VULCON Guidebook

20th ASF Conference Hamilton Victoria 1995

Earth, Water, Fire and Air
Vulcon

VULCON Guidebook

Lava Features and Limestone Karst of Victoria and South-Eastern South Australia

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1. Introduction

Vulcon Guidebook

This guidebook is produced as an introduction to the field trips for Vulcon, the 20th Biennial Conference of the Australian Speleological Federation, held at Hamilton, Victoria during January 1995.

A great debt is owed to *Victorian Caves and Karst*, produced for the *Cave Convict* 13th ASF Conference held during December 1980 and January 1981. *Victorian Caves and Karst* concentrated on the caves and karst of Eastern Victoria, whereas this guidebook emphasises Western Victoria and the Lower South-East of South Australia.

Western Victoria is where we continue to find not only new caves but new cave areas, despite it being a well settled agricultural area of the state. It is an area of volcanic caves and features, and the karst features of the Cainozoic limestones.

The reason we continue to have ASF conferences is at least partly to share with other cavers and speleologists the caving areas we enjoy. For those of us for whom the volcanic caves and the caves and karst of the Cainozoic limestones are our great enthusiasms in caving, this volume gives us an opportunity to share these with others. This will be even more so if people take part in the field trips and experience what we describe here.

Glenn Baddeley, as Editor of this field guide, has put together an excellent publication. I believe you will all enjoy using it, and I hope you will all enjoy the field trips to what are, in my mind, the **best** caving areas in Victoria.

Susan White

Chairman, Vulcon Organising Committee.

The Structure of this Guidebook

Chapter 2 provides an overview of the caves and karst areas of the whole of Victoria. The state is then divided into the two physically distinct Eastern and Western regions for further introductory discussion in the next two chapters.

Chapter 3 gives a very brief outline of the major caves and karst areas of Eastern Victoria. For more information, the reader must seek out the many other publications which cover these areas in great detail.

Chapters 4 to 8 make up the kernel of this guidebook and focus on Western Victoria. Chapter 4 outlines both the volcanic and limestone areas. The volcanic features and caves of Western Victoria are described in Chapters 5 and 6. The limestone caves and karst of Western Victoria are described in Chapters 7 and 8, based on the age of the host rock in the Tertiary and Quaternary Periods.

Chapter 9 describes the closely associated limestone caves and karst areas of the Lower South-East of South Australia.

The guidebook rounds out with a Glossary of some terms with which the reader may not be familiar, and an Appendix depicting some of the symbols used in cave maps, particularly of lava caves.

From the Editor

In this emerging age of real power in desk-top computers and graphical word processing software, a single person can confidently undertake an editing and production task which once seemed daunting for even a group of people, and without the need for typists.

This guidebook was wholly prepared 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 do 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. Chapter 9 was obtained using electronic mail (email) via Internet.

Despite the disparate sources of text, a consistent, good quality and readable presentation has been achieved using the Bitstream Inc. font *Century Schoolbook* throughout. Most of the figures were produced using a digitiser and CAD package by Ken Grimes, the rest were hand drawn and manually pasted. The final artwork was rendered on a 1200 DPI plain paper imagesetter and reproduced using an offset print process.

Glenn Baddeley

Editor

Field Trips

The field trips are an official part of the conference programme, but this summary is only a guide and is subject to variation. They are supervised and coordinated by members of VSA or CEGSA. You must check in with them to participate in any cave visits. There are also self-guided surface field trips at the end of Chapter 5.

Table 1-1: Field Trip Summary

When	Where	Type	Coordinator(s)	Comments
Pre-conference Tue. 27 Dec. 1994 - Sun. 1 Jan. 1995	Mt. Eccles National Park	Drop in or camping. Walk or drive to local caves.	Ken Boland Peter Stewart	BYO everything. Follow signs to camp-site 3. $2.50 / person / night. Toilets and showers.
During conference Wed. 4 Jan. 1995	Byaduk	Half day trip covering several lava tunnels.	Susan White Tony Watson Brett Wakeman Ken Grimes	1:30pm depart Hamilton. 6:00pm arrive back at Hamilton.
Post-conference Fri. 6 Jan. 1995 - Sun. 15 Jan.	Mt. Eccles National Park	Drop in or camping. Walk or drive to local caves.	To be advised.	BYO everything. Follow signs to camp-site 3. $2.50 / person / night. Toilets and showers.
Sat. 7 Jan 1995 and Sun. 8 Jan.	Skipton Cave (H-1)	Two single day trips.	Tony Watson Brett Wakeman Margot Watson	Details to be advised.
Mon 9 Jan. 1995 - Thur. 12 Jan. 1995	Bats Ridge	Cave visits.	Susan White	Details to be advised. Only one of these areas will be visited on any particular day.
	Glenelg	Cave visits, likely to include Princess Margaret Rose Cave (G-6)	Miles Pierce	
	Codrington	Cave visits.	Nick White Sam Berryman	
Sat. 7 Jan 1995 - Sun. 8 Jan.	Mt. Gambier	Cave visits.	Peter (Crunchy) Kraehenbuehl	Details to be advised.
Fri. 13 Jan 1995 - Sat. 14 Jan.	Mt. Gambier	Cave visits and snorkelling.	Peter (Crunchy) Kraehenbuehl	Details to be advised.

Acknowledgements and Credits

The Vulcon Committee and the Editor wish to thank the following people for their valuable assistance and contributions to this guidebook:

Samantha Berryman and Susan White (figure 8-2, redrawing figures 2-1, 2-2, 6-6, 6-7, 7-1); Susan White (figures 8-3, 8-4, table 2-2); Ken Grimes (figures 4-1, 4-2, 5-1, 5-2, 5-3, 5-4, 5-5, 6-1, 6-3, 6-4, 6-5, 6-8, 6-9, 6-10, 6-11, 6-12, 6-13, 6-14, 9-1, A-1, A-2, redrawing figure 6-2); Geoff Hammond (redrawing figure 8-1).

Brett Wakeman (cover photograph); Jenny Watson (proof reading); Raia Wall, Peter Ackroyd, Peter Matthews, Roger Taylor (reviewing and proof reading); Geoff Hammond (cover layout, printing production); Ken Grimes, Susan White, Kevin Mott, Tony Watson, Glenn Baddeley (authors). Members of the Victorian Speleological Association Inc. (VSA) and the Cave Exploration Group of South Australia Inc. (CEGSA) for verifying parts of the text and coordinating and leading the field trips.

Conservation and Land-owner Relations

Caves and their contents are in general susceptible to damage from inexperienced visitors. Likewise inexperienced visitors can damage themselves in caves. V.S.A. is therefore careful about the distribution of its cave information. The information is not available to the general public but is available for legitimate speleological research and land management. Likewise, even experienced cavers need to recognise the damage they can do to caves if they are not very careful. Please be careful.

In Victoria we have been able to avoid having complicated access arrangements in many cases, as we have been mostly able to reach satisfactory agreements with the land-owners and managers.

The following guidelines apply at all times to visiting caves on farmland and private property. Most areas have been very dry recently and so the farmers are fairly edgy. Anyone who offends will be asked to leave the area immediately.

1. Always ask permission before entering farmland, unless told otherwise by the area co-ordinator for conference field trips.
2. Leave all gates as they are. If they are closed when you reach them, close them after you. If they are open, leave them open. This is very important as expensive breeding programs can be wrecked by one moved gate.
3. Avoid the animals, especially calves and ewes with lambs.
4. Take care of fences; avoid climbing over them as it stretches wires.
5. Remove all rubbish.
6. Don't pollute water supplies.
7. No digs on farmland.
8. Replace rocks, logs or wire covering up holes after leaving them.
9. Use common sense.

In most cases on public land we have been able to organise access to particular areas, but please check with the area co-ordinator first.

2. Overview of Victorian Caves and Karst

Susan White

Introduction

The purpose of this chapter is to provide an overview and introduction to the various karst and cave areas of Victoria with special emphasis on their geological setting.

Tables 2-1 and 2-2 show the various types of caves encountered in Victoria, whilst Figure 2-1 shows where they occur in the state. Table 2-3 indicates the time-scales involved for the periods and epochs of the host rock.

Table 2-1: Victorian Cave Types (after Mill et al., 1980)

ROCK TYPES	PERIOD / EPOCH	AREAS
Limestone	Quaternary	Bats Ridge, Cave Ridge, Cave Hill, Codrington, Cape Bridgewater
	Tertiary	Glenelg River, Warrnambool, Nowa Nowa, Timboon
	Devonian	Buchan, Murrindal, East Buchan, New Guinea Ridge, The Basin, Jackson's Crossing, Gillingal, Bindi
	Silurian	Limestone Creek, Indi, Mitta Mitta
Basalt	Late Tertiary to Pleistocene	Western District Lava Plains to Parwan, including Mt. Eccles, Skipton, Mt. Hamilton, Mt. Napier
Granite	Late Devonian	Labertouche, Britannia Creek, Mt. Buffalo

Table 2-2: Victorian Sea Caves

ROCK TYPE	PERIOD / EPOCH	AREAS
Basalt	Pliocene	Cape Bridgewater
	Eocene	Cape Schanck
Limestone	Tertiary	Port Campbell coast
Sandstone	Cretaceous	Cumberland River, Cape Otway, Cape Paterson
Mudstones	Devonian	Cape Liptrap

Table 2-3: Geological Time Scale (after Cochrane et al., 1991)

ERA	PERIOD	EPOCH	DURATION[1]	COMMENCED[2]
Cainozoic	Quaternary	Holocene	0.01	0.01
		Pleistocene	1.6	1.6
	Tertiary	Pliocene	3.4	5
		Miocene	18	23
		Oligocene	13	36
		Eocene	17	53
		Palaeocene	12	65
Mesozoic	Cretaceous		80	145
	Jurassic		60	205
	Triassic		45	250
Palaeozoic	Permian		40	290
	Carboniferous		70	360
	Devonian		45	405
	Silurian		31	436
	Ordovician		74	510
	Cambrian		50	560
Proterozoic			1940	2500
Archaean			2100	4600

[1] Million years
[2] Million years before present

Victorian Cave Types

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

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

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

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

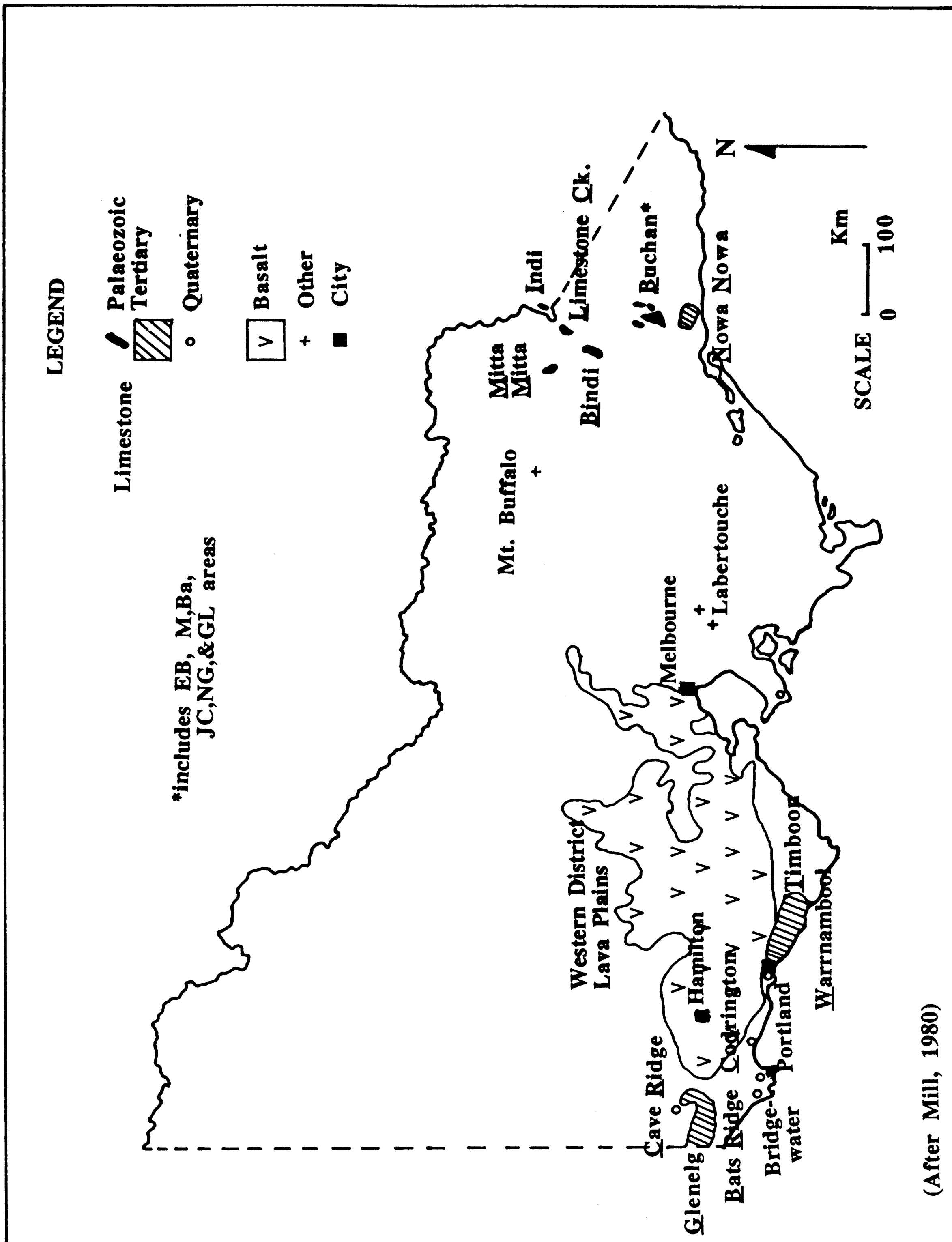

Figure 2-1: Victorian Caving Areas (after Mill et al., 1980)

1. Palaeozoic limestones

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

(a) Stream Passage Caves

Formed by perennial and intermittent streams, some examples show older abandoned high levels. Many are well decorated but not all are. Good examples include the tourist caves at Buchan, and Wilson Cave (EB-4).

(b) Vertical Potholes

These vary from blind shafts, eg. Baby Berger (M-14), to complex examples with both vertical and horizontal development, eg. Honeycomb (M-41) and Exponential Pot (M-125). Again there is a great variety of decoration. These caves form as a result of solution along the intersection of joint planes.

(c) Collapse Caves

These caves formed due to the collapse of roof material, eg. Anticline (M-11). Karst areas where such caves are found include the Buchan Valley, Limestone Creek, New Guinea Ridge and some other small areas in East Gippsland.

Research over the past 10 years shows that many of the caves in areas such as Buchan are extremely old, and places such as the Potholes have been subjected to inversion of relief, ie. what is now on the top of a main ridge, 200 m above the present river valleys, was the valley bottom (Finlayson et al. 1992). The caves were therefore formed below the water table before the landscape was lowered by erosion. These areas are described in some detail in Chapter 3.

2. Cainozoic limestones

There are large areas of Cainozoic limestone in Western Victoria and South-Eastern South Australia, but not a great deal of cave development in all areas of this western province. There are some areas with intense karst development, and yet other areas, sometimes not far away, where there is little development at all. The reasons for this are not very well understood, but appear to be related to the purity of the limestone. There is certainly sufficient rainfall. Compared with the caves in Palaeozoic limestones, there is more variation in the limestones, lower relief and very few joints .

Examples of Cainozoic limestone cave areas include Glenelg, Bats Ridge, Codrington, Timboon, Warrnambool, and Naracoorte. These caves tend to be horizontal, have collapse features, and are often multi-entrance. The quantity of calcite decoration is highly variable, the most common is moonmilk. The presence of solution pipes is a prominent feature in many areas.

Some Quaternary dune limestones show syngenetic karst development where prominent features include a cemented (calcreted) cap-rock near the surface, vertical solution pipes and low wide horizontal maze caves either just beneath the cap rock or at the level of the surrounding plains. The poorly consolidated nature of the rock means that collapse plays a very important role.

In all of the Cainozoic limestone areas solutional, subsidence and collapse dolines are important, and there is a large doline field in the Peterborough area that is largely undescribed. Other areas are described in more detail in Chapters 7 and 8.

3. Basalt

The Western District lava plains extend from Melbourne to about 50 km west of Hamilton, with an isolated flow at Mt. Gambier. They were formed in periods of volcanic activity in the late Tertiary and early Quaternary. Fluid lava erupted from fissures and shield cones and spread across large areas. One theory is that as the top layer of lava cooled, the still liquid lava below drained away, leaving lava tubes and caves. They vary from simple tubes to complex branching and multi-level tubes and other forms as well, eg. Mt. Eccles, Byaduk. Other spectacular volcanic features are also present such as volcanic cones, tumuli, and stony rises. The details on these features and areas are included in Chapters 5 and 6.

4. Acid igneous rocks

These have never been thought to be very important but are now shown to be more common and extensive. The main rocks are granite and granite-like rocks and examples of caves are found at Labertouche, near Warburton, Tynong, and Neerim South. Other igneous rocks also show cavities similar to this. A small cave on Mt. Bogong is an example. Very interesting small and rare opaline decoration is found in some.

There is a variety of forms from rockfall type to enlargement of joints in solid granitic rock. These areas are not described in detail in this field guide. The cave areas in this rock type are generally in eastern Victoria, but there are features similar in the Black Range granites in the Grampians area and Melville's Caves near Inglewood.

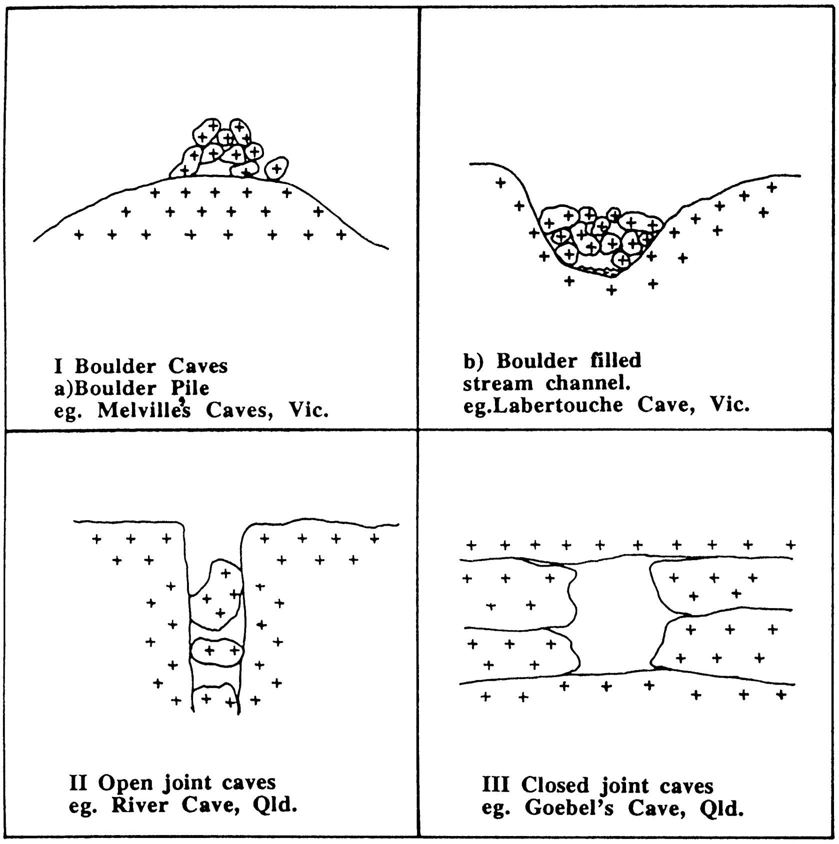

Figure 2-2: Types of Granite Caves (after Finlayson, 1986)

Finlayson (1986) describes three different types of caves in granite; boulder caves, open joint caves and closed joint caves, as shown in Figure 2-2.

The boulder cave type includes two sub types; caves in boulder piles, such as Melville's Caves and caves in boulder filled channels, such as Labertouche Cave. In both cases the more weathered material around the boulder cores are removed.

Open joint caves are formed by weathered material being removed from an open joint and roofed by boulders dislodged during the excavation of the joint. The best known example of this is River Cave, Girraween, in southern Queensland.

Closed joint caves are formed by erosion along a joint. The only known example is Goebel's Cave at Girraween, Queensland.

Granite boulder caves are not uncommon in Victoria. The best known and particularly well developed example is located in the headwaters of Labertouche Creek about 100 km east of Melbourne. The bedrock is a late Devonian granite known as the Tynong Granite. The cave is formed in a blind valley with the crest of the col terminating the valley about 25 m above the stream level. The 175 m of cave passage is comprised of spaces between the boulders.

Other caves of this type in Victoria are at Britannia Creek near Warburton, Mt. Buffalo and Neerim South.

5. Miscellaneous

These include sea caves in basalt (Cape Bridgewater), sometimes with limestone overlying the basalt; mudstones (Cape Liptrap), sandstones (Cape Patton, Cape Otway area, Cape Paterson, San Remo, Mt. Speculation), and caves behind waterfalls such as Den of Nargun in Mitchell River National Park. Included with this group is the extensive series of overhangs in the Grampians which are still undescribed in cave or karst terms, but which have important art features on their walls.

In most of these cases, erosion of weathered material has occurred along planes of weakness or by abrasion from high energy waves or streams. The arkosic sandstones and mudstones of the Otway Group and Strezlecki Group sediments in southern Victoria have significant joint enlargement caves at or just above sea level and at the coast. The caves along the Otway coast are briefly described in Chapter 4.

Summary

Caves in Victoria have been known and used by man for a long time. Aboriginal Victorians have left evidence of using caves as habitation sites (Cloggs Cave, East Buchan) and as art sites (Grampians and New Guinea Ridge). European interest in caves in the Buchan area is reasonably well documented since the visits by geologists such as Howitt and Stirling in the 1880s.

Nineteenth century interest in the caves of western Victoria is less well known but occurred. James Bonwick, a school's inspector who travelled around south-western Victoria published descriptions of caves and karst in 1858. Many detailed descriptions of the unusual mineralogy in Skipton Lava Cave were published in the 1870s and 1880s. The volcanic caves have been described in detail over the past century but less was done on the karst areas of the Cainozoic limestones. Some descriptions are available but they are often hidden among other geological material.

The perception that Buchan is the only cave and karst area of interest in Victoria is no longer current. The impression that one has about Victorian caves and karst areas is that there is immense variety of types and forms. There are many areas with small but very interesting caves in host rocks which are unusual, and new caves and new areas continue to be discovered.

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3. Cave Areas of Eastern Victoria

Glenn Baddeley

Introduction

The landscape conditions in Eastern Victoria makes caves relatively sparse and in a variety of rock types, except for concentrations of caves in the isolated limestone areas. Nearly all of the cave areas in Eastern Victoria (Figure 2-1) have been mentioned in Chapter 2, and the major caves have been described in detail elsewhere (Mill et al. 1980, Nicoll & Brush 1976).

This chapter summarises some of the knowledge from a geological and geomorphological perspective, and a bit of Buchan local history, including some of the developments from work done in the 15 years since the *Victorian Caves and Karst* guidebook was published.

Eastern Victoria is bisected and dominated by the Eastern Upland belt, a portion of the "Great Dividing Range" between the Snowy Mountains in New South Wales and the Western Uplands in Victoria. There are 12 peaks in the Eastern Uplands exceeding 1800 m above sea level, with the general trend in elevation dropping off towards the west, to Kilmore Gap which is at only 335 m. There are a several extensive "high plains" above 1300 m formed on mostly granitic rocks at least 200 million years ago, but the soils are immature and mostly organic.

The Eastern Uplands are the remnant of an extensive palaeoplain developed in the Mesozoic from a series of volcanic basalts, granites, sandstones and other rocks. These suffered episodic elevation and warping during various epochs of the Cainozoic, with the formation of a series of older volcanic plugs and flows in the mid Tertiary and a few newer volcanics in the Pliocene. The lavas flowed down river valleys of the time.

A long process of stream erosion, with intermittent uplifting of the landscape, has produced significant dissection, with steep sided valleys separated by high narrow ridges. The older volcanic lavas have been deeply weathered and the eruption points are difficult to recognise (Hills 1975, Cochrane et al. 1991).

There are many caves in the confined limestone areas of Eastern Victoria. Buchan is a major cave area and is well worth describing.

Buchan Area

In the Early Devonian, the Buchan Basin was a wide sea embayment in Eastern Victora. This formed after the movements of the Bowning Orogeny at the end of the Silurian and renewed subsidence in the Early Devonian. The Buchan Basin extended from Nowa Nowa near the coast to the headwaters of the Murray River around Indi.

During the early period of subsidence around Buchan, the explosive eruptions of Snowy River Volcanics overlaid the steep valleys, which were filled with river gravels. As the subsidence continued, the sea flooded in from the south and laid down the Buchan Caves Limestone in shallow water. The Murrindal Limestone and Rocky Camp Limestone were formed near a shoreline during a relatively stable period. As the sea became deeper, the mudstones and nodular limestones of the Taravale Formation were deposited. During the Tabberabberan Orogeny of the Middle Devonian, 375 million years ago, the entire area was uplifted and became dry land (Cochrane et al. 1991).

By the Eocene, about 50 million years ago, the Buchan area had developed a stable drainage pattern consisting of the ancestral Buchan-Timbarra and Murrindal-Snowy Rivers in much wider valleys than they are now. The rivers flowed across the Murrindal and Buchan Caves Limestones, and caves started to develop beneath the water table. Joint systems enlarged by slow moving ground-water formed the vertical nothephreatic caves typical of the Potholes area, eg. Oolite Cave (M-56).

Basalt eruption in the late Eocene disturbed the stability significantly, with lava flowing down the ancestral river valleys, and forcing new rivers to form along the edges of the basalt flow, against valley walls. Incision by these rivers of up to 400 m proceeded since then, with help from a total of about 180 m of uplift which occurred in several stages. The down-cutting of rivers around the volcanics is evidenced by gravels on top of spurs and hills, and basalt flows on the higher ridges. Eventually the water table dropped below the level of the Murrindal Limestone, allowing the secondary deposition of calcite speleothems in the caves.

Periods of extensive down-cutting and still-stand have occurred since the mid Miocene, which have erased some caves completely, left terraces of river gravels, and allowed the development of horizontal epiphreatic caves. The 3 km long Dukes Cave System in the Buchan Caves Limestone consists of the interconnected Dukes Cave (B-4), Federal Cave (B-7), Royal Cave (B-6) and Fairy Cave (B-5). Examination of this system shows three levels which correspond to terrace levels in the Buchan River valley. The system also runs more or less parallel to the strike of the limestone, but the well-developed flat roofs of the passages indicate stable groundwater levels which have sliced through the bedding planes, so the structural control is not strong. Collapse and rockfall have modified the roof in some places (Mill & Whitehouse 1992).

In-filling of caves with gravel and clay sediments has occurred since the Miocene, as well as further removal of sediments by incision of down-cutting streams, which resulted in the development of vadose canyons in the lowest levels of the epiphreatic caves. Caves which are only 10 - 20 m above the present river level have had speleothems dated at more than 350,000 years, indicating that they had drained before then.

The Buchan limestone area is now completely surrounded by non-karst rocks and extends about 20 km north-south by 2 - 10 km east-west, ranging in elevation from 40 - 260 m above sea level. Over 500 karst features have been documented in the area (Fabel 1989c, Fabel 1992a, Finlayson et al. 1992).

In modern history, the Buchan valley was first used for grazing in 1838. The caves were first mentioned in 1840 (Hamilton-Smith 1992). Guided cave tours were in operation in the 1880s, with reference to Wilson Cave (EB-4), which is today used as a training ground for wild caving.

James Stirling, the Government Geologist, visited Buchan in 1889 and was shown several caves, mapping some of them. In Stirling's report he suggested caves should be developed for the public. It wasn't until after the 1900 visit by the then Government Geologist A.E. Kitson, who recommended Reserves be proclaimed around important cave areas, and enthusiastic support from the Director Geological Survey, E.J. Dunn, that the Victorian Government began to take more notice (Kitson 1900, Dunn 1905, Hamilton-Smith 1988).

Locally born Frank Moon was appointed in 1906 by the Lands and Survey Department to find more caves as possible tourist attractions. He opened up Kitson's Cave (B-8) and discovered Fairy Cave (B-5) within a year, and was conducting guided tours through these and other caves. Moon also invited John Flynn (of the inland) to photograph some of the caves.

In 1907, the Government appointed F.J. Wilson from Jenolan Caves as the Buchan Caves supervisor, and at 66 years of age, he began setting up steps and wire netting in the caves. They were open for business in 1907, with a package tour available for the public from Melbourne. In 1910, Royal Cave (B-6) was discovered by pushing a rockfall in Fairy Cave by Wilson, Moon, and H. Brown, the local constable (Brown 1920, Hamilton-Smith 1988).

Various improvements such as electric lighting and access tunnels to the tourist system were constructed up until the late 1920s. The Buchan Caves Reserve received the status of a National Park in 1938, and a kitchen, toilet blocks, swimming pool and tennis courts were added (Hamilton-Smith 1988).

Cave exploration at Buchan and around the rest of Victoria was formally organised with the creation of the Victorian Cave Exploration Society in 1957. Interest in cave diving saw the formation of the Sub Aqua Speleological Society in 1960. The amalgamation of these two bodies occurred in 1967, to form the present day Victorian Speleological Association Inc.

The Friends Of Buchan Caves Inc., formed in 1987 and incorporated in 1991, are a group of people interested in helping the Department of Conservation and Natural Resources promote public awareness and understanding and foster conservation of caves and karst landscapes by undertaking various volunteer projects in the Caves Reserves.

The Rimstone Cooperative was formed in 1974 and has share-holding members. It owns and operates Homeleigh, a former guest house at Buchan which is mainly used by cavers. Rimstone also provide research grants for caves and karst related projects.

Field Trips

The Caves Reserve at Buchan is very busy with visiting and camping tourists at Christmas and New Year, taking in the marvellous bush setting, summer activities such as canoeing, and the several very fine guided tourist caves on offer. Wild caving in the main reserve is not permitted at this time of year.

There are various accommodation possibilities at Buchan, including camping in the main Caves Reserve, motels, cabins, hostels, or at Homeleigh. Booking in advance is essential for all these options.

There will be no conference field trips organised in the Buchan area, or in any other parts of Eastern Victoria. People wishing to visit any of these caving areas are requested to make their own arrangements or to contact VSA.

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4. Cave Areas of Western Victoria

Susan White and Ken Grimes

Introduction to Landscape and Caves

The landscape of Western Victoria is an interesting geological and geomorphological setting of recent volcanics and limestones. Although to the north of the area, such as in the Grampians, there are older rocks and landscapes, the cave and karst areas are generally in rocks less than 35 million years old. The landscape is much flatter, with prominent volcanic scoria cones of the Newer Volcanic Province and the windswept calcareous dunes of the coastal limestone areas.

The detailed descriptions of the volcanics are in Chapters 5 and 6, and of the limestone areas in Chapters 7, 8 and 9.

The cave areas can be grouped into three main categories:

1.	Lava caves:	Byaduk, Mt. Eccles and other volcanic areas.
2.	Quaternary limestone areas:	Bats Ridge, Codrington, Cave Ridge.
3.	Tertiary limestone areas:	Glenelg River, Portland, Warrnambool, Timboon and coastal areas.

Newer Volcanic Province

The Newer Volcanic Province of the Western District shows a number of interesting geomorphic features related to the lava flows. It is a flat to rolling basaltic lava plain dotted with fairly small volcanic cones which are the points of eruption. The volcanic province extends from the Melbourne area almost to the South Australian border, and the isolated volcanoes at Mount Gambier are a western outlier of the Province. The majority of the features of interest to cavers are in the Hamilton area.

Very few of the volcanic cones are over 150 m above their base and most are less than 100 m and, although distinctive in the landscape, relate to only 1% of the lava erupted. Volcanoes take the form of basalt shields, scoria cones, maars and complex cones. Other interesting structures are scattered across the area and include tumuli and stony rises as well as caves. Lakes are common as a result of disrupted drainage patterns, eg. Lake Corangamite, and most occupy the site of the former much larger 'Lake Corangamite'.

The Newer Volcanic Province ranges in age from the Pliocene (about 5 million years) up to very recent times. A large number of volcanic cones can be seen from the road. Some of the most interesting are Mt. Elephant (at Derrinallum), Mt. Napier (near Hamilton), Mt. Eccles (near Macarthur) and maars such as Tower Hill (near Warrnambool), Bullenmerri, Gnotok, Leura and Purrumbete. Mt. Elephant is the highest (237 m) and most perfect scoria cone on the Western Plains. The youngest volcano is Mount Gambier which has been dated at about 4,000 years old, while the two main volcanoes in the Hamilton area, Mt. Napier and Mt. Eccles have erupted in the last 20,000 years.

The areas with caves within the province are shown in Figure 4-1 (Grimes 1994). These are Byaduk, Mount Eccles, Mount Napier, Mount Hamilton, Parwan, Gisborne, Lady Julia Percy Island, Panmure, Mount Porndon, Skipton, Smeaton and Warrion Hill. Many of these areas only have one or two caves but Byaduk, Mount Eccles, and Mount Napier have the greatest numbers.

The Byaduk Caves are on the Harman Valley lava flow and there are a number of caves accessible. They vary from large spectacular tunnels, arches and collapse dolines where the main feeder tunnel in the lava flow has collapsed to smaller more complicated systems. The surface of the flow at Wallacedale (near Byaduk), has some excellent examples of surface pressure ridges and clusters of tumuli, or rounded steep sided domes of lava up to 10 m high and 20 m across. These lava 'blisters' have been interpreted by Ollier (1964) as being tumuli pushed up by lava.

Mt. Napier is a scoria cone from which the Harman Valley lava flow erupted. The flow contains many interesting features and the cone itself is worth a visit. A number of small caves are found on the flanks of the cone.

Mt. Eccles is a low basaltic cone with a small scoria hill on its south-east slope. Adjacent to this is Lake Surprise, a lake filling the cavities left by the elongated crater of the main basaltic cone. Mt. Eccles was the eruption centre of large quantities of basalt for an extensive lava plain in the south-west. From the cone area several lava channels or 'canals' were the main routes for lava at the time of eruption; lava flowed along them, occasionally spilling over the sides and building a 'levee bank' of basalt. The main canal commences at the northern end of Lake Surprise and divides into two; one branch flowing westerly into a complex system of slopes and valleys, the other more or less south-westerly into The Stones State Faunal Reserve. Another canal is to the south of Mt. Eccles and passes through Gothic Cave (H-10).

For details of the caves see Chapter 6.

Mount Hamilton has one large complex, multi-level cave developed on one side of the cone and several smaller caves nearby. At Warrion Hill five small lava caves have been recorded in the stony rises country. The longest is about 50 m of low wide tunnel (Frank, 1971). Mount Porndon has some interesting surface features and two lava tunnels (Skeats & James 1937, Ollier & Joyce 1968).

There are several areas with only one known cave: Panmure, a single bifurcating lava tunnel which has been intersected by a quarry (Gill 1944a, Gill 1944b, Ollier & Joyce, 1968); Parwan, a single tunnel with several low and broad arched chambers, considerably modified by collapse (Rees & Gill 1959, Mill, White & Mackey 1980); Skipton, which consists of two connected big chambers and several small chambers at the end which are modified by collapse (Ollier 1963); and Smeaton, where Armchair Pot is a single small shaft about 9 m deep with wall coated by melted rock (Smith 1979a, 1980b).

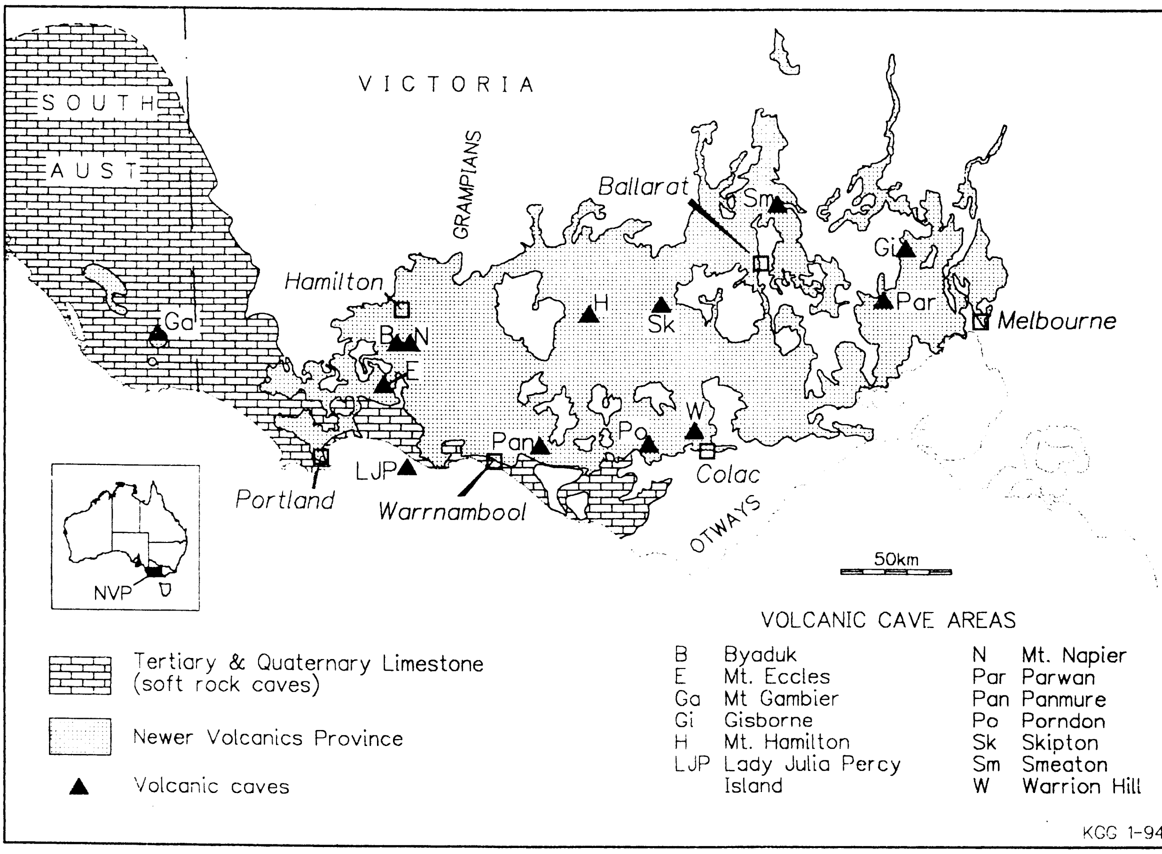

Figure 4-1: Caves of the Newer Volcanic Province, Victoria and South Australia

The Gisborne Bone Cave is an interesting feature in weathered tuff beneath basalt. It is not a primary lava cave and possibly could be due to piping rather than solution. It has been an important palaeontological site (Selwyn 1859, Gill 1964, Smith 1980a). Lady Julia Percy Island is reported as having two caves in basalt (Dewhurst 1937) but access is restricted as it is a State Faunal Reserve. Rocky shores, high waves and sharks also restrict access.

Tower Hill near Warrnambool is the largest of the Victorian maars. Like most of them it is nested, with a number of small scoria cones and a small lava flow inside an older crater. The first eruption was violently explosive, forming the maar and the final eruptions were more gentle, forming scoria cones (Figure 5-1). The whole complex is about 3 km across with exposures of pyroclastics around the edges. The pyroclastics are ash and lapilli and the beds dip at low angles away from the centre, with frequent cross bedding due to explosive gas blasts and base surges.

Ash extends for over 8 km east of the volcano and the area covered indicates a south-westerly wind during eruption. The main crater floor surrounding the scoria cones is occupied by a lake. Limestone bedrock is exposed near the shoreline of the lake under the tuff. Tower Hill is a State Faunal Reserve administered by the Department of Conservation and Natural Resources and has an interesting Natural History Study and Visitors Centre.

Cainozoic Limestones

West of the Cretaceous sediments of the Otway Ranges the coastline is predominantly Tertiary limestone or Quaternary calcarenite dunes. Karst in Western Victoria is in these two relatively young limestones, the Pleistocene calcarenites (aeolianites) of the Bridgewater Formation and the Tertiary Port Campbell Limestone of the Otway Basin (Kenley 1971). See Figure 4-2. The Cainozoic geological era includes the Tertiary and Quaternary periods. This time-frame therefore spans about 65 million years of which the last 35 million are of interest for limestones.

The Tertiary limestones were deposited in a shallow sea that flooded the region in the Oligocene and early Miocene (20 - 30 million years ago) and are extensive in Western Victoria but are of variable carbonate purity. Therefore, only limited areas show major karst development despite the extensive area of carbonates. These are Glenelg River area, Kentbruk (Kentbruck on the topographic maps), Timboon, Warrnambool and Drik Drik as well as some coastal areas such as the Port Campbell coast between The Twelve Apostles and Peterborough. The coastal areas have some impressive scenery and karst features (Baker 1943). The Glenelg River area and the coastal karst of the Port Campbell and Peterborough areas are described in more detail in Chapter 7.

More extensive karstification occurs in the Pleistocene aeolian calcarenite (aeolianite). These near-coastal dune systems show karst development which is indicative of lithification or syngenetic karst. One significant area is Bats Ridge (White 1984, White 1989, White 1994) which is a series of Pleistocene dunes in the Bridgewater Formation, inland from Cape Bridgewater. Other areas of syngenetic karst are found at Cave Ridge, Portland area, Cave Hill (Heywood), Warrnambool and Codrington. In some places such as Glenelg River and Warrnambool these Pleistocene dunes overlie the Tertiary carbonates and show karst development into the Tertiary limestones (White & Pierce 1993). The Bats Ridge and Codrington areas are described in detail in Chapter 8.

Coastal Caves and Features

Marine influence is shown in the sea caves along the western Victorian coast. Sea caves are found in the basalt cliffs around Cape Bridgewater. These have the interesting feature of secondary calcite formation and tufa associated with them as they are overlain by the Pleistocene calcarenites and the percolating water from the groundwater deposits calcite over the basalts. Although marine action is important along the Port Campbell coast as can be seen in the rock stacks offshore and other features, the area does show evidence of karst solution from ground water and underground streams.

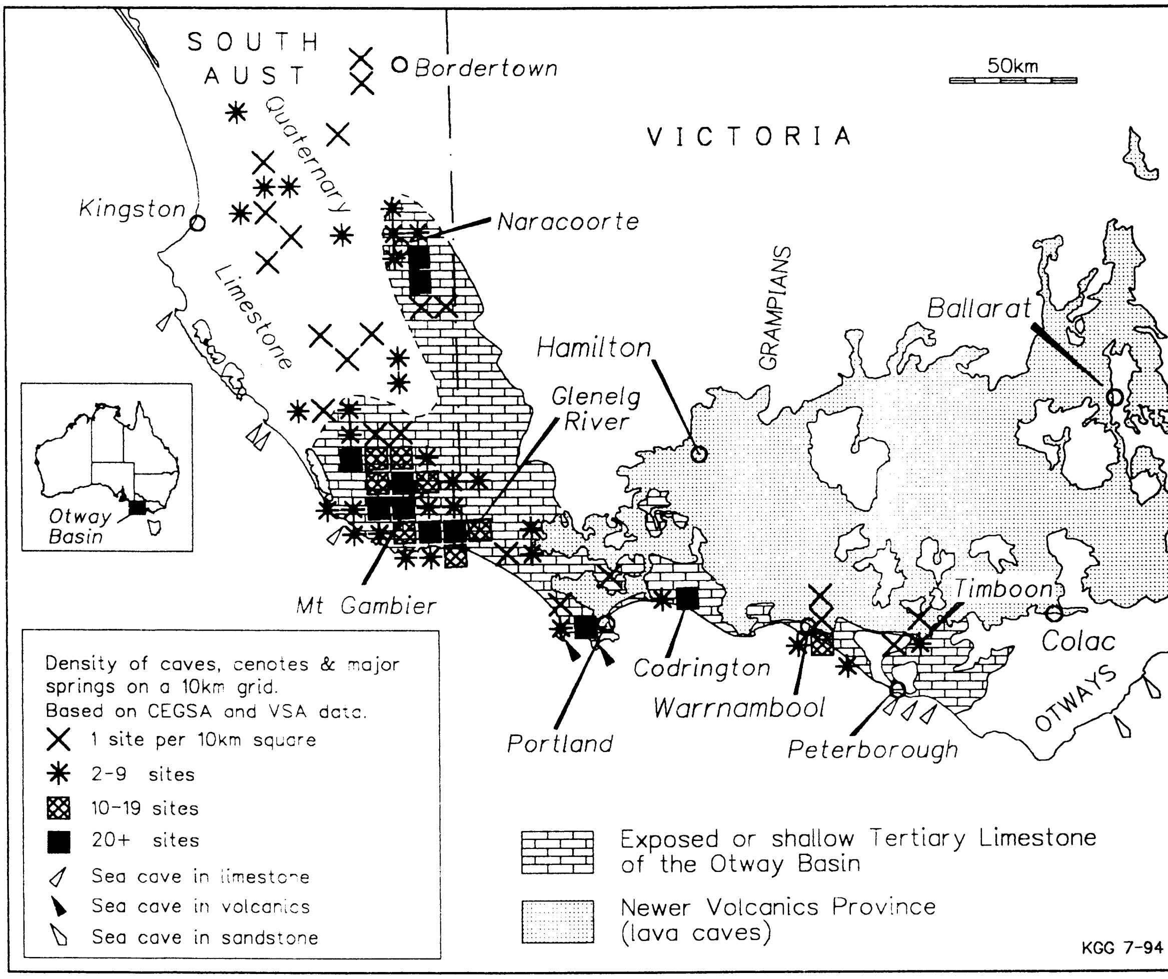

Figure 4-2: Distribution of Limestone Caves of the Otway Basin Region

There are a few caves along the coast of the Otway Ranges. These typically show joint enlargement in the arkosic sandstones and mudstones of the Mesozoic Otway Group sediments. A typical example is Ramsden's Cave (SW-4) at Cape Patton. The cave consists of two chambers joined by a narrow passage, totalling 60 metres in length. The entrance is concealed and almost totally blocked by fallen rock from the overlying slope and cliff. The cave floor is about 12 m above sea level and is mainly covered by large pools of water. Some decoration is present. This is one of the larger coastal caves in Victoria and is the largest cave in the Mesozoic sandstones (Hardy 1910, Rosengren 1984).

The coast has other small caves in either sandstones or in small lenses of limestone such as at Airey's Inlet.

Apart from the cave features there is fabulous coastal scenery along the Great Ocean Road between Lorne and Warrnambool.

The Grampians

The gently folded sandstones of the Grampians have weathered to form a confusing mess of cliffs and sculptured blocks, stacks, 'rock cities', and grike-like fissures. There are also many overhangs, rock shelters, blockpile caves, fissure caves and rumours of some 'real' caves with dark zones. For example: Frank (1984) describes a 20 m long sandstone cave 'just off the track halfway twixt the car park and the fire-watchers hut' at Mt. Bepcha. It cuts through a ridge of sandstone and is sufficiently dark to discourage unlighted exploration.

The main cluster of aboriginal art 'caves' (ie. rock shelters) is in the Buandik area on the western side of the Victoria Range, eg. the Glenisla shelter, the Cave of Fishes, Bilimina Shelter, and the Cave of Hands. Others occur at the northern end of the Grampians, near Mt. Stapylton, eg. Flat Rock and Cave of Ghosts. There are also art 'caves' in the Black Range, to the west of the Grampians.

Thomas (1986) gives descriptions and location information for some of the better known art sites, which unfortunately have had to be protected by mesh screens. The art is typically in red ochre, or white pipe-clay, with some yellow and black. The styles include human figures, positive and negative hand prints, animals and animal tracks, and initiation strokes.

One of the better sites, and also one that is easily reached, is the Glenisla Shelter about half a kilometre north of the Buandik picnic ground. Also in this area is the Cave of Hands, about 3 km south of the picnic ground. The Cave of Hands is in the north face of a rock stack, which can be climbed (with care) from the south-east for a good view of the Victoria Range.

Whilst not perhaps 'heavy sporting caves', the cave features and their surroundings are aesthetically very pleasing. There are also some first class rock-climbs on the sandstone cliffs and stacks.

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5. Volcanoes and Lava Fields of Western Victoria

Ken Grimes

Introduction

The Newer Volcanic Province of Western Victoria is one of the world's larger volcanic plains. It is a flat to rolling basaltic lava plain dotted with volcanic hills, which extends from Melbourne almost to the South Australian border, and the isolated volcanoes at Mount Gambier are a western outlier of the Province (see previous Figure 4-2). Lava tubes, lava caves, and related features are scattered across the province, but the majority of them are in the Hamilton area where they are associated with two of the younger eruptions in the region.

Skeats and James (1937) were the first to describe the features of the lava flows in detail. Ollier (1967) has written an overview of the volcanic province and its features. Cass & others (1993), Nicholls & others (1993) and Birch (1994) give more recent reviews of the volcanicity and describe specific volcanic sites in the province. Whitehead (1991) provided additional interpretations of the lava flows and related features at Mt. Napier.

A Glossary at the rear of this guidebook lists unusual terms used in describing volcanoes and lava tubes.

Surface landforms

The Newer Volcanics mainly range in age from Pliocene (about 4.6 million years) up to very recent times, and further eruptions could occur in the geological future. The volcanics are dominantly built up from lava flows, but there are numerous small volcanic cones built from explosive activity, as well as the larger maar lakes formed from major explosions (Figure 5-1).

Nearly 400 volcanic centres have been recognised, which if averaged over the 4.6 million years of eruptive history indicates one eruption every 11,500 years, though events were probably not as evenly spaced as that. Isotope dating suggests that at least seven volcanoes have erupted in the last 25,000 years; Mount Leura, Red Rock, Tower Hill, Mount Eccles and Mount Napier in Victoria, and Mount Schank and Mount Gambier in South Australia.

The youngest volcano is Mount Gambier, which has been dated at about 4,000 years old. In the Hamilton area, Mount Napier erupted about 8,000 years ago, and Mount Eccles in several stages between 20,000 and 7,000 years ago. See Head & others (1991). The flows associated with these younger eruptions show better caves and surface features than those of the older volcanics. None-the-less, several of the caves found further east are in flows several million years old. The younger lava flows show a number of interesting surface features in addition to the caves and tubes.

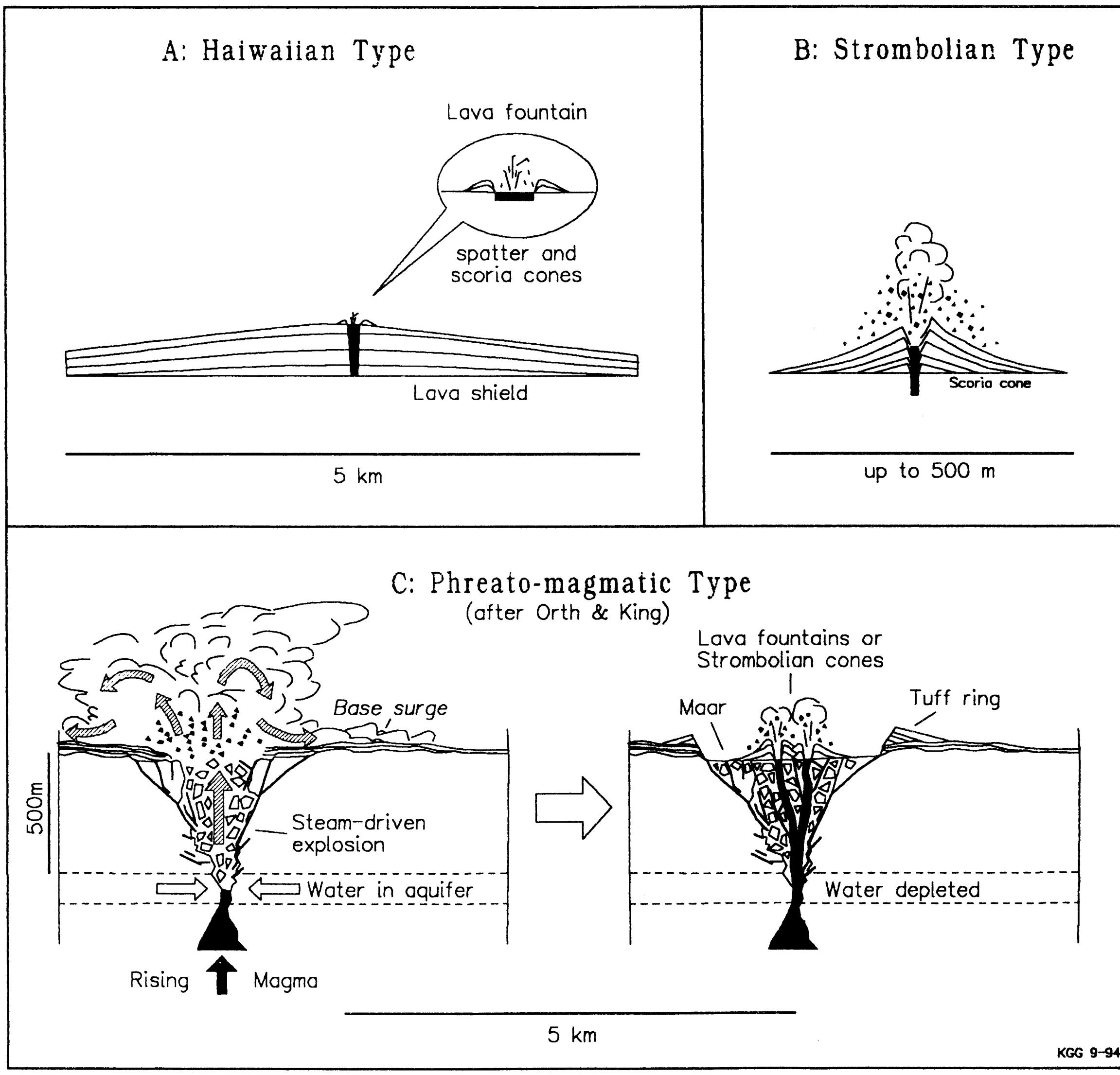

Figure 5-1: Types of Volcano found in the Newer Volcanic Province

The best modern model for the nature of vulcanism in this region is provided by the *Hawaiian volcanoes* (Figure 5-1A). There we see broad lava shields built up by successive flows of very fluid basaltic lava spreading out from a central crater or fissure. In the crater area we see lava pools with fountains jetting into the sky and building local small cones of welded spatter or loose scoria. The long lava flows are seen to be fed either by surface channels, or underground by lava tubes.

Examples of lava shields are the lower slopes of Mount Napier and the lava fields surrounding Mount Eccles. However, in Victoria we also have Strombolian eruptions (Figure 5-1B), slightly more explosive than the Hawaiian vents, which build larger scoria cones; and also the maar lakes, which are large but shallow craters formed by major steam driven explosions (Figure 5-1C).

Vents, Cones, Craters and Maars

Spatter cones (Figure 5-1A) are formed by lava fountains driven by either liquid or gas pressure in a lava pool within the vent. The ejected material is still hot and plastic when it lands so it forms welded spatter rather than loose scoria. The line of small cones that runs south-east from Mount Eccles was probably formed by a chain of lava fountains along a fissure. The Shaft (H-8) is one of these spatter cones in which the throat is still open, and can only be entered via a 23 m vertical drop.

Strombolian scoria cones (Figure 5-1B) are built up by rhythmic explosive activity driven by expanding gas bubbles in the magma (molten rock). The rhythm is a consequence of alternating build up of pressure beneath a crust, and then sudden explosive removal of that crust. The cones show all gradations from loose scoria to welded spatter. More violent explosions occurred in some of the volcanoes, throwing out larger sized bombs and blocks of both magma and country rock such as limestone. The upper, steep, part of Mount Napier is an example of a Strombolian cone.

Maars (Figure 5-1C) are a distinctive type of volcanic crater characterised by their broad but shallow form, their extent below the level of the surrounding country level, and the relatively low, but broad tuff rings that surround them. Maars are formed by deep-seated (*Phreato-magmatic*) explosions that occur when uprising magma (at about 1200° C) encounters groundwater in a porous rock strata. The resultant steam pressure creates an explosion that literally 'blows the top off' to form a crater and associated widespread ash (tuff) deposits.

Commonly the violent steam driven explosion is followed by a quieter lava fountain or strombolian phase in which spatter or scoria cones are built up within the crater. Because they extend below the level of the surrounding country, most maars contain lakes. Tower Hill and Lake Purrumbete are the two largest maars in the region (respectively, 4 km and 3 km in diameter). Orth & King (1990) provide an excellent booklet on the geology of the Tower Hill crater and maar lake.

Composite vents result from a variation of style during an eruption, or the coalescence of several vents. Thus Mount Napier is a composite cone comprising a basal gently-sloping lava shield and a superimposed steeper scoria and spatter cone. Mount Eccles is actually a group of vents and scoria cones, that follow a north-westerly fissure, and it also has extensive lava flows associated with it. The main scoria cone shows some evidence of steam driven explosions near the beginning of the eruption. The crater lake is at the level of the regional water table, and fills three overlapping craters. Mount Gambier is a complex group of overlapping scoria cones and maars, with only minor lava flows.

Lava Flows

Basalt is a hot (1000 - 1100° C) liquid that can flow readily when first erupted, but becomes more viscous (thicker) as it either cools, or loses its gas content. There are two main forms of basaltic lava flow, which grade into each other (Figure 5-2). *Pahoehoe* (pronounced pah-hoey-hoey) which is the Hawaiian word for 'smooth', and *aa* (pronounced ah-ah with a glottal stop) which is an Hawaiian expression of pain. Pahoehoe lava is the most liquid form, characterised by the formation of thin smooth skins that become wrinkled (hence its alternative name of 'ropy lava'). Pahoehoe lavas advance as a succession of lobes, each of which develops a skin, is inflated by the liquid pressure within, then ruptures at one or more points to release liquid lava that forms new lobes.

Pahoehoe (or ropy) lava forms on fluid lava. As the lava loses gas and cools it becomes frothy and stiffer, and breaks up into *aa* (block) lava. Transitional forms occur.

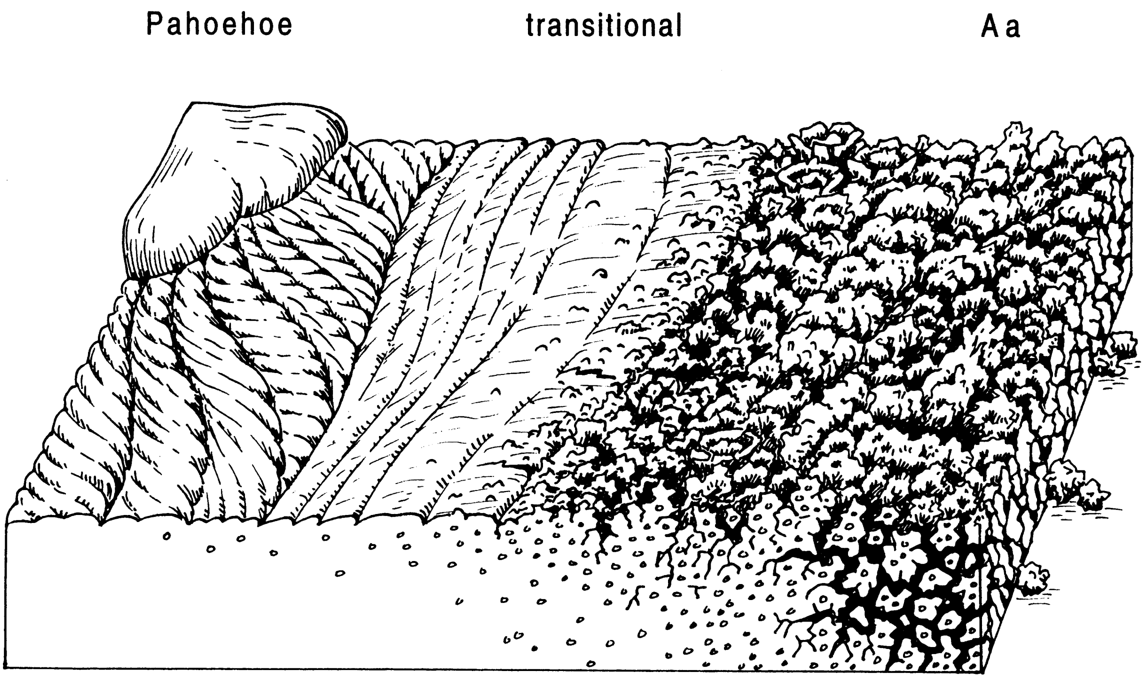

Figure 5-2: Types of Lava Surface

As pahoehoe loses gas and cools it becomes frothy and more viscous. The surface tends to crack, twist and break into angular, often spiny, blocks to form what is called *aa* or 'blocky' lava. Aa advances as a rubble wall in a manner akin to a caterpillar track with fragments from the surface falling down the face and being buried beneath the advancing front. Unfortunately the terminology is confused by the common occurrence of transitional types. Thus one author might refer to a flow as 'spiny pahoehoe', while another would call the same flow 'cauliflower aa'.

Lava flows can form broad sheets built up of multiple flows, or may be confined to a pre-existing valley. Figure 5-3 illustrates some of the surface features of a lava flow. Major 'wrinkles' or pressure ridges tend to form either transversely across the flow (*transverse ridges*) or parallel to the edges (*lateral ridges*) where the lava is moving more slowly than the central area. Ridges can also form as residual high areas at the edge of a flow when the central part subsides as a result of drainage of the lava from within it. In aa flows rubble is piled up at the edges to form lateral *rubble ridges*.

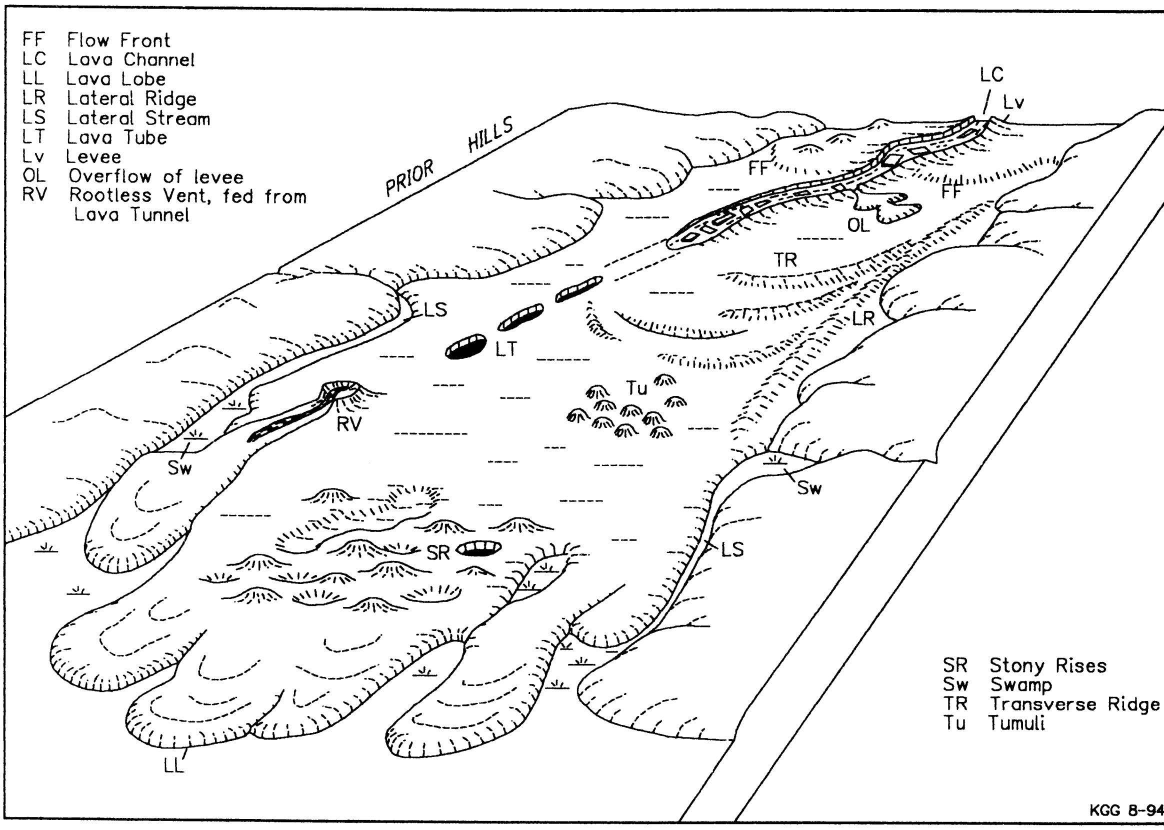

Figure 5-3: Some Surface Features of a Basaltic Lava Flow

Lava flows commonly have irregular surfaces with a local relief of up to 10 m. These are known locally as *Stony Rises* (Figure 5-4). Part of this irregularity is due to the initial nature of the overlapping lobes of lava (Figure 5-4A). However, after the surface of a flow has solidified, pressure from the liquid lava below may inflate it in several ways:

- Evenly, to raise the crust into a smooth convex surface,
- Irregularly, leaving some areas behind as hollows,
- Pushing up weak spots up to form small steep walled domes, called *tumuli.*

See Figure 5-4B and 5-5, and Walker (1991).

Alternatively a reduction in pressure can let the surface crust subside, either evenly, leaving lateral ridges of solidified material, or more unevenly to form a hummocky surface (Figure 5-4C). The stony rises can therefore form by either inflation or deflation (or both), but the general principal is that of uneven movement of a solidified crust floating on a liquid core. There are some very good examples of *tumuli* in the Harman Valley. These were originally thought to be 'gas blisters' possibly formed by steam when the flow ran across a swamp; however, Ollier (1964b) showed that they were solid.

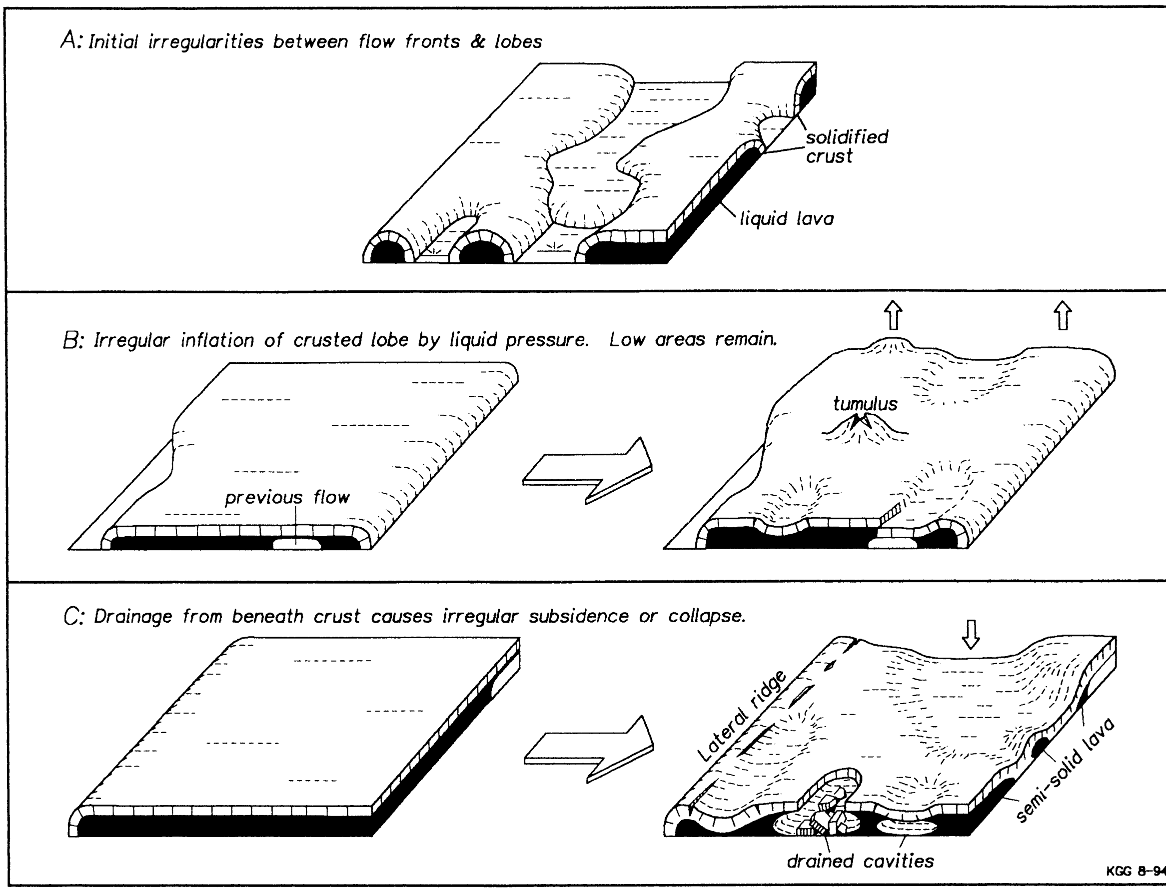

Figure 5-4: The Irregular Topology of the 'Stony Rises' is Formed by a Combination of Three Processes

Behind the advancing lava front the lava movement is restricted either to narrow surface *channels* (Figure 5-3), surrounded by solidified material, or internally beneath a surface crust (typically in lava tubes). Overflow from the surface channel builds up a levee bank of thin sheets or spatter. Larger flows across the levee can feed lateral lava lobes with small internal lava tubes. A major breach of a levee may result in a large side flow, fed by its own channel, and the original channel may be abandoned. Good examples of lava channels (locally referred to as 'canals') occur at Mount Eccles. A number of shallow lava tubes are known in flows that have run off the sides of these channels.

Lava tubes are discussed in Chapter 6. They form either by the roofing over of a surface channel, or by concentration of the flow beneath the crust into linear or branching tubes. An internal flow in a lava tube may burst out at the surface to from a *rootless vent* at some distance from the source (Figure 5-3). This may build up a scoria cone, or feed surface flows. An example of a rootless vent that feeds a channel and several lava tube segments occurs on the western slopes of Mount Napier (H-62 to H-65).

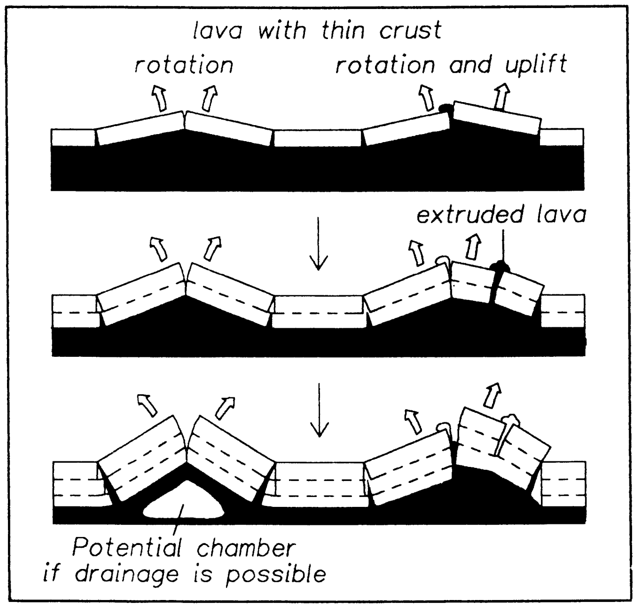

Figure 5-5: Formation of Tumuli

Lava tubes provide good insulation for the hot lava flowing within them. This allows the formation of very long flows such as the 50 km Tyrendarra Flow from Mount Eccles, which extends offshore across the continental shelf (which was dry at the time), and the older 60 km flow from Mount Rouse, which may also extend offshore (Figure 6-5).

When a lava flow follows a valley. as in the Harman Valley west of Mount Napier, it disrupts the drainage. Twin *lateral streams* may run down each side of the original valley (Figure 5-3). *Swamps* or *lakes* will form where the flow enters the valley, and where tributary valleys have been dammed by the flow. An example is Lake Condah, which has been dammed behind the Tyrendarra flow from Mount Eccles.

The older volcanoes of the region have degraded features, and thick lateritised soils, which make their recognition difficult. One example is Mount Hicks, the rounded hill with the microwave tower north of Mount Eccles.

Self Guided Field Trips

These tours of surface features of the volcanics are mainly car based, but require some walking at Mt. Napier, Byaduk, Mt. Eccles, and Cape Bridgewater if you wish to see all the features described. Grid references refer to the 1:100,000 topographical maps (Coleraine 7222, Hamilton 7322, Portland 7221, Warrnambool 7321), or the local fire maps.

There are two alternatives beyond Mt. Eccles; east via Port Fairy to Tower Hill, or west to the Portland area. Allow at least half a day, especially if walking is to be done. You may also wish to include some of these stops while travelling between cave areas. Use Figure 6-5 for reference.

Stop 1: Mt. Napier

Include this stop only if you intend to climb the peak. You will see other quarry exposures elsewhere (Mt. Eccles and Tower Hill). From Hamilton take either the Port Fairy Road or the Mt. Napier Road to the Buckley Swamp Murroa Road, and follow it east or west respectively. Where Murroa Lane comes in from the north, turn south and follow a gravel track into the forest country, diverging to the left at a Y-junction about one kilometre in. This goes in about 4 km to Menzels Pit (922058), a disused quarry in an old scoria cone. The last few hundred metres is a bit rough but can be negotiated by most cars.

The quarry walls have exposures of loose scoria (dangerously so in some of the vertical faces, so be careful when looking closely at it and do not try to dislodge material from the faces). A walk of about 1.5 km (and a climb of 150 m) takes you to the top of the mountain. A new track is planned from the quarry to the top and may be under construction by the time of the conference. If there is no new track, follow the existing 4WD track south from the quarry for about 500 m then head bush up a ridge eastwards to the mountain top.

Alternatively you can come in from the east. Follow the Mt. Napier Road from Hamilton and about 3 km past the Buckley Swamp Road turn right and follow a track in to a parking area. Continue walking along the track to climb the mountain from the north-east side. At present this is the better track to the mountain, but the Parks Service intends closing it once the track from Menzels Pit is completed.

The top of the mountain is a set of large cinder cones, and you can look at the view (several other volcanoes can be seen on the skyline) and also at the remains of the main crater which is 50 m across and 20 m deep, with a breach on the north-western side. On the western side of the crater the cliff has been built up of welded spatter and 'breadcrust' and 'cowpat' bombs to form a vertical rampart. On the inner side you can see patches of fluid spatter that started flowing back into the crater, and there are several lava 'tide marks' indication standing levels of a small lava lake that must have partly filled the crater. If you are a 'birdo', watch for Peregrine Falcons which nest in the cliffs. There are also several smaller scoria cones and craters to the north-east of the main crater.

From Menzels Pit you can also follow the fence to the north for 400 m and then climb over to the eastern side to see a large explosive pit.

Stop 2: Byaduk Caves

Travelling south down the Port Fairy Road look for a signpost to the left (east) saying 'Byaduk Caves' about 0.5 km north of the settlement of Byaduk North. The turnoff is just over a rise and easy to miss if you are going too fast. Follow the dirt road east then south to the valley and along it a short distance to a parking area at a gate (855038, 3.5 km in from the main road). The floor of the valley comprises stony rises on a young lava flow that came down the valley from Mt. Napier, which you can see to the east as you drive in.

See Figure 6-3 for locations of the main collapse dolines and caves, which are part of a set of large feeder tubes that ran down the valley. The closest doline and cave (Harman Cave, H-11) is about 150 m south-east from the gate, along a rough track. See Chapter 6 for cave details. If you walk east from the gate (no track) for about 300 m you will come to a group of big holes with a bridge between them. Unless you intend some caving there is not much point in going further in.

Stop 3: Harman Valley

Continue south down the Port Fairy Road. About 3 km south of Byaduk North, pull up where the road starts to drop down towards a deep valley (831027). This is the Harman Valley. To the east is an excellent view up the valley to the volcanic peak of Mount Napier. The peak has a timbered broadly sloping base that is a 'lava shield' built up from flows, but the steep and grassy upper part is a scoria cone formed by explosive strombolian activity. The lava flow in the valley below you comes from the mountain. It has stony rises, and a short section of a lava channel with rubble levees on each side.

Stop 4: Old Crusher Road

From Stop 3, go south down into the valley, and turn off to the right (west) into Old Crusher Road. This turns left and climbs out of the valley, and about 1 km to the south you turn right to follow Old Crusher Road to the west. Continue west for 5 km to a valley (776005). The valley floor is lava that has backed up from the main Harman Valley to the north. The obvious sharply rounded hills scattered across the paddock to the south are the tumuli (see earlier description in the main text). These were initially thought to be steam blisters formed where the lava ran over a swamp, but are now known to be solid, and probably were weak points in the crust of the flow that were pushed up by pressure from the liquid lava below.

If you continue another kilometre to the west you come to a T-junction (766004). There are some well developed lateral pressure ridges to the south of this junction, at the edge of the valley, and good stony rises to the north. If you follow the northern road for a couple of kilometres you will see additional examples of both stony rises and more lateral pressure ridges on the north side of the valley. Beyond that the lava is lost beneath swampy deposits, a result of damming of the valley by lava flows from Mt. Eccles some distance to the south.

Stop 5: Mt. Eccles - Lake Surprise

This is reached by following signposts west from the centre of Macarthur. As you approach the mountain you get a good view of the main peak (a cinder cone) with an obvious quarry scar on its side. The quarry face has an interesting set of layered scoria deposits for geologists, with some old soil horizons, including one that yielded roots that Ollier (1981) dated as 'over 19,750 years before present'. Lake Surprise (808867) is hidden until you arrive right at the edge. It is an elongated composite crater resulting from the overlap of three explosive points. The crater is about 65 m deep, including a reported water depth of 14 m. 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-north-west and to the south-south-west (see Stop 7).

About 8 - 10 lava flows are exposed in the crater walls, and at the southern end spatter ramparts (including 'breadcrust' bombs) have built above these. There are two circular walks around the crater. The longer one around the top of the crater includes the cinder cone of Mt. Eccles itself with good views of the surrounding country, including an older volcano (Hicks Hill) which is the rounded hill with the Telecom tower to the north, Mt. Napier to the north-east, and flat-topped Lady Julia Percy Island on the horizon to the south. The Tunnel (H-9) is a large diameter lava tunnel with an entrance beside the upper track where it crosses the western canal (see Chapter 6). The second walk is a shorter one along the edge of the lake, but involves a bit of climb back out.

Stop 6: Mt. Eccles - Natural Bridge

From the information centre at Mt. Eccles, take the road back out to the T-junction next to the quarry. Turn right here onto a dirt road and follow signs to 'Natural Bridge' for about 2 km. The road circles over the bridge and you park on top (805859). The bridge is at the end of a small lava canal that flows west from one of the small cones in the line running south-east from the main crater (see Chapter 6). It seems to have formed by overgrowth of levees over the running channel. The convoluted layers seen within the cave would have resulted from downward slumping of hot linings built up on the sides and roof.

Stop 7: Mt. Eccles - South Lava Canal

There is a walking track from Lake Surprise, down this canal, and circling back via Natural Bridge to the lake again. The round trip is about 6 km and can be done in a couple of hours if you hurry, but it is better to allow a half day and detour to look at caves etc. (several entrances occur right beside the track). Within the canal you will see some preserved sections of the original vertical walls, with layers built up by overflows, in places hidden by thin linings plastered over them, but generally the original wall has collapsed and is buried under rubble. Large blocks have rolled or slid down from the sides in places. A couple of higher areas in the floor might be old roofed sections, now partly collapsed, or the might be 'log jams' of crustal fragments that were floating on the surface of the lava.

For a short trip, stop at this stage and go back to Hamilton. Otherwise you can choose to continue on via Port Fairy to Tower Hill (Stops 10 - 12), or else to go to the Portland area (Stops 20 - 23).

Eastern Stops (alternative route)

Stop 10: Orford - Port Fairy road

Travel south-east on the Port Fairy Road between Orford and Port Fairy. There is no need to 'stop'. You are driving past and over the southern end of a long lava flow that comes from Mt. Rouse 50 km to the north. You can see the steep flow fronts where the lava overlies the flat swampy coastal plain, and also examples of stony rises. Closer to Port Fairy you pass a processing plant that uses the basalt to make facing and dimension stone for the building industry.

Stop 11: Port Fairy - sea shore

From the centre of town drive east to Gipps Street, and follow this south (parallel to the river) and then continue on to the ocean and park at a lookout on a rocky headland overlooking the Southern Ocean (080494). This is where the lava flow from Mt. Rouse meets the sea, but at that time the sea level was probably lower so the flow could well extend some distance offshore. If you walk around the headland to the west, and on to the next one you will see the remains of basalt lobes running across the beach and into the water.

Naturalists might wish to look at the mutton bird site on Griffith Island (a walking track from the parking area at the southern end of Gipps Street circles the island). Historians could visit the lighthouse at the eastern end of the island and will find many interesting buildings in the town.

Stop 12: Tower Hill

Tower Hill is just north of the Princes Highway about 12 km west of Warrnambool (190580). This is a large maar formed by steam driven explosions which occurred when a rising body of hot magma intersected water bearing beds about 600 m below the surface (see Figure 5-1C). The rim is built up of bedded scoria and finer material that was blown out of the crater. A group of smaller scoria cones were built up after the main explosion and occupy the centre of the crater, surrounded by a shallow lake. There is a good view from several points on the rim and the high centre cone.

Where the southern road drops down into the crater, there is a quarry on the right which has a good exposure of bedded scoria, lapilli and ash, with occasional larger bombs embedded in the layers. Some beds show small-scale dune bedding that resulted from the outward blasts of hot gases. Limestone bedrock underlies the volcanic deposits and is exposed near the shoreline. There is an information centre further into the park which is worth a visit.

Western stops (alternative route)

This route may include a 4 km walk along the cliff top from Cape Bridgewater (Stop 21) to Cape Duquesne (Stop 22), which requires a car swap or pickup.

From Mt. Eccles (Stop 5), travel east towards Macarthur, and turn off to head south via Bessiebelle to Codrington. Travel west along the Princes Highway.

Stop 20: Tyrendarra Flow

The Princes Highway at Tyrendarra (680694) crosses the Tyrendarra flow, a long tube-fed flow that came from Mt. Eccles about 20,000 years ago and continues south for 15 km across what is now the sea floor. The flow filled the valley it followed so that we now see twin lateral streams: Darlot Creek diverted to the east side, and the Fitzroy River diverted to the west. Flow ridges can be seen in places on the surface.

Stop 21: Cape Bridgewater

Cape Bridgewater is about 15 km west of Portland (360500). Park beside the beach at the western end of Bridgewater Bay. To see the rocks, follow the beach and wave-cut platform south for about a kilometre (you can't get much further and should watch the tides, and beware of unexpected large waves on the wave-cut platforms). The initial cliffs are dune limestones (Quaternary), but farther on you will find interbedded ash, lapilli and scoria, with some basaltic lavas at the far end. In one place an irregular body of lava appears to have intruded an ash bed; possibly wet ash that was fluidised by the generated steam.

For a more scenic view follow the track along the cliff top to the cape itself about 3 km south of the starting point. Look out for seals on the rocks below in the final section. There are several big sea caves below you, but they are difficult to see from above.

From Cape Bridgewater you can continue following the cliff top west for 4 km to Cape Duquesne. To do this you must arrange for a car swap or pickup at Stop 22.

Stop 22: Cape Duquesne

From Bridgewater Bay, continue following the bitumen road which zig-zags west to the far side of the Cape. The road ends at a parking area (320518). The nearby lookout views a (generally disappointing) blowhole in basalt flows, which underlie dune limestones. Go south-east to the 'Petrified Forest' to see a wind eroded area in which calcite deposits have formed around small roots, and there are larger vertical soil filled pipes with cemented rims which are NOT petrified tree trunks, as once supposed, but karstic solution pipes.

There is also a track following the cliffs to the north-west, which takes you (a long) 2 km to The Springs. Climb down the cliffs to view springs that run out from the contact between the dune limestone and the underlying basalt to build up a series of large tufa terraces and pools just above the high tide mark. If you hunt about on the basalt you can find bands of small vesicles filled with agates and zeolites. Again, be wary of unexpected large waves and avoid this area in rough weather. Several people have been washed off the rocks hereabouts.

Stop 23: Bridgewater Lakes

From Bridgewater Bay (Stop 21) start back towards Portland, then follow a back road to the north-west to the Bridgewater Lakes (350580), or else from Portland take the road past the airport and keep going west. This is not a volcanic site but worth a detour to look at old sea caves (complete with speleothems) in dune limestone in an old coastal cliff behind the lakes; and to admire the lakes themselves which have been dammed up behind younger dunes. A foot track runs out over the dunes to the beach.

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6. Volcanic Caves of Western Victoria

Ken Grimes and Tony Watson

Lava tubes

Lava tubes form in the flows by two main processes:

- Crusting over of surface lava channels that have fluctuating levels (Figure 6-1A to 6-1C).
- Draining of still molten material from beneath the solidified crust of a flow (Figure 6-1D).

For more detailed descriptions of the processes see Greeley (1971,1987), Greeley & Hyde (1972), and Wood (1974, 1976, 1977).

Figure 6-1A, 6-1B and 6-1C illustrate the formation of a lava tube by the *roofing over of a surface channel.* The roof can form in several ways. A solidified surface scum can accumulate and thicken until it is strong enough to form a roof. On a stationary or very slow moving flow the crust may form over the whole channel at once, but more usually it will begin to develop at the edges and progressively expand across the surface until it is entirely covered and then thickened from below (Figure 6-1A). With stronger or fluctuating flow rates, this initial crust may break up and the fragments be rafted downstream to accumulate as a 'log jam' that may be welded into a thick roof (Figure 6-1B). Overflow or spatter can build up levee banks at the sides of the channel, and for narrow channels these may grow inwards as overhangs that eventually meet (Figure 6-1C). The last case is probably responsible for the pointed 'gothic' roofs seen in some caves, eg. Natural Bridge (H-10) at Mount Eccles and H-66 at Mount Napier.

In the Natural Bridge the wall linings show convoluted layering which could have resulted from the downward slumping of the hot layers as they formed. If the lava levels in a channel are fluctuating several roofs may form at different levels to produce a stacked multi-level tube. Roofed channels are typically simple but large linear tubes. However if the initial surface channel had several branches or a braided form then the resulting roofed tube will also have this form. Also if smaller tubes have developed in overflows on the side of a channel these may remain connected to the master tube to produce a complex pattern, as in the case of Chocolate Surprise Cave at Byaduk (H-74). See Mansfield (1990).

Figure 6-1B illustrates the formation of tubes by *draining from beneath a crusted flow.* At the front of an advancing pahoehoe lava flow the lava is delivered by a channel or major feeder tube, but then spreads out into a series of lobes. These grow by a process of 'budding' in which a small lobe develops a skin, and is inflated by the lava pressure until the skin ruptures in one or more places. Lava escaping through the rupture develops new lobes and so on. Within the earlier lobes the lava may drain out to form a low but wide chamber, or it may become concentrated into linear tubes that feed the advancing lobes, while the remaining stagnant areas solidify.

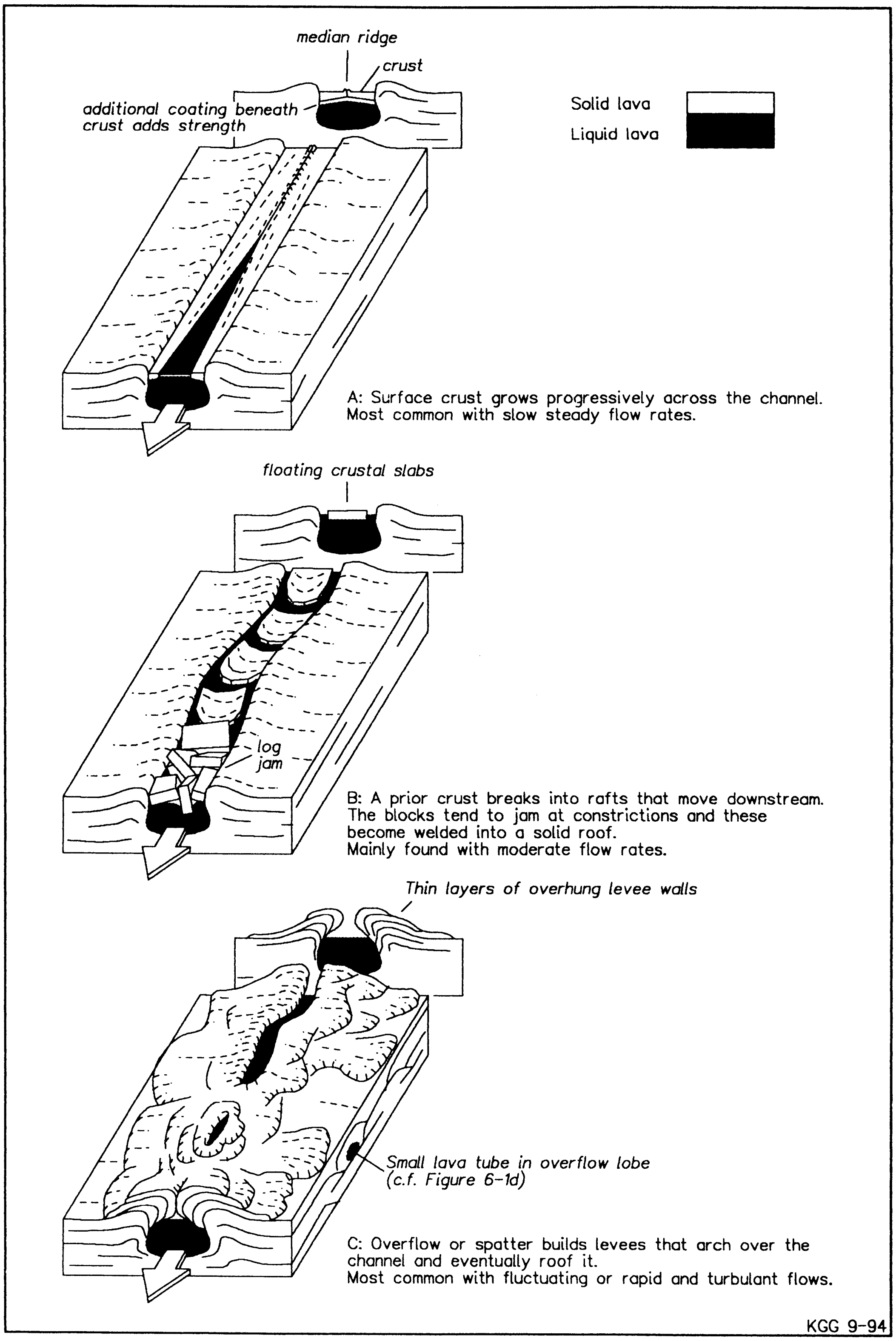


Figure 6-1: Formation of Lava Tubes

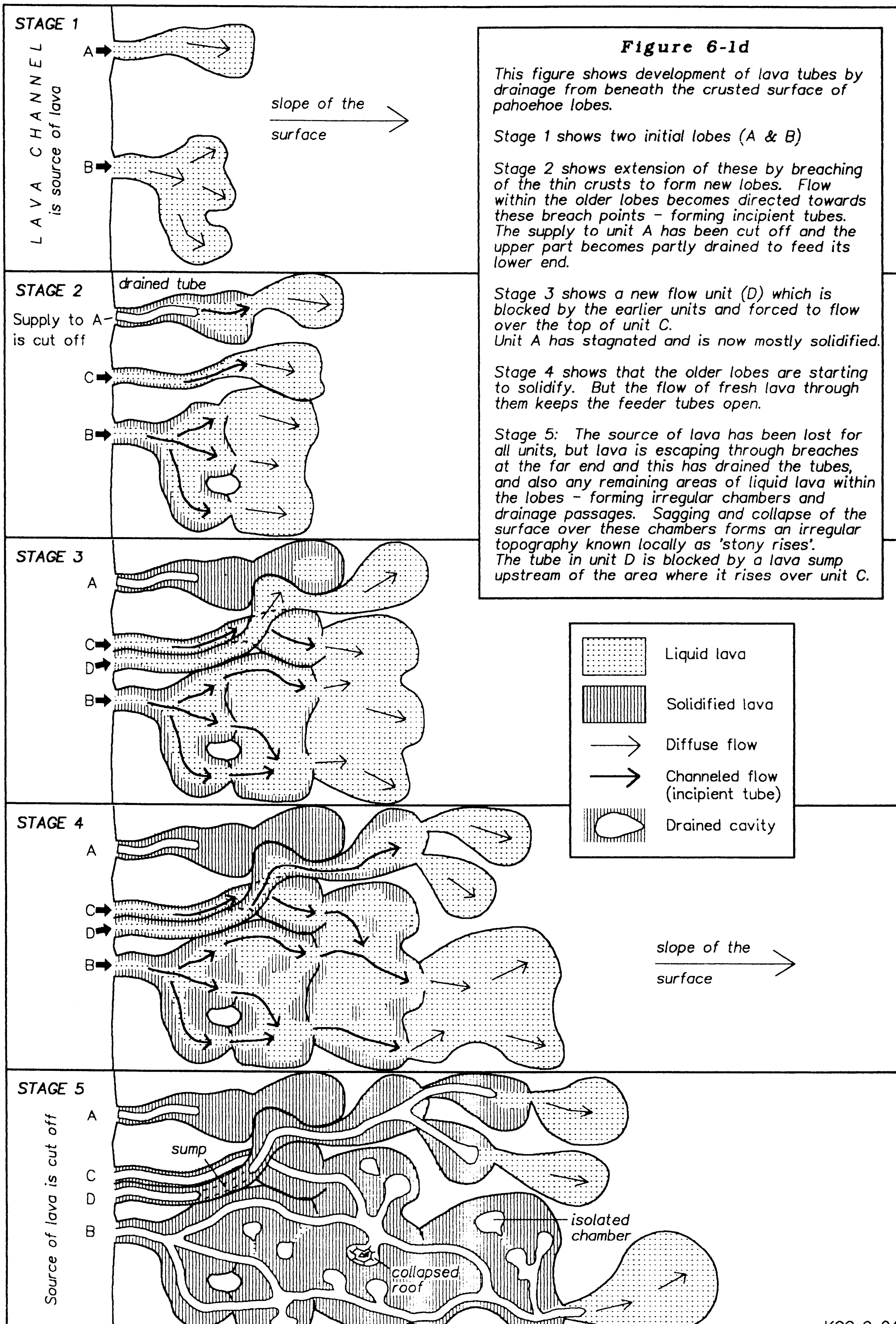


Figure 6-1d

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.

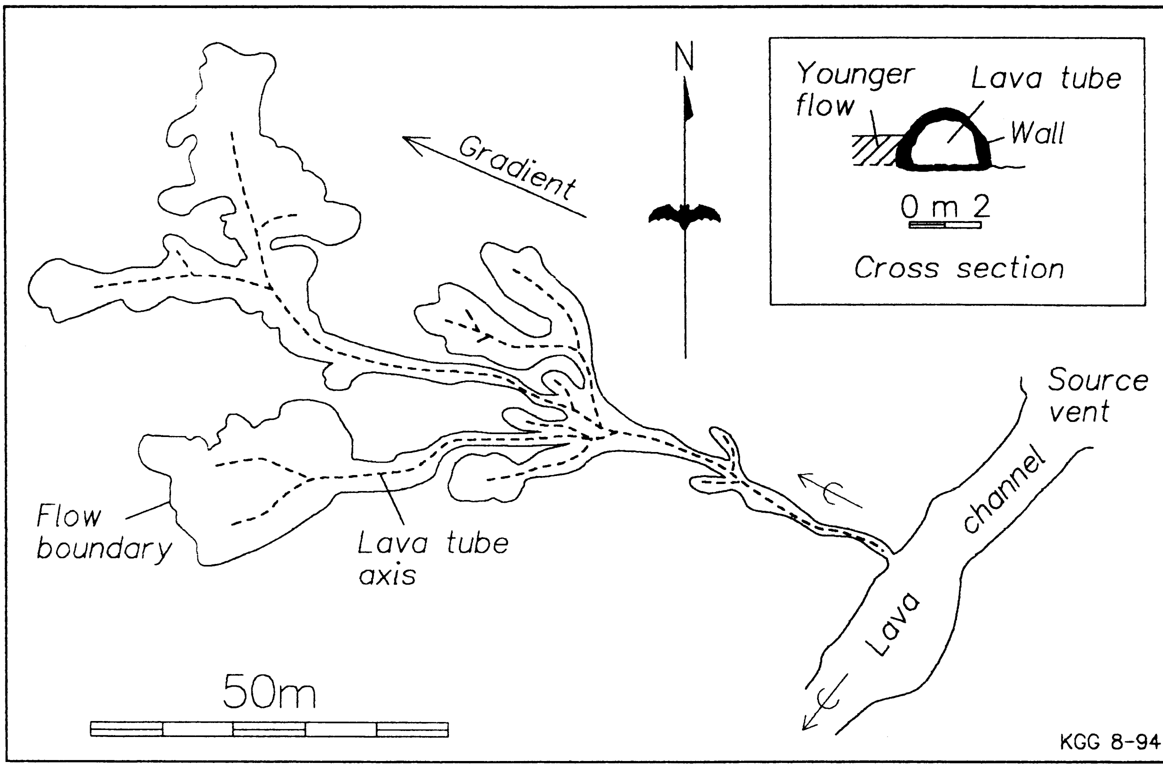


Figure 6-2: Example of a Distributory System of Small Lava Tubes feeding Pahoehoe Lobes from near Bend, Oregon, USA (After Greeley, 1987)

Figure 6-2 is an example of a set of lobes with drained tubes that was mapped by Greeley (1987). Lobes can be stacked vertically as well as advance forwards so that a complex three-dimensional pattern of branching tubes forms. Tubes formed in this way are generally smaller than those formed by the roofing of a channel. However, if flow continues after they are formed, several small tubes may coalesce by breakdown of their thin walls or floors to form a larger feeder tube. In some cases most of a lobe is drained to form a broad but low-roofed chamber.

A few caves have branching, multi-level forms of complex origin, for example, Mount Hamilton Cave (H-1), and The Theatre (H-33) at Byaduk. Complex branching and multi-level systems can evolve by a combination of several factors. The initial form may have been complex, as described above, or younger tubes can break through the ceiling of older tubes and re-occupy them. Blockages in a tube may force the lava upwards, to break out at the surface and form a new flow, which in turn will develop tubes. Stacked tubes can result from the development of lava bridges formed when the tube was only partly filled. A flow within a tube may crust over and develop a smaller tube within it, a feature referred to as a 'tube-in-tube'.

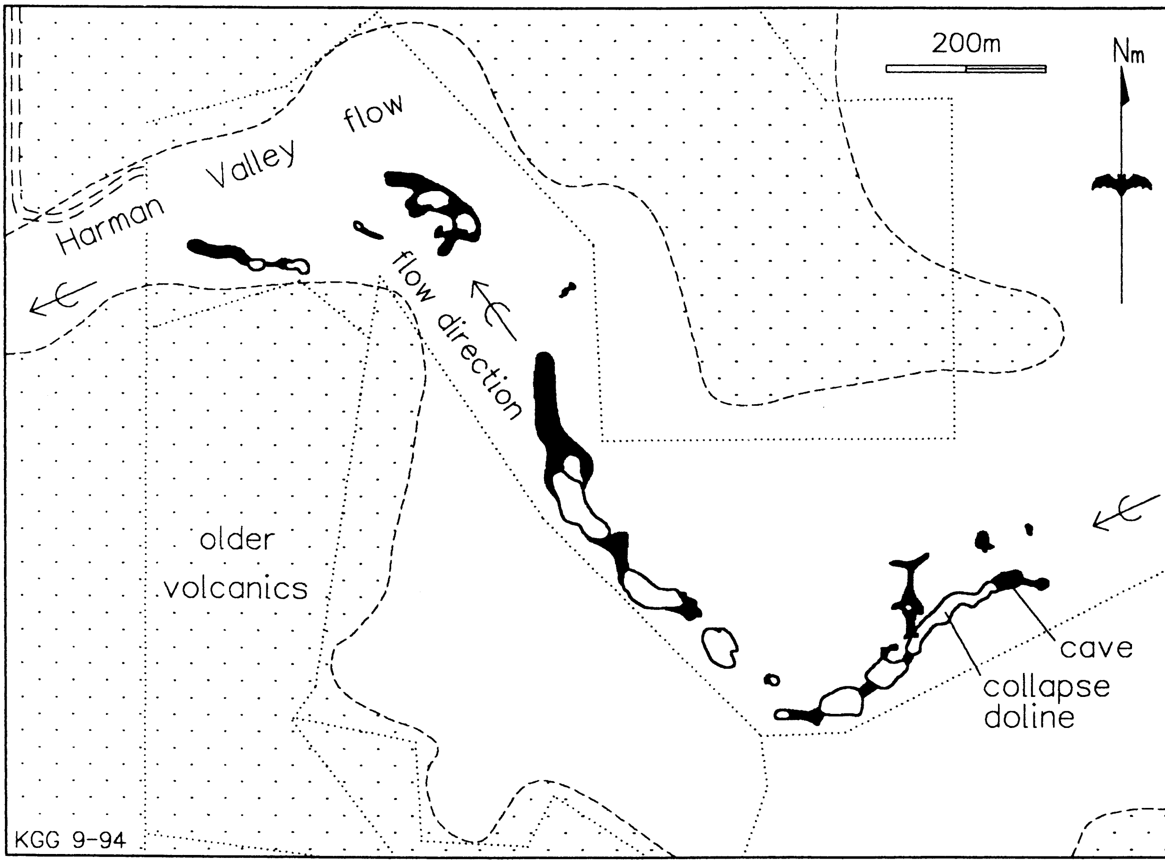


Figure 6-3: Development along a Major Feeder Tunnel at Byaduk Caves

The longer lava flows in the region would all have been fed by large cylindrical lava tubes that continued to carry hot lava for tens of kilometres through the insulated core of a partly solidified flow. These long-lived feeder tubes are self modifying and destroy much of the evidence as to their original mode of formation. In a few places, as at Byaduk, the large feeder tubes have been partly drained and are now accessible through a set of large collapse dolines (Figure 6-3). These tubes have impressive domed cross sections up to 10 m high and 18 m wide.

This discussion so far refers to the formation of lava-filled tubes. In any area only a small percentage of the tubes will be drained and accessible to cavers; most remain filled with solidified lava at the end of the eruption or are interrupted by solidified lava sumps in the lower parts (not recommended for cave divers). Older tubes may be buried by younger flows and become inaccessible.

The lava caves contain a distinctive suite of decorations, some of which are illustrated in Figure 6-4. Small round-tipped lava stalactites, or *lavacicles*, form where molten lava has dripped from the roof, or dribbled down the walls of the cave (lava runs or dribbles). If the floor was already solid (unusual) these drips can build up lava stalagmites. Stalagmites often have a form in which the original drips can still be seen welded together as a lumpy mass.

The level of lava within the caves tended to fluctuate during the course of the eruption, and so we find thin linings plastered onto the walls and roofs, and 'tide-marks' are indicated by benches on the sides of the tubes. The linings can break free, peel back and curve over to form draperies and even small chambers. Sometimes the lining appears to have burst open under pressure of gas built up behind it. Lava 'hands' of pasty material can be exuded through cracks or holes in the lining. Some forms that have been extruded or dribbled through small orifices evoke scatological terms, suggested polite substitutes are 'stoolites' or 'faecicles'. Analogies to sheep, dog, cow, etc. can be seen.

The floor can be smooth or have a 'ropy' surface of pahoehoe lava with wrinkles and other patterns that indicate the flow direction. Final flows through tubes tend to be a stiffer lava that breaks up into a knobby or hackly, welded rubble (aa lava), which eats both overalls and their contents. Small lava mounds, or tumuli, may be heaved up by pressure from below.

Lava 'puddings' or 'boils' can form from pasty lava that oozes up through holes and cracks. In some caves the crusted floor has buckled and broken into a jumble of heaved up plates, or cracked into a mosaic of jostling plates with rounded or upturned edges. Splash concentrics are frozen ripples formed where a piece of roof has fallen into the liquid lava. Lava cascades or falls form where lava flows or drops from a higher level. Where a lining has pulled away from the wall we may find stretch forms resembling toffee or shark's teeth.

Other Types of Volcanic Cave

Lava tubes are not the only type of cave that can form in volcanic rocks. Wood (1976) summarises a range of other volcanic cave types, several of which are recorded in the Newer Volcanics. The Shaft (H-8) is an explosive cavity and throat within a spatter cone that remained open after the volcanism ceased. Armchair Shaft (H-47) at Smeaton appears to be a similar but smaller feature called a *hornito* formed by the venting of hot gases and minor spatter through a shaft connected to a lava tube.

Several small caves have been reported in the scoria of the upper part of Mount Napier. These are probably the result of erosion of the loose scoria from beneath a partly welded layer.

In the Stony Rises small caves form by the irregular draining of cavities beneath the crust of a broad lava flow (Figure 5-4). The process is similar to that which forms tubes (Figure 6-1D), 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' remains, as at H-78 at Mount Eccles (Figure 6-14). This type of cave has previously been referred to as 'blister caves' but that term is best restricted to chambers formed by gas pressure.

Cracks develop in surface ridges or at edges of flows where the solid crust has either subsided or been pushed up. These can form small fissure caves.

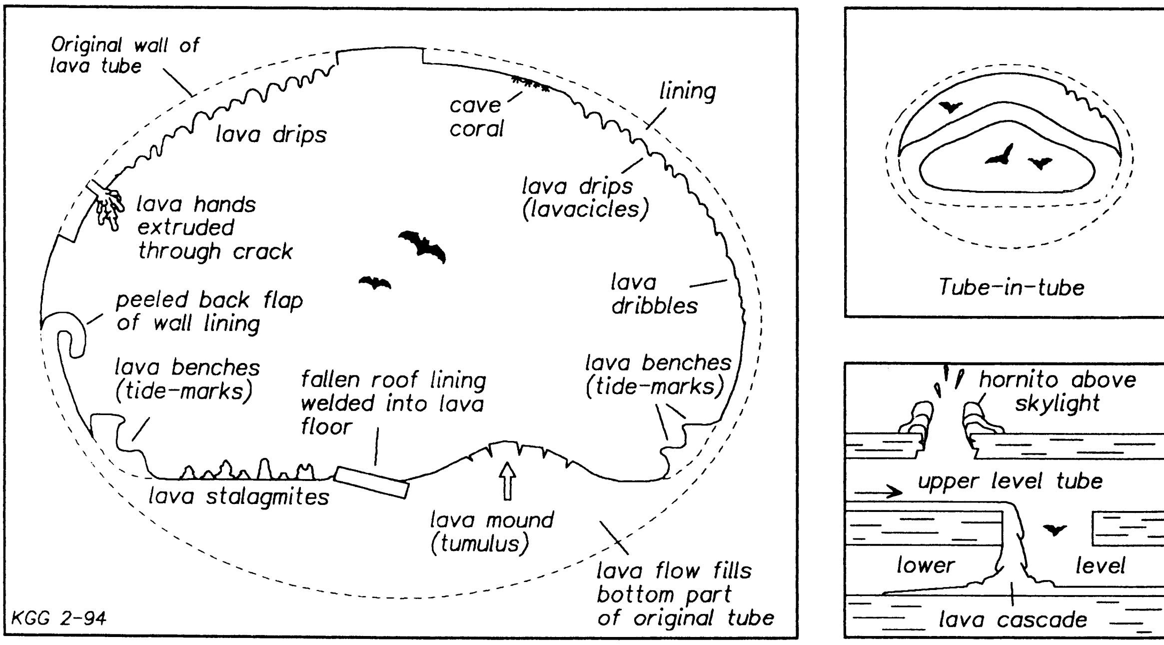


Figure 6-4: Features and 'Decorations' found in Lava Tubes

Cave contents

Basalt caves tend to have a greater range of *mineral deposits* than limestone caves because of the greater range of minerals in the wall rocks and the presence of volcanic fumes which could react with them (Webb, 1986). Unusual mineral deposits can also result from guano reacting with the basalt and its soils. Cave coral is a common secondary carbonate mineral form, and moonmilk has been reported from some lava caves.

Lava caves contain significant *ecosystems*. Many of the lava caves and tubes have collapsed entrances in the roof that have formed pit-fall traps for animals, and so contain interesting bone deposits. Bat populations appear to have dwindled in recent years, compared to the numbers in early reports. The insect populations may also have suffered. The large collapse dolines at Byaduk are important environments for rare species of ferns and other plants.

Volcanic Caves in the Newer Volcanics Province

The distribution of volcanic cave areas within the Newer Volcanics is shown in Figure 4-1. The major areas are discussed here in detail, along with a few of the other areas. This is followed by descriptions and maps of particular caves from these regions.

Mount Napier

At Mount Napier a few small caves occur in the scoria of the summit crater, and several small lava tubes and an arch are known on the slopes of the mountain (Gill & Elmore, 1974; Joyce, 1976). About 2 km west of the peak a scoria cone may be a rootless vent fed from a lava tube. It feeds a short channel with several roofed segments (H-62 to H-65). There are also some interesting subsidiary explosive craters on the sides of this mountain.

A long lava flow runs down the Harman Valley to the west of Mount Napier, and contains the extensive Byaduk Caves.

Byaduk

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 (Ollier & Brown, 1964, 1965; Webb & others, 1982). Collapse of parts of the main feeder tunnel has exposed the largest and most spectacular tunnels, arches and collapse dolines in the region (Figure 6-3). 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, and a multi-level system was recently discovered (H-33), see Grimes (1992). This has a shallow surface maze, and two lower levels connected by lava cascades and chutes where the lava drained downward to the lowest level (see Figure 6-9).

Further down the valley the surface of the flow has excellent examples of surface pressure ridges and clusters of 'tumuli', which are rounded steep-sided domes of lava up to 10 m high and 20 m across that formed when the crust was pushed up by pressure from below (Ollier, 1964b).

Mount Eccles

At Mount Eccles the main volcano has a deep steep-walled elongate crater which contains Lake Surprise. The crater wall has been breached at its north-western end by a large lava canal that flows west and then branches into two main channels running to the west and to the south. A line of smaller spatter and cinder cones and craters extends to the south-east from the main crater. One of these contains The Shaft (H-8), a still open throat 3 m across that bells out into a volcanic chamber that is 23 m deep and 24 m across (Ollier, 1964a).

Another small but well-defined lava canal runs southwards from a small spatter cone near The Shaft and ends at the Natural Bridge (H-10), which is a roofed over section of the canal. The pointed 'gothic' roof of this cave suggests that it was roofed by levee overgrowth (cf. Figure 6-1C), and the contorted layers visible in its walls would be layers that were built up and then slumped while still hot.

Beyond this central area, basalt flows form a lava field about 16 km long and 8 km across. 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, indicating that it formed at a time of lower sea level. This must also have had a major feeder tube, but no drained sections have been discovered to date.

Most of the longer caves at Mount Eccles are in or adjacent to the lava canals, 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. The stony rises on the surfaces of the lava flows do not lend themselves to easy exploration, or navigation! The caves associated with the canals are generally formed in the levee banks on each side and would have fed small lateral lava lobes or sheets when the canal overflowed (cf. Figure 6-1D). Some are simple linear feeder tubes, but many have branching forms and complexes of low broad chambers which suggest draining from beneath the solidified roof of a series of flow lobes. They show a good range of lava 'decorations' (Figure 6-4). Additional information on the caves and surface features at Mount Eccles is given in Joyce (1976, 1980), Ollier (1964a), Webb & others (1982) and Grimes (in press).

Other Volcanic Cave Areas

Mount Gambier is a set of large scoria cones and craters and a maar lake, which contain several small weathering caves in the ash deposits (Horne 1993, see L-256, L-257, L-306). There are also a few small lava flows, and Sheard (1978) reports several small lava caves in the base of these flows.

The *Gisborne Bone Cave* (H-27) was first described and mapped by Selwyn (1859) and remapped by Smith (1980a). It is a small but complex network of small passages at two levels, most of which were originally nearly filled with sediments (and bones). It has a small outflow stream, presumably fed by seepage from the hill above. The cave is in weathered tuff beneath basalt, and not a primary lava cave. Its origin is uncertain, Gill (1964) suggested that it may have been 'dug out by fossorial animals'! From the descriptions, this might be a 'piping cave' formed by the seepage water carrying away the fine clay minerals to leave small tunnels. If so, it is a different type of pseudokarst and unrelated to the volcanism.

Mount Hamilton has one large, complex, multi-level, lava cave (H-2) developed on one side, and several smaller caves occur nearby (see Figure 6-7). The large cave has about 1200 m of passage reaching to depths of 15 m below the surface, and is the longest and most complex in the province. It is a set of branching and networked tubes up to 5 m high and 6 m wide with smaller constrictions at intervals. Ollier (1963a) suggested that the complex form was due to the breaching and draining of a single thick flow that was partly solidified. An alternative explanation might be a multi-level variation of the drained lobes process illustrated in Figure 6-1D.

Lady Julia Percy Island has two caves in basalt (Dewhurst, 1937). Their genesis is uncertain, but they may be primary lava tubes now modified by the sea. The illustrated cross section of one cave has a form that is typical of lava tube.

Parwan, near Bacchus Marsh, has a single 240 m tunnel (H-4) with several broad low arched chambers, considerably modified by collapse (Rees & Gill, 1959). The floor is of red soil, and several interesting minerals have recently been collected, including one, 'Parwanite', which appears to be a new type (Webb, 1986). This may be one of the oldest caves in the region as similar basalts 25 km to the east-south-east have been dated at 2.5 to 2.7 million years.

At *Panmure* a single bifurcating lava tube (H-5) has been intersected by a quarry (Gill, 1944; Ollier & Joyce, 1968). This one still has many bats, possibly because it is seldom visited. This appears to be in a 0.54 million year old flow.

Mount Porndon has some interesting surface volcanic features and two lava tubes (Skeats & James, 1937; Ollier & Joyce, 1968). Porndon Arch Cave (H-6) is a simple 100 m long tunnel with a typical arched cross-section up to 15m wide and 9 m high. It has a well developed lava bench (see map by Smith, 1979b; and in Webb & others, 1982). The Rubbish Cave (H-7) appears to be more interesting as Ollier & Joyce (1968) report that the floor and roof have a similar curvature and the floor rises to join and match the roof at the end of the cave, suggesting that either there is a tube-in-tube or that the present floor might be a roof lining that has sagged down to the floor! This cave was reported to originally have been longer but the entrance section collapsed at some time in the 1930s.

At *Mount Widderin*, the single Skipton Cave (H-1) (Figure 6-6) has been described by Ollier (1963b). It consists of two connected broad chambers and several smaller chambers at the end, all much modified by collapse. The cave had a large bat colony in the last century but these had already left by 1895. The guano deposits contained an interesting insect population (Hamilton-Smith, 1968) and a number of unusual mineral deposits (Webb & others, 1982, Webb, 1986). It is the type area for several phosphate minerals as well as for an insect species. Unfortunately it has suffered from heavy visitation, so both insects and minerals have probably now been trampled into oblivion.

Near *Smeaton*, Mount Kooroocheang is a large composite ash cone which contains two hornitos. Armchair Shaft (H-47) is a single small shaft about 9 m deep with walls coated by melted rock (Smith, 1979a, 1980b; Webb & others, 1982). A low rock wall, the 'armchair', partly surrounds the entrance. The shaft probably developed by the escape of gas and molten material through a break in the crust of a lava flow and the 'armchair' was probably built up from semi-solidified spatter blown out of the shaft. The second hornito is nearly filled with a convex basalt plug (Webb & others, 1982).

At *Warrion Hill* five small lava caves have been recorded in stony rises country by Frank (1971). The longest is about 50 m of low wide tunnel.

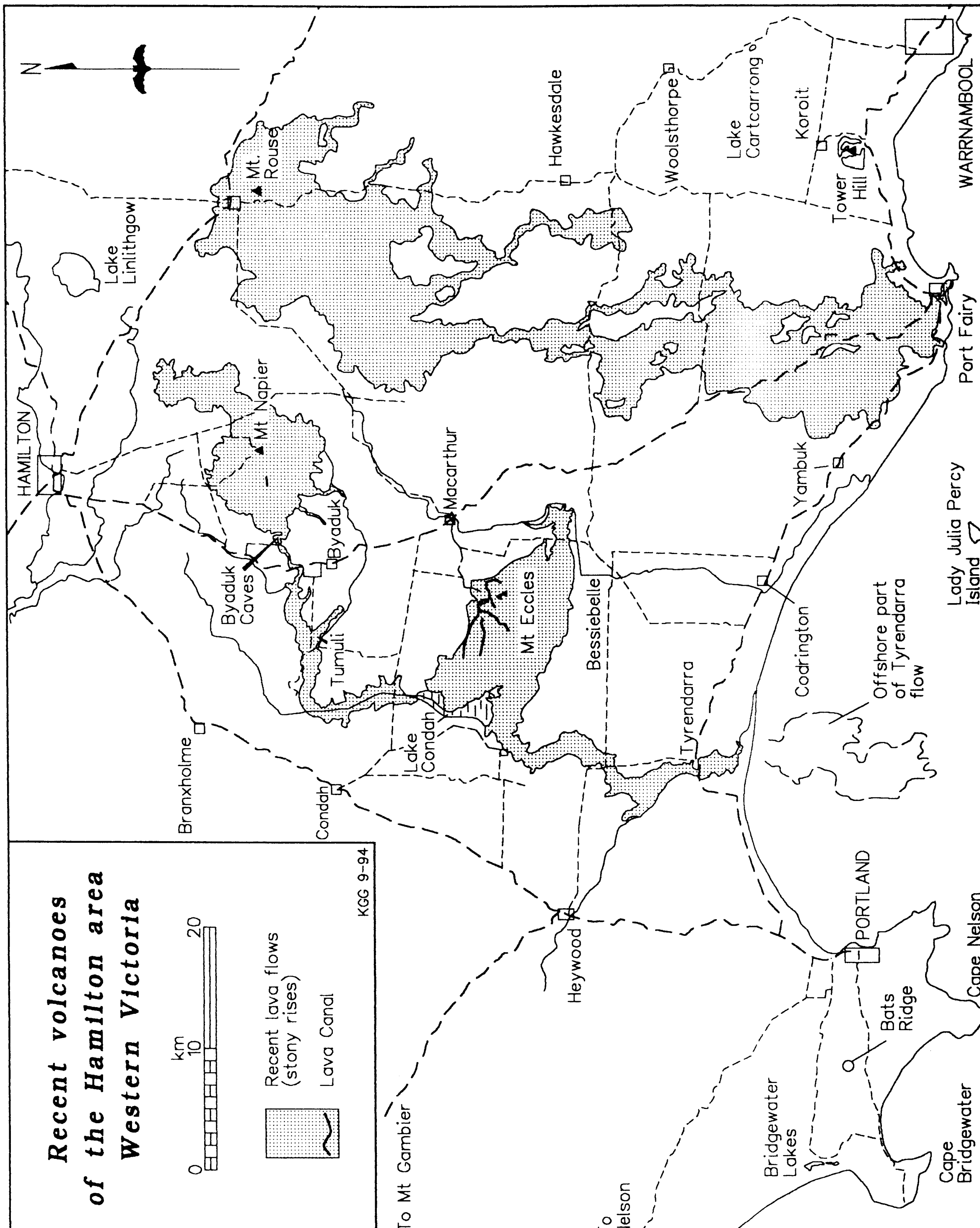


Figure 6-5: Recent Volcanoes of the Hamilton area, Western Victoria

Volcanic Cave Descriptions

Cave Number: 3H-1 **Cave Name: Skipton Cave**

Area: Skipton.

Cave Type: Very large lava tunnels formed in a deep lava flow from the old and eroded Mt. Widderin volcano.

Entrance: Small cave type, at the end of a large collapse doline.

Surface access time and difficulty:

The cave is on private property and is only five minutes walk from the homestead car park.

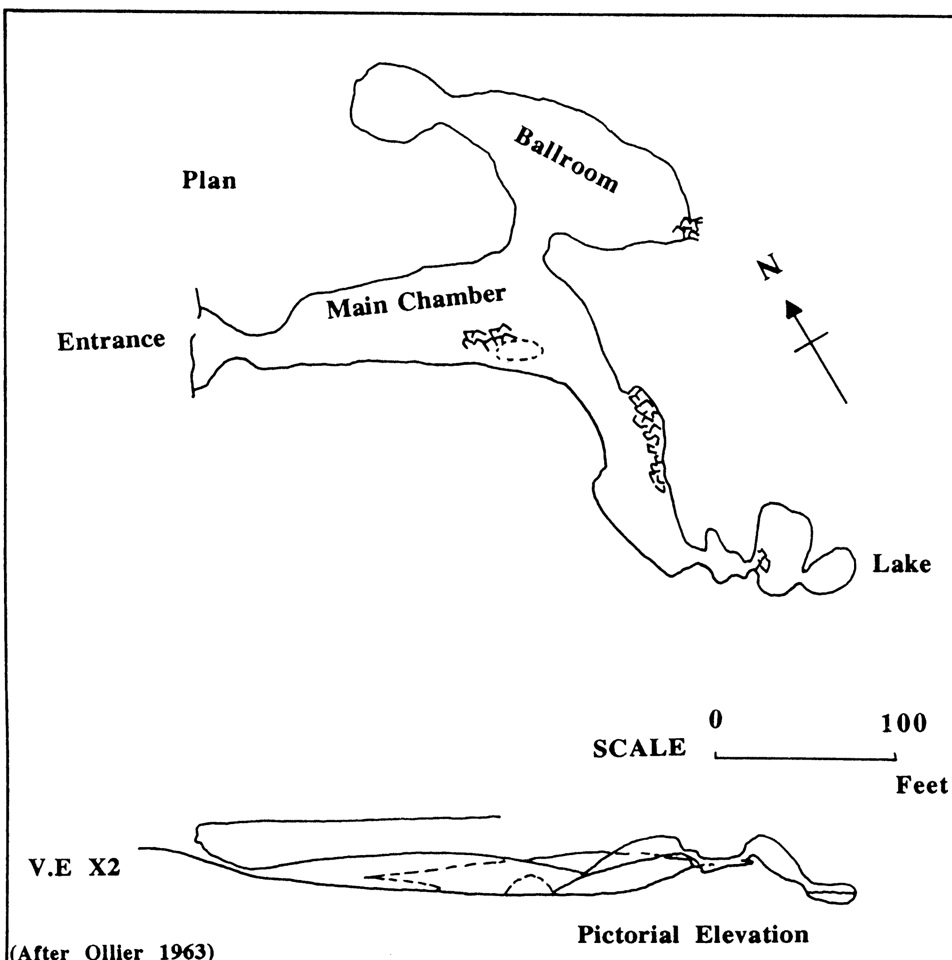


Figure 6-6: Map of Skipton Cave (H-1) (After Ollier, 1963b)

Brief description of cave:

Two parallel tunnels, (The Main Chamber and The Ballroom) joined by an arched 'doorway' at their mid sides. At the far end of the Main Chamber, a crawl leads to another large domed chamber containing a deep lake, which once supplied all the water for the homestead and gardens. Large quantities of guano were also mined from the cave for fertiliser.

Approximate time underground: 2 - 3 hours.

Equipment needed:

Lights and normal caving clothes suitable for horizontal limestone caving. This is a very old lava cave and doesn't have too many sharp edges.

Cave Number: 3H-2 Cave Name: Mt. Hamilton Cave

Area: Mt. Hamilton.

Cave Type: Complex branching lava tunnel.

Entrance: Pothole, tight squeeze and approx. 6 metres vertical. A rope or ladder is needed.

Surface access time and difficulty:

A two and a half hour drive from Hamilton, towards Melbourne. The cave is on private property.

Brief description of cave:

This is the longest and most complex complete lava cave in Victoria. Total tunnel length is 1200 metres. The cave system is on several levels and has many branching tunnels, both features being most unusual to this extent in lava caves. A permanent pool of standing water is located at the extreme southern end of the system. Tunnels range from 3 to 5 metres in height and 6 metres wide, down to very tight crawlways.

Approximate time underground: 3 to 4 hours.

Equipment needed:

A rope, or a caving ladder, for the vertical entrance pitch. Lights and clothing suited to lava caves. Some of the tunnels are tight, with sharp lava.

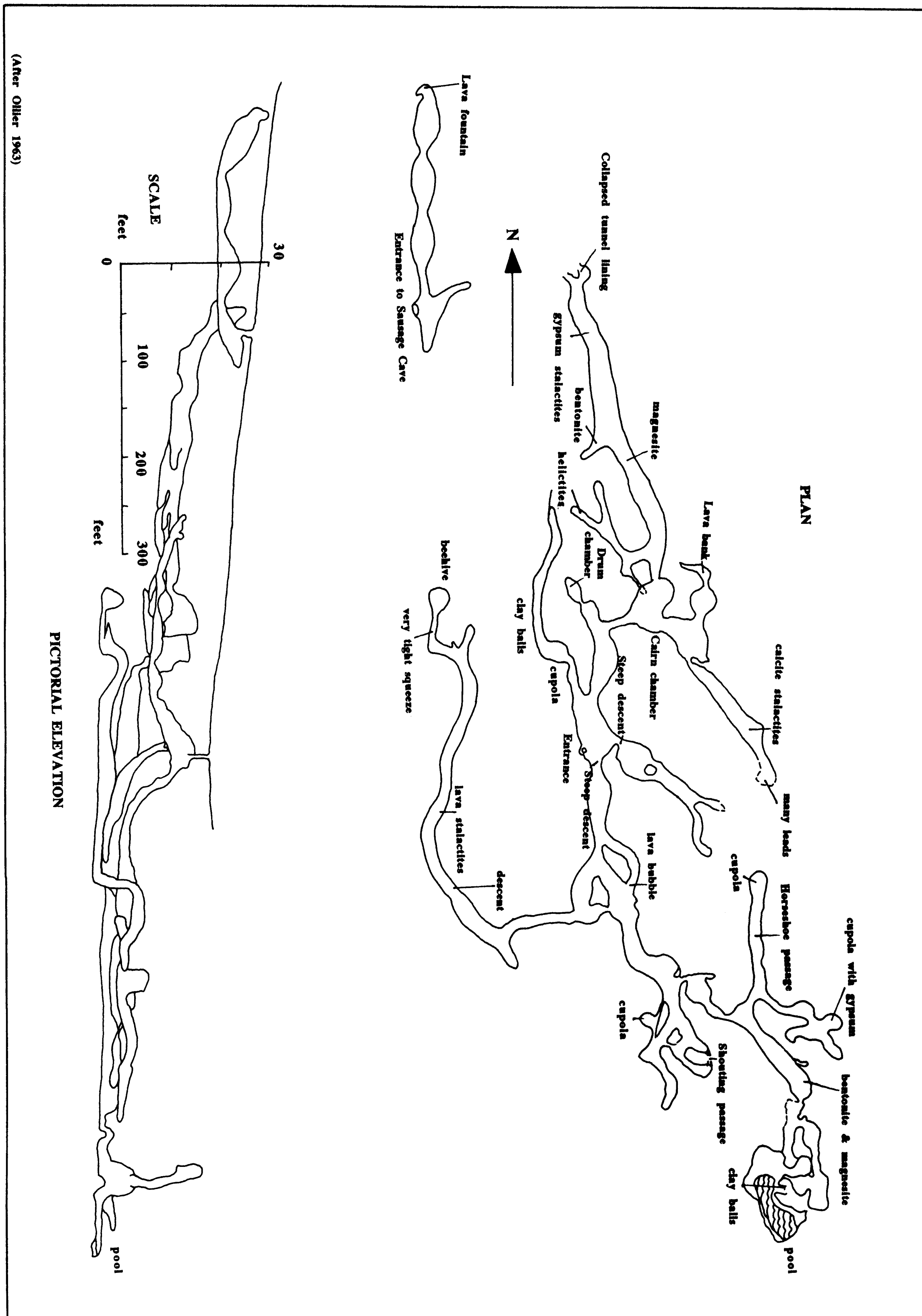


Figure 6-7: Map of Mt. Hamilton Cave (H-2) (After Ollier, 1963a)

Cave Number: 3H-8 Cave Name: The Shaft

Area: Mt. Eccles.

Cave Type: Volcanic vent.

Entrance: Vertical shaft.

Surface access time and difficulty:

A ten minute walk along a rough track. Caution is required as The Shaft is unfenced and the slopes and overhang around it are slippery. The nearest anchor point is 10 metres from the overhang.

Brief description of cave:

A shaft in the bottom of a funnel shaped hollow in a small spatter cone opens up at the base into a large elongated chamber. Contains moss covered lava stalactites. See also Grimes (1994b).

Approximate time underground:

10 minutes on the bottom, but the SRT or ladder access takes longer. Avoid big parties.

Equipment needed:

23 metre SRT pitch or ladder with belay. An additional 20 m of slings are required to rig to a large block on the outer south-east slope. Not a good place for beginners.

Work needed:

Input to management concerning public access, viewing platforms and safety fences etc.

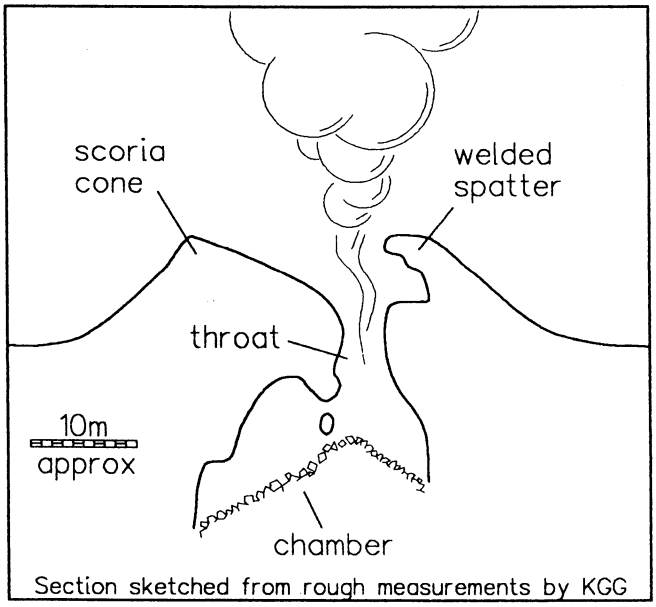


Figure 6-8: Section sketch of The Shaft (H-8) at Mt. Eccles

Cave Number: 3H-9 Cave Name: Tunnel Cave

Area: Mt. Eccles.

Cave Type: Large lava tube beside main canal.

Entrance: Walk in cave entrance.

Surface access time and difficulty:

5 minute walk on easy graded track from main tourist car park at Mt. Eccles.

Brief description of cave:

Horizontal entrance leads down rubble slope to 60 metre long simple large flat floored tunnel with arched roof and a low bit at the end. In one spot near the far end the roof lining has sagged away allowing a view into the opened up cavity behind it. Contains lava stalactites. Low benches at base of walls.

Approximate time underground:

15 minutes.

Equipment needed:

Lights and head protection only. Not even a light for the entrance chamber.

Work needed:

A more detailed map.

Cave Number: 3H-10 Cave Name: Gothic Cave (Natural Bridge)

Area: Mt. Eccles (Natural Bridge).

Cave Type: Lava tube, roofed channel.

Entrance: Horizontal walk in cave entrance.

Surface access time and difficulty:

10 minutes drive on park track, park on top of the bridge!

Brief description of cave:

Short tunnel under roofed part of a small lava channel. Angular (gothic) roof with daylight hole. Sagged wall linings visible.

Approximate time underground: 10 minutes.

Equipment needed: Nil.

Work needed:

Needs a more accurate map with multiple cross sections.

Cave Number: 3H-11 Cave Name: Harman One Cave

Area: Byaduk.

Cave Type: Large lava feeder tube.

Entrance: Easy climb down into a large collapse doline into a large entrance.

Surface access time and difficulty:

4 minutes walk from local car park.

Brief description of cave:

The original tunnel is broken by two large roof collapse dolines. H-11 is the downstream end of the tunnel and is approx. 150 metres long and 10 to 14 metres wide.

Caving involves scrambling over a number of large roof blocks. In places original lava floor and benches are visible. The main features are the ferns and mosses at the entrance and the large circular chamber at the far end with a complete domed lava floor. A crawlway connects the two dolines.

Approximate time underground: 1 - 2 hours.

Equipment needed:

Old clothes, helmet and lights and caving footwear.

Work needed:

1. A survey of the cave with sections and profiles.
2. A new biological survey. What has been lost in the last 30 years?

Cave Number: 3H-15 — Cave Name: Church Cave One (West)

Area: Byaduk.

Cave Type: Large lava feeder tube.

Entrance: Access is via a careful but easy climb down into a large collapse area into a large cave entrance.

Surface access time and difficulty:

From local car park, 20 minute walk over flat but rocky and uneven country along the edge of the flow.

Brief description of cave:

This is the largest of the caves in the area and is a roosting site for the Bent Wing Bat. H-15 is the downstream end of a system which is now broken by three very large roof collapse dolines. The cave is a large tunnel approximately 130 metres long, 15 metres wide and 8 metres high, with a side tunnel and crawl to a high level entrance in the side of the doline.

Approximate time underground: 2 hours.

Equipment needed:

Helmet, lights, old clothes and caving footwear.

Work needed:

1. A plan survey of the cave with sections and profiles.

2. A biological re-survey to see what has been lost.

Cave Number: 3H-16 — Cave Name: Church Cave Two (Arch)

Area: Byaduk.

Cave Type: Natural arch (segment of large lava feeder tube).

Entrance: Large walk-in entrance at east end of collapse doline.

Surface access time and difficulty:

From local car park, 20 minute walk over flat but rocky and uneven country along the edge of the flow.

Brief description of cave:

A large spectacular daylight tunnel (60 m long, 15 m wide and 10 m high) connects the two elongated collapse dolines. Mostly collapse and rubble, but some lava levels are visible on the north-west wall. From the appearance of this awesome daylight cavern, it is likely that the original use of the name 'Church Cave' was applied to this feature rather than to the equally large, but dark, H-15 tunnel to the west.

Approximate time underground: 15 minutes.

Equipment needed: Nothing special, not even lights.

Cave Numbers: 3H-19, 3H-20, 3H-21, 3H-22, 3H-24 — Cave Names: Flower Pot, Bathtub, Tunnel Cave, Shepherds Cave, The Turk

Area: Byaduk

Cave Type: Large lava flow tube, mostly collapsed and exposed to view from the surface.

Entrance: Five collapses give access to this series of short segments of cave.

Surface access time and difficulty:

From local car park, 30 - 40 minute walk on rough stony rises.

Brief description of cave:

Excellent photographic subjects, The Turk shows the best variety. It has many distinctive patterns in lava and roof linings. Ropy lava floors (pahoehoe), and asymmetrical tunnel, lava stalactites and dribbles. The original Tunnel was over 400 metres in length, and much longer if the continuation segment of Church Cave is included.

Approximate time underground: 1 - 2 hours.

Equipment needed:

Camera, old clothes, helmet and lights and caving footwear. Sturdy footwear is needed even for surface trogging.

Work needed:

Remapping with profiles, sections and detail.

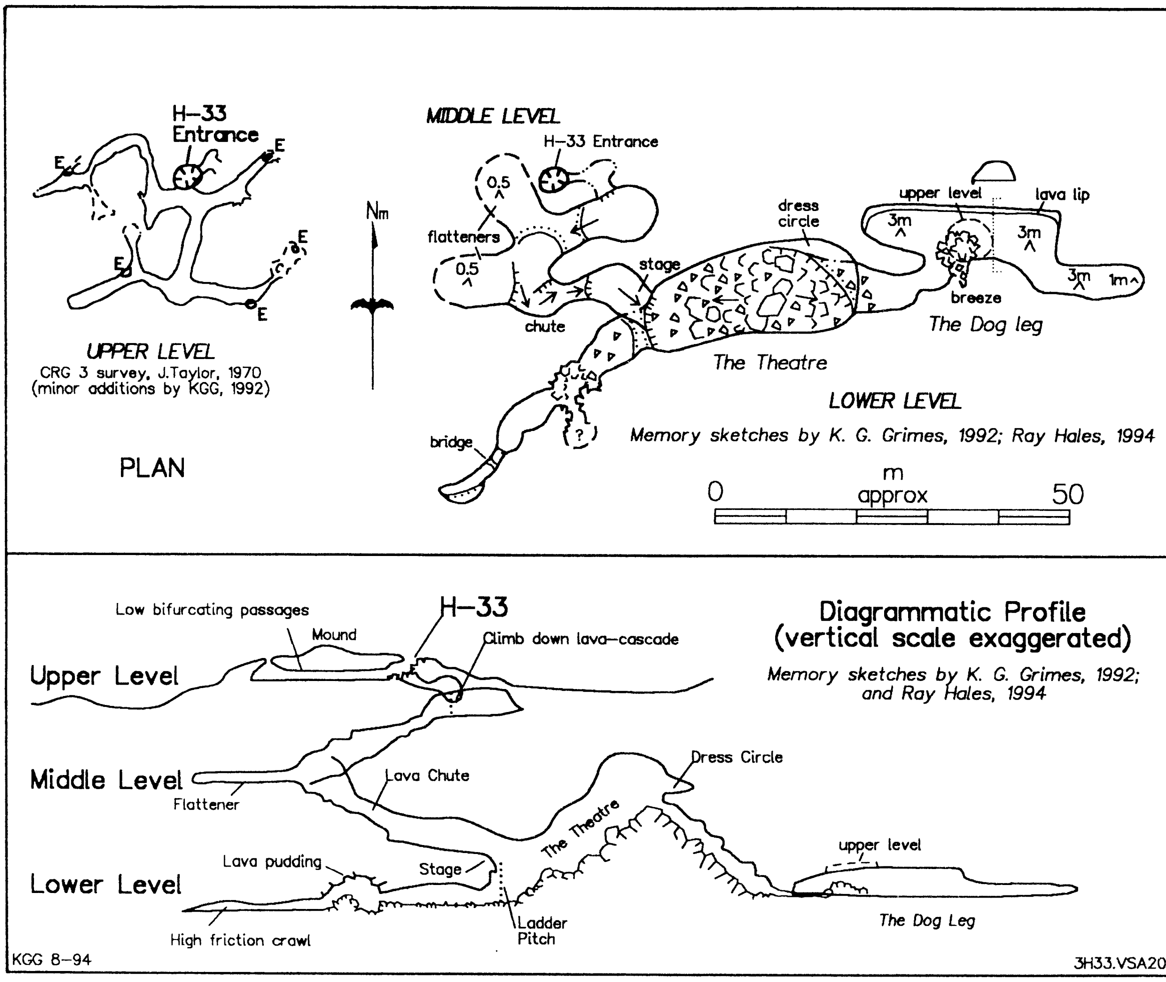


Figure 6-9: Map of The Theatre (H-33)

Cave Number: 3H-33   Cave Name: The Theatre

Area: Byaduk.

Cave Type: Complex multi-level lava cave.

Entrance: Small cave type with a 2 metre drop inside. A ladder makes entry and exit easier.

Surface access time and difficulty:

From local car park, 40 minutes walk over rocky and uneven untracked ground.

Brief description of cave:

The most complex and interesting cave in the area. The upper level is branching crawlways, the middle level is several chambers connected by lava cascades, and the lowest level is a large tunnel with a big collapse dome. There are excellent lava cascades, as high level (later) lava flows have broken into the lower level pre-existing caves. A second ladder and belay is required to descend into the large lowest chamber and tunnel. See also Grimes (1992), Grimes (1993) and Wall (1993).

Approximate time underground: 2 - 3 hours.

Equipment needed:

Helmet, lights, 'lava caving clothes', 2 ladders with steel traces, belay ropes and rigging.

Work needed:

A proper survey. Some leads still to be pushed.

Cave Number: 3H-51 Cave Name: North Pole Cave

Area: Mt. Eccles.

Cave Type: Lava tube in levee beside the main lava canal.

Entrance: Cave type entrances in sides of 2 collapse dolines and in canal wall.

Surface access time and difficulty:

From local car park, 15 - 20 minutes drive on Park tracks (parking limit of 4 vehicles), then a 10 - 15 minute walk on bush tracks.

Brief description of cave:

Main tunnel large enough for stooping walk. The cave takes its name from a magnetic rock (North Pole) which makes surveying interesting. The back area of this cave is a complex system of well preserved looping and branching passages (crawling country), and has excellent roof features and pahoehoe and aa lava floors.

Approximate time underground: 'The full treatment' takes 1 1/2 to 2 hours.

Equipment needed:

Lava caving clothes, helmet and lights, note book etc.

Work needed:

1. Still some tight and painful leads.

2. Sketches and photographs.

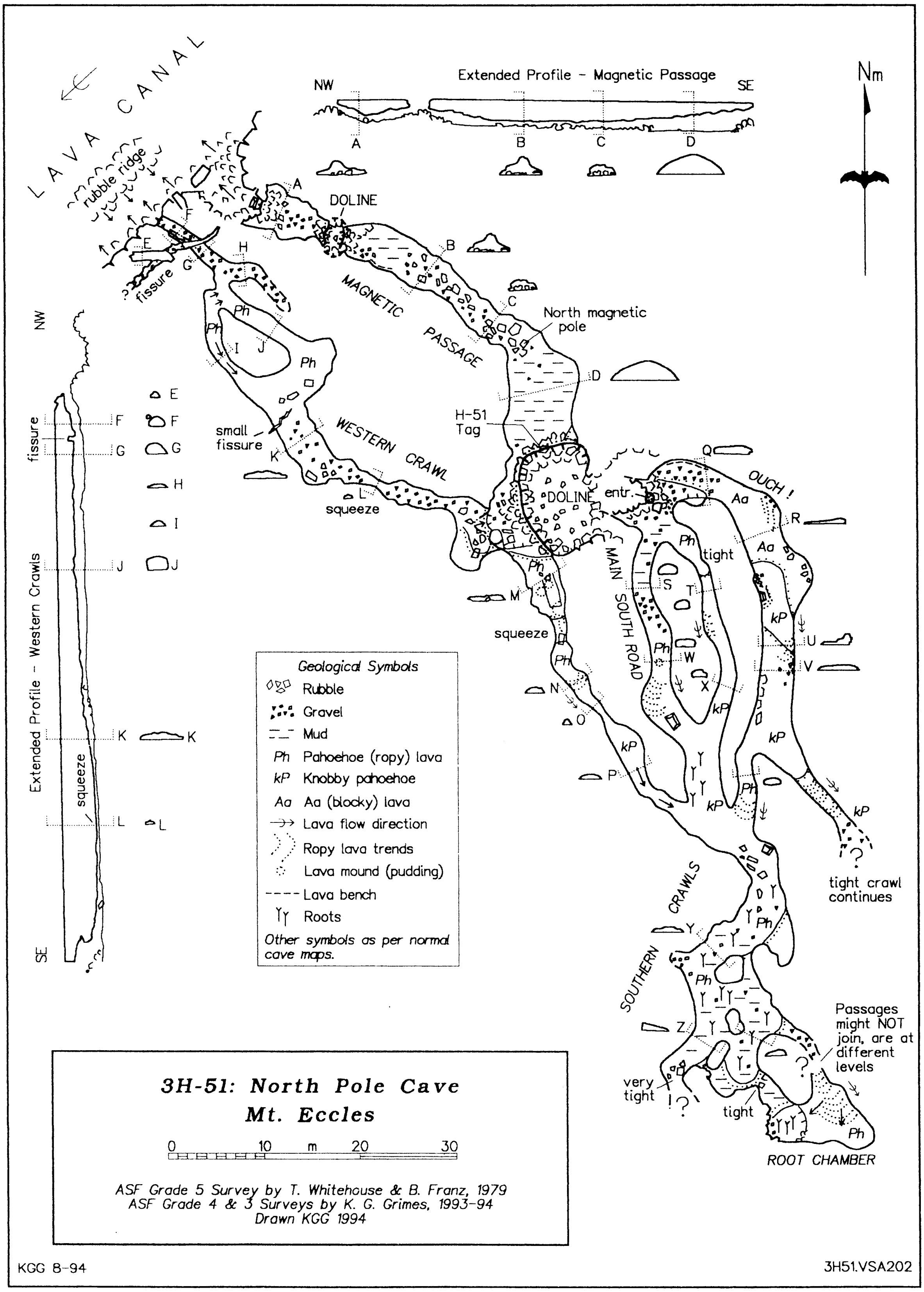


Figure 6-10: Map of North Pole Cave (H-51)

Cave Number: 3H-53 Cave Name: None

Area: Mt. Eccles.

Cave Type: Lava tube in levee beside the main lava canal.

Entrance: The canal entrance is high in the west wall. The back entrance is via a collapsed dome chamber.

Surface access time and difficulty:

From local car park, 15 - 20 minutes drive on Park tracks (parking limit of 4 vehicles), then a 10 - 15 minute walk on bush tracks.

Brief description of cave:

An interesting through trip with a bit of a tight squeeze in the middle to pass some lava mounds, which may be up-thrust tumuli.

The canal entrance when reached provides a nice photo opportunity and view of the canal.

Approximate time underground: 1 hour.

Equipment needed:

Caving clothes, helmet and lights, camera.

Cave Number: 3H-54 Cave Name: Foote Cave

Area: Mt. Eccles.

Cave Type: Lava tunnel with large entrance into a collapsed dome.

Entrance: Large cave type in collapse doline. Easy sloping climb down.

Surface access time and difficulty:

From local car park, 15 - 20 minutes drive on Park tracks (parking limit of 2 vehicles at the signpost), then a 10 minute walk on a bush track.

Brief description of cave:

Entrance via a collapsed slope into the remains of a domed lava floor of a large 'blister' or dome chamber. At the side of the rock fall, a tube leads to a small terminal chamber with lava benches. See also Grimes (1994b).

One unusual feature in the tunnel is the partial melting of the left hand wall, allowing adjacent lava to spill into this tunnel from a high level flattener.

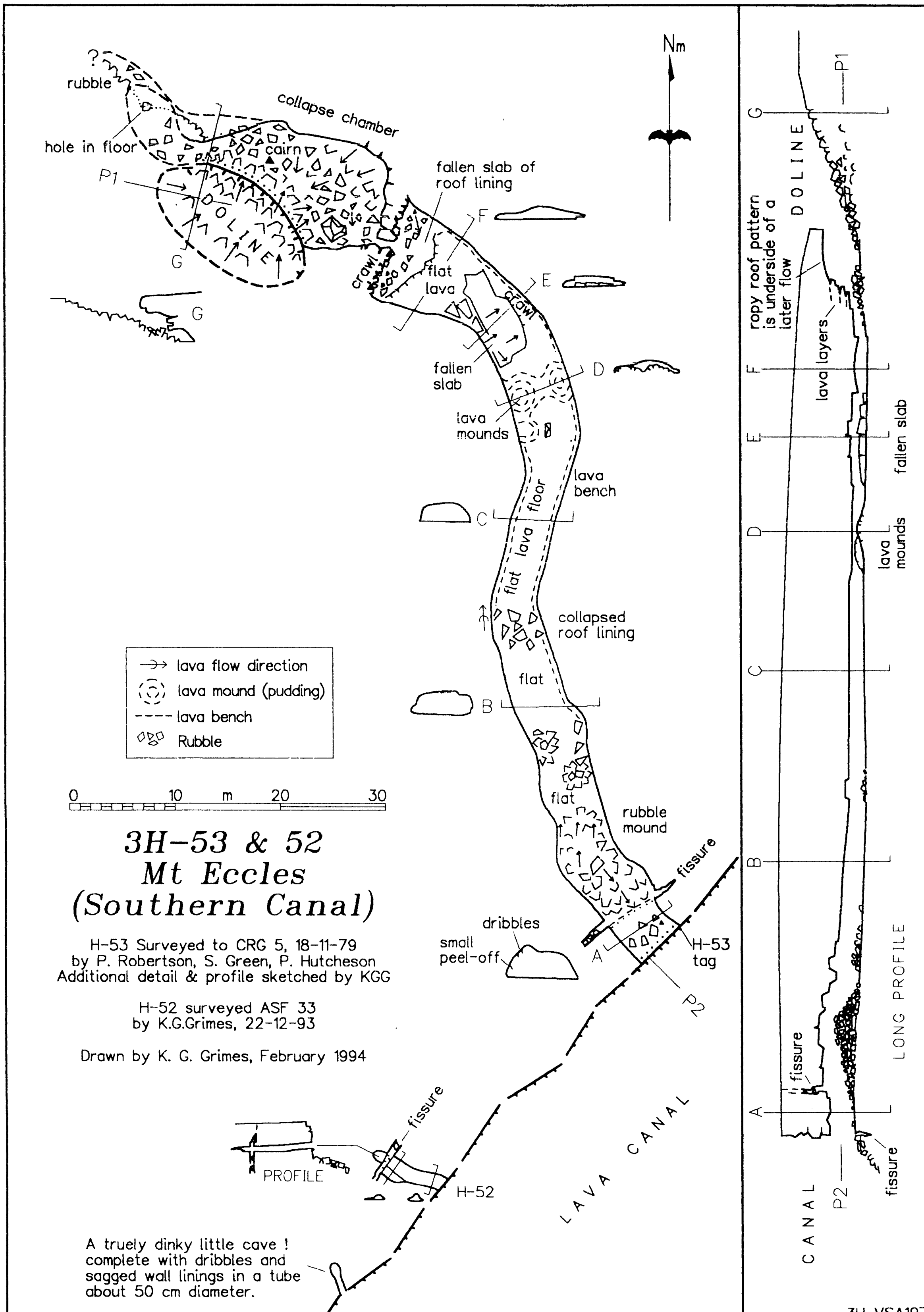


Figure 6-11: Map of H-53 and H-52

Approximate time underground: 1 hour.

Equipment needed:

Entrance area chamber: Nil. The tunnel: Lava caving clothes, helmets and lights.

Work needed:

1. Interpretative reports.
2. A more accurate map.

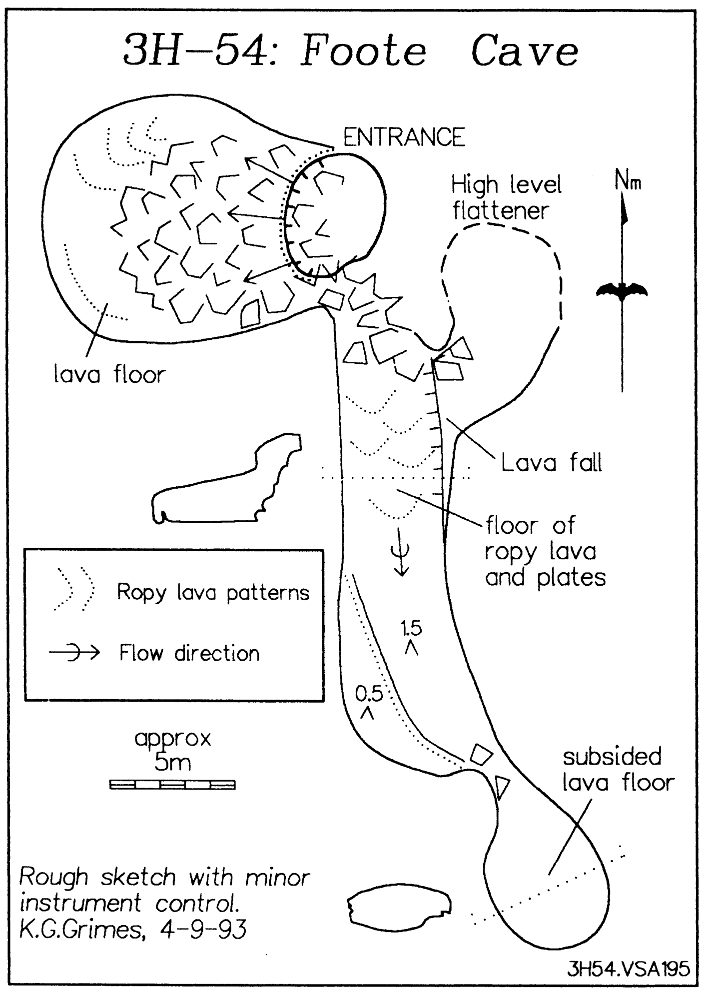


Figure 6-12: Map of Foote Cave (H-54)

Cave Numbers: 3H-70 **Cave Names: Carmichael Cave,**
3H-71 **Maze Cave,**
3H-79 **None**

Area: Mt. Eccles.

Cave Type: Two level branching lava tube in levee beside canal.

Entrance: Small cave type in collapse doline.

Surface access time and difficulty:

From local car park, 15 - 20 minutes drive on Park tracks (parking limit of 4 vehicles), then a 10 - 15 minute walk on bush tracks.

Brief description of cave:

Carmichael Cave is mainly low branching passages and chambers at a higher level than Maze Cave. Maze Cave is a large older flow tunnel with well preserved lava floors and drainage patterns. The roof and walls exhibit drips and sags. The unusual feature is the three high level tubes from Carmichael Cave which have drained aa lava into the main tunnel.

Approximate time underground:

1 - 2 hours. Allow 3 hours and lava caving clothes to access the northern chamber from the H-70 entrance.

Equipment needed:

For simple walk into entrances: Torch and camera. For hard caving: Caving clothes, lights, gloves and helmet.

Work needed:

1. Finish surveying and recording floor and wall detail.

2. Assessment of the processes of formation.

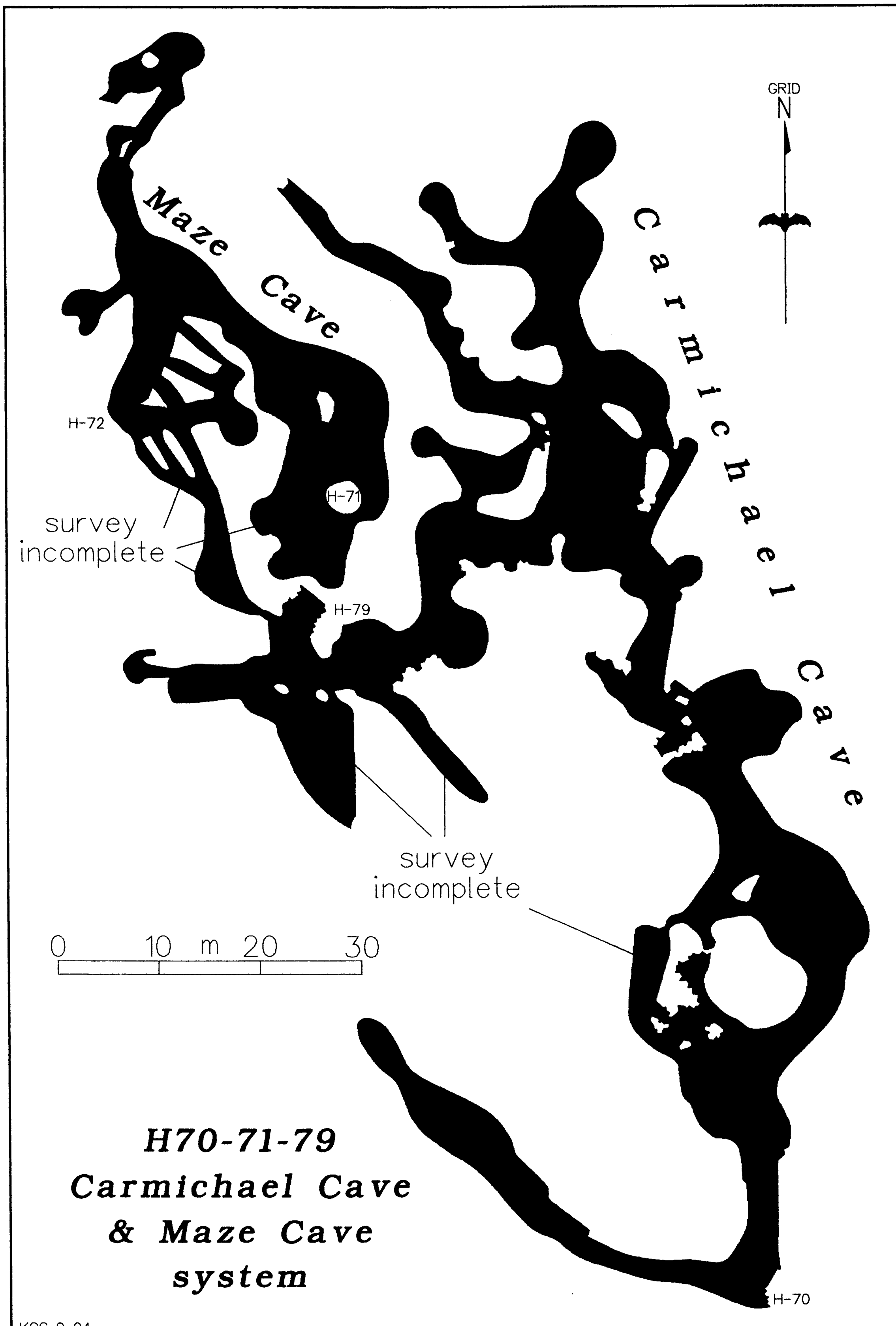


Figure 6-13: Map of Carmichael Cave (H-70), The Maze (H-71) and H-79

Cave Number: 3H-78 — Cave Name: Halfway Cave

Area: Mt. Eccles.

Cave Type: Lava cave in stony rises country.

Entrance: Horizontal through rockpile.

Surface access time and difficulty:

15 minutes drive on park track from car park. Right beside Park South Track. No long term parking!

Brief description of cave:

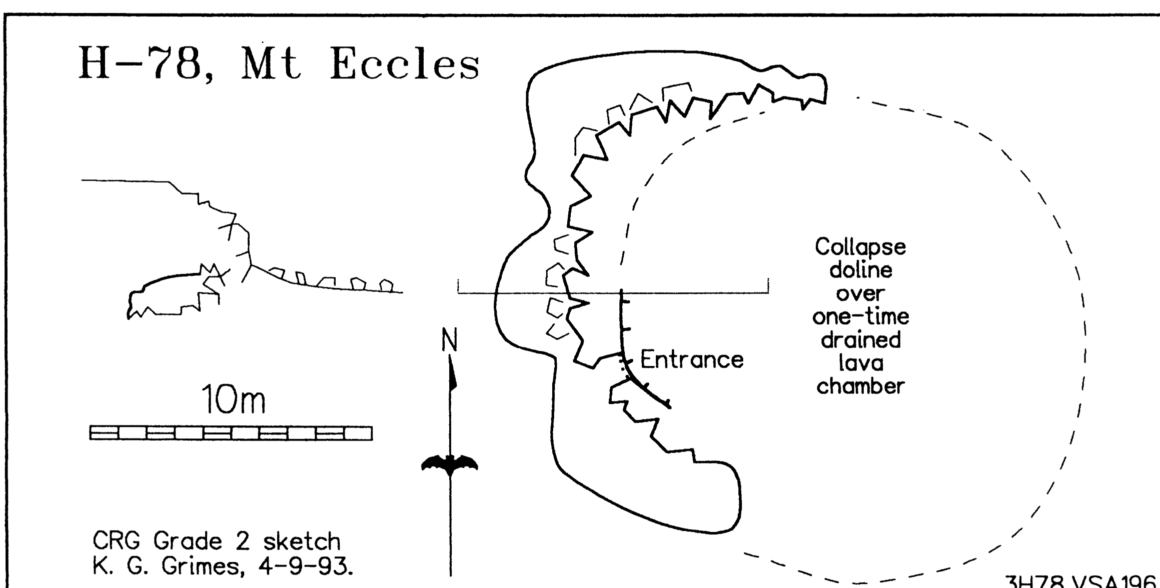
A peripheral remnant of a drained lava chamber. The main chamber has collapsed to form a doline, but the outer parts are still accessible through rockpile. Solid outer wall, inner wall is breakdown. See also Grimes (1994b).

Approximate time underground:

10 minutes.

Equipment needed:

Normal caving gear: trog suit, light, boots, helmet.



H-78 is a typical example of a peripheral remnant cave, left after the collapse of the main part of a drained lava chamber

Figure 6-14: Map of Halfway Cave (H-78)

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7. Tertiary Limestone Areas of Western Victoria

Susan White

Introduction

West of the Cretaceous aged sediments of the Otway Ranges, the coastline is predominantly Tertiary limestone, and often topped with Quaternary calcarenite dunes. Although caves are present in some localised areas in this Tertiary limestone, karst features are limited and small for such a relatively large area of exposed limestone. This is quite different to the Tertiary limestone areas in the western part of the Otway Basin in South Australia.

The Tertiary limestones are predominantly Miocene in age and were deposited in the shallow sea which covered the area in the Oligocene and Miocene (20 - 30 million years ago). The sediments wedge out rapidly towards the Kanawinka Fault along the western half of the northern boundary of the Otway Basin. Drilling along the coastline has indicated a Tertiary section of up to 1500 m thickness, resting conformably on the Upper Cretaceous (Abele, et al.,1988). There was a lack of standardisation of nomenclature in the early literature, although this situation has been improved by work done in the 1970s, which reappraised the entire stratigraphy of the Otway Basin.

The limestone is relatively soft in the subsurface but develops case hardening and calcrete cappings on exposure. It is locally well jointed with a dominant north-west trend. Caves are present in a few localised areas, but are not the dominant karst feature in the extensive limestone province. The limestones are similar to those of the Nullarbor and there are also some similarities of cave style. The influence of both the vertical jointing and the horizontal bedding are exhibited in the cave passage forms, however there are none of the huge passage systems that occur on the Nullarbor.

Coastal Karst

The coastal karst is extremely spectacular with the interplay of the jointed well-bedded limestone with the coastal processes and solutional processes. This results in arches, stacks and small caves at different levels in the cliffs.

The coast can be divided into five major sections which show the main features of the interaction of marine and karst processes:

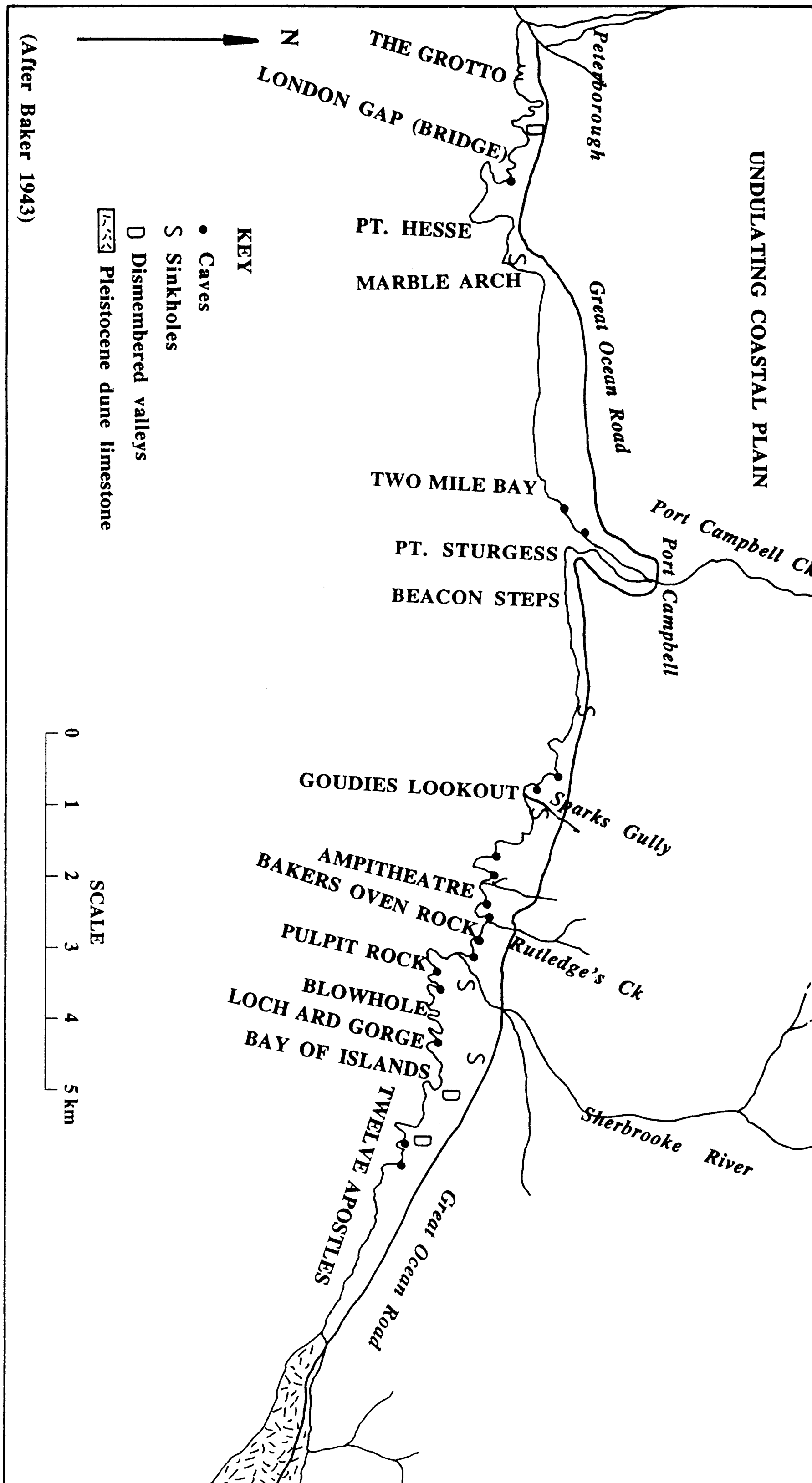

Figure 7-1: Coastal features in the Port Campbell area (After Baker, 1943)

1. The Twelve Apostles to Childers Cove

The Miocene Port Campbell limestone has cliffs up to 60 m high sometimes topped by calcareous and / or siliceous sand, or dune limestone.

The Port Campbell limestone is thinly bedded with concretions and secondary limestone deposition along the bedding, dipping seawards. Prominent jointing which strikes north-west / south-east parallel to some coastal features controls the gorge and promontory formation; vertical jointing controls cliff development and cave formation. The nearly vertical cliffs show a wide range of spectacular features including reefs, offshore rock stacks, overhanging cliffs, hanging valleys up to 50 m above present sea level, wave cut benches, and notches at various levels. About 45 caves are recorded at the cliff base with several about 5 - 10 m above sea level.

The limestone plain (50 m above sea level) also has a number of karst features. Sinkholes up to 300 m in diameter have developed in an area with very little surface drainage.

The most spectacular of the karst features along this section of the coast are shown in Figure 7-1, and include:

i) The Grotto

A dissected sinkhole opening onto the cliff through an archway, and containing a boulder beach 13 m above sea level.

ii) London Bridge / London Gap

One of the more spectacular sites is the remains of London Bridge which was a promontory with two arches until 1990. In January of that year the larger arch collapsed leaving an arched rock stack. A 20 m block is on the beach to the west which fell before 1943.

iii) Marble Arch

The floor is 6 m above sea level.

iv) Two Mile Bay

An emerged marine platform.

v) Goudie's Lookout

A narrow promontory 60 m high, over 150 m long and 5 - 15 m wide. There are caves on both sides.

vi) Bakers Oven Rock

A rock stack with a tunnel 6 m above sea level.

vii) The Blowhole

A joint controlled collapse 45 m long and over 18 m deep, in a cave which extends for 1 km inland from cliff face. Access to the cave is extremely difficult.

viii) Loch Ard Gorge

Loch Ard Gorge is developed along the direction of the jointing and has a narrow entrance widening to form two small bays separated by a headland. The Gorge is named after the clipper "Loch Ard", which was wrecked in the area in 1878. There were two survivors who sheltered in Miss Carmichael's Cave (SW-3) and Tom Pearce's Cave (SW-2) (Loney, 1981).

The two caves at Loch Ard Gorge are good examples of the karst development along the joints and they show underground fresh water streams, and percolating groundwater and speleothem development. These features show the definite joint control exhibited in the karst in the Tertiary limestones which relates to other features in the area as well.

Miss Carmichael's Cave (SW-3) is a single chamber at the western end of the beach with sand stalagmites formed by cemented loose sand on the floor immediately below dripping stalactites. Tom Pearce's Cave (SW-2) is at the head of the eastern bay and receives the discharge from a gully-fed sinkhole above and has a rocky floor (White & Grimes, 1992). See the cave descriptions later in this chapter. There are also other features nearby such as a large collapse doline and a blowhole.

ix) Bay of Islands

Rock stacks with prominent basal notches.

x) The Twelve Apostles

The spectacular rock stacks extend 1 km east of the Bay of Islands to Castle Rock. Castle Rock is a promontory 200 m long, 2 - 10 m wide and 15 - 35 m high. These are the best examples of the rock stacks along the coast here and show prominent basal notches. The taller stacks can be as high as 50 m.

xi) Doline field

Just inland from the coast between Curdie's Inlet and Peterborough is an extensive doline field which can be seen very clearly from the air or in aerial photographs, but is less obvious from the main roads in such a flat landscape. None of the dolines appear to lead to caves but some lead to small swamps where the collapse has exposed the water table.

2. Childers Cove

Childers cove consists of aeolianite dunes with cliffs predominately 30 - 60 m high. The aeolianite extends down to 25 m below sea level where it overlies Miocene limestone. A few small caves can be found in the Childers Cove area, such as Caleb Cave (W-22), described later in this chapter.

The Cove itself is a large doline which has been invaded by the sea and there are some small caves around the cliffs. The area warrants a more detailed look than has previously been given.

3. Warrnambool

Warrnambool is built on top of calcareous aeolianite at 50 m above sea level, but much of the karst is in the Tertiary limestone to the east of the city. Between the town and the sea lies Lake Pertobe (now an adventure playground area) which is cut off from the sea by Holocene coastal dunes. Swamp deposits overlie a beach deposit resting on the aeolianite. Warrnambool has a number of tourist attractions including Flagstaff Hill with its historical associations, as well as beach activities. It is the major town in the district and has a large shopping area.

This is a caving area of dune limestone overlying Tertiary limestone in which there are a number of small caves and a couple of large ones.

The best known large cave is Starlight Cave (W-5), which has a large 25 m diameter chamber, with daylight holes in the roof, and is about 40 m high. The cave is on private land, making it hard to visit. It is also an important bat maternity site and the site of an old guano mine which still contains large deposits of guano (Gill, 1948).

A number of caves are found along the coast. These include, amongst a number of small coastal caves, Gaul's Cave (W-9), and Pillar Cave (W-10). Low tide is advisable for some visits and some require clambering up rather crumbling cliffs.

Two small caves (W-1, W-2) can be visited if access is organised with the owner. Both are well explored and are probably influenced by the water in the Lake Gillear drain. Although the area has some caves they are generally not very spectacular, with the exception of W-5. They do offer an opportunity for wandering along the beach 'messing about in caves'. See also the cave descriptions later in this chapter.

4. Timboon

This area has a number of small caves and karst features in Tertiary limestone. The limestone in the area is generally capped with a thin layer of basalt of the Newer Volcanics, except where streams have cut through this and exposed the limestone in deep valleys. The caves are all small. They show the existence of limestone under volcanics. The area is not intended to be visited in the post conference trips.

5. Glenelg River

Caves in this area are found mainly in the Miocene limestones. Although extensive karst development in the dune limestones has occurred elsewhere, in the Glenelg River area there are overlying aeolianites containing solution pipes or dolines, which allow access to the joint controlled cave systems in the Tertiary limestones.

One of the more spectacular features is the gorge of the Glenelg River itself, as this is a permanent river with its headwaters outside the limestone province. The gorge is up to 100 m wide with sheer sided limestone cliffs rising up to 35 m above the river level. The river and bushland in the southern part of the area is within the Lower Glenelg National Park. State Forest (with pine trees) occupies much of the land immediately north of the river.

Although about 70 caves are known in the area, very little karst work has been done on the Victorian side of the border; more work has been done on the South Australian side.

Cave Descriptions

Cave Number: 3G-4 Cave Name: Curran's Creek Cave

Area: Pine forest.

Cave Type: Through cave.

Entrance: Multiple walk in.

Surface access time and difficulty:

The top entrance is used. 15 - 20 minute walk from car. Access **must** be arranged with the National Park.

Brief description of cave:

Multi-entrance through cave, with small stream, large semi-daylight passages and low maze-like crawl passages. Developed from a two or more stage joint enlargement. Some solution pipes. Cave opens to river. See also Ackroyd (1993).

Approximate time underground: 1 - 2 hours.

Equipment needed: Basic.

Cave Number: 3G-10 Cave Name: None

Area: Pine forest.

Cave Type: Pothole.

Entrance: Vertical solution tube about 15 m deep.

Surface access time and difficulty:

Sometimes difficult to find.

Brief description of cave:

A narrow vertical tube 'death-trap' leads to a very small chamber with some rock fall. The entrance is very tight and the solution tube acts as a speaking tube for those on the surface listening to the problems of someone in the tight section at the base!

Approximate time underground: Depends on how stuck people get!

Equipment needed: Basic plus ladder and rope.

Cave Number: 3G-14 Cave Name: None

Area: National Park.

Cave Type: Stream cave.

Entrance: Walk in.

Surface access time and difficulty:

10 minute walk from campsite. Access **must** be arranged with the National Park.

Brief description of cave:

A joint controlled stream passage, 220 m long, ending in a choke of rock and earth. A lower level passage of similar character is accessible near the choke. Some calcite speleothems. Used by *Miniopterus schreibersii* and *Miniopterus adversus*. See also Ackroyd (1993).

Approximate time underground: 1 - 2 hours.

Equipment needed: Basic.

Cave Number: 3G-22 Cave Name: Snake Cave

Area: Pine forest, planted in 1991.

Cave Type: Pothole.

Entrance: Two vertical solution tubes.

Surface access time and difficulty:

Easy walking, but the cave is not easy to find.

Brief description of cave:

Vertical solution tubes drop 9 m to a cave chamber 25 m long and about 10 m wide, with rock fall. Mapped (Ackroyd, 1993).

Approximate time underground: 1 hour.

Equipment needed: Basic, plus ladder and vertical gear for 10 m.

Work needed: Further leads possible. Survey and mapping.

Cave Number: 3G-43S Cave Name: Runaway Waterhole or Runaway Hole

Area: Unplanted area in pine forest.

Brief description of cave:

This is a surface feature in an area of interesting karst. There is no actual cave, but a large depression in the Tertiary limestone, and a spring.

Work needed:

A detailed surface survey would be useful.

Cave Number: 3W-1 Cave Name: None

Area: Warrnambool.

Cave Type: Phreatic system.

Entrance: Walk in.

Surface access time and difficulty:

5 minutes walk from car.

Brief description of cave:

Series of phreatic joint controlled passages with water at lower levels. Reasonably well explored.

Approximate time underground: 1 - 2 hours.

Equipment needed: Basic.

Work needed: Survey and map.

Cave Number: 3W-2 Cave Name: None

Area: Warrnambool.

Cave Type: Horizontal cave.

Entrance: Collapse doline walk in.

Surface access time and difficulty:

5 minutes walk from car.

Brief description of cave:

Small cave with collapsed phreatic sections connecting to standing water.

Approximate time underground: 1 hour.

Equipment needed: Basic.

Cave Number: 3W-9 Cave Name: Gaul's Cave

Area: Warrnambool.

Cave Type: Sea cave.

Entrance: Two large entrances facing the sea.

Surface access time and difficulty:

Long walk from car along beach. Need low tide for easiest access.

Brief description of cave:

Sea cave with large entrances leading to two domed chambers. These are connected by a low passage. Mapped (Ackroyd, 1984).

Approximate time underground: 15 to 30 minutes.

Equipment needed: Basic.

Cave Number: 3W-10 Cave Name: Pillar Cave

Area: Warrnambool.

Cave Type: Sea cave and rock shelter on cliff.

Entrance: Wide entrance in sea cliff.

Surface access time and difficulty:

Long walk from car along beach. Need low tide for easiest access.

Brief description of cave:

Shallow sea cave about 5 m above base of cliff with old calcite formation.

Approximate time underground: 15 - 30 minutes.

Equipment needed: Basic.

Work needed: Map and survey.

Cave Number: 3W-22 Cave Name: Caleb Cave

Area: Childers Cove.

Cave Type: Cave in both the dune limestone and the overlying Tertiary Limestone.

Entrance: Small inclined entrance in the scrub.

Surface access time and difficulty:

It takes about 30 minutes to find in the scrub.

Brief description of cave:

Entrance leads down a sandy slope to a spacious chamber which is connected to a second chamber by a low short crawl. Both chambers appear to be controlled by the dip of the bedding. Mapped (Ackroyd, 1991).

Approximate time underground: About 1 hour at the most.

Equipment needed: Basic.

Work needed:

Some leads at the south end of the second chamber need pushing.

Cave Number: 3SW-2 Cave Name: Tom Pearce's Cave

Area: Loch Ard Gorge.

Cave Type: Walk in sea cave.

Entrance: Walk in entrance at beach level.

Surface access time and difficulty:

20 minutes from car. Easiest at low tide.

Brief description of cave:

The wide cave is 15 - 20 m long in line with the gorge at the head of the western bay. It has good deposits of flowstone and columns with deep red colouring and a floor of sand, and pebbles with flowstone in a few places.

Approximate time underground: No dark zone, 20 minutes.

Equipment needed: None.

Work needed:

A map is needed for this cave despite being known for many years.

Cave Number: 3SW-3 Cave Name: Miss Carmichael's Cave

Area: Loch Ard Gorge.

Cave Type: Sea cave.

Entrance: Walk in.

Surface access time and difficulty:

30 minutes from car, but only accessible at low tide.

Brief description of cave:

Large spacious cave of about 70 m long with some decoration.

Approximate time underground: 30 minutes.

Equipment needed: Basic, plus an ability to swim if you miscalculate!

Work needed: Map needed.

Conclusion

The limestones of Tertiary age in Victoria have some karst development, but this is mainly in the form of small solutional features. In comparison to the Tertiary limestones of south-eastern South Australia, the Nullarbor, and Cape Range in Western Australia, they are unspectacular except for the coastal scenery, and there is little cave development. The reasons for the paucity of actual caves, especially of large systems in such an extensive area and depth of limestone, is worth investigating.

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8. Quaternary Limestone Areas of Western Victoria

Susan White

Introduction

In southern Australia, aeolian calcarenite dunes generally occur in areas of reliable rainfall, which ensures sufficient water for solution processes to occur. Consequently, karst in calcarenite ridges is more extensive in Australia than on any other continent, and further study in Australia is likely to be rewarding. Although the areas of calcarenite ridges in south-western Victoria, described as Bridgewater Formation, have not attracted extensive speleological work, they provide an opportunity to look at the karst landforms and the processes of their development in this material.

Bats Ridge in particular, is a site where extensive karst development in calcarenite is evident. The existing theories of karst processes are usually applied to relatively pure, hard, compact and well jointed limestones. There are particular problems of understanding karst processes in softer less compact limestones such as chalk, coral reefs, and calcarenite. The issues of karst in indurated aeolian calcareous dunes can be understood within the context of the controls on karst processes, especially those related to variation in rock characteristics.

Calcarenites are limestones with diffuse permeability and high intergranular porosity. They show little or no jointing, although the cross bedding structures of the dune deposition are still obvious. The purity of the limestone is very variable, often as low as 50% $CaCO_3$, but can be as high as 95% $CaCO_3$. The Pleistocene aged Bridgewater Formation of sediments is composed primarily of bioclastic calcareous sand derived from the underlying shelly Tertiary beds. The dunes were deposited primarily as strand dunes as the coastline receded during the Pleistocene sea level adjustments and were then subjected to terrestrial weathering conditions resulting in the formation of caves.

Preliminary dates from the Warrnambool area show that the dunes were deposited from about 400,000 years ago episodically to the present day dune building phases. Generally caves are found in the older, more consolidated and inland dunes. The probable mode of formation is that the calcareous material was dissolved, seeped downwards in solution, and was re-deposited as a secondary limestone layer, leaving a residual surface layer of unconsolidated silica sand (Mallanganee Sands).

During arid periods this silica sand has been transported by prevailing winds to the lee of the dunes. The secondary limestone or calcarenite cap rock forms the necessary structural conditions for the formation of shallow linear caves. Such simultaneous processes of lithification and karst formation are called syngenetic karst. There are a number of ridges which have good karst development.

Codrington

Codrington is a karst area on dune ridges west of Port Fairy which has caves reported from 1857 (Bonwick, 1858). Two unconsolidated calcareous dunes are found along the coast and about 1 km inland from these are at least two relict Pleistocene dunes and interdune swales. The dunes are predominantly composed of calcareous sand although there is some coarser material present in a few limited locations. The dunes have several karst features on them; caves, collapse dolines and notches in particular. There are about 40 numbered caves in the area; horizontal maze systems with extensive collapse, low flat passage shape and multiple entrances.

The caves are very dependent on the swamps in the dune swales and are at the same level as the notches on the edges of the swamps (Berryman, 1994). The relationship of the caves, dunes, notches and swamps is seen in Figure 8-1. The karst features including the caves are typical of syngenetic karst areas and very good evidence has been found at Codrington for the karst occurring simultaneously with the diagenesis of the limestone. The cave development is similar to that at Bats Ridge.

There is a great deal of underground and surface exploration and mapping still to be done at Codrington. The caves are low and crawly but there is a lot of unexplored or little explored passage. It is a great place to find new cave passage.

There is also good potential on other properties, both east and west of the property we have been working on, but we are concentrating on understanding the caves on one property first, before opening access negotiations with other landowners.

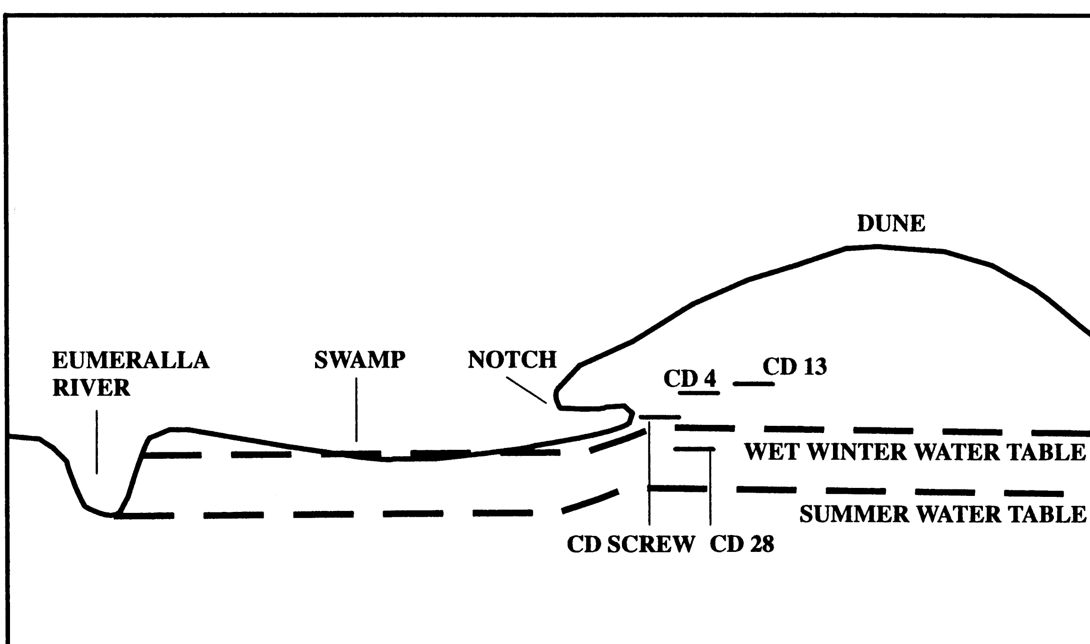

Figure 8-1: Schematic representation of Spatial Relationships of Karst Landforms and Dunes at Codrington (Berryman, 1994)

Codrington Cave Descriptions

Cave Number: 3CD-4 Cave Name: Rabbit Trap Cave

Cave Type:

Shallow linear cave in dune limestone, multiple entrances.

Entrance:

Small collapse entrances. Collapse dolines. Walk in and roof windows. Several entrances are easily accessed.

Surface access time and difficulty:

15 minutes walk from car. Hazards are tiger snakes.

Brief description of cave:

A shallow linear cave with at least four entrances. A long maze cave with a lot of collapse into the base level. A lot of low crawly passages sometimes with muddy floors. Some limited decoration. See also Ackroyd (1991).

Approximate time underground:

1 to 5 hours depending on how much you explore and how much crawling you like.

Equipment needed: Lights and helmet.

Work needed: More exploration to connect the various parts.

Cave Number: 3CD-28 Cave Name: Milliways

Cave Type:

Low maze cave with at least 2 entrances.

Entrance:

Impressive low collapse entrance just above swamp level.

Surface access time and difficulty:

10 minutes walk from car. Private land.

Brief description of cave:

Low maze cave in dune limestone. The cave is a low flat crawl on a muddy floor. The cave floods in wet seasons. See also Ackroyd (1992b, 1993).

Approximate time underground:

1 hour.

Equipment needed: Basic.

Work needed: Survey in progress.

Cave Number: 3CD-13 Cave Name: Claw Cave

Cave Type:

Shallow linear cave in dune limestone, multiple entrances.

Entrance:

The best entrance is through a small modified solution pipe near the ridge top. The second entrance is a typical collapse under a caprock beam.

Surface access time and difficulty:

20 to 30 minutes easy walk from the road. Hazards are tiger snakes and bulls.

Brief description of cave:

After the entrance rubble chute, the cave opens out to a low phreatic maze with a very muddy floor. A lot of resolution on the lower walls and roof. Some collapse chambers at intervals. Some decoration on the roof where there has been collapse, and the roof is above the flood level. The claw is an unusual redissolved limestone roof pendant with a 'claw' of calcite on the end. See also Ackroyd (1992a).

Approximate time underground:

1 to 3 hours depending on how much you explore.

Equipment needed:

Lights and helmet.

Work needed:

This cave is partially surveyed but more exploration is needed into side passages.

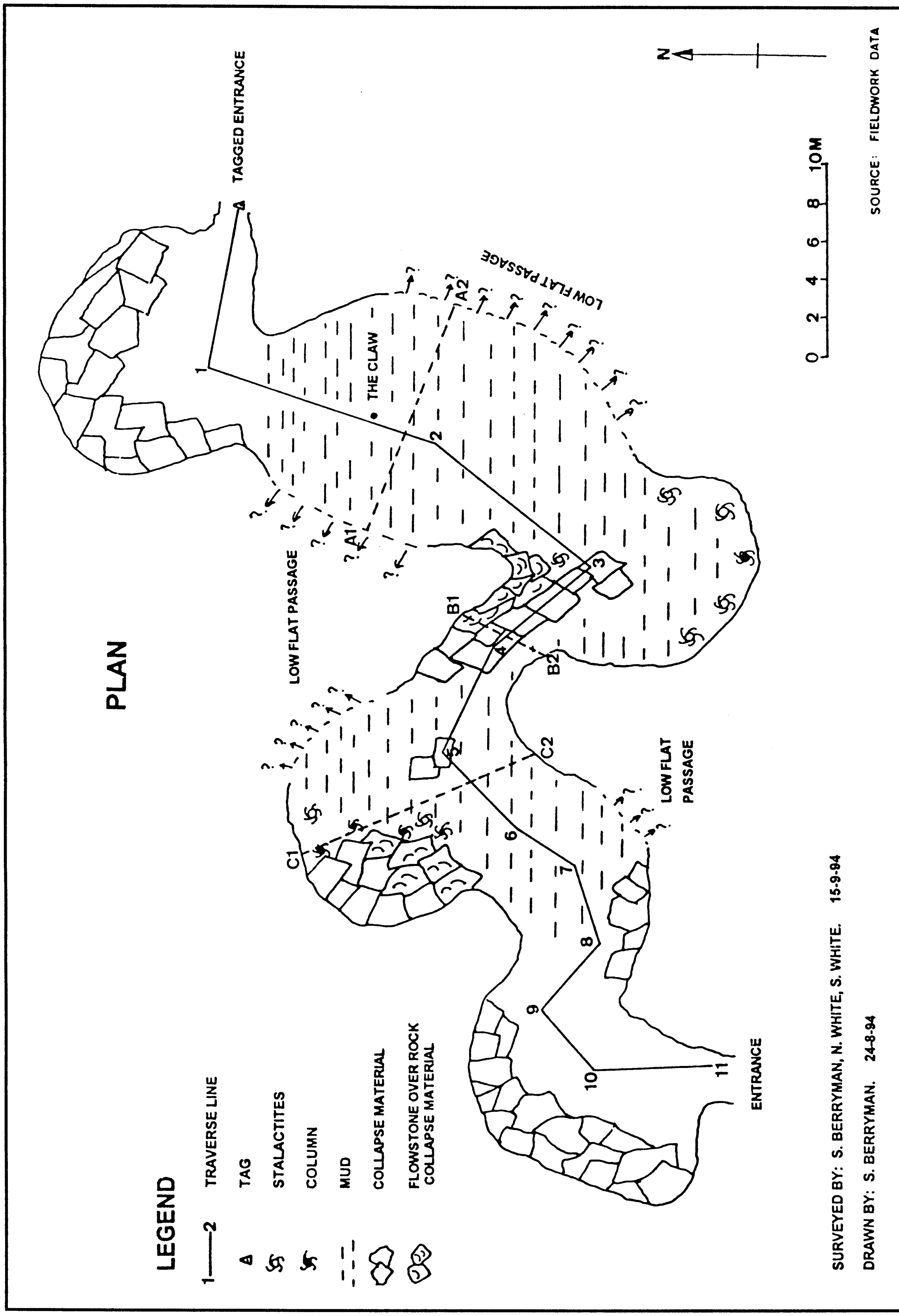

Figure 8-2: Map of Claw Cave (CD-13)

Bats Ridge

Karst features occur in Pleistocene aeolian calcarenite dunes at Bats Ridge between Cape Bridgewater and Portland. It is primarily a State Faunal Reserve, administered by the Department of Conservation and Natural Resources, but caves are found on other Crown Land and private property adjacent to the Reserve. Bats Ridge is the official geographical name for the area, but it is also known as Bat Ridges or Bats Ridges.

There are about 80 numbered caves but many of these are multi-entrance. The area is typical of the Tertiary to Pleistocene calcareous ridge systems of the Otway Basin which were deposited as the sea retreated from the coast during the last major marine regression. Karst landforms are found in similar ridges, eg. Mumbannar, Strathdownie, Puralka, but the ridges at Bats Ridge show more intensive karst development than these other sites.

The surface and underground features show that the caves are sinuous shallow systems often with a number of entrances. The caves are mainly on spurs on the northern side of a ridge running north-west / south-east. These spurs are separated by swampy swales or hollows, some of which hold water in wet seasons. The ridge is about 100 m above present sea level and has a relative relief above the surrounding plain of 38 m. It is variable in width and asymmetrical in cross section with a steep seaward slope facing south-east and a more gentle landward slope.

There are peat swamps on both northern and southern sides of the dune. The swamps to the north are more complex and connect with swamps in the swales between the spurs. The ridge has the appearance of a longitudinal strand-line dune which has been subjected to "blow outs" at right angles to the dune axis during periods of sand instability. These enclosed depressions, such as the Bats Ridge lake appear to be swale lakes modified by solution (White, 1989).

The characteristic landforms associated with the calcarenite strand-line ridge at Bats Ridge are the result of karst processes of solution and collapse. The caves are shallow with horizontal development and have formed under a hardened cap rock or kankar layer in the calcarenite dune. This cap rock is a cemented relatively hard layer within the dune. Collapse breakdown has been significant; entrances, passage and chamber shape have been extensively modified by collapse processes. The cave floors, as well as having rock piles, are covered with sediments derived predominantly from the insoluble residues of the calcarenite host rock.

The caves contain a range of calcite speleothems. Of particular note are large expanses of moonmilk, composed of calcite needles with high water content between the crystals. Overall, large areas of cave walls are covered in either moonmilk or the dehydrated moonmilk. Solution pipes, roof avens and foibes are common, as in other areas of calcarenite karst in Australia. However no soil pipes were found at Bats Ridge, despite their presence in other areas of Bridgewater Formation.

Karren forms are not common on the exposed limestone but some examples, especially of an uneven form, appear on areas of exposed cap rock. Exposures of the more cemented cap rock are generally restricted to the collapse cave entrances (White 1989, White 1994).

The caves appear to have developed on the spurs of the main ridge and at the top level of a previous water table in the dune. The caves show a common base level at about 90 m above present sea level, which is between 5 to 8 m above the present water table. This concentration of caves may be due to the effect that the small swampy depressions and lakes have had on modifying the aggressiveness of the ground water.

The aggressiveness of the water at the top of the water table combined with the relative purity of the limestone resulted in suitable conditions for karst development. The karst features appear to have developed simultaneously with the lithification of the dunes, leading to the conclusion that the karst features are due to syngenetic processes.

The existence of the caves in the dune ridges has been known for many years. Coulson (1940) reports visiting a number of caves and makes reference to their particular character. Systematic exploration and documentation by V.S.A. was not started until 1973. The dunes support a complex mosaic of coastland heath communities as well as eucalyptus woodland and acacia scrub. This has been subjected to grazing as well as limited lime quarrying.

The caves have the characteristics of syngenetic karst; shallow and linear with extensive areas of low unsupported solutional ceilings. These ceilings appear to relate to the formation of secondary cap rock which provides sufficient structural strength to permit the development of extensive caves. Floors are typically covered with either insoluble residues of the solution process or collapse debris or both. The majority of these caves have collapse entrances down slope from the ridge top. Solution pipes are common, including a spectacular pipe (BR-58) which is an entrance to Chimney Cave (BR-1).

Speleothems are not prominent but they do commonly occur as two major groups, implying two periods of active calcite deposition in the caves. The older more massive form is no longer active but a younger active series of helictites, straws and flow stone is maintained by surface water. Moonmilk and cave coral can also be found. Exposed bedrock shows varying examples of secondary surface solution features such as rillenkarren and mottling (White 1989, White 1994).

Bats Ridge Cave Descriptions

Cave Number: 3BR-1 Cave Name: Chimney Cave

Cave Type: Shallow linear cave in dune limestone, multiple entrances.

Entrance:

The best access is through a partially sand filled doline at the western end (BR-1) leading onto a relatively spacious tunnel passage of 4 to 10 m width and up to 6 m high. A well formed solution tube entrance (BR-58) of approximately 1 m diameter drops vertically some 7 m into the cave below. This forms a classic animal trap. There was no protection of the tube on the surface for many years, although it is now fenced.

Surface access time and difficulty:

15 minutes from car along easy track. Leeches and tiger snakes are a hazard.

Brief description of cave:

A shallow linear cave with four entrances. A short crawl section over collapse blocks at the end of the main tunnel leads to a roughly circular collapse chamber about 10 m across and 4 to 6 m high. From this chamber the cave extends into a wide sand floored section 3 to 6 m high with an extensive unsupported area of horizontal ceiling trending easterly along the ridge axis. This flattener leads to the bat chamber containing well formed phreatic ceiling domes which are used by bats. Guano accumulations confirm bat use over a long period.

The extension of the cave is via a small dig into another flattener which leads to another entrance (BR-57E). This northern extension contains some very pretty, active calcite straws. The fourth entrance (BR-56E) also connects with the northern extension via the rockfall squeeze. The cave is aligned along the east-west orientation of the dune ridge and has developed linearly. The flat unsupported ceilings appear to be related to an unconformity in the dune bedding and correspond with similar features in other caves, eg. Big Cave (BR-5). Length is 200 m. A map has been published (Pierce & White, 1977).

Approximate time underground: 1 to 5 hours.

Equipment needed: Basic.

Cave Numbers: 3BR-2 & 3BR-6 — Cave Name: Hut Cave or Organ Cave

Cave Type: Shallow linear cave in dune limestone, multiple entrances.

Entrance:

BR-2 entrance is in a large collapse doline, BR-6 entrance is a smaller collapse doline.

Surface access time and difficulty:

Five minutes from the cars, very easy access, but leeches and tiger snakes are a hazard.

Brief description of cave:

The 230 m long cave system is located very close to the campsite and has many entrances. It is seen in two sections which are connected by a narrow crawlway. The BR-2 end of the cave has four entrances in an obvious collapsed doline (only one of these entrances numbered), and a narrow crawlway passage which connects to BR-6. The entrance descends down a collapse cone and includes an awkward vertical squeeze to the crawlway connecting with BR-6. Some dry speleothems are present. The BR-6 entrance leads to large domed chambers with a rock pile and sediment floor. This section also has extra entrances. The cave shows horizontal linear development with rock collapse, dome roof structures and some speleothems. It can be quite wet at periods when the lake is full. Mapped (White, 1984).

Approximate time underground:

Anything between 15 minutes to several hours for a full through trip.

Equipment needed: Basic.

Cave Number: 3BR-4 Cave Name: River Cave

Cave Type: Shallow linear cave in dune limestone, multiple entrances.

Entrance: Several collapse entrances around the lake.

Surface access time and difficulty:

10 minutes to 20 minutes easy walking from the cars. Hazards are leeches and tiger snakes.

Brief description of cave:

River Cave is the largest of the known caves at Bat Ridges and has a current surveyed length of 1,250 m. It has nine known entrances, BR-4, BR-16E, BR-14E, BR-25E, BR-26E and BR-32E, mostly collapsed dolines. The cave is a large linear network and complex maze of low flat passages, rock fall chambers and tunnel passages with rock pile and mud floors. There are a lot of low passages interspersed with larger chambers. The cave is complex as a result of its length but shows low passages as well as larger chambers. The floor alternates between rockfall and soil.

Cave coral and other speleothems exist in various parts of the cave. The cave floods during periods in the wet seasons when the lake is full from the Bats Ridges drain diversion, and has inflow and outflow entrances. Evidence of vadose modifications of the floor sediments from these wetter periods can be seen and the height of water level can be seen in many passages. Mapped (White, 1984).

Approximate time underground:

Anything from one to 6 hours depending on how much you want to explore.

Equipment needed: Basic.

Cave Number: 3BR-5 Cave Name: Big Cave

Cave Type: Shallow linear cave in dune limestone, multiple entrances.

Entrance: Two collapse entrances.

Surface access time and difficulty:

Located on private property to the east of the Reserve. About 20 to 25 minutes walk along an easy track. Hazards are leeches and tiger snakes and the electric fence.

Brief description of cave:

It is a large multi entrance cave showing large collapse chambers and low flat passages. Entrances are all collapse dolines (BR-5, BR-12, BR-13, BR-40). Large collapse domed chambers with rock fall floors and low "flatteners" with silt floors are the dominant passage types. Speleothems include stalactites, stalagmites, moonmilk and straws. Length 1,230 m, mapped (White, 1984).

Approximate time underground: 3 hours to explore it all.

Equipment needed: Basic.

Cave Numbers: 3BR-7 & 3BR-8 Cave Names: None

Cave Type: Shallow linear cave in dune limestone, multiple entrances.

Entrance:

Small entrances close together. Two entrances are small collapses but the third is a vertical sided circular doline about 3 m in diameter and 3 m deep.

Surface access time and difficulty:

15 to 20 minutes from the car near the Reserve entrance. Hazards are leeches and tiger snakes.

Brief description of cave:

BR-8 has two collapsed solution tubes which have coalesced into a single window. A cave with three medium sized chambers (one with large rock pile) and three entrances. Passage shape influenced by cross bedding. Old massive formation and moonmilk present. Predominantly sediment floor but one chamber is almost filled with rock pile. The entrance shows inclined bedding accentuated by solution and circular doline shows remnant evidence of solution tubes in the side. Length 50 m, mapped (White, 1984).

Approximate time underground: Half an hour

Equipment needed: Basic.

Cave Number: 3BR-18 Cave Name: Hammer Cave

Cave Type: Shallow linear cave in dune limestone.

Entrance:

Low entrance in collapse doline with soil slope down to soil floor with evidence of water.

Surface access time and difficulty:

Easy 20 minute walk.

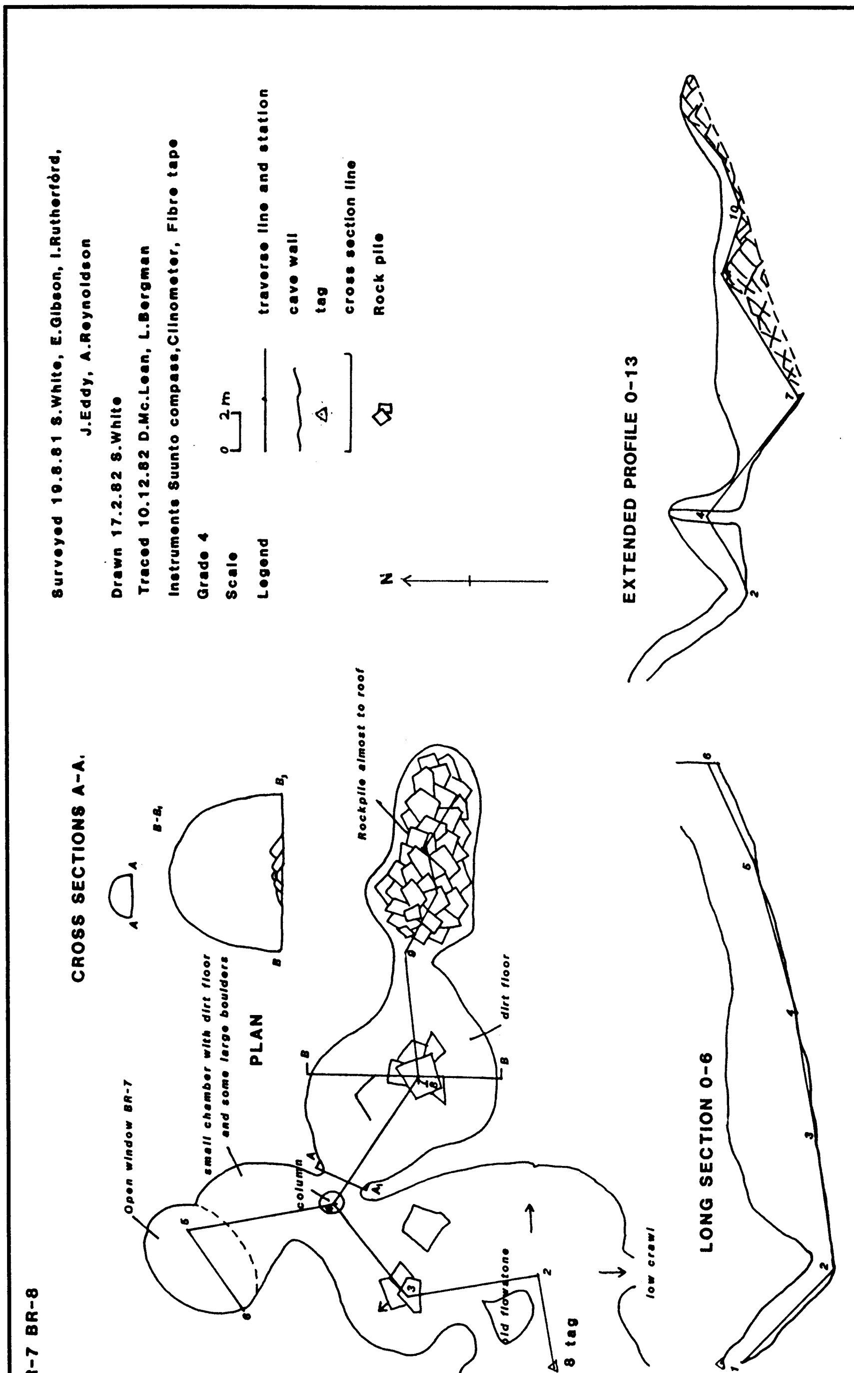

Figure 8-3: Map of BR-7 and BR-8

Brief description of cave:

Passage develops into a large collapse dome with rock pile. A second passage is developed towards the north also by collapse. This enters into a collapse dome almost filled with collapse material. Vertical rifts on sides of rock pile. Length 100 m, mapped (White, 1984).

Approximate time underground: 1 hour.

Equipment needed: Basic.

Cave Number: 3BR-36 Cave Name: Remembrance Cave

Cave Type: Shallow linear cave in dune limestone.

Entrance: Small entrance with soil slope into ridge.

Surface access time and difficulty:

20 to 30 minute easy walk. Private Property. Hazards are leeches and tiger snakes.

Brief description of cave:

The cave goes to the west over rock pile to a small chamber with good active speleothem decoration including stalactites, stalagmites, straws, columns, tiered column, flowstone and small shawls. Evidence of wet conditions. The cave is not very large but impressively decorated compared to other local caves. Length 90 m, mapped (White, 1984).

Approximate time underground: 1 to 1 1/2 hours.

Equipment needed: Usual.

Cave Number: 3BR-35 Cave Name: Root cave

Cave Type: Shallow linear cave in dune limestone.

Entrance: An entrance pipe with old tree trunk.

Surface access time and difficulty:

20 minute easy walk. Private Property. Hazards are leeches and tiger snakes.

Brief description of cave:

An entrance pipe which is approximately 0.5 m in diameter and 3 m deep drops into a collapse dome chamber almost filled with rock fall debris. This chamber leads to a second collapse dome in the south-eastern direction. Collapse is relatively fresh and with very little residue or soil on the top. The entrance still contained an old tree trunk and roots when first entered. Collapse is along the strike of limestone. Limited decoration, old moonmilk on ceiling. Contains spiders, wetas. Length 20 m, mapped (White, 1984).

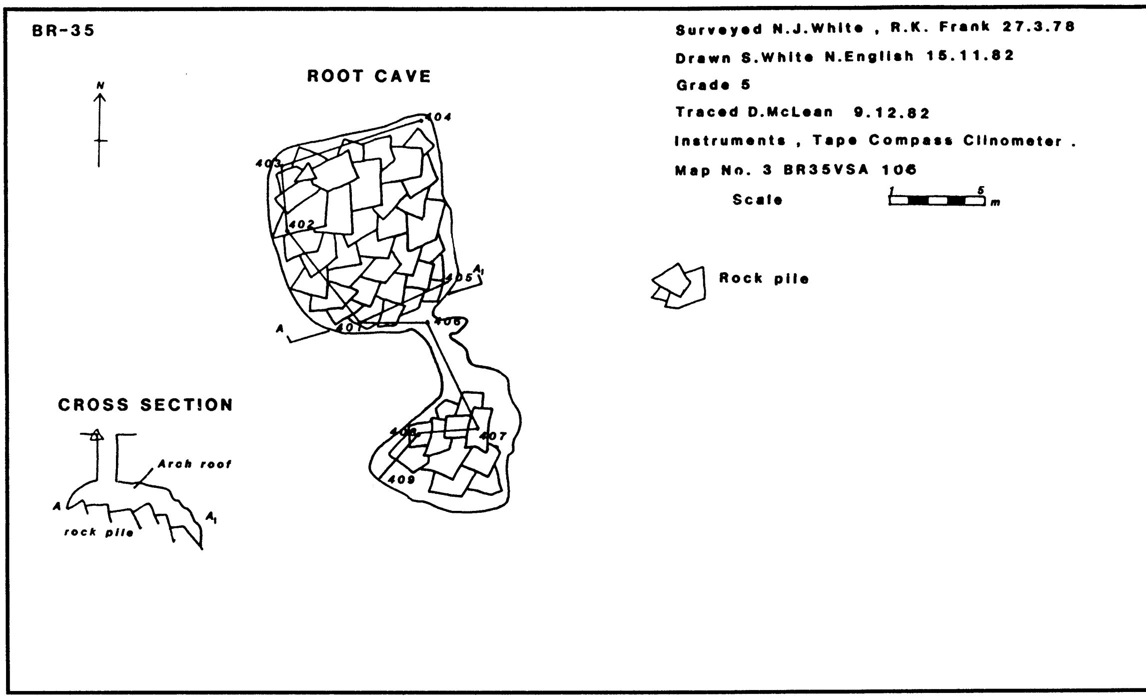

Figure 8-4: Map of BR-35

Approximate time underground: Half an hour to 1 hour.

Equipment needed: A hand line is useful.

Cave Number: 3BR-10 Cave Name: Waterfall Cave

Cave Type: Linear cave in dune limestone.

Entrance: Collapse entrances.

Surface access time and difficulty:

Located on private property to the east of the Reserve. About 20 to 25 minutes walk along easy an track. Hazards are leeches and tiger snakes and the electric fence.

Brief description of cave:

Three entrances lead into a relatively spacious sand floored cave with considerable rock collapse, a flat sediment floor and rock pile. Some calcite speleothems and moonmilk. Several entrances nearby which may connect. Old graffiti. Unsurveyed.

Approximate time underground: 1 hour plus.

Equipment needed: Basic.

Work needed: Survey and more thorough exploration.

Cave Number: 3BR-11 Cave Name: Old Cave or 1864 Cave

Cave Type: Linear cave in dune limestone.

Surface access time and difficulty:

Located on private property to the east of the Reserve. About 20 to 25 minutes walk along an easy track. Hazards are leeches and tiger snakes and the electric fence.

Brief description of cave:

Spacious cave with several inter-connecting chambers with rock pile and sediment floors. Some chambers modified by collapse, but a low flat section with active formation. Four known entrances, only one numbered. Entrances are collapse dolines. Old graffiti, 1864 dates. Unsurveyed, grade 1 sketch map made in 1976. Length 60 m.

Approximate time underground: 1 hour plus.

Equipment needed: Basic.

Work needed: Survey and more thorough exploration.

Cave Ridge

This is one of a number of caves in the Pleistocene dunes, in this case a dune west of Mumbannar. It has proved unbelievably difficult to map as it is a maze of passages. The main hazards are snakes in the entrance and getting lost in the maze! A map of sorts has been published (Mill, 1984).

Cave Description

Cave Number: 3CR-1 Cave Name: Cave Ridge System

Cave Type: Low maze cave with multiple solution pipe entrances.

Entrance:

Impressive solution pipe entrances, variously recorded between 9 and 14 holes, some of which are exposed on a limestone pavement 500 m long.

Surface access time and difficulty:

Private land. Close to road.

Brief description of cave:

The multiple solution pipe entrances lead into a large chamber from which passages are developed on three levels. Many extensive low passages display calcite speleothem decoration. Cave is reported as having prehistoric markings (Bednarik, 1986).

Approximate time underground: 1 to 3 hours.

Equipment needed: Basic and a ladder for the first entrance.

Work needed: Survey in progress.

Port Fairy to Portland

Mobile and fixed dunes, predominantly calcareous, overlie Tertiary limestones and Pliocene volcanics. These are interspersed with Pliocene coastal volcanic forms, including offshore islands such as Lady Julia Percy Island. Minor Karst areas are known along this coast but only one area, Codrington, has been extensively explored. The existence of Portland Bay in the Tyrendarra Embayment of the Otway Basin is due to the formation of continuous sandy beach barriers usually terminated along shore by headlands. Deflection of wave diffraction has occurred after the building of Portland harbour resulting in the extensive erosion of the coast along Dutton Way. Attempts to minimise the damage has resulted in placing of basalt blocks along the beach on Dutton Way.

A nearby coastal site known as The Craggs shows coastal exposure, a sequence of dune calcarenites, and two separate palaeosols which are overlain by two modern soil sequences. This site looks interesting but has had no interpretative work on it, so no dates are available as yet.

Portland to Cape Bridgewater

This area also has a series of mobile and fixed calcareous dunes and coastal barriers. The area is variably dissected coastal plateaux with veneers of residual, fluvial and / or dune ridge and lagoonal deposits on marine sediments or Pliocene basalts.

Cape Bridgewater has a number of sea caves in the basalts overlain by the Pleistocene calcarenites. As a result, the sea cliffs and the caves show tufa and other secondary calcite deposits from the calcite saturated springs along the coast.

An area on Cape Bridgewater has been labelled a "Petrified Forest" after the tree-like features. These features are solution pipes in the calcarenite which are quite common in the less exposed areas of Bridgewater Formation. The pipes at Cape Bridgewater have formed in the dune limestone, been infilled with calcareous sand and / or soil which has been cemented and then been exposed again by further erosion. The erosion increased dramatically after the introduction of rabbits in the 19th century but present day management practices appear to have reversed this. The "Petrified Forest" is is similar to the Pinnacles area north of Perth in Western Australia. The interpretation of the area has been confused by inadequate understanding of dune limestone syngenetic karst processes, as in the term "Petrified Forest".

Bridgewater Caves and Lakes

This site indicates drainage disruption by the coastal barriers . Similar coastal barriers have resulted in the major diversion of the Glenelg River near Kentbruk (Kentbruck on the topographic maps). Bridgewater Caves are relict sea caves in relict sea cliffs. These cliffs and other features have been correlated with the Andara or "twenty foot" sea level (Sprigg, 1952). In the Bridgewater area much of this former coastline has been obscured by the mobile Discovery Bay Sands.

Cave Description

Cave Number: 3P-9 Cave Name: Bridgewater Cave

Area: Portland, Bridgewater Lakes.

Cave Type: Old Sea cave.

Entrance: Large entrances in old sea cliff.

Surface access time and difficulty:

5 minutes from car, easy access.

Brief description of cave:

Large daylight chambers with some old dead decoration. Cliff nearby exposes the geological section of the Bridgewater Formation.

Approximate time underground: 20 minutes.

Equipment needed: Basic.

Work needed: Survey would be useful.

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9. Caves of Lower South-Eastern South Australia

Kevin Mott

Introduction

The Lower South East cave and karst region is that part of south-eastern South Australia lying below the Robe to Penola road. The terrain is relatively flat. The main topographic features are dune ridges and volcanic outcrops. Pasture and softwood forestry are the main uses for the land.

The area lies within the Gambier Embayment of the Otway Basin. Most of the caves occur in the Tertiary Gambier Limestone. This is generally a weakly cemented bryozoal limestone laid down in the shallow seas of the Oligocene and Miocene periods. Limestone thickness varies from about 300 m at the coast south of Mount Gambier to about 100 m in the Naracoorte area. Around the Dismal Swamp region the Gambier Limestone is almost non existent in places. Soil cover is generally thin and in the Kongorong and Mt. Schank areas there are excellent exposures of karst pavements.

In places the Gambier Limestone is overlain by stranded coastal dunes of Pleistocene deposits in a series of parallel ridges oriented north-west / south-east. This dune limestone is known as the Bridgewater Formation. The interdunal areas are generally flat and swampy and consist of clays and marls.

There is very little natural surface drainage in the region. Man made drainage systems have drained the interdunal areas. Most of the surface water percolates through the porous limestone. This means the cave systems in the area are vulnerable to contamination from surface pollutants. The surface of the aquifer in the Gambier Limestone is high in the Dismal Swamp area and generally drains towards the coast. Flows are very slow, in the order of tens of metres per year. Discharge of groundwater can be seen in emergent springs and ponds along the coast line.

During glacial periods the sea retreated creating a net lowering of the water table. This lowering of the water table has been postulated to be as much as 100 m and had a marked affect on cave development. Karst development occurred well below the current sea level. Divers have reported features such as The Shaft (L-158) reaching depths of 90 m and speleothems have been observed at depths of 22 m in some water filled caves.

The majority of caves occurring in the Gambier Limestone demonstrate development along north-west / south-east alignments. Horizontal development along bedding planes is also a feature of caves in the area. This however is most probably the result of standing water rather than a structural control.

Most of the caves are of phreatic origin with little vadose development. Many phreatic passages or chambers have subsequently been modified by collapse. Entrances to the caves can be either vertical solution tubes, collapse windows or collapse dolines. Some of the most spectacular features of the area are the sinkholes and cenotes. These occur mainly in the southern portion of the area and are a mecca for cave divers.

Caves occurring in the Bridgewater Formation generally consist of broad low chambers. Most occur at the level of adjoining swamps and plains. Due to the poor consolidation of this limestone in places many of the caves also exhibit collapse features. It is not uncommon to have multiple entrances in these systems. As with caves in Gambier Limestone, entrances may be solution tubes, collapse windows or collapse dolines. Many of the caves in the dune limestone are probably syngenetic, in that they were developing at the time the calcareous dunes were consolidating into limestone.

Mount Gambier Area Cave Descriptions

Cave Number: 5L-1 Cave Name: Snowflake Cave

Cave Type: Collapse dome with joint and bedding plane enlargement.

Entrance: Window in collapse doline.

Surface access and difficulty:

Thirty minute drive south of Mount Gambier. Five minute walk across pasture.

Brief description of cave:

The collapse dome of the entrance area leads down to multi-level joint enlargement with lateral development along bedding planes. Well developed moonmilk in places.

Approximate time underground:

1 hour.

Equipment needed:

Caving clothes, helmet and torch.

Cave Number: 5L-10C Cave Name: Caroline Sinkhole

Cave Type: Collapse doline and cenote.

Entrance: Collapse doline with pathway around eastern and northern walls.

Surface access time and difficulty:

Twenty minutes drive south of Mount Gambier. Tiger snakes abound in the sinkhole.

Brief description of cave:

It is a large (60 m diameter) open sinkhole with water exposed in the southern end. Access to the water can be difficult due to dense cutting grass. Good exposure of the interface between the Bridgewater and Gambier Limestones occurs in the walls. The sinkhole also contains aboriginal rock shelters.

Approximate time underground:

Half to one hour.

Equipment needed:

None. Perhaps a stick or suitable clothes for snake protection.

Cave Numbers: 5L-19 5L-20E — Cave Name: Engelbrecht Cave

Cave Type: Joint controlled phreatic development that is partially submerged and modified by collapse.

Entrance: Collapse doline.

Surface access time and difficulty:

Cave is located in Mount Gambier and is run as a tourist facility. Access is via a guided tour. Dives must be booked through Lady Nelson Tourist Information Centre.

Brief description of cave:

The collapse dome at the entrance leads into the western and eastern sections of the cave. The eastern section of cave shows good phreatic sculpting and development along joints and bedding planes with a large chamber at water level. The western side is greatly modified by collapse. Volcanic ash overlying the limestone can be seen on the surface.

Approximate time underground:

Tour is approximately half an hour.

Equipment needed:

Tour: nice clothes. Diving: appropriate gear for CDAA classification.

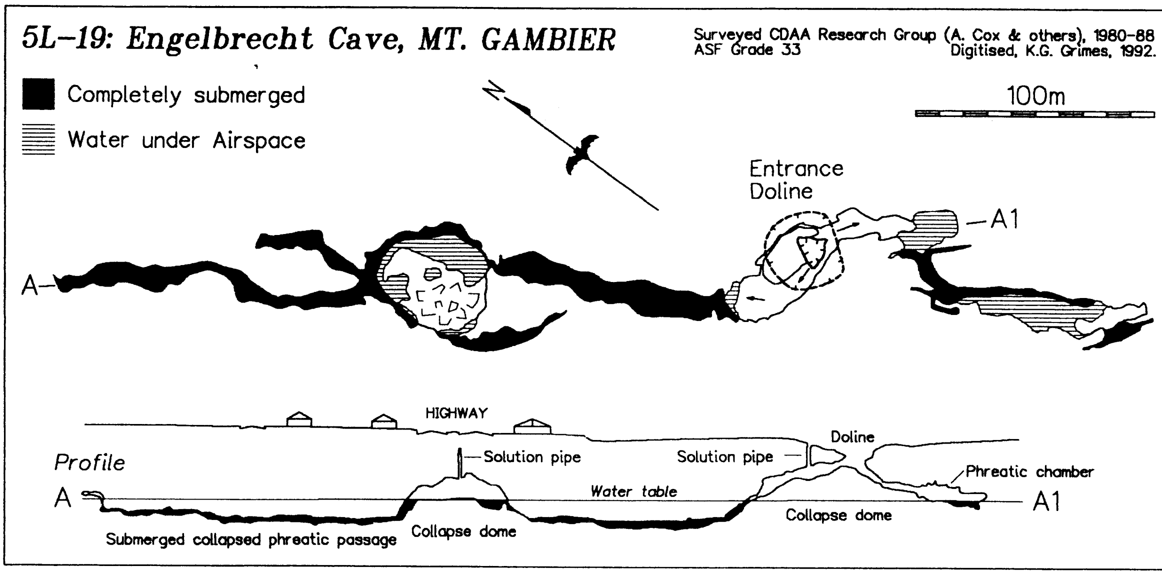

Figure 9-1: Map of Engelbrecht Cave (5L-19)

Cave Number: 5L-34 Cave Name: Morgans Cave

Cave Type: Joint controlled passages with bedding plane development.

Entrance: Small doline with 6 m deep tube.

Surface access and difficulties:

Twenty minutes drive north-west of Mount Gambier. The last five minutes are through forest tracks. Permit required from Department of Primary Industries (Forestry).

Brief description of cave:

North-west from the entrance the cave is an enlarged joint with horizontal development off the sides. Extensive graffiti exists in this end.

The south-east end is a single joint with no horizontal development. Numerous tree roots fill the south-eastern passage. Pools of water exist in both ends.

Approximate time underground:

2 hours.

Equipment needed:

Ladder or SRT gear for the entrance. Helmet, torch and caving clothes.

Cave Number: 5L-40C Cave Name: Hell's Hole

Cave Type: Cenote.

Entrance: Open sinkhole.

Surface access time and difficulty:

Twenty minutes drive south of Mount Gambier.

Brief description of cave:

It is a steep sided collapse doline 45 m in diameter. The walls are undercut. Water is 30 m below the ground surface. A central talus mound is 5 m below the water surface with the maximum water depth being approximately 25 m.

Approximate time underground:

Surface only. Half an hour.

Equipment needed:

None for the surface. Ladder or SRT gear if you wish to visit the water.

Cave Number: 5L-72 Cave Name: Piccaninnie Ponds

Cave Type: Pond.

Entrance: Pond.

Surface access time and difficulty:

Twenty minutes drive south of Mount Gambier. Car park adjacent to edge of pond. Permits from Department of Environment and Natural Resources are required to dive or snorkel in this feature. Diving requires the appropriate CDAA certification.

Brief description of cave:

Piccaninnie Ponds is part of a series of complex ponds and submerged karst features. Groundwater emerges from some of these features as springs.

From the car park the first feature is a pond known as the "First Pond". It is approximately 30 x 40 x 10 m deep. It contains abundant aquatic flora and fauna. On the western edge is the area known as "The Chasm". This is a slot 30 m long x 5 m wide and is approximately 75 m deep. A chamber off the western end of "The Chasm" is known as "The Cathedral".

Equipment needed:

Snorkelling: Wetsuit, mask, snorkel. Diving: Appropriate gear for CDAA classification.

Cave Number: 5L-74 Cave Name: Unnamed

Cave Type: Collapse cave.

Entrance: Collapse doline.

Surface access time and difficulty:

Fifteen minutes drive north of Mount Gambier. Permit required from Department of Primary Industries (Forestry).

Brief description of cave:

The cave consists of a couple of collapse chambers. The final chamber has a dig in the end. The end of the dig has not been reached but digging is very awkward and the breeze tantalising. The central chamber contains extensive bat guano. A crevice off the north-west side of the this chamber leads to a sandy floored passage that may be a remnant streamway.

Approximate time underground:

1 - 2 hours.

Equipment needed:

Helmet, torch, caving clothes and gloves.

Cave Number: 5L-119 Cave Name: Snake Hill Cave

Cave Type: Syngenetic development in Bridgewater limestone

Entrance: Main access in collapse doline. 36 alternate entrances consisting of solution tubes, collapse windows and collapse dolines.

Surface access time and difficulty:

The cave is 15 minutes drive north-east of Mount Gambier. The last section is through a forest fire break. Permit required from Department of Primary Industries (Forestry).

Brief description of cave:

The cave is formed in the Bridgewater limestone and consists of broad chambers interconnected by horizontal phreatic flatteners. The largest chambers are located below the crest of the hill. The cave is similar to those at Codrington. There is some good examples of cross bedding in the dune limestone and some excellent rimpools.

Approximate time underground:

2 hours for a through trip from the southern to northern entrance. For those wishing to explore the extremities allow 4 - 5 hours.

Equipment needed:

Caving clothes, helmet and torch. Those on the through trip may wish to take a camera.

Work needed:

Floor details and sections.

Cave Numbers: 5L-159R 5L-160R 5L-161R — Cave Name: Ewens Ponds

Cave Type: Ponds with interconnecting streamway.

Entrance: Pond.

Surface access time and difficulty:

Twenty minute drive south of Mount Gambier. Car park adjacent to first pond. Permit to snorkel required from Department of Environment and Natural Resources.

Brief description of cave:

Ewens Ponds is a series of three ponds within the Eight Mile Creek system. The creek is spring fed and the ponds which are probably submerged collapse features are also spring fed. The first pond is about 75 x 50 x 9 m deep. The second pond is about 45 m diameter with the third pond about 30 m diameter. The boiling sands of the of the submerged springs in the second pond are an interesting feature. The shallow streamway connecting the ponds abounds with aquatic flora and fauna.

Approximate time underground:

Tourist visit to the site: 30 minutes. Snorkel pond 1 to pond 3 (200 m): 45 minutes. Snorkel pond 1 to coast (2.5 km): 3.5 hours.

Equipment needed: Wet suit, snorkel, mask and fins.

Cave Number: 5L-304 — Cave Name: Unnamed

Cave Type: Phreatic development in bedding planes.

Entrance: Collapse dolines.

Surface access time and difficulty:

Fifteen minutes drive north of Mount Gambier. Permit required from Department of Primary Industries (Forestry).

Brief description of cave:

Structure of the cave is not yet fully understood. It contains about 150 m of passage which shows sign of phreatic development along bedding planes. There areas of considerable silt infilling. Some passages appear to be joint oriented and there is some evidence of recent streamways.

Approximate time underground:

1 - 2 hours.

Equipment needed:

Helmet, torch, caving clothes and gloves.

Work needed:

Finish survey.

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Glossary

Ken Grimes

Some Volcanic, Cave and Karst terms

Aa	A type of lava surface in which the surface was too stiff to flow well, and so broke up into fragments. It is characterised by broken material which can vary from simple lumps to very sharp prickly fragments. It grades to pahoehoe (qv).
Aeolian	Pertaining to the wind. Used for landforms generated by the wind, or sediments transported by the wind.
Aeolianite	A rock formed from calcareous dune sands, a dune calcarenite (qv).
Anthodite	Speleothems (qv) formed from clusters of needle or quill like crystals. Most anthodites are formed from the mineral aragonite (qv).
Aragonite	An orthorhombic crystal form of calcium carbonate, typically occurring as many small acicular needles (see anthodite). Calcite (qv) is the more common crystal form of calcium carbonate.
Arkose	A sandstone which contains 25% or more feldspar grains, derived from granitic sources. Arkosic is the adjective.
Ash	Sand sized or finer-grained volcanic ejecta. Coarser material is called lapilli (qv).
Bench	A horizontal shelf along the wall of a lava tunnel, generally close to floor level. It is formed at the edge of a lava flow level, by cooling and solidification of the edge followed by a lowering of the level. Some 'benches' form differently by the rolling down of a long flap of wall lining. Gradations can occur, eg. where a thin bench breaks free and starts to roll downwards.
Bioclastic	Containing grains composed of fragmented and transported organic material, eg. shell fragments.
Blind Valley	A valley that is closed off at its downstream end, all its water sinking at or near that point.
Blister cave	Strictly, a cave formed by gas pressure pushing up a surface crust. True blisters are rare, and generally too small to enter. Some large ones are known overseas. The term has been misused locally for lava caves that are single simple chambers formed by localised drainage of liquid lava from beneath 'stony rises'.

Bomb	A large fragment of volcanic ejecta. Some bombs show twisted forms indicating that they were still liquid when ejected, but solidified before landing. 'Breadcrust' and 'cowpat' bombs are named for their appearance.
Bryozoa	'Lace corals', a fossil that was common in warm shallow Tertiary seas.
Burst	See 'flap'.
Cainozoic	The last of the geological eras, includes the Tertiary and Quaternary Periods. Extending from about 65 million years ago up to the present.
Calcarenite	An indurated (qv) sand composed mainly of detrital (qv) calcium carbonate fragments. A sand sized limestone.
Calcilutite	A fine grained (silt and clay sized) limestone.
Calcirudite	A coarse (gravel sized) limestone. The clasts may be fossils or broken fragments of limestone.
Calcite	The common (trigonal) crystal form of calcium carbonate [$CaCO_3$], typically occurring in caves as massive or finely crystalline speleothems (qv) or as larger crystal forms.
Calcrete	An indurated (qv) surface formed by weathering process involving cementation of the surface soils and weathered rock by calcite.
Cambering fissure	A fissure that forms behind and parallel to a cliff line, as a result of the outward rotation or sliding of large blocks.
Cave	As used by speleologists, this means an underground cavity, fissure, or tube large enough for penetration by humans. Speleologists exclude 'rock shelters' (qv) and most 'sea caves' (qv), by either stipulating that the cavity must penetrate further into the ground than the largest dimension of its opening, or by requiring that it should have a permanent dark zone. For the layman, the term 'cave' is commonly used to include rock shelters, and also to describe a single chamber within a cave system. This latter use can result in some confusion in the media, eg. 'the cave was destroyed' may merely mean 'one chamber was destroyed'. The term 'cave system' is sometimes used for the more complex caves, or to avoid the type of confusion mentioned above.
Cave coral	A form of speleothem (qv) that has nodular, prickly, globular, pop-corn or coral-like form. Its origin is a matter of some controversy, but is most likely due to seepage through the porous crystal structure and precipitation on the outer surfaces. It also occurs in lava caves as a secondary deposit.
Cenote	A type of steep walled, collapse doline that extends below the water table so as to contain a pool or lake.
Col	A hollow or saddle between hills.

Collapse dome	A chamber formed by progressive upward collapse of the roof until it reaches a stable dome-shaped form. A rubble mound will generally be present on the floor. Collapse is often initiated by the removal of hydrostatic support when the water level falls in a cave.
Cross bedding	Sets of inclined layers or beds, typically in dunes.
Deflation	The removal of loose fine grained material from a surface by wind action. One way of forming hollows that are not karst (qv).
Detritus	Material formed by mechanical breakage or abrasion of parent rocks. Detrital is the descriptive term.
Diagenesis	Post-depositional modification to a sediment. Typically involves compaction, cementation and induration (qv).
Doline	A closed depression formed by karst processes. Collapse Dolines form by collapse of the surface rocks into an underground cavity. Solutional dolines form by direct solution at the surface. Subsidence dolines form by the downward movement of loose surface material such as soils into an underground cavity. A cenote is a special case of the collapse doline that contains a water-table pool.
Dry Valley	A valley in karst terrain that no longer has a surface flow of water. The talweg (qv) of such a valley may undulate with many closed depressions, and there may no longer be a distinct channel.
Duricrust	An indurated (qv) surface formed by weathering processes involving cementation of the surface soils and weathered rock by calcite (calcrete), iron oxides (ferricrete, or laterite), silica (silcrete) or other cements.
Epiphreatic zone	The uppermost part of the phreatic (qv) zone, just below the air-water contact. This is commonly an area of enhanced solution and therfore cave development.
Eustatic	Pertaining to world-wide changes of sea levels.
Flap	A section of wall lining in a lava tube that has broken free and sagged or rolled down away from the wall. Where only a small patch has been pushed off by gas pressure from behind it may be referred to as a 'burst'.
Flowstone	A general term for speleothems formed by precipitation from mineralised waters moving in films or sheets over a large surface area.
Fluvial	Produced by the action of a stream or river.
Foibe	A blind or dead-end shaft.
Foredune	A dune ridge built up behind a coastline. Generally higher and more extensive than a beachridge.
Grike	A surface landform comprising a solutional trench cut into the limestone along a joint.

Helictites	An unusual type of speleothem which has contorted branches that appear to defy gravity. Their origin has been a matter of some debate.
Hornito	A small spatter cone up to 5 m high which spits out red hot drops of lava.
Indurated	Soils and sedimentary rocks which have become hardened or cemented.
Kankar	A deposit, often nodular, of calcium carbonate formed in soils of semi-arid regions. Sometimes forms cave roofs. Similar to Calcrete (qv) and caprock.
Karren	Small scale sculpturing formed by solution processes on limestone and other soluble rock surfaces either exposed to the rain or buried beneath the soil.
Karst	The general term for landforms which includes caves, dolines (qv) and sculptured rock surfaces. Such landforms are formed in areas where solution processes, rather than mechanical erosion processes, predominate. Karst is most often seen in limestone.
Knobby pahoehoe	A form of pahoehoe (qv) lava in which the smooth surface is broken by numerous small knobs and lumps.
Lapies	A synonym for karren (qv), used mainly in the special case of Marine Lapies which form on limestone surfaces exposed to the sea, or to sea-spray. See also Phytokarst.
Lapilli	A general term for pebble to granule sized volcanic ejecta. Angular frothy fragments are called scoria. Finer material is ash and coarser fragments are called bombs or blocks.
Laterite	An iron rich deep weathering profile. Lateritised means containing laterite.
Lava	Molten rock that is capable of flowing on the surface or in lava tubes. See 'pahoehoe' and 'aa' for specific types.
Lava cave	A general term for any cave in lava. Most are lava tubes (qv), but some can form in other ways.
Lavacicle	Small round-tipped lava stalactites (qv), formed where molten lava has dripped from the roof, or dribbled down the walls of the cave.
Lava dribbles	Drips and associated runs of smooth surfaced lava on a vertical or sloping wall in a lava tube. Formed from a molten lining.
Lava drips	Short smooth-surfaced drips of lava on a ceiling or upper wall, formed from a molten lining. Grades to flatter 'lava dribbles' (qv) on the walls.

Lava hands	Groups of elongated finger or grape-like extrusions formed on a wall or roof where pasty lava has been forced out through a crack or hole in the lining. Matching 'lava stalagmites' (qv) may occur on the floor below. See also 'lava turds'.
Lava stalactites	Longer and thicker than 'lava drips' (qv). Rare straw-like lava stalactites have been recorded overseas.
Lava stalagmites	Mounds or columns of lava built up on a floor. Some may resemble 'lava turds' (qv), others are built up of numerous small semi-solid droplets to form agglutinated stalagmites.
Lava tube	A cave in lava formed by removal of liquid material from beneath a solid roof.
Lava turds	An appropriately descriptive term for small lava extrusions. A thick pasty lava has been forced out of a small orifice in the wall lining or floor. Analogies to dog, sheep, cow, etc. have been seen. See 'Lava hands' for a more polite, but less descriptive, term. 'Stoolite' and 'faecicles' have also been suggested!
Length of a cave	When cavers refer to the length of a cave, they generally mean the total passage length. This is invariably more than the distance from one end of the cave to the other (referred to as 'cave extent'), as the passages will wind, branch or even form complex mazes. Total passage length is a useful guide to the significant size of a cave, but ignores the visual significance of large chambers. This approach can confuse laymen (and the media) who may think of the length as referring only to the largest chamber, or the overall extent of the cave.
Levee	An outward sloping raised area on each side of a lava channel. Analogous to a river levee, it is built up by successive lava layers whenever the channel overflows.
Limestone	A rock composed of more than 50% calcium carbonate [$CaCO_3$]. Dolomite is a variant that is rich in magnesium. Because of its solubility limestone is the most common host rock for caves.
Lithification	Hardening of sediment to form a rock.
Marl	A calcareous clay, or impure fine grained limestone.
Moonmilk	A soft, white, plastic speleothem composed of calcite and a variety of hydrated carbonate minerals in combination with water. It typically forms cauliflower-shaped areas which are initially soft and moist, but may become hard or powdery if they dry out.
Mottling	Blotchy or patchy color patterning.
Nothephreatic	Slow deep phreatic (qv) circulation of water.

Pahoehoe	A type of lava in which the surface was relatively fluid and so formed smooth or porridge-like surfaces. Variants include wrinkled or 'ropy' surfaces, like flowing pitch, and surfaces with small rounded knobs.
Palaeosols	Ancient soils.
Phreatic	That part of a cave environment that lies or once lay below the water-table. Also refers to the processes that act within the phreatic zone.
Phytokarst	A type of small scale solutional sculpturing or karren (qv) which forms with the assistance of certain algae and other micro-organisms that secrete acid solutions. Commonly occurs as a part of marine lapies (qv), and also as light oriented features below the water level in some cenotes (qv). Not the same as stromatolites (qv), which are depositional structures.
Puddings	A local term for small tumuli (qv) within lava tubes, but also applied to porridge like mounds of pahoehoe (qv) that have been squeezed up through an opening in a crusted floor.
Quaternary	The youngest of the geological periods, extending from the end of the Tertiary (qv) 1.6 million years ago up to the present. It is divided into the Pleistocene, and the Holocene which is the last 10,000 years. The Quaternary is the time of the great ice ages with widely fluctuating climates and sea levels.
Regression	A withdrawal of the sea from the land, due to uplift or a eustatic (qv) drop in sea level. See transgression.
Rhizomorph	A calcareous structure formed around roots, and preserving the form of the root.
Rillenkarren	A pattern of narrow (1 cm), vertically oriented solutional grooves in a sloping limestone surface. A type of karren (qv).
Rising	Another term for a spring. A feature where water returns to the surface from an underground body of water.
Rock shelter	A cavity formed by overhanging rocks, typically at the base of a cliff. Rock shelters are often referred to as 'caves' by laymen and can be significant for archaeology, but speleologists prefer to exclude them from the definition of a 'true' cave (qv) as they do not penetrate any distance into the rock, and generally have no dark zone.
Ropy lava	Another term for pahoehoe (qv), especially the type with curved and twisted ridges.
Scoria	Refers to the angular pebble-sized frothy fragments that have solidified while flying through the air. Lapilli (qv) is a more general term for pebble to granule sized ejecta. Finer material is referred to as ash, and coarser fragments as bombs or blocks. Tuff (qv) is the name for consolidated ash.

Sea cave	Small chambers and fissures formed in coastal cliffs by wave action and salt spray weathering. When formed in limestone they may be true karst caves which have been exposed by marine action. See also 'Cave'.
Sink	A place where a surface water course disappears underground. Also known as 'streamsink'.
Sinkhole	Strictly, a hole or doline (qv) which acts as a streamsink. Unfortunately, the word has become debased by common misuse as a synonym for a doline (qv), especially a collapse doline.
Solution pipe	A vertical cylindrical shaft, often about 0.5 m across and up to 20 m deep, which is a characteristic of syngenetic karst areas.
Spatter	Molten material that was ejected from a vent or turbulent flow and which stuck together on landing to form a knobby rock in which the individual lumps are still just recognisable.
Speleogen	A sculpturing feature of the walls or roof of a cave, usually formed in the parent rock by solution or by erosion from running water.
Speleothem	A general term for all secondary mineral deposits in a cave. Includes stalactites, stalagmites, flowstone, and crystal growths. Terms such as 'formation' or 'decoration' are sometimes used in a similar manner, but can cause confusion, eg. with geological formations.
Spring	A feature where water returns to the surface from an underground body of water. Also known as a 'rising'.
Stalactite	A hanging speleothem formed by the dripping of water from a roof.
Stalagmite	A speleothem built up from a floor by water dripping from above. It will commonly have a matching stalactite above, and the two may eventually join to form a column.
Strandline	A coast line, present or ancient.
Stromatolite	A calcareous deposit, secreted by calcareous algae in the form of laminated domes and columns. Occurs in many cenotes (qv).
Swale	A linear hollow or depression found between dunes or beachridges. Generally marshy or swampy, or may contain small lakes.
Syngenetic karst	Karst landforms that are generated at the same time as the host sediment is being consolidated to become rock. A characteristic feature of the Australian Quaternary dune calcarenites.
Talweg	The line of lowest points along a valley floor, normally the stream channel. Also spelt 'Thalweg'.
Tectonic	Pertaining to large scale movements of the earth's crusts, such as Folding and faulting.

Terrigenous	Shallow marine sediments consisting of material derived from the land surface.
Tertiary	The geological time period lying between the Cretaceous and the Quaternary (qv), extending from about 65 to 1.6 million years ago. It occupies the bulk of the Cainozoic era. From oldest to youngest, the subdivisions are Palaeocene, Eocene, Oligocene, Miocene, and Pliocene. Tertiary climates in Australia were mainly warm and humid, with aridity first appearing towards the end of the Miocene and becoming widespread in the Pliocene.
Tidemark	A horizontal bench or a marking on a wall of a lava tube which indicates a prior lava level.
Transgression	An advance of the sea across the land, due to subsidence of the land, or a eustatic (qv) rise in sea level. Opposite of Regression (qv).
Tuff	A consolidated form of volcanic ash (qv) or lapilli (qv).
Tumulus	A rounded, sharply convex, mound of lava, frequently with radial or polygonal cracks, where a semi-solid crust has been pushed up by pressure from below. Normally used for large features on surface lava flows, but can also be applied to small mounds on a lava tube floor. See 'Puddings'. Plural is 'tumuli'.
Unconformity	A time break in a depositional sequence.
Uvala	A composite karst depression consisting of several smaller closed depressions coalescing into an irregular form.
Vadose	That part of the cave environment that lies or once lay above the water table. Also refers to the erosional processes that act in that zone.
Vadose flow	Refers to stream flow within the vadose zone, ie. a cave stream in contact with air.
Vadose seepage	Refers to water moving downward through the vadose zone, either in narrow fissures, or on the walls of air-filled caves.

References

For further information on general karst and speleological terms see:

Jennings, J.N., 1985, *Karst Geomorphology,* Blackwell, Oxford.

Jennings, J.N., 1985, Cave and Karst Terminology. IN: Matthews, P.G. (Ed), 1985, *Australian Karst Index,* Australian Speleological Federation Inc, Melbourne, pp 14-1 to 14-13.

For additional information and photographs of cave minerals see:

Hill, C.A. & Porti, P., 1986, *Cave Minerals of the World,* National Speleological Society, Alabama, USA.

Appendix: Map Symbols

Ken Grimes

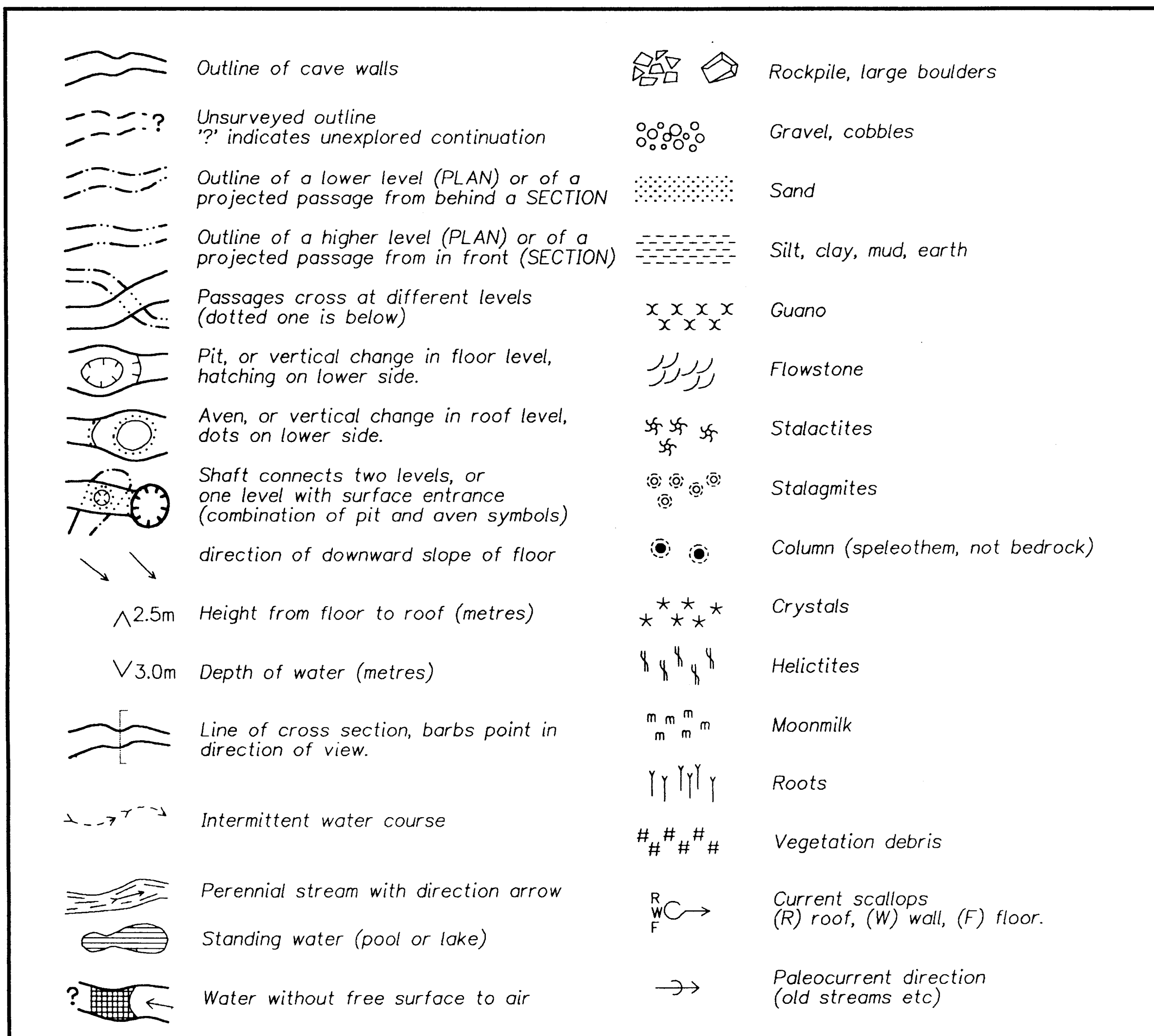

Figure A-1: Common Symbols used in Cave Maps, based on the ASF Standard (after Anderson, et al., 1985)

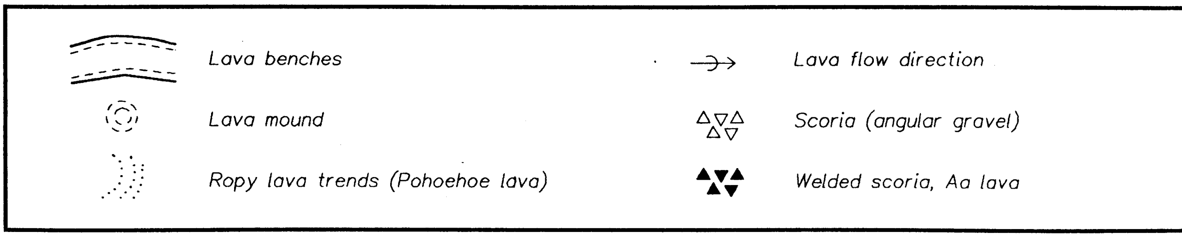

Figure A-2: Additional Symbols for Lava Cave Maps

References

For additional symbols see:

Anderson, E.G., et al., 1985, Cave Survey and Map Standards. IN: Matthews, P.G. (Ed), 1985, *Australian Karst Index,* Australian Speleological Federation Inc, Melbourne, pp 18-13 to 18-17.