VULCON

Precedings

20th ASF Conference Hamilton Victoria 1995

Earth, Water, Fire and Air

Vulcon

VULCON Precedings

Papers submitted for presentation

Edited by: Glenn Baddeley

Vulcon 1995

20th Biennial Conference

Australian Speleological Federation Inc.

Hamilton, Victoria 2 - 6 January 1995

Published in Melbourne, January 1995 by the
Victorian Speleological Association Inc.
G.P.O. Box 5425C
Melbourne VIC 3001

for the 20th Biennial Conference of the
Australian Speleological Federation Inc.
P.O. BOX 388
Broadway NSW 2007.

National Library of Australia Cataloguing-in-Publication entry:

Australian Speleological Federation. Conference
(20th : 1995 : Hamilton, Vic.)
Vulcon precedings : papers submitted for presentation at the 20th
biennial conference Australian Speleological Federation.

Bibliography.
ISBN 0 646 21647 3.

1. Caving - Australia - Congresses. 2. Caves - Australia - Congresses. 3. Speleology - Congresses. I. Baddeley, Glenn, 1960- . II. Title.

796.5250994

Example reference:

Rowling, J., Investigations of the Wyanbene caves area, IN: Baddeley G. (Ed), 1995, *Vulcon Precedings*, Victorian Speleological Association Inc., Melbourne.

Printed by:
Australian Industrial Publications
131 Church Street
Hawthorn VIC 3122
(03) 819 4855

Cover: A lava cave at Mt. Eccles, photograph by Rudy Frank, 1979

Table of Contents

Preface

Introduction from the Chairman

The 20th Biennial Conference of the Australian Speleological Federation resulted in an interesting collection of papers submitted for presentation and publication. With a central theme of volcanic caves there is also a wide range of other papers of speleological interest. These include papers on conservation, cave biology, international caving, speleological history and discussions on various Australian caving areas.

The Vulcon committee has chosen to have Precedings available at the commencement of the conference rather than Proceedings being published after it is all over. This has the dual values of having the articles and abstracts available during the actual conference time and to avoid the possibility of late or sometimes the non-production of papers after the enthusiasm of conference organisation has dissipated. Unfortunately not all presenters have been able to prepare their complete papers in time for printing, but we have been able to collect enough to make up a useful volume.

I would like to thank all those involved in the production of these precedings, especially Glenn Baddeley, the Editor, who has produced an excellent companion volume to the *Vulcon Guidebook.*

Finally I would like to thank the Vulcon conference organising committee: Tony Watson (secretary), Glenn Baddeley (treasurer), Margot Watson, Jenny Watson, Ken Grimes, Bryan Gardam and Brett Wakeman for the hard work of organising this conference, and the myriad of other helpers without which it is impossible to function.

Susan White

Chairman, Vulcon Organising Committee.

From the Editor

The papers in these precedings were edited and prepared for printing using the Microsoft Word for Windows 2.0c word processor on 386 and 486 IBM compatible Personal Computers, running Microsoft MS-DOS 5.0 and Microsoft Windows 3.1. These may not be the latest versions available at the time but they have proven reliability and flexibility.

The manuscripts originated from a number of sources. Some of the text was digitised from printed paper using a flat-bed scanner and processed via Optical Character Recognition software. The bulk of the text was imported into Word for Windows from either Word Perfect on the IBM PC, or Word on the Apple Macintosh, or just plain ASCII text files. Some of the papers received by fax were retyped as they could not be scanned successfully.

Despite the disparate sources of text, a consistent, good quality and readable presentation has been achieved using the Bitstream Inc. font *Century Schoolbook* throughout. The final artwork was rendered on a 1200 DPI plain paper imagesetter and reproduced using an offset print process.

Glenn Baddeley

Editor.

Acknowledgements

The Vulcon Committee and the Editor would like to thank all of the authors for contributing papers to the *Vulcon Precedings.*

The assistance of the following people is also appreciated:

Rudy Frank (cover photograph); Alice White (retyping); Samantha Berryman, Susan White (redrawing figures on pages 44, 46, 75, 76); Peter Ackroyd, Ken Grimes, Anne Atkinson (selective proof reading and reviewing); Geoff Hammond (cover layout, printing production, redrawing figure on page 29 and annotation of some figures); Susan White (paper chase).

The Undara Lava Tube System, North Queensland, Australia:

Updated Data and Notes on Mode of Formation

Anne Atkinson

P.O. Box 505, Ravenshoe, Queensland 4872

Introduction

The Undara Lava Tube System, North Queensland, Australia, is remarkable not only for its geology, but also for unique flora and vertebrate and invertebrate fauna. Some aspects of its geology will be considered. This paper has been abridged from a previously published paper (Atkinson, 1991).

More than 60 caves and arches have now been discovered in the system. Most caves are less than 200 m long but the system includes Australia's longest lava tube, over 1350 m. More than 6 km of tubes have been surveyed.

The Undara volcano erupted 190,000 years ago (Griffin & MacDougall, 1975). With an average gradient of only 0.3°, one of the flows extended more than 160 km. This great length is attributed to very high effusion rates, favourable topography and lave tube efficiency.

The lava tube system extends more than 110 km and includes caves, arches, and an almost level ridge that is 35 km long and is known as "The Wall". "The Wall" is considered the best Earth volcanic feature analogous to the smaller basaltic ridges on the Moon.

Adjacent to, or aligned with, the caves and arches there are oval and elongate depressions. Most of these depressions are much wider than the caves and arches and appear to have formed contemporaneously by the draining of lava ponds.

Comparison of the Undara tubes with currently active and Recent Period tubes elsewhere in the world, indicates that the tubes of the Undara System were formed by the draining of roofed lava channels, whose locations were determined by palaeo-topography.

Location and Geological Setting

The Undara lava tubes are found within basaltic lava flows from the Undara Volcano which is located approximately 200 km south-west of Cairns in northern Queensland, Australia. This volcano is situated near the centre of the McBride Province (Figure 1) which covers approximately 5,500 km^2, and topographically forms a broad dome. Only one volcano, Kinrara, is younger than the Undara Volcano (White, 1962). There are over 160 vents in the province (Griffin, 1976).

The Undara Volcano (Figure 2) is the highest point in the McBride Province. Its impressive crater is 340 m across and 48 m deep with inner slopes of up to 40°. The rim rises only 20 m above the surrounding lava field. Outward slopes from the rim vary from 30° to 5° on the north-west side where the major outflows occurred. The crater walls are mainly covered by angular blocks of highly vesicular to massive lava, up to several metres across.

The Undara lava flows cover 1550 km^2 in the province. One flow to the north is, in part, rough spinose "aa" basalt but most of the Undara lava field is of the smooth pahoehoe type. It is in pahoehoe flows that the long lava tubes of the world have formed and can currently be observed forming on the Island of Hawaii (Greeley, 1971b, 1972, 1987; Peterson & Holcomb, 1989; Peterson & Swanson, 1974; Rowland & Walker, 1990).

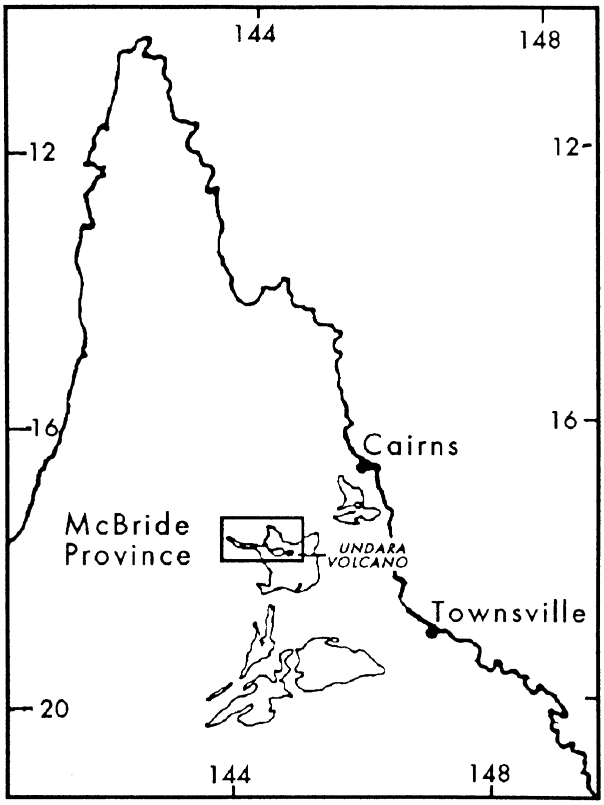


Figure 1: The main areas (provinces) of Cainozoic basalt outcropping in north-eastern Australia. The boxed area is shown in Figure 2.

The feeding channels of pahoehoe can be extremely complicated. Flow patterns frequently consist of an internal network of interconnecting conduits which sometimes attain considerable vertical and horizontal complexity (Wood, 1976). However, almost all the tubes of the Undara System are simple in plan and appear to be single-level. To date, the only multi-level tube discovered in the McBride Province is in three levels on the flank of the source volcano in an adjacent flow of slightly greater age.

Lava flowed in all directions from the Undara Crater, but the main flow was to the north-west (Figure 2). The flow to the north was approximately 90 km long and entered the Lynd River. The voluminous north-west flow followed precursors of Junction Creek, Cassidy Creek and the Einasleigh River for more than 160 km to become the longest single lava flow in the world (Walker, pers. comm., 1989). He considers that to reach a length in excess of 160 km, Undara's eruption may have continued for several years.

Walker (1973) concluded that very long lava flows reflect continued high effusion rates. Stephenson & Griffin (1976) reached a similar conclusion in a study of eight long basaltic flows in Queensland.

The lava tube system from the Undara crater has been divided into four sections (Figure 2) in order to describe the locations of the caves and arches.

The distribution of caves within the lava flow is as follows: The Crater and the Yaramulla Sections contain both caves and arches. In the North Section, only three caves have been found, but a line of collapse depressions suggested the presence of a lava tube. The author believes that the Wall Section contains a major lava tube with a very thick roof, but to date no access to such a tube has been discovered.

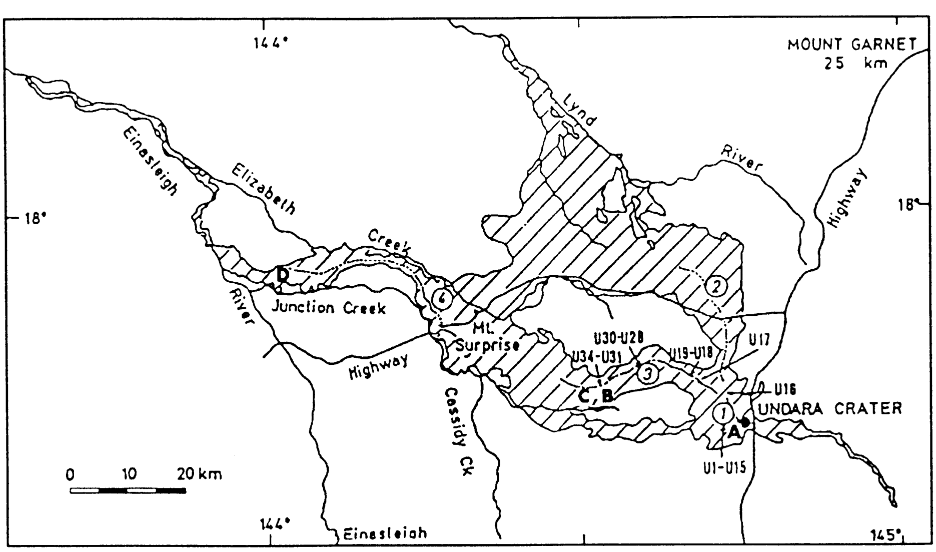


Figure 2: The Undara lava field. Circled numbers denote sections of the lava tube system referred to in the text, namely: 1. Crater Section; 2. North Section; 3. Yaramulla Section; 4. Wall Section.

Investigations

The Undara lava tubes were described briefly by Twidale (1956), Best (1960) and White (1962). The first speleologists to visit the area were from the University of Queensland Speleological Society. They explored and mapped Barkers Cave (Shannon, 1969). In 1972 the author's studies were commenced (Stevens & Atkinson, 1975; Atkinson & others, 1975; Atkinson, 1988a, 1988b, 1990a, 1990b, 1991). At the same time, and subsequent to this investigation, the speleologists were continuing exploration of the caves. Grimes (1973, 1977) published a compilation of the results of earlier studies of Undara lava tubes. In the *Australian Karst Index*, Matthews (1985) recorded the cave names, numbers and brief descriptions.

The Chillagoe Caving Club commenced exploration of the lava tubes in 1988. In addition, a number of expeditions from the Explorers Club (New York) examined the lava tubes and researchers sponsored by the Explorers Club consider that the invertebrate community in Bayliss Cave makes it one of the world's most biologically significant caves (Howarth, 1988).

In 1989, 100 volunteers (in groups of 20) from London-based Operation Raleigh camped on site for three months to investigate areas not explored by the author. Under the guidance of a Q.N.P. & W.L.S. officer, they surveyed collapse depressions in the new Undara Crater National Park and in the 10 km upflow from Bayliss Cave, an area never previously studied. They discovered and surveyed five new caves. Their systematic search in the North Section resulted in the first discovery of caves in this section, viz. Dingbat Cave, Hot Hole and Wishing Well Cave, about 21 km north of the crater. Their assistance in collection of specimens and data of flora and fauna led to valuable additions to the records of the Undara lava field.

Caves and Arches

The Undara lava tube system can be clearly located on aerial photographs. It stands out because most of its collapse depressions support rainforest type vegetation which contrasts sharply with the open forest of the surrounding country. Some of the caves, for example Barkers Cave and Road Cave, have been known for more than eighty years. The majority of caves, however, were located by systematic exploration of the collapse depressions since 1972.

61 arches and caves have been discovered in the Undara Lava Tube System up to 1991, and a total length of over 6 km of lava tube caves has been surveyed. The largest passage yet measured is in Barkers Cave where the passage width reaches 19.8 m and a height of 13.5 m.

Features of the Caves and Arches

Although the Undara lava tubes formed 190,000 years ago, they have retained many original features. These features show minimal alteration due to their protection from weathering.

Figure 3 shows plans of representative caves. Most of the cave passages are elongate in the direction of the lava flow. Figure 4 shows longitudinal profiles through representative caves in the Crater Section and Yaramulla Section of the lava tube system. These profiles illustrate the variation in shape, size and roof thickness of the caves.

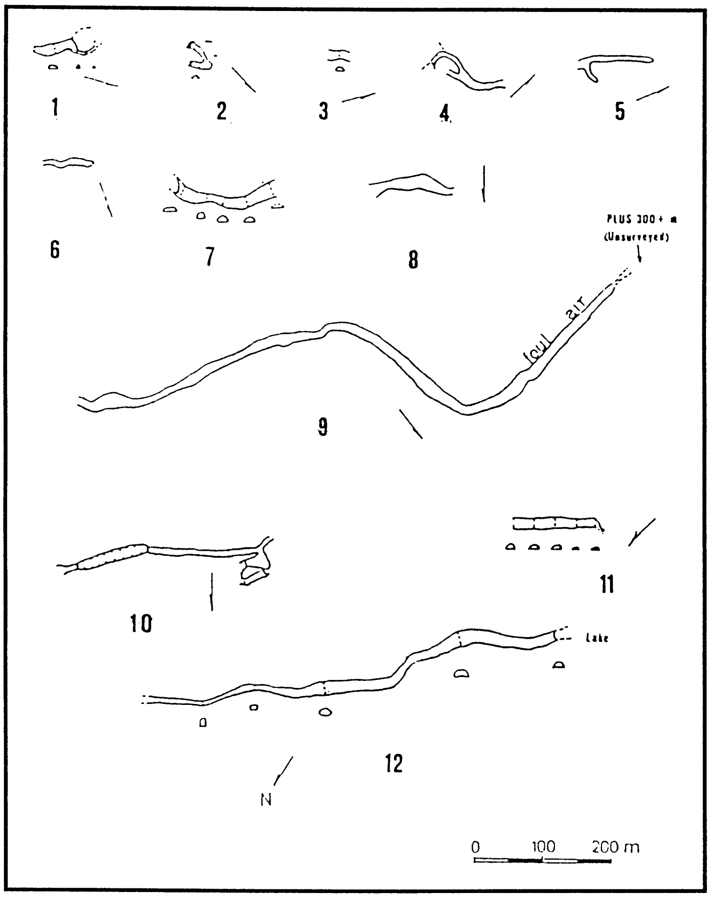


Figure 3: Maps of selected caves with some cross sections.
1. U-4 Taylor, 2. U-8 Ollier, 3. U-9 & U-10E Harbour Bridge, 4. U-11 & U-12E Greeley, 5. U-15 Peterson, 6. U-16 Stevens, 7. U-17 Pinwill, 8. U-28 Road, 9. U-30 Bayliss, 10. U-41 Inner Dome & U-42 Wind Tunnel, 11. U-31 Darcy, 12. U-34 Barker

The largest cave passages are found in the Yaramulla Section and they are mostly simple tubes. The only lava tube cave in this area to show complex development is Wind Tunnel and Inner Dome Complex but the development is on one level and is characteristic of the tendency of lava rivers to braid.

Lava tube floors

Floors of the caves, when not covered by sediment or water, represent the final flow of lava in the tube. With the exceptions of areas of rough, spinose aa basalt on the floor of Pinwill Cave, Yaramulla Section and Wishing Well Cave, North Section, the exposed floors are typical pahoehoe.

At the entrance to Barkers Cave, the floor is arched, with a single ropy structure running down-flow. Beyond this, the floor has distinct marginal gutters up to 1 m deep. Fine lava level lines on the outer walls of the gutters correspond, but are absent on the inner walls, which show some evidence of formation as levees. The raised central portion of the cave is therefore interpreted as a final channel flow in this cave.

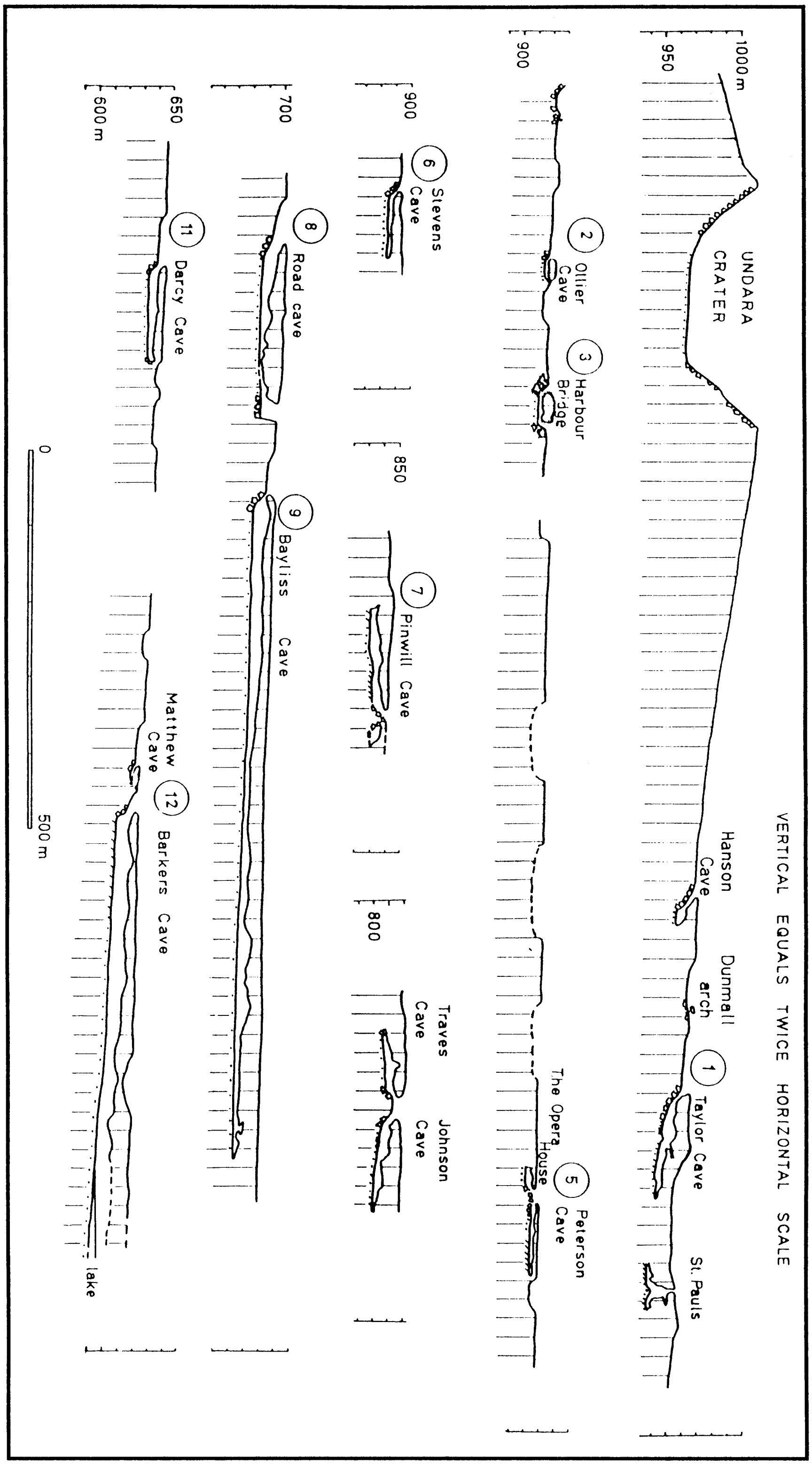


Figure 4: Longitudinal profiles of various caves in the down flow from Undara Crater. Floor symbols: Sediment (......), Ropy lava (//////) (Atkinson et al., 1975)

Good examples of ropy lava are visible in Pinwill Cave and the South Chapel of St. Paul's. In a central position near the entrance to Barkers Cave, rafted crust fragments, approximately 8 cm thick, have been tilted at varying oblique angles in a manner similar to ice slabs on a frozen river. In Peterson Cave, there is a small floor surface where lava drops from the roof appear to have pitted the floor, as rain drops pit a muddy surface. Prolonged flow at constant level is evidenced by the "benches" in Taylor Cave.

Walls and roofs

There is a lava lining on the walls and roof of most caves. Typically the lining is a single layer up to 20 cm, but in places may approach 1 m in thickness. At various locations the tube lining has fallen off the wall to expose the host lava behind it. The lining is sometimes multi-layered. The best example of this is in Pinwill Cave where 15 layers, 2 - 4 cm thick are revealed at one location. At the entrance to the same cave, a thin slab of lining called The Table has become dislodged and now rests in a near horizontal position.

On most walls and roofs are some areas of very low vesicularity showing drip and dribble structures resembling candle wax. At the entrance to Barkers Cave, Collins Road Cave and Picnic Cave these drips are deflected. In historic tubes such surfaces have been seen to be formed by remelting and because of their lustre are appropriately termed "glaze". In the Undara tubes the remelt surfaces have weathered to a dull or earthy lustre.

In places there are lavacicles (lava stalactites), commonly 2 cm to 3 cm and occasionally up to 8 cm long, suspended from the roof, inclined walls and in wall cavities. Lava stalagmites are rare, as are lava columns. No "straw" stalactites have been found - no doubt because of their extreme fragility.

In most caves, lava level lines and ledges on the walls represent fluctuating lava levels. The highest levels are usually evident close to the roof, as seen in many caves: Taylor, Road, Arch, Ewamin, Picnic I, Picnic II and Barkers. The lava level lines usually slope down-tube at low angles, probably reflecting the original tube slope.

Termination of the lava tubes

The caves generally terminate down-flow with collapses, or with a gentle downward curve of the ceiling to a silt floor. Barkers Cave ends in a lake, the cave ceiling steadily declining to water level. Several caves have down-flow entrances and have little or no silt on their floors. Pinwill Cave, The Opera House, Picnic Cave and Wishing Well Cave terminate with vertical walls.

Collapse depressions and their relationships to caves

This account would be incomplete without reference to the collapse depressions associated with the Undara Lava Tube System. For convenience these depressions are divided into two types, namely: narrow depressions, 30 - 50 m wide, and wide depressions 50 - 100 m wide. Their appearance is comparable with an historic lava pond in Hawaii (MacDonald & Abbott, 1972, p 42)

Narrow depressions

Narrow depressions commonly give entry to the lava tube caves suggesting that they were formed by the collapse of segments of the tube. Vegetation within these depressions differs little from that of adjacent open forest. However, rainforest trees and vines are found at most cave entrances, often concealing them and, as a result, cave entrances are difficult to locate on aerial photographs.

Wide depressions

Wide depressions form a strong linear pattern, made conspicuous by rainforest vegetation. They seldom give access to caves and display features which distinguish them from the narrow depressions. Wide depressions vary in shape from circular or oval, to elongate in the direction of the lava flow. An exception to this is seen west of Barkers Knob where depressions are less regular in shape and location, although there is some indication of three branching alignments.

Most wide depressions have elevated rims, suggesting that they represent former lava ponds as are seen associated with historic flows in Hawaii. Rims and slopes of the depressions are made up of blocks of various shapes and sizes. Local areas of blocks possessing flat upper surfaces with low vesicularity are thought to be segments of lava pond crust because of the similarities to collapsed lava pond crusts in Hawaii and Oregon, U.S.A. (Peterson & Greeley, pers. comm. 1974; Greeley, 1971a). Near the base of some depressions, the lower surfaces of some blocks are moulded and occasionally contain embedded fragments. In rare cases, blocks have retained an original ropy lava surface.

Peterson and others of the U.S. Geological Survey in Hawaii (written communication, 1975) have observed that lava becomes ponded in specific areas, particularly where the slope is small. Once formed, the ponds tend to perpetuate themselves during the life of the flow, even when the flow front has advanced further. These ponds crust over and the molten lava beneath the crust is interconnected with lava tubes that had been developing in the flow both upstream and downstream from the pond. The crusted surfaces of these ponds have been observed to subside as the flow dwindles and the ponded lava drains back into the tube. The wide depressions of the Undara lava flow have been interpreted as former lava ponds.

There is a depression 60 m north of the entrance of Taylor Cave (Figure 5). This long depression lies directly in line with the entrance section of the cave. The cave was found not to terminate in a collapse beneath the depression, as was expected, but close to the edge of the depression. The cave branches and the two passages roughly follow the outer margins of the depression. Each branch closes to an inaccessible tunnel and near its termination the east branch divides again. The lava level lines in the east branch are nearly horizontal and proceed along both sides of the cave and across the wide pillar at the end.

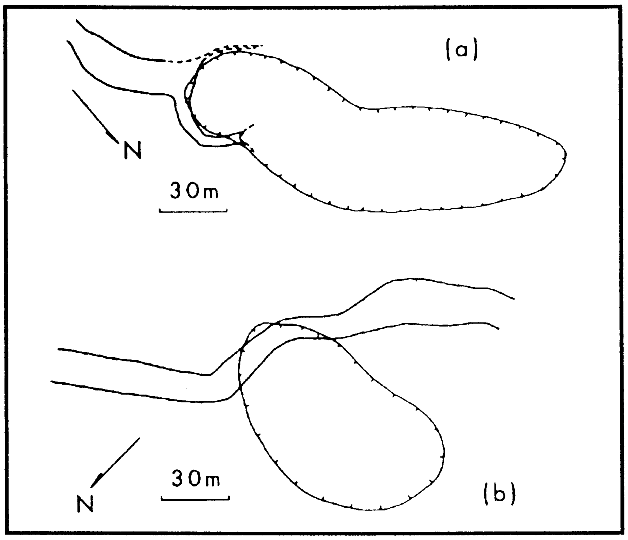


Figure 5: Relationship between surface depressions and caves: (a) Taylor Cave; (b) Barkers Cave. (Atkinson et al., 1975)

The relationship of the Taylor Cave passages to the depression suggests the collapse interfered with the still functioning tube. When the lava pond drained and its crust collapsed the tube bifurcated around the collapse, but was then constricted and eventually dammed. Subsequently the dammed lava inside the tube drained through minor outlets. A cylindrical vent in the roof of Taylor Cave is interpreted as a location where some of the lava that ponded above the main tube drained back into it. A minor lavafall, approximately 1 m high, emerges from under the floor of the west terminal branch of the cave and is interpreted as another point of "drain back".

Figure 5 shows how Barkers Cave changes its course, deviating around a major depression 220m west of the cave entrance. There is a small cavity in the cave roof under the eastern end of the depression and circular holes up to 1.5 m across on the inner slope of the depression. This seems to indicate that the lava which had ponded in the depression drained back into a flowing tube, forcing it to alter its course.

Mode of formation of the Undara lava tube system

Lava channels and associated tube systems are the main distributors of the liquid rock during a pahoehoe lava eruption. The lava tube systems and caves associated with them form in a relatively short time. Earlier estimates of the time taken for their formation have to be modified in light of current tube activity on the island of Hawaii. Evidence of how the Undara lava tube system and the caves in it formed has been preserved for 190,000 years. This, together with observations of caves forming in active and recent lava flows in Hawaii (Jaggar, 1947, cited in Wood, 1976; Wentworth & MacDonald, 1953; Greeley, 1971b, 1972a, 1987; MacDonald & Abbott, 1972; Cruikshank & Wood, 1972; Peterson & Swanson, 1974; Peterson & Holcomb, 1989), and Iceland (Kjartansson, 1949, cited in Wood, 1976), has resulted in the following discussion of the mode of formation of the Undara lava tube system (Figure 6).

A river of pahoehoe lava, confined in a valley, quickly crusts over and develops a roof. The flow also begins to solidify against the valley walls and floor (Figure 6A). The roofing occurs in several different ways including growth of semi-solid surface crusts by cooling, crusts floating down the channel jamming and accumulating at obstructions, and by the growth of levees from the channel sides through repeated overflows, splashing and splattering. Examination of the roofs in the Undara lava tubes indicates that most of the roofing took place by the growth of semi-solid surface crusts.

As solidification of the roof, walls and base continue, the flow becomes concentrated within a cylinder (Figure 6B). If the eruption ceases and the tube drains completely its cross section is circular.

When the supply of lava diminishes during an eruption, it no longer fills the whole tube. Volcanic gases escaping from the flow into this cavity may ignite producing temperatures considerably higher than that of the molten lava. This may cause some remelting of the roof with drips of lava forming lavacicles (Figure 6C) which are commonly vertical. Deflection of drips is rare and is thought to be caused by a current of very hot air. In the Undara lava tube caves deflection has been noted near the entrance to Picnic I Cave, Collins Road Cave and Barkers Cave.

Effusion rates fluctuate during an eruption but whenever a constant rate is maintained, near-horizontal ledges of lava solidify on the tube walls at lava level lines. Further diminution of the flow lowers the level in the tube and finally the flow congeals to form the floor (Figure 6D).

Many or most of the lava tubes in a flow will remain filled with lava and caves form only if the tube drains or partially drains. Examination of recent lavas in Hawaii and Iceland has shown that many entrances form during eruption. Other entrances are opened by roof collapse, weathering processes or excavation by man.

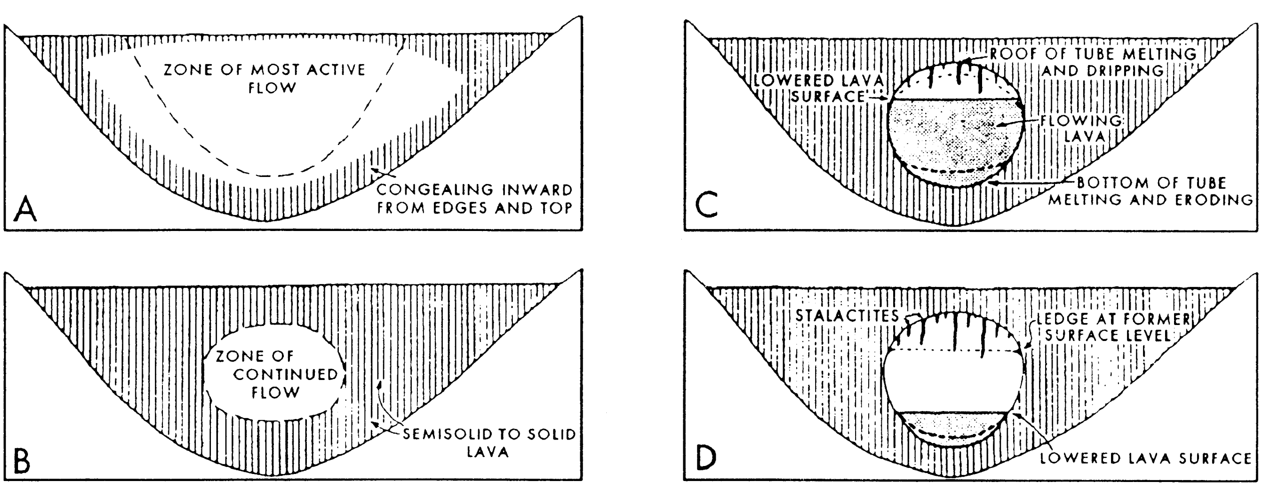


Figure 6: Stages observed in the development of the lava tubes in Hawaii (after Macdonald & Abbott, 1972). Examination of evidence in the Undara Lava Tubes indicates that this explanation is directly applicable.

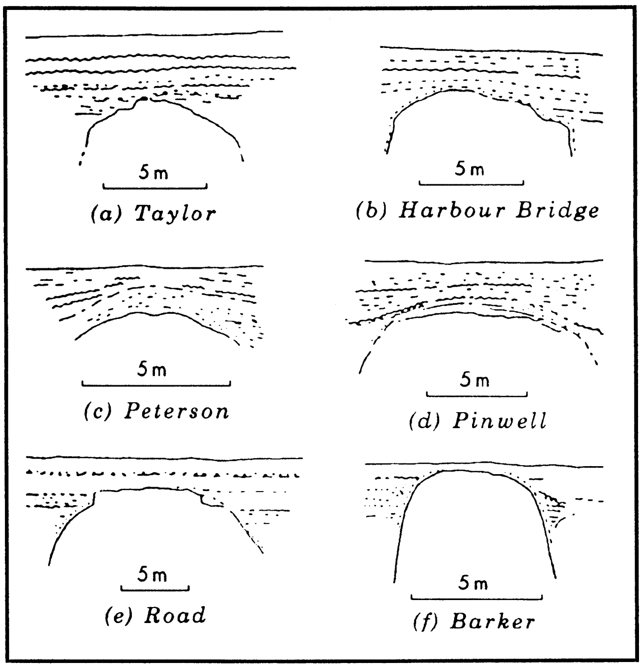


Figure 7: Cave entrance structures showing thickening of roofs by successive surface flow units. Flow units are represented by wavy lines for recognised flow units surfaces. Other near-horizontal lines are major vesicle zones. (Diagram: P.J. Stephenson)

Once the Undara lava tube system was formed in the major eruption, there was subsequent thickening of tube roofs by later flow units. Some of these flow units passed over ropy surfaces and now bear ropy imprints on their lower surfaces. The low incidence of ropy surfaces and imprints at Undara support the observation by Macdonald and Abbott (1972) that ropy structure is often evident only over a small proportion of any flow. Figure 7 shows the thickness of various lava tube cave roofs.

Subsequent flows, as well as thickening the tube roofs, may form additional lava tubes. If these connect with existing caves, a complex cave system will develop. In the Undara lava flow there is such development in the Crater Section and in the proximity of the Wind Tunnel.

Conclusion

Favourable topography and a very high rate of effusion, coupled with an efficient lava tube system, allowed one flow from the Undara Volcano to extend 160 km to become the longest single-volcano flow in the world. This flow contains the longest lava cave in Australia. Within the caves and arches of the lava tube system, protection from weathering has allowed the preservation of many features similar to those in active and recent lava flows. From such features it can be concluded that the lava tube system and the caves in it formed in a manner similar to those that have been observed forming during historic eruptions of pahoehoe lava.

Acknowledgements

The author is indebted to many people for their help and assistance in the field and elsewhere; too many to name here. Special thanks are due to: Associate Professor Stephenson and Dr. Griffin for permission to use material from our joint paper. My husband, Vernon, and our family. Peter Stanton (Q.D.F. & H.), Associate Professor Stephenson, Professor Greeley (Arizona State University), Drs. Halliday (Tennessee), Peterson (U.S.G.S.) and Stevens (U.Q.), Julia James (S.U.) for their continued interest and enthusiasm. Mick Godwin (Q.D.F. & H., Cairns) who has done so much toward completing the Undara records and who arranged my safe entry to (and return from!) the caves discovered in 1989. The advice and assistance of Susan White, Ken Grimes and Glenn Baddeley in the preparation of this abridged paper are gratefully acknowledged.

References

ATKINSON, F.A., 1988a: The Remarkable Undara Lava Tube System - a geologist's view. In: PEARSON, L.M. (ed.), Pre-prints of the 17th Conf. Aust. Speleo. Fedn.: 39-56.

ATKINSON, F.A., 1988b: Vulcanspeleology- Extra-terrestrial Applications & the Controversy: Mode of formation of lava tubes. In: PEARSON, L.M. (ed.), *Proc. 17th Conf. Aust. Speleo. Fedn.*: 57-63.

ATKINSON, F.A., 1990a: The Remarkable Undara Lava Tube System, North Queensland. Points of interest as a background to its unique biology. *Jour. Tasmanian Karst and Cave Research Group.* May 4 1990.

ATKINSON, F.A., 1990b: The Undara Lava Tube System and its Caves. (Abridged and updated from Atkinson, 1988a, 1988b) *Helictite* 28(1) : 3-14.

ATKINSON, F.A., 1991: The Undara Lava Tube System, North Queensland, Australia: Updated Data and Notes on Mode of Formation and Possible Lunar Analogue. Pre-print for 6th International Symposium on Vulcanospeleology, Hawaii, August 1991.

ATKINSON, F.A., 1993: *Geological Features of the Undara Lava Tube System, North Queensland - with particular emphasis on the features in the caves and environs to be used for tourist visitation from 1993.* Report for the Department of Environment and Heritage, Queensland (unpub). 112 pp, incl. 15 maps.

ATKINSON, F.A., & ATKINSON, V., 1995: *Undara Volcano and its Lava Tubes - A Geological Wonder of Australia in Undara Volcanic National Park, North Queensland.* (In press) GOPRINT, Brisbane, Queensland. 96 pp.

ATKINSON, F.A., GRIFFIN, T.J., & STEPHENSON, P.J., 1975: A major lava tube system from the Undara Volcano, North Queensland. *Bull. Volcan.* 39(2): 226-293.

BEST, J.C., 1960: Some Cainozoic basaltic volcanoes in North Queensland. *Bur. Mineral Res., Geol. Geophys., Aust. Record* 1960-1978 (unpub).

CRUIKSHANK, D.P. & WOOD, C.A., 1972: Lunar rilles and Hawaiian volcanic features: possible analogues. *The Moon*, 3, 412-47.

GODWIN, M.R., 1993: *Undara and associated Lava Fields of McBride Plateau - a Speleological field guide, North Queensland, Australia.* Report issued by Chillagoe Caving Club. (unpub).

GREELEY, R., 1971a: Geology of selected lava tubes in the Bend Area, Oregon. *Oregon Dept. Geol. Min. Ind. Bull.* 71: 47.

GREELEY, R., 1971b: Observations of actively forming lava tubes and associated structures. Hawaii. *Mod. Geol.* 2: 207-233.

GREELEY, R., 1972: Additional observation of actively forming lava tubes and associated structures. Hawaii. *Mod. Geol.* 3: 157-160.

GREELEY, R., 1987: The role of lava tubes in Hawaiian Volcanoes. In: DECKER, R.W., WRIGHT, T.L. & STAUFFER, P.H. (eds.) *Volcanism in Hawaii*, U.S. Geol. Surv. Prof. Paper 1350: 1589-1602 (Chapter 59).

GRIFFIN, T.J., 1976: The McBride Basalt Province. Ph.D thesis J.C.U.N.Q. (unpub).

GRIFFIN, T.J. & MCDOUGALL, I., 1975: Geochronology of the Cainozoic McBride Volcanic Province Northern Queensland. *J. Geol. Soc. Aust.* 22(4): 387-396.

GRIMES, K.G., 1973: North Queensland Lava Tunnels. *Down Under* 12(4): 121-125.

GRIMES, K.G., 1977: Undara lava tunnel, North Queensland. *Down Under* 16: 118-128.

HOWARTH, F.G., 1988: Environmental ecology of North Queensland Caves: or Why are there so many troglobites in Australia? In: PEARSON, L.M. (ed.), Pre-prints of the 17th Conf. Aust. Speleo. Fedn.: 76-84.

KJARTANSSON, G., 1949: Nyr hellir i Hekluhrauni. *Natturufraedingurinn*, 19: 175- 184.

MACDONALD, G.A. & ABBOTT, A.T., 1972: *Volcanoes in the Sea - The Geology of Hawaii*, University Press, Hawaii. 441 pp.

MATTHEWS, P.G. (ed.), 1985: *Australian Karst Index*, Aust. Speleo. Fed., Melbourne, 481 pp.

PETERSON, D.W. & HOLCOMB, R.T., 1989: Lava tubes in Mauna Ulu, Kilauea Volcano, 1972-1974. *Proceedings I.A.V.C.I. Symposium*, 1989. Santa Fe.

PETERSON, D.W. & SWANSON, D.A., 1974: Observed formation of lava tubes during 1970-1971 at Kilauea Volcano, Hawaii. *Studies in Speleology* 2(6): 209-224.

ROWLAND, S.K. & WALKER, G.P.L., 1990: Pahoehoe and aa in Hawaii: volumetric flow rate controls the lava structure. *Bulletin of Vulcanology* 52: 615-628.

SHANNON, C.H.S., 1969: Barkers Cave, Mount Surprise. *Down Under* 8(3): 18-19.

STEPHENSON, P.J. & GRIFFIN, T.J., 1976: Some long basaltic flows in Northern Queensland. In: W.R.Johnson (ed.) *Volcanism in Australia,* Elsevier Scientific Pub. Co., Amsterdam. 41-51.

STEVENS, N.C. & F.A. ATKINSON, 1975: The Undara Lava Tubes, North Queensland, Australia. In: HALLIDAY, W.R. (ed.) *Proceedings of the International Symposium on Vulcanospeleology and its Extraterrestrial Applications.* A special session of the 29th Conv. of the Nat. Speleo. Soc., White Salmon, Wash., Aug. 16, 1972. 58-63.

TWIDALE, C.D., 1956: A physiographic reconnaissance of some volcanic provinces in North Queensland, Australia. *Bull. Vol.,* 2: 2-23.

WALKER, G.P.L., 1973: Lengths of lava flows. *Phil. Trans. R. Soc. Lond.* A 274: 10 7-118.

WENTWORTH, C.K. & MACDONALD, G.A., 1953: Structures and forms of basaltic rocks in Hawaii. *U.S. Geol. Surv. Bull.* 994: 98.

WHITE, D.A., 1962: Einasleigh, Queensland. *Bur. Min. Res., Geol. Geophys. Aust.,* 1:250 000 Geological Series Map and Explanatory Notes.

WOOD, C., 1976: Caves in rocks of volcanic origin. In: FORD, T.D., & CULLINGFORD, C.H.D. (eds.), *The Science of Speleology.* Academic Press, London, 127-150.

Lava caves and channels at Mount Eccles, Victoria

Ken Grimes

PO Box 362, Hamilton, Victoria, 3300

Introduction

Mount Eccles and nearby Mount Napier are two of the youngest volcanoes in the Newer Volcanic province of Victoria. Summaries of both the surface landforms and the volcanic caves of the province appear in the *Vulcon Guidebook* (Grimes, in press; and Grimes & Watson, in press). The earlier lava cave literature by Ollier, Joyce and others is reviewed in the *Vulcon Guidebook*, and in Webb & others, 1982, and Grimes, 1994.

The Newer Volcanics range in age from Pliocene (about 4.5 Million years) up to very recent times. Recent isotopic dates from Condah Swamp (Head & others, 1991) support the previously suggested 20,000 BP dates for the onset of the volcanism at Mount Eccles, but there is no definite date for its end, though this would seem to have been prior to 7000 BP.

At Mount Eccles the main volcano is a deep steep-walled elongated crater which contains Lake Surprise. The south-eastern end is a high cinder cone, but at the north-western end the crater wall has been breached by a lava channel that flows west and then branches into two main channels (referred to locally as 'lava canals') running to the north-northwest and to the south-southwest (see Figure 1). Extending to the southeast from the main crater there is a line of smaller spatter and scoria cones and craters and a second smaller scoria cone (Little Mount - now largely removed by quarrying). One of the spatter cones contains 'The Shaft' (H-8), a still open throat and volcanic chamber. Further southeast, another possible volcanic throat was The Pit (H-28), reportedly destroyed by recent quarrying.

Beyond this central area of explosive activity, basalt flows form a lava field about 16 km long and 8 km across (see district map in the *Vulcon Guidebook*). From the western end of this lava field a long flow, the Tyrendarra Flow, runs 30 km southwards to the present coast and continues offshore for a further 15 km. This must have had a major feeder tube, but no drained sections have been discovered to date.

Lava Channels

The lava channel that leaves the western end of the main crater branches almost immediately. The Main West Canal extends about 3 km to a 'wrinkled' area of strongly developed transverse pressure ridges and from there it fed most of the northwestern part of the lava field (Figure 1). The other branch (the Main South Canal) runs about 3 km to the south and south-southwest. It is not as wide but is deeper and has better developed levee banks along its sides. This channel ends abruptly, and probably originally flowed into a tube, but no entrances have been found to date. The flow continues south then west, and may have been the one that fed the long Tyrendarra Flow.

In addition to the two main lava channels there are several smaller, and less well-defined channels (Figure 1). A set of narrow and discontinuous linear depressions can be seen on the air photos running westward between the Main West Canal and the Main South Canal; this could be a partly roofed channel and would have potential for drained lava tubes between the surface depressions. A broad but shallow lava channel starting at the Dry Crater, immediately to the southeast of Lake Surprise, runs east and feeds a major flow that then runs south and southeastward. Another narrow but well-defined channel runs west-southwest from a small spatter cone near the Little Mount quarry and ends at the Natural Bridge / Gothic Cave (H-10). The western part of this 'channel' may have originally been a tunnel which has been exposed following collapse of most of its roof: Natural Bridge is the remaining part of this tunnel. A small lava channel also runs through the camping area north of Lake Surprise.

The channel gradients are generally steepest near the source vent, but vary between channels (Table 1). The depths of the channels varies and lava mounds and ridges are found along the floors. Joyce (1976) measured the west channel as being from 140 to 220 m wide and 4.5 to 5 m deep. The southern channel is deeper (6 to 12 m) but not as wide (60 to 120 m). Channel walls can be steep to even overhanging. They have been considerably modified by collapse and cambering.

Table 1: Gradients of lava channels (from map contours)

	In channel		Flow beyond
Channel	At top	At bottom	channel end
Main West Canal	1: 175	1: 175	1: 175
western canal & tubes	1: 100	1: 125	1: 75 ?
Main South Canal	1: 60	1: 163	1: 300
eastern channel	1: 55	1: 75	1: 125
Natural Bridge channel	1: 25	1: 30	1: 48 ?

Lava Caves

Lava tubes can form by two main processes: by the roofing over of surface lava channels (Figure 3A-C); and by the draining of still molten material from beneath the solidified crust of a flow (Figure 3D). Both types occur at Mount Eccles. For a more detailed description of the processes see the text and figures in the *Vulcon Guidebook* (Grimes & Watson, in press) which are based on the work of Atkinson (1988), Greeley (1987), Joyce (1980) and Wood (1977).

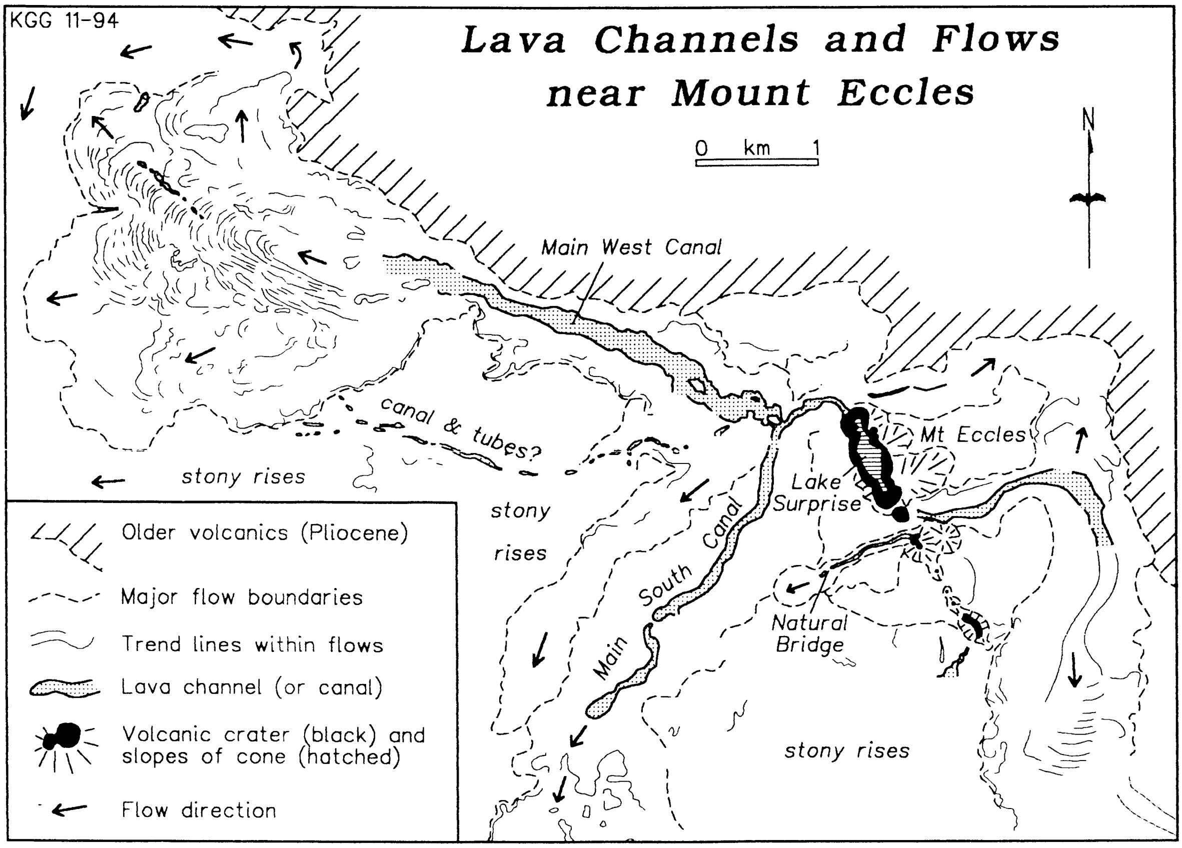


Figure 1: Lava Channels and Flows near Mount Eccles

Most of the longer caves known at Mount Eccles are in, or adjacent to, the lava channels, but there are a number of small caves scattered throughout the area, and the known distribution may simply reflect the more intensive exploration along the main canals. There are several types of lava cave in the area. Roofed channels include H-10, and also possibly H-9. Drainage caves include two types: complex, lateral, levee-breach systems on the sides of the major lava channels, e.g. H-51; and small, isolated, drained chambers within the stony rises (e.g. H-78) - see maps in Grimes & Watson (in press). The Shaft (H-8) is an explosive cavity and throat within a spatter cone that remained open after the volcanism ceased.

The genesis of Natural Bridge / Gothic Cave (H-10) by roofing can be seen from its obvious location at the end of a narrow surface channel, though the present cave is just a remnant of what was originally a longer roofed section. The exposure of numerous thin and contorted linings in the walls and roof, together with its pointed 'gothic' roof outline, suggest that it formed by the inward growth of overhanging levees, which slumped inwards and downwards while hot to produce the contortions (see also Joyce, 1976, 1980). The genesis of Tunnel Cave (H-9) is less obvious, but its large, high-arched passage and the floor level, which is close to that of the adjoining canal, suggests that it was a major feeder tube which may have originated as an open channel at much the same time as the main canal, but was later roofed over.

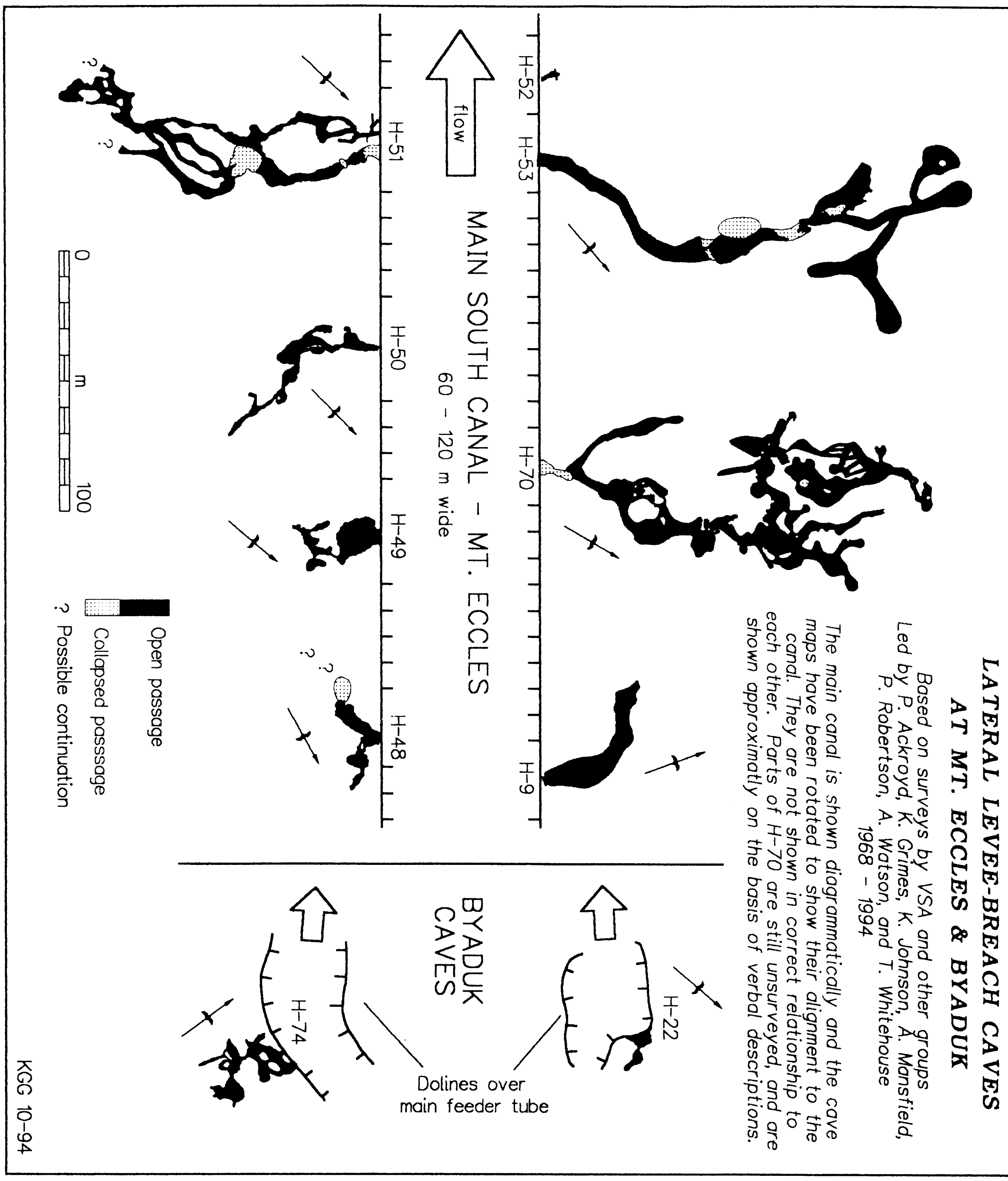


Figure 2: Lateral levee-breach caves at Mt. Eccles and Byaduk

The lateral caves associated with the canals are generally shallow systems formed in the levee banks on each side and would have fed small lateral lava lobes or sheets when the canal overflowed or breached through the levee (Figure 3D and 4). Figure 2 shows the lateral caves associated with the Main South Canal. The canal is shown diagrammatically, and the cave maps have been rotated to show their orientation relative to the canal wall. H-9 has been included in Figure 2, even though I feel that it is a major feeder tube and has a different origin to the others.

Some caves start as simple linear tubes (e.g. H-53), but mostly they are branching systems with complexes of low passages that bifurcate and rejoin, or open out into broad low chambers. The form suggests draining from beneath the solidified roof of a series of flow lobes. Some of the passages are large enough to stand in, typically (but not always) those nearest the canal entrance (e.g. H-48, H-53, H-70), but most of them are crawlways about a metre high with low arched roofs and flat lava floors. Some of the smallest passages have an elliptical cross-section. The roof is generally only a metre or so below the present surface, and in places breakdown has exposed the bases of overlying pahoehoe flows, indicating that the original roof was less than a metre thick. In some chambers the roof has sagged down in a smooth curve to reach the floor. The floors are generally pahoehoe, with smooth, platy or ropy surfaces; but sharp aa lava floors occur in several places (e.g. H-51 and H-70). Some transitional forms (which I call 'knobby pahoehoe') also occur. Small tumuli and lava boils or 'puddings' occur on the floor in places.

Where not disrupted by breakdown the walls and roof typically have thin (2 - 20 cm) linings with lava drips and runs, and occasional pealed back flaps. Some linings have a hackly surface, possibly due to bursting of gas bubbles. Lava 'hands' have been squeezed out through cracks in the linings in a few places and small agglutinated stalagmites may occur beneath some of these. Most caves are at a single level, but some show evidence of several levels (only a metre or so apart vertically) that either have coalesced into a single passage or chamber (e.g. H-51) or are joined by short lava falls (e.g. H-70).

In the stony rises small caves form by the irregular draining of cavities beneath the crust of a broad lava flow (See Figure 5-4 in the *Vulcon Guidebook*, Grimes, in press). The process is similar to that which forms tubes (Figure 3D), but less organised so that only isolated low chambers appear to result. Commonly the chamber roof sags (while hot) or later collapses so that only a crescentic 'peripheral remnant' survives, as at H-78. This type of single chamber cave has previously been referred to as a 'blister cave' but that term is best restricted to chambers formed by gas pressure.

The Byaduk Caves

The Byaduk Caves are near the start of a long, tunnel-fed lava flow that runs down the Harman Valley to the west of Mount Napier, 20 km to the north of Mount Eccles. Collapse of parts of the main feeder tunnel has exposed the large tunnels, arches and collapse dolines (see map in the *Vulcon Guidebook*). The largest tunnels are up to 18 m wide, 10 m high and extend to depths of 20 m below the surface. There are also some smaller but more complicated caves, including two (H-22 and H-74, Figure 2) that seem comparable to the lateral levee-breach systems described above. H-74 (Chocolate Surprise) is the most convincing - this is a high level system entered half way up the side wall of a large collapse doline formed over the main feeder tube (Mansfield, 1990). It is a set of low branching passages and chambers very similar to those found beside the channel at Mount Eccles. I therefore suggest that the main feeder tube at Byaduk was initially an open channel which built up high banks by repeated overflow before roofing over to form the large tubes. The 'layered lava' reported by Ollier & Brown (1965) in the walls of the big tube may be thin lateral flow units of the levees, and H-74 would be a cave system developed in one such overflow.

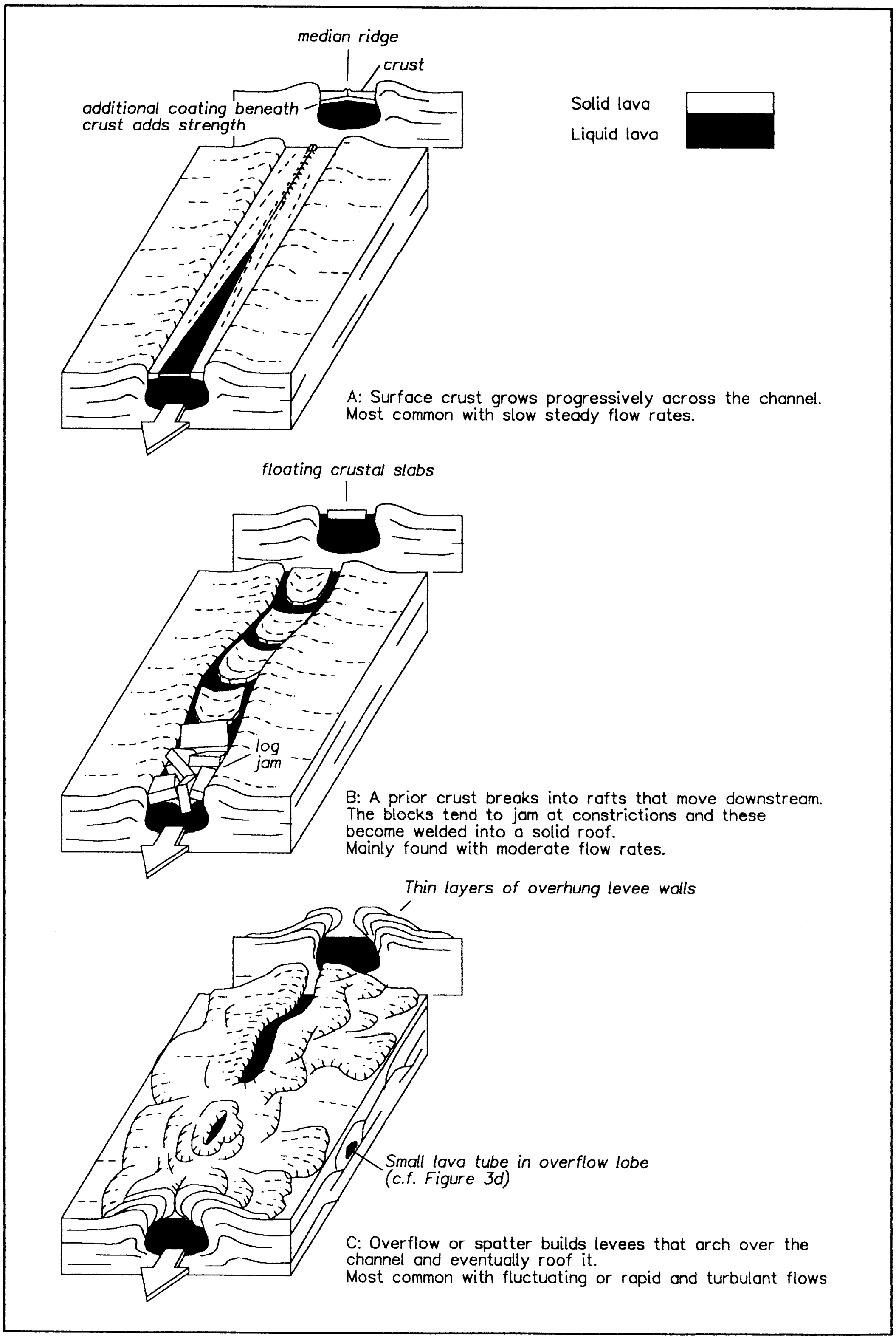


Figure 3: Formation of lava tubes, by roofing over of a lava channel (A-C), or by drainage from beneath crusted lava lobes (D, next page)

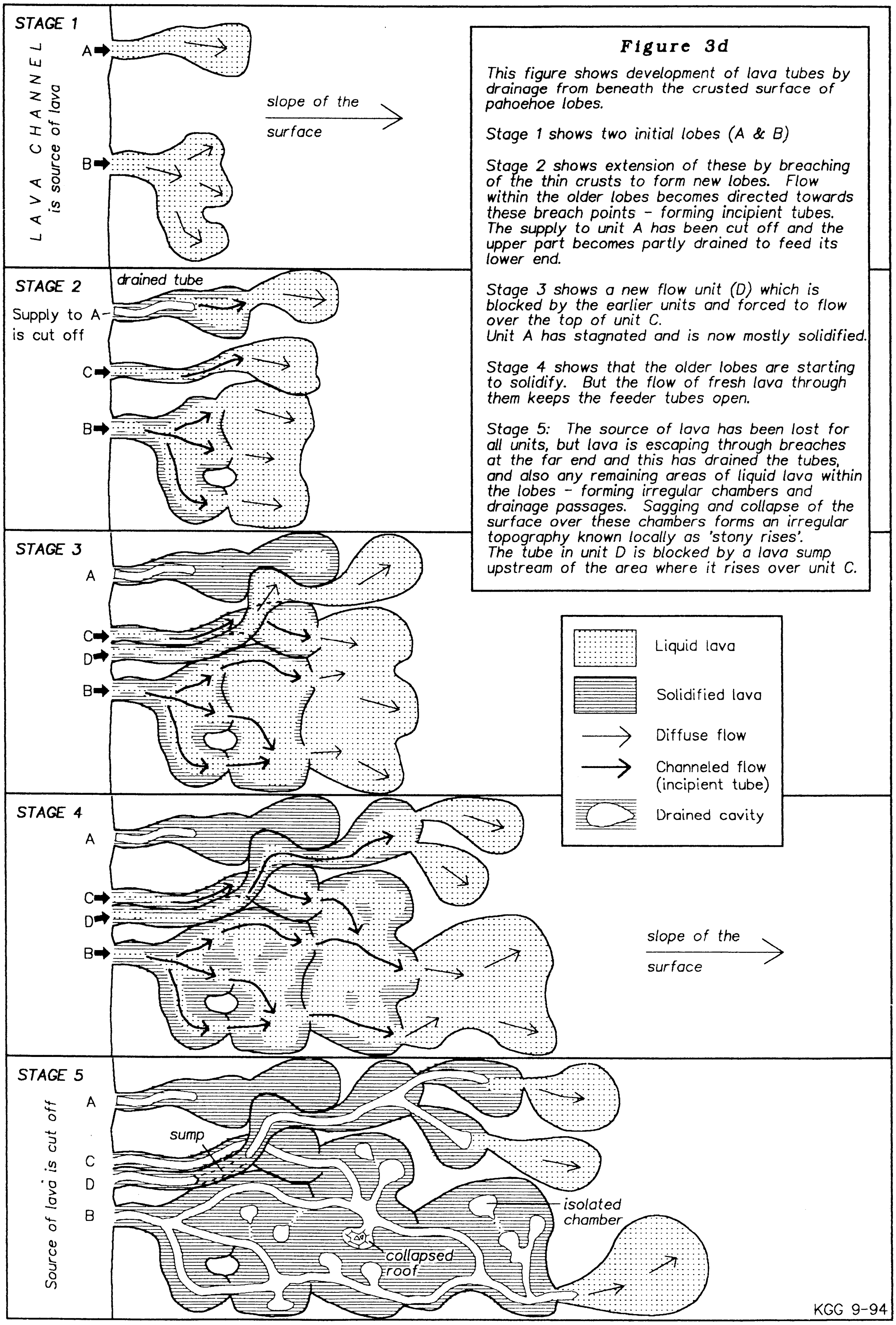


Figure 3d

This figure shows development of lava tubes by drainage from beneath the crusted surface of pahoehoe lobes.

Stage 1 shows two initial lobes (A & B)

Stage 2 shows extension of these by breaching of the thin crusts to form new lobes. Flow within the older lobes becomes directed towards these breach points - forming incipient tubes. The supply to unit A has been cut off and the upper part becomes partly drained to feed its lower end.

Stage 3 shows a new flow unit (D) which is blocked by the earlier units and forced to flow over the top of unit C.
Unit A has stagnated and is now mostly solidified.

Stage 4 shows that the older lobes are starting to solidify. But the flow of fresh lava through them keeps the feeder tubes open.

Stage 5: The source of lava has been lost for all units, but lava is escaping through breaches at the far end and this has drained the tubes, and also any remaining areas of liquid lava within the lobes - forming irregular chambers and drainage passages. Sagging and collapse of the surface over these chambers forms an irregular topography known locally as 'stony rises'.
The tube in unit D is blocked by a lava sump upstream of the area where it rises over unit C.

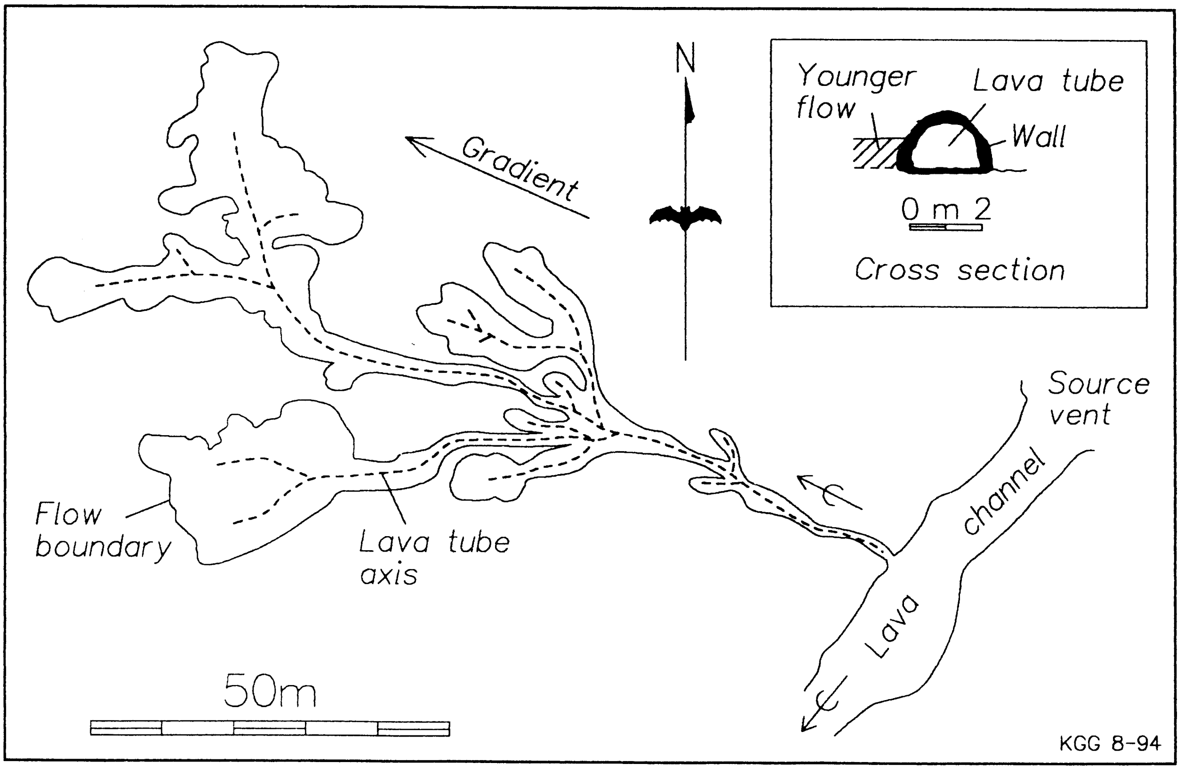


Figure 4: Example of a distributary system of small lava tubes feeding pahoehoe lobes. From near Bend, Oregon. (After Greeley, 1987)

Bibliography

ATKINSON, F.A., 1988: Vulcanospeleology - extraterrestrial applications and the controversy: Mode of formation of lava tubes. *Proc. 17th Conf. Aust. Speleo. Fedn.*, pp 57-63.

GREELEY, R. 1987: The role of lava tubes in Hawaiian volcanoes. *US Geol. Surv. Prof. Paper* 1350, pp 1589-1602.

GRIMES, K.G., 1994: The volcanic caves of western Victoria. *Australian Caver* 136: pp 9-14.

GRIMES, K.G., in press: Volcanoes and lava fields of western Victoria. IN: BADDELEY, G., (Ed.) 1995 *Vulcon Guidebook.* Vict. Speleo. Assoc. Inc. Melbourne. pp 25-38.

GRIMES, K.G., & WATSON, A., in press: Volcanic caves of western Victoria. IN: BADDELEY, G., (Ed.) 1995 *Vulcon Guidebook.* Vict. Speleo. Assoc. Inc. Melbourne. pp 39-68

JOYCE, E.B., 1976: Lava channels and associated caves in Victoria, Australia. *Proc. Int. Symposium on Vulcanospeleology and its extraterrestrial Applications.* Seattle, U.S.A. pp 51-57.

JOYCE, E.B., 1980: Layered Lava, lava channels and the origin of lava caves. *Proc. 13th Aust. Speleo. Fedn Conf.*, Melbourne, published 1987, pp 40-48.

MANSFIELD, A., 1990: Caving at Mt Eccles and Byaduk lava caves. *Nargun* 23(10): p 86

OLLIER, C.D., & BROWN, M.C., 1965: Lava caves of Victoria. *Bull. Vulcanology* 28: pp 215-229.

WEBB, J.A., JOYCE, E.B., & STEVENS, N.C., 1982: Lava caves of Australia. *Proc. Third Int. Symposium on Vulcanospeleology*, Oregon, USA. pp 74-85.

WOOD, C., 1977: The origin and morphological diversity of lava tube caves. *Proc. 7th Int. Speleol. Congress*, Sheffield, England. pp 440-444.

Karst in recent dunes, Codrington, Victoria

Samantha Berryman

Department of Geography, University of Melbourne

Susan White

**School of Australian & International Studies,
Deakin University, Rusden, Clayton**

Introduction

Aeolian calcarenite is formed when calcareous fine sand size particles are mobilised by wind action and deposited as dunes, when then undergo diagenesis and lithification. We have examined the formation of karst features in aeolian calcarenite dune limestone at Codrington and the relative base level positions in the landscape of surface and subsurface features. By examining the spatial relationships between the karst features and the dunes it can be determined whether or not terrain in the study area has been influenced by solutional processes. The swamps between the dunes are primary dune swales which show evidence of solutional modification, eg. notches and cliffs. The lithified dunes contain caves which show solutional features at the same levels as the notches and the base of the swamps.

The Codrington karst landscape

The area is situated on farming land used for cattle grazing at Codrington, south-west Victoria. Codrington is approximately 30 km from Port Fairy and approximately 35 km from Portland. The study area is 3 km^2, approximately 1 km inland and the strandline dune ridges represent a former coastline. Within the study area there are three distinct calcarenite dunes. These dunes have been identified as Dune A, B and C for convenience of discussion. Swamps are present in the interdune swales between the dunes, and the Eumeralla River flows through the study area. The area studied does not cover the entire outcrop of aeolian calcarenite dune ridges in Codrington which extend for at least 20 to 30 km along the coast. The dunes in the study area were assumed to be representative of those found throughout Codrington and nearby areas. The area was chosen due to its accessibility, minimal previous study, numerous karst features in a relatively small area and because it complements similar studies of karst on the calcareous dunes in south-west Victoria.

The aeolian calcarenite limestone dune ridges at Codrington are mainly composed of calcareous sand which was derived from the calcareous Tertiary sediments of the Port Campbell limestone. These sediments were mobilised and redeposited in strandline dunes during the higher sea levels of the Pleistocene. As the sea retreated from the region during the Pleistocene the exposed sand fragments were carried by the wind and deposited as dunes.

This series of dune limestone ridges has been described as the Bridgewater Group (Orth, 1988). The preservation of the dune ridges was due to rapid 'case-hardening' of the calcareous sands by calcrete development. Calcrete development began when the sand became stabilised by vegetation (von der Borsch et al., 1980; White, 1984, 1989, 1994; Grimes, 1992).

Syngenetic caves and karst features are predominant in these partly consolidated Bridgewater Group calcarenite dunes. The karst features were developed as the sands were being cemented into limestone (Kenley, 1988; Grimes, 1992; White, 1984, 1989, 1994). The Bridgewater Group calcareous dune ridges at Codrington contain an interesting series of caves and karst features and the dunes are separated by interdune swales which are presently swamp hollows (Bonwick, 1858; Kenley, 1988). The large swamps in the interdune flats are most likely to be the remains of primary coastal lagoons and swamp features (Grimes, 1992).

Caves of the study area

The existence of caves in the dunes at Codrington have been known for over 100 years. Bonwick (1858, p.88) mentions seeing caves in the district in 1857, ie. "several rises of limestone appear amidst the swamps of Eumeralla, and contain interesting caves". Systematic exploration and documentation of the caves by VSA was not started until 1990.

The location of the caves in the study area is dependent on the drainage direction in the area, ie. north to south. The caves are generally down drainage, especially where swamp water has increased the aggressivity of groundwater. The caves were formed at the top of the water table by solution in conditions of mixing corrosion and evidence of solution by slow moving water can be found in rock pendants protruding from cave walls near the ceiling in CD-13. These pendants were of varying dimensions smoothed by solutional activity but evidence of dynamic phreatic water was absent in the caves studied. Evidence of past vadose flows was present in mud deposits on the extensive collapse rockfalls in the cave passages, eg. CD-13. Lateral solution at or near the water table along lines of weaknesses in the rock, eg. cross bedding planes resulted in roof collapse. However, the caprock has enabled caves to have some structural support and therefore entire collapse of the caves has not occurred.

Cave passages are sinuous rather than straight in plan, eg. CD-13 (Figure 1). The shape of the passage is dependent on the dune bedding planes in conjunction with the geometry of the water table. Collapsed roofs show cross bedding influences, eg. CD-4. The cave passages are flat with only slightly arched roofs and a few domed chambers and consist of a caprock with weaker material below. The cave passage cross sections were generally either low in height and wide horizontally, or were as wide as they were high in the domed chambers (Figure 2). Passage shape is often modified by collapse. Passages can be increased in size by collapse, eg. in CD-13 collapse has resulted in a large domed chamber approximately 15 m high and 20 m wide. In other cases, eg. CD-4, passages are blocked by extensive collapse material. The extended profile of CD-28 shows clearly the flat cave passage and the low horizontal roof with minimal collapsed domes. The domes in CD-28 were very small (1.5 m high) in comparison to CD-4 and CD-13 (6 - 8 m high). The extended cave profiles of CD-4 and CD-13 were similar, ie. both cave passages comprise of high dome chamber ceilings and low horizontal ceilings.

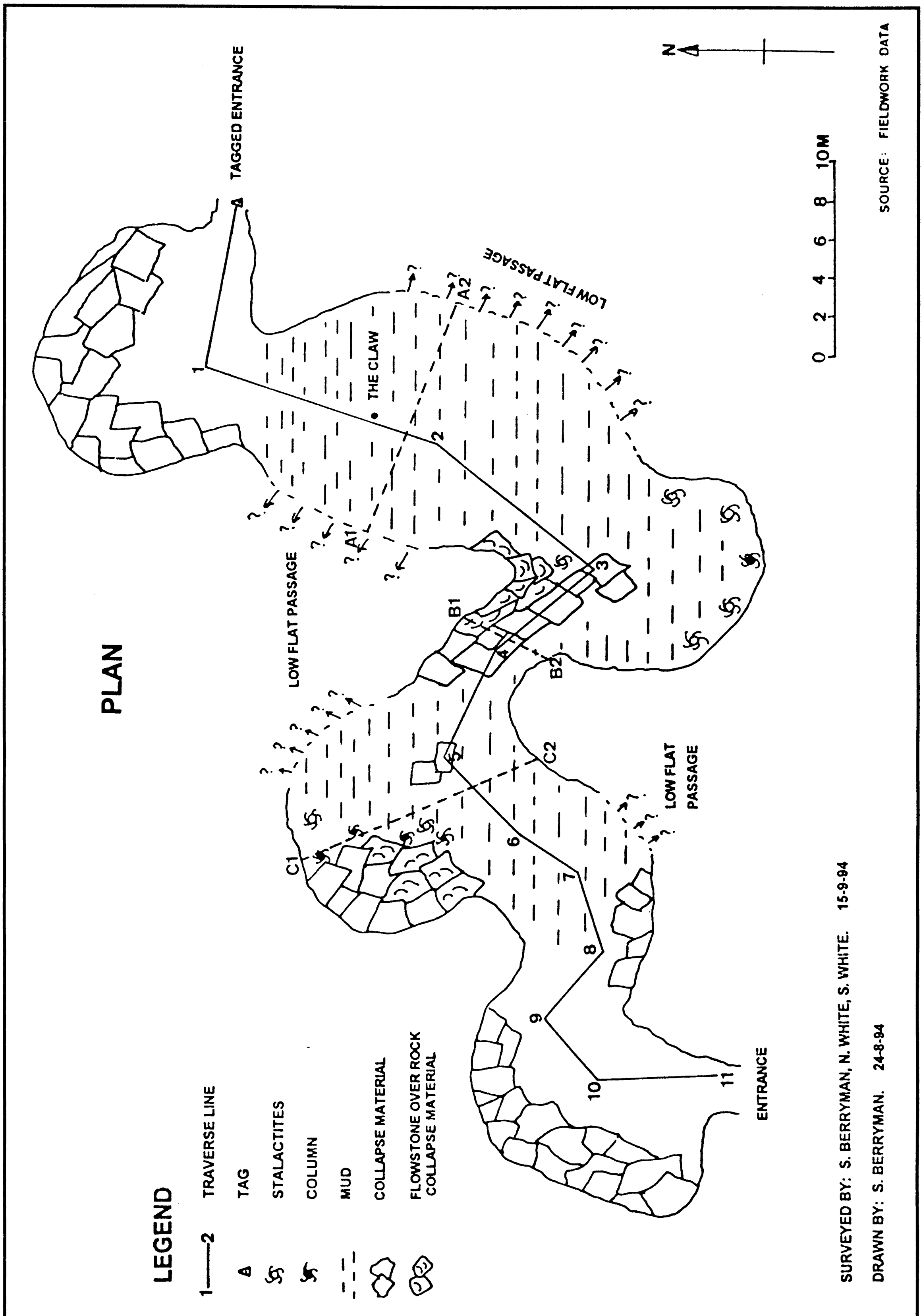


Figure 1: Plan map of Claw Cave (CD-13)

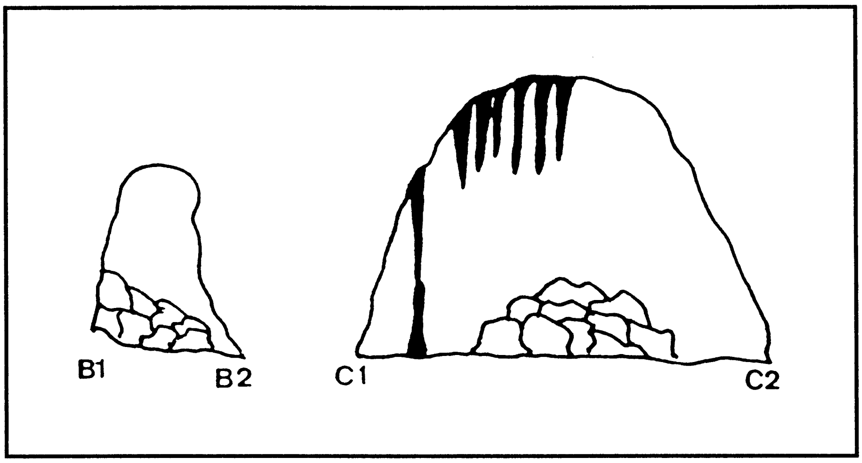


Figure 2: Cross sections of Claw Cave (CD-13) illustrating collapse

All of the caves studied had multiple entrances. The tagged cave entrance to CD-13 is an example of a modified smooth sided solution pipe. The pipe has been modified by some collapse and there is debris funnelling at the entrance composed primarily of soil. The other entrance to CD-13 and the multiple cave entrances to CD-4 and CD-28 have formed through roof collapse.

Diagenesis of Calcarenite

Changes in the mineralogy, geochemistry, texture and fabric of a sediment after deposition are known as diagenesis (McLaren, 1993). Diagenesis of the host rock plays a very important role in the development of karst features, eg. caprock.

Before diagenesis occurs the unlithified calcareous sediments in the dunes are free-draining in the vadose zone. A supply of water rapidly moving through this vadose zone results in water concentrating at points of grain contact allowing meniscus cements to precipitate (McLaren, 1993). Any water between the grains is held within the pores by capillary forces. As the pores become smaller and less well connected in the course of diagenesis, the capacity for more water to remain longer within the primary pores is likely to increase. In most cases, porosity decreases over time with carbonate diagenesis until it is finally occluded, or remains stable at low levels (Gardner & McLaren, 1993). In the initial stages of diagenesis meniscus cements develop. In the next stage magnesium is lost from high-Mg calcites before the dissolution of aragonite. As a result of the re-precipitation of the dissolved aragonite, pore-filling cement occurs. Pore-filling is when cement fills the small pores and spaces within the calcareous sediments. The identification of these separate stages suggests that local variability is low (Gardner & McLaren, 1993).

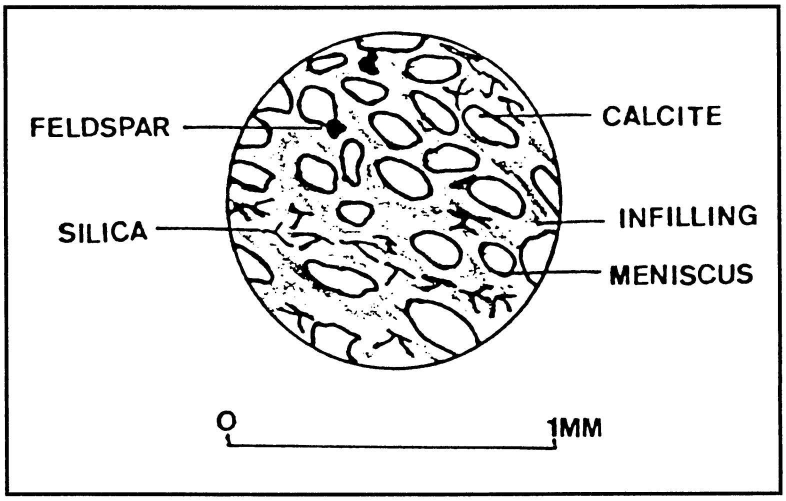


Figure 3: CD-5 Thin Section

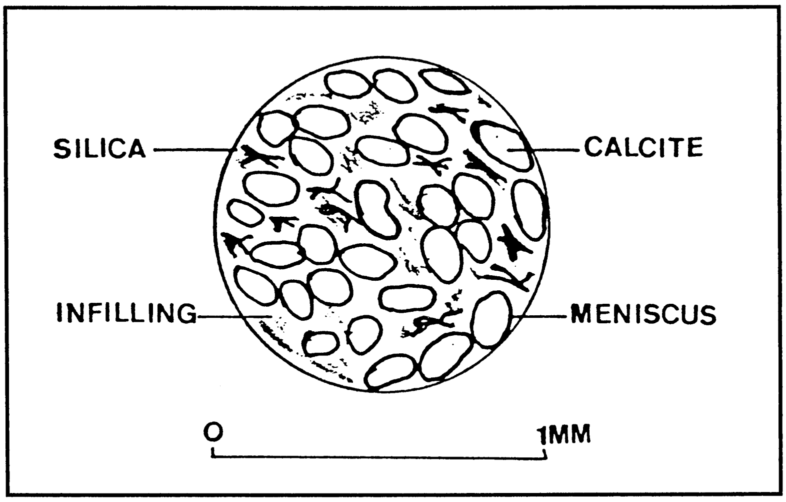


Figure 4: CD-13 Thin Section

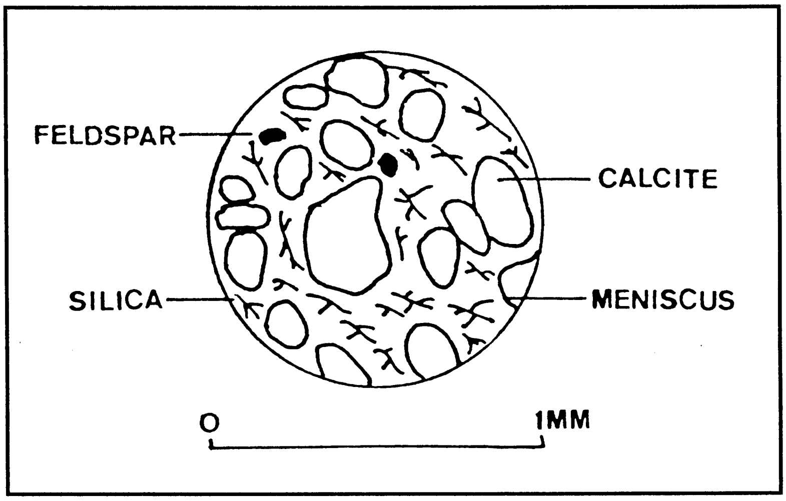


Figure 5: CD-28 Thin Section

Hand specimens of the Bridgewater Group rock were taken from the caprock at CD-5, CD-13 and CD-28 cave entrances. Of the thin sections studied, the rocks showed low diagenetic development, ie. pore-filling cement was low and restricted to the finer-grained laminations, eg. CD-5. The thin section of CD-5 showed that meniscus cement surrounded some of the grains in the sample however the grains were well cemented with abundant pore-filling cement. Small-rounded calcite and silica grains were easily identified under the microscope and a few fragments of feldspar. There were more calcite grains than silica grains (Figure 3). The thin section of CD-13 was very similar to that of CD-5 however pore-filling was less abundant and meniscus cement was the main cement. The rounded grains of calcite and silica were slightly larger than CD-5 (Figure 4). The thin section of the rock sample taken at CD-28 showed that the rock was comprised of large rounded calcite and silica grains with a predominantly meniscus cement at grain contacts. This thin section displayed a lot more silica than the other two samples. Minor fragments of feldspar were also present in the thin section (Figure 5).

The silica compositions and grain size in the thin sections of CD-5 and CD-13 were less than that of CD-28. These characteristics are related to deposition conditions; perhaps Dune C was deposited at a different time to Dunes A and B and is of a different age, however more research is required to determine this.

The analyses shows that there is evidence of diagenesis still occurring in the calcareous dunes at Codrington. The first stage of diagenesis, the meniscus cement formation, was clearly seen in all of the thin sections. The pore-filling cement seen in the CD-5 sample illustrates the beginning of the second stage of diagenesis. This evidence indicates diagenesis is occurring at the same time as cave formation.

Spatial relationships of karst landforms and dunes

The spatial relationships between the dunes, notches, Eumeralla River, swamp water, swamp base levels and cave base levels in the study area have been influenced by solutional processes (Figure 6).

The notches located at the dune/swamp interface are associated with the episodic high swamp levels. The notches are prominent at the southern end of the swamps where swamps drain towards and into the dunes. The cave base level near one of the multiple entrances to CD-4 (tagged with a screw) correlates to that of the base of a notch on Dune A. This relationship indicates that the cave floor and notch probably formed at the same water table height.

The water table level under areas of higher relief is normally higher than under low relief areas. Figure 6 shows that the water table height under the dunes is higher than under the swamps. CD-4 and CD-13 cave base levels exist above the present water table level in the dunes. However CD-28 base level is at the same height as the present wet winter water table level. The Eumeralla River water level is the local base level for the area and correlates to the depths of the water table measured under the swamps.

The caves are only located in the dunes, they do not extend under the swamps. The swamp material has insufficient strength to form the roof beam required for cave passages. The caves appear to be confined to parts of the dunes, especially on Dunes A and B (Figure 6). The caves are generally on the northern side of the dunes in close proximity to the swamps. Only a few caves are known to exist on the south side of the dunes. This spatial pattern of the caves indicates that cave formation is dependant on the drainage of the water table through the swamps which is a southerly direction towards the sea.

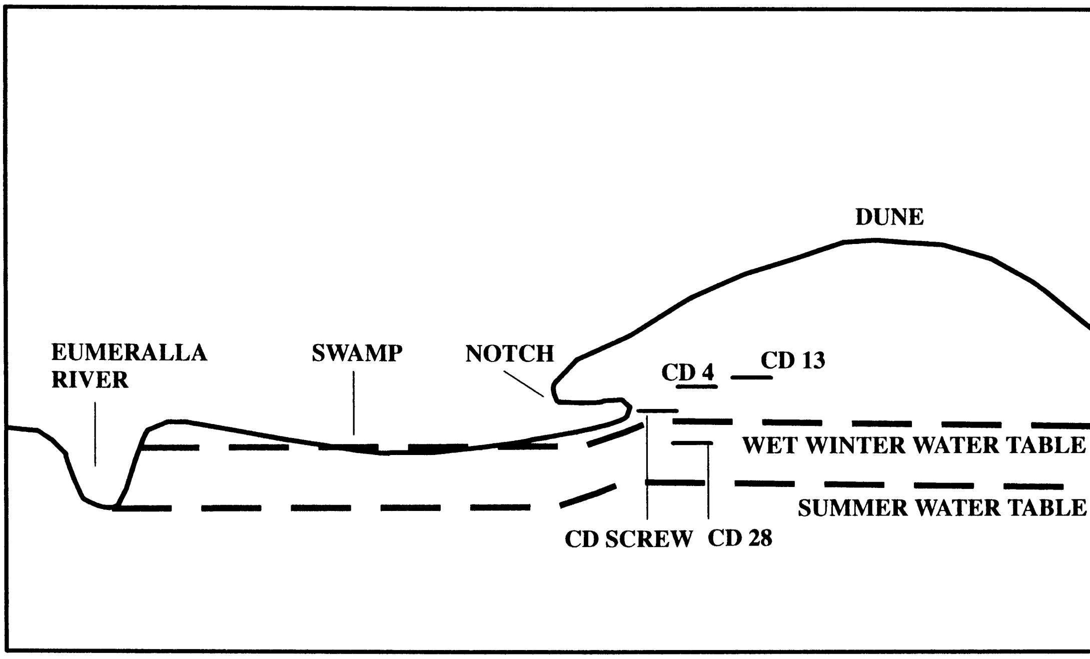


Figure 6: Schematic representation of Spatial Relationships

Speleogenesis at Codrington

Although no absolute dating has occurred at Codrington it is known that the calcareous dunes at Bats Ridge, Portland (White, 1984) and Warrnambool (B. Oysten, pers. comm.) date from the Mid to Late Pleistocene. Therefore it can be assumed that the calcareous dunes at Codrington would be of a similar age. The dunes are geologically young and insufficient time has lapsed for diagenesis of the dunes to occur first, then subsequent development of karst features.

Speleogenesis in aeolian calcarenite dunes occurs concurrently with diagenesis. Evidence of this process is the limestone dune bedrock thin sections displaying only the first stage of diagenesis completed. Therefore the dunes at Codrington contain syngenetic karst.

Syngenetic karst may also be recognised by its characteristic features due to the variable degrees of consolidation and lithification of aeolian calcarenite, eg. linear caves and collapse dolines. These characteristic features were observed at Codrington. The caves have formed where there is lateral solution at the water table resulting in the linear cave system. Collapse dolines have resulted due to weaknesses in cave roofs.

The notches in the study area appear to have formed when water table levels were slightly higher and the swamps had high water levels. Figure 6 shows notch levels to be near and/or at the same level as cave base levels in the dunes. This relationship indicates that the notches have probably formed at the same time as the caves and supports the argument that syngenetic karst processes are occurring at Codrington.

Conclusions

This study, whilst describing the karst landforms and their geomorphic evolution, raised many unanswered questions which could be answered if a more detailed study were carried out. In particular, the question of 'what is the time involved for karst development?' remains unanswered. As noted previously, if it is assumed the dunes at Codrington represent the same sequence as those at Warrnambool, it can only be assumed that the karst landforms at Codrington are younger than 400,000 years old.

These assumptions form the major limitations of this thesis, and if proved wrong would have a major impact on the conclusions reached. To eliminate these assumptions a major integrated study of the entire aeolian calcarenite dune ridges at Codrington and nearby areas would be necessary.

Evidence that the karst landforms have developed simultaneously with the lithification of the dunes is found in the cementation of the dunes. Only the first of the four stages involved in dune limestone diagenesis is strongly evident in the area, although evidence of the start of the second phase is present. This shows clearly that syngenetic karst processes are operational at Codrington.

The area shows strong similarities to other areas of karst in aeolian calcarenite in southern Australia, in particular Bats Ridge near Portland. Although there are some differences (Bats Ridge is further inland, is basically uncleared Eucalyptus woodland and is on a ridge of higher altitude above sea level), the relationships to the swamps, the linear horizontal cave systems, and the prominence of collapse features are similar. Codrington is another area which adds to our knowledge of karst processes in dune limestone.

References

Bonwick, J. (1858). *Western Victoria. Its Geography, Geology and social condition.* William Heinemann, Australia Pty. Ltd., Facsimile edition 1970.

Gardner, R.A.M. and McLaren, S.J. (1993). Progressive vadose diagnosis in Late Quaternary Aeolianite deposits? IN: Pye, K. (Ed). The dynamics and Environmental context of Aeolian sedimentary systems. Spec. Pub. Geol. Soc. London 72 : 219-234.

Grimes, K. (1992). The southeast Karst province of South Austalia. IN: Gillieson, D. (Ed). Geology, Climate, Hydrology and Karst formation : field symposium in Australia, Guidebook. Spec. Pub. 4, Department of Geography and Oceanography, University College, Australian Defence Force Academy, Canberra, Australia. 25-63.

Kenley, P.R. (1988). Otway Basin, western part, Mesozoic. IN: Douglas, J.G. and Ferguson, J.A., *Geology of Victoria,* 2nd Ed., Victn. Divn. Geol. Soc. Aust. Inc., Melbourne. 217-222

McLaren, S.J. (1993). Use of cement types in the palaeoenvironment interpretation of coastal aeolianite sequences . IN: Pye, K. (Ed.). The Dynamics and Environmental Context of Aeolian Sedimentary systems. Spec. Pub. Geol. Soc. London 72 : 235-244.

Orth, K. (1988). Geology of the Warrnambool 1:50,000 Map. *Geological Survey Report* 86 : 50-80.

von der Borch, C.C., Bada, J.L., and Schwebel, D.L. (1980). Amino acid racemization dating of Late Quaternary strandline events of the coastal plain sequence near Robe, southeastern South Australia. *Trans. Roy. Soc. S.A.* 104(6) : 157-170.

White, S. (1984). Karst landforms and their relationship to Pleistocene dune ridges, Bats Ridge, Portland, Victoria. Unpubl. M.Sc. Thesis, Department of Geograpghy, University of Melbourne.

White, S. (1989). Karst features in Pleistocene dunes, Bats Ridge, western Victoria. *Helictite* 27(2) : 53-71.

White, S. (1994). Speleogenesis in aeolian calcarenite : A case study in western Victoria. *Environmental Geology* 23 : 248-255.

Management of Parks and Reserves in far South West Victoria

Peter Novotny, Brett Beecham and Bruce Allen

National Parks Service,
Department of Conservation and Natural Resources, Portland

This paper provides some information on parks and reserve management in far south west Victoria which will be of interest to members of the Australian Speleological Association and those with an interest in the area's caves and karst features.

Mt Eccles National Park and Mt Napier State Park Proposed New Works

These parks contain a range of volcanic features that are of world and national significance, including volcanic caves, cones, craters and eruption points. We consider them the most accessible and extensive lava caves in Australia.

Our aim is to protect these features by encouraging responsible recreational caving in accordance with accepted caving ethics.

A management plan has been prepared in recent years with the assistance of a local advisory body which included representation from the Australian Speleological Association. The management plan is a public document published by the Department of Conservation and Natural Resources and is available for sale from local offices and the Department's bookshop in Victoria Parade, East Melbourne.

One of the many management strategies relevant to caves is to develop the Byaduk Caves within Mt Napier State Park. The proposed development is currently in the design stage and includes the provision of established walking paths, safe access into Harman One Cave for members of the general public and the installation of interpretation information on the area's many natural values. It is hoped that such developments will stimulate greater public appreciation of lava caves and their many other volcanic features in these parks. In addition, by providing this quality access to selected sites capable of withstanding visitor pressure, the National Parks Service aims at minimising adverse pressure on other sites that contain important natural features including rare plant species.

Managing recreational impacts on threatened flora in cave and karst areas: Two case studies

When we think of the negative aspects of people visiting cave environments we usually consider the impacts that visitors have underground. However, visitors can also have a substantial impact on the environment surrounding a cave. The following two case studies will hopefully illustrate that cave and karst areas can be managed successfully for both recreational activities and the conservation of threatened plants.

Limestone Spider-orchid, Bats Ridges Wildlife Reserve

Bats Ridges Wildlife Reserve has an area of approximately 320 hectares and lies 10 kilometres west of Portland. Some of the caves are well visited by both locals and organised parties from outside the area. The reserve is also home to several rare or threatened plant species. The Limestone Spider-orchid (Caladenia calcicola) is perhaps the most significant of these.

The Limestone Spider-orchid (Caladenia calcicola) was only recognised and described as a distinct species in 1986 (Carr, 1986) and is regarded as vulnerable in Victoria. It is endemic to south-western Victoria, and grows in open shrubland on limestone ridges (Beecham & Fisher, 1992). The largest known population for this species occurs in Bats Ridges Wildlife Reserve in close proximity to one of the more frequently visited caves. Uncontrolled visitor access has damaged some of the orchid's habitat through the creation of an informal car-parking area and a well worn track leading to the cave. Whilst intensive monitoring of the species only commenced in 1993 it is apparent that some damage to individual plants close to the car-park and walking track is occurring (B. Beecham, unpubl. data). As this is habitat critical to the survival of this species it was decided to re-route and formalise access to the cave to minimise further degradation and protect the area.

A number of actions are proposed to implement the habitat protection objectives. These will involve:

- Turning the existing vehicle track leading to the car-parking area into access for walkers and management vehicles only.
- Creating a new walking track to provide access to the cave away from important areas.
- Placement of signs to alert visitors to the new walking track.
- Blocking-off the old car-park and walking track to allow revegetation and regeneration to progress. Some brush matting and signposting may also be required.

Once this work is completed future monitoring should reveal an increase in the numbers of the Limestone Spider-orchid as individuals re-establish in the regenerating areas.

Lime Fern, Lower Glenelg National Park

Lower Glenelg N.P. lies in a large karst province covering parts of south west Victoria and south eastern South Australia. Numerous caves occur within the park and 61 are considered significant.

In Australia the Lime Fern (Pneumatopteris pennigera) is found close to water in limestone areas (in New Zealand it is not restricted to limestone and is widespread). In Victoria the fern is known only from a few populations in the Lower Glenelg National Park and the Otways region.

In 1988, the Draft Management Plan for Lower Glenelg National Park was released for public comment. One of the recommendations made was that Davey and White (1986) classification of Curran's Creek cave as an 'adventure cave' not be adopted due to the presence of the Lime Fern near the cave's entrance. Subsequent monitoring of the fern populations in the vicinity revealed that an unknown pathogen was seriously damaging one of the populations, leading to dieback of the fronds and possible death if defoliation continued.

To ensure that the unidentified pathogen was not unknowingly spread to other healthy populations by visitors of park staff a quarantine zone was established to restrict access to the site, including the Curran's Creek cave. Implementation of the quarantine area was achieved by:

- Inspecting the site with representatives from the Australian Speleological Association and DC&NR to discuss the issues and informing them of the restrictions.
- Placement of signs and production of pamphlets informing visitors of the restricted area.
- Erecting barriers and the revegetating key access points to discourage visitors from entering the quarantine area.

Recent monitoring revealed an increase in the numbers and health of ferns in the affected population, and the pathogen did not appear to have spread to other sites. It has taken several years to identify the pathogen responsible for the fern dieback but it appears that at least two species of fungus were responsible (Cropper, 1993). More recently a species of thrip has also been implicated in causing frond dieback. At this stage quarantine is still in effect and monitoring of the Lime Fern is continuing.

During the disease outbreak spores were collected from nearby healthy populations and propagated at the Royal Botanic Gardens in Melbourne. This was done to ensure that if the Lime fern was eliminated from the area there would be a chance to re-introduce it. This has proved unnecessary and the 140 plant successfully grown have recently been returned to the Lower Glenelg National Park and re-established at several sites, including Curran's Creek.

There are numerous plants and vegetation communities that are only found in association with limestone areas. Thus there may sometimes be a potential for conflict between recreational access to a cave or karst area and the need to protect the surrounding environment. Hopefully the above examples show that with careful management both recreation and conservation can be accommodated.

The Rewiring of Princess Margaret Rose Cave

In January 1993, Bruce Allen took over as ranger in charge of the P.M.R. Cave, moving over from the park headquarters at Nelson. With his background in cave management from South Australia where he managed Kelly Hill Caves on Kangaroo Island, and the Naracoorte Caves, he could see the need for various improvements and upgrading of facilities.

The lighting system in the P.M.R. Cave had been in operation for around 20 years. It was a 32 volt system running off a bank of batteries which were constantly charged by a load regulated charger. The cabling was all exposed running along the cave walls about 3 metres up, and its entire length. The cables and fittings were all about at the end of their life span and the system was very restrictive in that it only just had enough power to take one group of people at a time into the cave and with large groups, two guides had to be used, one at each end of the group to operate the switches. A main priority was identified to rewire the cave.

Towards the end of the 1993 financial year there was some uncommitted money available, enabling the purchase of one hundred 12 volt lights and transformers and fittings. This was about $11,500 plus $7,500 for cable, conduit and fittings. A further budget was made available for '94-'95 year and in July Bruce Allen started on a design plan for the new system whenever time could be found in before tours of a morning.

A couple of large 12 volt tractor batteries, heaps of old lighting cable and several of the new lights were used, and with the help of two guides, three categories of light were set up:

- Path lights for going in section by section.
- Two way switched scene lights to point out features rather than using a torch.
- Exit path and feature lights, two way switched at either end of the cave.

In hindsight it would have been better to have closed the cave for two or three days, rather than run out and pack up cables and lights numerous times.

Preparation of the cave in readiness for the new system was undertaken by upgrading the pathways, taking out some of the rises, widening and cutting and digging cable trenches in the floor of the cave and down the wall of the stairway into it.

The electricians that wired the Naracoorte and Tantanoola caves were chosen because of the expertise they had developed, this proved to be very valuable and save considerable time and hence money. The cave was closed on 1st September 1993 and the Thursday, Friday, Saturday and Sunday were used to open up the trenches and install a polythene water line through the cave. On the Monday the three electricians arrived and commenced the wiring, while this was going on the transformer and switch enclosures were recessed into the cave walls. The system was running by Friday and over the weekend most of the lights were fitted and grooves cut into the walls for the cables to each one. The next five days were used to remove the old cable and lights and to back fill the trenches and grooves after the S.E.C. inspection on the Wednesday and the cave was reopened on the Saturday, 16th September 1993.

The work was undertaken by the chief guide for sixteen long days, the cave's maintenance worker, the cave's two casual guides, two maintenance workers from Nelson Work Centre for the last three days to carry in about forty bags of premixed concrete and concrete over the mains cables under the floor, and three electricians for 6 days. All this was done for a total cost of $40,000. The tourist cave now has updated wiring.

References

Beecham, B. and Fisher, J.T. (1992). Action Statement No. 23. Limestone Caladenia Caladenia calcicola. Department of Conservation & Environment, Melbourne.

Carr, G.W. (1986). Caladenia calcicola (orchidaceae), a new species from Victoria, Australia. *Muelleria* 6:185

Cropper, S.C. (1993). *Management of Endangered Plants.* CSIRO, Melbourne.

Davey, A.G. and White, S. (1986). *Victorian Caves and Karst: Strategies for Management and Catalogue.* Applied Natural Resource Management, Canberra.

Research on the Camel Cricket *NOVOTETTIX naracoortensis* (Richards) (ORTHOPTERA : RHAPHIDOPDORIDAE) in the Naracoorte Karst System

Ron Simms and Ruth Lawrence

1. Introduction

The cave crickets located in the Naracoorte caves were first identified by Aola M. Richards, from specimens collected from Haystall Cave (5U-23), Corner Fence Cave (5U-24) and Smoke Cave (5U-42) by P. Atkins in 1962. In 1966, Richards classified and raised the Genus and Species for the cave cricket as follows:

Order	*Orthoptera*
Family	*Rhaphidophoridae*
Genus	*Novotettix*
Species	*naracoortensis*

As well as classifying *N. naracoortensis*, Richards (1966) made a number of observations relating to the Naracoorte cave crickets:

1. That "Alexandra Cave contains a colony of over 1500 *N. naracoortensis*, in contrast to the rather sparsely populated caves in south-eastern Australia".

2. That about two thirds of the insects were located on the walls 30 metres inside the entrance, and the remainder extended another 20 metres or more into the cave.

3. That the temperatures of Alexandra Cave and Victoria (Fossil) Caves were around 63° F (17° C) and that those caves were the warmest habitat so far recorded in Australasia.

4. That no crickets were found in those caves which were bat habitats and vice versa.

Other locations in Australia where members of the Rhaphidophorids are found include New South Wales, Victoria, Flinders Island in Bass Strait, Tasmania and the Nullarbor Plains in south-eastern Western Australia.

Rhaphidophorids are found world wide in New Zealand, South Africa, southern Europe, North and South America.

2. Study Area

This study was primarily undertaken to:

(a) Record the caves supporting populations of *N. naracoortensis*,

(b) Analyse cave cricket population variations,

(c) Record the seasonal population variations,

(d) Determine what effects human intrusion into the caves have on the cricket population.

Although some problems in the study areas were foreseen, many were not. Sorting through the many variables, classifying and prioritising them as they occurred, caused many delays.

3. Methodology of this Study

This paper is a report of the results of a survey conducted with the assistance of members of the South Australian caving organizations. The data was collected by many different people, but each observer was equipped with a standard recording sheet and information as to the definition and characteristics of a nymph, juvenile, male and female (Table 1).

Table 1: Simplified Guide for the Identification of Cave Crickets (*NOVOTETTIX naracoortensis*) when undertaking a Cave Census

Type	Body Length (mm)	Characteristics
Eggs	L <= 1.5	Will not be seen under normal circummstances as they are buried in small holes in the cave roof.
Nymph	L < 4	Newly hatched nymphs can be difficult to see; antennae fine and long and can exceed body length, identical to adults shape without showing sexual characteristics.
Juvenile	4 > L < 9	Abdomen filling out; hind legs larger than nymph's; antennae longer; sexual characteristics develop with each shedding of exoskeleton; possible six or seven stages of development (instars); last stages an be difficult to differentiate from adults.
Male	L > 9	Two small projections (cerci) from base of abdomen; hind legs long and spindly; antennae approximately five times the body length.
Female	L > 9	Long spur (ovipositor) projecting from base of abdomen; hind legs are shorter and thicker than the male's; antennae approximately five time the body length.

These characteristics were developed as a quick easy guide for a large number of inexperienced and unskilled people assisting in the study. It eliminated the need for teaching a complex list of taxonomical reference criteria.

A summary of the data, recording populations of *N. naracoortensis* collected from the caves visited is listed in Table 2. The data on cave cricket distribution, numbers and characteristics has been collected over a period of ten years. A total of 48 caves site were visited, 41 examined and 36 contained specimens of *N. naracoortensis*.

Table 2: Summary of Data from Caves with *N. naracoortensis*. (Mean Values)
41 Caves Entered, 36 Recorded Crickets

Cave Number	Cave Name	No. of Visits	No. of Nymph	No. of Juvenile	No. of Male	No. of Female	Total
U-1	Victoria Fossil	8	2.6	6.1	5.1	4.1	18.0
U-2	Bat	3	1.3	4.0	2.0	2.8	10.0
U-6	Blanche	3	0.0	0.0	2.3	1.3	3.7
U-7	Appledore	30	44.3	67.5	18.1	14.3	143.8
U-9	Blackberry	18	33.6	66.8	20.1	14.3	134.8
U-11	Stick	27	21.3	29.8	21.3	15.0	87.9
U-13	Cathedral	1	0.0	0.0	0.0	1.0	1.0
U-14	Brown Snake	2	0.0	0.0	0.5	1.0	1.5
U-15	Beekeepers	1	8.0	12.0	7.0	4.0	31.0
U-17	Robertson	6	0.0	0.8	3.8	1.3	6.0
U-22	Fox	4	6.5	13.3	12.3	9.0	41.0
U-24	Corner Fence	3	0.0	91.0	17.3	20.3	128.7
U-26	V.D.C.	3	0.0	30.3	12.0	8.0	50.3
U-31	Hoods	1	24.0	10.0	4.0	2.0	40.0
U-35	Specimen	7	0.0	0.0	0.1	0.1	0.3
U-38	Joanna Bat # 1	2	11.5	4.0	6.0	4.0	25.5
U-39	Joanna Bat # 2	2	13.0	7.5	27.5	20.0	68.0
U-42	Smoke	2	4.5	296.0	72.0	95.0	420.0
U-44	Little Victoria	16	25.6	38.8	19.3	10.6	94.2
U-46	Joanna Bat South	2	6.0	0.5	3.0	3.5	13.0
U-47	S 102	7	10.0	20.6	6.6	3.4	40.6
U-48	Anderite	6	6.8	16.8	25.0	15.7	63.3
U-50	Not Named	1	10.0	54.0	4.0	5.0	73.0
U-51	Not Named	1	16.0	33.0	22.0	20.0	91.0
U-58	Wombat	8	0.0	0.0	0.0	0.0	0.0
U-62	Saddle	1	0.0	86.0	69.0	28.0	183.0
U-63	Mosquito Creek	2	0.0	0.0	1.0	3.0	4.0
U-66	Rabbit	1	0.0	3.0	4.0	1.0	8.0
U-71	Not Named	1	0.0	6.0	4.0	2.0	12.0
U-81	Possum # 1	1	0.0	0.0	0.0	0.0	0.0
U-82	Possum # 2	1	0.0	0.0	0.0	0.0	0.0
U-89	Peppertree	1	0.0	0.0	0.0	0.0	0.0
U-90	Alexandra	9	8.2	8.9	13.1	10.6	40.7
U-98	Little Cathedral	1	0.0	0.0	0.0	0.0	0.0
U-102	Not Named	1	0.0	10.0	28.0	3.0	41.0
U-106	Stink Pot	2	287.0	188.0	22.5	14.5	512.0
U-108	Locks	2	9.0	8.5	18.5	8.0	44.0
U-125	Cable	13	107.8	187.3	57.3	30.4	338.9
U-127	Not Named	1	3.0	15.0	7.0	5.0	30.0

4. Behaviour and Morphology

The curved body shape of Rhaphidophorids gives the crickets the international common name of 'Camel' cricket. The body length varies between nine and eighteen millimetres with the female being longer. The dimensions of the rear femur and tubular also show sexual differences with the males having longer and slightly thinner legs than the female.

The female's ovipositor was not measured. The female's ovipositor has a long sturdy character and is as long or longer than the abdomen. Usually the ovipositor is a rusty colour which could indicate maturity or fecundity stage. Both the male and female's antennae are thin and long, reaching approximately four to five times the length of the body. A more taxonomical description of *N. naracoortensis* can be found in Richards (1966).

All Rhaphidorid crickets have well developed compound eyes. Communication within the human hearing range has not been noted although sounds have been detected within the ultra-sonic range attributed to cave crickets. By what means they produce and receive this form of sound has yet to be determined. Other crickets can produce sounds ranging from 15 to 32 kHz and 15 to 93 kHz, with grass hoppers from 13 to 75 kHz.

Although actual copulation between the male and female hasn't been observed, the cave crickets have been observed in the 'court-ship' behaviour and the position prior to copulation. The procedure of mating following the observed behaviour by Hubbell (1978) in Mammoth Cave in Kentucky, U.S.A.

Although the act of egg laying has not been positively identified, the females have been observed with their ovipositor inserted into the roof and upper walls apparently depositing their eggs in the small hole and cavities. Rhaphidophids overseas have been recorded depositing their eggs in the silt or mud on the cave floor and it may be due to the lack of suitable material on the Naracoorte cave floors that *N. naracoortensis* have utilized the roof area. Because of the omnivorous feeding habits of the crickets, probably only a single egg is deposited in each hole. The period of incubation is still unknown.

When hatched, nymphs are replicates of the adult form, without the sexual dimorphisms which appear about the fourth and fifth instar stages. They are difficult to locate as they hide and blend into the roof strata.

Caves which are located in areas with the surface dominated by exotic flora have either no cave crickets or only a very small number. For caves located in the Pinus radiata forests, there have been no observed cave cricket population in those caves.

Whereas *N. naracoortensis* are largely inactive during the daylight hours, they become active approximately one hour prior to sunset. Greatest activity occurring just after sunset when majority decend to the cave floor or exit the cave searching for food. The remainder of the night is alternated between rest and active periods with the crickets returning to the upper cave areas prior to dawn.

5. Observations on Feeding Habits

What the food preferences are outside has not been recorded. Due to the tenuous supply of food within the cave system, the cave crickets are feeders of opportunity, utilising a large range of food. This includes fresh and decaying vegetation, fungi, spores, moulds, faeces, dead vertebrate animals, and many forms of invertebrates - either dead or alive, including their own species.

The crickets have also been observed feeding on the carcasses of possums, snakes, frogs and other indescribable items. Adult *N. naracoortensis* have also been seen eating juvenile crickets. After shedding their exoskeleton during moulting the cricket consumes it while their new integument is hardening.

Numerous individuals have been observed with a leg missing, especially the hind leg. An observation in April 1994, recorded a male *N. naracoortensis* consuming its own rear legs (Simms, in press).

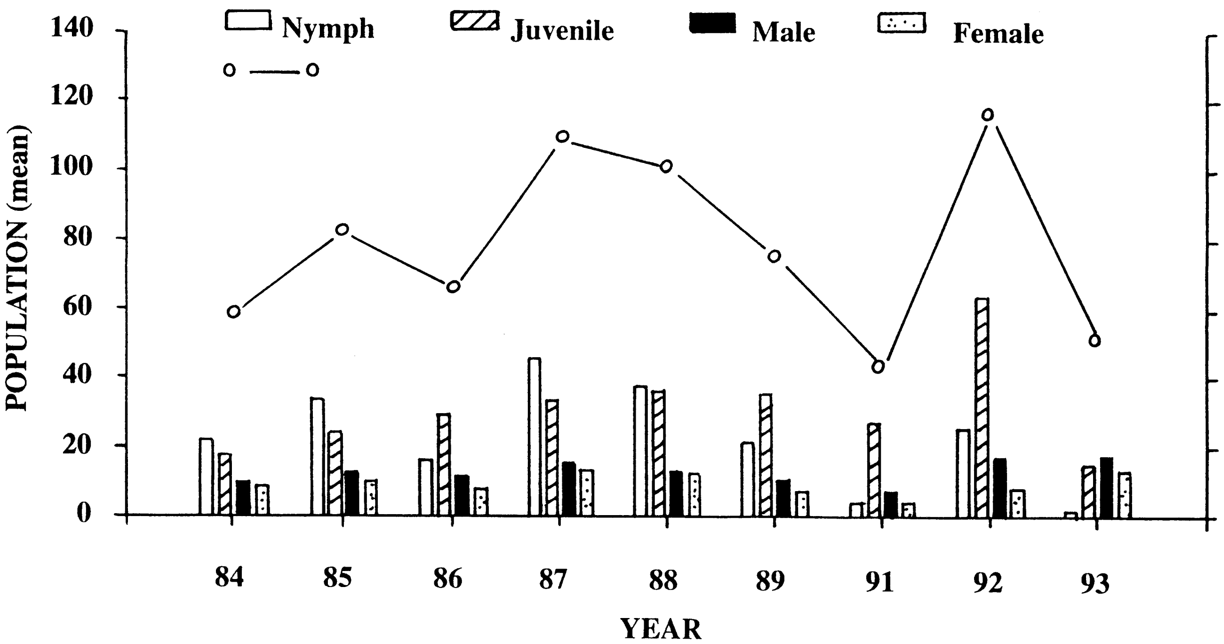
Feed lines have been used to determine if the cave crickets have preferable foods and would utilise food not usually associated with the cave environment. This experiment was conducted several times using different caves with no more than four food types being used at any given time. Food made available to the crickets included dry and moist rolled oats, milk soaked rolled oats, peanut paste, tomato, over-ripe banana, celery, lettuce, apple, bread, vegemite, sardines, cooked and fresh meat. It was found that the cave crickets generally ignored the tomato, celery, dry rolled oats, fresh meat and vegemite. The food was first detected by the antenna which would sweep the air sampling the odours present. On locating the food, the antenna would sweep over the food, possibly sampling the odours before selected food for consumption. The observations indicate that *N. naracoortensis* are primarily opportunist, omnivorous scavengers, consuming a wide range of food types.

6. Geographic Extent of Habitat and Population Relation

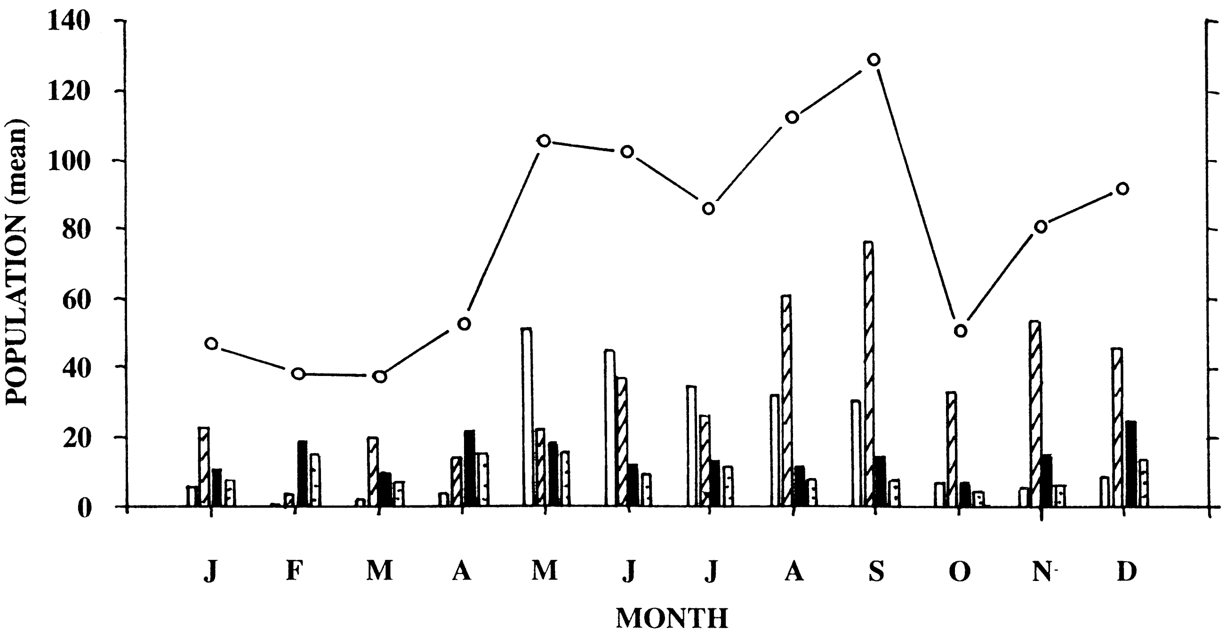
The research was confined to the Naracoorte Karst area which ranges from fifteen kilometres north of Naracoorte to twenty five kilometres south. It is evident that in the distribution of caves in which the crickets appear, no part of the Naracoorte Karst area would not be suitable as a habitat for *N. naracoortensis*. The controlling factor being the surface usage and vegetation. Caves located in fertilised pastures have low or no cricket populations. Also caves found within the pine forests haven't recorded any crickets (native insects are extremely rare in pine forests). Some caves with native vegetation surrounding the entrances have also recorded low or no cricket populations. The reason for this is unknown.

Table 3: Naracoorte Cave Cricket Research

Annual Mean for Years 1984 - 1993



Monthly Mean - All Caves 1984 - 1993



7. Seasonal Trends in Population Numbers

From the data collected, it is apparent that there is a seasonal population variation within the year. The lowest population numbers occur during February - March, peaking in August - September. Nymphs appear in large numbers at the end of April peaking during May. The juveniles numbers peak during August and September.

The adults show no dramatic fluctuation in population although peaks have been recorded in February, April and December, with low periods in January, March and October. The low recording in October is not dependable because of the low number of observations recorded for that month. The low number of observations in February may render that month's data unreliable. The adults appear to peak twice within the year; in April and December.

It is acknowledged that the number of *N. naracoortensis* observed would be below the actual numbers present, due to the inaccessible recesses, cracks and holes in which they rest.

The survival ratio of nymph/juveniles into adults is typical to that of most other insects with the over-all mean of 41% achieving the adult stage. For the 1984-89 period the ratio are 39.6% and the 1991-93 period 42.3%.

8. Trends in Population over time

The data collected on the N. naracoortens is population in the Naracoorte area allows for an analysis of trends in the numbers over the nine year period for some popular and well frequented caves.

There is an annual trend in the population with the nymph's major hatching occurring in April/May with the juvenile crickets maturing during the September/October period. The adult population appears reasonably stable for most of the year, with an increase in December followed by a decline during January/March.

A periodic peak and low population pattern has emerged over the study period. The cause has not yet been identified, but periodic aerial spraying of chemical on the adjacent pastures by the local property owners could have a contributing factor.

A natural decline in one cave has been noted due to a massive increase in lublinite appearing on the cave walls. Cave entrances with a predominance of lublinite have not recorded populations of the cave crickets.

9. Impact of Visitor Numbers on Populations Numbers

As indicated earlier, *N. naracoortensis* are sensitive to disturbance by humans. This is evident in the statistics when the caves are classified according to land tenure (National Parks or Private), and development for tourist/caver usage or restricted access.

Using six classifications for cave usage, an interesting pattern developed which shows a relationship for caves with high human usage and low cricket populations, against caves with low or nil human usage and high cricket populations. The caves with high tourist usage have small cricket populations while the caves located within natural native vegetation with restricted access recorded the highest population numbers.

When the total numbers of *N. naracoortensis* observed for all caves with each category are correlated, the implication of human impact on the cricket populations appears as a major factor.

The classifications are:

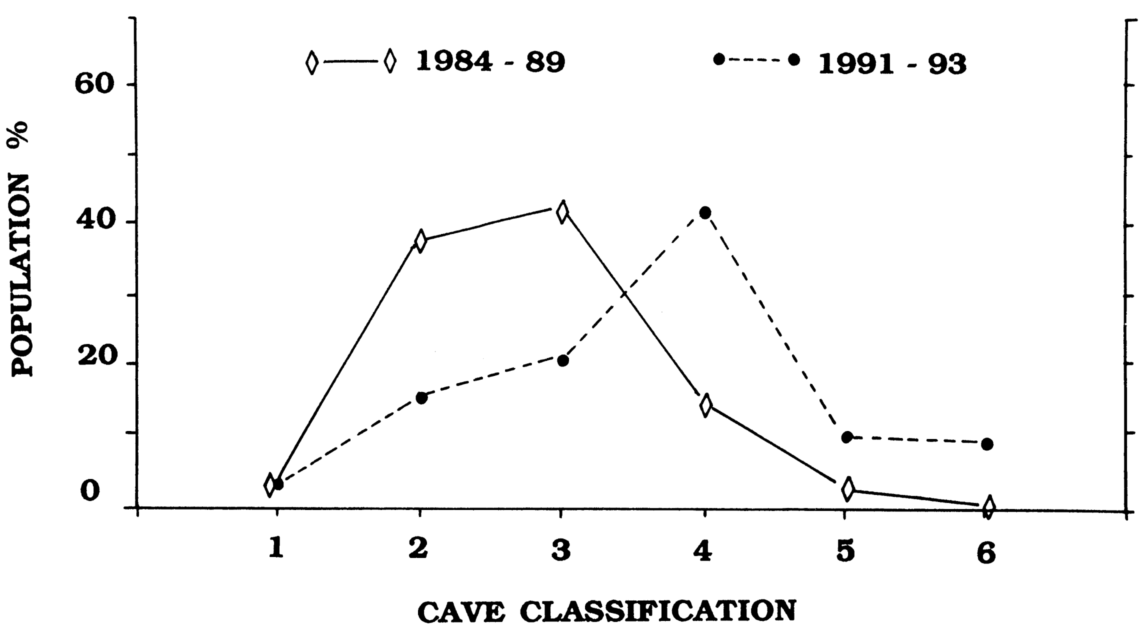
N.G.T. National Parks Guided Tours
N.W.T. National Parks Wild Guided Tours
N.W.U. National Parks Wild Unrestricted Access
N.W.R. National Parks Wild Restricted Access
P.W.U. Private Wild Unrestricted Access
P.W.R. Private Restricted Access

Cave cricket populations rated with cave classification range from the lowest number to the highest in the following order, as used by Table 4:

1. N.G.T. National Parks Guided Tours
2. N.W.T. National Parks Wild Guided Tours
3. P.W.U. Private Wild Unrestricted Access
4. N.W.U. National Parks Wild Unrestricted Access
5. P.W.R. Private Restricted Access
6. N.W.R. National Parks Wild Restricted Access

The impact caused by the number of people using the caves are not the only factor affecting the cave cricket populations, other factors include tourist facility improvements, washing and cleaning the formations, inflow of detritus material, other living cavernous forms, rainfall, humidity, temperature, usage of the surrounding surface, aerial pasture spraying, predators etc.

Table 4: Cave Usage Annual Variance, Cave Classification VS Cricket Population



Conclusion

In conclusion, it is apparent that *N. naracoortensis* has a wide distridution within the Naracoorte Karst system. Their population densities depends on a stable environment, being vulnerable to:

(a) Current pasture usage,

(b) Human interference to the biology of the caves,

(c) Volume and frequency of human visitation to an induvidual cave,

(d) Geolomorhpology within the cave entrance area..

The pattern of behavour shown by the camel crickets and the effects of human influences have on their environment mirrors in many ways what is happening world wide.

The balance for their survival in large numbers in Naracoorte and possibly for all cave crickets in Australia, appears for them to be able to access undisturbed caves located within natural vegetation.

References

Complete details were not available at the time of going to press.

Richards, 1966:

Hubbell, 1978:

Simms, in press:

Multi-Level Maze Cave Development in the Northern Territory

Peter Bannink, Guy Bannink, Karen Magraith and Bruce Swain

Introduction

In 1991 the Top End Speleological Society discovered a three dimensional maze cave (BAA38) at Limestone Gorge, Northern Territory. This cave is unique in the region in its extent and developmental complexity. The cave has been extensively explored, and surveyed in detail, but this is still far from complete. In this paper features of the cave system are described. Based on analysis of survey data and observations made over the course of many field trips, some concepts regarding the development of the cave are presented and discussed. It is anticipated that as more of the cave is explored and surveyed, these concepts will be further developed and modified.

Limestone Gorge is located 60 km south of Timber Creek in Gregory National Park, Northern Territory. Limestone Gorge is situated on the Victoria River Plateau and is developed within the Skull Creek Formation which is composed of blocky crystalline dolomite with minor interbeds of siltstone (Sweet 1973). The formation is 220 metres thick with a bedding plane which locally dips South East 2°. Limestone Creek and the East Baines River have cut directly through the formation, revealing the lithological sequence.

The topography is characterised by rounded stepped hills formed from the Upper Skull Creek Formation. The most prominent layer in this formation is the Supplejack Member, which has been measured at a thickness of 18 m, and lies approximately 135 m above the base of the Skull Creek Formation. The Supplejack Member is thick and relatively uniform in composition, and it is more resistant to weathering. Typical tropical karst topography has developed on exposed sections of Supplejack Member, with examples of rillenkarren, trittkarren and kamenitza. The Lower Skull Creek Formation forms a series of thick beds below this (Sweet et.al. 1971).

Exploration of the caves has revealed a more detailed lithology of the Lower Skull Creek Formation. The upper boundary is a layer of dolomitic mudstone 0.5 m thick. Beneath lies a 2 m layer of shale followed by another layer of mudstone 0.5 m thick. A 10 m thick layer of dolomite, 2 m of shale and two more sequences of dolomite (2.4 and 7.2 m) are evident at the limit of exploration (Figure 1).

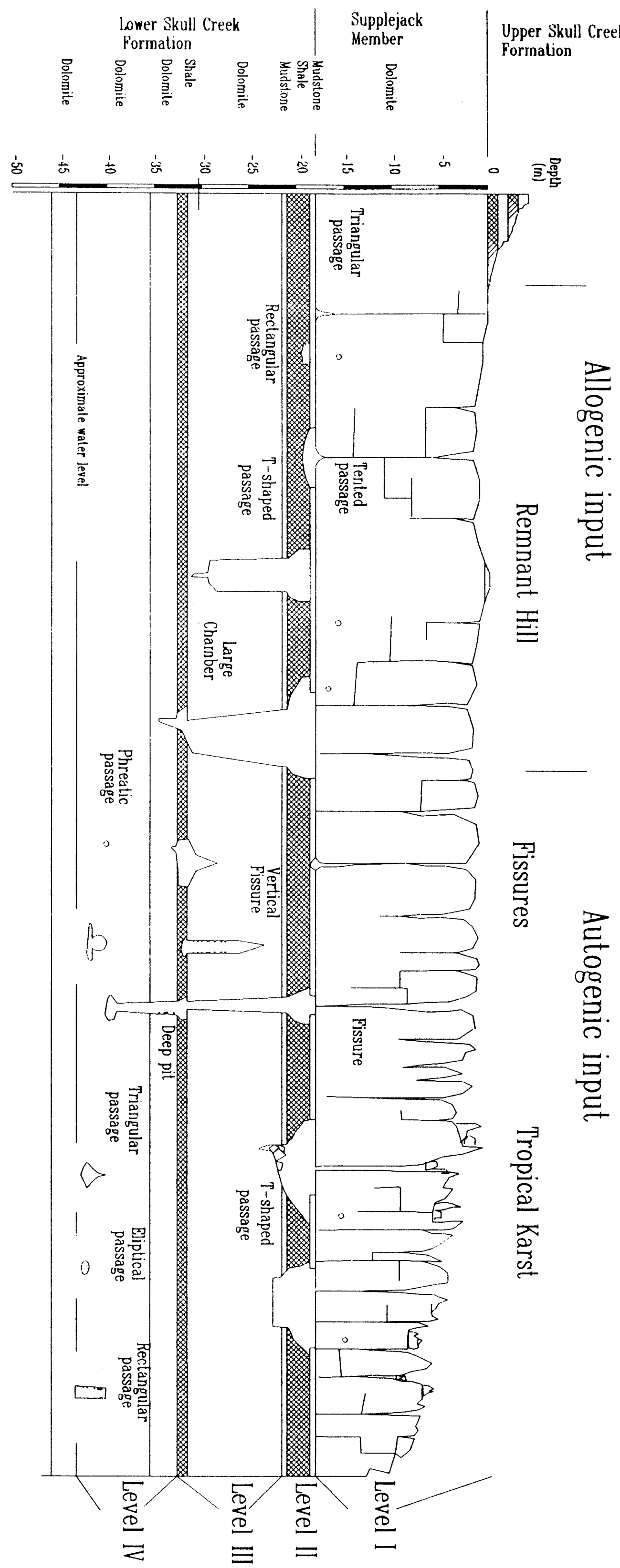


Figure 1: Schematic diagram illustrating passage shapes and their relationship to the lithology

Passage Morphology

The cave is developed within a major peninsular of karst. The southern section of the outcrop has the greatest relief, and passages have developed on four levels over a depth of approximately 47 m. The majority of passages are formed within the Lower Skull Creek Formation and jointing occurs predominantly at 220°. This region of the cave has been used to explain the developmental sequence of the system. Four levels of cave passage have been identified; each level is characteristic of the lithological unit in which it is predominantly formed:

- Level I Phreatic and vadose development within the Supplejack Member.
- Level II Vadose development just below the Supplejack Member.
- Level III Joint controlled vadose passages in the Lower Skull Creek Formation.
- Level IV Phreatic and vadose stream way at the lowest level.

Level I

Passages with phreatic characteristics occur near the base of the Supplejack Member and meander for 2 - 10 m. The origin and development of these passages is unclear. Vadose passages at this level are controlled by joints developing within the Supplejack Member exclusively. These narrow linear fissures develop into a distinctive triangular form as a result of lateral corrosion at the base of the joint. Passages in this level control and concentrate autogenic water to the cave below.

Level II

Erosion of the mudstone floor of the level I passage allows entrenchment into the shale layer below. Dominant lateral erosion increases the width of the passage within the shale interface. Two types of passage can be distinguished. Those which have developed from the level I, **tented passages**, and those which have are developed only within the shale interface, creating **rectangular passages**. The latter have a characteristic flat roof, and they are not influenced by the joints of the level above. Both types of passage ultimately cut deeper into the Lower Skull Creek Formation creating joint controlled vadose streamways. This creates distinctive **T shaped passages**, which increase in depth and basal width through mechanical erosion and breakdown.

Level III

Vadose passages cut deeper into the Lower Skull Creek Formation, and create a lower level following a different jointing pattern localised to level III. **Deep vertical fissures** (6 - 10 m), **meandering streamways** and **canyons** are frequently encounted. Extensive collapse of the lower dolomite passages give rise to **large chambers**. Where there is an intersection of major joints deep pits 14 - 23 m descend through the length of the Lower Skull Creek Formation to level IV.

Level IV

This level is the deepest and most constricted region of the cave. The passages vary from **triangular** or **rectangular** to **elliptical** in shape. The passages are generally joint controlled, except in a few areas where it appears that recent phreatic passages have developed in regions where old passage has been blocked by collapse. Many are partially filled with gravel and fossil breccia. The sediment depth in these passages has not been determined. Sediments also suggest active flooding and flowing water in the wet season.

Hydrology

The region has a monsoonal climate with a short intense rainy season (December - March) and a long dry season. Slopewash off the Upper Skull Creek Formation conducts allogenic recharge into focal inputs at the junction of the Upper Skull Creek Formation and Supplejack Member. Diffuse recharge is also added by autogenic water falling directly onto the exposed Supplejack Member. The existence of mudstone and siltstone layers form aquitards, making the sequence less permeable and more directly controlled by the lithology (Ford & Williams 1992, Palmer 1984).

The mudstone layer at the base of the Supplejack Member causes water to lateralised along jointed passages, developing level I into a two dimensional maze. At points where this aquitard is breached, recharge is focused into the shale layer beneath, and the process of lateralisation is repeated in level II. Autogenic water usually falls directly into the levels below as both layers of mudstone have been eroded. As each subsequent level develops there is convergence of the water into fewer, more constricted passages below ultimately causing flooding in level IV. All the water moving through level IV passage flows towards the only known point of discharge in the cave. The convergent drainage system appears to direct all water towards the efflux. The volume of allogenic and autogenic recharge entering the whole outcrop (±1.5 km^2), appears inconsistent with the small size of the level IV drainage system and the efflux. This suggests that an extensive amount of new passage remains undiscovered.

1 km of passage has been mapped at level IV in the southern region of the outcrop. Water reaches this level by vadose canyons, deep pits and fissures as described above. Many of the junctions have branches which have breccia on walls and floor, suggesting recent passage development in older passages filled with fossiliferous clastic sediments. Exploration of level IV has also revealed four water-filled sumps indicating the presence of a perched or deeper and permanent watertable. The presence of Stygobiont amphipods suggests that there could be a connection to a larger permanent body of water.

Development

The topography of the Upper Skull Creek Formation is distinguished by low hills and valleys. This provides a variety of fronts along which the Supplejack Member becomes exposed. The Upper Skull Creek Formation converges allogenic recharge into valleys and depressions where premature erosion of the Supplejack Member occurs. Cave formation appears to begin at the intersection of the Upper Skull Creek Formation and the Supplejack Member, where many adjacent but isolated caves develop as small networks of various sizes in level I.

Occasionally these are connected to each other via one or two small passages. Continuing development results in erosion of the aquitard. When the aquitard is penetrated there is a drop in the piezometric surface and development continues into level II. In addition, erosion of the lower mudstone aquitard causes recharge to be concentrated into the deeper levels. As the Upper Skull Creek Formation is sequentially eroded, the points of allogenic recharge are redistributed. The rearrangement of recharge points and the development of deeper passages from former ones represent sequential phase development (Ford & Williams 1992).

Surface karst erosion is related to the length of time the karst has been exposed. Thus the oldest points of recharge correlate with the most eroded regions in the outcrop and are now represented by collapsed valleys and dolines. These areas are thought to be associated with the initial phases of development in the outcrop. The most recent phases are represented by level I passage developing at the newly exposed regions of the outcrop as well as the deepest passages forming along the hydrological gradient towards the edge of the outcrop.

Where allogenic recharge has entered the outcrop, phase development predominates, but once the caprock has been removed completely, the Supplejack Member is exposed to autogenic (or diffuse) recharge, and maze development is initiated. Diffuse recharge is supplied uniformly to all joints within the caverniferous zone, so that each fissure experiences comparable rates of solution, creating an angular grid of interconnecting passages of similar size (Palmer 1975).

A network maze develops upon the existing phase system, creating high narrow passages along the major joints (fissures) in the Supplejack Member. Isolated caves are commonly joined together through the enlargement of these fissures. Deeper passages are thus influenced by both allogenic and autogenic recharge. This results in a complex network of passages whose origin is a combination of both phase and maze development. Maze development has its greatest influence on levels I and II, whereas deeper levels are largely the result of phase development. Attributing the origin of any particular area in the cave to one of these types of development is difficult because both act simultaneously and continuously at all regions of the outcrop.

In addition to phase and maze development, there is evidence that clastic sediments also influence the development of the cave. In areas with high relief, superficial sediments appear to be rapidly moved into the cave where the aquitard is penetrated close to the recharge points. Sediment loads accumulate in the lowest passage and effect development in these levels. In areas of low relief, clastic sediments slow the penetration of the aquitard close to the recharge points. The sediment load becomes confined to level I. Arched passages are formed through lateral erosion of fissures in Supplejack Member. These sediments also enhance the lateralisation process within the level II aquitard, promoting lateral erosion in the shale layer by diverting streamways to characteristically undercut the Supplejack Member, create wider passages and chambers.

Discussion

The cave is an example of an ideal water table cave as described by Ford and Ewers (1978). Close to the outcrop where the caprock is being stripped away fissure frequency is low and the piezometric surface is intact. Passage is initially under the influence of phreatic development and controlled by the aquitards on three levels. As fissure frequency increases, a drawdown vadose system develops to the lowered piezometric surface. Allogenic water entering the Supplejack Member attacks all the layers vertically and simultaneously until it reaches the depth of the water table, below level IV.

The influences of topography, slope and sediment load on the hydrological controls of the cave appear to account for many of the karst features which can be observed in this case. These factors also explain why this cave has developed differently to other maze caves in the region as outlined by Smith & Storm (1991) and Dunkley (1993). If the slope is small and the sediment load high, passage formed through allogenic inputs lateralise above the aquitard maintaining development within the Supplejack Member (Palmer 1984).

Passages initiated by allogenic recharge then lateralise until they join the rest of the cave. This results in maze cave formation at level I, rather than vertical development to lower levels. Autogenic input then widens the fissures above enhancing entrenchment into the level II aquitard. High sediment load will also fill deeper passage masking any evidence initial phase development. On the other hand, where the relief is high and sediment levels low, as in this example (where the outcrop is a peninsular of karst). The amount of sediment entering the cave from the surrounding caprock is considerably smaller. Phase development is initiated, followed by maze development, resulting in the creation of a three dimensional maze cave.

Acknowledgements

We would like to thank the Conservation Commission of the Northern Territory for their assistance. Special thanks to Keith and Sally Claymore for their support over several years. Thanks also to members of TESS and BESS (Stuart Nicholas and Chris Davies) who contributed considerable time and effort in surveying and exploring this system.

References

Dunkley, J.R. (1993) The Gregory Karst and Caves, Northern Territory, Australia. *Proc. XI th Int. Conf. Speleo.*

Ford, D.C. & Ewers R.O. (1978). The Development of Limestone Caves in the Dimensions of Length and Depth. *Can. J. Earth Sci.* Vol 15, p 1783-1798.

Ford, D.C. & Williams P.W. (1992). *Karst Geomorphology and Hydrology.* Chapman & Hall London, pp 601

Palmer, A.N. (1984). The Geomorphic Interpretation of Karst Features, Chapter 8 IN: *Ground Water as a Geomorphic Agent.* Ed. La fleur R.G. Allen & Unwinn Inc Sydney, p 173-209

Palmer, A.N. (1975). The Origin of Maze Caves. *The NSS Bulletin* Vol 37(2), p 56-76

Storm, R. & Smith D. (1991). The Caves of Gregory National Park, Northern Territory, Australia. *Cave Science* Vol 18(2), p 91-98

Sweet, I.P. et al. (1971). The Geology of the Waterloo, Victoria River Downs, Limbunya and Wave Hill 1:250 000 Sheet Areas, Northern Territory. *Bur. Miner. Resour. Aust. Rec.* 1971/71 (Unpubl.)

Sweet, I.P. (1973). Victoria River Downs, N.T. 1:250 000 Geological Series. *Bur. Miner. Resour. Aust. Explan.* Notes SE/52-4

The Sailor of the Nullarbor - Captain J. Maitland Thomson

Elery Hamilton-Smith

P.O. Box 36, Carlton South, Victoria 3053

Introduction

Captain Maitland Thomson (1902-1986) emerges as one of the more remarkable figures of Australian speleology. His caving not only took place at a time when caves were virtually neglected by others, but he developed his own techniques, adapting or pioneering a range of new ideas.

Not surprisingly, his work is often seen as wanting by current speleologists. All of us have, at one time or another, bemoaned his lack of systematic record-keeping. However, if we properly locate his efforts in the culture of the time, his lack of systematic recording is all too typical. Rather, we should recognise his remarkable pioneering; the extent to which he inspired others, either directly or indirectly; and the fact that at least he summarised his knowledge and published it in the scientific literature - something which all too few cavers do, even today.

The Captain had a very well-developed curiosity about natural phenomena, and his interest in the Nullarbor was first sparked by seeing the Catacombs marked on an Admiralty chart.

The Expeditions

So, when he found himself as Harbour master at Thevenard, it was only natural that he would seek to find the Catacombs and see them for himself. In 1933, along with E.T. Wheare and F.H. Adams, he made his first venture to the Plain. This proved to be merely a reconnaissance, in which he familiarised himself with what would be necessary to explore the caves.

Thus, the first full-scale trip was in 1935, when the Captain had moved to Port Lincoln, and was somewhat different to those which followed. H.G. (Gwyn) Watson, a Ceduna mechanic with a keen interest in photography, joined the party. It was almost certainly he who introduced Thomson to the blow-through magnesium lamp which later became known as the 'Diprotodon' and certainly, Watson's photographs provide a useful documentation of this expedition. He also lent his own equipment, which he had apparently built himself, to Thomson for use on future expeditions.

This expedition party also included Les Dunnett, who accompanied a number of later expeditions. Albert Blumson, also of Ceduna, was present, and was responsible for building the canoes used by Thomson over many years. Others were J. Leath, R.T. Harvey and J.R. Dridan.

But the most striking aspect was that the party included two wives - Mrs. Blumson and Mrs. Watson. One can only speculate as to whether they provided part of the reason for the Captain's almost total rejection of women on future caving trips! Many of the Watson photographs also show that the Simon family, including Roma and Mrs. Simon, then of Eucla Station, also joined in.

By now, Thomson was better prepared as a result of his experience in 1933, and the expedition was equipped with his 80 feet rope ladder and a ten feet canoe. Petrol lamps were used for lighting. Transport involved two cars and a truck, laden with water, petrol, food and equipment.

They visited Weebubbie, Abrakurrie, Chowilla, Koonalda, Koomooloobooka, the 'Graveyard' (now Ivy Cave), the Murrawijinees, and searched without success for the Catacombs. Several press reports of the expedition stated that a recent flood had washed out part of the Chowilla rockfall, and a 250 foot tunnel provided access to a chamber some 300 feet in diameter. This has never been open on any succeeding trip, and so, assuming the reports are accurate, the 1935 party are the only people known to have seen it.

The other remarkable discovery, the potential value of which was unrecognised at the time, was a naked footprint in the Art Gallery at Koonalda. The relationship between that tunnel and the lake below was not realised at the time. Disappointment Cave was also discovered and named on this expedition.

Most of the caves had been previously visited, and one of the discoverers of Weebubbie had actually swum to the end of the lake, but the Captain surveyed the caves and explored the lakes with his canoe. He also appears to be the first to formally report the hand prints in Murrawijinee. So, it was an important expedition in the extent to which it started to develop a more systematic understanding of the Nullarbor caves.

By 1937, Thomson had met pilot Len Diprose, who used to stop regularly at Ceduna to refuel his plane on the Adelaide-Perth flight. Diprose was able to give him adequate directions to find the three small caves which Thomson named after him. The 1937 expedition located the Diprose caves, and again searched unsuccessfully for the Catacombs, although they explored a deep and extensive cave in the Catacombs area.

A new cave was also discovered near Nullarbor homestead, and the major caves explored in 1935 were visited again. The party this time was a much smaller one - Thomson, both Orville & Les Dunnett, Handtke, Langsford and Denton.

Having been fired with enthusiasm for airborne caving, Thomson learned to fly, being taught by Ian McRitchie of the Spencer Gulf Aero Club. The amazing McRitchie ('Pelorus', 1991) then accompanied him to the Nullarbor in 1939, both of them being backed by a ground party led by Ted Harris.

It seems clear that Thomson was the first, anywhere in the world, to use aeroplanes as a means of locating caves, and on this expedition, located and explored a total of 42 previously unknown caves.

The war put a halt to all expeditions, but the 1947 expedition which followed was one of the more successful. The expedition included Ted Harris and Les Dunnett again, together with Eugene Dunnett, K. Foster, Keith and Ron Knowles, F.E. Ellis (Harbours Board surveyor), Don King (Geology Department of University of Adelaide), R. Smith, and David Morris. By this time, the rope ladder was supplemented by a winch and derrick.

Again, Morris's photograph album provides a valuable record of the expedition.

This party discovered five caves, including Knowles Cave, and two blowholes, and succeeded at last in reaching the Catacombs. They also established the relationship between the two major tunnels of Koonalda. Thomson reported that rock had fallen in some caves, although he only specifically identifies Ivy Cave as an example. Perhaps most importantly, this expedition resulted in papers by both Thomson and King (1949) in the *Transactions of the Royal Society of South Australia* and a more popular article by Thomson in *Walkabout* (1947).

In several ways, the 1952 expedition was a landmark. It introduced to the Nullarbor Harry Wheeler, Keith Quartermaine and their colleagues as well as Fred Elliott and others from Geelong College to the Nullarbor. The continuing work by Quartermaine and Wheeler is a remarkable story in itself, leading to the most consistent and comprehensive documentation of Nullarbor Caves yet.

Thomson obviously enjoyed the company of the schoolboys from Geelong College, St. Peters College (Adelaide) and Le Fevre Technical School who constituted he major part of the expedition, and his future journeys generally involved the leadership of school expeditions.

We are particularly fortunate in the documentation of this expedition that Ken Peake-Jones took both colour slides and a movie film of the whole venture. The movie has recently been resurrected by Ken, presented to Max Meth and myself, and Athol Jackson of CEGSA has copied it to videotape.

The expedition was a particularly energetic one, using Keith Quartermaine's Ford Prefect as a 'scout car', in spite of the Captains initial derision at bringing such a small car to the Plain, and visiting a total of 32 caves.

The numbers of people in the party also enabled the Captain to use the technique of lining up expedition members to walk abreast across the Plain seeking new caves, and at least one was discovered as a result. Rock falls were again reported (in both Warbla and the Catacombs).

The Captain never reported the major rock fall which occurred in the left-hand tunnel of Abrakurrie. However, Peake-Jones vividly remembers this happening immediately after the firing of the 'diprotodon' at that site. Evidently the heat from the flare had loosened part of the ceiling sufficiently for it to fall, fortunately just as the party moved away from the site.

Later expeditions were even less adequately documented, and received less media attention. However, it seems that most simply re-visited the sites of the earlier expeditions, usually with large (c. 30) parties of schoolboys.

Women were never welcome, and after the 1935 party, the only woman to ever accompany Thomson to the Nullarbor was his oldest daughter Marlene in 1954. He steadfastly refused to take other members of the family.

It is not at all clear, even to those who knew him, why he was so staunchly opposed to women going caving. It may well have resulted from his enthusiasm for nudism, and an attitude that this was not appropriate in mixed company; but this was clearly coupled with some other objections, probably rooted in ideas about appropriate gender roles. His public explanation was always in terms of lack of privacy, as 'there are no trees on the Nullarbor'.

It is perhaps also appropriate to consider the extent to which he visited caves in other areas. It is clear that these were seen as inferior to the Nullarbor but certainly, the Nullarbor had an attraction which went far beyond the caves. He certainly did visit Punyelroo and Oraparinna Caves, each only on one occasion. I recall him telling me that neither were worth the trouble.

Then I persuaded him to join a group of us in a visit to Corra-Lynn sometime in 1954. He enjoyed the cave, but was annoyed that there was a lady present, and when CEGSA was established, absolutely refused to have anything to do with an organisation that allowed women to go caving.

He lent us his famous 80 ft. ladder for a first visit to the Curramulka Well Cave, and this certainly convinced us that we just had to build our own ladder! Imagine even the task of assembling a ladder from 100 metres of 2.5 cm. Manila rope, with rungs each consisting of an 45 cm. long piece of Jarrah measuring some 8 x 4 cms. The ropes were threaded through holes drilled in each rung, then tied in a thumb knot before threading the next rung. Then one had to lower it into the cave, fix it in position, batter one's shins in order to descend and climb it, haul it out of the cave, and then repeat the assembly process in reverse!

There are still further potential sources of information to pursue, and these may throw more light upon the Captain and his exploration - but what is already available to us allows at least some assessment of his place in Australian speleology.

Review and Assessment

By the end of World War I, cave exploration in Australia had come to a halt. Although there was considerable visiting of caves by bushwalkers and others, none appeared to undertake exploration, and a total lack of interest in any documentation was the norm. The few exceptions were, interestingly, mainly in South Australia, where prospectors searched for guano caves, and where both Tantanoola and Kelly Hill Caves were discovered more or less by accident.

But the Captain demonstrated a concern for genuine exploration which not only represented a new thrust in itself, but he fully recognised the potential importance of the Nullarbor plain, and made it an area of great interest to many people. He was, in a very positive way, out of tune with his time and something of a visionary.

His seaman's capacity for navigation obviously served him well in both finding his way and recording both his routes and major sites. Other adaptions to the Nullarbor environment include his system for driving on a compass course. Once the vehicles were lined up on the right bearing, the driver of the front vehicle would keep a line on the rear vision mirror aligned with a specific marker on the front of the rear vehicle, while the rear vehicle followed precisely in the wheeltracks of the other. Searching either involved the whole party walking in line abreast across the plain, or driving with the Captain standing on the roof of the driver's cabin, and either whistling or thumping his boot on the roof to convey instructions.

The Captain's photography is well known, and showed a remarkable grasp of using the blow-through lamp effectively. He has often been credited with its invention, but as I will show in another paper (1995), this was certainly not so.

But his most remarkable feat in the technology of exploration was the use of aircraft to locate caves. Although cavers take air photographs or even landsat imagery for granted today, it was a remarkably visionary step back in the 1930s. Strangely, and perhaps as an indication of shared imagination, the inventor of the blow-through lamp was also the first man to take aerial photographs (from a hot-air balloon).

In brief, he was a great innovator and adaptor, and able to translate his vision of Nullarbor exploration into effective technology.

He was, by the standards of his day, a remarkably effective communicator. His use of the media and his slide lectures all communicated the great excitement of what he was doing. Similarly, in his paper in the *Transactions of the Royal Society of South Australia*, he was able to explain his understanding of the cave systems, and this was certainly a very analytical paper, again by the standards of the day. It must be remembered that at that time, there was virtually nothing of equivalent quality on any other Australian cave area.

His lack of recording remains a tragedy to present day cavers. Of some 165 caves which he claimed to have visited, only some 20 can be identified and located today. But this was in keeping with his times; of the many who explored cave areas in earlier years, only Trickett kept comprehensive and detailed records. Thomson certainly surveyed both routes and caves, yet none of this work remains today. Similarly, he collected specimens and handed them over to scientists, but virtually none were ever described in the literature, and they cannot be traced in the collections where they were lodged. Even in his popular accounts, details are sometimes blurred or contradictory. For instance, one account of the 1947 expedition reports Knowles Cave as being separate from the great doline which provides its entry.

So, on the negative side, people might say he was sexist, careless about records, sometimes jealous of his 'ownership' of the Nullarbor caves, sometimes exaggerated his achievements, did not suffer idiots gladly - in other words, he shared many of the characteristics of most humans.

But, apart from his personal achievements, perhaps one of his more important legacies is the extent to which he inspired and encouraged others to follow in his tracks. Many of them, in turn, have fired others with a love of the Nullarbor or of caving. Ian Lewis and myself have both written of our own experience in an obituary tribute to the Captain; the work of Keith Quartermaine, Harry Wheeler and their colleagues is now recognised as a remarkable contribution to Nullarbor studies.

Talking with many of those who accompanied him, even if only on one expedition, has shown that all look back on a multitude of ways in which the Captain stimulated them to new ideas and wider understandings. He deserves our great respect.

References

Much of this paper rests upon piecing together bits and pieces from press reports, photograph albums, together with interviews with both Thomson himself and others who have shared in his expeditions. The detail of all these are available, but too complex to list here. However, the following are some of the more accessible:

Hamilton-Smith, E. & Lewis, I., 1987, Farewell Captain J. Maitland Thomson - Some Recollections of a Determined Individual, *Australian Caver*, 113 : 21-22.

Hamilton-Smith, E., 1995, Lighting Australian Caves, IN: Baddeley, G., (ed.) 1995, *Vulcon Precedings, 20th Aust. Spel. Conf.*, Aust. Spel. Fedn., Melbourne.

King, D., 1949, Geological Notes on the Nullarbor cavernous limestone, *Trans. Roy. Soc. S. Aust.*, 73 : 52-58.

'Pelorus', 1991, A wave at Moorabbin to breaching the prison walls at Amiens, *Aircraft,* Oct. 1991 : 22-23, 52.

Thomson, J.M., 1947, Nullarbor Caves, *Walkabout,* 13 (7) : 29-36.

Thomson, J.M., 1949, The Nullarbor caves system, *Trans. Roy. Soc. S. Aust.,* 73 : 48-51.

Lighting Australian Caves

Elery Hamilton-Smith

P.O. Box 36, Carlton South, Victoria 3053

Introduction

Artificial lighting is, of course, absolutely vital to seeing caves except for those species fortunate enough to possess the capacity for echo-location. This paper is an endeavour to bring together details of the Australian experience in cave lighting, and will deal with it in three sections - exploration, public display and photography.

Although there has been considerable misunderstanding amongst cavers of the story of lighting, this paper will try to correct common errors, and to demonstrate that the outstanding feature of the Australian experience is the extent of innovation which took place here.

Exploration

The first people commonly both visited and lived and worked in caves. They used fire or fire sticks to light their way, and the remains of their lighting have therefore appeared as ash in archaeological excavations (Flood 1993). Few burnt sticks have remained, although scattered references to fire sticks being seen in the Nullarbor Caves occur in the *Eucla Recorder* (1898-1900). Similarly, the early Aboriginals do not appear to have knocked ash from their fire sticks by hitting them on the wall and leaving marks as the early people of the Mammoth Cave (U.S.) or of the Pacific islands did.

The first white arrivals also used fire sticks or brush torches. Augustus Earle (1826), in his water-colour which is the first documentation of a visit to the Wellington Caves, gives a graphic depiction of the use of these. Many years later, Broome (1886) was able to describe the technological advance of soaking stringy bark in kerosene! However, candles seem to have been the preferred lighting of many early explorers and are frequently mentioned in their accounts.

Petrol or kerosene lanterns were commonly used during the 1920's and later. Thomson continued to use petrol-fuelled mantle lamps throughout this exploration of the Nullarbor Caves.

Acetylene lamps were widely used over many years for other purposes in Australia, including home lighting, vehicle head lamps, theatre and photographic lighting and even camp lighting by drovers and cattlemen (Rauleigh Webb, pers. comm.). There are surprisingly few references to their use in cave exploration until the 1950s, although they were certainly used in guano mining in some caves.

The advent of contemporary speleology in the late 1940s and early 1950s certainly brought with it the use of both carbide and a wide variety of electric lights. The story of speleological lighting is continuously evolving (e.g., Michie 1993), and does not need further attention here.

Public Display

Organised public visits to caves commenced in this country at Wet Cave, otherwise known as Oakden's Cave or the Chudleigh Caves, and now known as Honeycomb Cave, at Mole Creek, Tasmania (Hamilton-Smith 1993). Descriptions of these early tours only refer to the use of candles, but a fine engraving showing visitors in these caves depicts the use of brush torches with plumes of smoke which again suggest the use of kerosene or other oil.

Similarly, early accounts of visits to Jenolan and other public access caves on the mainland refer to the use of candles. Photographs taken in the 1880s and 1890s show that spring-loaded holders with a shield to catch dripping wax were commonly used, each visitor being provided with one.

But Jenolan was the site of Australia's major innovations in cave lighting. The invention of magnesium ribbon in 1864 led in turn to lamps which burnt magnesium ribbon as a means of photographic lighting. These initially consisted of a reflector with a hand-operated roller to thread the ribbon through as it burnt. However, more sophisticated models, driven by a clockwork mechanism appeared later in the same year.

Caretaker Jeremiah Wilson was quick to recognise the value of these as a means of showing the Jenolan caves to visitors. It is not clear exactly when he commenced doing so, but Havard (1934) reports that the Whalan family had used hand-held ribbon prior to 1870, and doubtless Wilson did so at about the same time.

Regrettably, the known reports of his use of lamps and the exorbitant charges which he demanded of visitors are in undated press cuttings in the Mitchell Library (see Dunkley 1986). The first formal notice of testing an 'improved' lamp from Europe is in the Annual Report of the N.S.W. Department of Mines for 1898. In 1900, it was reported that the lamps had been purchased and modified. However, a magnesium lamp in use was shown in a view of the Exhibition Chamber in Garran's *Picturesque Atlas of Australia* (1886 : 153).

From about 1901, clockwork lamps were manufactured in Australia by Esdaile's, a Sydney firm of instrument makers. The use of these lamps spread to other Australian cave areas. In 1900, the South Australian Conservator of Forests and William Reddan of Naracoorte Caves visited Jenolan Caves, and amongst other things, arranged to purchase magnesium lamps. They were used at Yarrangobilly at least by 1900 and almost certainly used at the same time in other N.S.W. cave areas; introduced to Western Australia and to Buchan by Frederick Wilson; and used at Mole Creek. Their use continued into at least the 1930s.

Although widely used for photography, I have not been able to find any record of ribbon lamps being used for cave display in other countries. It must be remembered that Australia of the 1880s was a relatively affluent country; few countries could have even considered Wilson's charges of twelve shillings per head for the ribbon used in a single tour! However, this should not obscure the fact of Wilson's sense of innovation and marketing being responsible for the widespread use of magnesium.

It is appropriate here to report one of the more amusing incidents of cave illumination. Tim Connelly, guide at the Margaret River caves, used the traditional candles together with a ribbon lamp to highlight the features of the caves. Then the special demands of World War One meant that magnesium ribbon was no longer available in Australia. Connelly wrote to the Hotels Board, who were his masters, seeking supply of an alternative lamp. This duly arrived in the form of a Lucas Brothers motorcycle head lamp, powered by carbide.

Connelly wrote back politely, thanking them for the very nice lamp, but pointed out that it was hardly adequate when a single tour party spread over as much as 80 feet of path way! The response was to forward a 'gasolene' (mantle) lamp. Connelly was delighted with it, but wrote seeking a supply of mantles. The Hotels Board clerk wrote back, pointing out that a mantle had been included with the lamp! Connelly's reply has not survived.

Returning to Jenolan, the next innovation was the installation of electric lighting by Col. E.C. Cracknell, experimentally on 22 July 1880, and permanently in 1884 (Havard 1934). This was not only the first use of electricity for cave lighting anywhere in the world, but it was well in advance of most street lighting systems. Ludovico Hart, who was one of the party of ten who assisted Cracknell in 1880, and who photographed the caves under their new illumination, wrote ,

. . . to convey the faintest notion of what the scene was like when lit up by the electric light is quite impossible, more particularly when different coloured glasses rendered the walls and stalactites red, blue, yellow, etc.

This first experimental installation relied upon electrolytic batteries, but the permanent installation was powered from a steam-driven dynamo in the Grand Arch. This would only provide sufficient power for 25 lights, and the need for extension soon arose. So, a Leffel wheel hydro-electric system was installed and drove a Crompton dynamo. This was further innovation in that it was the first hydro-electric plant in the country. (A later hydro plant also led to Australia's first fish ladder!) The most valuable historic relics at Jenolan include the Leffel Wheel and the original lighting in the Shambles (above the Chifley Cave) complete with its carbon filament globes and knife switches.

The other major light source in show caves has been acetylene gas from on-site generation. I have already referred to its very brief use at Margaret River. It was tried at Jenolan in 1900, but rejected for cave use because of its smell. However, it was used at least once for lighting a concert in the Grand Arch. But it was accepted and used for relatively lengthy periods at Mole Creek in Scott's Cave (1908-17), Baldock's Cave (1910-c.1925) and King Solomon's Cave (dates unknown). The guide at Gunn's Plains used a hand-held acetylene lamp for many years. It seems likely that such lamps were also used at Chillagoe because of the close association with mining, and certainly, when those caves were re-opened in the 1960's, guide Vince Kinnear had a stock of Queensland Drovers' carbide lamps for hire to visitors undertaking self-guiding tours. There are no other genuine records of such use, although it has been stated erroneously that it was installed at Naracoorte Caves.

Photographic Lighting

The story of photographic lighting is perhaps one of the more intriguing. Most early photographers used hand-held magnesium ribbon, and often obtained fine results. Some learned to move the ribbon about and so eliminated harsh shadows, but also led to the production of rather flat and uninteresting pictures. The most effective use of this method was probably by James H.A. MacDougall, initially at Buchan and later at both Yallingup and Margaret River in South-western Australia.

His photographs show the fine textured surfaces of cave decoration better than any of his contemporaries, and better than many modern photographers. It is so characteristic of his work that I can usually pick his photographs without needing to see his name on them.

Doubtless, some photographers used the ribbon lamps, but there is no record of this in the literature.

Jenolan proved an irresistible magnet to photographers; early photographers of note include John Paine, Henry King, H.C. Beavis, Charles Bayliss, Ted Cooke, Oliver Trickett, Ron Bailey, Ebenezer Caney, Joseph Rowe, J.J. McCarthy, George Rose, Harry Phillips, George Kitch and, of course, Anon. Those who came later included the famous Frank Hurley and Curator Tant Bradley.

However, the great cave photographer of the late 19th. century was Charles Kerry, partly because he had the opportunity to photograph many caves in N.S.W. within a few days of the first entry to them. He was also the most effective publisher of his images as postcards, cabinet or larger prints and souvenir booklets, selling probably hundreds of thousands of cards at Jenolan alone, and publishing series from all other major cave areas in New South Wales.

Kerry certainly used hand-held ribbon initially, a variety of lamps, generally of the blow-through type, and then flash powder. It is of interest to read a little of the advice in his 1903 paper on cave photography:

It is commonly known that of the hundreds of dry plates and spools of film exposed yearly within the Jenolan Caves, an almost incalculably small percentage only are so manipulated as to produce satisfactory reminders or records.

. . . if some special formation is being photographed, and the light is retained in one position, detail may be lost from one portion of the subject, whilst heavy conflicting shadows will result in another. I have found it to be of great advantage to move the light in various directions during exposure . . . for the purpose of breaking up shadows.

The best lamp is one having a fairly large reservoir, holding from one to two ounces of powder and giving a flame up to 18 inches or two feet in length.

In the case of mystery formations, almost all of them are transparent 'helictites' and require special treatment . . . to use a quick weak flash from the side.

The paper is not unlike what might be published in a popular photography magazine today. It contains much sound advice, together with interesting examples, and the statement that:

The man (sic) *who would systematically explore the caves and make photographic records of them should be of muscular build and have great strength and endurance. One is constantly forced to place himself in most awkward positions and places, perhaps himself and his camera on an extremely narrow ledge where it is necessary to remain for some time. In climbing about I have had many falls and have in cave working smashed up three camera beyond repair.*

Despite his good advice, and the number of his cave photographs with remarkably even lighting and fine definition of detail, most are so evenly lit as to totally lack any sense of magic. Not surprisingly, some of his helictite photographs are probably his best. His friend, Oliver Trickett, who made no claim to photographic expertise, often produced much more interesting photographs even when using precisely the same camera position, simply because he used light more imaginatively.

Kerry was also a fan of new technology - what we might today call a 'gear freak'. He owned and used the incredible Cirkut Camera for taking panoramic photographs of immense size, but in particular, he experimented with the development of blow-through lamps. These were built for him by his friend H.J. Quodling, and probably they achieved the greatest of all such lamps, fitted with six heads and a pump-up air reservoir (Millar 1981 : 10).

At this point, we need to trace something of the history of the blow-through lamp and its evolution. It was invented by a Paris photographer, Gaspard Felix Tournachon, generally known as Felix Nadar. Trained as a surgeon, Nadar turned to journalism, play-writing and cartooning, and the latter led him in 1852 to photography. As an enthusiastic balloonist, that led him to the invention of aerial photography (in 1858) which he patented and used to good effect.

In 1861, having become expert in the use of artificial light in the studio, he decided that in addition to being the first to take photographs above the earth, he would be the first to photograph underground, and embarked on a project to photograph the Catacombs of Paris. This venture was a great success, but the use of electricity proved cumbersome and expensive.

Various photographers experimented with ways of burning magnesium power, including Larkin in 1866 with a primitive ancestor of the blow-through lamp, but most turned to various chemical mixtures. In the 1880s, experimenters turned again to the blow-through lamp, and the first truly successful version was developed by Paul Nadar, son of Felix (Howes 1989). This became widely accepted and used by French cave photographers, and as we have already seen, by Charles Kerry in Australia.

By 1905, and perhaps earlier, the blow-through lamp was a mass-production item in Australia, and both their own 'Austral' lamp and various others were being marketed by Baker and Rouse (c. 1905).

When Captain Maitland Thomson commenced caving on the Nullarbor, he found that H.G. (Gwyn) Watson of Ceduna had already photographed the caves, using blow-through lamps which he had built himself. He lent his lamps to Thomson, who used them with great success.

Then in 1955, soon after I first became acquainted with Thomson, he expressed considerable regret that he no longer had such a lamp. Shortly afterwards, I was able to buy a secondhand Austral at Camera Supply in Flinders St., Adelaide. After some discussion, and with the help of other CEGSA members, this was mounted on a fire extinguisher cylinder with a pump, and was presented to the Captain with our compliments.

Later developments include those by Fairlie-Cunninghame (n.d. but 1957), who produced a lightweight device using a meteorological balloon to pressurise the propellant air. Crowle modified this to further reduce weight and powder consumption. Hill (1966) probably made the most important contribution to the effectiveness of blow-through lamps by recognising the very different character and properties of high density magnesium powder, developed for use in rocketry practice. His version also had a carefully controlled powder flow rate, and so exposures could be much more accurately calculated, and he developed an exposure calculator to accompany it. Finally, Poulter (1977) developed a still further improvement, using liquid petroleum gas as a propellant.

However, with faster films, great improved electronic flash technology, and different practices in lighting for photography, the blow-through lamp, despite its perfection in Australia, is probably becoming nothing more than a historical relict.

References

Baker and Rouse, c. 1905, *Photographic Apparatus and Supplies, Melbourne Catalogue No. 20,* Melbourne : Baker and Rouse.

Broome, R.S. ('Tanjil'), 1886, *Our Guide to the Gippsland Lakes and Rivers . . . ,* Melbourne : M.L. Hutchinson.

Dunkley, John R., 1986, *Jenolan Caves as they were in the Nineteenth Century,* Sydney : Speleological Research Council.

Earle, Augustus, 1826, *Mosman's Cave,* # 3 & 5, Water colours in Pictorial Collection, National Library of Australia.

Fairlie-Cunninghame, Henry, n.d. but 1957, Photographic Report on the Australian Speleological Federation 1957 Nullarbor Expedition, unpublished ms.

Flood, Josephine, 1990, *The Riches of Ancient Australia,* Brisbane : University of Queensland Press.

Garran, A. (ed.), 1886, *Picturesque Atlas of Australasia,* Sydney : Picturesque Atlas Publishing Company.

Hamilton-Smith, Elery, 1993, Some Historical Materials on Tasmanian Caves, *Conference Papers, Tastrog 1993* : 90-94.

Hart, Ludovico, 1880, The Fish River Caves, for the first time illuminated by the electric light, in Newspaper Cuttings Book, Mitchell Library, Sydney. [no source details]

Havard, Ward L., 1934, The Romance of Jenolan Caves, *J. Roy. Hist. Soc.,* 20 (1) : 1-48.

Hill, A.L., 1966, Photography, in Hill (ed.), *Mullamullang Cave Expeditions 1966,* Adelaide : Cave Exploration Group of South Australia, Occasional paper 4 : 27-31.

Howes, Chris, *To Photograph Darkness,* Gloucester : Alan Sutton.

Kerry, Charles, 1903, Photographing in Caves - Jenolan, N.S.W., *The Australian Photographic Journal,* 12 (10) : 217-220.

Michie, Neville, 1993, Recycling Mine Lamps, *TasTrog Conference Papers.* 19th Conf. Aust. Spel. Fedn. pp 102-109.

Millar, David P., 1981, *Charles Kerry's Federation Australia,* Sydney : David Ell Press.

Speleogenesis: A brief insight into the spatial and temporal distribution of Australian karst

James Maxlow

Speleological Research Group Western Australia

In searching through past conferences for a suitable paper to write it became increasingly apparent that cavers in general very rarely consider the why, or how a particular cave, or cave locality, came to be where it is. Far easier to discuss first hand observations such as karst processes, troglobitic fauna, or surveying than to ponder how it all came about.

Introduction

In this paper I will be introducing the concept of spatial (occurrence in space) and temporal (existence in time) distribution of our major Australian caving areas, concentrating on what geological factors have lead to their deposition, prior to onset of karstification. What has this to do with caving? Not a lot. Caving is now, the origins of many of our limestones range in age to around 560 million years ago, yet if certain key events hadn't happened when and where they did, we wouldn't have the caves as we know them, nor would we have the need for cave conferences. The fact that the caves are there gives you an opportunity for a far broader understanding of the factors governing their existence in time and space. Just because they are there doesn't imply that they have always been there.

Spatial and Temporal Distribution

Broadly speaking, the major caving regions of Australia fall into four main categories dependent on age:

(I) Palaeozoic (Cambrian to Mid-Devonian; 560 to 380 million years ago) reefal limestone complexes, eg. Napier Range WA and Eastern Australian regions;

(II) Cainozoic (Mid Eocene to Early Oligocene; 50 to 35 million years ago) shallow marine shelf limestone, eg. Nullarbor Plain, Otway Basin;

(III) Quaternary (2 million years ago to the present) lava caves, eg. Western Victoria and;

(IV) Pleistocene (250 thousand years to the present) coastal dune calcarenite, eg. WA and SA.

This deposition of limestone and volcanic rocks in Australia is intimately linked with the breakup and dispersal of Gondwanaland (southern supercontinent) and, in particular, the breakup and dispersal of Australia and Antarctica.

Prior to the Upper Cretaceous (110 million years ago) Australia was firmly joined to Antarctica, with Tasmania nestled in against Victoria in what is now the northwestern Ross Sea region of Western Antarctica. This, and the subsequent breakup and dispersal of the two continents is shown in Figures 1 to 6, established from age dating of the Southern Ocean basin floor. At this time the Palaeozoic reefal limestone complexes of eastern and northwestern Australia were already in existence, long since having been uplifted and exposed to erosion and karstification by mountain building processes active between about 420 to 320 million years ago.

The Eucla Basin (Nullarbor Plain) lay well within the Eastern Gondwanaland supercontinent, essentially barred from any marine incursions, with Antarctica firmly locked in against the Southern Australian margin. Processes operating from deep within the Earth's mantle began to slowly stretch the Gondwanaland supercontinent, with breakup and dispersal of the two continents beginning in earnest around 55 million years ago. At this time the Eucla Basin, and associated Otway Basin to the east, were increasingly subjected to marine breakthroughs from the west along a narrow rift zone, possibly similar to the Red Sea rift zone between Africa and Saudi Arabia today.

During this period of Cainozoic continental dispersal successive marine ingressions led to extensive carbonate deposition in the Eucla Basin and terrestrial sedimentation, with lesser marine carbonates, in the Otway Basin. The Eucla Basin developed as a broad, arcuate, northward-shallowing ramp, the margins of which approximate the present day basin (Nullarbor Plain) margins.

Draining of the Eucla and Otway basin regions during the Lower Oligocene (approximately 35 million years ago) coincided with breaching of the south Tasman Rise, between Tasmania and Antarctica, and subsequent lowering of sea-level, estimated to be upwards of 200 to 250 m above present sea-level. This left the onshore Eucla and Otway basins emergent and subject to erosion, consolidation and karstification of the carbonates.

Volcanic activity in Victoria was fairly continuous during this period of Cainozoic continental breakup and separation. Older Volcanic activity peaked during the Palaeocene/Eocene (60 to 55 million years ago) coinciding with the period of initial breakup and rifting of Gondwanaland, while the Newer Volcanics peaked during the Pliocene/Pleistocene (2 million years ago to the present), possibly representing a period of reactivated rifting between Tasmania and the Australian mainland. The Newer Volcanics, prevalent throughout much of western Victoria, are of interest to cavers because of their lava caves, formed by draining of molten lava from beneath a solidifying crust, and/or steam bubbles.

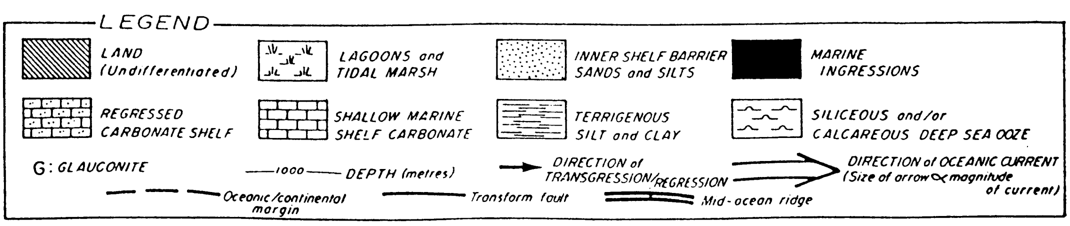
More recently, a series of rapid (geologically speaking) glacio-eustatic sea-level fluctuations, caused by periods of cyclical glaciation and glacial melting during the past 250,000 years, have given rise to extensive dune calcarenite (sandy limestone) deposition along much of our coastal regions, in particular Western Australia and South Australia. These dune systems were developed during periods of global warming and sea-level rise by the migration of foreshore beach/dune sequences, initially deposited during periods of low sea-level, and accumulating parallel to the coastline at peak sea-level. In WA, in particular, the cyclical sea-level rise and fall resulted in a stacked succession of dune ridges, whereas in SA they tend to form parallel singular dune ridges reaching well inland from the present coastline.

Conclusions

Okay, what has all this to do with caving? Palaeozoic reefal limestone complexes, outcropping in the Kimberleys and along the Australian east coast, were already uplifted and exposed to karstification long before crustal disturbances in the Late Cretaceous began fragmenting and dispersing the Gondwanaland supercontinent. Climatic conditions favoured deposition of a thick bryozoan limestone succession in the widening Eucla to Otway Basin rift zone between the Australian and Antarctic continents. Dispersal of the two continents during the Palaeocene/Eocene was marked by extensive older vulcanism in Victoria while breaching of the south Tasman Rise during the Lower Oligocene resulted in a draining of the Eucla to Otway Basin regions with exposure of the regions to erosion and karstification.

Vulcanism peaked again in Victoria during the Pliocene/Pleistocene as a result of renewed rifting between Tasmania and the mainland while, more recently, glacio-eustatic sea-level fluctuations during the Pleistocene gave rise to extensive coastal dune limestones along much of the Australian (and overseas) coastlines.

It is hoped that this necessarily brief introduction to the spatial and temporal distribution of caving areas in Australia has given you a better appreciation of why caves are where they are. It is important to realise that if these major geological events hadn't happened when and where they did, "The Earthy limestones and the Water that dissolves them, the Fiery volcanos and, in particular, the hot Air at this conference" would not be.



Legend for Figures

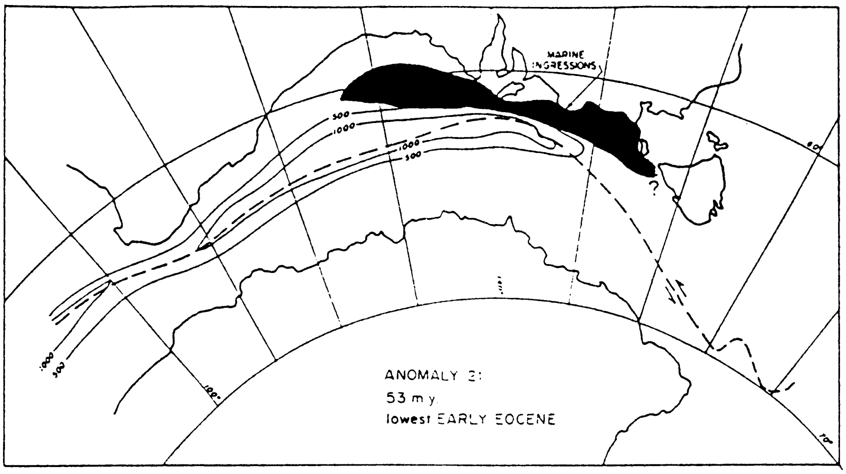


Figure 1: Paleocene to Lower Eocene marine ingressions in the Southern Ocean

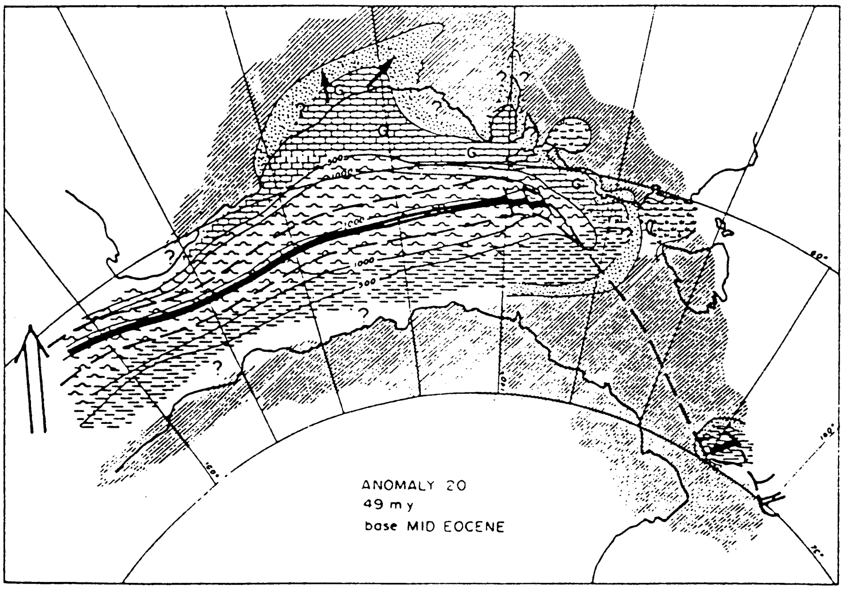


Figure 2: Lower Mid-Eocene depositional environments: Southern Ocean

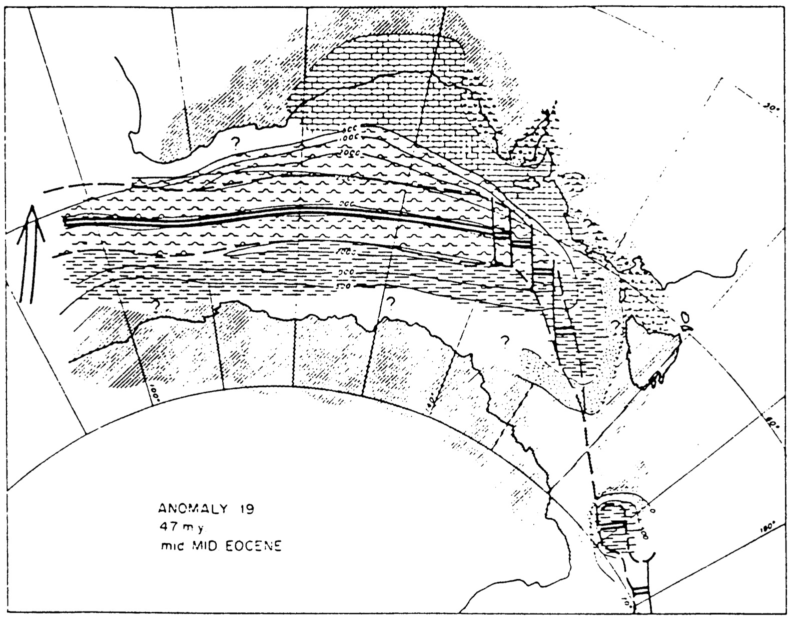


Figure 3: Upper Mid-Eocene depositional environments: Southern Ocean

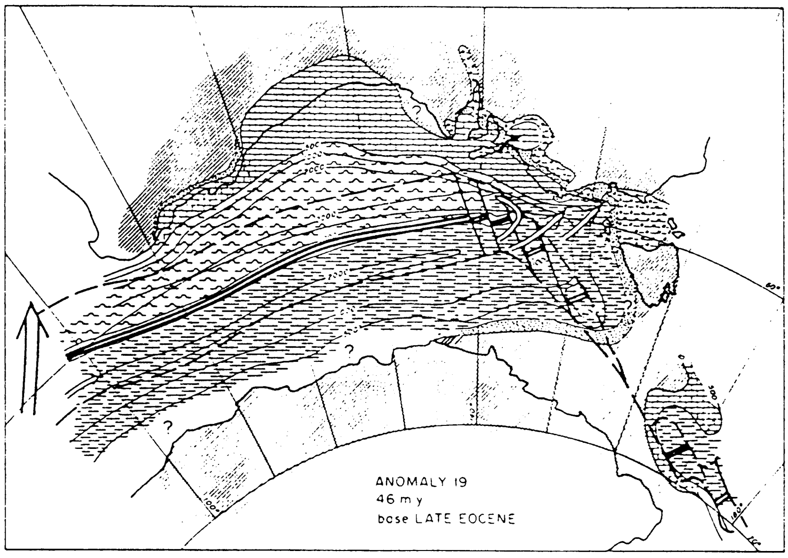


Figure 4: Late Eocene depositional environments: Southern Ocean

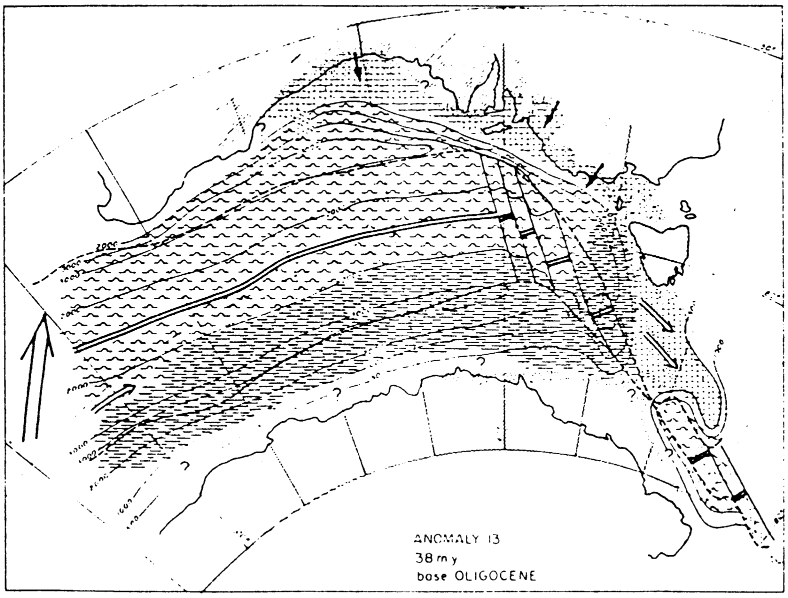


Figure 5: Lower Oligocene depositional environments: Southern Ocean

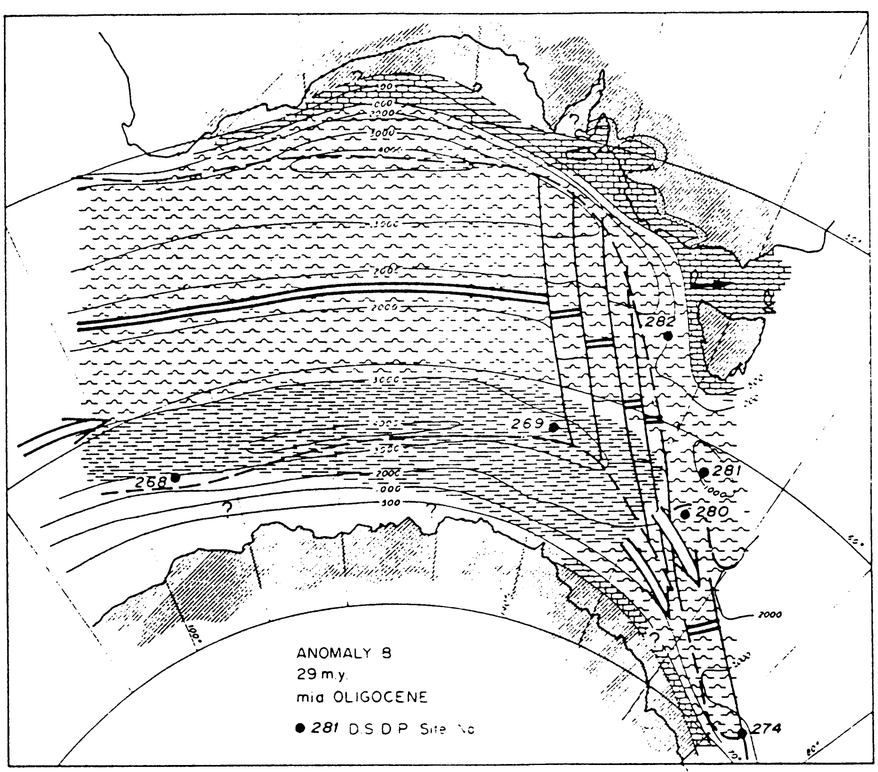


Figure 6: Upper Mid-Eocene depositional environments: Southern Ocean

Investigation of visitor impacts at Jenolan Caves

Neville A. Michie

Abstract

A study has started of dust and carbon dioxide gas in the tourist caves at Jenolan. The study Also involves the analysis of the cave climate. The history of the problems and the techniques used are outlined.

Introduction

At Jenolan Caves an investigation is being conducted of the effects of the visitors to the caves. About one quarter of a million cave visits are made in a year, and although the impact of each visit is very small, the accumulated effects can be significant.

The particular problems being investigated are the dust and the carbon dioxide. As the cave climate is a major influence on these two problems, it is also being investigated.

Previous work

The impact of visitors on the caves has been of concern for many years. Collecting of souvenirs was prevented quite early in the history of the caves. Discontinuance of the use of candles and carbide because of the soot problem was a major reason for the early introduction of electrical lighting of the caves. The ingestion of dust and smoke through the Binoomea Cut was prevented by the installation of airtight doors. The previous damage was repaired by steam and water cleaning and track improvements were made to reduce mud and dust problems. The impact of each visitor has now been reduced to the introduction to the caves of a tiny quantity of dust, a little metabolic heat, some carbon dioxide gas and possible traces of other pollutants that have not yet been identified. If compared to wild caving, the impact is almost non-existent.

The study of dust had its origins in the cleaning programs that have been conducted in the caves in the last 20 years. Steam cleaning and then water jet cleaning have been used at Jenolan to remove thick dust deposits from the caves, with a high degree of success [1]. The physical processes that cause dust to be deposited in the caves were studied in the late seventies [2], but the size of the task was a bit larger than the department in charge of the caves was prepared to support.

The study of carbon dioxide has been made in many caves. Some in N.S.W. have concentrations greater than five per cent (5%), but in this case there was no major difficulty with carbon dioxide but some spot measurements had shown there were occasional instances of noticeable amounts.

The Jenolan Caves Trust has decided to sponsor the study, which is in line with its efforts to investigate the visitor carrying capacity of the caves.

Method

The dust study was initiated using some of the methods used fifteen years previously. The quantities of dust are very small and the logistics of collecting samples over a period of time were best accomplished by continuous collection at many sites and periodic *in situ* measurements.

A special optical densitometer that was developed in the first program of measurements was upgraded and is used to measure the transmission of light through calibrated Petri dishes which are left in the cave to collect the dust as it gravitates to the floor of the cave. Trials from the previous program had shown the robust nature of this measurement and its excellent sensitivity.

A network of the Petri dishes, placed on plastic picnic plates, has been distributed through the cave systems. The statistics of the number of visitors, the geometry of the cave and the cave climate variables will be used to analyse the processes that control the deposition of dust.

The carbon dioxide measurements are made with a non-dispersive infra-red gas analyser which was purchased as a printed circuit card and then built into a humidity proof enclosure with rechargeable batteries, a display unit and a micro-power sampling pump to enable the unit to be left in a cave while its output is recorded to find the temporal patterns of carbon dioxide concentration. The instrument measures over a range of zero to 3 per cent of carbon dioxide in air with a resolution of 0.005 percent, but only records with a resolution of 0.02 percent.

The cave climate is being determined by periodic measurements through the caves with a small aspirated psychrometer (wet and dry bulb thermometer) to measure air temperature and humidity, and intensive periods of two days to two weeks when a large number of meteorological variables are measured with up to six , eight channel data loggers with directional vane anemometers, cup anemometers, screened thermometers, barometers, micro-manometers rain gauges and water level transducers.

The technique of cave climate investigation involves developing a model of each cave system and verifying the model, modifying it as necessary until the reaction of the cave to external stimuli can be predicted with the desired degree of accuracy.

The caves at Jenolan have two major chimney systems operating, the northern caves have an upper entrance in the Elder Cave, with vigorous air flow through the Imperial and Chifley Caves. See Figure 1. In cold weather (below 10°C) the air enters the Chifley (not shown) and Imperial entrances and flows through the cave, cooling the cave and evaporating water from the walls, eventually rising and leaving the cave through the Elder Cave entrance and other small cracks. The lower parts of the cave are then very well ventilated and no carbon dioxide is detected. In warm weather, (over 20°C) the flow is in the reverse direction.

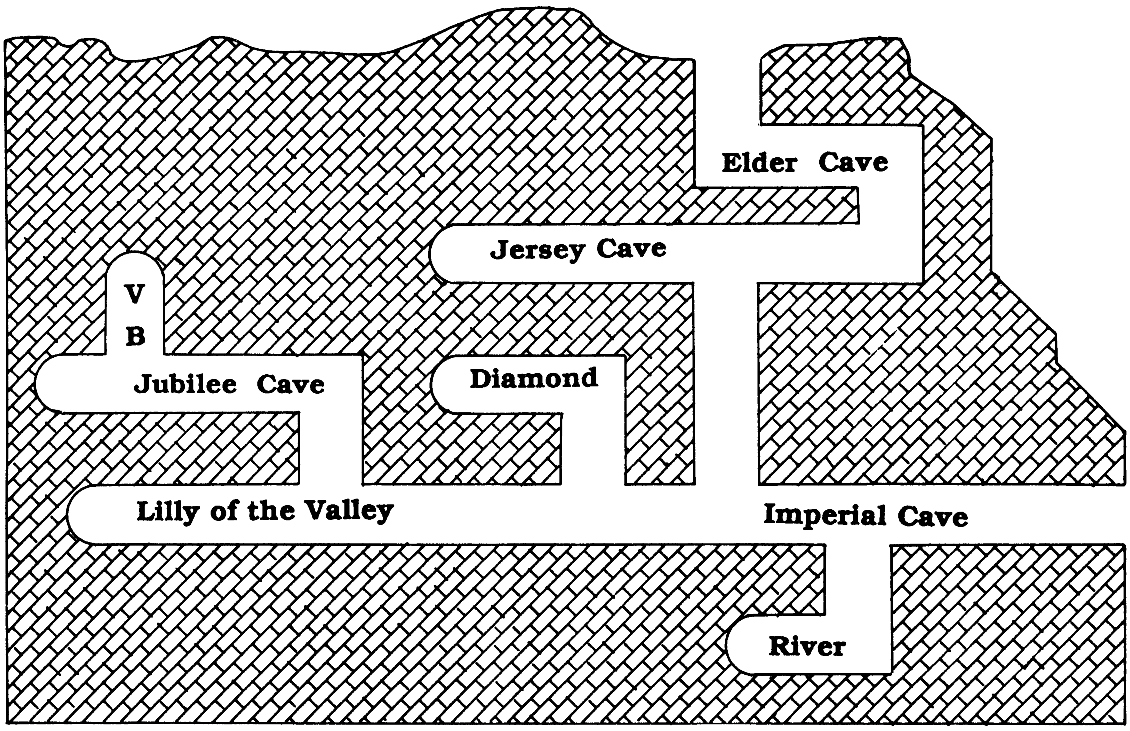


Figure 1: Simplified elevation of the northern caves. The Elder Cave assumes the role of the upper entrance, and the Imperial Cave entrance is the lower entrance.

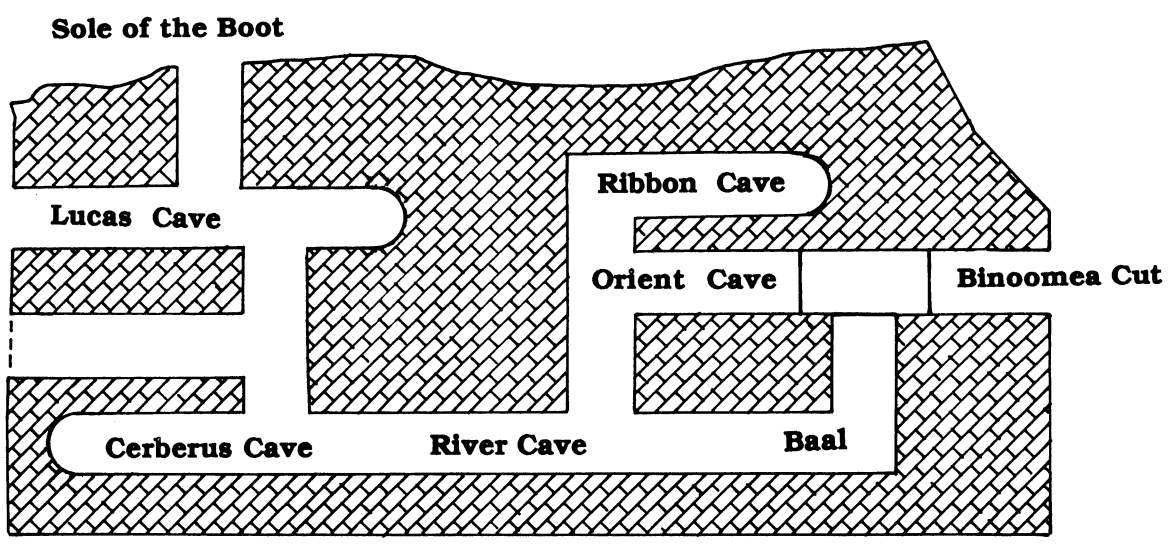


Figure 2: Simplified elevation of the southern tourist caves. The Sole of the Boot is the main upper entrance, the lower entrances are in the Lucas Cave. The Binoomea Cut would be a middle entrance, but is usually sealed by refrigerator style doors.

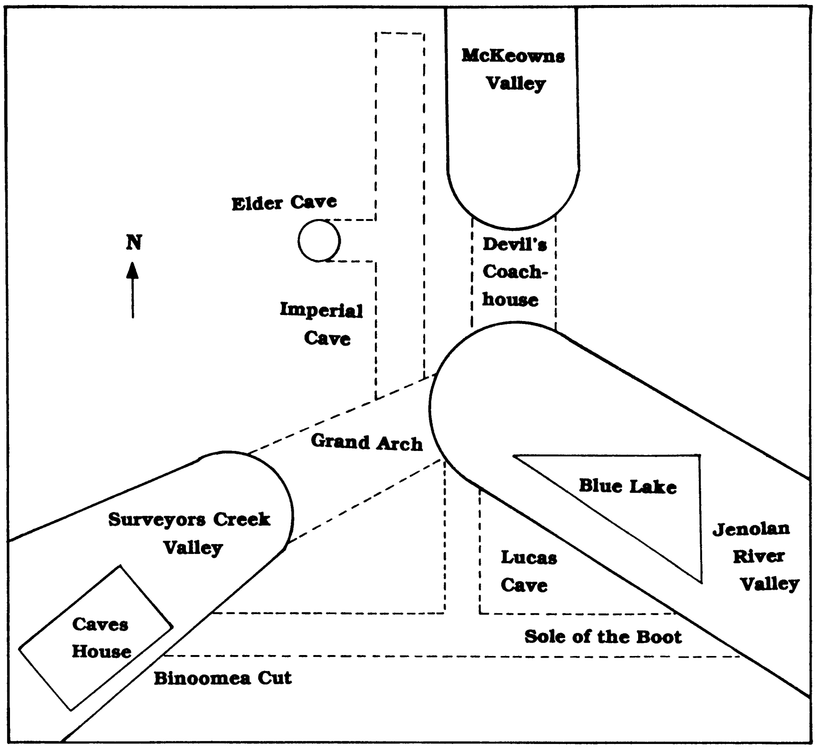


Figure 3: Simplified plan of the area showing the relationship between the valleys, the arches and the caves. The Elder Cave is on the saddle between McKeowns Valley and the valley with Caves House.

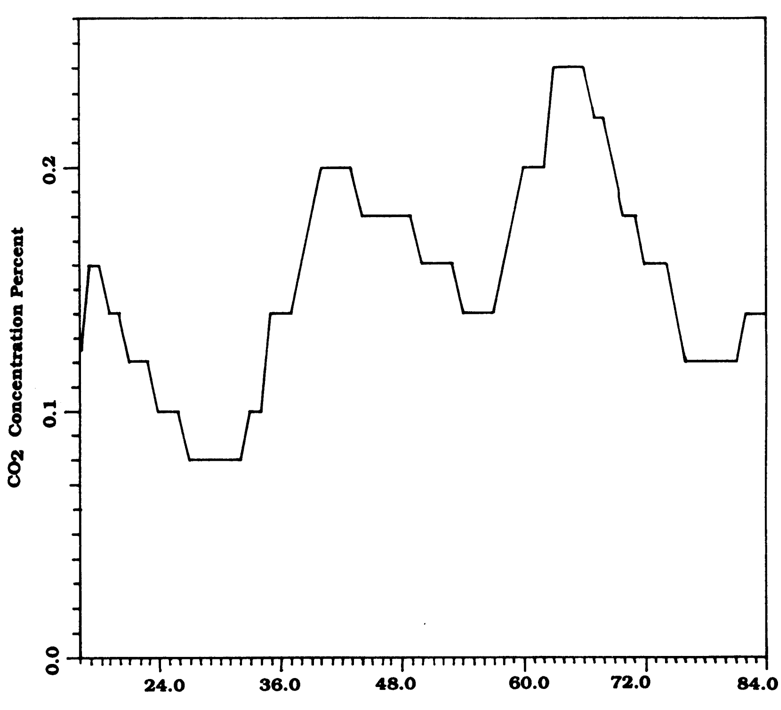


Figure 4: Record of carbon dioxide concentration in the Temple of Baal Cave over the October long weekend 1994. Time starts at midnight.

The southern caves have the Sole of the Boot as an upper entrance with vigorous air flow through the Lucas Cave through several entrances. See Figure 2. The Cerberus Cave area acts as a cold trap, cooling all winter with cold night air, but becoming stable all summer as the outside air is warmer and less dense. In summer carbon dioxide levels may rise in the low sections of both caves, but more data are needed to make these patterns clear.

The climate in the caves is dependant on the climate outside the caves, and the Jenolan River Valley, the Surveyors creek valley and the gorge at the end of McKeowns Valley have quite individual micro-climates which makes them quite distinct from the general climate in the area. The differences between the climates in the valleys and gorge give rise to the Arch Winds, strong air currents that blow through the Devil's Coachhouse and are usually blowing strongly. Figure 3 shows a simplified scheme of how the caves relate to the valleys and arches. The same effects that cause the Arch Winds also influence the circulation in the caves. Analysing the external climate of the caves may be more difficult than determining the climate inside the caves.

Results

There are only preliminary results at this stage of the project. The dust measurements from fifteen years ago showed that there were places in the caves where the dust fall in one year was extremely small. Most of the cave though, had substantial dustfall. A recent observation in Lucas Cave with an aerodynamic particle sizer showed that the air in the cave was cleaner than most clean rooms, but when people entered the dust levels rose to high levels and took nearly and hour to subside.

The carbon dioxide levels may be high in summer, readings of 0.6 percent have been made, but in winter the readings were much lower. The section of the Jubilee Cave called Victoria Bower is a small section at the top of a ladder (see VB in Figure 1). Warm air becomes trapped in this section, and after a tour party has visited, the carbon dioxide has been measured above 0.6 percent. Continuous readings in the Temple of Baal on an October holiday weekend are shown in Figure 4, the tours in the daytime caused elevation of the carbon dioxide levels which fell during the following night.

Conclusion

This is only an initial overview of the project, the work that will be done may be changed as preliminary results are analysed.

The impact of each visitor to the tourist caves has been reduced to quite a low level, but there is still the possibility to reduce it further. Massive development in the caves, such as track building, has been responsible for the low level of impact.

This type of study may be applicable to wild caves as cavers become more serious about cave preservation.

References

[1] Michie, N.A. (1978) The Dust Sampling Programme at Jenolan. *Journal of the Sydney Speleological Society,* Vol.22 No.7, pp 164 - 165.

[2] Newbould, R.L. (1974) Steam Cleaning of Orient Cave, Jenolan Caves, N.S.W. Jenolan Caves Historical and Preservation Society, Occasional Paper No 1, Published by Jenolan Caves Historical and Preservation Society, Jenolan, N.S.W., pp 24.

Investigations of the Wyanbene Caves area

Jill Rowling

SUSS October 1994

Abstract

The Wyanbene Caves are located about 50 km south of Braidwood, NSW and about half way between Canberra and the coast. The main Wyanbene Cave is 580 m long with 1830 m of passage. It is presently used for recreation under a permit system which is managed by the National Parks and Wildlife Service of NSW from their Narooma office. The cave contains extensive speleothem deposits, a perennial stream and has a locked gate about a quarter of the way in. This paper discusses some preliminary findings by the author concerning the structure of this and other caves in the area.

Introduction

I first became interested in Wyanbene after visits to the caves in 1979, 1986 and 1990. Figure 1 shows the location of Wyanbene Caves in NSW. Figure 2 shows a general plan of the area. The caves are part of the Deua National Park. To the east of the main cave (WY-1) there are some abandoned mine addits. Further to the east lies the Minuma Range which divides the Shoalhaven drainage from the Deua drainage. To the south of WY-1 lies Wyanbene Caves Mountain.

The SUSS library has a copy of the excellent maps of WY-1 (by Brush et al. of NUCC), drawn in the 70's. After studying the maps, I realised that not only were there several interesting structural features of the cave, but the area hydrology was also unknown. This raises some interesting questions:

- Where does the cave get its water from? Is it the Shoalhaven side north of Wyanbene caves mountain, the Shoalhaven side south of Wyanbene caves mountain, or the Deua side?
- Where is the cave with respect to the topographic map?
- What are the soft, vertically bedded dyke-like structures found throughout the cave?
- Why do many of the cave cross-sections display a tilt toward the west?
- Is there a relationship between the avens of the cave and geological structures on the hillside?

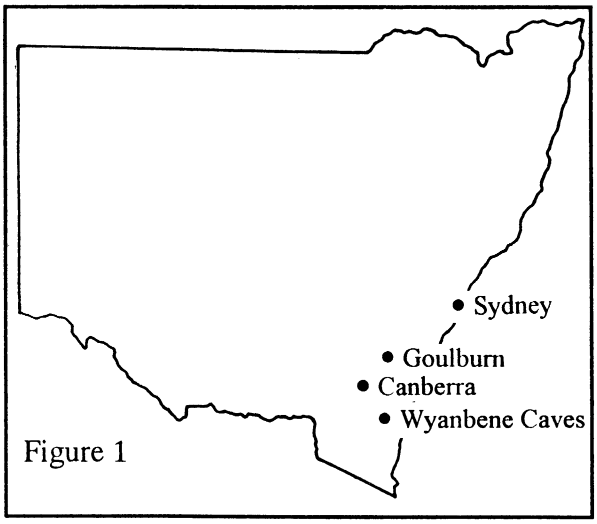


Figure 1: Location of Wyanbene Caves in NSW

This year (1994), Mike Lake and I surveyed from the car-park near the cave entrance to the trig station on top of Wyanbene Caves Mountain. We used both forward and backward bearings at each survey station to help reduce errors because of the known magnetic ore deposits in the vicinity. Figure 2 shows how this survey positioned the cave on the topographic map, together with approximate positions of the other caves, mines and other features in the area. Note how the cave runs fairly straight in a north to south direction.

Figure 3 is an elevation of the cave, looking to the west. This drawing has a vertical exaggeration of 2 times in order to show vertical features. Errors in the positioning of the cave features and/or the topographic map have resulted in the top of one of the avens (the Gunbarrel - GB) being drawn about 5 metres above the surface of the mountain! The cave ends in a sump called Frustration Lake, marked FL in figures 2 and 3.

Avens

There are several avens of interest. The Gunbarrel is by far the most spectacular and well known, rising some 110 m to what is either a boulder choke or part of the conglomerate and sandstone cap of the mountain. The evidence for this includes a large non-limestone boulder in the base of the Gunbarrel, together with many smaller pieces of sandstone and conglomerate. Figure 4 is a cross section through the Gunbarrel looking north. Note that the Gunbarrel is actually a double-barrelled aven. The height of the larger aven of the Gunbarrel was measured by members of NUCC in the early 1970's using helium filled balloons. It has been climbed to about 80 metres by Alan Warild, who reported that above this point "it narrows, then widens," and "the limestone was becoming poor and crumbly". The smaller aven is coated with a reddish mud.

Figure 4 also shows an aven in upper Rockfall Chamber. Rockfall Chamber is, strictly speaking, part of Caesar's Hall (CH on figures 2 and 3) which itself contains two avens, one at each end. Note also that the lower access to the Gunbarrel is virtually at creek level; this would help to explain why there is usually a puddle in this chamber. It would appear from figure 3 that the steeper parts of the hillside are directly above the avens in the cave. Aitcheson's Avens are marked AA in figures 2 and 3.

Evidence For North-South Jointing

The cross sections of figure 5 are all looking north. They were taken from the NUCC map. Note the passage shapes; they seem to follow a joint of some sort which is dipping steeply to the east. It is unlikely that the passage follows the bedding, as this was measured by the author to have a dip of 20° in the direction 268° (ie. approximately west) in Goat Cave (WY-5), high on the Deua saddle. This was measured along a contiguous band of fossil shells on the roof and both sides of the passage.

During a recent SUSS trip (3rd July 1994), Armstrong Osborne measured the bedding at the WY-2 entrance of the main cave and found it to be much the same. On that trip, we were able to follow a huge joint structure on the surface, over the cave and up the hillside until it disappeared under loose conglomerate rubble. Additionally there are some north-south trending grikes (3°) on the main hillside (that is, the most obvious bare limestone hillside which you see as you drive to the area). These could be solutionally enlarged north-south joints.

Other Caves

Near the lower (north) end of the most pronounced grike is WY-6, an insignificant cave, and a couple of tufa terraces which form a feeble efflux of sorts during wet weather. Near the top (south) end is WY-9, a tight vertical shaft some 23 m deep as estimated by rope length. Continuing in a southerly direction to the Deua side we find Goat Cave (WY-5), then what looks like an oxide band, then Ridge Mine Pot (see figure 2).

Goat Cave is a small two-chambered cave with an earth floor. It is an important roost for Horseshoe bats and faces the Deua side. Ridge Mine Pot is a 60 m deep vertical cave, choked with calcite and generally similar to WY-9. Jennings (ref 2) wondered about the relative altitudes of the WY-1 creek and the bottom of Ridge Mine Pot. From his article and from field observations by Norton (ref 3), I have estimated its bottom level to be about 100 m above the WY-1 creek and maybe 60 m above the WY-6 efflux. Is it possible that at some earlier time, Ridge Mine Pot was part of a cave system which took water from what is now the Deua side to the Shoalhaven side of the Minuma Range?

Clarke's Cave (WY-7), also known as Bushranger Cave, is a rock shelter which lies on the unconformity between the limestone and the conglomerate. It also appears to contains a large joint or dyke filled with reddish material. The limestone at the conglomerate interface is not flat; rather, it has conglomerate-filled solution-like features which suggest it has been subject to weathering prior to deposition of the conglomerate.

According to the NSW Geological Survey (ref 4), the ages of the Wyanbene limestone and conglomerate are late Silurian and late Devonian respectively. This leaves about 50 million years in between, during which time the limestone may have been exposed to weathering. There is a doline about 100 m to the north, below Clarke's Cave, on the scree-covered slope. One wonders whether the two features are hydrologically connected.

Conglomerate and Sandstone Cap of Wyanbene Caves Mountain

At the top of Wyanbene Caves Mountain is a sandstone cap. This is broken up into pillow-sized boulders and rocks with lenses of a soft reddish material. These rocks have rounded, almost solution-like features. Below this lies a maroon conglomerate layer, which overlies the limestone. The conglomerate is made of angular volcanoclastic material which is cemented together. To the northwest and downslope of the trig, the conglomerate is more intact but terraced. There are steep to overhanging structures resembling faults about 2 m high. They also occur near the saddle to the east of the trig, where they are oriented in the direction 338°.

The boundary between the conglomerate and the limestone is usually hard to find because of scree. The conglomerate also occurs in the WY-1 cave all along the streamway as loose pebbles which have been washed in somehow. The conglomerate cap corresponds approximately to the end of Far Caesar's Hall, where the nature of the cave changes from an open hall to a narrow, vertical rift system. The conglomerate may be impervious to water, except at the "fault" structures. If so, surface water may be able to reach the limestone under the conglomerate via these structures.

East-West Banding

The limestone has almost vertical bands of reddish material running approximately east-west. This material does not follow a straight line, but tends to wander a bit both in dip and strike. In WY-1, these structures show up as walls through which the streamway has eventually made its way. One of the most pronounced is right near the WY-1 entrance, about 25 m in along the streamway. Inside the cave, this material is soft, brown and chemically altered, but on the surface it shows up as reddish bands in the limestone. Some of these surface bands are lined with quartz. The limestone nearby appears to be dolomitised. A particularly spectacular band winds its way across the lower terraces of the main hillside. This band contains sparkly material described as Maghemite by Cooper (ref 7) and is still being investigated. The "oxide band" near Goat Cave appears to be a similar structure.

I would propose that the "West Passage" of Ridge Mine Pot is developed along one of these structures, whereas the "North Passage" may be developed along a joint (ref 2). The NSWGS report describes similar structures (as found near the mines) as hydrothermally deposited base metal ore bodies (ref 4). It would seem (from looking in the field) that the north-south jointing postdates the east-west banding.

Breccias

On the surface, at the saddle between Clarke's Cave and the steep eastern side of the Minuma Range, the rocks are a breccia of limestone fragments surrounded by dark reddish material. In WY-1, a similar material forms the floor of the area known as the Chamber Pot near Anderson's Wall (AW in figures 2 and 3). Some of this material can be magnetised (see below).

Magnetics

I was concerned that the original survey may have been affected by remnant magnetism of the "oxide material", as some key stations were located on "oxide bands" so Mike and I tested some of the surface material. The brecciated material affects a compass only very slightly, around 1° when the compass rests on the material. After it is placed in a strong magnetic field the material becomes permanently magnetic! (ferromagnetic). This means that the survey is probably accurate to ASF survey grade 5. One should be careful when using a compass in this area.

Mineralogy

Aragonite is found in WY-1 in the form of "flos ferri" (literally "flowers of iron") associated with bands of "oxide material" in the north-south trending joints. "Flos ferri" are tangled helictites of aragonite. Aragonite is also found in Caesar's Hall and near Frustration Lake in the form of radiating masses. It is possible that calcium carbonate has precipitated into the aragonite crystal form as a result of the presence of magnesium in dolomitised limestone near the joints.

Gypsum is present in the floor of Helictite chamber (marked HC in figures 2 and 3). It is possibly the result of oxidation of iron pyrites in the ore bodies reacting with the limestone. Note that both pyrite and goethite is mentioned as occurring in the mines area (ref 4). Some of the chemical reactions are as follows:

1. Iron pyrites is oxidised in the presence of water and air forming hydrated iron oxide (goethite) and sulphuric acid (there are a few other possible reactions forming different iron oxides).

$$4\,FeS_{2(s)} + 14\,H_2O_{(l)} + 15\,O_{2(aq)} \Rightarrow 4\,Fe(OH)_{3(s)} + 16\,H^+_{(aq)} + 8\,SO_4^{2-}{}_{(aq)}$$

2. Sulphuric acid in water reacts with calcite in limestone to form gypsum and carbon dioxide (and holes in the limestone). Note that gypsum has a higher solubility in water than has calcite.

$$2\,H^+_{(aq)} + SO_4^{2-}{}_{(aq)} + CaCO_{3(s)} + H_2O \Rightarrow CaSO_4 \bullet 2\,H_20 + CO_{2(g)}$$

Calcite in the form of extensive flowstone is found in the cave before the water crawl. Some of the flowstone is cracked. It is possible that it has been affected by gypsum crystals wedging from underneath the flowstone. Note that the presence of gypsum in solution will cause calcite to precipitate from solution (the common ion effect). Is this the reason for the extensive flowstone in this section?

Other minerals in the cave especially in Caesar's Hall and Rockfall Chamber have not yet been identified, however they could be an unusual form of calcite.

Of interest is the list of elements from the nearby mine addits and dumps described by the NSW Geological Survey: gold and silver (minute quantities), copper, lead, zinc, iron, arsenic, tin, tungsten, molybdenum, nickel, cobalt, bismuth and cadmium. This list would give one second thoughts about drinking the cave water, especially as the "ironstones" described were rather high in some of these elements.

Conclusions

Wyanbene is a most fascinating area. There is still much more work to be done: nomenclature of surface features, tagging, surface surveying, mineralogy, speleogenesis, geomorphology and hydrology.

Acknowledgements and References

1. "Wyanbene Cave", Map by J. Brush, J. Furlonger, K Palmer, D. Hughes, M. Ellis, E. Collins, M. Coggan, C. Keppie, A. Harding, W. Allen and C. Collins, National University Caving Club 1972-3.

2. "Ridge Mine Pot, Wyanbene, New South Wales" by J. N. Jennings, M.A., "Helictite" January 1963.

3. Chris Norton, Sydney University Speleological Society: Personal comments regarding tag numbers and SUSS trip to Ridge Mine Pot on 3rd July 1994.

4. "A Rock Chip Geochemical Survey of the Wyanbene Base Metal Prospect, near Braidwood" by S.J. Richardson, J. Byrnes and P. Degeling, Metallic Minerals Section, Geological Survey of New South Wales Department of Mineral Resources (GS1981/430, M79/2979).

5. Andy Spate, NSW National Parks & Wildlife Service - personal comments and assistance.

6. John Brush, Canberra Speleological Society - personal comments regarding survey of WY1.

7. Ian Cooper, Sydney University Speleological Society: personal comments regarding ore bodies at Wyanbene during SUSS trip 31st October 1993.

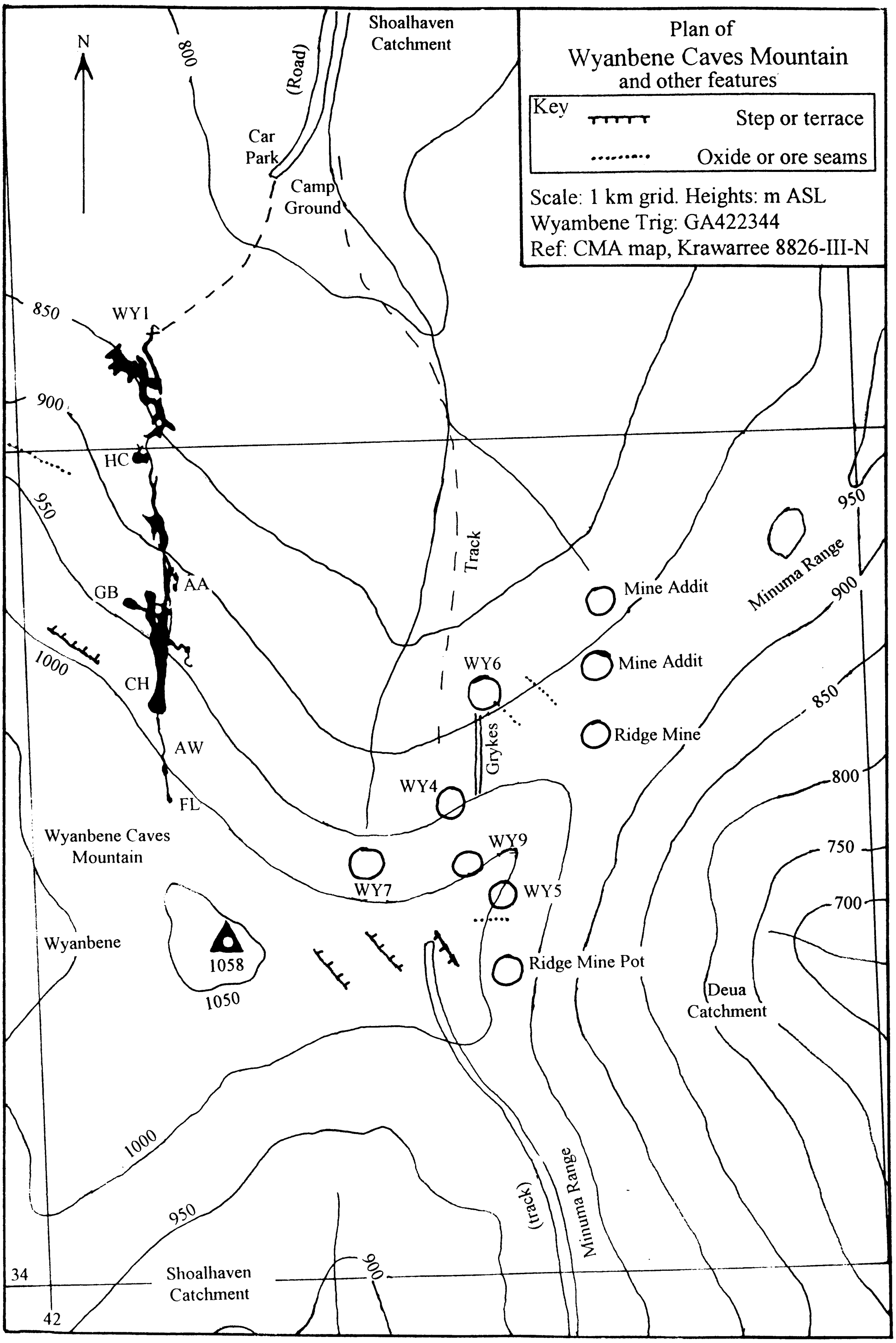


Figure 2: Plan of Wyanbene Caves Mountain and other features

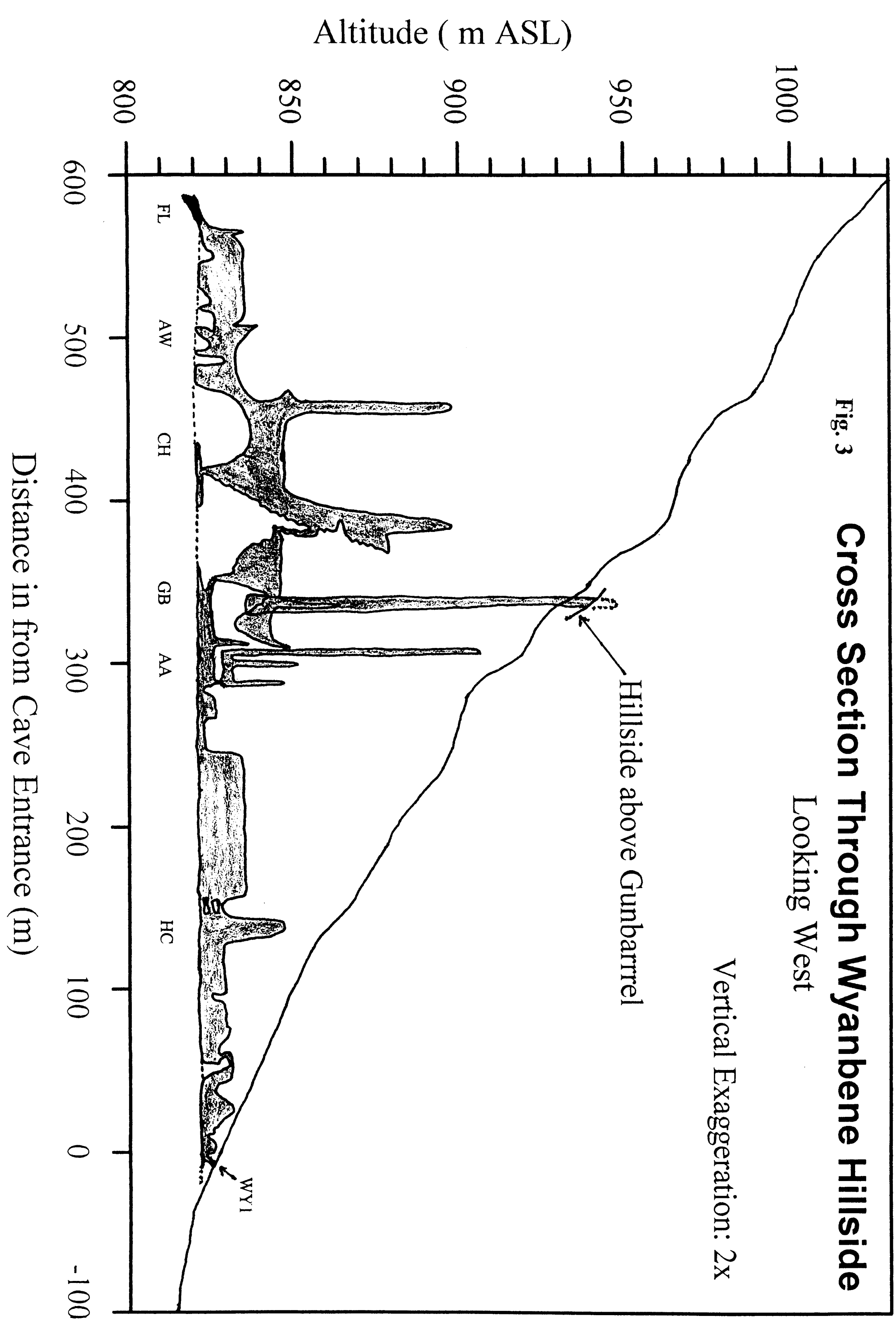


Figure 3: Cross Section Through Wyanbene Hillside

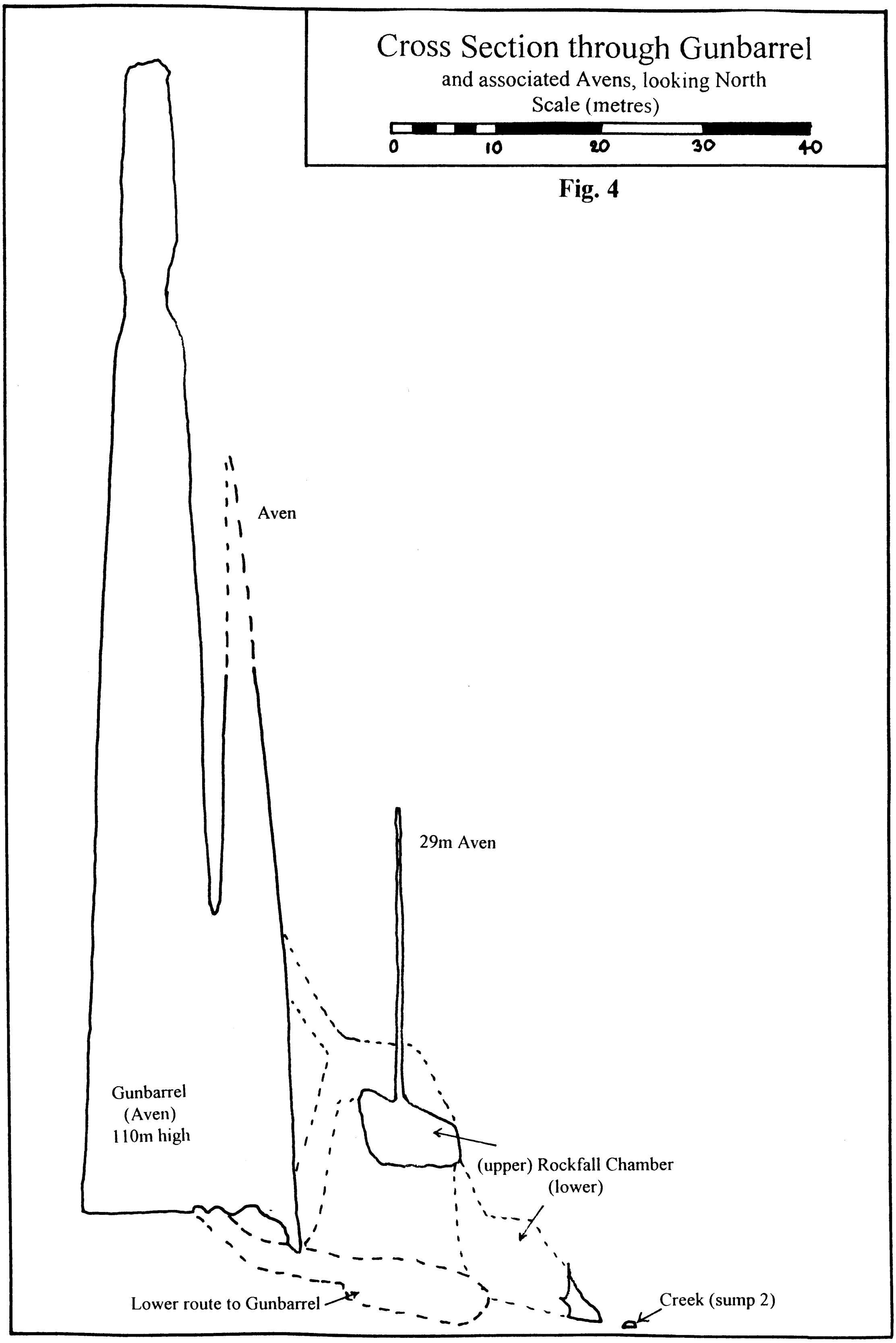


Figure 4: Cross Section through Gunbarrel

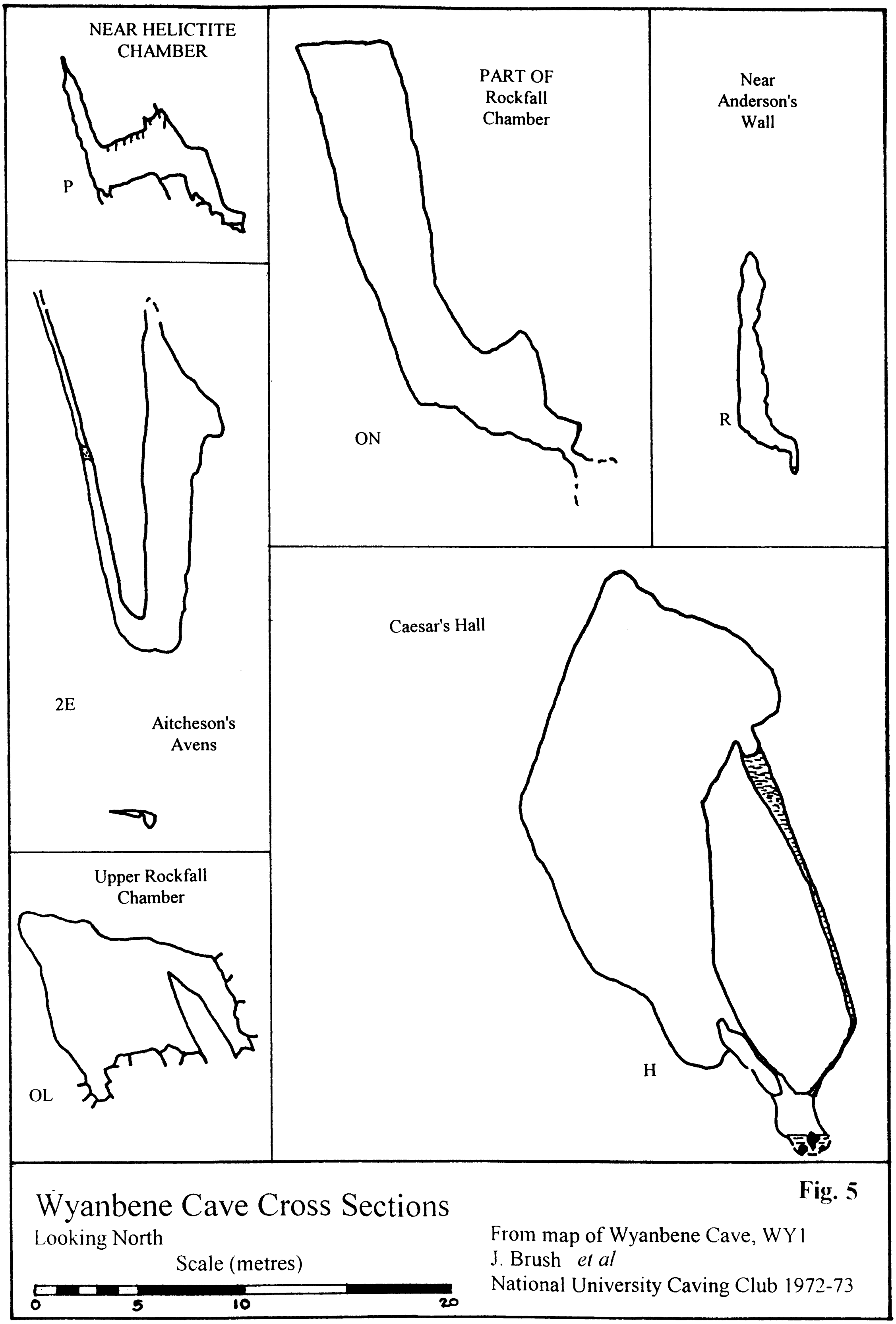


Figure 5: Wyanbene Cave Cross Sections

Caves in Thailand: A Historical and Cultural view

John R. Dunkley

Caves have been utilised by man in Thailand since prehistoric times and continue to play a significant role in cultural traditions and local economic development.

More than 100 are of archaeological significance, providing evidence of prehistoric occupation, burial and art sites dating since long before the arrival of the Thai people. Some provide evidence of early hunter-gatherer communities 11,000 years ago, others in the north and west contain wooden coffins, among the few artifacts of a culture which inhabited the remote mountains for a millennium before disappearing perhaps a thousand years ago. In central and southern Thailand several house Buddhist images created by the Mon, a civilisation whose very existence was until their discovery known virtually only from Chinese sources. Two hundred or so are currently used by the Buddhist community as places of worship, meditation or retreat; some have been so utilised for a thousand years or longer, providing through their religious art and sculpture an insight into the ebb and flow of civilisation and history and forging a strong affinity between the country's caves and its culture. In southern Thailand several important caves have been exploited for birds' nests for several hundred years.

In Central Thailand particularly few records survived the fall of the capital Ayutthaya to the Burmese army in 1767. During the invasion caves were reputedly used to cache artifacts and shelter local people and some have given up relics of this period. Although European contact preceded this defining event in Thai history, the first references to caves date from re-opening of the country in the 1820s, and many travellers during the following century added their often Eurocentric observations on the great temple caves particularly.

In recent years economic growth, improved transportation and increased leisure opportunities have greatly increased cave visitation and pressure on cave and karst resources from quarrying, forestry, dam projects and rampant commercial developments in sensitive areas. Nearly half the 65 or more national parks contain caves and more than 50 caves including many cave temples are visited by perhaps 2 million tourists a year, providing financially rewarding attractions to local communities. Although some 11% of the land surface is protected in some form, environmental debates have raged in a manner similar to those in Australia and elsewhere. Recognition of the need to conserve and manage these resources is well advanced despite limited funding.

Poster Summary:

Cave Numbering System

Norman Poulter

Speleological Research Group Western Australia

Cave numbering is an essential part of caving. Not only does numbering keep track of the number of features in a given area, it is also a simple method of referring to a cave that has not been named (a desirable attribute in today's geographical mapping climate), and to identify one cave from another (especially important where there are multiple entrances close together).

Many methods of cave numbering have been used in the past. None appear to have been universally successful, mainly due to environmental problems. Many tags were hard to see because they blended into the colour of the rock or were 'lost' due to the size of the cave entrance.

SRGWA advocated using 50 mm reflective discs with attached 30 mm stamped, plain aluminium discs during the 1993 TasTrog conference (Poulter 1993). SRG has used these discs to attach number tags to caves at Kununurra (1988 and 1989), Nullarbor Plain (1991-) and Wanneroo. The tags have also been used by the Top End Speleological Society in the Northern Territory.

The use of reflective number tags (*NumTags*) is endorsed by Western Australia's Department of Conservation and Land Management (CALM) for the identification of Nullarbor caves under its jurisdiction.

SRGWA is advocating the standardised adoption of NumTags throughout Australia.

References

Poutler, N. (1993). Protecting Caves From People. *TasTrog Conference Papers.* 19th Conf. Aust. Spel. Fedn. pp 80-89.

Poster Summary:

Track Marking System

Norman Poulter

Speleological Research Group Western Australia

SRGWA, like many other societies throughout Australia, have been concerned for quite some time about the damage that visitors cause in caves. During the late 1970's SRG began looking for inexpensive sources of reflective material; the best source ultimately being damaged road signs.

In the early 1980's, a small quantity of damaged signs were acquired for testing in caves. These signs were cut into 20 mm discs and quite a few found their way into Bob Woolhouse's Kubla Khan (Tasmania) clean-up project of that period.

In the late 1980's, more signs were acquired from the Western Australian Main Roads Authority on an ad-hoc basis and a semi-mass production system set up. Following the formation of a regional cave management advisory committee with WA's Department of Conservation and Land Management (CALM), moves were made towards a standardised approach to track and route marking with caves throughout Western Australia.

During 1993 and 1994, a colour coding system was formalised for use throughout CALM's cavernous regions, and several authorities were approached for funding enabling more efficient production of reflective 30 and 50 mm discs. The track marking funding project led to the development of the multi-purpose *TrackTag*, a PVC "price tag" for use in conjunction with reflective discs to designate routes, track widths and "fishing line" barricades.

SRGWA is advocating a standardised adoption of track marking codes throughout Australia.

A small quantity of materials will be available for sale at Vulcon.

Abstract:

Long basaltic lava flows and lava tubes and channels - Is there a relationship?

E. B. Joyce

School of Earth Sciences, University of Melbourne

Long basaltic lava flows are found in the young volcanic provinces of Queensland and Victoria, in the southern USA, and in recent eruptions in Hawaii. Flows which are young enough to retain 'stony rise' surfaces can be readily traced, and flow length, width, gradient and volume determined. Older flows are more difficult to trace continuously, but there is no reason to suppose that the earliest flows in the Newer Volcanics of Victoria were not also long 'stony rise' flows.

Lava tubes are relatively common in both Queensland (Stephenson and Griffin 1976) and Southeastern Australian provinces (Webb, Joyce and Stevens 1993). Most lava tubes are in flows which have been dated as or are obviously young. An age range of 2 Ma to present, and in most cases considerably less than 1 Ma, is most common. These are the Rouse and Eccles Regolith Terrain Units of Ollier and Joyce (1986). Amongst the older lava tubes in Victoria are Parwan Cave (perhaps 2Ma) and Panmure Cave at 0.57 Ma, and the youngest include the Byaduk Caves in the Harman Valley flow of Mt Napier at about 8000 BP and small tubes at Mt Gambier at 4,400 BP.

Tubes occur in a variety of topographic settings (Webb, Joyce and Stevens 1993) including at the foot of scoria cone complexes (Mt Napier), in the flanks of lava shields (Mt Hamilton), at the distal edge of a flow (Panmure) and at varying positions within a flow (Mt Napier and Mt Eccles).

An obvious suggestion is that confinement of a flow in a channel or tube is necessary to allow a long flow to develop, and tubes are sometimes closely associated with lava channels as at Mt Eccles and Mt Napier (Joyce 1987) but sometimes are not, as at Mt Porndon and Mt Hamilton.

So do all long basaltic flows have tubes or channels or both? And do such tubes and channels differ in any significant way from tubes and channels in different settings, eg. are long tube systems only found on long basaltic flows?

References

Joyce, E.B., 1987. Layered-lava, lava channels and the origin of lava caves. in Mackey, P.J. (ed.) Proceedings of the XIII Biennial Conference of the Australian Speleological Federation, held in Melbourne, Victoria, December 1908, pp. 40-48.

Ollier, C.D. and Joyce, E.B., 1986. Regolith terrain units of the Hamilton 1:1 000 000 sheet area, Western Victoria. B.M.R. Record 1986/33.

Stephenson, P.J. and Griffin, T.J. 1976. Cainozoic volcanicity of North Queensland, 25th IGC Excursion Guide 7A, 39pp.

Webb, J.A., Joyce, E.B. and Stevens N.C. 1993. Lava Caves of Australia. Proceedings of the Third International Symposium on Vulcanology, Bend, Oregon 1982, pp.74-83.

Abstract:

Conservation of lava caves: Evaluating heritage significance and developing management techniques

E. B. Joyce

School of Earth Sciences, University of Melbourne

Lava caves are a subset of caves in general, and differ in often being high and wide, not very long, and simple in plan and elevation (I know this is a gross generalisation!). Lava caves often occur in groups, but are generally restricted to discrete localities such as valley flows, flanks of cones or shields, or associated with lava channels in stony rises. They are often approachable by car, and relatively easy to enter on foot.

Because of these general attributes, lava caves are ideal localities for making measurements and mapping features, and contrasting and theorising about processes of formation and subsequent development. A good example of a set of caves to do this is the Byaduk Caves, in the Harman Valley flow from Mt Napier.

Having a set of related caves also allows for management techniques which control visitor access, developing where necessary access to only one or several caves while limiting access to others.

Popular presentations using displays, field signage, leaflets, booklets and maps (for example as done over past years for the volcanic features and caves at Mt Eccles National Park), perhaps also with colour slide shows or multimedia presentations, can help generate interest, and direct and control visitor access.

So is this in any way different to what is done with other caves? The more direct relationship between surface landscape and landforms, including the general volcanic landscape, allows a ready appreciation of the past but rapid processes of volcanic activity, and involves visitors in a different way to the appreciation of limestone and other caves. I believe a methodology of lava caves conservation can be justified, and this paper will present some ideas for such a methodology.

Reference

Joyce, E.B. and Webb, J.A., 1993. Conservation of lava caves: Examples from Australia. Proceedings of the Third International Symposium on Vulcanology, Bend, Oregon 1982, pp 121-123.

Abstract:

The Formation of Volcanic Caves

Ken Grimes

This paper discusses the formation of caves in volcanic rocks, particularly basalt. Lava caves form in flows by the processes involved in the draining of still molten material from beneath a solidified crust and also by the crusting over of surface lava channels that have fluctuating lava levels. The variety of underground and surface features which form in these circumstances are discussed in the context of the western Victorian lava province.

Recent information on the formation of volcanic caves is found in Grimes & Watson (1995) and Grimes (1994).

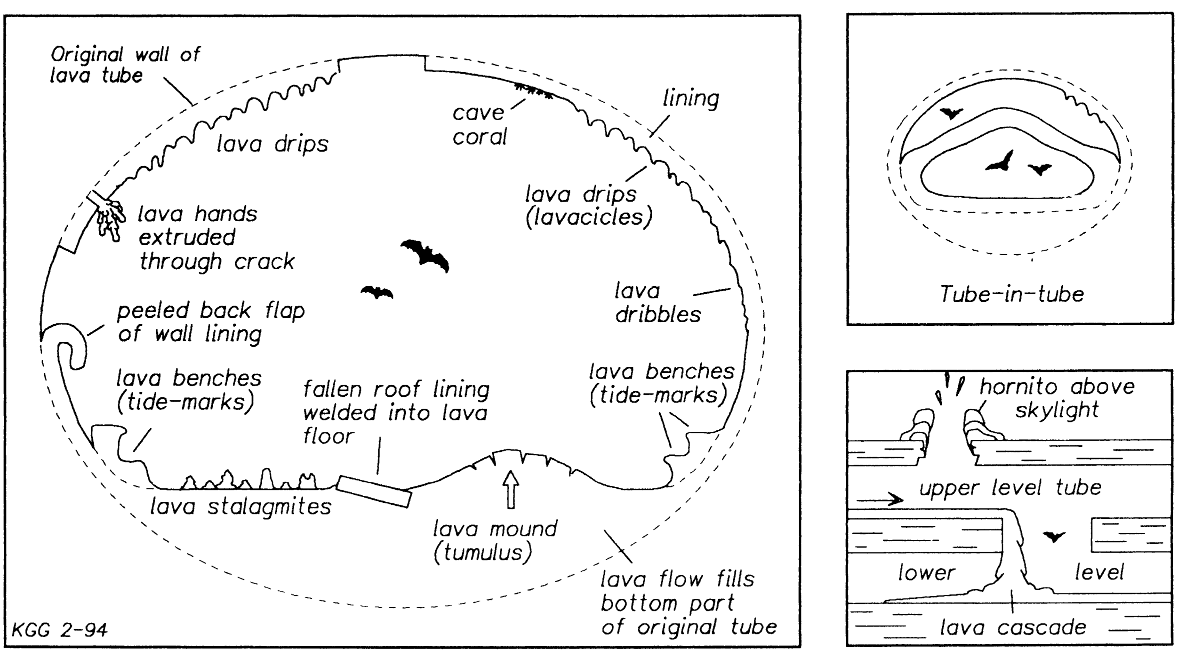


Figure: Features and 'Decorations' found in Lava Tubes

References

GRIMES, K.G., 1994, The Volcanic Caves of Western Victoria, *Australian Caver* 136: 9-14.

GRIMES, K.G., & WATSON, A., 1995: Volcanic caves of Western Victoria. IN: BADDELEY, G., (ed.), 1995, *Vulcon Guidebook,* Vict. Speleo. Assoc. Inc., Melbourne, pp 39-68

Abstract:

Structural Limitations on the Capacities of Voluntary Speleological Organisations

Patrick Larkin

The author examines how constitutional, administrative, financial and other 'structural' limitations faced by voluntary speleological organisations in Australia affect the abilities of such organisations to meet external and internal challenges. Particular attention is paid to the last decade of the Australian Speleological Federation's experiences and reform. The present 'structural' limitations of ASF and its member bodies are examined and the future of these bodies considered.

Abstract:

Sellicks Hill - Past, Present and Future

Mac Macdonald

Cave Exploration Group of South Australia

Many Australian cavers have generously donated funds and their time to support the Sellicks Hill Quarry Cave issue; the first part of this paper presents a brief report of what happened at Sellicks Hill and the events which followed.

All Australian cavers will be affected by the Sellicks Hill affair. The second part of this paper examines why it happened, the current status and likely outcomes, and how Australian cavers will be affected in the future by what has happened at Sellicks Hill.

Abstract:

Caves and Caving in Today's Romania

Botez Mihai

President, Transylvanian Speleological Society (TSS), Romania

Romania has now over 12,000 caves, considering caves longer than10 m or with a height difference bigger than10 m. This is the result of the creation of the first Speleological Institute in the world, at Cluj, Romania, in 1920, by Emil Racovita, with all the consequences concerning the scientific research in caves and the hard work of the amateur cavers, who explored and mapped most of these caves. In 1978 the National Speleo Competition 'speosport' was 'born', which had in part both good and bad results. The good results are the exploration and mapping of more than 11,000 caves, lots of scientific work, the professional cavers and the bad results were the fights and arguments between the clubs and the leadership at that time (not very democratic).

Before 1990 in Romania there were more than 60 caving clubs and one national Commission as part of the Tourism and Mountaineering Federation. In 1990 this commission was broken into five regional or national organisations; the Transylvanian Speleological Society, the Romanian Society of Speleoplogy and Karstology, the Speleological Society of Banat, Group for Underwater and Speleoplogical Explorations and the Central Speleological Commission from the Romanian Federation of Tourism, Mountain Rescue and Speleology - a government body. After 5 years of discussions, in October 1994, these organisations founded the Romanian Spelological Federation as a non-government and non-profit organisation.

Because of the events from 1989 and 1990 and because of the lack of interest in and money for speleology, the activity of the Romanian cavers decreased. In 1993 it began to increase again, but not as much before 1989. Now there are only a few speleo organisations (about 15) with any real activity.

In these condtions the most important results of the last years are:

1990 3 km explored in the longest Romanian cave - Vintului Cave (44 km) (the Amateurs Caving Club from Cluj).

The Pothole Polenita reached from - 100 m depth to a depth of 247 m and the system (the Humpleu System) a height difference of -347.6 m (the Politehnica Speleo Club from Cluj).

1991 2 km explored in the Humpleu System (34 km length) (Speleo Club 'Emil Racovita' from Cluj).

1992 The Pothole V5 reached a depth of -273 m (the T.S.S. Summer Caving Camp).

The Pothole from Grind reached a depth of -505 m (the Politehnica Speleo Club from Cluj).

1992-1993 5 km explored in the Cerbului Cave.

1993 7 km explored in the Pothole Adrian for the total depth of -250 m (the T.S.S. Summer Caving Camp).

1994 7 km explored in the Pothole Adrian for the total depth of -265 m - and a length of 11,718 m mapped. (the 'Z' Oradea Speleo Club and the T.S.S. Summer Caving Camp).

During the same time several caves and potholes no longer than1 km or deeper than 100 m were explored, and also few important caves were re-mapped.

In particular the Adrian Pothole (Bad Valley) was found in 1986 by a 5 year old child, son of one of the greatest Romanian cavers of the 70s and 80s - Liviu Valenas, founder of the 'Z' Oradea Speleo Club. During 1990 the cave was explored to 200 m length and 32 m depth. In 1990, during an inter-club caving camp 'Z' Oradea, Ursus Spelaeus Tirgu Mures, Speleotex Cluj, the pothole Labirint Bucuresti reached 1k m length and 118 m depth. The terminus point was represented by a narrow diaclase. In May 1993 Zih Ioska passed the narrow place and explored few hundred metres of gallery. During the 1992 T.S.S. Summer Caving Camp (July 19 - August 4) and a T.S.S. Caving Trip in August (16-22) the pothole reached 6 km length and 250 m in depth. In October 1993 during a caving trip another 2 km of new galleries were found. In 1994, another 7 km of gallerieswere explored, the cavity was mapped on 11,718 m length for 265 m depth and the second entrance was found. This new entryrance makes it easier access to the terminal point - the second siphon downstream. Also in 1994 was found the possible outlet spring of the cave.

The Adrian Pothole is developed in dolomites and grey anisian limestones of the Ferice structure, under the andezitic Cirligati - Cornu Mutilor - Fintina Rece. The extension of the karstificable rocks is only small at the surface, corresponding to a band150-300 m in width, but it increases under the surface to 2 km in width in the Popii Valley. The limestones and dolomites are limited by Werfenian and Permian quartz sandstones.

The cavity has big rooms (90/20/30 m, 50/30/30 m), and high galleries. It represents a cavity with the biggest surface area covered with gypsum in Romania and it has some 'tops' as concerning the dimensions of the gypsum formations anthodite of 34 cm length, needle pmonocrystal of 28.5 cm length, needle monocrystals (0.2 - 0.3 mm thickness) of 15 cm length, gypsum rope (angels' hair) of 15 cm length.

It should be mentioned the presence of other minerals such as: quartz, limonite, malachite, celestine, hydromagnesite, and aragonite. The calcite formations are present in many places and various forms (stalactites, stalagmites, pool basins, helictites, monocrystals 5-6 cm length).

The exploration and the mapping activities were stopped for a while, because of the difficult access and bad weather, but the cave still continues. A scientific research concerning the minerology and the bio-speleology was started in November, during a three day caving trip (4-6 Nov.), in collaboration with two speleologists from the 'Emil Racovita' Speleological Institute from Cluj, both members of the T.S.S.