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Helictite

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Blue stalactite, Cliefden Garry K. Smith

Helictite

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Helictite was established in 1962 by Edward A. Lane and Aola M. Richards who were the foundation editors. It is intended to be wide ranging in scope from the scientific study of caves and their contents, to the history of caves and cave areas and the technical aspects of cave study and exploration. The territory covered is Australasia: Australia, New Zealand, the near Pacific Islands, Papua New Guinea and surrounding areas, Indonesia and Borneo.

In 1974 the Speleological Research Council agreed to support the Journal with financial assistance and in 1976 took over full responsibility for its production. From 1974 to 1997 the Journal was edited by Julia James assisted by other members of the Speleological Research Council Ltd. In 1998 Susan White and Ken Grimes took over as editors with Glenn Baddeley as Business manager.

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Contents

Cover: Blue stalactite in Murder Cave, Cliefden. Photo by Garry K. Smith. See paper by Ken Turner in this issue.

Helictite, Volume 38, 2002 will consist of two issues. Price per volume is Aust. $25.00 post paid (Australia and New Zealand) and Aust $27.00 (rest of the world). *Helictite* is printed and published by the Australian Speleological Federation Inc.

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Editorial

Susan White and Ken Grimes

This *Helictite* contains several short papers ranging from palaeokarst geology through cave-physics to biology. This is an indication of the range of interesting speleological work being done at present in Australia. We hope that this variety of papers will continue to be supplied to us for publication.

Palaeokarst is perhaps more extensive than many people realise (Armstrong Osborne excepted!). This may be partly because it is often described in geological or mining reports which do not use karst terminology, and which tend not to be seen by many speleological workers. The two short papers in this issue partly redress that gap and we plan some further short notes summarising geological reports on possible paleokarst bearing formations in other areas of Australia.

The short report on page 24 covering the recent megafauna discoveries in the Nullarbor highlights the importance of systematic exploration. As well as discovering these special deposits, the use of ultralight aircraft flying a regular grid pattern with ground support teams waiting to follow up the features seen is producing a dense and statistically valid set of data for selected parts of the Nullarbor. This will allow a much better scientific interpretation of the distribution and density of the various karst features.

You will see that we are making our first attempt at a colour cover. We felt that the effect of the blue stalactite was too spectacular to be represented in black and white. We have our fingers crossed concerning the quality!

Helictite web page

The *Helictite* web page is maintained by our Business Manager, Glenn Baddeley.
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The web site provides subscription information, a list of contact addresses, information for contributors, and contents and abstracts for all issues of *Helictite*. We now also provide a download area where readers may obtain data files for specific papers. The temperature data for the Sanderson & Bourne paper in this issue is available as a tab-delimited ASCII text file at:

http://home.pacific.net.au/~gnb/helictite/data.html

.PDF files for authors

Commencing with this issue authors may request a pdf format file of their paper in addition to the usual twenty free reprints.

Helictite (2002) **38(1):** pp. 3-6.

Chromophores Producing Blue Speleothems at Cliefden, NSW.

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Abstract

Osborne (1978) has described in some detail the blue stalactites that occur in Murder and Boonderoo Caves at Cliefden, NSW and reports “that the colour is due to some impurity in the aragonite and not to refractive effects”. In this study, small samples from the Boonderoo and Taplow Maze blue speleothems have been chemically analysed. Based on these chemical analyses it is suggested that the major chromophore is copper, with secondary contributions from chromium (Taplow Maze only) and perhaps nickel.

Introduction

Blue speleothems occur in Murder (CL2), Boonderoo (CL3) and Taplow Maze (CL5) Caves in the Cliefden Karst area in Central Western NSW (Figure 1). The caves are located in the Belubula River valley about 30 km north east of Cowra. The sky-blue stalactites (Figure 2) in Murder and Boonderoo Caves are reported to occur at the boundaries of the Upper and Lower Units of the Boonderoo Limestone Member and the Boonderoo and Large Flat Limestone Members respectively (Osborne, 1978). Osborne examined an Australian Museum sample (specimen number D36380) of the Boonderoo blue stalactite using optical microscopy and X-ray powder diffraction and found that the stalactite consisted of an inner zone of sparry calcite and an outer zone of aragonite. The author further concluded that “the blue colour is due to some impurity in the aragonite”. In addition to the blue stalactites discussed by Osborne, a number of blue speleothems occur in Taplow Maze Cave, including two aqua-blue columns (approx. 250 mm high) and two pale-sky-blue columns (approx. 300 mm high) surrounded by some flowstone. These are the only reported occurrences of blue speleothems in the Cliefden Caves system. The straight line distance from Murder to Taplow Maze cave is about 1.1 km (Central Mapping Authority, 1978). Note that the scale bar on Osborne’s topographic map is in error.

It was considered that the only way to establish the origin of the blue colour in the Cliefden Caves speleothems was to chemically analyse samples of the material. Fortunately, modern chemical analysis techniques, which have very high sensitivity, have made the study of *in situ* speleothems feasible. Meaningful chemical analysis data can be obtained from samples of only a few milligrams. Such samples can be carefully collected (essentially without causing damage) from the surface of an *in situ* speleothem. In conjunction with the Orange Speleological Society, arrangements were made to collect and analyse representative samples of the blue speleothems. To avoid ambiguity and to provide baseline compositional data, samples of adjacent white speleothems were also included in the study.

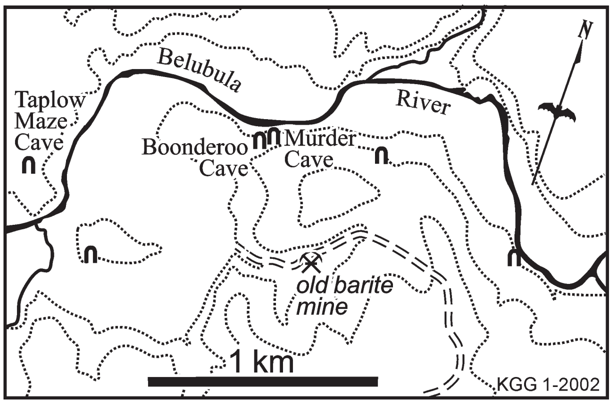

Figure 1: Location of Boonderoo, Murder and Taplow Maze Caves and nearby abandoned Barite Mine.

Sample Collection and Chemical Analysis

Boonderoo Cave

In late 1995 members of the Orange Speleological Society collected a sample weighing approximately 40 milligrams from the blue stalactite located in Boonderoo Cave. The sample was carefully scraped from a small area of the stalactite using a steel blade. The sample was subsequently analysed using laser ablation inductively coupled plasma mass spectrometry (laser ablation ICP-MS), which is a technique well suited to the analysis of small solid samples. However, it is difficult to fully quantify the results and the data should be treated as semi-quantitative. Concentrations are expressed in parts per million (ppm). An extremely small (less than 10 mg) reserve sample was subsequently analysed using graphite furnace atomic absorption spectrometry (GFAAS). GFAAS is a very sensitive technique for the determination of trace elements. The limited sample mass restricted the analysis to copper and reduced the accuracy of the analysis. Results are summarised in Table 1.

Figure 2: Blue stalactite in Murder Cave (CL3), Cliefden Caves. Photo by Garry K. Smith.

In addition, a sample from Boonderoo Cave was also available from the Australian Museum collection (specimen D23544). In this instance it was decided to try to obtain a more accurate analysis by using conventional solution-based ICP-MS rather than laser ablation ICP-MS. The samples were dissolved using a mixed acid digestion prior to analysis. Unfortunately, severe interference from the high levels of calcium present, coupled with the very small sample masses available resulted in unreliable analytical results from this approach.

Taplow Maze Cave

More extensive sampling was carried out in Taplow Maze Cave by members of the Newcastle and Hunter Valley Speleological Society in November 1996. Six samples were collected from a blue column and adjacent fallen broken white stalactite, two areas of blue flowstone and two areas of adjoining white flowstone. All samples were collected using a titanium scraper to carefully scrape material from the surface of the speleothem onto clean glazed sampling paper. The sample was then transferred to a zip seal plastic bag. Sample mass ranged from about 30 to 80 mg for all samples except the fallen broken white stalactite, from which a sample mass of about 5 g was collected.

As with the Boonderoo material, these samples were analysed using conventional solution based ICP-MS but again with disappointing results. Fortunately, reserve samples were available for the blue column and adjacent fallen broken white stalactite. These reserve samples were subsequently analysed using GFAAS. Due to the very limited sample mass, analysis was restricted to the elements considered most likely to contribute to the blue colour of the speleothems. The GFAAS results were validated using Certified Reference Materials. Results of this analysis are summarised in Table 2. Concentrations are expressed in ppm.

Results and Discussion

The chemical analyses show high levels of copper in the Taplow Maze Cave sample and detectable levels of copper in the Boonderoo Cave sample. Most copper compounds are blue, blue green or green in colour and hence it can be concluded with some confidence that copper is the predominant chromophore. The Cu^{2+} ion can substitute for Ca^{2+} in the calcite or aragonite lattice (White, 1997). Cu^{2+} substitution in aragonite has been reported to produce blue (Cabrol, 1997 and White, 1997) and blue-green (Eraso, 1977) colourations. The presence of copper is not surprising given the extensive copper mineralisation in the general geographical area (Markham, 1975).

The Taplow Maze Cave sample also has significant levels of chromium and detectable levels of nickel. Most chromium and nickel compounds containing the Cr^{2+} and Ni^{2+} ions, respectively, are green or blue green and it is thus likely that these elements are secondary chromophores. Cr^{2+} is easily oxidised and as a result extremely unstable in water. It is rare in the cave environment (White, 1997). It is thus unlikely that Cr^{2+} will replace Ca^{2+} in calcite or aragonite in speleothems. However, Cr^{2+} is reported to impart deep blue colours to silicate minerals (White, 1997). While most compounds containing the Ni^{2+} ion are green, substitution of Ca^{2+} by Ni^{2+} in calcite results in a yellow colour (White, 1997). This is due to the ionic radius of Ni^{2+} being smaller than that of Ca^{2+} (Weast and Selby, 1967). The resultant distortion of the Ni^{2+}-substituted Ca^{2+} site causes the changes in the observed colour. White (1997) reports that a green aragonite in Timpanogos Cave, Utah, is due to minor amounts of a silicate mineral mixed with the aragonite. It is thus reasonable to assume that if the chromium and nickel are acting as chromophores, then they are probably present as the Cr^{2+} and Ni^{2+} ions in minor amounts of admixed silicate minerals.

The Boonderoo Cave sample also contains significant levels of strontium and barium. While these elements are unlikely to contribute to the blue colour, their presence is not unexpected. Both strontium and barium can isomorphously replace calcium in the aragonite lattice and strontium is a common minor constituent of

Table 1
Boonderoo Cave Blue Stalactite Analysis
Concentration in Stalactite (ppm)

Element	Semi-quantitative Laser Ablation ICP-MS Analysis	GFAAS Analysis (validated using Certified Reference Materials)
Iron #	46	
Magnesium	2	
Nickel	1	
Copper	2	65
Zinc	26	
Strontium	130	
Barium	150	
Lead	2	
Uranium	1	
Manganese, zirconium & antimony	Probably present (not conclusive)	
Rare earths	Not detected	

The iron detected in this sample may be present in the sample or could, at least in part, be due to contamination from the steel blade used to collect the specimen and/or the abundant red (iron-rich) cave sediments.

Table 2
Graphite Furnace Atomic Absorption Spectrometric Analysis
Taplow Maze Cave Blue Column and Adjacent (Fallen) White Stalactite.

Element	Concentration in Blue Column (ppm)	Concentration in White Stalactite (ppm)
Chromium	27	<1
Copper	2520	<1
Nickel	4	2

aragonite. Significant barium mineralisation occurs in the area with a barite mine once being operated close to the karst area (Figure 1).

The colour of the blue speleothems varies from very pale blue flowstone in Taplow Maze Cave to the azure blue stalactites in Boonderoo and Murder Cave and columns in Taplow Maze Cave. This variation in depth of colour may be due to variation in the concentration of the chromophores and/or thickness of the blue layer.

Acknowledgments

I would like to thank all those who contributed to this project, including members of the Orange Speleological and the Newcastle and Hunter Valley Speleological Societies who assisted with specimen collection. Dr John Watling (Chemistry Centre of WA) ran the ICP-MS analyses, and Wayne Aurisch and Christine Foster (BHP Integrated Steel Laboratory Services, Hunter Laboratory) provided the GFAAS data. Australian Museum specimen D23544 was kindly made available by Mr Ross Pogson (Collection Manager). Brian England provided a critical review of the manuscript during various stages of its preparation. The ongoing assistance and access privileges to these caves extended by Rosalin and Anthony Dunhill, owners of "Boonderoo" is gratefully acknowledged. Russell Drysdale is thanked for his review of a draft of this paper.

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Cave Temperatures at Naracoorte Caves

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Abstract

Temperatures in four different caves at Naracoorte were logged for periods of up to two years, during 1998–2001. In Bat Cave temperatures near ground level were 19.0–21.1°C in the maternity chamber, and 10.3–15.6°C near the entrance. In Victoria Fossil Cave temperatures near the fossil chamber were 16.9–18.3°C. In Blanche Cave and the outer chamber of Robertson Cave temperatures were 9.4–15.0°C, with temperatures in the inner chamber of Robertson Cave 14.2–15.0°C. Cave chambers with little air flow had seasonally stable temperatures, and those with high air flow showed seasonal temperature variations of 5–6°C.

Keywords: cave temperature, air flow, Naracoorte Caves.

Introduction

Temperatures in four different caves at Naracoorte Caves National Park (36°58'S, 140°48'E) were logged over periods of up to two years, during 1998–2001. The caves are Bat, Blanche, Victoria Fossil and Robertson (Figures 1, 2). Bat and Blanche Caves are near the Visitor Centre, Victoria Fossil Cave is about 1 km south-south-east, and Robertson Cave about 8 kmt south-south-east from the Visitor Centre. The inner dome of Robertson Cave, which had been opened for guano mining sometime in the 1800s, was sealed in mid 1993 (described by Baudinette *et al.,* 1994) in order to return the cave to a state which might be attractive to bats. Bent-wing bats (*Miniopterus schreibersii*) return to Bat Cave each spring (Hamilton-Smith, 1972), with the first arrivals in the last three years (1999–2001) being in August. They remain in Bat Cave over summer and then disperse to other caves from about April, with some bats remaining in the outer, cooler parts of Bat Cave over winter, and some bats moving to Robertson Cave from February onwards (Sanderson, 2001). Temperature logging was carried out in association with observations of bent-wing bat occupancy of Bat and Robertson Caves, to see if there were any obvious temperature changes that might be used by the bats as cues for movements between caves. Data loggers were also placed in Blanche and Victoria Fossil Caves for comparison purposes, and to check a commonly held belief that temperature in the caves remains constant at 17°C all year.

Methods

T-Tec dataloggers (Temperature Technology, Adelaide, South Australia) were programmed to take readings of temperature at 2 hour intervals, and placed in caves as shown in Table 1. The outer locations in Bat Cave (~28 m inside cave entrance) and Robertson Cave

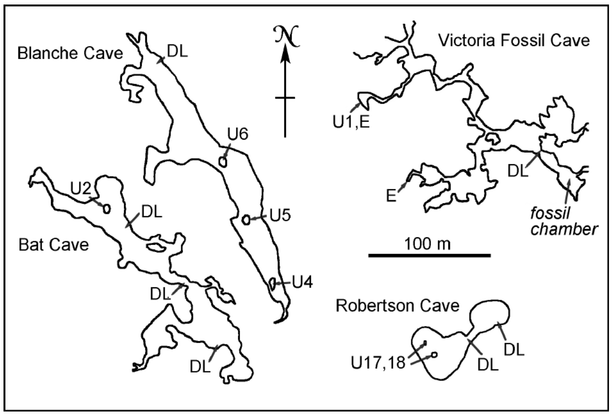

Figure 1: Maps (plan view) of the caves, derived from maps in the Management Plan for the Naracoorte Caves National Park (National Parks and Wildlife SA, 2001: Bat, Blanche and Victoria Fossil Caves) and in Baudinette *et al.* (1994: Bat and Robertson Caves). Locations of dataloggers (DL) are indicated. U1,2,4,5,6,17,18,19 are the codes assigned to the cave entrances (see Management Plan). E = entrance, exit for Victoria Fossil Cave. N = north. Bat and Blanche Caves are shown in true relation to each other, Victoria Fossil Cave and Robertson Cave are actually about 1 and 8 kms distant in a south-south-east direction.

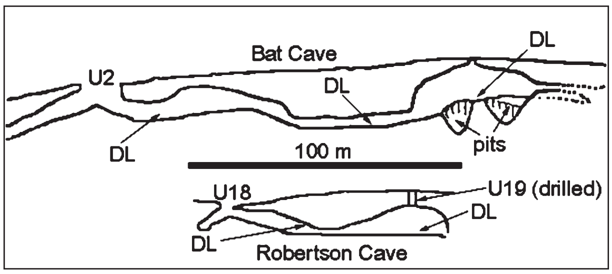

Figure 2: Longitudinal sections of Bat Cave, (from Baudinette *et al.* 1994) and Robertson Cave (mapped 2002 by Steven Brown, Steven Bourne and Liz Reed), showing locations of dataloggers (DL).

Table1: Summary of temperatures and relative humidities (RH) recorded at different locations at Naracoorte Caves 1998-2001 (with dataloggers), plus records of Naracoorte temperatures (from Bureau of Meteorology)

Site Details	Period	Annual (or period) range	Daily Range
Ambient, Naracoorte	Jul 1998 - Dec 2001	-2–43°C	2–32°C
Bat Cave: ~28 m into cave, near ground level	Feb 1998 - Feb 2000 (two years) Sep 1998 - Sep 1999	10.3–15.6°C > 90% RH	0–1.4°C
Bat Cave: ~100 m into cave, near ground level	Feb 1998 - Oct 1998 Nov 1998 - Apr 1999 Dec 1998	13.5–17.3°C 15.0–17.3°C > 90% RH	0–0.9°C 0.1–0.6°C
Bat Cave: ~150 m into cave, near ground level	Jul 1998 - Dec 1999 Sep 1998 - Mar 1999	19.0–21.1°C > 90% RH	0–0.2°C
Blanche Cave: ground level, 200 m into cave (100 m from nearest roof window) in a large airy chamber without constrictions	Dec 1997 - Apr 1998 May 1998 - Feb 2000	12.2–14.4°C 9.4–15.0°C	n.a. 0–0.7°C
Robertson Cave: outer chamber, ~2 m above ground level	Feb 1998 - Nov 1998 Dec 1998 - Feb 2000	8.6–14.3°C 9.4–15.0°C	0–1.0°C 0–1.1°C
Robertson Cave: inner chamber, ~1.5 m above ground level. The tunnel to the inner chamber was gated, and there was only slight air flow into the inner chamber.	Feb 1998 - Feb 2000 (two years)	14.2–15.0°C	0–0.2°C
Victoria Fossil Cave: front of Fossil Chamber, near ground level	Dec 1999 - Feb 2000 Oct 2000 - Mar 2001 Aug 2001 - Nov 2001	16.9–17.3°C 16.9–17.3°C 17.1–18.3°C	0–0.2°C 0–0.2°C 0–0.7°C

(outer chamber) were near where many bats have been seen in a rather inactive state over winter (Sanderson, 2001). Manufacturer's specifications (checked Feb 2002) indicated that data loggers were accurate to ±0.2°C over the range 0–70°C. Confirmation that these specifications are likely to be correct was obtained from replicate temperature data (from loggers placed side by side in Bat Cave) which varied by no more than 0.2°C, and from a logger placed in ice water for 4 hours (Feb 2002), which equilibrated to ice water temperature in

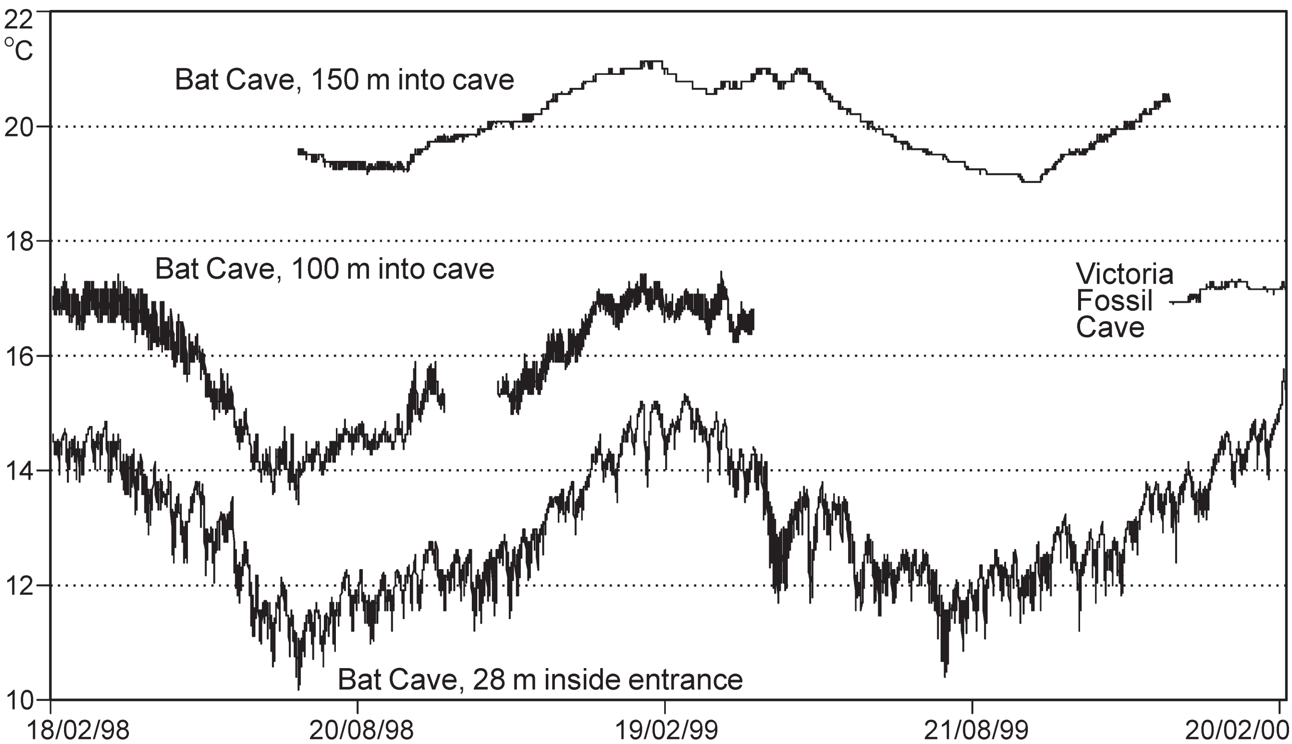

Figure 3. Temperature (°C) logged at 2 hour intervals near ground level at three locations in Bat Cave, and at the front of the fossil chamber in Victoria Fossil Cave.

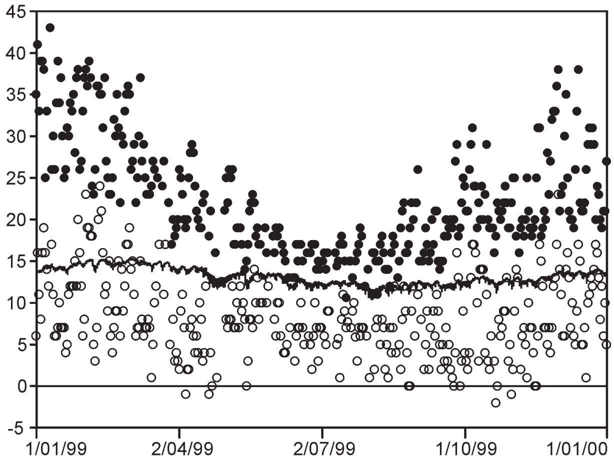

Figure 4. Naracoorte ambient daily maximum (filled circles) and minimum (open circles) temperatures (°C) (from Bureau of Meteorology) plus temperatures logged ~28 m inside Bat Cave (continuous line) for 1999.

about one hour, and then gave measurements at one minute intervals of 0±0.2°C for the next three hours. Ambient temperature data for Naracoorte from July 1998 to December 2001 were provided by the Bureau of Meteorology, Adelaide. Relative humidities (RH) were also recorded with T-Tec dataloggers placed in Bat Cave, as shown in Table 1. Manufacturer's specifications indicated an accuracy of ±3% RH. However we reported values above 90% simply as >90% since it was our perception (also shared by a reviewer) that measurements above 90% RH were not accurate.

Results

Temperatures recorded in the caves are shown in Table 1 and Figures 3-6. Figure 3 shows temperature records at the three locations near ground level in Bat Cave, and at the front of the fossil chamber in Victoria Fossil Cave. The temperature records for Bat Cave show a gradual fall from summer to winter. Near the entrance to Bat Cave, temperatures ranged from winter (June-August) minima of 10–11°C and summer (January-March) maxima of 14–15°C, while 150 m into Bat Cave, the temperature range was 19–21°C. Relative humidities logged near ground level were high (90% or more). Measurements made by Baudinette *et al.* (1994) in February 1993 and 1994 also showed a vertical temperature profile in the maternity chamber of Bat Cave ranging from 22°C at floor level to 30°C within bat roosts in the dome of the chamber, and Hamilton-Smith (1972) reported similar temperature profiles in Bat Cave, both vertically and from the maternity chamber outwards. Figure 4 shows temperatures near the entrance to Bat Cave in relation to Naracoorte ambient maximum and minimum temperatures, for the calendar year 1999. Inspection of figures 3 and 4 shows that significant rapid drops in cave temperatures typically occur following a number of cold nights. Thus the fall in temperature ~28 m inside Bat Cave from 14.2°C on 20 April 1999 to 11.7°C on 27 April 1999 occurred with minimum ambient temperatures of -1, 4, 0 and 1°C recorded in Naracoorte on 22, 23, 24 and 27 April 1999 (minima for 25 and 26 April were not available).

For Victoria Fossil Cave temperatures near the fossil chamber did not vary much from 17–18°C. Blanche Cave had winter minima of 9-10°C and summer maxima of 14–15°C. Temperatures logged in Blanche Cave and in the outer chamber of Robertson Cave were very similar, as shown in Figure 5, where they have been superimposed. Temperatures in the inner chamber of Robertson Cave remained in the range of 14–15°C. Figure 6 illustrates the daily range of temperature variation for Bat (entrance) and Blanche Caves during 1999.

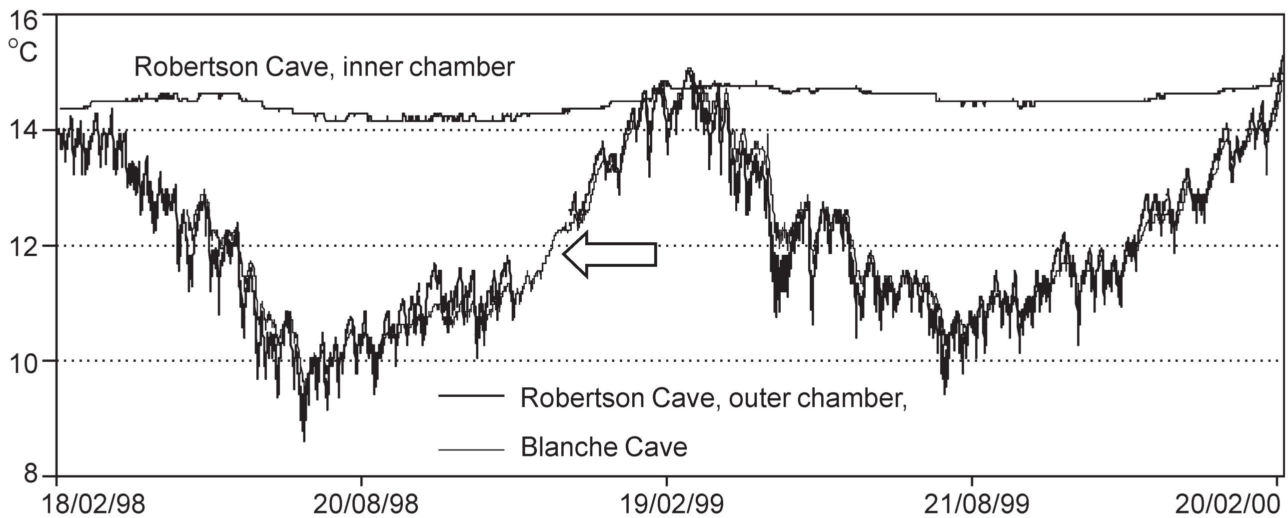

Figure 5. Temperature (°C) logged at 2 hour intervals at 1.5–2 m elevation in the inner and outer chambers of Robertson Cave, and near ground level in Blanche Cave. Arrow indicates period from 19 November to 22 December 1998 when data were collected from Blanche Cave, but not from outer chamber of Robertson Cave. Note that temperatures logged in Blanche Cave and 8 kms away in the outer chamber of Robertson Cave were very similar

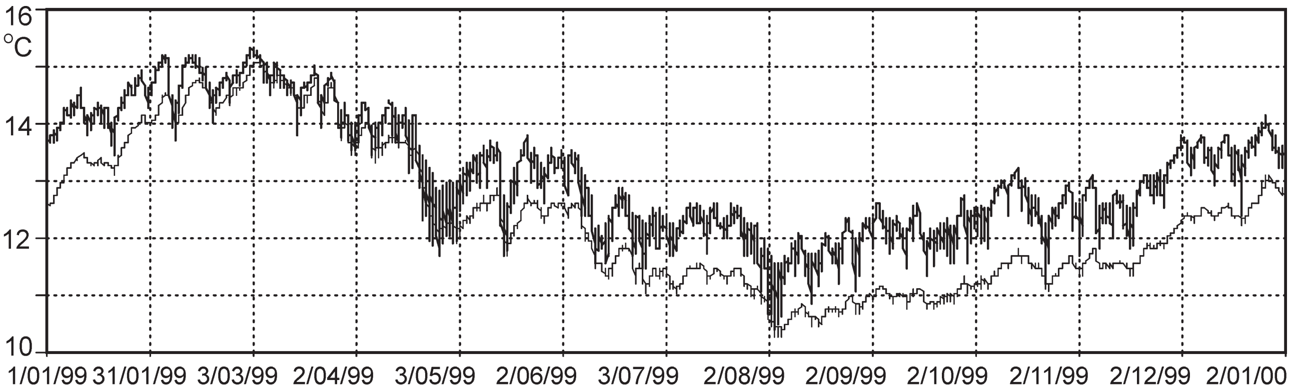

Figure 6. Detailed temperature records for the year 1999 for Blanche Cave (lower, pale record) and Bat Cave (near entrance, upper, dark record), showing daily and seasonal temperature variation.

Discussion

The recordings of cave temperatures show the following:

a) Deep in caves, or where there is little airflow, cave temperature does not change much seasonally. Thus the inner chamber of Robertson Cave remained at 14–15°C from February 1998 to February 2000, the fossil chamber in Victoria Fossil Cave was 17–18°C both summer and winter, and the maternity chamber in Bat Cave near ground level was 19–21°C over a period of 17 months.

The higher temperatures in Bat Cave can be attributed to the bats themselves (Baudinette *et al.,* 1994). The differences in temperature between Victoria Fossil Cave and the inner chamber of Robertson Cave may be due to the fact that the fossil chamber is further into Victoria Fossil Cave, which has entrances sealed by doors, or there may be some increase in temperature in Victoria Fossil Cave attributable to artificial lighting and a regular flow of visitors in the cave.

b) Where there is significant airflow in caves, there can be considerable seasonal variation in cave temperatures. Thus temperatures in the outer chamber of Robertson Cave and in Blanche Cave varied by up to 6°C from summer to winter. This sort of variation has been reported in other caves (Nepstad and Pisarowicz, 1989).

c) Locations favoured by bats for winter roosts (outer chamber of Robertson Cave, near the entrance to Bat Cave) have relatively cool winter temperatures (9–11°C). There may be cues for bat movement between caves that are based on cave temperatures, but these were not obvious from inspection of the temperature records, particularly since some movements occur in late summer.

Acknowledgements

Flinders University provided funds for purchase of data-loggers. Steven Brown and Liz Reed helped draw up a longitudinal section of Robertson Cave. Neville Michie is thanked for his review of the manuscript, and Ken Grimes for expert editorial oversight.

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Data Files

The cave temperature data described in this report can be downloaded as a tab delimited ascii text file from the *Helictite* web page at:
http://home.pacific.net.au/~gnb/helictite/data.html

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Systematic composition and distribution of Australian cave collembolan faunas with notes on exotic taxa

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Abstract

Collembola (springtails) have been collected from caves in Tasmania, northwestern Western Australia, Victoria, New South Wales and Queensland more intensively in recent years than in the past. A sharp boundary in the composition of faunas of southern and northern Australia was found with the highest diversity of troglobitic forms in southeastern Australia and Tasmania. No extreme examples of troglobitic genera have yet been found in Western Australia. A single record of *Cyphoderopsis* was made from Christmas Island in the Indian Ocean, a common genus in caves in Sumatra. The Jenolan cave system has been most completely sampled with nearly 100 samples from fourteen caves. This system contains over twenty species of which three genera, *Adelphoderia, Oncopodura* and a new genus near *Kenyura*, are exclusively troglobitic with locally endemic species of conservation and phylogenetic interest. Compared with some Tasmanian caves, the Jenolan fauna appears to harbour more species that are likely to have been introduced.

Keywords: Collembola; caves; Australia; distribution.

Introduction

Australia has extensive cave-containing karst areas in carbonate rocks in all states. However, few karst areas have been systematically sampled for Collembola, Tasmania and eastern New South Wales being exceptions. Jenolan, in New South Wales, is currently the most intensively sampled cave system (Greenslade 1989) but Collembola have also been collected more widely from caves in New South Wales by Eberhard (1993a), Eberhard & Spate (1995) and from Tasmania by Eberhard *et al*. (1991) and Clarke (1997). In Western Australia, a number of collections from caves were made by Lowry in the 1970's but her records remain unpublished.

The first record of a springtail from Australian caves was made by Rainbow (1907) who described *Isotoma troglodytica* from the surface of pools in Yarrangobilly Caves in New South Wales. This species was subsequently shown to be a synonym of *Proisotoma minuta* (Axelson) by Womersley (1934). The first record from Jenolan was by Richards & Lane (1966) who recorded *Lepidosinella armata* Handschin, identified by J. T. Salmon, from the Indian Chamber of the Orient Cave. This species was otherwise known only from termite mounds in Java (Yosii, 1989). The Jenolan specimens seen by Salmon were subsequently identified as *Sinella* (*Coecobrya*) sp. (Greenslade, 1992). It is here recorded as *S.* (*C.*) *communis* Chen and Christiansen and is considered an exotic introduction. Richards & Lane (1966) also noted a record of what were probably Collembola on Lot's Wife, a stalagmite, also in Imperial Cave, but a few hundred metres from the site at which *L. armata* was found. Since then there have been no taxonomic studies on Australian cave Collembola although a number of collectors have been active, and produced several reports, notably Gibian, Smith & Wheeler (1988), Eberhard (1993a, b), Eberhard & Spate (1995), Eberhard *et al.* (1991), Clarke (1997). Greenslade (1991) provides further information on the morphology, taxonomy, ecology and distribution of Australian Collembola. The ecology, adaptations and taxonomy of cave collembolan faunas from Europe, North America and Asia have been reported by Thibaud (1994), Christiansen (1982) and Deharveng & Bedos (2000) respectively.

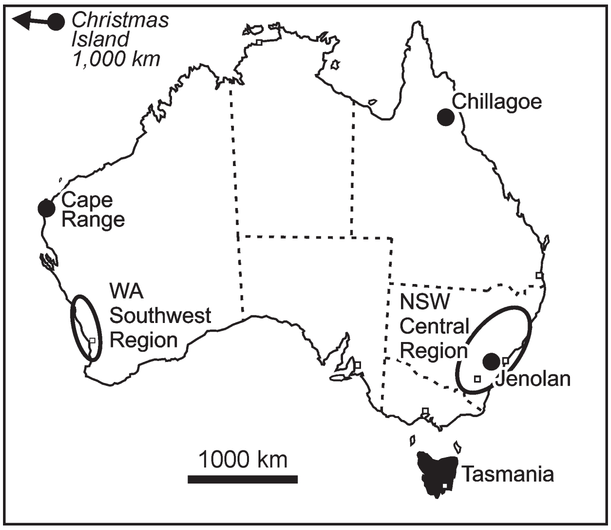

Figure 1. Map showing localities from which collections of cave Collembola are recorded.

Methods

Material from collections made available to me by J.K. Lowry (from Western Australia), A. Clarke (from Tasmania), S. Eberhard (both Tasmania and New South Wales), G. Smith, M. Gibian (both from New South

Table 1. Genera recorded from Australian caves per State

Including troglobites, troglophiles, and trogloxenes (terminology of Massoud and Thibaud, 1973). Genera with exotic species are in **bold** and ★ denotes exclusively troglobitic genera or those known to contain troglobitic species

WA – Western Australia; NSW – New South Wales; TAS – Tasmania; QLD – Queensland.

Neanuridae				
Subclavontella		NSW		
Odontella		NSW		
Ceratrimeria		NSW		
Lobellini	WA	NSW		
Australonura		NSW	TAS	
Pseudachorudina			TAS	
Pseudachorutes			TAS	
Megalanura			TAS	
Womersleymeria			TAS	
★n. gen. nr *Kenyura*		NSW		
Brachystomellidae				
Setanodosa	WA			
Brachystomella	WA			
n. gen.			TAS	
Hypogastruridae				
Triacanthella		NSW		
Ceratophysella		NSW		
Hypogastrura			TAS	
Mesogastrura		NSW		
Xenylla			TAS	
Onychiuridae				
Tullbergia	WA	NSW	TAS	
Mesaphorura		NSW	TAS	
Onychiurus		NSW		
Dinaphorura		NSW		
Isotomidae				
Folsomina	WA			
Folsomia		NSW		
Cryptopygus	WA	NSW		
Isotoma (*Isotoma*)	WA	NSW		
Isotoma (*Parisotoma*)		NSW	TAS	
Isotomodes	WA			
Folsomides	WA	NSW		
Entomobryidae				
Entomobrya	WA			
Drepanura	WA			
★*Sinella (Coecobrya)*	WA	NSW	TAS	QLD
Lepidosira	WA			
★*Pseudosinella*	WA		TAS	QLD
Willowsia	WA			
Lepidocyrtoides	WA	NSW		
Lepidocyrtus	WA	NSW		
Ascocyrtus		NSW		
Tomoceridae				
Lepidophorella			TAS	
Novacerus			TAS	
Paronellidae				
cf. Salina		NSW		
Paronellides		NSW		
★*Cyphoderopsis*	WA			
★n. gen. nr *Troglopedetes*			TAS	
Oncopoduridae				
★*Oncopodura*		NSW	TAS	
Sminthuridae				
★***Arrhopalites***		NSW	TAS	
★*Adelphoderia*		NSW	TAS	
Neelidae				
Temeritas		NSW		
Megalothorax		NSW	TAS	
Neelides			TAS	

Wales) and F. Howarth (from Queensland) have been used in this study. Collecting methods and sites were predominantly made by hand from the surface of pools, from rock walls, stalagmites and other surfaces, but some Tullgren funnel extractions were also taken from guano and flood debris—mainly leaf litter. A few pitfall traps, baited with arthropod remains, were operated briefly. All specimens were identified to genus and, where possible to species, but many species that have been collected remain undescribed.

Collections from seven karst areas, representing a latitudinal transect across Australia from north to south, were selected for comparison. These localities with their latitudes are listed in Table 3 and shown on Figure 1. All genera that contained endemic, troglobitic species likely to be locally endemic in these seven karst areas were noted.

The most complete information on any single karst area is that from Jenolan caves, which was intensively sampled between 1986 and 1989 by G. Smith, M. Gibian and other collectors and by S. Eberhard in 1993. The Jenolan collections, which consist of nearly 100 samples from fourteen caves, and the Collembola identified from them, are listed in detail in an unpublished report (Greenslade, 1989) and a summary of that report is given here (Table 2).

All the material, including most of the material from Jenolan, is lodged in the collections of the South Australian Museum, Adelaide, and in the Australian National Insect Collection. A small amount of material, collected before 1970, is deposited in the Te Papa Museum (Wellington) or in the Australian Museum (Sydney).

Table 2. Species list of Collembola from Jenolan Caves

Abundance of individuals: + = 1-5, ++ = 6-20, +++ = 21-50, ++++ = 51-200, +++++ = >200.
Ecological type: Tb = troglobite (troglobiont), Tp = troglophile, Ta = transient.
★Both *Ceratophysella* species were recorded but not distinguished in most collections. The data for the two species is therefore combined.

Family / Species	No. of Records	No. of Individuals	Ecological Type
Neanuridae			
Neanura muscorum Templeton	3	++	Ta
Brachystomella sp.	3	++	Ta
Subclavontella sp.	1	+	Ta
Odontella sp. 1	1	+	Ta
Odontella sp. 2	1	+	Ta
Odontella sp. 3	1	+	Ta
n.gen. nr *Odontella* sp.	1	++	Ta
Ceratrimeria sp.	1	++	Ta
Australonura nr *meridionalis* Stach	3	++	Tp
Lobellini sp.	2	+	Tp
n. gen nr. *Kenyura* n.sp.	2	++	Tb
Onychiuridae			
Onychiurus sp.	13	+++++	Tp
Tullbergia sp.	4	++	Tp
Mesaphorura krausbaueri Börner group	5	+++	Tp
Dinaphorura sp	3	+	Tp
Hypogastruridae			
Triacanthella sp.	3	+	Ta
Ceratophysella denticulata (Bagnall) / *Ceratophysella gibbosa* (Bagnall)	13★	+++++	Ta
Mesogastrura libyca (Caroli)	1	+	Tp
Isotomidae			
Isotoma sp.	1	+	Ta
Parisotoma sp.	1	+	Ta
cf. *Cryptopygus* sp.	1	+	Ta
Folsomides exiguus Folsom	1	+	Ta
Folsomia candida Willem	22	+++	Tp
Cryptopygus caecus Wahlgren	1	+	Ta
Entomobryidae			
Sinella (Coecobrya) communis Chen and Christiansen	6	++	Tb
Lepidocyrtus sp. imm.	3	+	Ta
Ascocyrtus cinctus (Schäffer)	1	+	Ta
Oncopoduridae			
Oncopodura sp.	11	+++	Tb
Neelidae			
Megalothorax sp.	1	+	Tp
Sminthuridae			
Temeritas imm	1	+	Ta
Adelphoderia sp.	30	+++	Tb
Arrhopalites sp.	1	+	Tp
Indet. imm. Sminthuridae	1	+	Ta

Results

Table 1 lists all genera, or tribe in one case, found in Australian collections from caves that have been studied so far from four States. Many of the genera also occur in ground-surface habitats such as leaf litter or more commonly in soil (Greenslade, 1994). Several troglobitic genera of interest have been recorded. As in the northern hemisphere, species of *Oncopodura* are common in caves but in Australia this genus is only found in the south eastern part of the continent and in Tasmania. Species in this genus have also been found in leaf litter in temperate *Nothofagus* rainforests (Greenslade, unpubl.). Two troglobitic genera of Paronellidae have been found. One is a new genus near *Troglopedetes* with two species in Tasmanian caves, one of which is highly cave adapted. The other is a species of *Cyphoderopsis* from a cave on Christmas Island which is a Commonwealth Territory in the Indian Ocean. This genus is common in caves of south east Asia including Sumatra (Deharveng, 1987; pers. comm.). A number of undescribed cave-adapted species of *Adelphoderia* have been collected from caves in southeastern Australia including Tasmania. This genus is currently only known from one described species, again from temperate *Nothofagus* rainforest, although another undescribed species has recently been collected from montane tropical rainforest litter in Queensland (P. Greenslade, unpubl.). Palacios-Vargas (1999) recently described a new genus and species belonging to the same small subfamily, the Spinothecinae, from caves in Argentina. No troglobitic genera have yet been collected from Western Australia and all genera recorded from that State also occur in eastern Australia (Greenslade, 1994). In the Northern Hemisphere, the genus *Arrhopalites* is relatively common in caves but it is very rarely encountered in Australia but it is not currently known whether troglobitic species occur here although two cosmopolitan species have been recorded, *Arrhopalites caecus* (Tullberg,1871) and *Arrhopalites pygmaeus* (Wankel,1860) (Greenslade, 1994). It appears that *Arrhopalites* is replaced by *Adelphoderia* in the southern hemisphere.

In Table 2, the species recorded from all collections from Jenolan caves are listed together with their ecological type using the classification of Massoud & Thibaud (1973) and Vannier & Thibaud (1986) where transient equates to accidental species. The number of records and approximate number of individuals of each species is given. Genera which are believed to have exclusively or predominantly introduced species in Australian faunas are marked in Table 1. The Jenolan species of most conserva-

Table 3. Distribution of troglobitic genera of Collembola in selected karst regions in Australia along a latitudinal gradient

Location Latitude	Christmas Is. 10°30'	Chillagoe 17°09'	Cape Range 22°05'	WA southwest 30°-32°	NSW central. 28°-38°	Jenolan 33°49'	Tasmania 40°-44°
Genus							
Cyphoderopsis	★						
Sinella (Coecobrya)		★		★	★	★	★
Pseudosinella		★		★			★
Adelphoderia					★	★	★
Arrhopalites					★	★	★
Oncopodura					★	★	★
n. gen. nr *Kenyura*						★	
n. gen. nr *Troglopedetes*							★

tion and phylogenetic interest belongs to a new genus near *Kenyura* and is currently only known from a single cave. When the Jenolan fauna is compared with the Tasmanian fauna (Table 1), it appears to include a noticeably larger number of genera with exotic species (Figure 2). These genera were more common in caves open to the public (Greenslade, 1989).

Eight genera which are exclusively or nearly exclusively troglobitic or deep soil living occur in the seven karst areas from the latitudinal transect and are listed in Table 3 together with the karst areas in which they occur. They include three endemic genera, *Adelphoderia*, n. gen. nr *Kenyura* and n. gen. nr *Troglopedetes*, that appear to be restricted to Tasmania and the extreme south east of Australia. The data indicates that there appears to be a trend of increasing diversity of troglobitic, relict taxa from north to south. It is probable that the seven genera of exotic taxa (Table 1) originate mainly from the northern hemisphere.

Discussion

Eberhard & Spate (1995) and Thurgate *et al.* (2001a) note that the karst areas of New South Wales support a diverse invertebrate subterranean fauna that compares favourably in taxon richness to other karst regions in Australia. A rich stygofauna has also been identified (Thurgate *et al.,* 2001b). These authors found that Jenolan is one of five karst areas in New South Wales that could be considered biodiversity 'hotspots' although to some extent this may reflect intensity of collecting. As well as high taxon richness and endemism, they note that relictual distributions and ancient lineages characterise the significance of the New South Wales invertebrate cave fauna in general (Eberhard and Spate, 1995; Hamilton-Smith and Eberhard, 2000; Thurgate et al., 2001b). As far as the collembolan fauna is concerned, Jenolan seems to reflect these characteristics since it harbours several species of *Oncopodura, Adelphoderia* and the new genus near *Kenyura*.

Latitudinal gradients in taxon composition across Australia are frequently encountered and reflect both the major dual origins of the fauna and differences in climate. On one hand there is a cool, moisture loving fauna of Gondwanan origin in the south, and on the other, a tropical, later incursion of Asian origin in the north (CSIRO, 1991). The higher diversity of southern cave faunas shown here by the Collembola, is therefore not surprising since Collembola are most diverse and have most endemic taxa in cooler moister climates of southern regions. However, it is possible that the low diversity in the north of the continent may only be reflecting less collecting effort there since Howarth (1988) and Humphreys (1993) found, unlike Collembola, there was a rich fauna of troglobitic arthropods in some tropical karst areas of tropical Australia.

The question as to whether the exotic species are impacting on the indigenous species in caves cannot be answered without more research. The only example of native Collembola being adversely effected by exotics in Australia is in faunas of fungal fruit bodies (Greenslade, Simpson and Grgurinovic, unpublished results). However, the introduced *Sinella* (*Coecobrya*) has only been found in a concrete drain at Jenolan, a site unlikely to be colonised by native species. The higher number of exotic taxa in the most frequently visited and

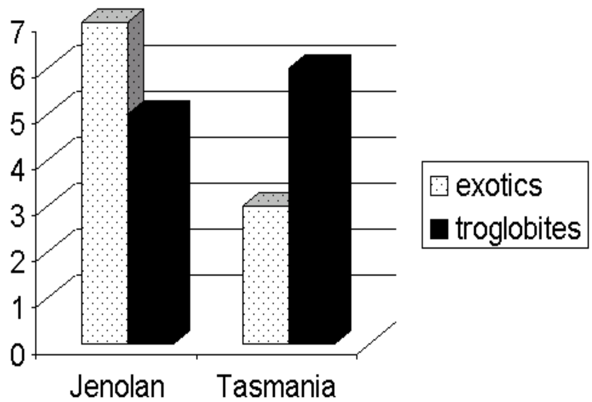

Figure 2. Comparison of exotic and troglobitic genera in Jenolan (NSW) and Tasmanian caves

earliest used tourist cave indicates a possible linkage that requires further investigation. However, there is clearly a need to control and monitor the impact of tourism and also scientific visits to caves of high conservation value especially as regards the possible human translocation of taxa within cave systems. Risk management strategies based on those used in current Australian border quarantine procedures could be applied to all such visits.

Acknowledgements

Thanks are due to the many collectors, too numerous to mention each individually, who have collected cave Collembola in Australia and to whose collections, I have been allowed access. Special thanks should be given to Arthur Clarke and Stefan Eberhard on whose efforts this paper largely depends.

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Palaeokarst in the Noondine Chert in Southwestern Australia: Implications for Water Supply and the Protection of Biodiversity

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Abstract

In southwestern Australia, karst features occur in geological formations other than the coastal calcarenites of the Tamala Limestone. The Noondine Chert was formed by the silicification of carbonate rocks and contains relict carbonate textures and palaeokarst features such as intense brecciation and the presence of subsurface voids. This geological formation is an important aquifer to the east of the Perth Basin where groundwater resources are otherwise limited, and the aquifer is highly vulnerable to contamination from agricultural land use. The Noondine Chert may also contain a rich stygofauna. This has not been taken into account in groundwater protection policies, and needs to be assessed as a matter of urgency.

Keywords: palaeokarst, stygofauna, groundwater, management

Introduction

Karst in southwestern Australia is usually thought to be exclusively associated with variably lithified Quaternary calcarenites of the Tamala Limestone that are distributed near the coast between near Shark Bay and the south coast of Western Australia. Although the Tamala Limestone contains karst landforms of national and international significance, the intense focus of karst researchers on this geological formation has distracted them from other potentially karstic geological formations in this region. This bias may be limiting the amount of information that karst landscapes can provide about the natural history of the southwestern corner of the continent.

This paper attempts to partially redress the balance by providing a review of available information on another geological formation in the south-west of Western Australia that has relict karst features. Although the Noondine Chert is unlikely to provide the caving opportunities of the Tamala Limestone, this formation is a regionally-significant groundwater source in an area to the east of the Perth Basin where water resources are otherwise limited, and is likely to be an important habitat for stygofauna in the region. It is hoped that information provided here will stimulate further research into the history of development of karst within this geological formation and its potential role as a subsurface habitat.

Geological setting of the Noondine Chert

The Noondine Chert crops out as a series of low hills to the east of the Perth Basin from near the town of Three Springs to Moora, a distance of about 150 km (Figure 1). This formation is of Proterozoic age and is part of the Moora Group that comprises sedimentary, volcaniclastic and volcanic rocks. The Noondine Chert was originally named the Coomberdale Chert by Logan and Chase (1961) from a type section at latitude 30^{o} 25' S and longitude 116^{o} 03' E near the small railway siding of Coomberdale.

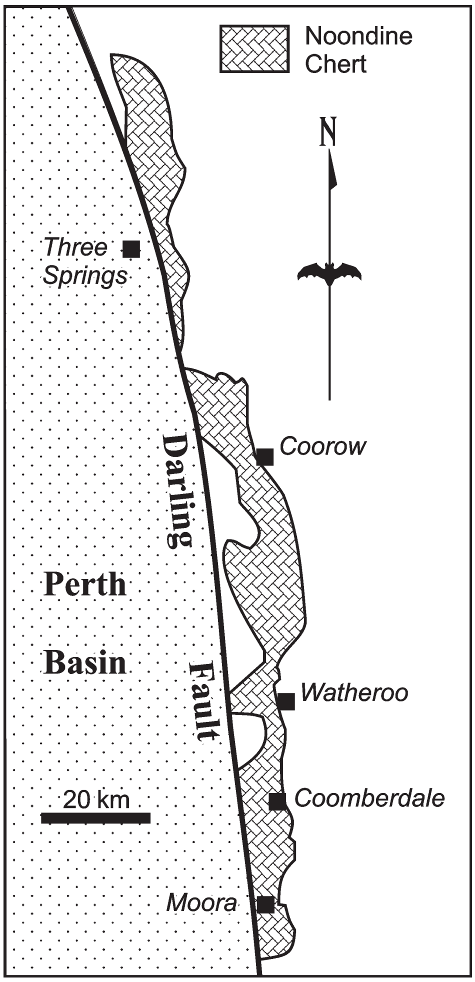

Figure 1: Map showing the extent of Noondine Chert (after Commander, 2001)

It consists of a 700 metre thick sequence of chert, quartzite, chert breccia and partly silicified (commonly dolomitic) limestone and dolostone. The rocks have been relatively unaffected by metamorphism or structural deformation (GSWA, 1990), so most of the original sedimentary textures are well preserved. The chert that makes up the major part of the formation is believed to be the end-product of silicification of carbonate rocks (Playford et al., 1976), and relict dolomite rhombs, oolitic textures, and other features of the carbonate rock are commonly observed in the chert. The formation also contains stromatolites and a "fossilum problematicum" that was identified by Öpik and Tomlinson (1955) as a tabulate coral, possibly belong to the Ordovician genus *Tetradium*. Playford et al. (1976) considered that the supposed fossil was of inorganic origin as the age was inconsistent with the known Proterozoic age of the Noondine chert.

Another possible explanation is that the tubular, hexagonal structures were correctly identified as fossils and were laid down within the limestone during a period of karstification in the Palaeozoic. There may have been several periods of karstification in the Noondine Chert, and extensive karst development probably continued until much of the carbonate rock mass was replaced by silica. The age of the silicification event and the source of the silica is unknown, but could be due to hydrothermal activity associated with the Darling Fault, the structure that forms the eastern boundary of the Perth Basin. The Darling Fault was most active during the Mesozoic during the break-up of Gondwanaland.

Playford et al. (1976) suggested that the Noondine Chert was deposited as a shallow marine limestone and that algal stromatolites grew prolifically in certain areas. They considered that much of the brecciation was due to the slumping of weakly cemented limestone, although much of the brecciation could also be due to later karst development. Playford et al. (1976) considered that the limestone was partially dolomitised, either soon after deposition, or early in its diagenetic history. The Noondine Chert was intruded by a number of dolerite dykes some time during the late Proterozoic, and the metasomatic alteration of dolomite near some of the intrusions created talc deposits such as the Three Springs deposit.

Another area of extensive palaeokarst occurs further north in the East Pilbara area as the Pinjian Chert Breccia that has developed on the Proterozoic Carawine Dolomite (e.g. Williams, 1989). That area also has scattered younger caves and dolines (Webb, 1994). A summary of that area is given by K. Grimes on page 20 of this issue of *Helictite*.

Development of subsurface voids

A few small caves and dolines have been listed for this area (the Moora Karst Area) in the Australian Karst Index (Matthews, 1985). Bastian (1962) described and provided a map of the largest cave (6M-1) near Coorow which has 550 m of joint- and strike-oriented maze passage and a bat colony. Bridge (1962) reported copper phosphate minerals from another cave (6M-6), near Watheroo.

There is ample evidence from drilling for water supply that the Noondine Chert is extensively fractured and contains substantial subsurface voids, although there is no information about the size of these voids. Commander (2001) indicated that the chert is cavernous and is capable of high bore yields, with yields of up to 1000 $m^3 day^{-1}$ being recorded from individual production bores (Berliat 1964; Playford et al., 1976). The origin of the voids is unknown, but could be due to the dissolution of residual carbonate minerals within the chert matrix.

Monitoring carried out in the Coomberdale water supply borefield has indicated that a large amount of groundwater flow also occurs in zones of highly brecciated chert (Water Authority, 1998). This monitoring has also indicated that there is a strong hydraulic connection between rubbly outcrops of Noondine Chert on high ground and shallow, high-yielding bores downslope, suggesting that fractures and voids in this formation are well inter-connected.

Implications for the protection of groundwater

The highly cavernous and fractured nature of the Noondine Chert make this aquifer particularly vulnerable to contamination from agricultural land use in the region. A number of towns either partially or totally rely on groundwater pumped from the Noondine Chert for water supply, including Moora, Coomberdale and Watheroo, and as a consequence protection plans have been developed (eg. Water and Rivers Commission, 1999a; 1999b) to ensure that groundwater contamination does not affect these water supplies.

Of more concern is the fact that groundwater protection planning has not taken into consideration the possible impact of groundwater contamination and pumping on stygofauna that may live in the Noondine Chert aquifer. Western Australia has a rich natural heritage of animals that have adapted to living within groundwater flow systems (Humphreys, 2002) and they are an important part of the State's biodiversity that is unseen and unrecognised by the general community. The size and diversity of stygofauna is greatest in aquifers with large void spaces, and the Noondine Chert may be an aquifer with a particularly rich subterranean fauna. This needs to be assessed as a matter of urgency. It would be tragic if this fauna was lost through inappropriate land use practices before it was even recognised.

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Helictite, (2002) **38(1):** page 20.

Short Note: Palaeokarst in the East Pilbara, Western Australia

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Further to the note by Steve Appleyard in this issue of *Helictite* describing palaeokarst in the Proterozoic Moora Group of southwest Western Australia, I shall summarise here some published information on an extensive, but little studied, area of palaeokarst developed on Proterozoic dolomites in the East Pilbara. The area extends from Mount Newman north to the Rippon Hills.

The palaeokarst unit described below is shown on the 1:250 000 geological maps of the region as the (multi-aged?) Pinjian Chert Breccia that has developed on the Proterozoic Carawine Dolomite (e.g. Williams, 1989). Palaeokarst features may also be associated with other Proterozoic dolomite units in the Pilbara region, such as the Wittenoom Dolomite.

Some of the manganese ore bodies in the region are associated with palaeokarst cavity-fills. For example, Fetherston (1990) reports that part of the Woodie Woodie manganese deposit is in a large pipe-like cave filling that has been mined to a depth of 30m.

Williams (1989) described the palaeokarst in the Balfour Downs map area as follows:

"Several episodes of silicification are evident in the [Carawine] dolomite. Late-stage fractures and joints generally contain cavities lined with quartz crystals."

"The Pinjian Chert Breccia ... overlies or replaces the Carawine Dolomite. The chert breccia forms casts of many large palaeokarst features where the pre-existing dolomite has been dissolved away. The chert breccia consists of angular chert fragments chaotically or crudely bedded, with a siliceous matrix locally enriched by iron and manganese oxides."

"The chert breccia was a residual and replacement deposit on the Carawine Dolomite and was cemented by secondary silicification during subaerial exposure in the Precambrian and later in the late Tertiary to recent. The Precambrian Pinjian Chert Breccia and later Tertiary siliceous capping can both be regarded as a silicified duricrust or silcrete. Although steep bedding traces are recorded, these are interpreted as primary dips associated with deposition on the steep karstic topography rather than deformation."

"More recent karst features occur where residual blocks of Carawine Dolomite, preserved within the Pinjian Chert Breccia, have gradually dissolved causing the overlying Pinjian Chert Breccia to collapse and form a younger group of dolines and sinkholes."

Williams' reports and maps led a group of WASG cavers to inspect some of the younger karst features (Webb, 1994). They found several small caves scattered through the area. The largest of the sinkholes was a spectacular steep-walled collapse doline 132m x 100m x 55m deep but it contained no accessible caves apart from several sloping rockpile chambers.

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BOOK REVIEW

SUBTERRANEAN BIOLOGY IN AUSTRALIA 2000,

Records of the Western Australian Museum, Supplement No. 64

Edited by W.F. Humphreys and M.S. Harvey.
Published 2001 by the Western Australian Museum 243 pp, ISBN 0 7307 7601 8

Reviewed by Nicholas White

This book is a valuable collection of papers presented to the subterranean session at the Dampier 300 Conference in December 1999. The volume is dedicated to Glenn Hunt, and Mike Gray provides some interesting background to Glenn's love of life, his earlier caving and then his later work at the Australian Museum on cave harvestmen. The papers provide an overview of the current state of research on underground biota and the context of its place in the study of evolutionary mechanisms, biodiversity, systematics, conservation and management.

The introductory paper, by Boulton, puts in context the continuum between surface waters and groundwater and for which caves provides an accessible portion of part of the available habitat. The importance of stygofauna as indicators of the health or otherwise of water habitats is examined, as is the question of timing of collection in relation to season and rain events.

The first scientific paper by Humphreys and Adams examined allozyme variations in a troglobitic millipede in caves from Cape Range, WA. The study identified three genetic provinces that broadly follow the geomorphology of the Cape Range and demonstrates that the populations do not intermix between provinces and even within a province, there was little or no gene exchange. There are many ramifications for management from this as each cave (36 caves studied) has an isolated population. It is the strength of such fundamental biological studies that bolstered the arguments against limestone mining on the Cape.

Eastern Australian subterranean biodiversity was examined in two papers by Thurgate et al, which show that NSW has a rich cave fauna. Earlier impressions of this being sparse were found to be inaccurate when important systematic studies were undertaken, particularly by Eberhard, in the 1990's. It is also apparent that much of the fauna has Gondwanan origins. What also shows up is the large number of undescribed species. The other paper in this section is on calcrete groundwater aquifer fauna by Humphreys. This examines the diverse fauna found in these previously poorly studied environments and increases the awareness of these environments. Such groundwater calcretes are found throughout much of arid Australia and this is an important introductory study of environments containing diverse and locally endemic fauna with ancient evolutionary lineages.

In the conservation and management section, Hamilton-Smith provides an overview paper on the importance of both cave fauna and the surface fauna and flora of karst areas to the adequate managemrnt and protection of the biodiversity of karst areas. Eberhard describes the use of gastropods as an indicator group for the study of the ecological impacts of limestone mining and rehabilitation after mining at Ida Bay. Knowledge of base-level ecology prior to mining would in all probability have resulted in changed mining methods in this operation and constrained both sediment throughput in the cave system as well as toxic inputs such as oil wastes.

There are a number of papers on the systematics of biota from both caves and groundwaters, which add to the published knowledge of Australian subterranean biota. Most of these are from Western Australia but this should not be regarded as a criticism of the book. One of the conclusions to be drawn from reading the volume is just how few of the cave invertebrates have been described and the gaps in collecting across Australia. Nevertheless, this volume is a valuable contribution to a wider understanding of subterranean biology

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Revision to Book Review

Karst of the Central West Catchment, NSW

Edited by J. Dunkley and P. Dykes

When I recently reviewed this important report (*Helictite,* **37(2):** p.75), I had not seen nor even been told about the second volume. This supplementary volume, which has not been widely circulated, is essentially a methodological report and inventory of the features examined. It thus negates my criticism in *Helictite* that precisely these details had been omitted.

Elery Hamilton-Smith.

The IAH Groundwater Conference at Darwin, May 2002

Ken G. Grimes.

The Conference

The conference, held in Darwin in May and run by the International Association of Hydrologists (IAH), was on the theme of "Balancing the Groundwater Budget". This included a session on karst, with a keynote paper by Stein-Erik Lauritzen (University of Bergen, Norway) on the Hydrology of Permafrost Karsts; and also a session on Stygofauna and Ecosystem Dependance with a keynote paper by Bill Humphreys (WA Museum) on Groundwater Ecosytems in Australia. The proceedings are available on a CD from steven.tickell@nt.gov.au.

Stein-Erik's paper was interesting and possibly relevant to past glacial conditions in Tasmania; karst solution and drainage **does** occur under permafrost and beneath glaciers! Some other papers of note included one on part of the English chalk aquifer (which has analogies to Australian softrock karsts) by Nick Robins. Scott Evans spoke about the problems of managing yearly allocations from a small softrock limestone aquifer in the Eyre Peninsula, SA, that had highly variable recharge, small storage and short residence times. But the prize for an interesting story must go to Salvatore Carrubba for his description of the ancient qanats ("homokarst"?) and limestone springs beneath the city of Palermo, Sicily, which have been exploited at least since the 10th century.

There were also papers on local karst features which we visited on the field trips: e.g. the management of the Howard Spring by Tho Tien and others; the Water Balance of the Daly River catchment, by Peter Jolly, and a poster by Danuta Karp on the Katherine sinkhole problem.

The Stygofauna sessions started with an excellent summary by Bill Humphreys of the rapidly growing field of Australia's groundwater ecosystems and some of the threats to them. Other papers in the session spoke of the groundwater faunas both in terms of their reliance on continuing water supply and quality (Susan Schmidt, and Stewart Halse both spoke on Western Australian examples), and also on their use as monitors for catchment quality (Holger Schindler and Hans Hahn both provided a European view). A ongoing theme was the desperate lack of information on these cryptic, but fascinating faunas.

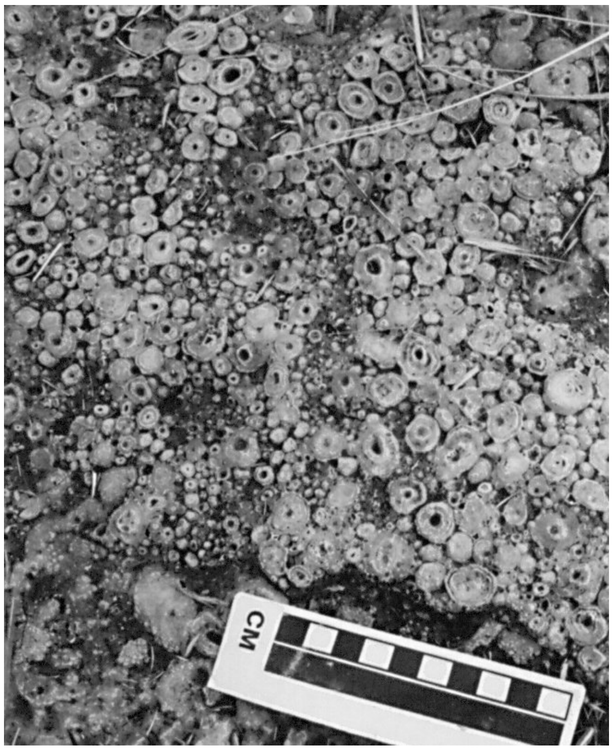
Trips during the conference visited a number of the local springs of the Darwin area. Many of these appear to be sourced from Proterozoic dolomite aquifers and reach the surface via fault lines or degraded dolines that have broken through the Tertiary laterite cover; which is itself a good (silicate karst?) aquifer.

Post-conference Trip: Daly River Karst

About a dozen delegates spent an excellent three days in the Katherine area. Our leaders were Danuta Karp (hydrologist with the NT Department of Infrastructure, Planning and Environment), Stein-Erik Lauritzen (University of Bergen, Norway, who has been working with Danuta on the karst for the last ten years) and Steve Tickell (from the same department as Danuta), together with Dirk Megirian from the NT Museum.

Lake Hickey, a large, irregular, shallow swamp on the western outskirts of Katherine was classed as a polje by Danuta Karp as she has evidence that the wet season flooding is fed by both surface and underground water—the latter entering via small dolines (estavelles) in the floor of the polje. The watertable can fluctuate by up to 10 m between dry and wet season, but surface flooding of the polje only happens after particularly strong wet seasons (such as the last few years).

A nearby ridge of the Cambrian limestone had grikes, clints and pinnacles which are a distinctive feature of the surface karst in this area, and also some "unroofed caves": palaeokarst deposits in old fissure systems that include bone material that has been studied by Marianelli (1995). The material contains old soil pisolites—or were they cave pearls? Speleothems in the deposits have been dated by Stein-Erik Lauritzen at the limit of the Uranium series method (about 350 ka).



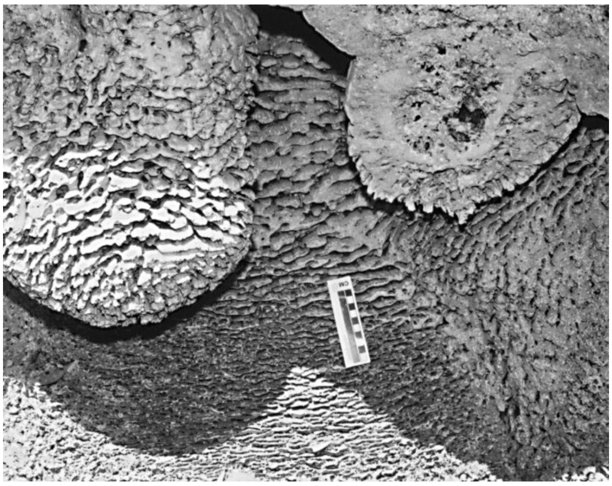
Palaeokarst fissure fill near Katherine: pedogenic pisolites—or cave pearls?

There are several so-called “hot” springs in the Katherine area. At 31-32 °C these are not truly “hot” but simply at the regional mean temperature and only seem hot to tourists who visit in winter when the air is cooler. Water tracing from the polje showed connections to two of these springs, but interestingly both springs showed two distinct arrival times (e.g. 3 and 14 days for the nearest spring). The water must be travelling through two distinct conduits.

Near the Cutta Cutta caves we were shown a knob of Cretaceous sandstone cover and several recent sinkholes in the limestone—including one right beside the Stuart Highway. Runoff from the bitumen, coupled with blocking of the prior surface drainage by an old railway embankment seems to have accelerated the normal karst processes.

At Cutta Cutta we visited the tourist cave where Stein-Erik Lauritzen pointed out features such as palaeokarst fills in old fissures in the roof and some possible large scallops that are the basis for interpreting the ancient drainage of the cave as being southeastwards towards the present collapse entrance. The cave is a linear system that follows a belt of en-echelon joints and the extensive solutional sculpturing suggests a largely phreatic development at a time of higher watertable. It has a complex history of alternating solution and sedimentation.

Further east are the Mataranka “hot” Springs. The aboriginal community had given special permission for us to inspect some interesting bulbous tufa deposits near here. These occur in vertical walls about 6 m high enclosing large closed depressions in the creek bed. The consensus was that they were subaqueous growths formed when the holes were full of water, so there are implications of climate change affecting discharge. In detail they had porous, slotted, growth structures that were reminiscent of some stromatolites in the Gambier cenotes. There were also obvious casts of pandanus trunks and foliage in the cores of some broken lobes.



Detail of slotted tufa lobes, including a broken section at the top right (scale is 10 cm).

Bulbous, subaqueous, tufa deposits

Reports on the Katherine Area

Danuta and Stein-Erik have produced two useful reports on the karst around Katherine—an area that has been poorly documented to date. The first (Lauritzen & Karp, 1993) was essentially a preliminary working document indicating what further work was needed. But it has a useful analysis of structural control on cave development, the paleo-flow analysis of the scallops, and discussion of the palaeokarst deposits. There are maps of several of the caves, but these lack detail or cross-sections, so it is difficult to get a picture of the passage style. The second report (Karp, 2002) is a detailed and well-illustrated analysis of the sinkhole problem, including a morphometric analysis and also information on the regional and local groundwater behaviour. It has two full colour maps at 1:50,000 scale which plot the sinkholes and other karst features on a background of (a) the geology, and (b) the land unit classification. Work is continuing so it will be a few years yet before we see their final karst reports.

Karp, D., 2002: Land degradation associated with sinkhole development in the Katherine Region. *Resource Assessment Branch, Department of Infrastructure, Planning and Environment, Northern Territory, Technical Report No* **11/2002.** 71 pp + 2 maps. This report and its maps are also available on CD as .pdf files.

Marianelli, P.C. 1995: *Palaeoenvironmental study of Quaternary fossiliferous fissure fills of the Katherine area, Northern Territory.* Unpublished Honours thesis, Flinders University of South Australia.

Lauritzen, S-E, & Karp, D. 1993: Speleological assessment of karst aquifers developed within the Tindall Limestone, Katherine, *Water Resources Division, Northern Territory Power and Water Authority, Darwin, Report* **63/1993**. c. 65 pp.

Coming Events

Next ASF Conference: Under WAy 2003

The 24th Biennial Conference of the Australian Speleological Federation Inc (Under WAy), will be held in Bunbury W.A., 2nd - 8th January 2003. It will incorporate the 3rd Australian Cave History Seminar and the 6th Australian Karst Studies Seminar. Details of the program of integrated events and the venue and costs can be obtained via email (underway@iinet.net.au); phone/fax (08) 9470 3023 or from the website at:

http://people.mail2me.com.au/~wayne/srgwa/conference/

Both seminars are open to academics, students and cavers alike to present results of past and on-going research projects in either oral, illustrated or poster format. The Conference will be opened by Dr. Brian O'Brien, the ASF's inaugural President back in 1956 before he went to work with NASA on the Apollo moon landing program and later became the first chairman of Western Australia's Environmental Protection Authority.

First Call For Papers, Posters and Workshops

The organising committee invites expressions of interest to present seminars, workshops and posters at the 2003 conference. The conference provides a unique opportunity for researchers, professionals and amateurs with an interest in caves and karst to interact and share knowledge in a congenial atmosphere. Presentations will be variable and normally of 20-30 minute duration, although longer presentations will be accepted subject to negotiation. Absentee presentations can also be accommodated. Posters are encouraged and will be displayed throughout the duration of the conference. A prize will be awarded for the best poster. Students and speleological club members are welcome and strongly encouraged to submit presentations. Abstracts and presentations are still required.

For further information contact:
Norm Poulter, PO Box 120, Nedlands WA 6906,
Telephone (08) 9276 2495 (a/h),

Note the revised email: underway@iinet.net.au

STOP PRESS
Megafaunal Discovery in Nullarbor Caves

A Victorian Speleological Association exploration trip recently discovered a new megafauna site on the Nullarbor. On notification, Curator Dr John Long from the Western Australian Museum led an expedition team to the site which recovered the world's first complete and intact skeleton of Australia's ancient predator, the marsupial lion, *Thylacoleo*. The dating on the site will be crucial to testing the theory that megafauna died out uniformly around 46,000 years ago in Australia. The discovery of preserved ancient DNA in the marsupial lion could be far more exciting news in providing new information about its evolutionary origins. The bones of several other *Thylacoleo* specimens were also found in the caves, as well as the remains of other types of extinct animals, including giant wallabies and kangaroos. Exciting times!

This discovery is one of the fruits of a continuing series of expeditions to the Nullarbor led by Ken Boland which have involved the systematic search for karst features from an ultralight aircraft flying in a grid pattern, with ground teams following up on the aerial sightings. Although officially organised through the VSA, the explorations teams have involved members of a number of speleological societies: in particular CEGSA, WASG, SRGWA and VSA.

A temporary display of the main *Thylacoleo* skeleton can be seen at the Western Australian Museum, or via its web site: http://www.museum.wa.gov.au/news/20020802.htm

Information for Contributors to Helictite

Scope

Contributions from all fields of study related to speleology will be considered for publication. Suitable fields include Earth Sciences, Speleochemistry, Hydrology, Meteorology, Conservation, Biospeleology, History, Major Exploration (Expedition) Reports, Equipment and Techniques, Surveying and Cartography, Photography and Documentation. Comprehensive descriptive accounts of the exploration and morphology of individual caves will be welcomed, but simple trip reports and brief cave descriptions are not adequate. Papers overall should not exceed 20 printed pages in length. Contributors intending to write at greater length or requiring any advice on details of preparation are invited to correspond with the Editors. All manuscripts will be assessed by referees. "News and Views", "Short Notes" and "Letters to the Editor", expressing a personal view or giving a preliminary report of interesting findings, are welcomed, and will be given preference for speedy publication.

Manuscripts

Submitted manuscripts should initially be in printed form. Manuscripts should be typed, double spaced, on one side of the paper. Do not use multiple columns - this manuscript is for the editors and referees use and does not have to look like the final production.

The **title** should be upper case bold and the author's names and addresses should follow. A brief and explicit summary of the notable aspects of the paper, headed **abstract**, should precede the main text. **Acknowledgements** should be placed at the end of the text before the references.

Once authors have dealt with referees comments, they are requested to submit a copy of their final manuscript by email or on floppy disk as well as hard copy. Disks may be 3 ½" or 5 ¼" in either IBM or Macintosh format. If sending text as a word processing document (Microsoft Word etc.), please also send a copy as plain text on the same disk. Illustrations and tables are best sent in separate files, not embedded in the main document. Separate instructions concerning electronic layout are available from ken-grimes@h140.aone.net.au.

References

References should be listed alphabetically at the end of the manuscript and cited in the text by the author's name and the year of publication, e.g. "(Gray, 1973)". Where there is more than one reference to the same author in one year the letters a, b, c, etc. should be added. If there are more than two authors, they should all be named at the first citation and in the reference list, but the first name followed by et al. should be used in subsequent citations. References should be checked particularly carefully for accuracy. If journal titles are abbreviated, this should follow the "World List of Scientific Periodicals", which is available in most large libraries.

The following examples illustrate the style:

GRAY, M.R., 1973 Cavernicolous spiders from the Nullarbor Plain and south-west Australia. *J. Aust. ent. Soc.* **12:** 207-221.

VANDEL, A., 1965 *Biospeleology. The Biology of the Cavernicolous Animals.* Pergamon, London. pp. xxiv, 524.

WIGLEY, T.M.L. and WOOD, I.D., 1967 Meteorology of the Nullarbor Plain Caves. *In:* J.R. DUNKLEY and T.M.L. WIGLEY (eds), *Caves of the Nullarbor. A Review of Speleological Investigations in the Nullarbor Plain. Southern Australia*: 32-34. Speleological Research Council, Sydney.

Illustrations

For papers that have a geographical location we will provide a small location map in a standardised style (typically a map of Australia with a dot, rectangle or arrow—see recent issues for examples). Figures and photographs should not duplicate information in tables or other material. Photographs should be relevant to the text, and supplied as clear black and white prints with sharp focus. Figures should be supplied as Laser prints or drawn in Indian ink on white card, heavy paper or tracing material and lettered using stencils or stick-on lettering. Ink-jet prints should be enclosed in plastic to reduce the risk of water damage in transit. Most computer drawn documents and photographic images can also be handled. Please ask for additional instructions on file formats, pixel widths and photo "enhancements".

All illustrations should be designed to fit within a full page print area of 170 x 258 mm and ideally should be a column width (80 mm) or double-column width (170 mm). They may be supplied larger provided that these proportions are maintained, but allowance for reduction must be made when choosing letter sizes and line thickness.

Fold-outs or colour photographs and maps will be subject to negotiation, and the authors may be asked to make a contribution to the production costs.

Figures and plates should be numbered in a single sequence and specifically referred to in the text. The numbers should be marked lightly in pencil on the margin or back of each illustration. An arrow and the word "top" should be used if orientation is not obvious. Captions should be typed on a separate sheet (or supplied at the end of the text file).

Units

The S.I. system (Australian Standard AS 1000) should be used unless citing historical data, in which case the original units should be quoted and appropriately rounded metric equivalents added; 100 feet (30 m) .

Offprints

Twenty free offprints of papers will be supplied after publication. Additional offprints can be arranged at the author's expense. The number required should be stated when submitting the final manuscript.

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