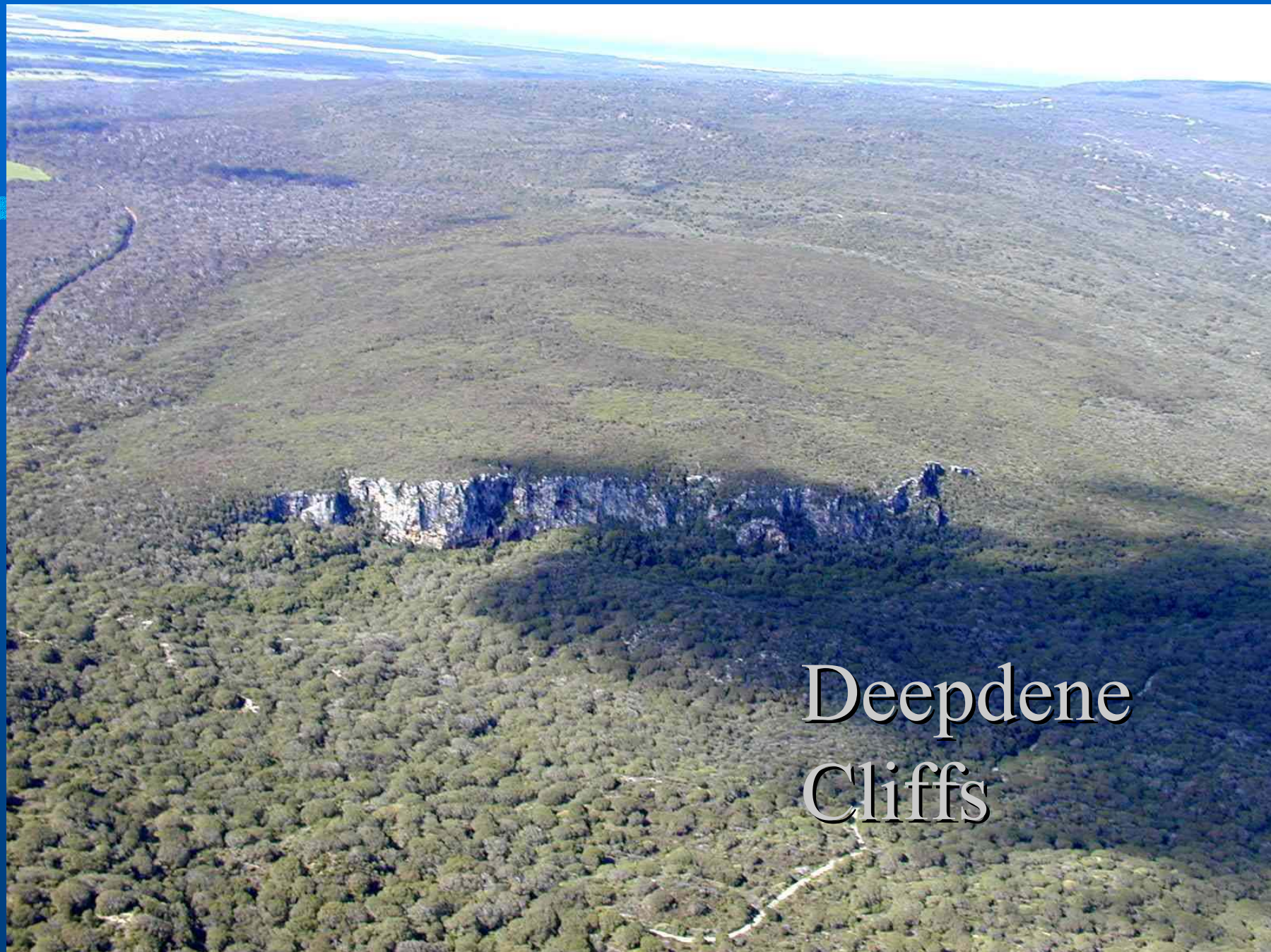


Pipes of a Cathedral Organ



The Mob Inside CLINC at Witchcliffe



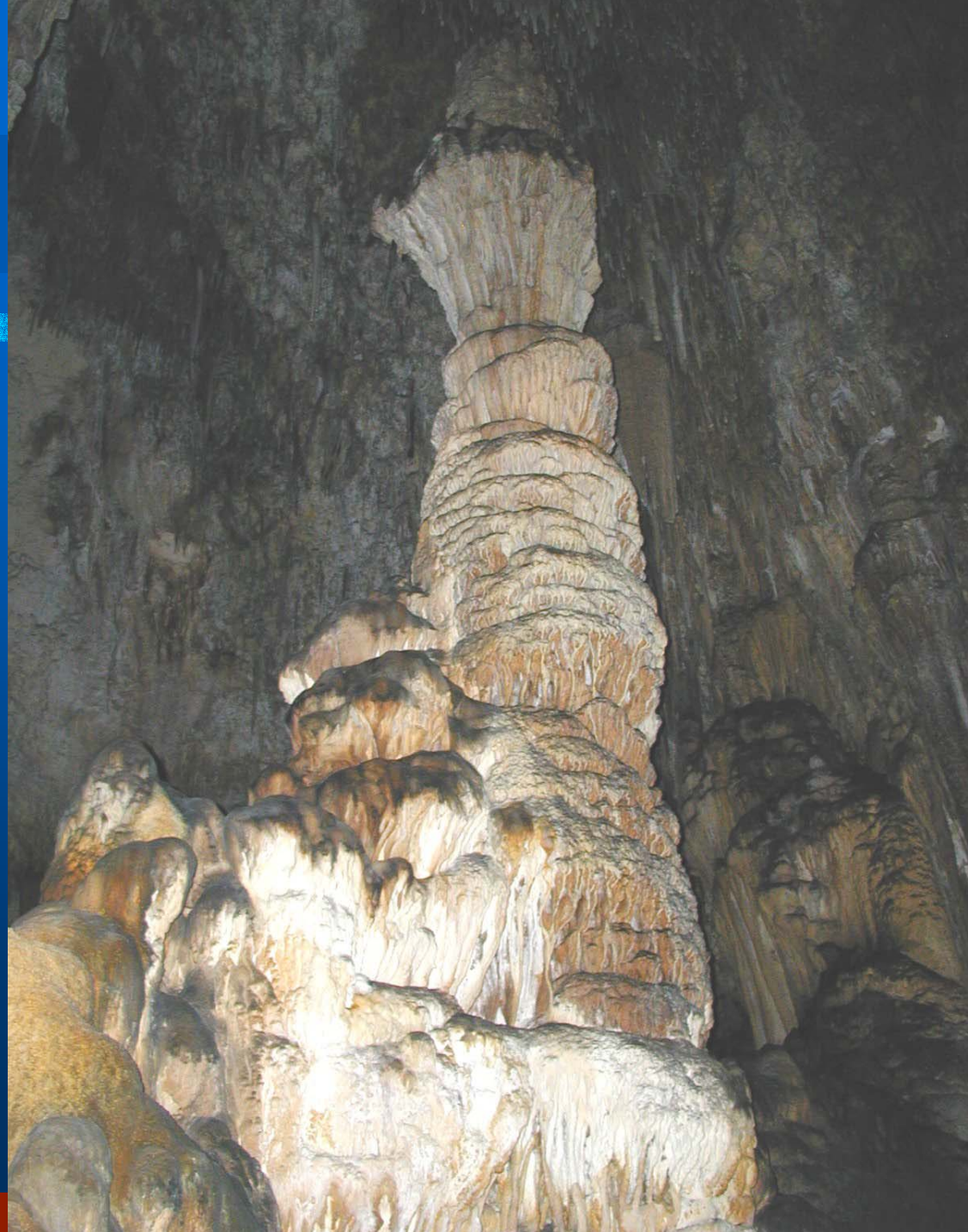

Deepdene
Cliffs

Deepdene



Crystal Pillar Deepdene Cave

20/01/2003



Column Deepdene



20/01/2003

Cavers Leeuwin Inc

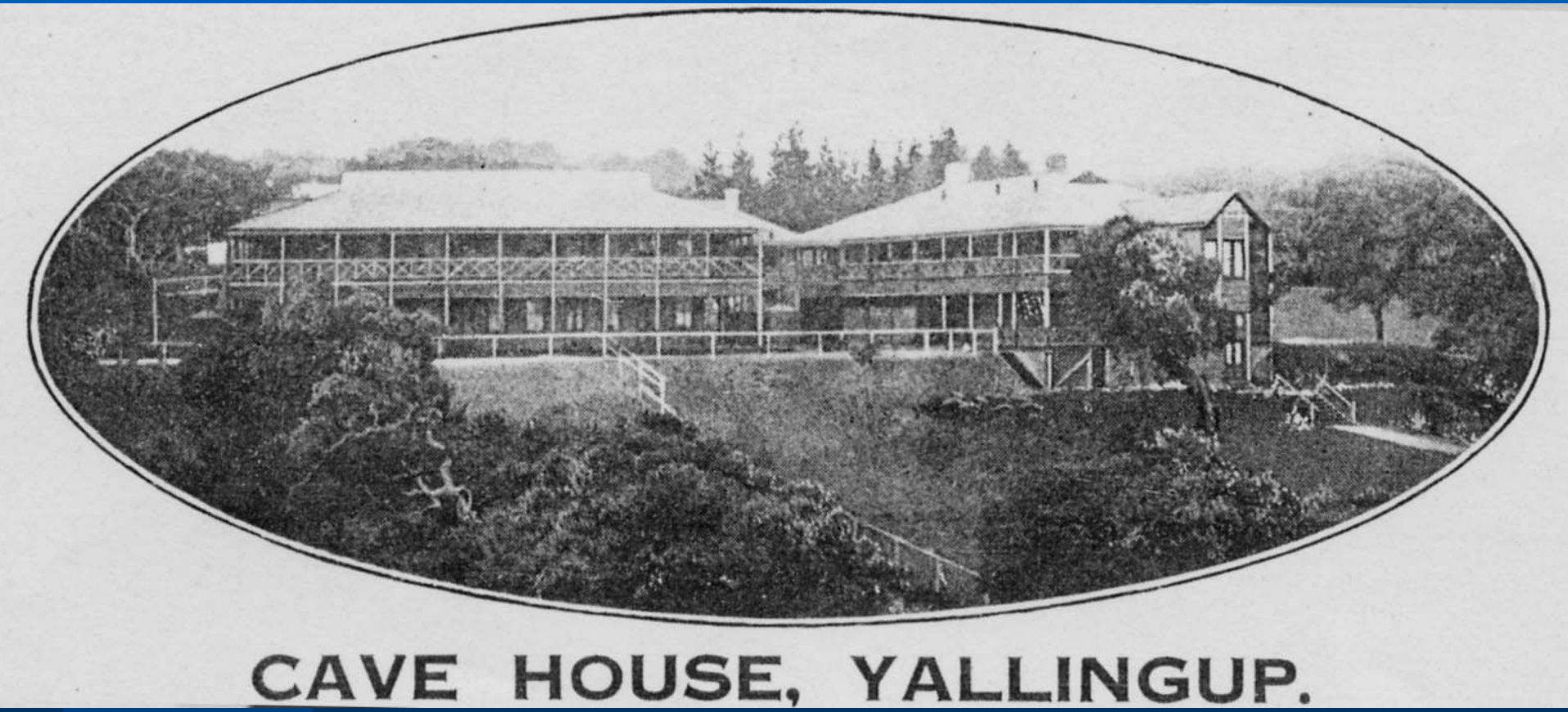
Connelly Appointed as Guide

- As a result of the C. E. May report Tim Connelly was appointed as a guide and caretaker on a salary of $100 (Fifty Pounds) per annum.
- Gates and Locks were installed.
- Magnesium Flares and Blackboy Torches were no longer used.
- Cave's Board formed.

Strongs Cave

- Recorded by Marmaduke Terry in a survey in 1900.
- Many other caves in the area recorded around this time.
- Terry married Filumina Bussell on St Valentines day 1900 about the time he was completing his survey.

Cave House was built in 1903



CAVE HOUSE, YALLINGUP.

Cave House in the 20's



Cave House



20/01/2003

Cave House Burns Down

- **In 1935 a disastrous fire swept through Cave House.**

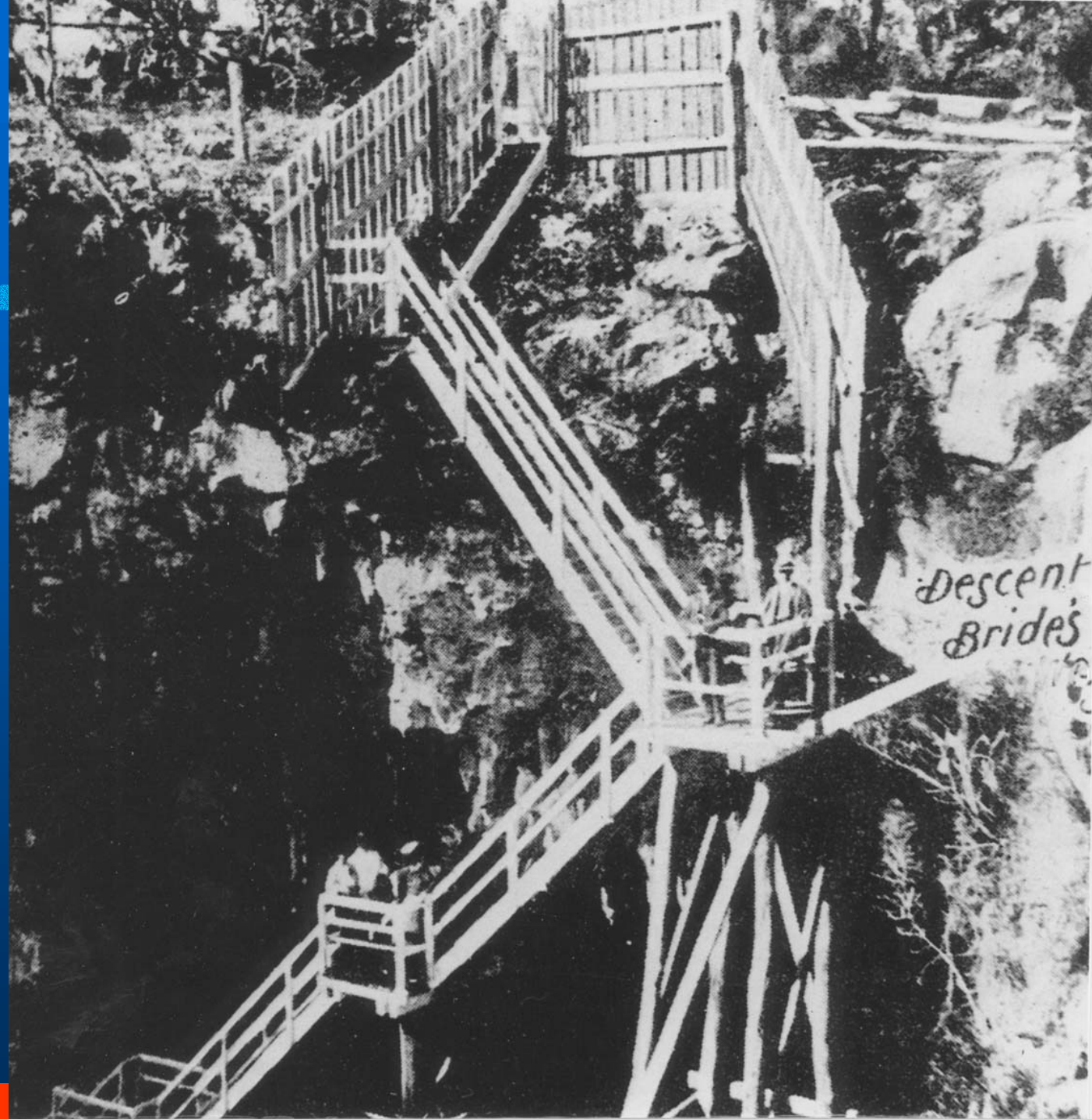
Cave House Reconstructed



Cave House Today



Bride's Cave Descent



20/01/2003

Jewel Cave

- Solution Pipe found by William Ellis in 1908 but not entered, called Windy Hole.
- Discovered by Cliff Spackman, Mr & Mrs Jack Burrows, Harley Webster and Tony Tapper in 1957.
- Jewel Cave will be covered in a specific presentation by Lloyd Robinson who first explored it in 1958 with Lex Bastian and Cliff Spackman.

Jewel Cave



Jewel Cave

Jewel Cave

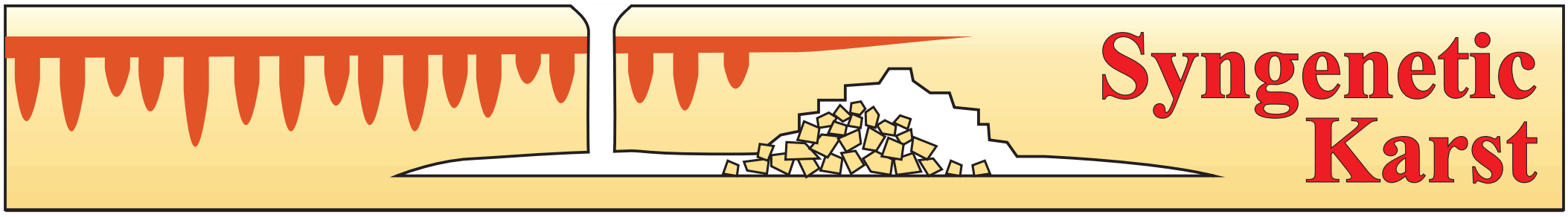


The History from the 1920's on is well recorded in SRG and WASG documentation.

Even today Witchcliffe Cave is not locked and is being used as a camp site. Many other caves still remain unlocked.

Thanks to Jeff Murray of DOLA

- **Without Jeff's assistance much of the material used would not have been found or confirmed to be accurate.**
- **Copies of the Ommanney and May reports will be included with the conference notes.**



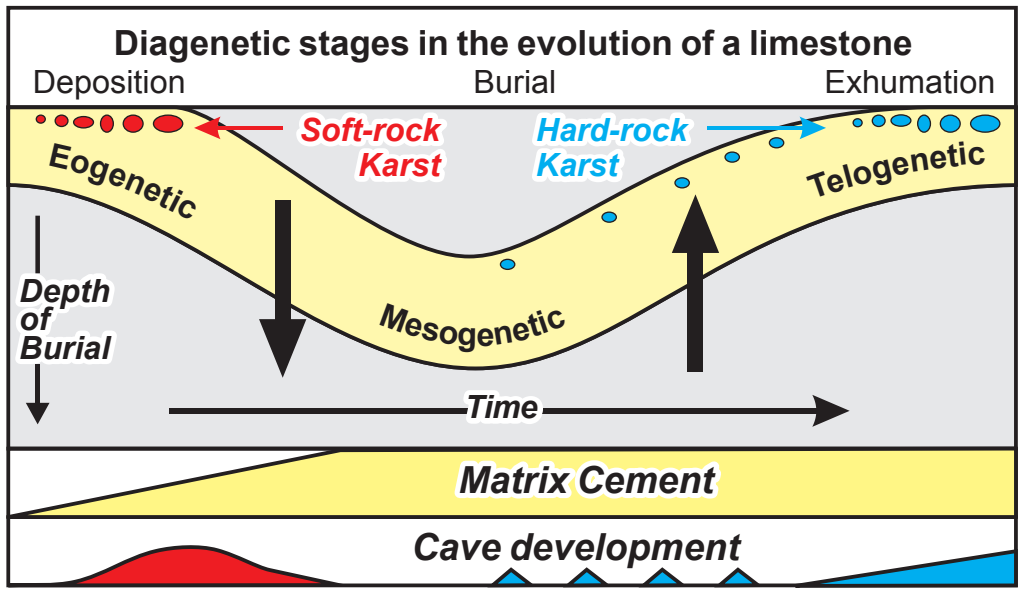
Syngenetic Karst

Terminology & General Concepts

Syngenetic Karst

In newly-formed calcareous sediments, the cementation that consolidates the sediment into a rock can occur at the same time as dissolutional development of karst cavities.

This process of simultaneous solution and induration is called **syngenetic karst.**



Terminology - Soft-Rock Karst

The field of **Soft-rock Karst** has several terms which deal with related and overlapping concepts. In all cases we are dealing with features in soft, poorly cemented sediments.

Syngenetic karst (Jennings, 1968) has been applied to recently formed karst features in sediments that were being cemented at the same time as the dissolutional cavities formed.

Early syngenesis is the stage prior to signif-icant cementation. It involves soil development (including calcrete hard-pans), and deeper solution with small-scale brecciation and subsidence structures, but the sediment is too soft to support large cavities.

Late syngenesis begins when the sediment is sufficiently cemented for larger cavities (caves) to form. However, the limited strength means that roof collapse will be common.

Soft-rock Karst is a more general concept that includes both early and late syngenesis, and also more mature sediments that have not been deeply buried and indurated, but in which the early cementation is essentially complete. In addition to the dune limestones, examples of soft-rock karst include the Cretaceous Chalk of Europe and the Tertiary (mainly Miocene) marine calcarenites of Australia.

Terminology - Diagenetic stages.

Eogenetic diagenesis (Choquette & Pray 1970) refers to processes affecting recently deposited sediments prior to deep burial . The processes include cementation and solution (with brecciation) by meteoric waters and replacement of aragonite by calcite.

Mesogenetic diagenesis starts after the sediment is buried; and for limestones involves further cementation, re-crystallisation and pressure solution (e.g. styolites)

Telogenetic diagenesis occurs after uplift and erosion returns the limestone to the surface where meteoric waters can dissolve the lime-stone and form "classic"(hard-rock) karst.

Early diagenetic effects can be preserved within later diagenetic textures. These include paleo-karst cavities, infills and breccias.

Suggested usage

Syngenetic Karst is best used for modern or recently-formed karsts in soft calcareous sediments.

Eogenetic Karst is better kept for discussion of paleokarst features associated with eogenetic diagenesis in the geological past.

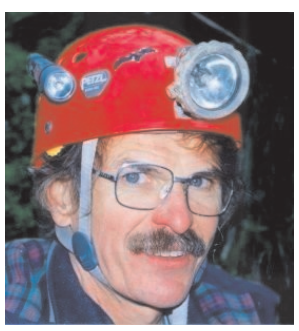
References

Choquette, PW., & Pray, LC., 1970: Geological Nomenclature and classification of porosity in sedimentary carbonates. *Am. Assoc. Petrol. Geol. Bull.* **54:** 207-250.

Jennings, JN., 1968: Syngenetic karst in Australia. *in* PW Williams & JN Jennings [eds] *Contributions to the Study of Karst.* Aust. Nat. Univ. Dept. Geogr. Pub. **G/5.**

Author: Ken G. Grimes,
Consultant Geologist,
Regolith Mapping, PO Box 362,
Hamilton, Vic 3300, Australia.

With acknowledgements to:
my co-worker, Susan Q White.
and to my predecessors: Lex Bastian, Alan Hill, Joe Jennings, and many other speleo-geologists.



Syngenetic Karst

Early Syngenetic Karst in Dune Limestones

Early syngenesis

In Early Syngenesis the sediment is too soft to support a cave roof.

Loose sand subsides at once into any incipient cavities, forming soft-sediment deformation structures.

Terra rossa or similar soils form at the surface.

At the base of the soil precipitation of carbonate forms a cemented and locally brecciated calcrete layer or hard-pan.

Early cementation about roots forms distinctive rhizomorphs or rhizocretions.

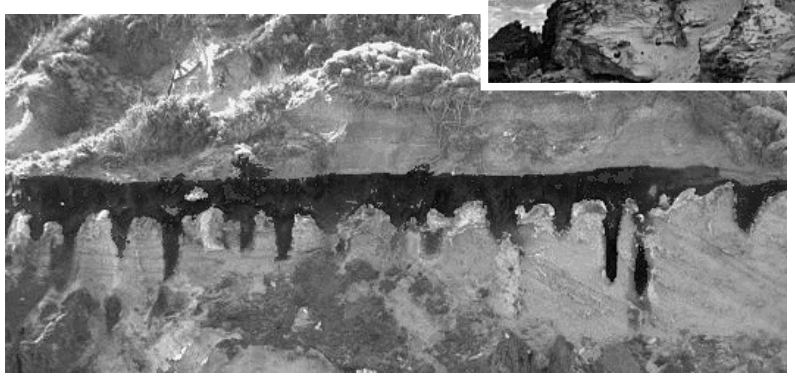
Small shallow caves can develop by subsidence of loose sand from beneath a cap-rock formed by the calcrete hard-pan.

Below the hard pan the downward percolating water becomes focussed to dissolve vertical "solution pipes", and simultaneously cements the surrounding sand.

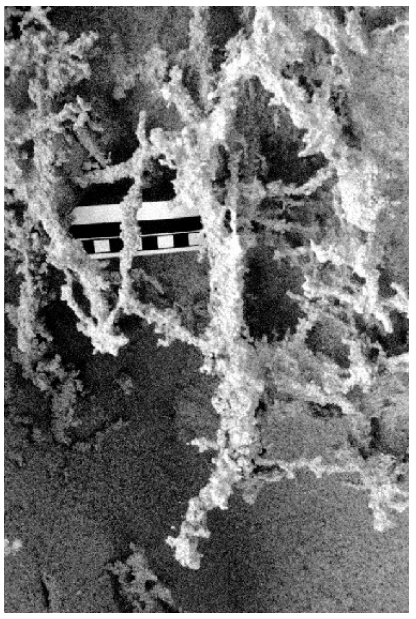
Eventually cementation is sufficient for caves to form - the **Late Syngenetic Stage.**



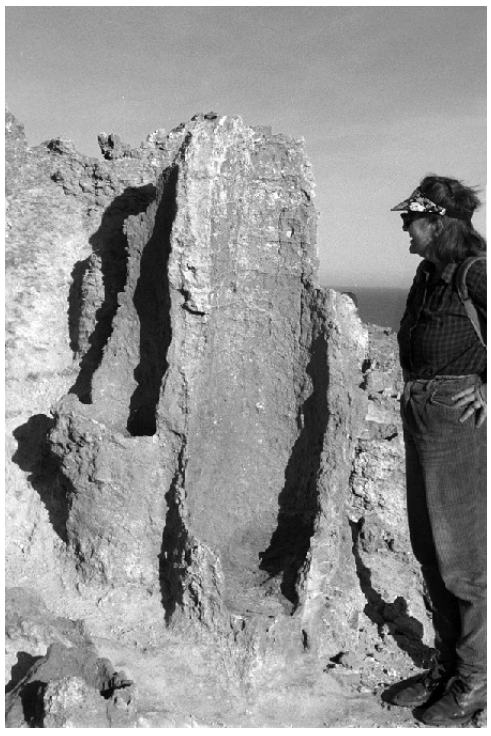
Calcrete hard-pan



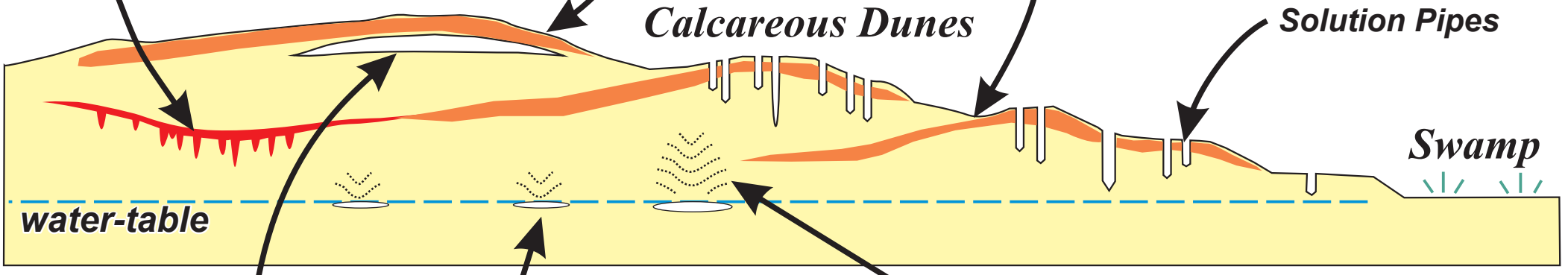
Paleosoil with filled pipes



Rhyzomorphs



Solution Pipes

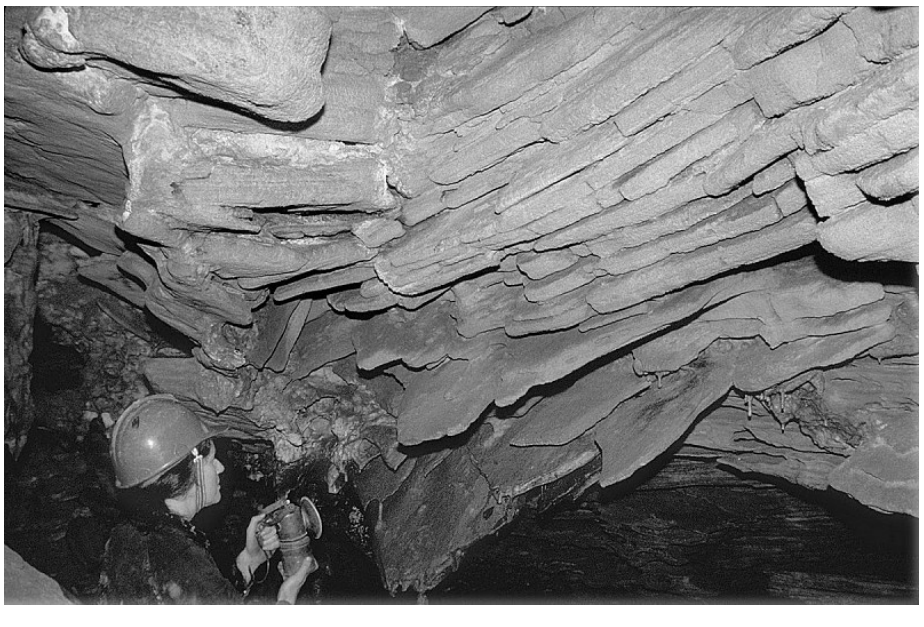


Initial solution at watertable does not form permanent caves.

Shallow caves under cap-rock



Subsidence structures & breccias



Syngenetic Karst

Late Syngenetic Karst in Dune Limestones

Late syngenesis

Late Syngenesis starts once the bulk of the rock is sufficiently hardened to support a cave

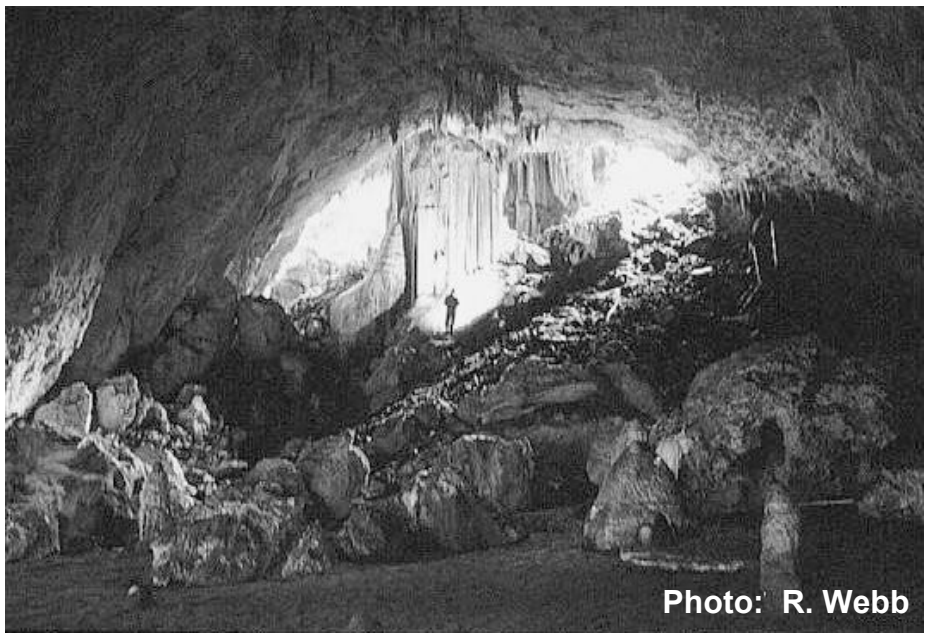
Mixing corrosion occurs where the percolation water meets the watertable; e.g. at the level of a nearby swamp - which also provides acid water.

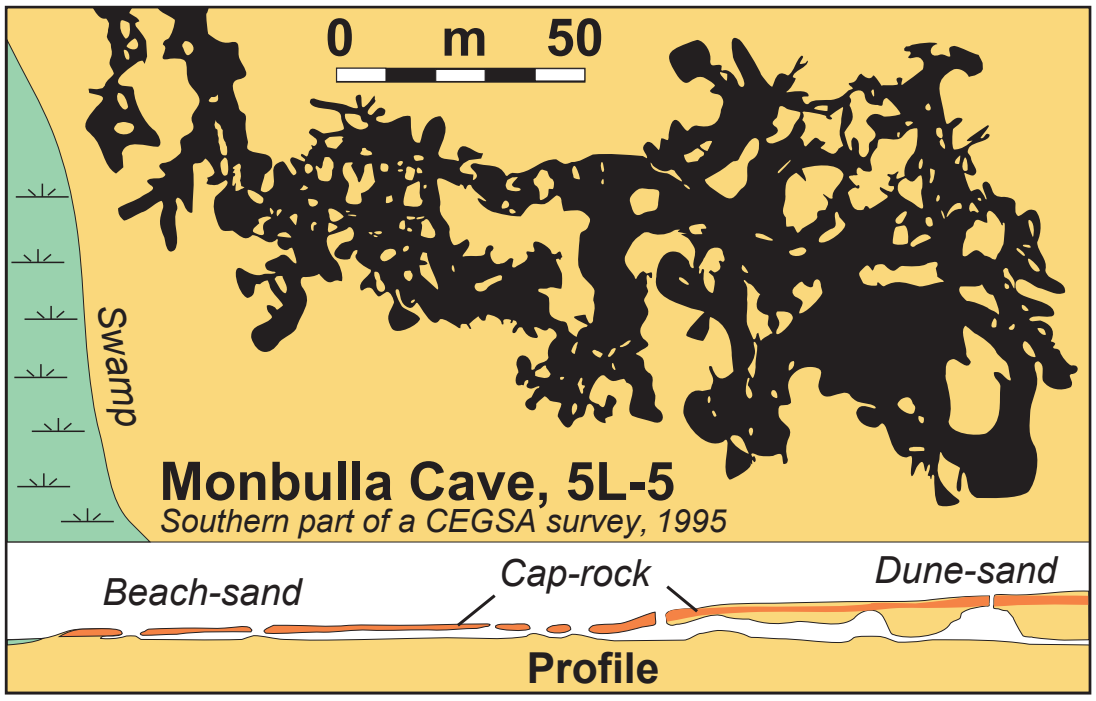
The uniform matrix porosity, slow moving groundwater, and lack of joint control means that directed linear conduits seldom form. Instead, horizontal maze cave systems of low, wide, irregular, interconnected chambers and passages form in the zone of maximum solution at the water table.

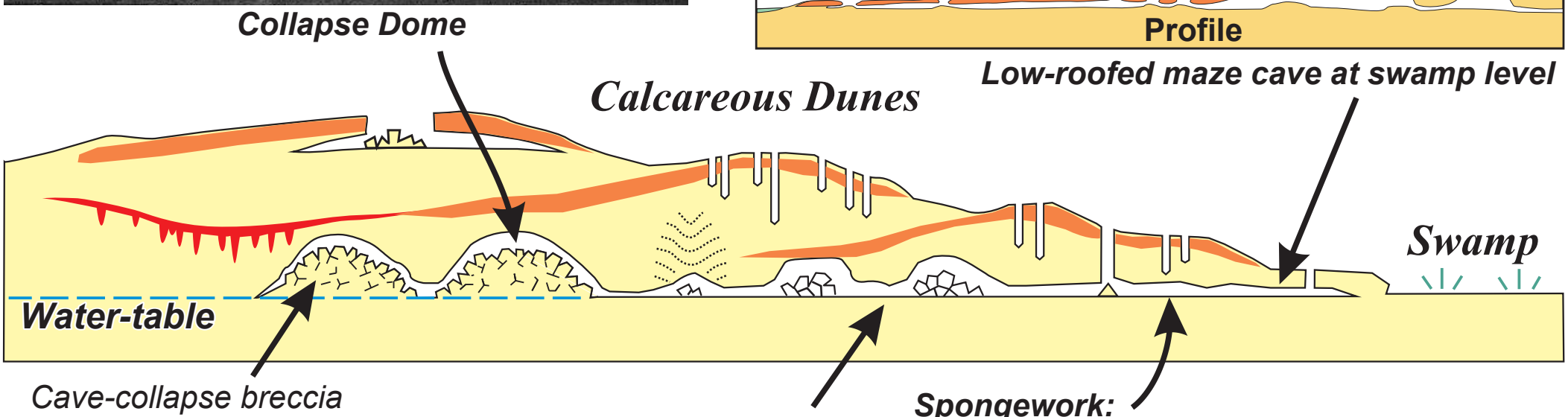
Flat cave ceilings are common: either marking the limit of solution at the top of the water table, or where collapse has reached the base of an indurated (cap-rock) zone.

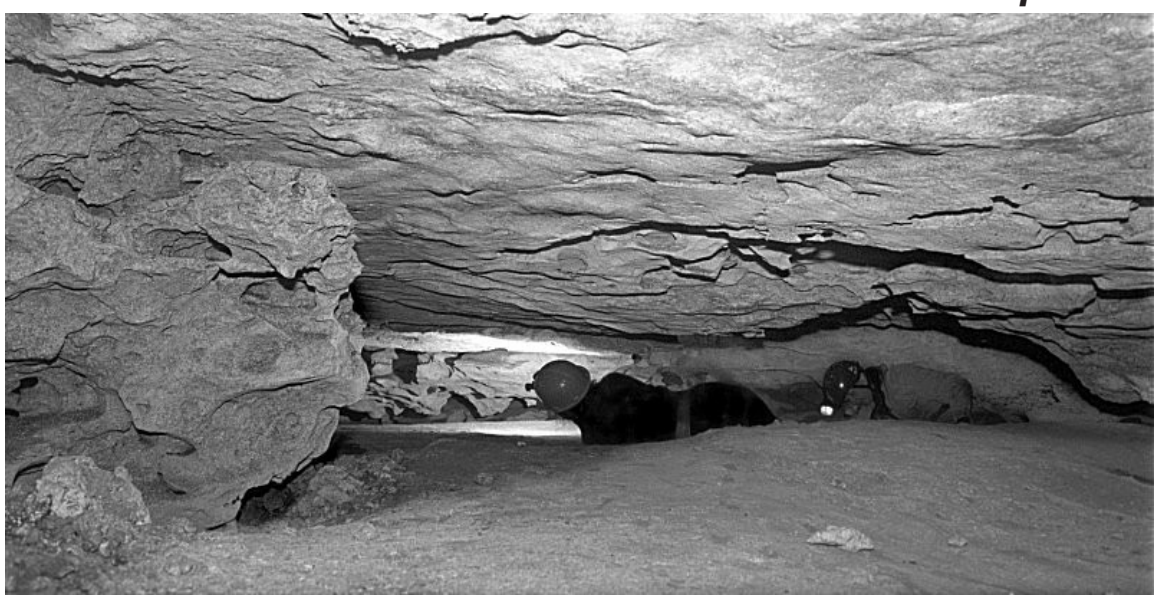
Breakdown of the weakly-cemented cave roof forms collapse domes.

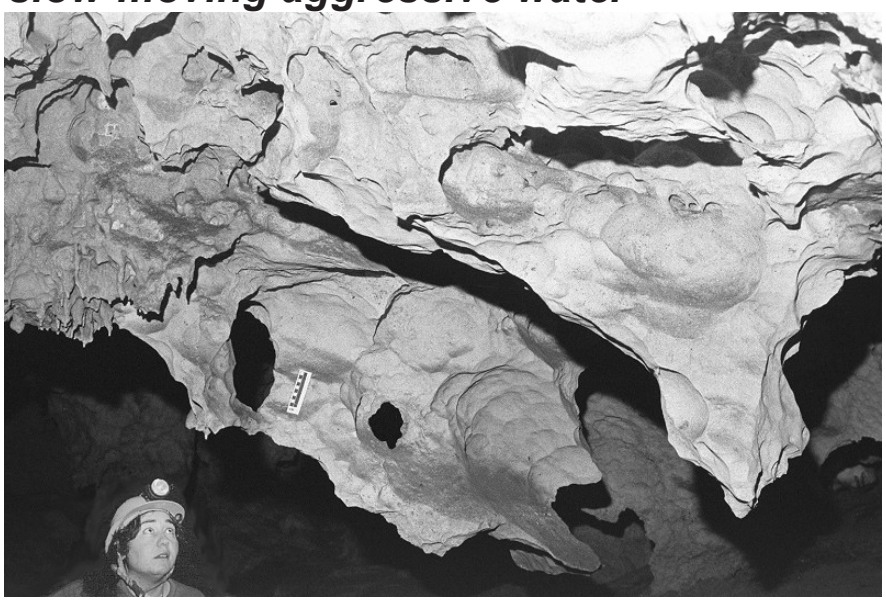
In the very late stage, some joint control may appear.











Syngenetic Karst

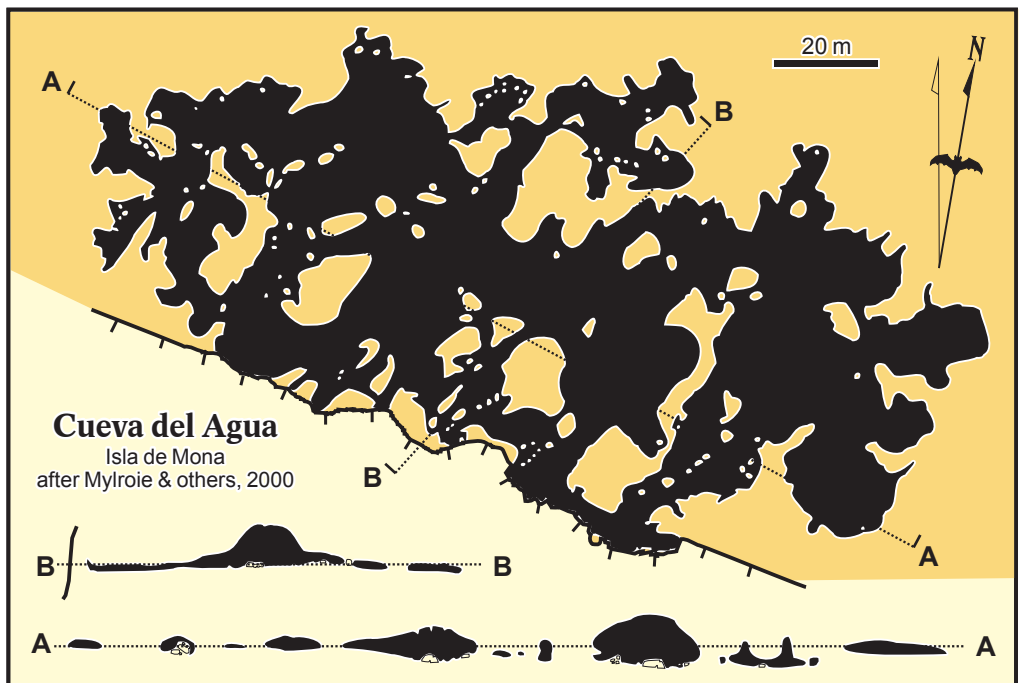
Coastal Karst (flank margin caves)

The Effect of the Sea

In coastal areas, a special influence is introduced by sea water.

Typically, in coastal aquifers a thin lens of fresh water floats over the denser sea water.

Mixing at the contacts causes strong cave solution.



A Flank Margin Cave - behind an erosional cliff

Coastal syngenetic karst

In coastal areas a fresh-water lens floating above sea water results in two mixing zones, above and below the thin lens (Mylroie et al, 2000, 2001).

Solution is strongest beside the coast where the lens thins so that: firstly, the two zones overlap (within the fluctuating zone of the sea level) and, secondly, the thinning of the lens causes stronger flow rates which also promotes solution.

The resulting "flank margin caves" form clusters along old coasts (Mylroie et al, 2000) and have an irregular form of interconnected "mixing chambers" and blind passages.

Tidal pumping can also contribute to circulation and solution.

Changing sea levels can generate multiple levels of caves. These can be used as indicators of past sea levels and uplift rates.

The bottom of the freshwater lens may be sharp (a halocline) or a diffuse mixing zone.

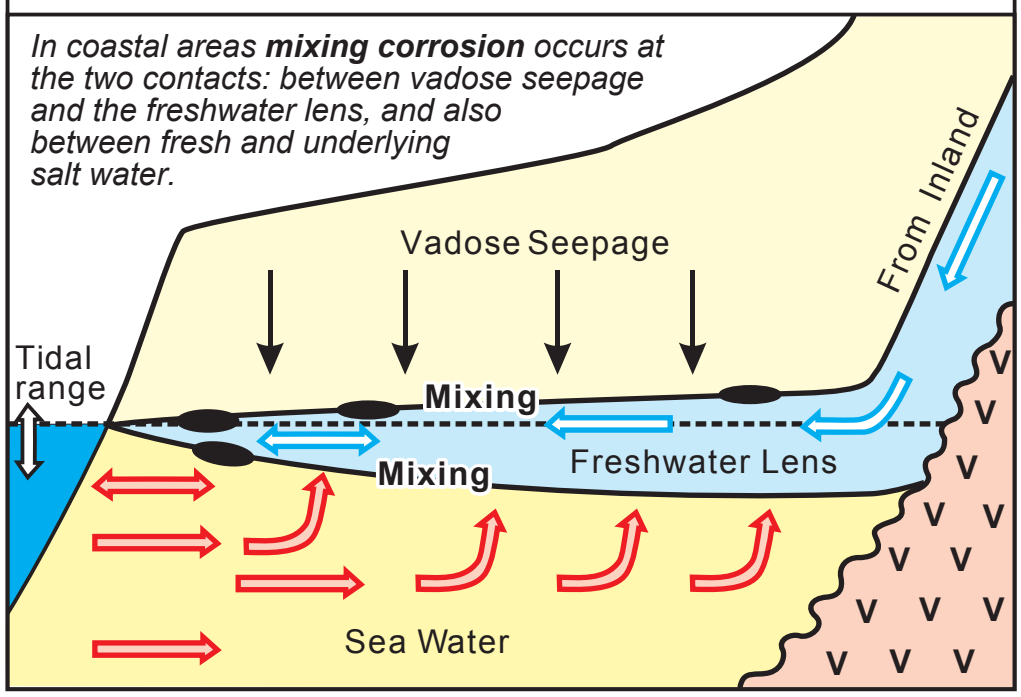
There is little conduit flow. Flow is diffuse through the porous sand, and even within the mixing cavities it is slow.

This slow water movement is reflected in the irregular plan of the chambers and the sponge-work sculpturing of the walls.

Where impermeable rocks occur beneath the limestone, these can perch and direct the flow towards the sea. Linear conduits can result.

The coastal freshwater lens

Note: the vertical scale is strongly exaggerated in all diagrams of this type. The slopes are not as steep as they appear.



Inland, beyond the limit of salt water intrusion, only a single mixing zone occurs. Scattered horizontal maze caves can form.

In all cases collapse and solution of the resulting rubble where it sits on the cave floor can form larger chambers.

References

Mylroie, JE., & Carew, JL., 2000: Speleogenesis in Coastal and Oceanic Settings. *in* A.B. Klimchouk, D.C. Ford, A.N. Palmer and W. Dreybrodt [eds] *Speleogenesis: Evolution of Karst Aquifers*, Huntsville, Alabama: National Speleological Society. pp. 226-233.

Mylroie, JE., Jenson, J.W., Taborosi, D., Jocson, J.M.U., Vann, D.T., & Wexel, C. 2001: Karst Features of Guam in Terms of a General Model of Carbonate Island Karst. *Journal of Cave and Karst Studies*, **63(1):** 9-22

Solution Pipes

Solution Pipes

Solution pipes (or dissolution pipes) are common and distinctive features of syngenetic karst on porous host sediments.

Solution pipes have been recorded from calcarenites worldwide (e.g. Lyndberg & Taggart, 1995).

They are vertical cylindrical tubes, typically 0.3 to 0.6 m in diameter, with or without cemented rims, which can penetrate down from the surface as far as 20 m into the soft limestone. The top is the present surface or a buried paleosoil. The bottom (where seen) is generally abrupt and hemispherical. The pipes may contain soil and calcified roots.

They occur as isolated features, or in clusters with spacings to less than a metre. Some pipes can intersect caves and act as entrances.



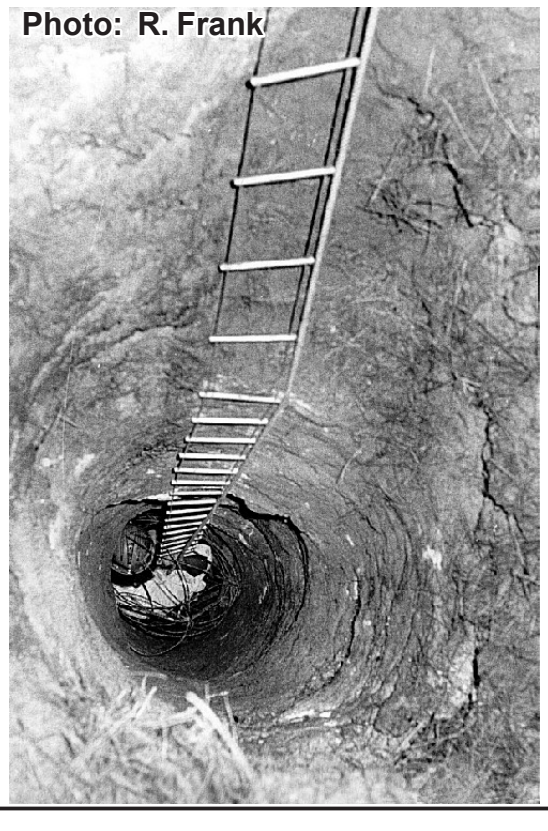
Solution pipes with well-developed rims at the Petrified Forest , western Victoria.



Cross-section of soil-filled pipes at an unconformity between two sand dunes.



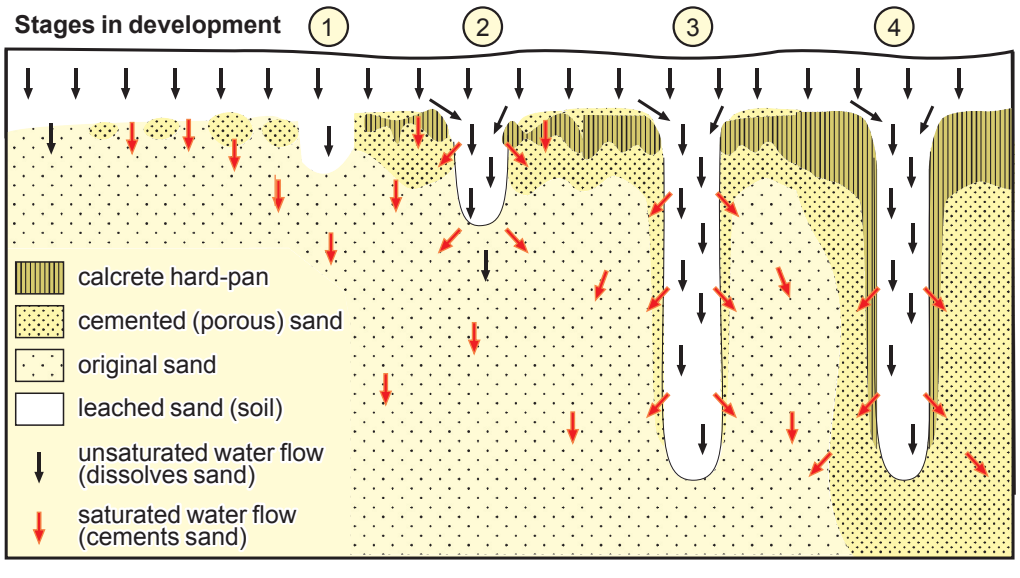
Hemispherical base to a pipe.



Solution pipe entrance to a cave

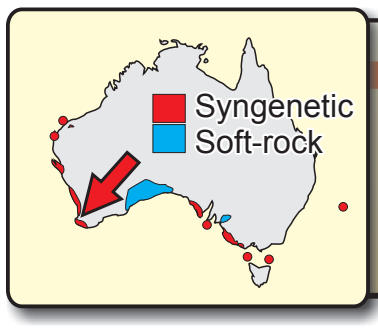
Formation of pipes, with rims, by focused vertical vadose flow

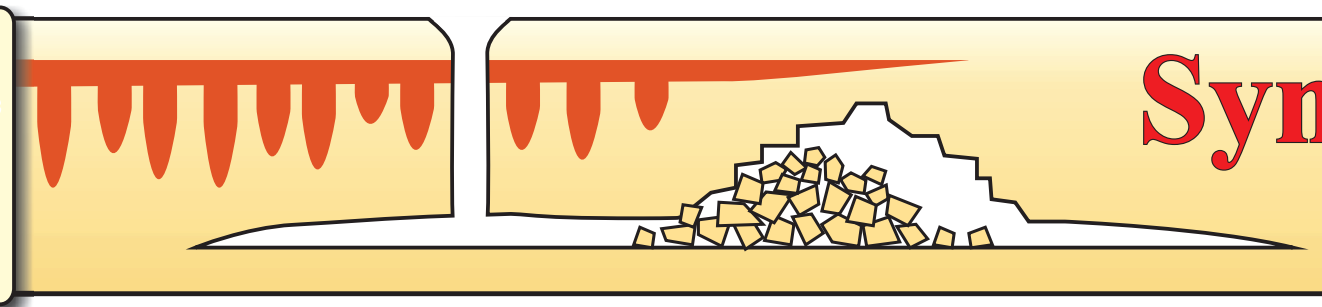
The pipes form by focussed vertical vadose flow through the porous sediment. The focussing may be spontaneous and associated with partial cementation of the hard pan of the soil, or it may be guided by other factors such as concentrated stem-flow, or along tap roots.



Reference

Lyndberg, J., & Taggart, B.E. 1995: Dissolution pipes in northern Puerto Rico: an exhumed paleokarst. *Carbonates and Evaporites* **10(2):** 171-183.





Syngenetic Karst

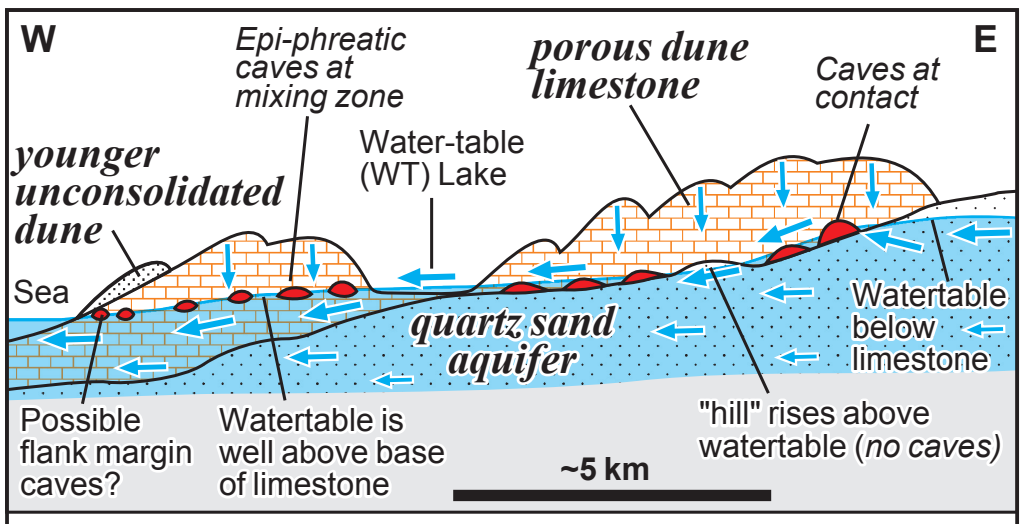
Examples: Western Australia

Southwest Australian Syngenetic Karsts

At Yanchep, aggressive water enters the base of the limestone from an underlying aquifer - forming watertable caves.

At Witchcliffe, an impermeable basement has directed water flow at the base of the dunes to form linear stream caves.

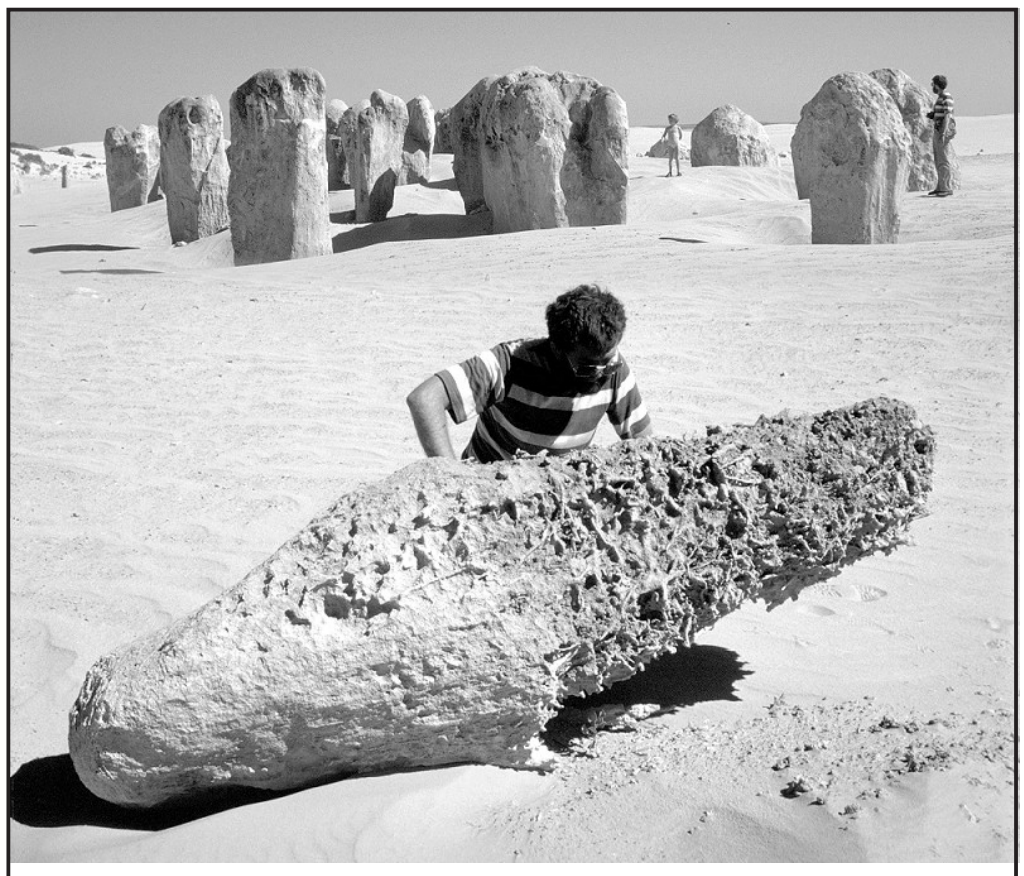
The Nambung Pinnacles are an unusual variant of solution pipes.



Water from below

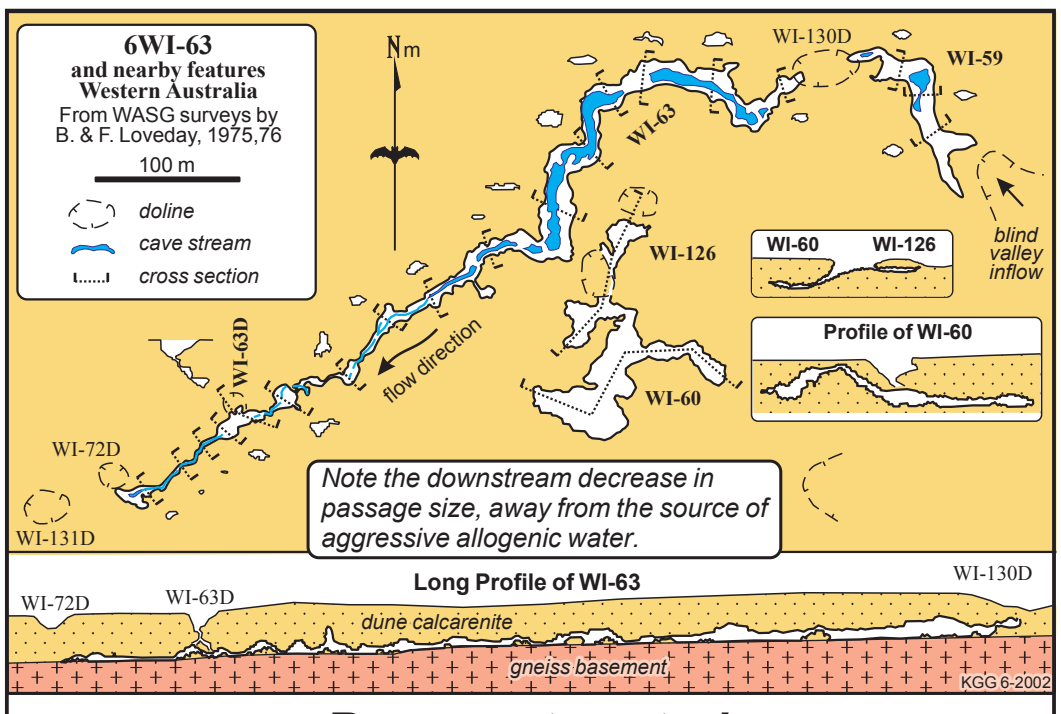
At Yanchep, the dune calcarenite overlies a quartz sand aquifer. Aggressive water moves upwards into the limestone and dissolves caves at the base of the limestone (Bastian, 1991).

A belt of caves forms along the eastern threshold where the water first rises into the limestone. The increased transmissivity of the caves captures diffuse flow from the adjoining sand and forms local streams which follow the base of the limestone. This high conduit transmissivity maintains the water table at the dipping contact.



Pinnacles at Nambung.

These pinnacles seem to be an extreme case in which solution pipes coalesced to leave only isolated cemented parts of the original dune (McNamara, 1995). They are exposed by wind erosion of the softer sand. In the uprooted specimen in the foreground, case hardening of the exposed upper surface has formed a smooth skin, in contrast to the softer buried core. Note the rhizomorphs in the core.



Basement control

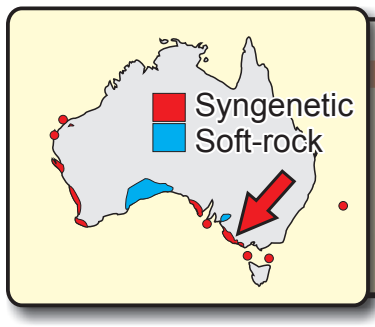
Where dune calcarenites overlie impermeable basement, water flow is concentrated at the contact and may be channeled by the basement topography into linear stream caves rather than irregular mazes (Williamson, & others, 1976).

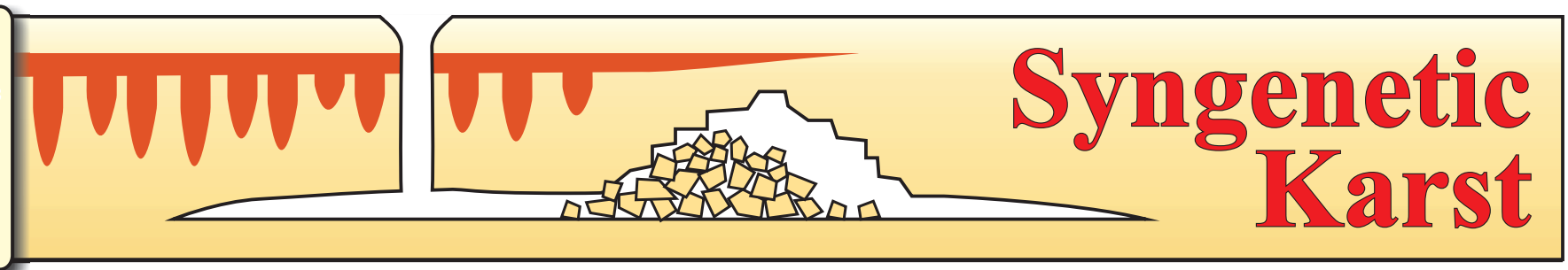
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Bastian, LV. 1991: The Hydrogeology and Speleogenesis of Yanchep. Proc. 18th Conference, Australian Speleological Federation. WASG, Nedlands. pp. 19-24.

McNamara, KJ., 1995: *Pinnacles.* Western Australian Museum. Perth. 24pp.

Williamson, K., Loveday, B., & Loveday, F., 1976: Strongs Cave and Related Features - southern Witchcliffe, W.A. *The Western Caver*. **16(3):** p 47-64.





Syngenetic Karst

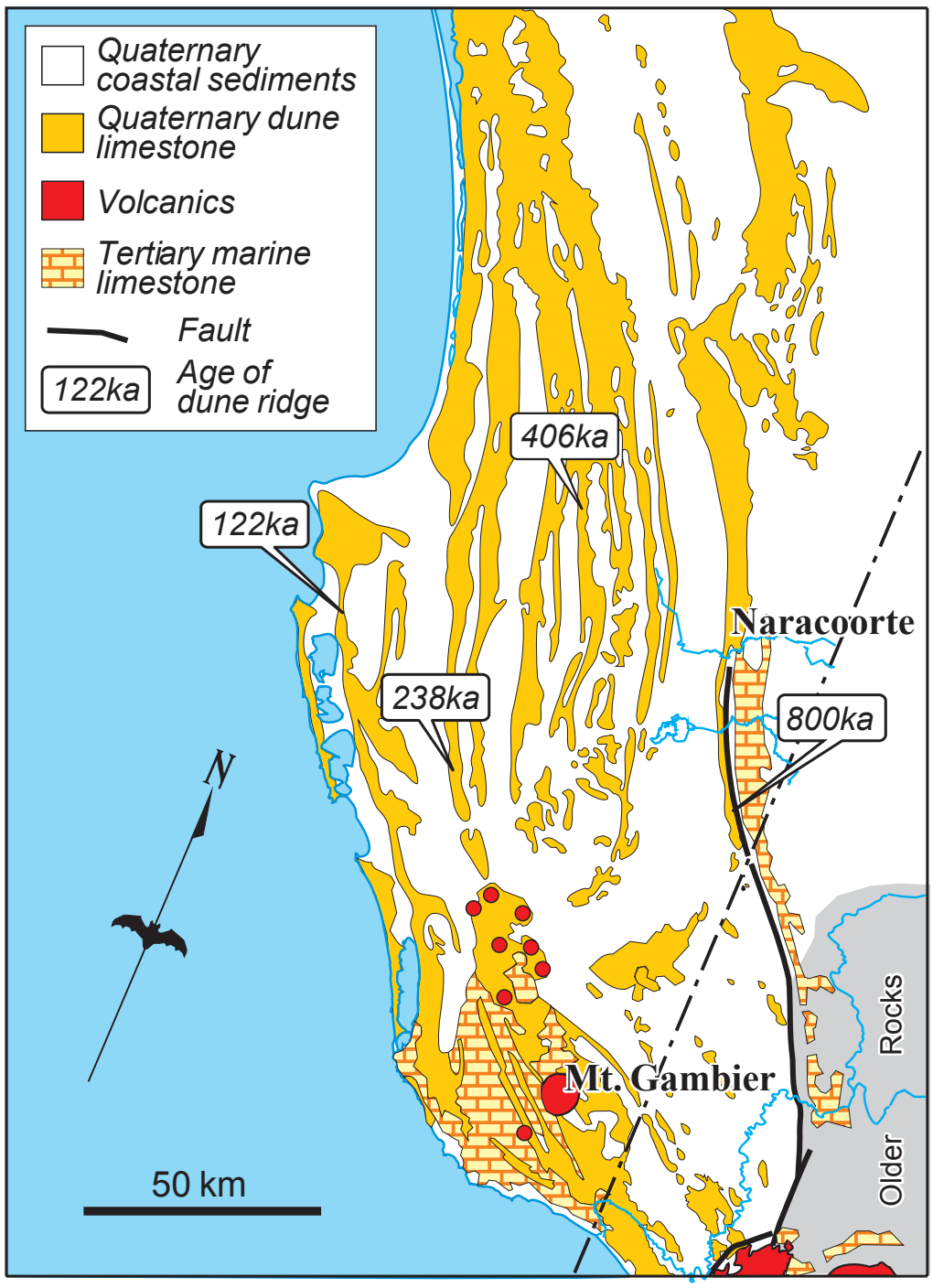
Examples: Southeast Australia

Syngenetic Karst on a prograding coast

In the Gambier region of SE Australia uplift coupled with sea-level changes has produced a broad sequence of coastal dune ridges and intervening swamps dating back at least 800,000 years.



Horizontal ceiling cut at at the water-table through a cross-bedded dune limestone.



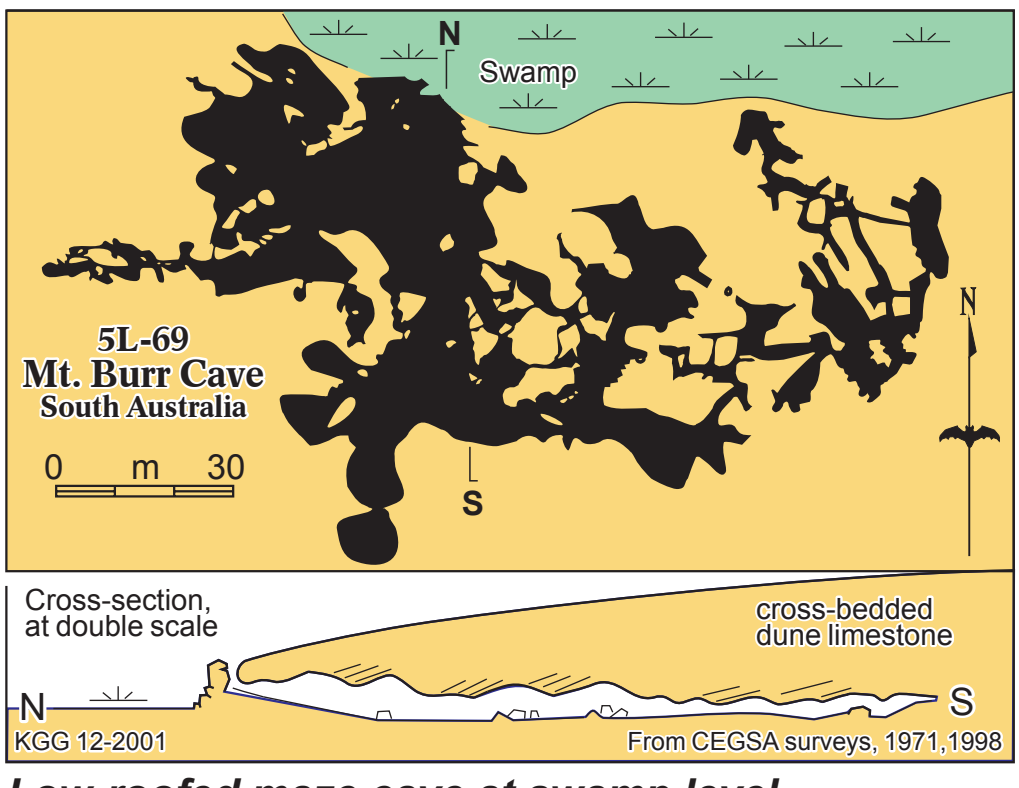
The Gambier Karst Region

Calcareous sand ridges of old coast lines alternate with broad swampy plains.

The plains have numerous shallow pans - some of which are karst dolines but others are degraded swales or drainage lines of the original coastal plain, or later deflation hollows.

Quaternary dune limestone overlies Tertiary marine (soft-rock) limestone. Many caves have entrances in the dune limestone, but their main development is in the underlying Tertiary limestone.

In the initial stages some flank margin caves may have formed in the dune ridges by fresh/salt-water mixing , but aggressive swamp water has been the major agent in cave formation.

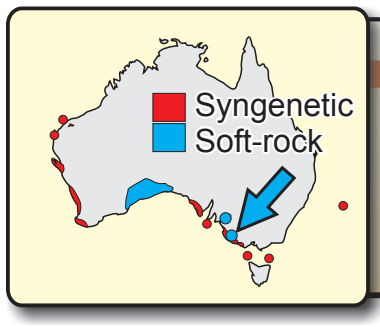


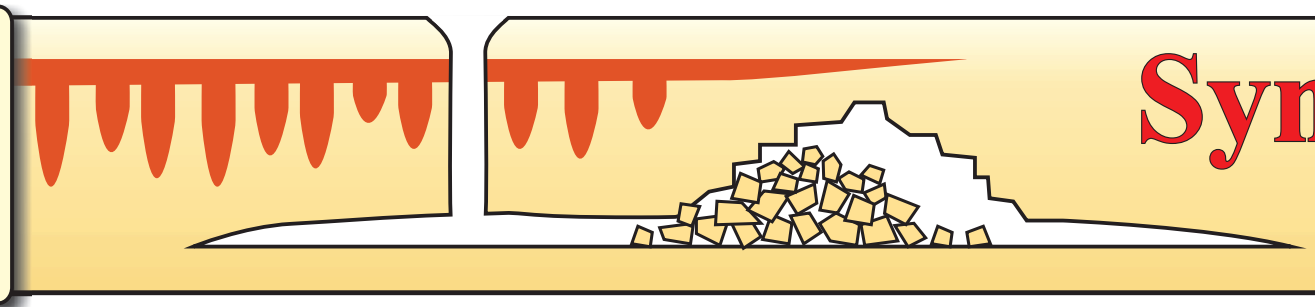
Low-roofed maze cave at swamp level

References

Grimes, K.G., Mott, K., & White, S., 1999: The Gambier Karst Province. *In* Henderson, K., *[ed]* Proceedings of the 13th Conference, Australasian Cave and Karst Management Association, Carlton South. pp.1-7.

White, S. 2000: Syngenetic Karst in Coastal Dune Limestone: A Review. *in* A.B. Klimchouk, D.C. Ford, A.N. Palmer and W. Dreybrodt *[eds]* Speleogenesis: Evolution of Karst Aquifers,, Huntsville, Alabama: National Speleological Society. pp. 234-237.





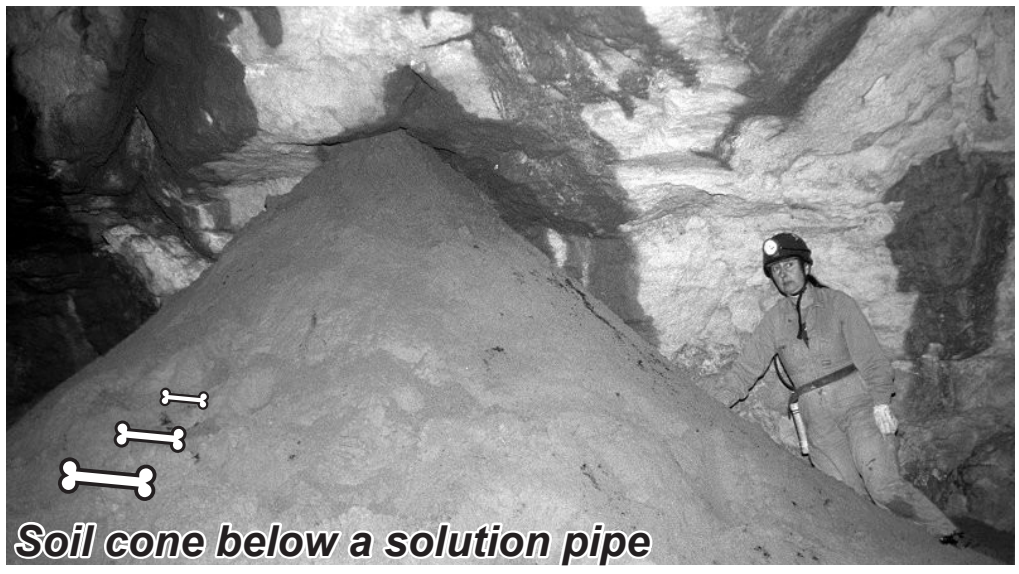
Syngenetic Karst

Examples: Soft-rock Karst

Soft-rock Karst in Tertiary marine calcarenites

The Gambier Limestone is a moderately consolidated porous calcarenite which shows some features similar to syngenetic karst.

However, it also has additional features resulting from its greater age, thickness and the evolution of geological structures such as well-developed joints.



Soil cone below a solution pipe

Similarities to syngenetic karst.

Water flows diffusely through a porous rock - so horizontal irregular mazes can occur at the well-developed water table.

Collapse modification is common in caves in the soft rock. Large collapse domes result.

Cemented hard-bands occur and can control cave ceilings

Solution pipes occur - but tend to be deeper although more scattered. Soil cones form in caves below the pipes.

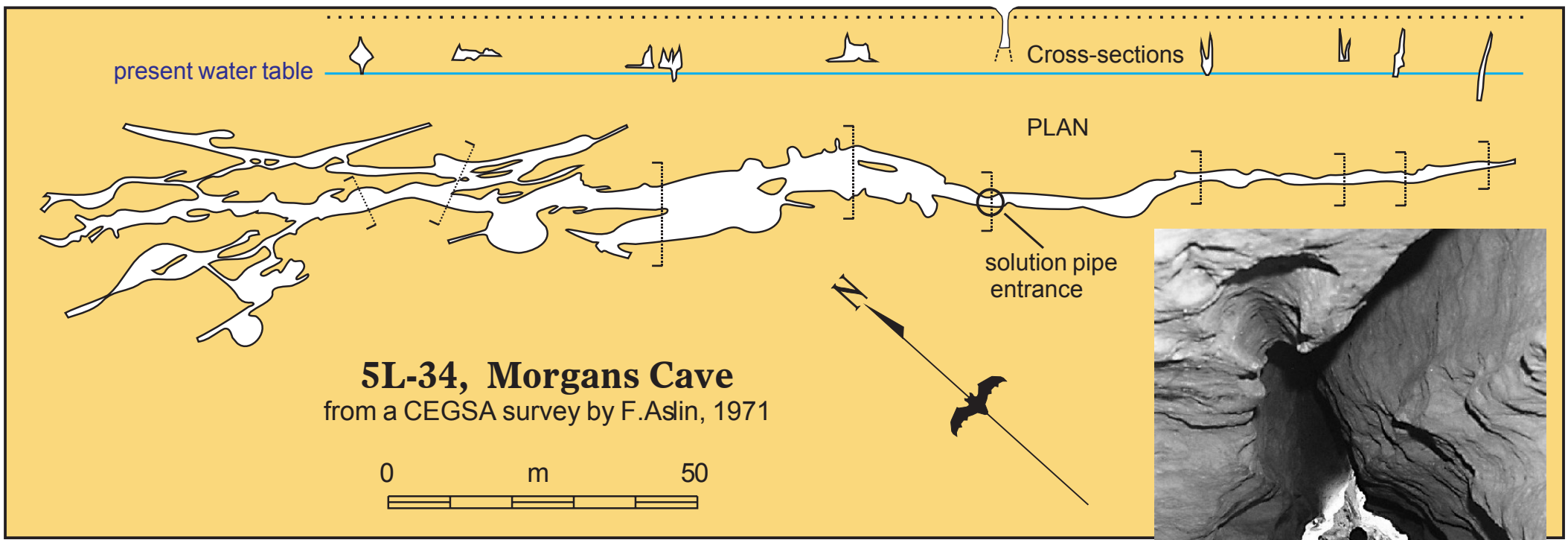
Differences from syngenetic karst.

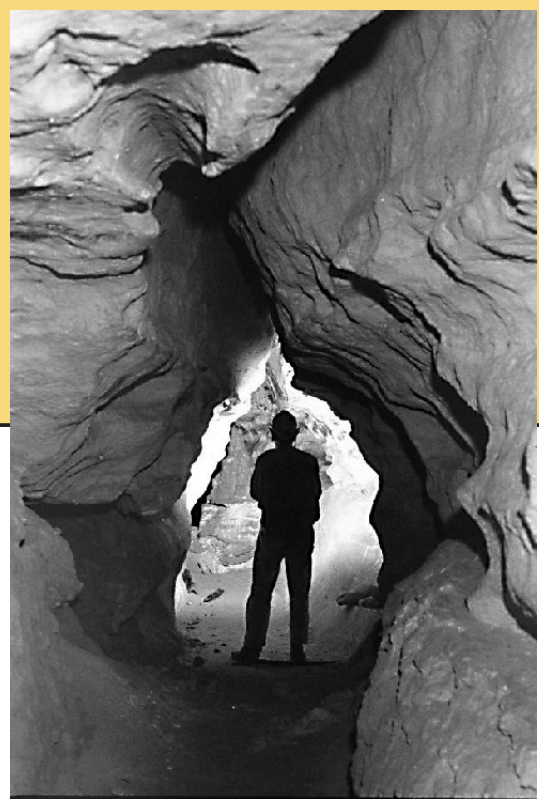
Greater age and thickness allows further induration and development of joints and other structure, as well as response to varying water levels due to tectonism or sea level change.

Joints can control the cave forms - e.g. to form rectilinear mazes

Changing water tables produce multi-level cave systems, including deep flooded systems up to 70m below the present watertable.

Soil cones beneath solution pipes, and entrance facies in general, can host fossil faunas of considerable age.





A joint-controlled cave developed in Gambier Limestone with a thin veneer of Quaternary beach sand.

Reference

Grimes, K.G., Mott, K., & White, S., 1999: The Gambier Karst Province. *In* Henderson, K., *[ed]* Proceedings of the 13th Conference, Australasian Cave and Karst Management Association, Carlton South. pp.1-7.