Journal of the

Australasian Cave and Karst Management Association

No. 104 September 2016 Australia Post- Print Post Approved: PP381624/02050. ISSN 1835-5374 Published Quarterly

The ACKMA Journal

Official Publication of the Australasian Cave and Karst Management Association Incorporated

Published quarterly in March, June, September and December

The opinions expressed in the ACKMA Journal are those of the individual authors and not necessarily those of ACKMA Inc. or its officers.

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Photos taken by the authors or editor unless otherwise acknowledged.

PRINTER: Hansen Print, Smith Street, Naracoorte, South Australia 5271. Ph: (08) 87623699

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FRONT COVER: Water droplets that appear to be associated with biological activity, in a cave at Naracoorte. Photo: Steve Bourne

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IN THIS ISSUE

EDITORIAL

Steve Bourne

This is possibly the best balanced journal I have had the pleasure of producing. It covers a range of topics. I have read the proposals and nomination documents for the Chillagoe - Mitchell-Palmer karst area and in this issue we have a great summary article by David Gillieson. The issue of listing a site for its heritage values, whether that is world, national, state or local, always raises plenty of discussion. I understand the proposal for this section of northern Queensland is no different. I have been to Chillagoe twice and learnt a lot more about the area from David's article, which was first published in the *North Queensland Naturalist.* I am grateful the editors of this journal gave ACKMA permission to reproduce it in our journal.

Calthemites - what are they? You all know what they are and have all seen many of them, but possibly never had a name for them. Garry K. Smith's study of calthemites provides some great material for cave guides to share with visitors. It is also a nice little science lesson in the chemistry of limestone and concrete secondary deposits. That gives a clue to what calthemites are - read on!

Kent Henderson provides two reports of caves in the Philippines. (I had to check multiple sources for the correct spelling of Philippines, my computer auto correct insisted it is one 'l' and two 'p's and I was sure it was the other way around. One for the computer.) One showcases some very good management, the other somewhat less so.

I was contacted some months ago by Tim Moore, Justice in the NSW Environment Court and good friend of Andy Spate. Tim has been a long term ACKMA member, over 25 years, and said he had never contributed to the journal. He has provided an article on the Blue Grotto on the island of Capri, I imagine a site few ACKMA members have visited. I am sure there are many other long term members yet to produce their first ACKMA article. I will be pleased to receive yours!!

ACKMA Journal 103 introduced a new format with some changes including smaller font and line spacings. As stated in this journal, it places approximately 20% more text on each page, but is barely noticeable. I didn't receive howls of protest (zero feedback) that the font was too small and difficult to read, so will continue with this format.

Intrepid traveller Greg Middleton featured in an airlines magazine titled *"Highlife",* with a story regarding his caving in the lava tubes of Mauritius. It was a good feature of Greg's work when, in 1998 while working for the Department of the Environment, Mauritius, he spent 5 months exploring, photographing and surveying 140 caves with a total passage length of over 16.5km. Nice work if you can get it!

The 17th International Congress of Speleology is rapidly approaching, I bet very rapidly for the organisers. The second circular is available on the conference website, see details below. One issue that is being worked on very seriously is minimising the risk of introducing the White-nose Syndrome fungus into Australasia. As members would be aware, this fungus has had a devastating effect on cave-dwelling bat species in the USA and Canada over the past decade. Some field trips, such as the one Liz Reed and I are running to Naracoorte, will provide all equipment. We will still have strict decontamination regimes for boots and other equipment brought into the country. I ask all cave managers to make themselves aware of the risk and the protocols being put in place by the conference organisers, and consider what other measures may be necessary for their cave site.

Capricorn caves owner Ann Augusteyn recently caught up with ACKMA life member Chester Shaw at Capricorn. I assume Chester was escaping the cold, wet Tasmanian winter.

Also in 2017 is the ACKMA AGM, to be held during the first week of May at Te Anau. The program will be slightly extended rather than the usual weekend AGM format with some elements specifically for cave guides. Next year is shaping up as a big year for those interested in caves so start planning (and saving now).

On a sad note, the caving world lost Ken Grimes in a tragic accident on his farm. Many thoughts were shared on the ACKMA email list, all reflecting that Ken had a wealth of knowledge on cave and karst matters, and was always generous with his time in sharing this. I look with sadness at my emails I had been sending back and forth to Ken on an issue, knowing that no more responses with be coming. The December journal will contain an obituary and tribute articles to Ken.

17th International Congress of Speleology
Registration is now open
Early-bird registration rates open until 31 January 2017

The congress will be a once in a lifetime event for Australian and New Zealand cavers as this event is unlikely to be held in the Australasian region again in our lifetimes. The congress will provide tremendous opportunities for local cavers to meet with international cavers, hear their presentations and make invaluable connections for visiting caves in other countries. With less than five months until early-bird registration closes, it's time to talk to your speleological colleagues about the many benefits of attending the 17th ICS. Full details at www.speleo2017.com

PRESIDENT'S REPORT

Dale Calnin

You can be sure there is always something happening in Cave and Karst Management and I am constantly reminded of the passion and commitment of our ACKMA members towards the conservation and protection of our cave systems.

I have always admired the efforts of our ACKMA leaders but I now hold a greater appreciation for the work carried out behind the four walls of the ACKMA committee, which can often be a thankless task.

Our Publications Officer Steve Bourne produced another great ACKMA journal in June that featured mostly the Rockhampton conference gathering, and 1 have no doubt this edition will again be full of exciting and interesting material. How Steve manages to find the time to juggle everything is amazing and a true testament to his dedication to ACKMA.

The committee have continued their review of our membership list to ensure those receiving the publication, either electronically or in print are current members, but we now need your help.

As you would appreciate, membership is incredibly important to the longevity of ACKMA; to maintain a vibrant organisation and more importantly that we are sustainable into the future. Therefore, 1 encourage members to renew your membership now.

To help build our numbers, 1 also feel that ACKMA needs to embrace the recruitment of cave guides who add that vital ingredient to cave management and the delivery of cave experiences. The membership form can be easily found on the website and ask that completed forms be sent to both Cath Loder and Steve Bourne.

On behalf of everyone 1 would also like to congratulate Cath on the safe arrival of their new baby boy Isaac George Loder. Cath is rapidly adjusting to the demands of motherhood and endeavouring to catch up with ACKMA stuff in her spare moments.

It is great to see that the energy and enthusiasm displayed by our cave guides at Capricorn Caves continue with the launch of the ACKMA Guides Community Group Facebook site. Congratulations to Jodie Anderson and Roslyn Hogno for implementing this initiative and 1 encourage not only ACKMA members but all guides at our many respected cave operation sites, to get on board. The site provides a wonderful platform for cave guides, managers and staff from across Australia and New Zealand to share thoughts, ideas techniques and experiences.

Other great work being done on behalf of ACKMA includes submissions to the draft Paparoa National Park Management Plan NZ and also the Kosciuszko National Park Management Plan NSW, which have implications for several important karst areas. Many thanks to Mary Trayers, John Brush and others that have contributed significantly to those responses.

Over the past month or so we have all been truly tested with some extremely sad and difficult times. The sad passing of our dear friends and long-standing ACKMA members Ken Grimes and Brett Farquharson has left us with heavy hearts. Our sincere condolences and thoughts are with both Janeen and Lesley, and families.

Fellow of ACKMA and good friend, John Ash is on the mend following a nasty fall off a ladder while pruning branches at the family home. John received a punctured lung and was in a great deal of pain. We hope his recovery is progressing well with the prospect of a return performance of "Captain Speedo" next year at Te Anau?

Once again major weather events have caused havoc a number of our commercial cave sites. Our good friends and active ACKMA members Trish and Geoff Deer of Gunns Plains Cave in Tasmania have dealt with the impact of another major flooding event. When 1 last spoke to Geoff, their cave tours were up and running again but still with a high number of lights needing repair or replacing.

There have been exciting times at Buchan with fossilized animal remains found in a cave forty years ago finally identified as the White-Footed Rabbit Rat, or Conilurus albipes, an extinct native mammal. This discovery reminds us how important the protection of our native wildlife is, how permanent extinction is and why we spend so much effort controlling feral predators to protect vulnerable species.

Neil Collinson, New Zealand Vice President and Operations manager of TE Anau/Manapouri, has put together an excellent and exciting program for our ACKMA AGM event in Te Anau next year. The program content looks very attractive to cave guides while also delivering the objectives of the organisation. Neil worked on a similar concept as the Capricorn Caves event and hopes to keep the continued combination of the guide school workshop together with the ACKMA AGM.

Really good work Neil and team and we are so looking forward to visiting you in May 2017.

Until next time take care everyone and keep up the excellent work you do in Cave and Karst Management.

President Dale thanking catering staff at the Waitomo Hotel, Waitomo, New Zealand at ACKMA 2013. ACKMA heads back to New Zealand in 2017, this time to Te Anau.
Photo: Steve Bourne

NATURAL HERITAGE VALUES of the CHILLAGOE and MITCHELL-PALMER KARST and CAVES

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Citation: Gillieson D. 2016. Natural heritage values of the Chillagoe and Mitchell-Palmer karst and caves. *North Queensland Naturalist* 46: 71-85

Abstract

Karst (limestone) landforms and associated features such as caves are distributed widely throughout the world. They have many natural heritage values and many are located in protected areas including several which are on the World Heritage List. In North Queensland, two areas notable for their karst geoheritage values have been evaluated as part of the National Heritage List process. The karst towers or bluffs at Chillagoe extend over a considerable distance and achieve heights of up to 65 m above the surrounding undulating terrain. Further north, the karst towers at the Mitchell-Palmer area achieve greater heights and extend over a distance of 80 km between the Mitchell and Palmer rivers. Tower karst is an unusual landscape type in Australia, with clearly the best examples found in the Chillagoe Karst Region. They may be potentially significant at a global level with the closest comparisons being in Cuba and Madagascar. Over 1000 caves have been recorded in the towers, and contain unusual calcite formations, fossil bone deposits and unique copper sinter deposits. A National Heritage List nomination for the Chillagoe and Mitchell-Palmer karst areas was submitted in 2009. The proposed boundaries of the Heritage place were adjusted to avoid current mining leases, reducing the total area by around 50%. The Australian Heritage Council has now assessed the Chillagoe Karst Region and has identified that the Chillagoe Karst Region (including parts of the Mitchell-Palmer Karst Belt) meets the National Heritage criteria for its outstanding karst limestone bluffs, towers and cave development. The Council's assessment was made available for public review and comment until November 2015, and following this the assessment and comments are now with the Minister for the Environment for a final decision. Current environmental issues include fire management, weed control, feral animals and the impacts of mining.

Introduction

Along the length of the the Eastern Highlands of Australia, from Tasmania to North Queensland, there are karst areas with caves developed in hard limestones of Ordovician to Permian age. As well as caves there are well-developed karst hydrologic systems, springs, dolines and other landforms. Other values of these karsts include highly significant palaeontological and biological aspects.

West of Cairns there are extensive Silurian limestone areas running in an arc from Chillagoe to the northwest and then north into the wild country between the Mitchell and Palmer Rivers. These karst areas have a high degree of biophysical integrity and are the best examples of tropical tower karst in Australia. Some of the Chillagoe towers are protected under National Park status, while the Mitchell-Palmer karsts are on remote pastoral properties and access is restricted by the owners. This paper describes some approaches to the assessment of cave and karst heritage in Australia, and applies these approaches to an evaluation of the natural heritage of the Chillagoe and the Mitchell-Palmer karsts of north Queensland.

Chillagoe is a small town located about 200 km west of Cairns in tropical north Queensland. Lying to the west of the Great Dividing Range, the perennial Mitchell and Palmer rivers drain the area to the Gulf of Carpentaria. The Mitchell-Palmer karst extends for 100 km between those two rivers in remote terrain accessible only by minor tracks. The region has a tropical monsoonal climate with an annual average rainfall of 830 mm, most of which falls in the short wet season from December to March. Daily maximum temperatures frequently exceed 38ºC in the wet season and over 25ºC in the dry season. The dominant vegetation of the area is a savanna woodland with various eucalypts including bloodwoods. Along streams and on the limestone, semi-deciduous vine forest and vine thicket dominate with figs, eucalypts and paperbarks as emergents. The dominant land uses are extensive cattle grazing and minor quarrying of the limestone for lime and building stone.

Chillagoe and the Mitchell-Palmer karst lie within the Eastern Australian Province, characterised by steeply dipping rocks forming narrow ridges extending along the strike (Gillieson 2004). The Silurian limestones are a series of marine deposits that were laid down along the continental shelf 420–360 million years ago. The limestone forms prominent and spectacular karst towers up to 65 m high near Chillagoe, and are separated by lower, undulating terrain formed on sedimentary deposits (chert, sandstone) and volcanic ridges. The ridges and towers run in a NW–SE direction near Chillagoe and more northerly in the Mitchell-Palmer Karst (Fig. 1). The towers are typically lens-shaped, up to 1 km long and 300–400 m wide. Detailed mapping around Mungana has shown that the towers are separated by thrust faults.

There are over a thousand caves recorded and mapped in the Chillagoe and Mitchell-Palmer karsts (Chillagoe Caving Club 1982). The longest is the Queenslander Cave, which attains a length of over 6 km and consists of a joint-controlled maze. Few cave entrances are known from the pediments, and most caves are entered from the upper surfaces of the towers or from the angle between the cliffs and the pediments. The dominant passage shapes are rifts that narrow upwards and may intersect the surface producing small daylight holes in the roof. Larger chambers 30–50 m wide are located at joint intersections and may connect upwards with clefts, giving daylight chambers.

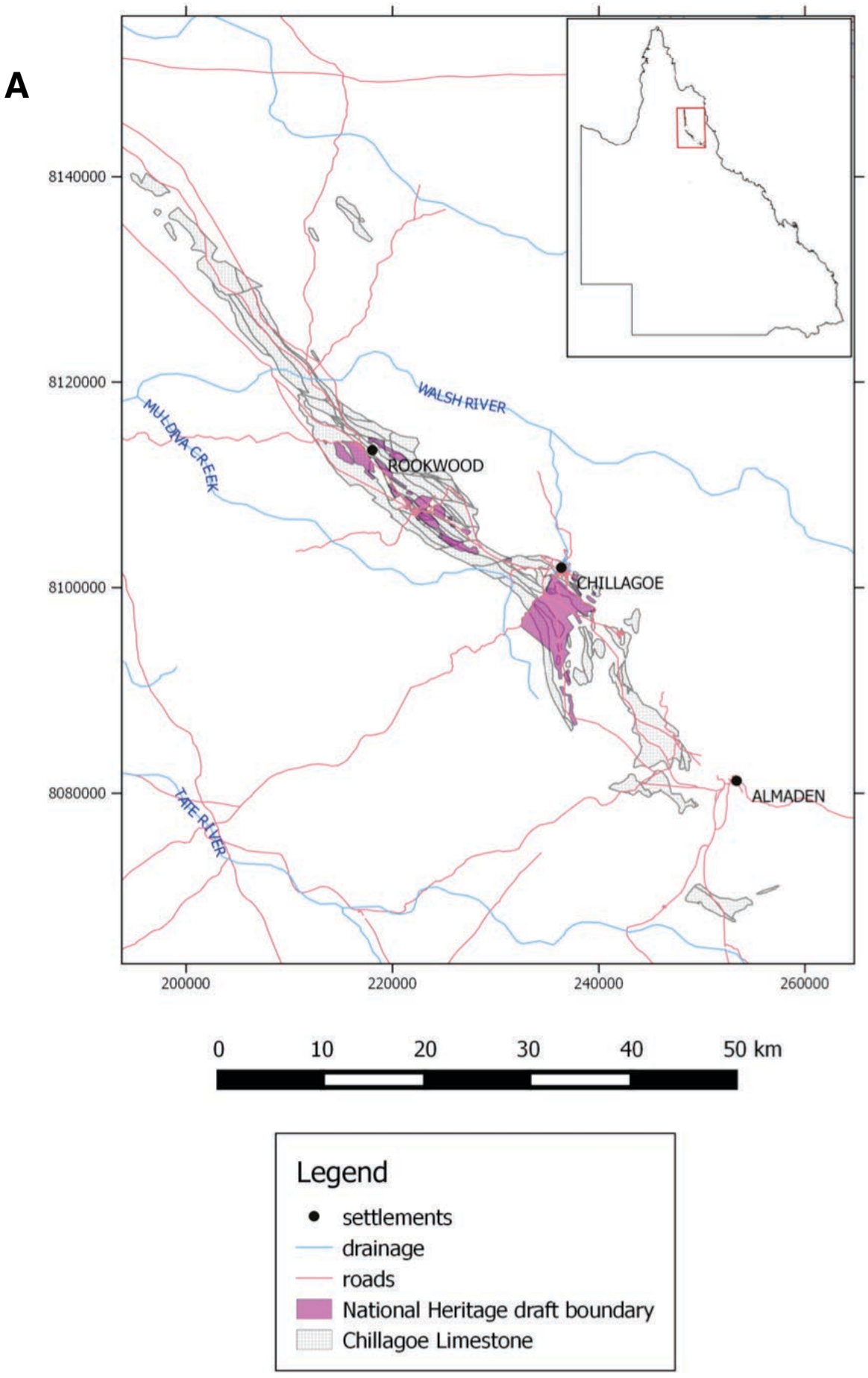

Figure 1. Extent of the Chillagoe (A) and Mitchell-Palmer (B – next page) karsts, with proposed National Heritage List boundaries (2015).

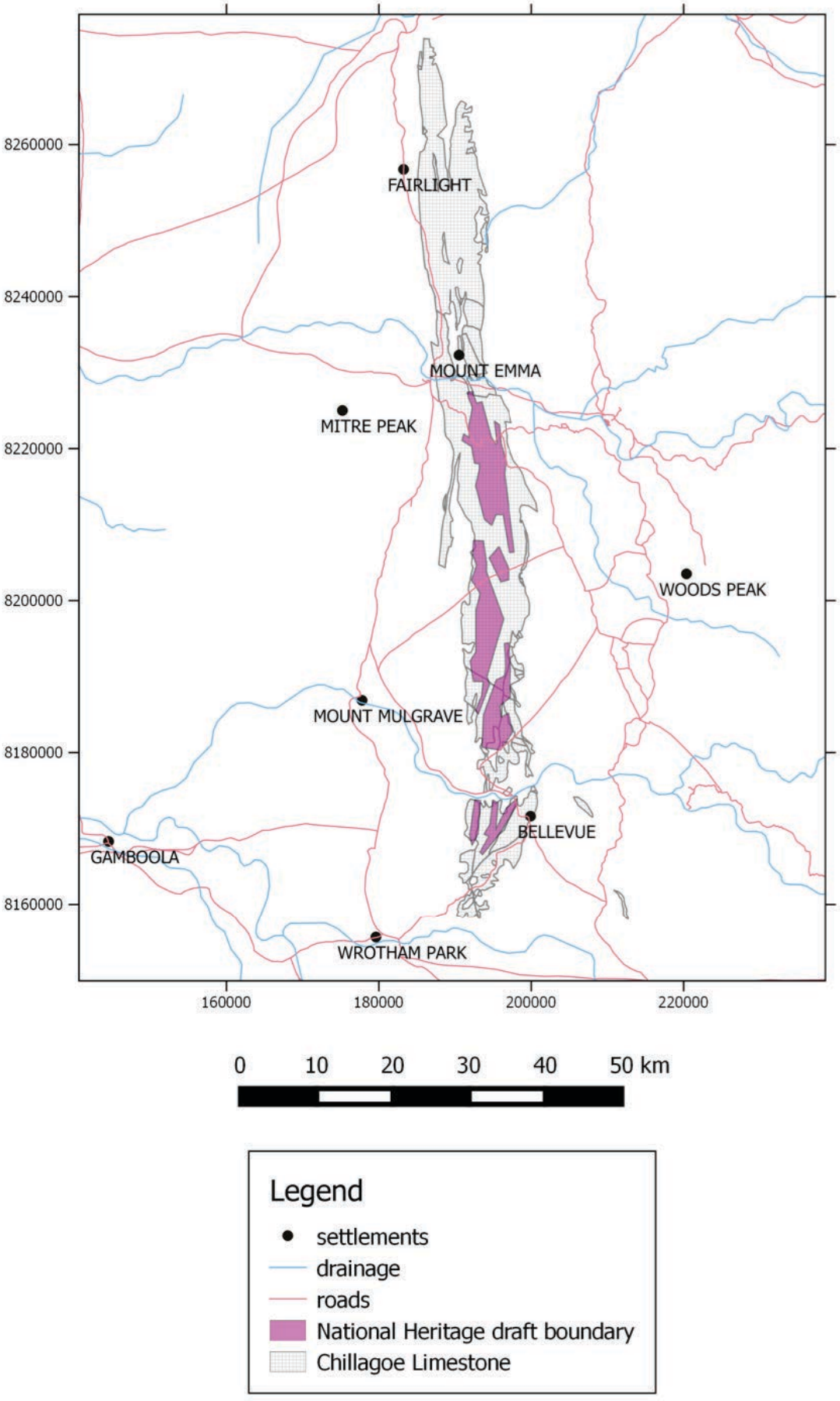
8260000
8240000
8220000
8200000
8180000
8160000
FAIRLIGHT
MOUNT EMMA
MITRE PEAK
WOODS PEAK
MOUNT MULGRAVE
BELLEVUE
GAMBOOLA
WROTHAM PARK
160000
180000
200000
220000
0
10
20
30
40
50 km
Legend
settlements
drainage
roads
National Heritage draft boundary
Chillagoe Limestone

Figure 1b.

Approaches to assessing cave and karst geoheritage values in Australia

Karst landforms and associated features such as caves are distributed widely throughout the world. They have many geoheritage values and many are located in various protected areas, including several which are on the World Heritage List (e.g. South-West Tasmania, Blue Mountains, Purnululu). The direct values of geological, landform and soil systems to humans, as our 'geoheritage', are the reasons most frequently cited to justify geoconservation, and these are indeed important reasons to value geodiversity.

Geoheritage comprises those elements of natural geodiversity which are of significant value to humans but do not involve the depletion or degradation of those elements (Houshold et al. 1997; Sharples 2002). The import of this definition is that it implies a distinction between the utilitarian resource values derived from the removal, processing or manipulation of rocks, landforms and soils by means such as mining, engineering or agriculture, and the conservation values of rocks, landforms and soils as heritage in their natural state.

Geoheritage may be of value to humans as:

- providing scientific evidence of the past development of the Earth, and of the evolution of life on Earth;
- sites of importance for research and education;
- features which inspire us because of their aesthetic qualities;
- features of recreational or tourism significance (eg. mountains, cliffs, caves, beaches, etc.);
- features which form the basis of landscapes that have contributed to the 'sense of place' of particular human communities; and
- features which play a role in the cultural or spiritual values of human communities (e.g. sacred caves and mountains).

Each of these points can form a theme or themes which can be developed and used to compare sites as part of a process of inscription on a heritage list such as the National Heritage List and World Heritage list. In 2006 the Federal Government Department of Environment convened a workshop to identify the most significant karst sites in Australia, and assess their values and significance. This was a precursor to listing some sites on the National Heritage List. The sites were discussed in broad groups to reflect karst 'types', which developed in different climatic and physiographic regimes. Within each type, karst sites have similar characteristics or developmental history; however each karst area or site also has unique aspects. The delineation of broad types gives a basis for comparison for many, but not all, of the features and values found in karst landscapes. Types included:

- Temperate Eastern Highland impounded karsts;
- Monsoonal tropical karsts;
- Southern Tertiary basin karsts;
- Coastal zone karsts;
- Island karsts; and
- Karsts of the arid zone.

Some karsts fall into more than one category (for example: the Chillagoe and Mitchell-Palmer karst area is part of the Eastern Highland impounded karsts, as well as representing a monsoonal tropical karst). Nevertheless, these groupings provided a useful starting point in which to highlight and compare values. Further to the identification of characteristics inherent within each broad type, a matrix was developed during the workshop which set out a series of heritage themes against which cave and karst values could be grouped, highlighted and compared, and within each major type. The themes fell into two main categories, each with a number of subcategories (Table 1). Note that the detailed consideration of fossil sites was excluded from consideration under the geodiversity category, although fossil values were noted where known. This was part of a separate exercise.

The practical implementation of geoconservation requires that significant elements of geodiversity – those requiring special management prescriptions – be identified on the ground through a process of inventory. The most detailed approach to developing systematic thematic inventories involves:

- developing or adopting a classification scheme for a theme under consideration;
- using available data and further fieldwork as necessary to identify all known examples of each classified group within a defined study area; and
- comparing the known examples in each classified group to identify which are the best expressed or developed examples of their type.

Table 1. Potential heritage themes for karst landscapes, as developed at a Department of Environment workshop.

Theme categories	Theme sub-categories
Geodiversity	• the evolution of Australia's geodiversity • presence of palaeokarst and multi-phase caves • complexity of the hydrology • bedrock type and complexity • karst geomorphology • importance for research
Biodiversity	• importance in illustrating evolutionary processes • importance as refugia • consideration of biogeography and isolating factors • species diversity • importance for research

There are a number of classification schemes in use for cave and karst geoheritage. Grimes (1995) has developed a broad scheme of geological and geomorphological types that can be used at a regional or national level. At the level of the individual cave, it is important to recognise that the values can fall into three main categories: geological, biological or cultural. An essential first step in the assessment of geological heritage is the compilation of a cave inventory. Any cave inventory should first consider the context in which the cave occurs. Thus the cave needs to be placed in its relationship with local geology and geomorphology and the extent to which it presents any typical or unusual features such as a cave developed in fault gangue, or a mineralized void related to skarn rocks. The second task is to compile an inventory of the cave contents. This should include the type and extent of calcite formations or speleothems, sediment deposits and bone deposits, water bodies, cave solutional features such as pendants and anastomosing tubes, rare or unusual minerals. Any natural hazards should also be noted at the time. Cave mapping is a very useful adjunct to record special features, determine potential impacts of either future visitors or local economic

developments. A set of accepted symbols endorsed by the International Speleological Union is used for mapping, coupled with accepted survey accuracy grades. In Australia, the Australian Speleological Federation has published a Karst Index (Matthews 1985) which is maintained online and contains data on over 10,000 caves in Australia. The Index also has details of many cave maps that have been produced and curated by individual clubs such as the Chillagoe Caving Club. The Index does provide a basis by which individual caves and karst sites can be classified and then compared for geoheritage evaluation. Similarly there is a State karst inventory for Tasmania and New South Wales. In all cases a proforma based on a classification scheme is used for recording basic data.

Karst areas may have sufficient significance to be inscribed on a Heritage List. The National Heritage List was established to recognise places of outstanding heritage significance to Australia. National Heritage listing does not change land tenure or ownership, and is not the same as an area becoming a National Park. If a place is listed the National Heritage values will be protected under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act). Approval under the EPBC Act is required for any action that could have a significant impact on the National Heritage values of a listed place.

Key tools used to decide a place's heritage significance are criteria and thresholds. Criteria are a collection of principles or characteristics used to help decide if a place has heritage values. There will usually be several criteria that might be applied to a place being considered:

(a) the place has outstanding heritage value to the nation because of the place's importance in the course, or pattern, of Australia's natural or cultural history;

(b) the place has outstanding heritage value to the nation because of the place's possession of uncommon, rare or endangered aspects of Australia's natural or cultural history;

(c) the place has outstanding heritage value to the nation because of the place's potential to yield information that will contribute to an understanding of Australia's natural or cultural history;

(d) the place has outstanding heritage value to the nation because of the place's importance in demonstrating the principal characteristics of: (i) a class of Australia's natural or cultural places; or (ii) a class of Australia's natural or cultural environments;

(e) the place has outstanding heritage value to the nation because of the place's importance in exhibiting particular aesthetic characteristics valued by a community or cultural group;

(f) the place has outstanding heritage value to the nation because of the place's importance in demonstrating a high degree of creative or technical achievement at a particular period;

(g) the place has outstanding heritage value to the nation because of the place's strong or special association with a particular community or cultural group for social, cultural or spiritual reasons;

(h) the place has outstanding heritage value to the nation because of the place's special association with the life or

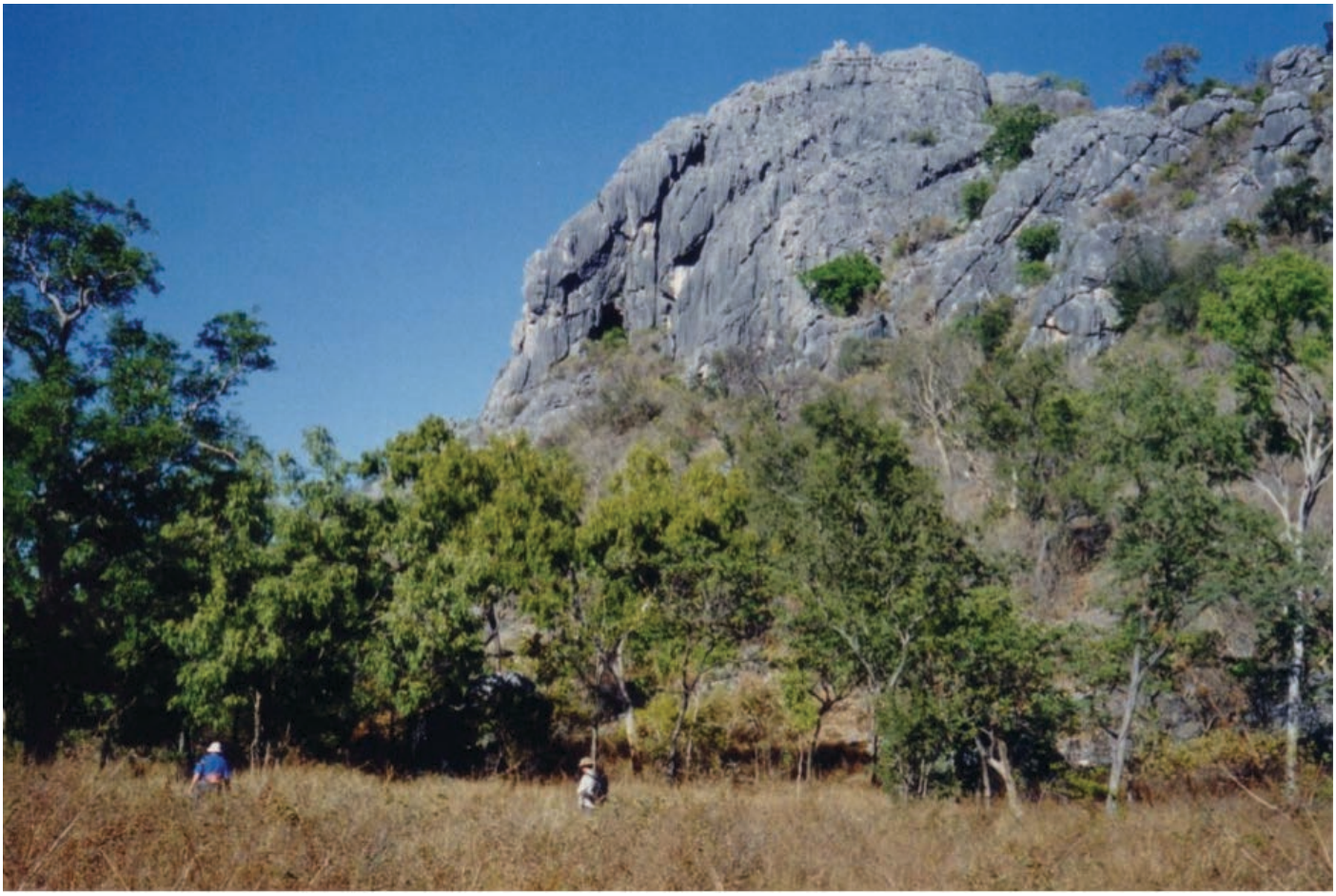

Figure 2. Mordor Bluff at the Mitchell-Palmer karst. This limestone tower is approx. 100m high above the surrounding chert plains. Photo: David Gillieson.

works of a person, or group of persons, of importance in Australia's natural or cultural history; or

(i) the place has outstanding heritage value to the nation because of the place's importance as part of Indigenous tradition.

Thresholds relate to the level or ranking of the heritage values that a place must possess in order to be placed on a heritage list. Usually a comparative analysis of similar places in Australia needs to be carried out. Criteria of integrity and authenticity of the place may also be important. Threshold determination may also need to rely heavily on relevant experts with access to a range of unpublished literature or relevant data. Although there are tools for assessing the biological values of a place, until recently there has been no comparable tool for comparative analysis of geological or geomorphological values. White and Wakelin–King (2014) have developed a semi-quantitative methodology for this purpose. The Earth Sciences Comparative Matrix (ESCoM) groups sites in process themes. Each site is assessed against National Heritage criteria and compared with other similar places according to their degree of unusualness, integrity, and authenticity. A site scoring well across multiple themes has increased heritage significance. The overall values of a site are quantified, leading to a ranking which enables a qualitative judgement on whether it achieves the threshold of outstanding heritage value. Gap analyses are a well-tested method for comparative analysis of a suite of possible sites (Sharples 2014). They have been applied to the assessment of potential World Heritage sites in karst (Williams 2008) and provide guidance for State Party nominators.

Figure 3. Copper sinter deposit associated with sediment infill in Tea Tree Cave, Chillagoe. Photo: David Gillieson.

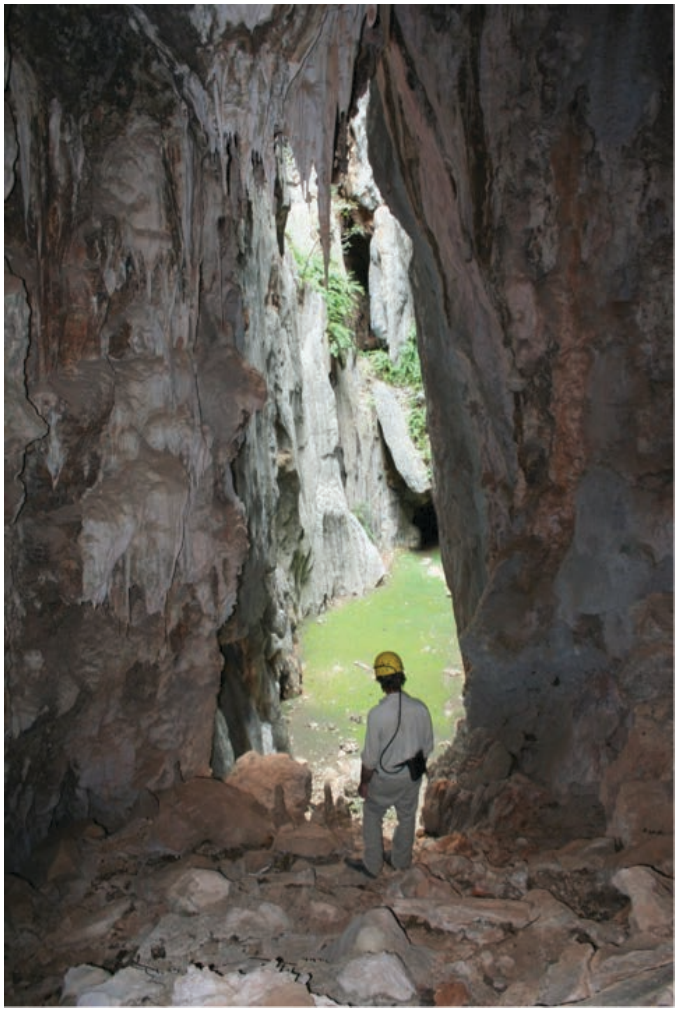

Figure 4. Solution corridor in Queenslander Cave, Chillagoe. Corridor intersections produce larger amphitheatre chambers which may contain ponds in the wet season. Photo: David Gillieson.

Geoheritage values – Chillagoe and Mitchell-Palmer karsts

The karst towers or bluffs at Chillagoe extend over a considerable distance in a series of sub-parallel blocks, and achieve heights of up to 65 m above the surrounding undulating terrain. Further north the karst towers at the Mitchell-Palmer area achieve greater heights (Fig. 2) and extend over a distance of 80 km between the Mitchell and Palmer rivers.

There is good evidence to suggest that the karst towers are least of Jurassic age (160 million years), as there is a demonstrated unconformity between the Chillagoe limestone and overlying Jurassic sandstones near Bellevue station. Blocks of Jurassic limestone also unconformably overlie the limestone at the top of Piano and Spring towers and also at the entrance of CH208 cave. Copper sinter deposits (Fig. 3) due to hydrothermal activity some 280 million years ago in the Permian (Nethery 2005) are also found in a few caves, and may provide a maximum age for the initiation of cave development.

Surrounding the Chillagoe towers and formed in the same limestone are low-angled pediments or ramps – inclined erosional surface covered with a thin layer of sediment. Some

are narrow (20–30 m wide) and have a steep slope (around 20º). Others are gentler and several hundred metres wide with rock pavements, thin veneers of soil and limestone rubble. Low bevelled limestone outcrops, showing rounded solutional forms, protrude through the soil on these pediments. Pediment development appears to be greatest closest to the main drainage lines. Close to the major rivers the karsts are covered with river sediments at their margins and small swamp slots are present. In the higher and more extensive Mitchell-Palmer Karst, the towers are flanked by steeper bedrock ramps with skeletal soils and some scree (rocky debris). In all cases cave entrances are commonly found at the junction of the ramps or pediments and steeper slopes above.

Most of the towers of the Chillagoe and Mitchell-Palmer Karst have very well developed solution rills which drain the upper surfaces of the pinnacles and feed larger solution runnels. Within the solution rills are often low sub-horizontal ribs of limestone (solution ripples). There are extensive solution pans on the upper surfaces of the towers, along with deep clefts and solution corridors (Fig. 4). Solution along vertical joints and bedding planes within the limestone has produced the clefts; these range in size from a few tens of centimetres across to extensive corridors that may be 10 m wide and 30 m deep. A few of the larger towers contain amphitheatrelike depressions filled with large limestone blocks; these probably represent large collapsed cave passages.

Some towers have developed in coarse sugary marble (sugarstone), formed by contact metamorphism around the margins of the granites. The marble towers have a rounded, domed appearance with extensive exfoliation sheets; some of these may relate to spalling after grassfires. Solution rills, if present, are shallower and rounder than on limestone towers, and may be absent altogether. The subsoil weathering of the marble produces a micro-pitted surface, particularly evident in finegrained varieties; this contrasts with the smoother subsoil surfaces formed on un-metamorphosed limestone.

Speleothem (cave calcite) deposits are common in almost all caves, and may completely block passages. The most abundant form is cave coral, rough knobbly protrusions usually only a few centimetres long that cover large areas of cave walls, along with a form of moonmilk. Two types of stalactites are common within the caves, normal stalactites and "suckerpads". Suckerpads are large stalactites up to 1 m across and 8 m long that terminate not in a point but as a subhorizontal plane covered in small cave coral. The outside surface of suckerpads is rough and chalky, though they appear to be active during the wet season, when water can often be seen dripping from their flat terminations. Their origin is uncertain; the flat terminations do not represent an old floor or water level, as they occur at a variety of heights within the one passage, and some are even slightly inclined.

Cave floors are composed of a mix of fallen rock slabs and flat silt or clay; many caves also have deep guano deposits. False floors are often present 10–20 m above the present floor. The sediment remnants beneath the false floors are reddish breccias that may contain bone deposits. These bone breccias (Fig. 5) have yielded a probable Pleistocene fauna (1.8 million to 12,000 years old) including several extinct mammals (*Phascolomys* and

Figure 5. Cave breccia containing subfossil marsupial bones in a Chillagoe cave.
Photo: David Gillieson.

Palorchestes), and a Ziphodont crocodile. Cemented bone breccias are also found on the surface of a few towers, along with eroded speleothem remnants, indicating the former presence of caves now almost completely removed by erosion. On the walls of many cave entrances and daylight chambers oriented rock needles with algal associations (phytokarst) are well developed.

Biological heritage values

Inland dry rainforests on limestone have strong affinities with the humid rainforests of the northern wet tropics and the eastern Australian coast. This suggests an evolutionary link between humid and arid (inland) communities (Fensham, 1995). Many of the animals and plants of the dry rainforests are restricted or endemic to these communities, while others have Gondwanan affinities. Many of the animals and invertebrate groups including spiders, beetles and butterflies are dependent on the dry rainforests for food, shelter and breeding sites. Leaf litter from the dry rainforests is also a critical food source for cave invertebrate communities. Although dry rainforests are widespread in their extent, their patchiness and small size contribute to their uncommon status.

The Chillagoe-Mungana Karst dry rainforest associations demonstrate the principal characteristics of this class of natural environments. The dry rainforest of the Mitchell-Palmer Karst has close affinities, but the diversity of species is slightly higher in the Chillagoe-Mungana Karst. Dry rainforest communities are considered to be uncommon and threatened at the national level and seventy-five percent of their original extent has been cleared. In particular, Semi-deciduous Vine Thicket (Regional Ecosystem [RE] 9.11.8) and its associated plants is listed as Near Threatened under the Qld Nature Conservation Act (1992).

The Chillagoe-Mungana dry rainforests contain four nationally rare or vulnerable plant species (*Graptophyllum excelsum, Alectryon tropicus, Atalaya calcicola* and *Macropteranthes montana*), two endemic plant species (*Terminalia chillagoensis* and *Brachychiton chillagoensis*), and two limestone-dependent plant species, *Graptophyllum* sp. and *Flueggia* sp., which also occur in the Fanning River Karst near Townsville.

Dry rainforests between Rockhampton and Chillagoe show eight major floristic groupings and 16 sub-groupings, some currently restricted in distribution, and others spread over a large area occurring on a large number of landforms and soils. These groupings overlap, forming three major centres of biodiversity. They appear to be regional refugia for these nationally restricted communities. The northern refuge, centred in the Chillagoe/ Mount Garnet area, has nine floristic groupings, seven of which are endemic (Fensham 1995).

The dry rainforests are floristically distinct from, but closely related to the monsoon rainforests of Western Australia, the Northern Territory and Cape York Peninsula in far North Queensland. There is also a strong degree of floristic overlap with the littoral rainforests of the Queensland coast with 87% of the inland woody species also occurring within 1 km of the seaboard (Fensham 1995). The exact nature of the relationships between these vegetation types and the inland dry rainforests of North Queensland is not known, and the puzzle is further complicated by generic (rather than species) overlaps with the rainforests of the Wet Tropics region. These complicated biogeographical relationships, coupled with the patchiness of distribution and lack of specific environmental preferences, have spawned a series of fierce debates as to the origins and evolution of the dry rainforests (Fensham 1995).

The habitats of the Northern Quoll (*Dasyurus hallucatus*) and the Greater Large-eared Horseshoe Bat (*Rhinolophus robertsi*) are both listed as Endangered under the EPBC Act and are closely associated with limestone outcrops and caves. The caves of the Chillagoe-Mungana karst are also important as roosting and maternity sites for the Chillagoe Australian Swiftlet, *Aerodramus terraereginae chillagoensis.*, and over 2,000 individuals have been recorded from here (Tarburton 1993). It is a poorly known bird suspected of being a nationally threatened sub-species, and also occurs in a few caves in the Mitchell-Palmer karst to the north.

The Chillagoe caves host 17 bat species including Bentwing Bats (*Miniopterus schreibersii* and *M. australis*), Common Sheathtail Bat (*Taphozous georgianus*), Horseshoe Bats (*Rhinolophus megaphyllus* and *R. philippinensis*), Leafnosed Bats (*Hipposideros ater* and *H. diadema*) and Eastern Cave Bat (*Vespadelus troughtoni*). At Mitchell-Palmer one cave contains a roosting site for the Ghost Bat (*Macroderma gigas*).

The invertebrate cave faunas of the Chillagoe and Mitchell-Palmer Karsts are not well known, but preliminary studies suggest the caves' faunas share common characteristics with the rainforest karsts across northern Australia. About 19 species of troglobites and two species of stygobites are known are known from the caves in this area (Howarth 1993). One of the more diverse invertebrate groups found in the caves of the Australian wet tropics are plant hoppers (*Homoptera*) of the fulgoroid families Cixiidae (especially the genus *Solonaima*) and Meenoplidae (especially the genus *Phaconeura*). North Queensland has the highest concentration of cave-adapted plant hoppers (*Fulgoroidea*) in the world (Hoch and Howarth 1989a,b). These are found in the caves of Chillagoe, but the number of species present has not been verified. Aquatic cave communities in these karsts have not been researched in detail, but of note is the endemic blind amphipod, *Chillagoe thea*. This amphipod colony in Tea Tree Cave has been the subject of water level monitoring and chemistry studies by the Queensland Department of Environment and Heritage Protection.

Evidence is increasing that a vast array of life forms exists underground in water-filled fractured limestone rock and caves (Culver and Pipan 2009). These invertebrate stygofauna are characterised by convergent morphological features including loss of eyes, pigmentation and elongation of appendages. From studies in Europe and America (Gillieson 1996), physiological and behavioural adaptations probably also occur, but knowledge of the basic biology and ecology is largely lacking. Initial work in Australia (Hamilton-Smith and Eberhard 2000) suggests that diversity is greatest in the tropical north. The Chillagoe and Mitchell-Palmer karsts have high potential for interesting research into the biogeography of tropical biological systems. The area is highly significant biologically but is poorly known in terms of described species or their ecology. Isolation of invertebrate populations in separate towers appears to have led to significant speciation but whether caves within towers represent isolated populations is completely unknown.

Comparative heritage analysis

The most obvious comparison is with the Limestone Ranges of the Kimberley in WA. The geologic context there is quite different, with Devonian reef limestones occurring in broad belts with original depositional structures still evident, for example at Windjana Gorge. The karst of the Limestone Ranges is also dissected by larger rivers such as the Lennard and Fitzroy, as well as smaller creeks and spring outflows such as at Brooking Gorge. The larger caves in the Kimberley are associated with major springs or antecedent stream capture eg. Tunnel Creek. Although there are some higher level caves, eg. Pigeon's Cave, these relate to former levels of the major rivers and there is no evidence of hydrothermal activity (though this is not impossible). Mimbi Cave is a very extensive floodwater maze cave with some phreatic features. In other areas of the tropics comparisons could be made with much smaller areas such as the Colless Creek karst (Lawn Hill), Broken River karst, Christmas Creek, Limestone Ridge and Mount Etna NP.

The Chillagoe karst demonstrates a greater diversity of karst landforms due to its structural complexity and lithological

variation. In addition the Chillagoe karsts are isolated outcrops of limestone or marble, arising from surrounding pediment slopes developed in cherts and other sedimentary rocks. The caves of the Chillagoe area also exhibit greater variation, ranging from extensive maze caves formed by slowly moving groundwater, to rift systems developed along fault alignments and vertical rifts with decorated chambers at their base. While these karst towers are not as extensive or spectacular as those near Guilin in China, they are exceptional in Australia and are comparable with the mogotes of Cuba and Puerto Rico, as well as tower karsts in Madagascar. They are also far more accessible and thus have significant educational value.

A nomination for the Chillagoe and Mitchell-Palmer karst areas was submitted by the author in 2009 and a lengthy correspondence with the Department of Environment ensued. The proposed boundaries of the place were adjusted to avoid current mining leases, reducing the total area by around 50%. Additional information and photos were provided to the Australian Heritage Council.

The Australian Heritage Council has now assessed the Chillagoe Karst Region for potential National Heritage values (Department of the Environment 2015). The Council has identified that the Chillagoe Karst Region (including parts of the Mitchell-Palmer Karst Belt) met the National Heritage criteria for its outstanding karst limestone bluffs, towers and cave development. The specific criteria met were as follows:

"B (Rarity) Tower karst is an unusual landscape type in Australia, with the best examples found in the Chillagoe Karst Region. Tower karst are distinctive steep sided limestone outcrops, some in the Chillagoe Karst Region attain heights of over 100m.

D (Principal characteristics of a class of place) The Chillagoe Karst Region contains the best examples of tropical limestone bluffs and towers in Australia, and is potentially significant at a global level with the closest comparisons being in Cuba and Madagascar. The cave systems include over 1,000 recorded and mapped caves, the largest extent of cave development in Australia.

E (Aesthetics) The Chillagoe Karst Region is renowned for its spectacular limestone towers that are the best examples of their kind in Australia".

The Council's assessment was made available for public review and comment until November 2015, and following this the assessment and comments are now with the Minister for the Environment for his final decision.

Ongoing conservation and management issues

Little is known about traditional Aboriginal burning practices in the Chillagoe area. It is likely that small patches were burnt seasonally to clean up country and provide a mosaic of regeneration favouring perennial plants and wildlife. Aboriginal burning was carefully controlled and timed to achieve these goals. Following the introduction of grazing by cattle, much larger areas were burnt in individual fires and the seasonality of burning changed (John Fred, QPWS, pers. comm.). Older residents assert that this has caused a change in composition of the grasslands to more annual species, and associated hydrological changes due to compaction and reduction in soil infiltration rates. Pastoral properties in the area currently favour early dry season burns (May to July), with fire exclusion in the dry season itself. Storm burns are then carried out at the onset of the wet season (November to December) to favour the growth of green pick (Crowley & Garnett 2000). This may also enhance the availability of grasses such as cockatoo grass (*Alloteropsis semialata*). Cockatoo Grass fills an important role in the tropical savannas of Australia, providing food for seed-eating birds and small mammals (Crowley 2008). It can be considered a "keystone" species for at least two animal species that rely on it to survive when other foods are unavailable, the Golden-shouldered Parrot (*Psephotus chrysopterygius*) and the Northern Bettong (*Bettongia tropica*). There is ongoing interaction between the pastoralists and the Parks Service, with a well-developed fire management system designed to provide a better prescription for fires for strategic purposes.

The dry vine thickets that cloak the limestone outcrops are vulnerable to fire (Fensham et al. 1994; Fensham 1995), and their margins may be degraded by fire spreading from adjoining grassland into areas where weed species have established. Under past intensive grazing regimes, fuel loads in grassland were kept low. The removal of grazing from many areas is creating a dense growth of native and introduced grasses, as well as some shrub encroachment. This promotes more intense fires which have the potential to burn onto the limestone and further reduce the total area of vine thicket. The edge of the burnt vine thicket is a key site for the invasion of Indian Couch (*Bothriochloa pertusa*), which will help carry fires further into the vine thicket vegetation.

In common with many other limestone area, weeds have been introduced throughout the European history of the area. There has been a long-term program in the Chillagoe area to reduce weed populations, with some success. The shrub chinee apple (*Ziziphus mauritiana*) was widespread in the area but has been brought under control following a vigorous eradication programme by QPWS. This has involved chemical control with Tordonax being used initially, then later Access, which is regarded as being very effective. The rubber vine *Cryptostegia grandiflora* has been widespread along watercourses and has invaded adjoining grasslands. It can be controlled by judicious use of fire and increased grassy fuel loads have assisted this. It is now reduced to isolated thickets in grassy landscapes. Invasive grass species such as grader grass (*Themeda quadrivalvis*), spread through disturbance, and have been reduced with fire exclusion in a five year trial at Royal Arch bluff. The tall weed *Hyptis suaveolens*, a problem throughout north Queensland and the NT, is controlled by spraying. Long term plans for weeds involve reduction in chemical spraying and strategic use of fire as a control measure.

Feral cats (*Felis catus*) have been recorded in many areas, and have significant impacts on bats and swiftlets within the caves. A trapping program near the Royal Arch tower to reduce numbers (Alanna Little, QPWS, pers. comm.) has been successful. A local decline in the numbers of the Northern Quoll may be due to competitive exclusion by cats. Feral pigs (*Sus scrofa*) are widespread and pose a problem throughout north Queensland. Trapping and shooting have been carried out opportunistically throughout the Chillagoe area. Feral pigs not only cause major ecosystem disturbance through uprooting and trampling of native vegetation, may act as disease vectors, and predate on frogs and other small vertebrates. Cane toads (*Rhinella* [*Bufo*] *marina*) are present in the area and guides eradicate them in developed caves whenever possible.

The region has a long history of mining and Chillagoe represented one of the largest metallurgical developments in Queensland before World War 1, with a focus on copper, lead, silver and gold (Fig. 6) (Kerr 1992). After the 1920s the profitability of operations in the district dwindled and had largely ceased by the end of World War 2. In the 1980s, and after exploration by a range of companies, Amoco Minerals identified potentially payable gold bearing ore near the former township of Mungana and in 1983 Mungana Mines Ltd was formed. Active mining operations commenced with the Red Dome Project in the mid-1980s, however this had largely ceased by 1997 apart from ongoing rehabilitation. In 2006 Kargara Ltd recommenced active operations in the Red Dome Project area with the development of the Mungana polymetallic underground mine. This has now closed, and a more recent 2012 proposal to

re-open the Red Dome mine by Mungana Gold Ltd has fortunately been shelved.

Some small-scale quarrying of marble by family businesses is carried out in the area. There has been concern over the de-watering of small quarries in the vicinity of Tea Tree Cave at Chillagoe, which might lower the cave pools and cause local extinction of the stygofauna therein. Any surface discharge of water might eventually enter the cave, and the main ongoing concern would be hydrocarbon pollutants in the pumped water. We know very little about the detailed hydrology of the Chillagoe area, and dye tracing in the wet season might help elucidate the flow paths through the caves and groundwater to the springs.

The impacts of visitors upon the surface and sub-surface features of a karst environment are well known to cave and karst managers everywhere, as are the challenges of regulation of commercial and recreational usage of these resources (Watson et al. 1997; Gillieson 2011). There has been a fairly standard approach adopted at Chillagoe, where people may choose to partake in a commercial guided cave tour, or visit a free-entry nominated self-guided site or walking track without the requirement for further permitting. Persons seeking a caving experience beyond these limits need to apply for a special activity permit if they intend to cave within the National Park or adjacent areas. The restrictions imposed on such applicants are aimed at protection of the resource, safety of the participants and reduction of the liability of the landholder. Currently, all guided cave tours in developed caves are conducted by QPWS staff. In the near future, it is proposed that these same caves be made available for other commercial tour guides to use. Guidelines for these operators will presumably be underpinned by the same basic tenets as for recreational caving.

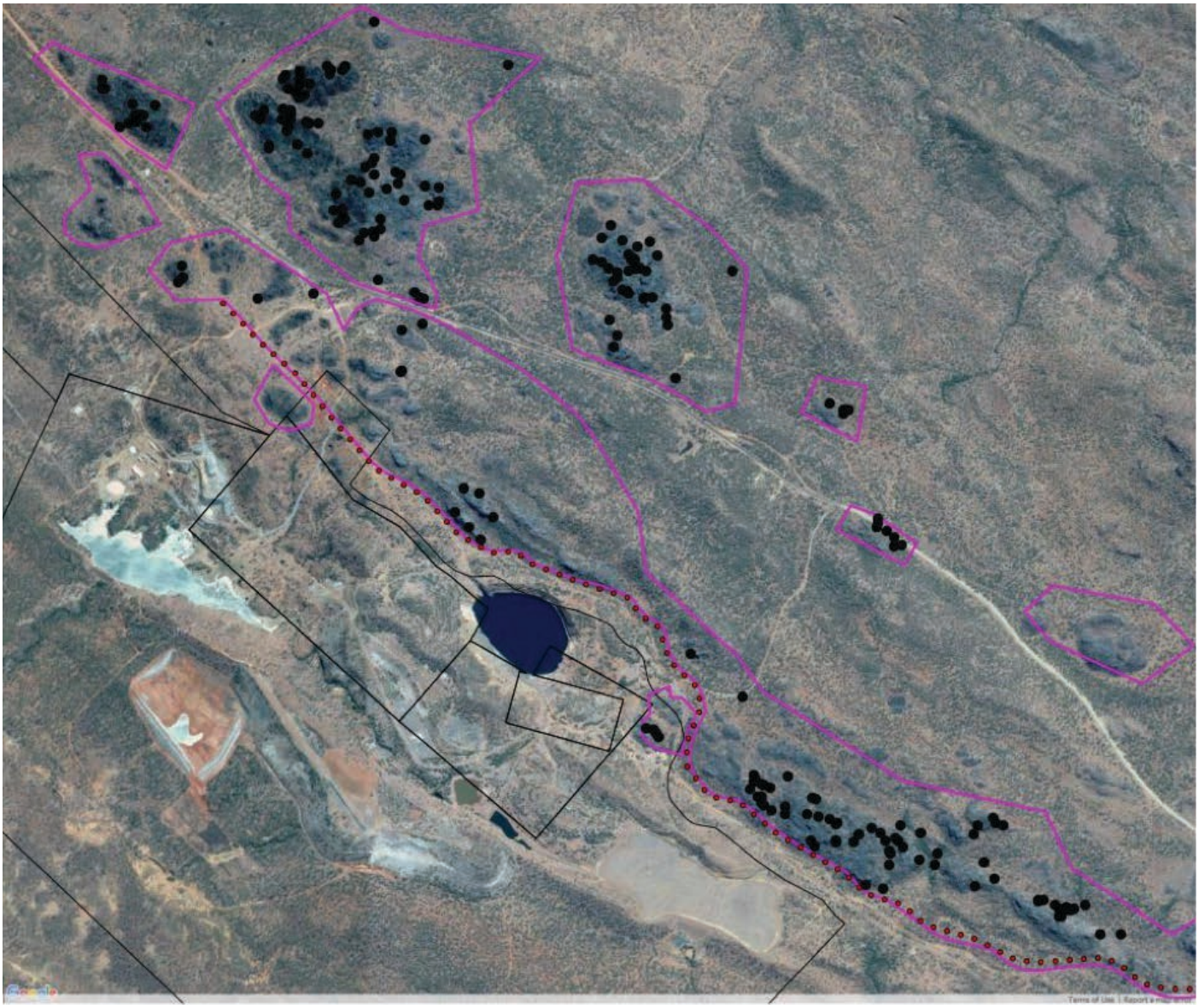

Figure 6. Limestone bluffs adjacent to former Red Dome Mine, Chillagoe.
Purple lines represent proposed National Heritage List boundary, black dots are cave entrances. Vector data from ERIN and Australian Speleological Federation; base map is an IKONOS satellite image dated 3 September 2010.

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CALCITE STRAW STALACTITES GROWING from CONCRETE STRUCTURES

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Abstract from the peer reviewed paper published in *'Cave and Karst Science', Vol.43, No.1 (April 2016).*

In this paper, the term 'calthemite' is used to encompass the various concrete-, mortar- or lime-derived secondary deposits consisting primarily of calcium carbonate ($CaCO_3$) that grow from man-made alkaline structures outside the cave environment. Calthemites are very similar in composition and form to speleothems in limestone caves, but in concrete-derived straws, carbon dioxide (CO_2) is a reactant as opposed to a product. The growth rates and corresponding drip rates of four stalactite straws growing beneath a concrete building were recorded over a ten month period. The major influencing factors determining calcite deposition were the supply continuity of leachate and the drip rate. Growth rates up to two millimetres per day were recorded. Minute calcite rafts were observed and photographed on the solution drop surface. Sporadic movement of rafts around the drop surface (induced by air movement), is identified as affecting straw diameter and wall thickness. Deposition of $CaCO_3$ straws derived from concrete is usually associated with hyperalkaline solution (pH > 9) as opposed to the near neutral pH to mildly alkaline solutions (pH 7.5 – 8.5) that commonly deposit speleothems.

I am sure that every cave guide has been asked sometime in their career to explain the difference between cave stalactites and those hanging under concrete buildings and bridges. This sort of question probably sends shivers down your spine as you reach to the depths of your knowledge on the subject.

There is certainly the short answer - "the stalactite under a bridge is a secondary deposit of calcium carbonate ($CaCO_3$) derived from the cement/concrete and the cave stalactite is $CaCO_3$ secondary deposit derived directly from limestone".

While there are similarities in appearance and morphology, there are considerable differences in the chemistry and growth rate.

Examples of Calthemite straws in an underground carpark

Example of Calthemite flowstone on concrete water tank

So how much time and explanation does one put into a description of the differences between a "speleothem" or those "other things" which look the same but grow under concrete structures? I personally think it is nice to impart a little more knowledge on the subject to that inquisitive tourist, rather than the short answer above.

Certainly, cavers like myself have pondered over the sight of such wonders. This prompted me to take on a study of these calcium carbonate secondary deposits under manmade structures and I learnt a lot along the way. So as not to bore you too much, I have written just a little on the background to this study and then briefly detailed some key findings followed by the chemistry. This should provide a few short answers, which can be pulled out of the hat when hit with that curly question from an inquisitive tourist.

The initial focus of the study was to determine how quickly the straws grew and what factors influence their growth. Chemical reaction causing calcium carbonate ($CaCO_3$) deposition soon grabbed my attention and was found to be closely related to solution pH. This proved to be just the starting point, which raised many more questions and widened the project scope. The quest for answers led to a number of interesting and previously undocumented observations and the introduction of a new word.

Examples of calthemite straws in an underground carpark

Photographing and measuring calthemite straws in an underground carpark

What term to use?

Concrete secondary deposits in the shape of straws, stalactites, shawls, flowstone, stalagmites etc, mimic cave speleothems in many respects. This led me to an extensive literature search for the appropriate term to use. Descriptions in published papers circumnavigate the question of a concise term to cover calcite precipitates on man-made structures. Examples from '*Cave Minerals Of The World'*, Hill and Forti (1997) include: "non-cave stalactites which derive their calcium carbonate from concrete", "formations under concrete structures" and "deposits in the outside world, while not speleothems in the strict sense, nevertheless mimic the forms taken by speleothems".

The term 'speleothem' by definition can only be used to describe, stalactites, straws, stalagmites, flowstone, etc, which were created in a cave. Hence, for the purposes of my study the term 'Calthemite' is used to encompass the various decorations mimicking speleothems, derived from man-made structures containing cement, mortar or lime. The word 'calthemite' is derived from the Latin calx (genitive calcis) "lime" + Latin < Greek théma, "deposit" meaning 'something laid down', (also Mediaeval Latin thema, "deposit") and the Latin –ita < Greek -itēs – used as a suffix indicating a mineral or rock.

So in essence the simplistic analogy is that 'calthemite' encompasses secondary deposits derived from manmade structures outside a cave environment, where as the term 'speleothem' describes secondary deposits inside a cave.

Summary of Findings

1. Continuity of solution and drip rate has the most influence on a calthemite straw's growth rate.
2. Evaporation due to atmospheric temperature and humidity, had no measurable effect on a calthemite straw's growth rate.
3. No straw growth occurred if the drip rate was more frequent than 1 drip/minute.
4. A maximum growth rate of 2mm/day was recorded when there was 11 minutes between drips.
5. The pH of the hyperalkaline solution influences which chemical reaction or reactions is/are depositing calcium carbonate at a particular time and location.
6. The hyperalkaline solution creating the calthemite straws is typically pH > 9 and commonly reaches pH 13.5, which can easily burn human skin.
7. Deposition of calcium carbonate as calthemite decorations, occurs when atmospheric CO_2 diffuses into the drop solution, as opposed to normal cave speleothem chemistry where CO_2 is degassed from solution.
8. Calcite rafts may form on the surface of solution drops and can influence a calthemite straw's growth, outside diameter and create surface irregularities.
9. When there is almost no air movement, calcite rafts form a latticework over the drop surface when drip rate is slower than approximately 1 drip every 5 minutes. Air movement or a pulse of solution through the straw will break up any latticework to create small rafts, which may spin violently. Stronger air movement can shear some rafts from the drop surface and push them onto the straw's outside surface.

As a comparison, speleothem straw growth is also influenced by the continuity of solution and drip rate. Likewise the evaporation of solution is considered to have little influence on deposition rate. So the big difference comes down to the capacity of the solution to carry calcium ions to the site of deposition. Calcium hydroxide which leaches from the concrete is about 200 times more soluble than calcite in water and therefore facilitates the rapid growth of calthemite straws compared to normal speleothem straws in limestone caves.

The growth rates of stalactites in natural limestone caves have been well documented by repeated measurements in well-known caves. Data show that stalactites in caves rarely grow more than 2 millimetres a year and may average only a little more than a tenth of a millimetre per year. In comparison a calthemite straw can easily grow 0.5mm per day to achieve 180mm in a year. During the study one calthemite straw grew an average of 2mm per day over several days, which in theory equates to a possible growth of 730mm a year if this rate remained constant. From these figures, it is easy to see the huge difference in growth rates between calthemite and speleothem straws.

Rafts Observed on Calthemite Solution Drops

A long period between drips (≥5 minutes) was sufficient time for absorbed CO_2 to cause precipitation of $CaCO_3$ from solution and form rafts on the drop surface, which were visible to the naked eye (up to 0.5mm across). Their sporadic movement around the drop surface aided by air movement and internal solution pulses, caused some rafts to be pushed onto the straw's outer surface. These rafts influenced the thickness and irregularities of a calthemite straw's outside diameter.

A 34 second video of rafts spinning on the surface of a solution drop can be viewed on YouTube at https://www.youtube.com/watch?v=G-gm_kN5Xes

Calthemite Properties

Just like speleothems, calthemites may be coloured due to iron, copper, zinc or various minerals, deposited in conjunction with the calcium carbonate ($CaCO_3$). Hence the predominately white calcium carbonate will be stained orange from rusting steel reinforcing bars. Another example is copper pipes passing through or near concrete, while less susceptible to oxidation, can produce a green or blue copper oxide, which discolours calthemites.

Specialist equipment was not available to determine the morphology of the deposited $CaCO_3$, however it is most likely being precipitated from solution as calcite, as opposed to the less stable polymorphs of aragonite and vaterite.

Calthemite Chemistry

When water is added to a dry concrete mix it reacts readily with the calcium oxide (CaO) in the cement to form calcium hydroxide ($Ca(OH)_2$), which can further dissociate to form Ca^{2+} and hydroxide (OH^-) ions. [Equation 1].

$$CaO_{(s)} + H2O_{(l)} \leftrightarrow Ca(OH)_{2(aq)} \leftrightarrow Ca^{2+}{}_{(aq)} + 2OH^-{}_{(aq)} \quad [1]$$

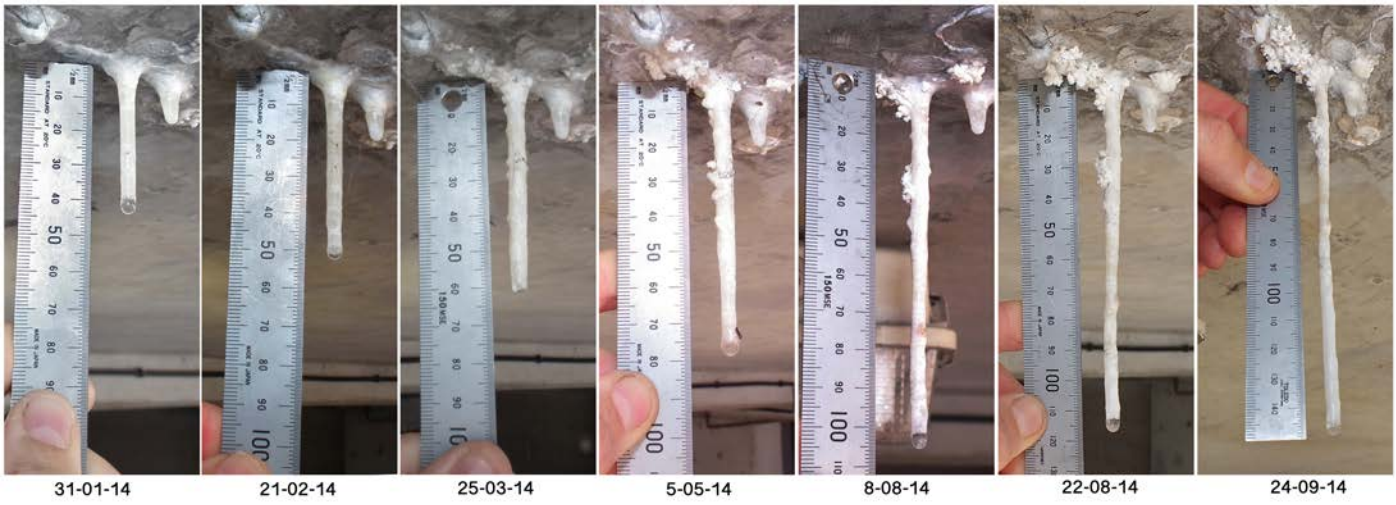
Any carbon dioxide (CO_2) trapped in the mix reacts with the $Ca(OH)_2$ to precipitate $CaCO_3$ within the concrete structure [Equation 2].

$$Ca(OH)_{2(aq)} + CO_{2\,(g)} \leftrightarrow CaCO_{3(s)} + H2O_{(l)} \quad [2]$$

Reaction [2] occurs within the concrete matrix until all the available free CO_2 in the mixture is used up. Setting concrete

Freely moving calcite rafts whirl around solution drop due air movement

Latticework of calcite rafts on slow dripping straw during period of very little air movement



Growth of calthemite straw No.1. The sequence shows the growth of 104mm in 237 days. When there was only one drip every 11 minutes, this straw grew at 2mm per day. The date below each image relates to date of measurement recording.

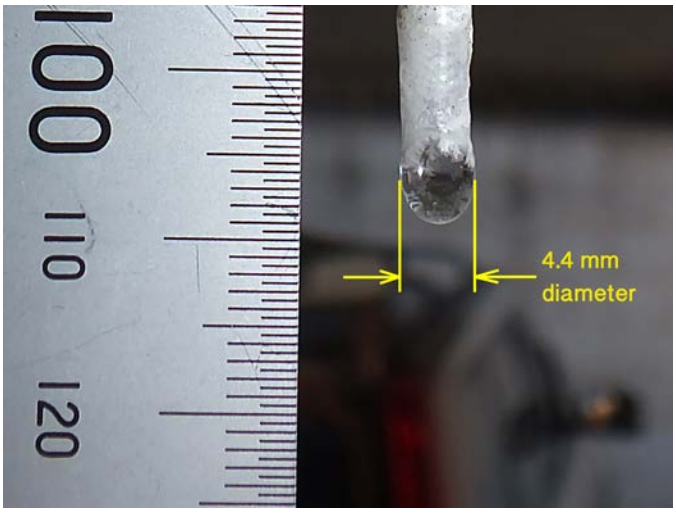


Image showing diameter of calthemite straw

exposed to the atmosphere containing more CO_2 will allow reaction [2] to continue to a shallow depth (commonly just a few millimetres) from the surface after which atmospheric CO_2 is unable to penetrate and carry on the reaction [Equation 2]. Hence, free $Ca(OH)_2$ remains within the structure of set concrete.

Rain or seepage water which penetrates microscopic cracks and air voids in set concrete, will readily carry $Ca(OH)_2$ in solution to the edge of the concrete where it reacts with atmospheric CO_2 to precipitate calcium carbonate [Equation 2], thus forming calthemite straws etc.

To complicate the issue, there is a period when the presence of potassium and sodium in new concrete will support a higher solution alkalinity of about pH 13.2 – 13.4. The hyperalkaline solution becomes supersaturated with Ca^{2+} compared to a mildly alkaline solution. When the hyperalkaline leachate emerges from beneath the concrete structure, CO2 is absorbed into the solution from the atmosphere [Equation 3] resulting in the dominant ion CO_3^{2-} reacting with Ca^{2+} to precipitate $CaCO_3$ [Equation 4].

$$OH^-_{(aq)} + CO_{2(g)} \leftrightarrow HCO_3^-{}_{(aq)} \leftrightarrow CO_3^{2-}{}_{(aq)} + H^+_{(aq)} \quad [3]$$

$$Ca^{2+}_{(aq)} + CO_3^{2-}{}_{(aq)} \leftrightarrow CaCO_{3(s)} \quad [4]$$

Over time the leachate pH will decrease to 12.5 as the majority of the more soluble potassium and sodium hydroxides are leached out and the dominant reaction reverts back to Equation [2]. As time passes, the available $Ca(OH)_2$ will leach from the cement paste along the seepage path and the pH will fall even further till carbonic acid (H_2CO_3) becomes dominant and the chemical reaction will change to a similar process to that which occurs in limestone caves. The weakly alkaline leachate has a low Ca^{2+} carrying capacity (compared to hyperalkaline leachate) and $CaCO_3$ deposition occurs under concrete structures when CO_2 is degassed from solution [Equation 5].

$$2HCO_3^-{}_{(aq)} + Ca^{2+}_{(aq)} \leftrightarrow CaCO_{3(s)} + H_2O_{(l)} + CO_{2(g)} \quad [5]$$

The reaction Equation [5] appears to only occur under specific circumstances relating to very old concrete or mortar (possibly 10s or 100s of years old) and is essentially the same as the reaction occurring in limestone caves.

For an in-depth look at the chemistry, refer to the complete paper published in *'Cave and Karst Science', Vol.43, No.1, P. 4-10, (April 2016).*

Details of full paper

This study was first presented at the ASF's 30th Biennial Conference, 21st – 26th June 2015, Exmouth, Western Australia and later published in *'Cave and Karst Science', Vol.43, No.1, P. 4-10, (April 2016), British Cave Research Association, ISSN 1356-191X.*

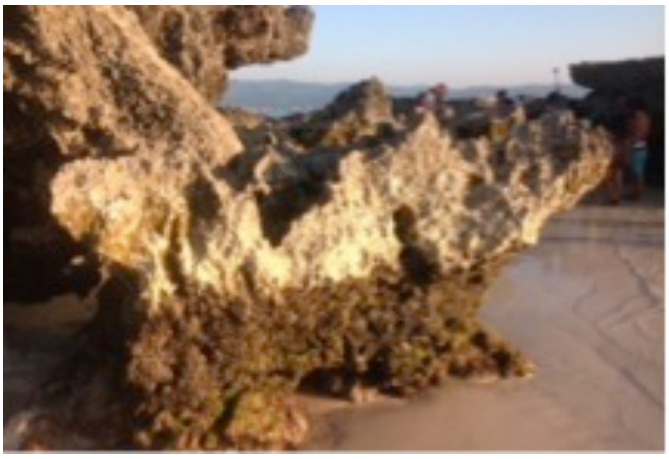
Acknowledgements

I would especially like to thank Dr Ken Turner whom I consulted on many occasions for advice on the chemistry, and Dr Andrew C Baker and Jodie Rutledge for critical review of the paper.

PHILIPPINE KARST ADVENTURES
Part 1 - BOROCAY

Kent Henderson

In March this year I found myself in the Philippines…for the want of crowns on ten of my teeth that were well past their use-by date. One said crown, in Melbourne, was quoted at $2500; the same in Manila cost $450. Clearly, a no brainer! While one is in the Philippines, apparently, one flies to the resort island of Boracay (pronounced Bore-rack-ky).



Lithified coastal karst

Dutifully, I did as I was told…for a week's stay. Boracay features a four kilometre white-sand beach, and over 200 'resorts' ranging from 5 star right on the beach down to the unfortunate the further away from the sand you get. I chose to stay at the former, buoyed by the 'profit' on my teeth! The beach is bordered by every conceivable hotel, restaurant and tourist trap imaginable….and vendors prepared to flog you absolutely anything.

100% of the local Filipino population is employed directly or indirectly in tourism, and their overriding aim is separate the unsuspecting visitor (largely 'ese these days…Chinese, Japanese…) from their money. And the cunning Filipinos have devised hundreds of ways to do just that. Water sports are the big 'industry'…from island hopping, to parasailing, to snorkelling to diving. If you can think of every possible water sport, these and many extras are available…at very reasonable prices (of course!). Actually, in truth, Boracay is not expensive. I had a one hour beach massage most days for the equivalent of $10.

And…to get to the real point…the Philippines in general to some extent, and Boracay in particular, is replete with karst. The Boracay coastline, that which is not pure white sand, is easily recognisable as karst – its heavily karrened features being obviously water and wind created. It is interspersed with a substantial number of sea caves of varying sizes (but mostly not big); as is the case on the many small to micro-sized surrounding islands. The karst, particularly around seashore areas, is largely lithified sand and limestone, which is especially high in magnesium calcite.

One of my first trips was to go island hopping, which is basically a boat trip to the nearby smallish island of Tagwatian, commercially renamed as Crystal Cove Island Resort (the word 'resort' is very loosely intrepreted in the Philippines). Very

Left. 'Cove 2', Crystal Cove Island Resort

Right. Manufactured 'stalagmite' structure - 'Cove 1',Crystal Cove Island Resort

largely karst, it is probably the most totally modified landscape I have ever seen. Every pathway, viewing tower, man-made pool, garden, and building was constructed with a mixture of concrete and rocks of hijacked karst, with the odd bit of wood or bamboo thrown in for added interest. Upon arriving by outrigger motor boat, my tour group was told that an hour was available to walk around, after which swimming back was the only other (impossible) option. Actually, the said hour was (then unbeknown to me) being quoted in Filipino Time, which has very little relationship to accepted chronology…adding at least half an hour later to what one might expect.

Crystal Cove Island Resort is also the home of two substantial sea caves…known as Cove 1 and Cove 2, roughly at either end of the island. We are not talking big here…one can quietly walk from one end of the island to the other in 10-15 minutes. The two 'coves' are entered by doubtfully engineered spiral staircases, though they are functional enough. Having descended into Cove 1, you are actually alighting 'mid-cave' with a view out to sea through the cave entrance.

At Cove 2 however, the foot of the staircase brings you to the mouth of the cave, whence you enter clutching bamboo hand rails and get quite wet, at least up to the crutch, in the process. Mind you, given that most tourists here, whether Eastern or Western, are invariably young and wearing not very much, this is hardly a problem. Management? Other than to

Karst-constructed 'viewing tower', Crystal Cove Island Resort

Coastal micro-stacks, Boracay

say the infrastructure, such as it is, will possibly avoid you being washed away, additional comment is superfluous.

Ah, but back on Boracay, there are other (sea) caves. The best known is the Bat Cave located in the north-east of the Island. Actually, there is Bat Cave 1 and Bat Cave 2, but I suspect they may well be separate entrances to the same cave.

The cave is actually well above sea level, perhaps indicating a more aged morphology than its assumedly younger sea-level cousins. The cave is the principal home of the local flying fox population, and also, evidently, a species of micro-bat. The Golden-Crowned Flying Fox (*Acerodonjubatus*), weighing up to

Willy's Rock, Borocay

The 'horror' of Willy's Rock...

1.2 kilograms, is the largest bat in the world and is highly endangered. This is largely because, I was advised, the locals have a great interest in consuming the said mammal either roasted, fried, boiled or fricasseed. As a result, the cave was officially closed about four years ago, apparently to stem the slaughter. The current state of the remnant population is anyone's guess.

The circular staircase into 'Cove 1', Crystal Cove Island Resort

Nonetheless, I determined to visit the cave entrance, at least. Thus I hired a motorbike tricycle, at the expected usury rate, to voyage to the site. Now local tricycle riders have, I discovered, an abiding interest in speed. Mine managed to come very close to breaking the land speed record on our journey – remember, time is money! So it was that I arrived at Ilig-Iligan Beach (below the cave) only marginally later than I departed…

Unfortunately, I discovered (nobody advises you of these things) that the track to the cave had been blocked off; so my excursion came to nought. But at least I was content in the knowledge that, probably, flying fox was not on the menu at any Boracay dinner table that evening… As an aside, I later discovered (and used them) that the majority of tricycles on Boracay (which comprise about 100% of public transport) are actually electric, with a four hour range, and one hour charge time. Oh, and of necessity they travel at sedate speeds too!

Power for Boracay comes from a substantial number of wind turbines on the adjacent (very large) mountainous island of Malay, and arrives via undersea cable, as does the island's water supply. So not everything about Boracay is environmental doom and gloom.

But back to the karst. The 'horror' stories do continue, I am afraid. There is a group of five small karst stacks just off the beach adjacent to a 5 star hotel.

So, what to with them; they obviously get in the way of clients view of the horizon! Easy…you level their tops, and concrete a continuous flat platform over the lot of them, with a restaurant thereupon. Wow! What a plan! Very sad indeed, but true. Good job the Twelve Apostles near Port Campbell, Victoria, are not near Boracay…

Then there is Willy's Rock, a small group of micro-stacks just off White Beach. What to do with them? Easy…why not cut stairs into the karst and put a 'Madonna Shrine' on top? Of course! This ensures that hundreds of people a day clamber all over it. It is a great tourist attraction!

Nonetheless…overall…if you can see your way past the heavy commercial exploitation of the karst and to some extent the natural environment generally – which is largely based on ignorance – then a visit to this otherwise idyllic area is most rewarding.

This is Asia, after all, with a different culture and set of values. So, if you are a fan of Bali, my advice is, forget it, go to Boracay!!

For more information:

http://boracaystories.com/forum/content.php?338-Geology-of-the-Seashore-Beach-Rocks

PHILIPPINE KARST ADVENTURES
Part 2 - THE MONTFORT BAT CAVE

Kent Henderson

In April I was back in Manila for a second round of crowns and on this occasion, during the necessary dental interregnum, I decided to fly south to Davao on the island of Mindanao, thence to the adjacent smallish island of Samal to stay at the Pearl Farm Resort (and very pleasant it was too). However, I had a dual purpose in travelling to this location, as Samal is also home to the famed Montfort Bat Sanctuary – which I visited with considerable alacrity!

My guide, Marly, in the superb Montfort Bat Sanctuary Interpretation Centre

The Montfort Bat Sanctuary has been the home of a large colony of 1.8 million Rousette fruit bats (*Rousetteus amplexicaudatus*) since recorded history. They cover 75% of the ceilings and walls of their 75 metre long cave. According to Guinness World Records, it is the largest single colony of its kind.

Many species of bat in Asia are endangered simply because their greatest predator is man, who kills them for food, as I noted with the bat population of Boracay. Happily, the Samal bats are fully protected. The Inigo-Montfort family has maintained the area since the 1900s. Norma Montfort is the current owner of the 57 acres of land surrounding the cave. She enclosed the property to discourage any possible bat hunters. Additionally, she hired 24 hour guards to protect the bats. In 2011 she was named Disney Worldwide Conservation Fund Hero. The cave is, not surprisingly, heavily aligned with Bat Conservation International.

The site is open to the public daily. I undertook a tour with the lowest possible expectations, given my past experiences of Asian cave and karst management. I have never been more pleasantly surprised in my life! The cave has five entrances – a widish normal type cave entrance, plus four collapsed doline entrances. It reminded me to some extent of a 'mini' Blanche Cave at Naracoorte.

The tour guide, Marly, was superb. She spoke excellent English, was highly trained, very knowledgeable as a result, and clearly had a huge passion for bats! The first point to make is that there is no public entry to the cave. As Marly quickly pointed out, unless you are an accredited bat scientist with at least a PhD, you do not get in! She had been guiding for over two years and had never set foot in the cave, nor did she have any desire to do so! Her interpretation was not just superb, it was compelling. She succinctly made the case for bat conservation, an extremely important message generally, but even more so in the context of the Philippines.

The main cave entrance

Bats clinging to the walls below a doline

Examples of interpretation panels

As may be appreciated, while not an expert; I do know a bat when I see one...but I learnt much. The Samal bats are very highly organised in their cave. The young bats reside collectively not far inside the main entrance. The next section of the cave, below the first doline, is inhabited by females. The next by males. Elderly bats, both male and female, live at the back of the cave below the last doline. I had never before been aware of this social structure amongst bats.

Rousetteus amplexicaudatus

I plied Marly with many questions, some rhetorical to test her knowledge, and she did not falter. A very impressive professional and something I did not expect to encounter.

And the cave management? Tremendous! All dolines are fenced with bamboo, the usual material for such in the Philippines – it is quite effective. The barricading was at a suitable distance to ensure no intrusion on the cave, yet close enough to allow excellent viewing. The tour progressed from doline to doline, having started at the main cave entrance. I attended late morning, but one can also book a tour at sunset to view the daily circadian flight. I didn't get to see this, but 1.8 million bats streaming out of the cave would undoubtedly be impressive.

During the course of the tour I questioned Marly about predators. Other than humans (sigh..), the main predators are

The bamboo infrastructure surrounding each doline – quite effective

crows, rats, pythons, and lizards. I am advised the floor of the cave is 'crawling' with 10 foot long pythons. The predation of crows is interesting. Sick bats fly out in daylight, and are attacked by the many crows perched in surrounding trees; which I actually observed to occur.

The Montfort Bat Sanctuary also has one of the best interpretation centres I have seen (and that is saying something!). It is 'sort of open air', roofed but with no walls – perfect in this hot climate. The myriad of interpretation panels were outstanding and completely covered all aspects of bat conservation. I was mightily impressed. Overall, I give the management and interpretation of this cave ten out of ten! This is something I never expected in Asia! Outstanding!

A view across a doline

IS CAPRI more than the BLUE GROTTO?

Tim Moore
Judge of the NSW Land and Environment Court

Capri is a Mediterranean island to the west of the Italian mainland. It is situated to the south-west of the port of Naples and is accessed by ferry services from Naples and Sorrento. The island is known to have been inhabited since early Roman times, acting as a retreat for the nobility. Indeed, during the last 10 years of his reign, the Emperor Tiberius resided on Capri, leaving only occasionally, ruling the Empire from the Villa Jovis.

In more modern times, Capri has become a major tourist destination. In the late 19th century, a significant colony of northern European expatriates lived on the island, living (as some commentators describe it) a libertine lifestyle. It is, however, not the intention of this article to traverse salacious stories of those times. More recently, conventional tourism has become by far the dominant economic driver for the island. There are two principal focuses of this tourism. The first is the ruins of the Villa Jovis, Tiberius' palace, whilst the second, the Blue Grotto – *Grotta Azzurra* (known and visited since early Roman times), provided the trigger for this article.

The vast majority of tourist visits to Capri are undertaken as day trips by ferry. The advent in the last 15 years or so of high-speed ferries that supplement the more traditional slower-running ferries has meant that, with an early departure from either Naples or Sorrento, coupled with a return on a late afternoon ferry, a comprehensive visit to the two major sites on Capri can be undertaken in a day.

In December 2015, I visited Capri with my wife and our 13-year-old daughter and 11-year-old son. I had carefully researched ferry timetables, walking times to the Villa Jovis from the head of the funicular running from the ferry wharf to Capri village, boat availability to visit the Blue Grotto, opening times of the Villa Jovis and the other range of matters needing to be ascertained. I was satisfied that an early ferry on a Tuesday (departing Naples at 8.30 am) would give us ample time for a visit. I had, however, underestimated what might be described as "administrative flexibility" in the Italian bureaucracy - such "flexibility" leading to the Villa Jovis being closed on Tuesdays in December rather than on the advertised Monday closing day.

However, this article can be regarded as the beneficial outcome of that "flexibility" as it enabled us to charter a small boat to take us not only to the Blue Grotto but also on a circumnavigation of the island. What I observed during the three hours or so of circumnavigation caused me to pen this, my first submission in some 25 years' membership of the Association.

Conventionally, visitors to the island wishing to see the Blue Grotto travel the three kilometres or so to the west along the northern shore of the island from the main jetty in aquatic versions of a tourist bus. When they arrive outside the Blue Grotto, they are obliged to transfer, in groups of two to four, to small open rowing boats to be conveyed inside the cave. This is necessary because the aperture to the cave is quite small – 2 metres wide and 1 metre high – (its size being a contributing factor to the blue effect in the water within the cave). Entry into the grotto is also only possible in calm seas and from about three-quarter tide down.

Access is a quite regimented and highly commercially sophisticated process. First, it is necessary to pay a fee to the Commune of Capri for the right to access the Blue Grotto. Second, it is necessary to pay a fee to the individual boatman (they all appeared to be men) conveying you into and out of the grotto itself. We understood, for our trip, it was also expected that, in addition to the formalised payment, there was also an unspoken (but impliedly mandatory) requirement to give a more than modest tip to the boatman upon return to the relevant mother craft.

An entry ticket to the Blue Grotto

When we visited, we had to await the processing of the 20 or so tourists on each of the two aquatic tourist coaches that arrived after but at approximately the same time that we did – bulk customers getting preference. There appeared to be about eight skiffs operating with four or five of them in the cave at each time. A photograph of a skiff emerging after a visit to the cave is reproduced below:

After successfully transferring from our modest open boat to a skiff, we were rowed to the opening where entry was effected by pulling us through the narrow aperture using a chain affixed along the rock for this purpose, the chain extending for two metres or so on both the outside and inside.

Once inside the chamber (illuminated only by an occasional camera flash), the luminescent blue effect that gives the grotto its name was immediately apparent. This effect is caused by -

> *…, the light comes from two sources. One is a small hole in the cave wall, precisely at the waterline, that is a metre and half in diameter. This hole is barely large enough to admit a tiny rowboat, and is used as the entranceway. In photographs taken from within the cave, the above-water half of this hole appears as a spot of brilliant white light. The second source of light is a second hole, with a surface area about ten times as large as the first, which lies directly below the entranceway, separated from it by a bar of rock between one and two metres thick. Much less light, per square metre, is able to enter through the lower opening, but its large size ensures that it is, in practice, the primary source of light. As light passes through the water into the cave, red reflections are filtered out and only blue light enters the cave.*[1]

[1] https://en.wikipedia.org/wiki/Blue_Grotto_(Capri)

Emerging from the Blue Grotto

The effect is quite startling and entirely unexpected given the usual grey-green colour of the sea outside the entrance.

The internal dimensions of the cave are that it is roughly oval with a domed roof and walls that are almost, but not entirely, smooth. Its approximate dimensions are 60 metres deep; 25 metres across and 10 metres high, in the centre, at mid-tide. The water has a generally uniform depth of 150 metres with a sandy bottom. At the rear, on the southern side, there are two

Our craft

The author's daughter in the Blue Grotto

small apertures, said by our boatman to have led to the entrance to a staircase to a now disappeared Roman villa that had been located above it. However, I subsequently discovered that this was an urban myth and they are dead-end passages. There is, however, no doubt that the cave has been visited since Roman times (including, it is believed, by the Emperor Tiberius himself during his residence at the Villa Jovis). A number of broken elements of Roman-era statuary have been recovered from the floor of the cave.

To understand why a discussion of Capri, in a karst context, is more than an "oo-ah" description of a visit to the Blue Grotto, it is necessary to start with a description of the location, settlement pattern and landform of the island.

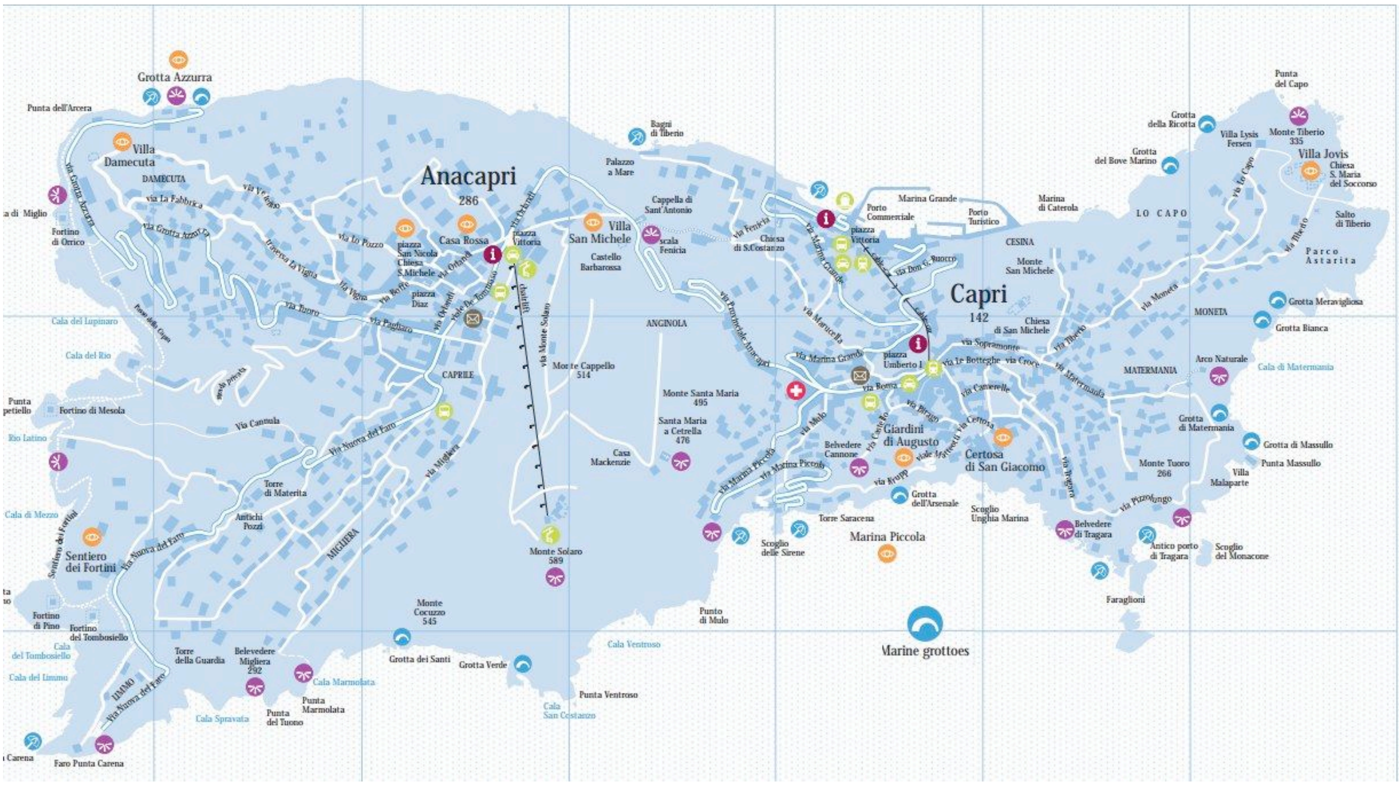
> *"Capri lies 31.5 km due southwest of Naples, and 4.8 km out from the Sorrentine peninsula. It is 6 km long, varies in breadth from 1200 m to 2.8km and covers an area of 1036 ha, of which Capri occupies 400 ha and Anacapri 636 ha. The high land in the west, which rises 590 m to the peak of Monte Solaro, and the less elevated area in the east, rising to 335 m at Monte Tiberio and there plunging precipitously into the sea, are formed of whitish-grey limestones. The intervening depression is filled by sandstones and marls. Capri abounds in natural grottoes; most are at sea-level, but a number are found at a considerable altitude. Capri was not always an island. It probably shook itself free from the mainland during eruptions which convulsed the whole Neapolitan region and left the deposits of volcanic tuff which occur above the limestone and immediately below the present land surface."*

A tourism map of Capri shows the location of a number of caves around the coastline of the island. The map describes them as "Marine grottos". Virtually all of these are only accessible by sea and, with the exception of the Madonna Cave and the Matermània Grotto, are features primarily caused by wave erosion and/or collapse at water level.

The features, other than the Blue Grotto, listed by the Tourism Authority where a cave has been regarded as especially notable appear limited to three locations.

The first of these, the Matermània Grotto, has been heavily modified for habitation/religious purposes with changes such as excavation and wall construction dating to Roman times. It is accessible from land and by sea and is described by one travel writer as follows:

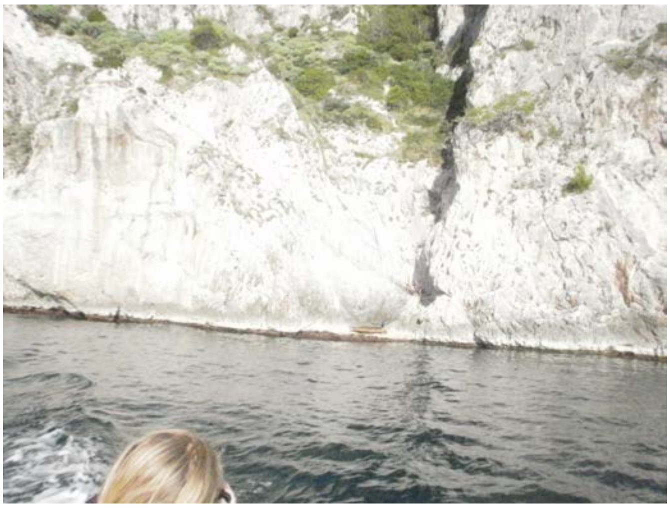
In antiquity, this had been a nymphaeum, or shrine to water



Map of Capri

nymphs, decorated with marble statues and glass mosaics, artificial pools and seashells. Legend holds that the grotto was also a place for the worship of Cybele, the pagan goddess of the earth, known as Magna Mater, or Great Mother, who gave it its name.

The second of these, what our boatman called the Madonna Cave, is a cave with a significant, conventionally created karst feature of a single large stalagmite. This cave is only accessible by sea and only at higher tides and in calm seas. The title, the Madonna Cave, is given as an interpretation by locals in the anthropocentric naming practice still, unfortunately, used in some cave guiding.



Landing point for the Madonna Cave

Madonna Cave and "Madonna"

Our boatman on our circumnavigation informed us, however, that there was no particular (at least contemporary) religious significance attached to the feature or its location. Photographs of the aperture of the Madonna Cave and its landing platform from the sea are reproduced below.

[2]*Money, James, Capri: Island of Pleasure, Hamish Hamilton, London, 1986, p xv – note all measurements have been converted to metric.*

[3]*http://www.capri.net/images/download/Capri-Island-Map.pdf*

[4]*OED: "A grotto or shrine dedicated to a nymph or nymphs" – not a place of debauchery as some might assume!*
[5]*http://www.smithsonianmag.com/travel/the-lure-of-capri-1003163/#EDSVXaTW1udPvyXJ.99*

Although the sea conditions were suitable for landing at the time we passed it on our circumnavigation, the tide was unfavourable and landing was not possible.

The third is the Arsenale Grotto which *"was used as a temple and nymphaeum in Roman times. Its name is derived from the military use to which it was put during the Middle Ages"*. However, Wikipedia also records:

> *It measures 4m long by 3.5m wide by 1.5m high. Excavations made in 1777 in the shingle, which still covers the floor to a depth of from 1.2-1.5m, showed evidence of traces in the walls of two or three rooms which were of Roman workmanship, along with a floor of coloured marbles, and some iron fragments, which have been identified as part of the plant of the ancient naval station, or perhaps of a Roman galley. Although the floor of the cave is 2.4 m above the sea, in southerly gales, waves hit it so forcefully as to render its use as a storehouse out of the question. The walls unearthed here indicate, therefore, that at the time they were built, this cave stood higher above the sea than it does at present.*

After our circumnavigation, an enquiry at the Capri Tourist Office brought the response that, with the exception of the Matermània Grotto, the only caves that were of any tourist interest were those that were approached by sea, dominantly the Blue Grotto and, are less frequently, the Madonna cave. There was no tourist value in any of the other known caves. As far as the staff of the Tourist Office were aware, there was no interest in exploration of any of the readily visible cliff caves and there was no present (or to her knowledge past) interest in examining any of the non-maritime limestone cliffs or other karst areas on the island.

Thus, the point of writing is not merely to describe what is identified by Capri Tourism as cave features of the island. It is to speculate what might be there and remains to be discovered if there were to be any determined speleological exploration of the island. This question crossed my mind during our circumnavigation as a consequence of the quite frequent appearance of apertures, shallow or otherwise being unknown, on the cliffs that were readily observable as we progressed in our journey. These features clearly showed aspects consistent with conventionally known karst formation processes with stalactites readily visible at the mouth of these apertures. A photograph of one such feature observed from our boat is reproduced below.

I could only ask myself what I might find had I had more time; several hundred metres of quality rope and proper climbing gear; and a wife and children prepared to indulge my folly. I suppose, to be brutal, I probably would have needed to have been there 20 years earlier as well!

Cliff-face feature showing stalactites

ANDYSEZ 56
SOURCES OF INFORMATION FOR CAVE GUIDES (AND OTHERS)

Andy Spate aspate1@bigpond.com

At the Guide Workshop at Capricorn Caverns recently I met a bevy of cave people all enthusiastic to learn more so I decided to amplify an earlier ANDYSEZ.

First and foremost — I will endeavour to answer your questions or send you off in the right directions to sources who might know better. I also have an *'Introduction to Speleology'* document for various Australian cave areas – much out of date but still useful – that I can make available.

Second – the 'members only' area of the ACKMA website (http://www.ackma.org) where there are about 50 "ANDYSEZ" columns that deal with the things you get asked about. Such as 'how do helictites form' or what are the 'ages of speleothems'. One of those ANDYSEZs (number 52) deals with information sources but after the wonderful Capricorn Caverns cave guide workshop in May I thought I might update things – maybe broadening the scope. ANDYSEZ 52 contains more detail about the various books mentioned here – except the more recent Speleothem Science – details of this below.

To see all the ANDYSEZ columns:

Log into http://www.ackma.org. Then login to MEMBERS ONLY. Once in there look for the black bar above the blue you will see PROCEEDINGS – click there and you will see a green menu with ANDYSEZ listed – click there and the rest is yours!

Going back to the ACKMA website – you can now search the conference proceedings and such of the Journal articles that are there as well us much as much else. If you have problems contact Rauleigh Webb at webmaster@ackma.org – but try to resolve any problems yourselves so as not to overload our great IT guru.

Moving right along … I believe that every Australasian cave guide (and manager) should have day-to-day access to at least these three books:

- *Beneath the Surface*
- *Caves: Processes, Development and Management*
- *Cave Minerals of the World*

see ANDYSEZ 52 for details

The first book is completely Australia related whilst the second travels more broadly but was written by an Australian and has many examples from this country.

Maybe these should be on your front counter or in your education area as well …

- *Cave Geology*
- *Karst Hydrology and Geomorphology*
- *Cave Conservation and Restoration*

see ANDYSEZ 52 for details

Why am I not providing details here? I want you to be using the ACKMA website resource. It is your site! Accessible if you are an ACKMA member or through your organisation's membership.

Cave Conservation and Restoration is a very hands-on book covering a multitude of subjects based on many years of practical experience. It was published by the National Speleological Society (of the USA). I strongly recommend this book to each cave workplace also.

Speleothem Science: From Process to Past Environments: by Ian Fairchild and Andy Baker, is a much more recent book (2012) and contains a wealth of information – although heavy going in places. The publisher's blurb states:

> *Speleothems (mineral deposits that formed in caves) are currently giving us some of the most exciting insights into environments and climates during the Pleistocene ice ages and the subsequent Holocene rise of civilizations. The book applies system science to Quaternary environments in a new and rigorous way and gives holistic explanations of the relations between the properties of speleothems and the climatic and cave setting in which they are found. It is designed as the ideal companion to someone embarking on speleothem research and, since the underlying science is very broad, it will also be invaluable to a wide variety of others.*

Students and professional scientists interested in carbonate rocks, karst hydrogeology, climatology, aqueous geochemistry, carbonate geochemistry and the calibration of climatic proxies will find up-to-date reviews of these topics here. The book will also be valuable to Quaternary scientists who, up to now, have lacked a thorough overview of these important archives.

There is a more thorough review in an earlier edition of the Journal (No. 87 June 2012) The publisher's list price is $130 and $104.99 as an E-book. I got my copy at a much better price from a British firm bookdepository.com – although checking now I find it is more expensive there now at W 110,424 (I am writing this in Korea so that is Korean currency – the won = about $127).

If you visit http://bcs.wiley.com/he-bcs/Books?action=index&bcsId=7193&itemId=1405196203 you can download the figures associated with each chapter as MS PowerPoint files – very well worth a look! You can also view the tables for each chapter as pdf files – perhaps much less useful.

Obviously there is an immense range of websites. Some are:

- International Show Caves Association: http://www.i-s-c-a.org
- National Speleological Society: http://www.caves.org
- Show Caves of the World: http://www.showcaves.com
- International Union of Speleology: http://www.uis-speleo.org
- Australian Speleological Federation (including access to the Journal Helictite); http://www.caves.org.au
- Slovenian Karst Research Institute publishes a free, multidisciplinary e-journal at: http://ojs.zrc-sazu.si/carsologica
- Andy: http://www.karstmanagement.com

And a zillion others. A google search on 'cave related websites' reveals 825,000 sites – enough for a couple of rainy afternoons!

I hope all of this helps you build your information base to underpin your presentations – but there was so much else conveyed and discussed at Capricorn Caverns – thanks to Cathie, John and David – but much more to the guides and others who participated in those wonderful days. Information is only part of the guiding experience!

ACKMA AGM WEEKEND 4 to 8 MAY 2017
PROPOSED PROGRAM for the CAVE GUIDES' GATHERING AND ACKMA AGM TE ANAU, FIORDLAND, NEW ZEALAND

Neil Collinson

The event will be based in Te Anau and will focus on sharing experiences in Fiordland National Park which includes both karst, caves and bush settings.

Fiordland is known as the "Mountains of Water" and rainfall in most of the areas to be visited is between 1.5 and 3.5m annually. In the heart of the park rainfall exceeds 7m annually. In May temperatures will be range between zero and 12 degrees.

Therefore all participants will need to be prepared for this climate. The areas to be visited is relatively remote and access to all sites is weather dependent so the program may be subject to change.

The activities will also require a level of fitness above that required for normal show caves visitation as all caves in the program, (apart from the Glowworm Caves and Clifden Caves) are, by ACKMA conference standards, remote. Access will require walking off track, often uphill, and some stream or river crossing may be required so participants will need to bring suitable clothing and equipment.

Within the program there are options for varied fitness levels (some trips while being off track are relatively flat) other will require good levels of fitness with extended periods of uphill walking. We therefore ask that trip descriptions are carefully considered and that you chose activities within your capability. As part of the overall risk management for the event we reserve the right to limit/amend options if there is any doubt to a participant's suitability to safely undertake the excursion.

Some trips will also be limited by permit restrictions, so pending demand we may switch options/dates around to provide maximum access within the rules. We are working with the Department of Conservation (DOC) to maximize the opportunity within the date ranges of the event.

While Te Anau has a wide variety of accommodation available we are hoping to negotiate special rates with one of the major accommodation providers which has everything from tent sites, shared dorms, individual rooms to the newest motel suites in Te Anau. We will provide further details in the next journal, the main point being that accommodation shouldn't be a problem in May.

There will be a combination of included and own cost meals during the program. Te Anau has numerous restaurants, catering for everyone.

Wednesday 3 May 2017

1800hrs - Welcome to Te Anau (informal BBQ dinner) arrivals are welcome throughout the day and pending numbers we may offer a coach connection ex Queenstown.

Thursday 4th May 2017

A WALK IN THE PARK

Following a group introduction to Fiordland (Te Waihi Pounamu) South West New Zealand World Heritage Area transport will depart for the following interpretative walk options. These walk are all on formed tracks and offer a range of different experiences. A local guide will accompany each group and during the walk there will be sessions on interpretation techniques and "guiding" principles. Each location offers something very different and will ensure we can keep group size appropriate to the locations.

Hollyford Valley – This option will be aimed at the guides, with a strong focus on the importance and value of developing thematic interpretation. This will be a relatively flat walk in the iconic Hollyford Valley alongside the Hollyford River. A key theme of this walk is Maori and early European history associated with the area. The trip will include a drive of approx. 1.25 hours into the Hollyford with approx. 4 to 5 hours on the track. This is the most remote walk to choose from and offers something very special walking under the peaks of the Dividing Ranges. Overall 8 hours return trip ex Te Anau.

Kepler Track – This option is aimed at those wanting a more leisurely walking experience with a link to conservation partnerships and a detailed look at predator control. A flat walk option close to Te Anau incorporating beautiful bush, river and wetlands landscape. You will walk to the shores of Lake Manapouri and Motu Rau Hut. During the walk you will hear about the Kepler Bird Song project (extensive network of pest management) and also learn about 'Kids Restore the Kepler" an Air New Zealand funded partnership with DOC providing local education programs with a conservation theme. This trip will be approximately 6 hours' duration return ex Te Anau and includes an easy walk of approximately 2 hours each way with some sightseeing on-route to the track.

Key Summit – This is a great opportunity for those that are physically fit and want to capture some world class scenery through their lenses. A taste of the iconic Routeburn Track. This walk climbs steeply from the Milford Road at the "The Divide" to an alpine area high above the roadway. In clear weather this location provides 360 degree views of all the high peaks of Fiordland. Suitable for those who are not allergic to hills. A good walking track but it is a steep climb and descent so a good level of fitness is required. Approximately 3 hours of steep track walking required.

Evening arrangements informal - meal at own expense

Friday 5 May 2017

CAVING

A full day program South of Te Anau into the Waiau Valley to visit Clifden and St Peters Caves. Proposed two groups that will switch morning and afternoon programs. Pending overall numbers.

Clifden Caves – A roadside cave which has been subject to unrestricted visitation for over 100 years and is today managed by DOC under a Conservation Stewardship Area. Easy Caving (some water?) On site inspection of historic and recent graffiti with the visit an opportunity to discuss on site current best practice re restoration/clean up options.

St Peters Caves - A small river cave system with excellent Glowworm viewing and remarkably interesting formations in its upper sections. This trip is a relatively flat walk of 3km on farm land and through bush from the carpark on unformed

tracks. It also requires a crossing of the mighty Waiau River (Jet Boat).

The trip and caves are not technically difficult but do require a good level of fitness and being prepared to get footwear wet. This cave was only discovered in 1989 and is off the beaten track and due to access in quite good condition.

Evening arrangements informal - meal at own expense

Saturday 6 May 2017

Depart by boat for the Te Anau Glowworm Caves. Introduction to the operation, a cave tour will be completed.

ACKMA AGM and lunch on site at Cavern House.

Return to Te Anau and visit Bird Park and Fiordland National Park Visitor Centre.

Session on Aurora Caves and overview of other significant remote karst sites.

Evening - Group Dinner

Sunday 7 May 2017

AGM Field Trip – Aurora Caves

This is a full expedition trip into the extensive caves system above the Glowworm Caves. There is in excess of 6km of passage ranging from dry to full river passages. The Cave is not technically difficult however access to the caves is only gained after a steep climb through the bush. The cave's entrance is a key highlight of any trip into Aurora and worth a visit in itself. This cave can only be visited by permit as the entire system falls within the Murchison Specially Protected Area which is closed to public to preserve the last natural habitat of the "Takahe" flightless bird. With the co-operation of the Department of Conservation we have arranged permits to enable simultaneous staggered visits to the site. Three options will be offered to cater for different capabilities and speed however all are off the beaten track.

Option 1 - a more leisurely trip with a slower paced walk up the hill to view karst and visit the main entrance area of the caves only (possibly to Twin Falls).

Option 2 – Main Entrance to "Big Room" and return – a mainly dry route alongside the river initially and then away from the water to the divide, heading to largest cavern within the caves.

Option 3 - Main Entrance to "Sewer System" and return - a slightly more challenging and physical route from the Divide and further down into the caves system with just enough water to test your sense of humour.

While none of the routes is technically difficult, they all begin with a steep uphill walk followed by a descent into the caves. Inside the caves the route is over variable terrain with obstacles that can safely be free climbed but both cave options require agility and flexibility. Cave temperature is approximately 10 degrees.

Alternative program Coach and Cruise to Milford Sound.

If weather conditions or demand exceeds what we can achieve in one day then we may run an Aurora trip also on the Saturday afternoon (day prior).

Evening arrangements informal - meal at own expense (some will no doubt want to soak in a bath.....

Monday 8 May 2017

Mt Luxmore Alpine Karst Area

Walking both ways – Requires extremely good level of fitness hiking up Mt Luxmore from Lake level on the excellent formed track (Kepler Track). This is a climb of approx. 600m. Will be an early start and the walk normally takes 3 to 3.5hrs. From carpark to Luxmore hut is 14kms, with 8kms of that being a steady uphill climb. Once on top there is a number of caving options. Excellent views from the tops looking down over Lake Te Anau and Manapouri.

Lunch at Luxmore Hut (a DOC Great Walks Hut with 60 beds) toilets etc available.

Luxmore Cave – Easy - has marked route from hut so has had heavy visitation over the years.

Luckless Cave – Moderate, not as well known so much less visitation and damage.

Both these caves are 15 minutes' walk from the hut on a formed track. They are both relatively small rift caves with good to excellent formations.

The return walk downhill walk can be quite tiring with a steady descent. It can be broken by getting taxi back from Broad Bay (saves 6km flat walk)

The walk each way option is approximately a 10 hour day including caving and lunch on the tops.

Fly up Walk down

Take a 5 minute scenic helicopter from the lakefront to the Helipad at Luxmore Hut. This will be an addition cost of approx. $80 per person one way. Once on the top caving options as described previous. Flying will also enable off track exploration (in the alpine basin) to view other caves entrances and possibly visit a more sporting and rarely visited Steadfast Cave.

Walk back down as described above.

Fly up, Fly down

Caving as described above with a full day on the tops. Flying both ways total of approx. $160 return for heli flights.

Evening - final survivors' dinner provided.

Tuesday 9 May 2017

Depart Te Anau or undertake post AGM visits to Milford Sound or Doubtful Sound (own cost) but good rates available.

Speleo 2017

Sydney | 23-29 July

Caves in an Ancient Land

Image of Chillagoe by Alan Pryke

17th International Congress of Speleology, Sydney 2017

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