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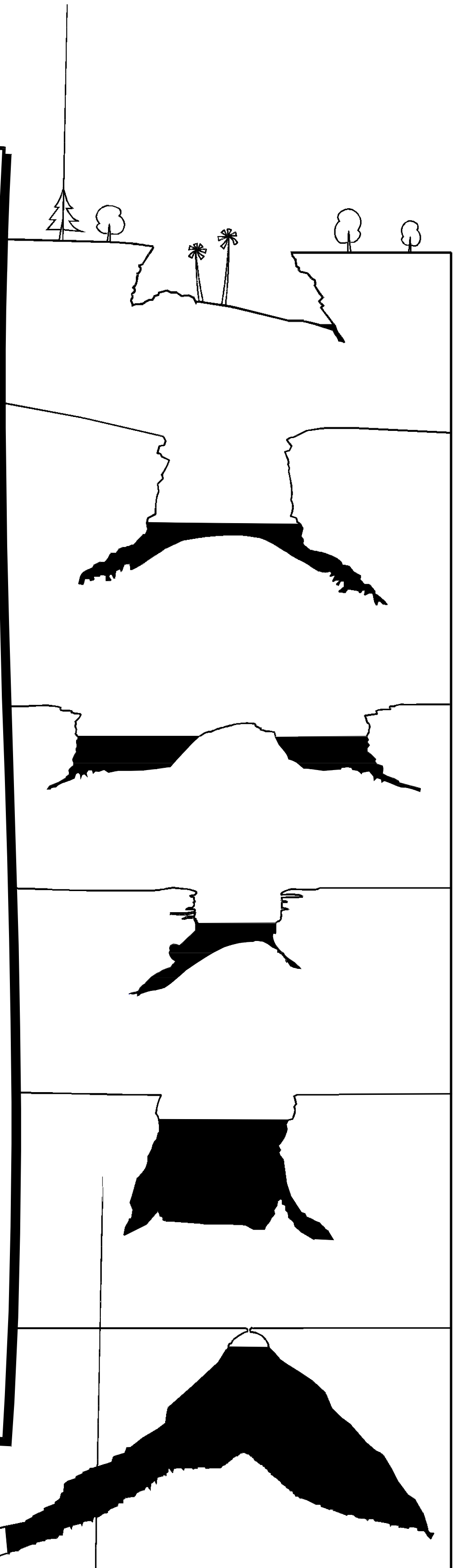
FIELD GUIDEBOOK
TO KARST AND VOLCANIC PSEUDOKARST FEATURES IN SOUTHEAST SOUTH AUSTRALIA AND WESTERN VICTORIA

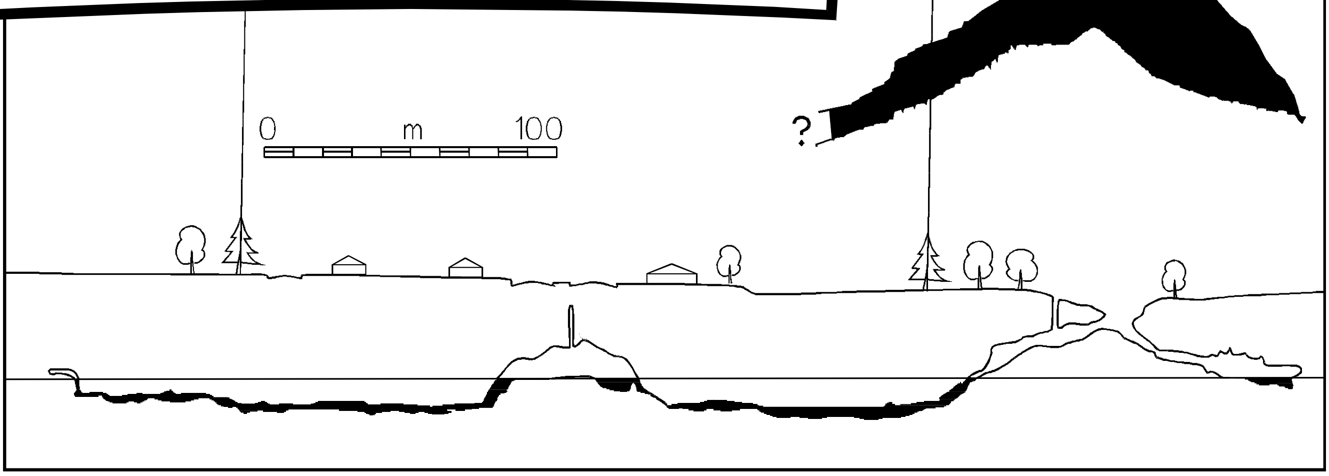
Compiled by
Ken Grimes, Kevin Mott and Susan White.

(revised edition, January 2001)

Australasian Cave and Karst Management Association Inc.

A revised version of a Guide Book published as part of the 13th Australasian Conference on Cave and Karst Management, Mt. Gambier, S.A., April, 1999





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Bibliography.

1 Karst - South Australia - Guidebooks. **2** Karst - Victoria - Guidebooks. **3** Volcanoes - Victoria - Guidebooks. **4** South Australia - Guidebooks. **5** Victoria - Guidebooks.
I Grimes, Ken (Kenneth George), 1944 - . **II** Mott, Kevin. **III** White, Susan, 1943 - .**IV** Regolith Mapping. IV Title.

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CONTENTS

PREFACE

This area of 'soft rock' caves developed on youthful, weakly consolidated limestones is quite different from the 'hard rock' indurated Palaeozoic limestone karsts of eastern Australia. The caves have an entirely different quality, characterised by cap rock effects, solution pipes, extensive low horizontal phreatic mazes, abundant collapse modification and extensive large flooded systems. The cenotes are unique within Australia. In addition to karst caves the Newer Volcanic Province of the Victorian part of the region has many lava tubes and other volcanic caves.

The first edition of this Guidebook was produced for the 13th Australasian Conference on Cave and Karst Management, at Mount Gambier, South Australia, in April 1999. That conference was organised by the Australasian Cave and Karst Management Association (ACKMA). The present version has been revised, with the permission of ACKMA, for the use of delegates to the February 2001 conference of the Australasian Quaternary Association (AQUA) at Port Fairy, in February 2001. The revisions involve correction of typographic and other errors and the addition of some minor new information, but this version is essentially the same as the first edition and the emphasis is still on karst and cave features.

The guide is in four parts. An introduction describes the geology and karst features of the Gambier Basin as a whole, followed by a discussion of the volcanic caves and associated features in western Victoria. The third part refers to sites in the Naracoorte - Mt Gambier area. The final part describes sites visited during a tour through western Victoria. Note that the field trips did not stop at all the sites described herein; we deliberately described some additional sites so as to cater for people who wished to visit these at other times (We are great believers in the continuing usefulness of field guides).

Note that most of the sites described here are on private land or in government reserves for which permission should be sought before entering. Entry to caves in South Australian National Parks requires a permit obtained from the National Parks and Wildlife, South Australia (NPWSA) at least one month beforehand. Diving in the cenotes and springs in South Australia requires a permit from NPWSA at Mount Gambier, and divers must show that they are suitably qualified. For Victorian caves permits are needed from Parks Victoria for all caves apart from those that are open to the general public. A requisite of entry permits is that you have suitable experience and equipment.

In accordance with the policy of the Australian Speleological Federation (ASF) we cannot print detailed location information concerning cave sites. Accredited scientists or speleologists can obtain access details from the Victorian Speleological Association (VSA) or the Cave Exploration Group, South Australia (CEGSA), or from the authors during the seminar.

ACKNOWLEDGMENTS

This field guide draws heavily from previous reports and guides, in particular from White & Grimes 1992, Grimes 1994, White 1995a & b, and Grimes & White, 1996. Brian Clark, Elery Hamilton-Smith and Kym Schramm provided additional information for some sites. Most importantly, this guide could not have been written without the extensive exploration, mapping and documentation efforts of numerous CEGSA, VSA and other cavers over the last 40 years.

THE GAMBIER KARST PROVINCE

The 'soft-rock' karst region of south-east South Australia and western Victoria corresponds to a large extent with the Tertiary Gambier Basin (Smith & others, 1995), although caves in Quaternary dune limestone extend northwest across the adjoining Murray basin. The region is generally low-lying and flat, with Quaternary dune ridges providing the most common relief. Locally, Quaternary volcanoes form unexpected hills. Many of the inter-dune flats were waterlogged for much of each year but have now been artificially drained. The Glenelg River is incised into the limestone to form a major gorge, and some rivers further east in Victoria are also incised. Coastal cliffs of limestone occur in many places, especially in the far east.

The karst is developed on poorly consolidated Tertiary and Quaternary limestones. It is also influenced by the thin younger sediments that overlie the limestones. Most of the karst is covered but some areas of bare karst occur southwest of Mount Gambier.

The climate of the western region is a 'Mediterranean' one with wet winters and cool dry summers. Annual rainfall increases towards the coast and from west to east; ranging from 550 mm in the Naracoorte area, through 850mm at Portland to nearly 1000mm at Port Campbell at the eastern end of the karst region.

During the Quaternary the present type of climate would have alternated with colder, drier and windier climates during the peaks of the glacial stages. The windy periods would be responsible for lunette ridges bordering some lakes, and possibly for deflation of some of the enigmatic shallow hollows in the old coastal plains. Much of the region would have

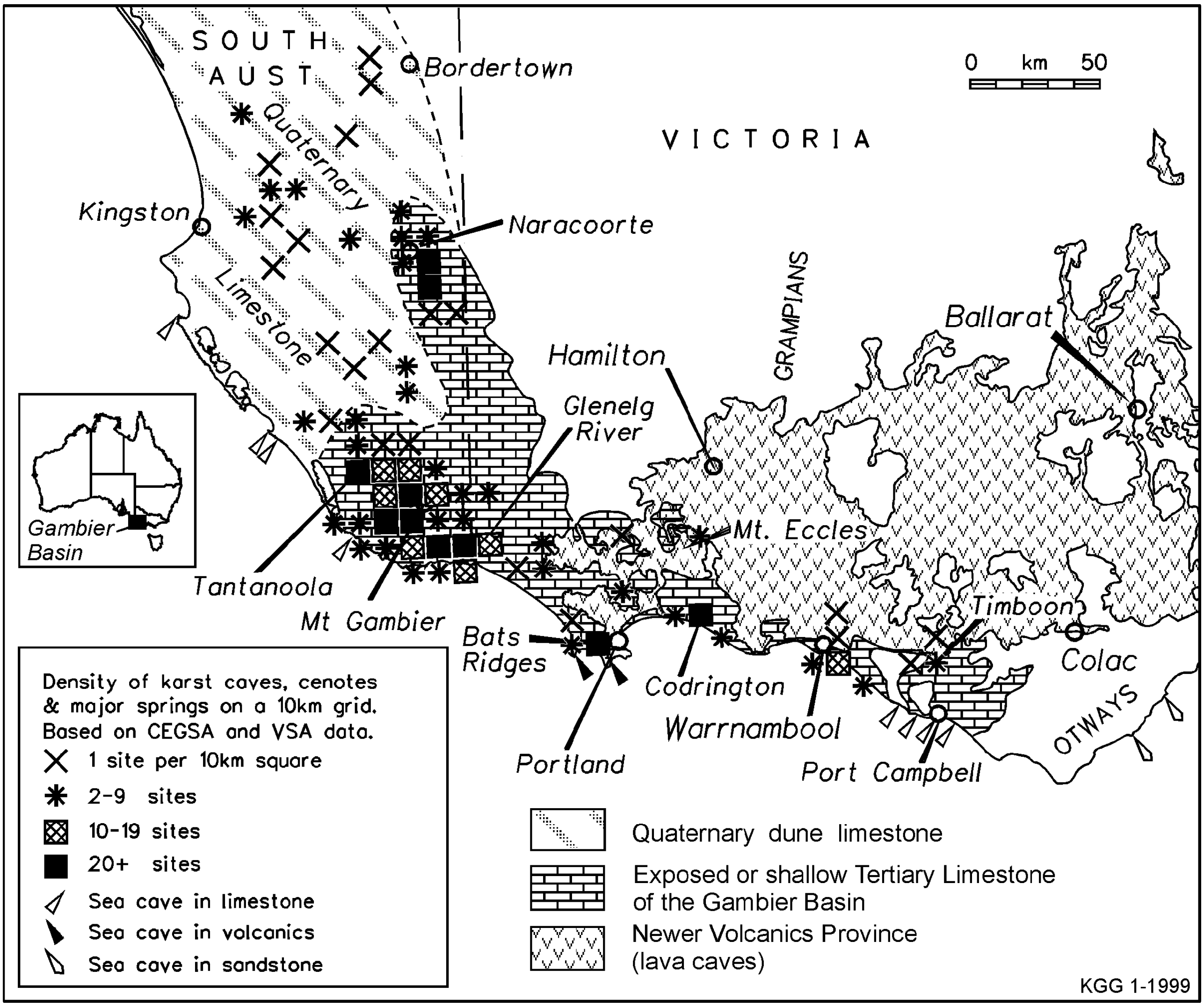


Figure 1: Distribution of limestone caves in the Gambier Karst Province.

been intermittently flooded by the sea during the interglacial periods of the early Quaternary.

GEOLOGY

See Marker (1975), Grimes (1994) and White (1994, 2000a) for details of the geology and karst systems. The limestones fall into two groups, both relatively young: the Tertiary (mainly Miocene) limestones of the Gambier Limestone and its equivalent Port Campbell Limestone further east, and the younger Quaternary calcareous dune limestones of the Bridgewater Formation and associated calcareous marine and coastal sediments of the inter-dune flats.

The ***Tertiary limestones*** were deposited in a shallow sea that flooded the region in the Oligocene and early Miocene (about 15-35 million years ago). Figure 1 shows the northern limit of these limestones for the purposes of modern cave development - they continue further to the north in South Australia, but with a progressively thicker cover of non-calcareous sediments. In Victoria the Tertiary limestones extend northwards beneath parts of the Newer Volcanics, but again the karst potential is limited.

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 in South Australia, but a north-east trend in the Port Campbell area. The influence of both the vertical jointing and the horizontal bedding are exhibited in the cave passage forms (e.g. Figure 27). The Tertiary limestones are similar to those in the Nullarbor, and there are similarities in the cave styles also, though here we have none of the huge passage systems that occur in the Nullarbor. The Kanawinka Fault and its related scarp have a major influence on the hydrology and karst development in the Naracoorte area (Figures 2 & 4).

In the Bool Region (Figure 8) the Gambier Limestone is mantled by ***late Pliocene marine*** calcareous quartz sands up to 17 m thick (Figure 2, Cook and others, 1977). Towards the Victorian border these quartz sands grade into shelly calcareous sands and muds of the Pliocene to early Pleistocene Whalers Bluff Formation.

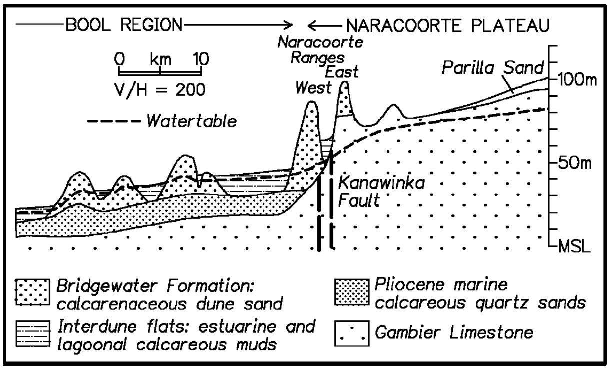


Figure 2: Cross-section in the Naracoorte area, showing geology and watertable.

The ***Quaternary dune limestones*** are a series of calcareous coastal dunes along old shorelines that developed during an overall regression of the sea during the Quaternary. In South Australia they form linear north-west trending ranges (Figure 8), which extend northwards beyond the limit of the Gambier Basin to overlie the sediments of the Murray Basin. In Victoria the distribution of the dune limestones is less regular, and east of Portland they are mainly restricted to a belt along the modern coast, though some older ridges (mostly without karst) occur further inland.

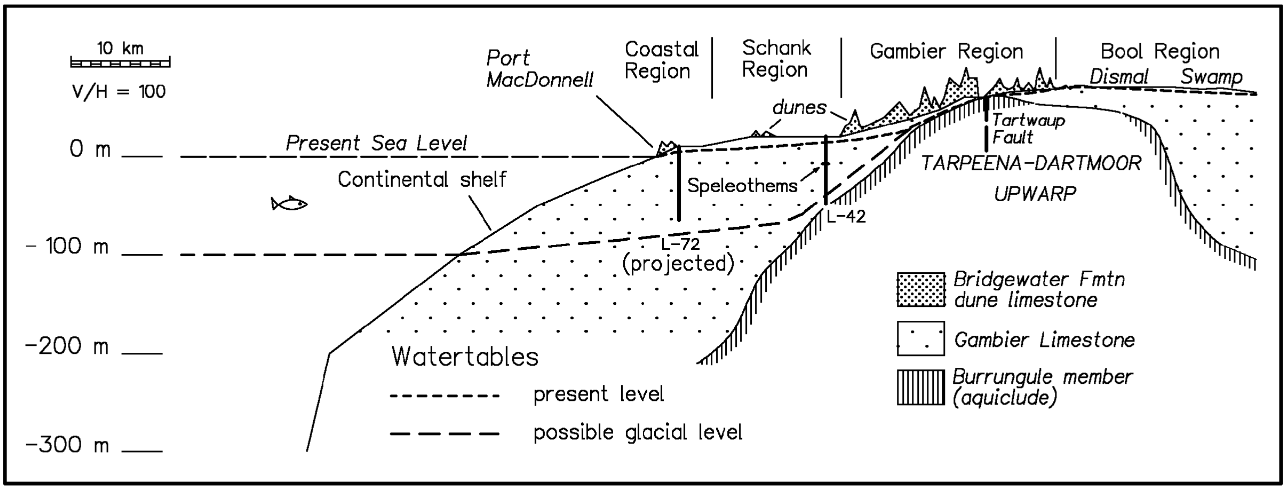


Figure 3: Cross-section in the Mount Gambier area, showing present and past watertables.

These Quaternary limestones are similar to those on Kangaroo Island, the Eyre Peninsula, and the coastal areas of West Australia. The dune ridges are now partly consolidated calcarenites and contain syngenetic karst features in which caves and solution pipes developed as the sands were being cemented into a limestone (see later). The limestone has well-developed dune bedding with shallow-angle medium to thin bedding in places. It shows little or no jointing. Some caves are developed mainly in the underlying Tertiary limestones but have their entrances in the overlying dune limestones. Some younger, reworked, dunes are dominantly quartzose.

Between the dune ridges there are extensive swampy plains. These are ***old coastal flats*** and comprise estuarine to lacustrine limestones, dolomites, marls and clays up to 13 m thick (Figure 2). These plains have many shallow swampy depressions of complex origin (Figure 7).

Pliocene to Holocene basaltic volcanics form the extensive Newer Volcanic Province of Victoria (Figure 9), and some isolated volcanoes of this province occur in South Australia. The southern margin of the volcanic area overlies the Tertiary limestones. Lava caves are associated with several of the volcanoes in Victoria (see later).

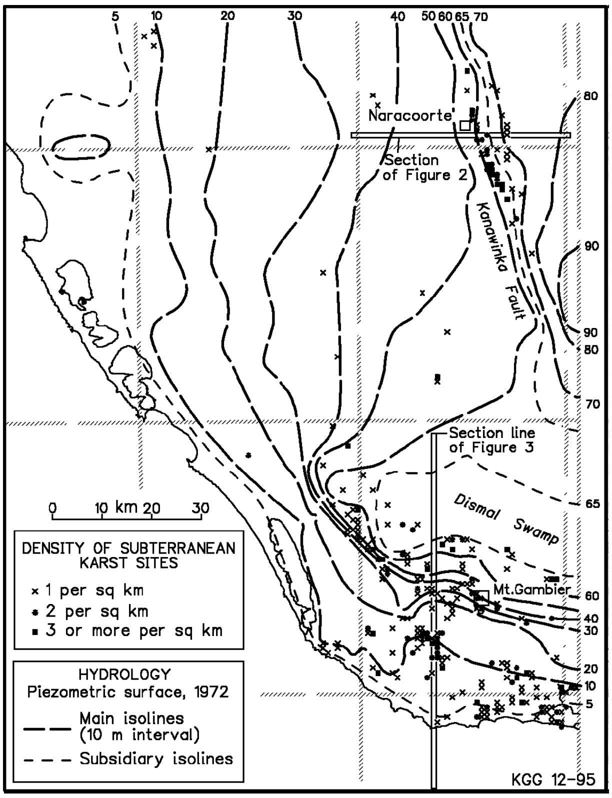


Figure 4: Ground water contours, after Holmes & Waterhouse (1983).

HYDROLOGY

The Tertiary Limestone forms a major aquifer in the region. The Gambier Limestone has been referred to as one of the best aquifers in Australia (Holmes & Waterhouse, 1983, Stadter, 1999). Much of the ground water from the Mount Gambier area is discharged in major springs along the southern coast, and divers have entered caves below some of these.

In South Australia there is a well-developed water table. This has a gentle slope towards the coast, with two zones of steeper gradients (Figure 4, Holmes & Waterhouse, 1983). One of these is along the line of the Kanawinka Escarpment (Figure 2), and the other passes north-west through Mount Gambier (Figure 3). Marker (1975) noted a correlation between high cave densities and the zones of steep gradients, and also with areas of greater than normal depth to the water table.

During glacial periods the lowering of sea levels would have caused a significant drop in the ground water levels in the coastal parts of the region – as shown by submerged speleothems and mudcracks in some South Australian caves. There is also evidence for recent drops in the water table. For example, stromatolites are found up to 2 m above the present water level in the cenotes, and there are historical records of higher levels in some cenotes. Fluctuations of over a metre have been recorded in association with land clearance (a rise) and the growth of pine plantations (a drop).

KARST LANDFORMS

Syngenetic Karst and Soft Rock Karst

In the calcareous Quaternary dunes some karst features are syngenetic, in that they have developed at the same time as the sand was being cemented into a rock (Jennings, 1968; White, 1989, 1994, 2000a, Grimes & Spate, 1997). Unconsolidated calcareous sand is converted to limestone gradually by solution and redeposition of calcium carbonate by percolating water. This initially produces a caprock or calcrete layer near the surface which is capable of supporting the roof of a cave (Figure 5). The downward percolating water also dissolves vertical solution pipes, and simultaneously cements the surrounding sand. At the same time, enhanced mixing corrosion occurs where percolation water meets the water table - typically at the level of an

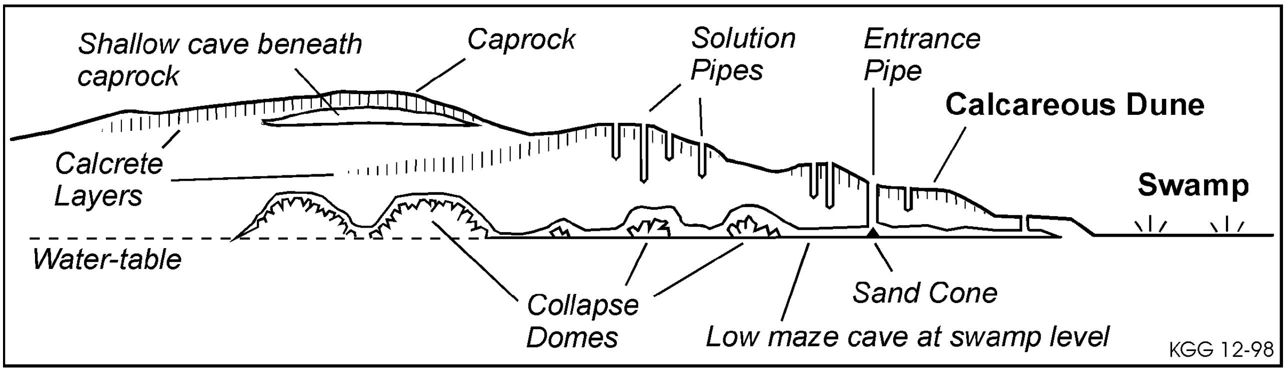


Figure 5: Features of syngenetic karst developed on a calcareous dunefield.

adjacent swampy plain. In the early stages, when the sea was present adjacent to the dune ridges, mixing between a freshwater lens and an underlying body of sea water could have also contributed to the development of horizontal maze caves. This is the "flank margin" model of Mylroie & others (1995) developed for the soft-rock caves of the Bahamas. In Australia this sea water effect may have less importance than the swamp waters.

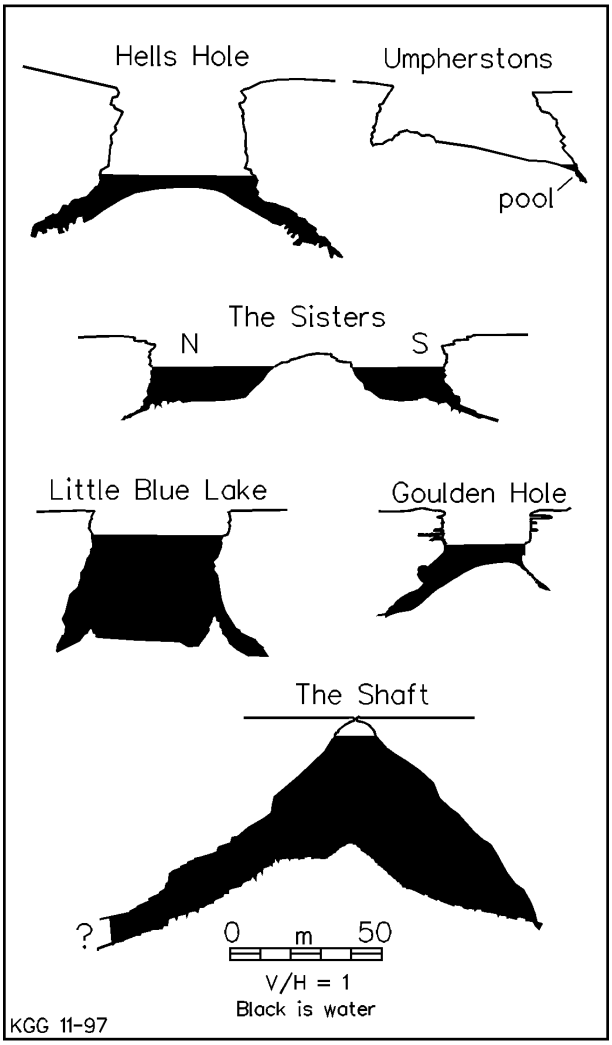


Figure 6: Typical cenotes

The main characteristics of syngenetic karst are the development of a cemented (calcreted) caprock near the surface, of vertical solution pipes, and of low, wide, horizontal maze caves either beneath the caprock or at the level of the adjoining swampy plains (Figures 5, 23 & 26). The poorly consolidated nature of the rock means that collapse plays a very important role from an early stage. Re-cemented breccias are seen in the walls of several of the dune limestone caves.

Solution pipes are one of the most distinctive features of syngenetic karst. They are vertical cylindrical tubes, typically 0.5 to 1 m in diameter, which can penetrate down from the surface as far as 20 metres into the soft limestone. The pipes may be associated with roots (though which came first is debatable), and their margins show a case-hardened cylinder. They occur as isolated features, or in clusters with spacings as close as a metre or so (e.g. Site 22). Many of the caves are entered via such pipes.

Syngenetic karst development is typical of the Quaternary dune calcarenites; however, the Tertiary limestone is also a relatively soft porous limestone, and consequently it shows some of the features of syngenetic karst, in particular the development of solution pipes and calcreted caprocks.

Surface Karst

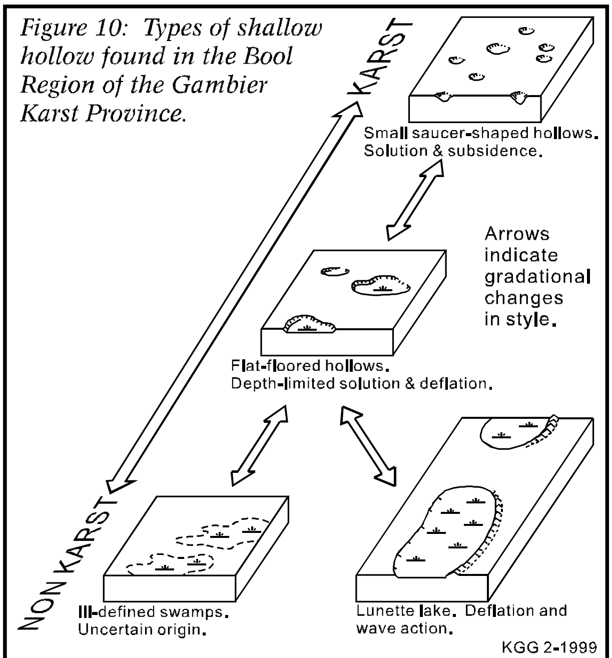
Surface karst features are extensive in some parts of the area, but inhibited by thick cover material in others. Features include uvalas, dry valleys, a variety of doline types, exposed subsoil karren and coastal phytokarst.

The most spectacular surface karst features are the ***collapse dolines***, especially those in the Mount Gambier area that extend below the water table to form ***cenotes***. These have formed by the collapse of large phreatic caverns. Figure 6 shows several typical cenotes and related features. In the Gambier region the watertable is lower and the collapse dolines have only shallow lakes (e.g. Hells Hole & Umpherstons), however, further south in the Schank region, the water levels are higher and we find deep lakes (e.g. Little Blue Lake). The Shaft (Figure 6) is an example of the situation before the roof of a large flooded collapse dome falls in to form a cenote - the present entrance is a small solution tube.

Fields of shallow dolines and uvalas are extensive in South Australia and extend into the westernmost part of Victoria (Figure 19). Isolated doline fields also occur further east. These shallow hollows generally have sandy or muddy floors and rarely have cave entrances.

In the Pleistocene coastal plains which form the Bool Region many of the shallow hollows are polygenetic; with solution, deflation and other processes operating in parallel, or in sequence, or alternating in step with glacial - interglacial climatic fluctuations. The resulting hollows range from small well-defined saucers which appear to be true karst to large shallow lunette lakes which appear to owe their origin mainly to deflation and wave modification of primary coastal lagoons, though there is a possibility of subjacent karst influences in places (Figure 7, Grimes, 1996). Some ill-defined hollows are irregular in plan or form chains which suggest the influence of the original drainage on the coastal plain.

Figure 10: Types of shallow hollow found in the Bool Region of the Gambier Karst Province.



In the dune ridges many of the larger depressions are dune hollows, but these may be modified by karst solution to produce uvala-like features. The distinction between dune hollows and karst depressions is difficult to make in many areas. The 'hummocky' terrain north of Mount Gambier is a case in point (Site 3).

Caves

The caves in the Tertiary limestones are dominantly phreatic in origin, i.e. formed by slow moving ground water below the water table. The syngenetic caves are mainly epiphreatic - formed in the zone of mixing just below the water table; but vertical vadose seepage is responsible for the solution pipes. The limited local relief means that vadose stream flow features are extremely rare in South Australia, but some vadose streams occur in the caves of the Glenelg River gorge in Victoria, and also further east in the Warrnambool and Timboon regions. Both joint and bedding plane control can be seen, but solution at temporary water-table levels can make the latter hard to recognize in this area of flat bedded limestone. Many of the primary phreatic caverns and passages have been modified by breakdown to form collapse domes and rubble filled passages (Figure 18).

Cave diving has demonstrated the existence of extensive underwater cave systems in South Australia. It appears that in the southern part of the Lower South-east area the bulk of the cave development may be below the present water table though these passages would have been partly or wholly drained during the low sea levels of the last glacial period.

Typical syngenetic cave forms in the dune limestones are shallow horizontal systems developed beneath the caprock or at the level of an adjoining swamp (Figure 5). They have multiple entrances (often via solution pipes or the collapse of the surface crust) and an irregular outline of chambers, pillars and short connecting passages, generally with a roof height less than one metre throughout (Figures 23 & 26). The walls are often difficult to see (and map) as they are out of reach where the roof slowly drops to floor level. The caves in the Tertiary limestone are similar but generally have larger chambers and passages, and also show better joint control, with many fissure-style passages (Figures 15 & 27).

Speleothems are generally not abundant – a consequence of the frequent collapse. However, there are

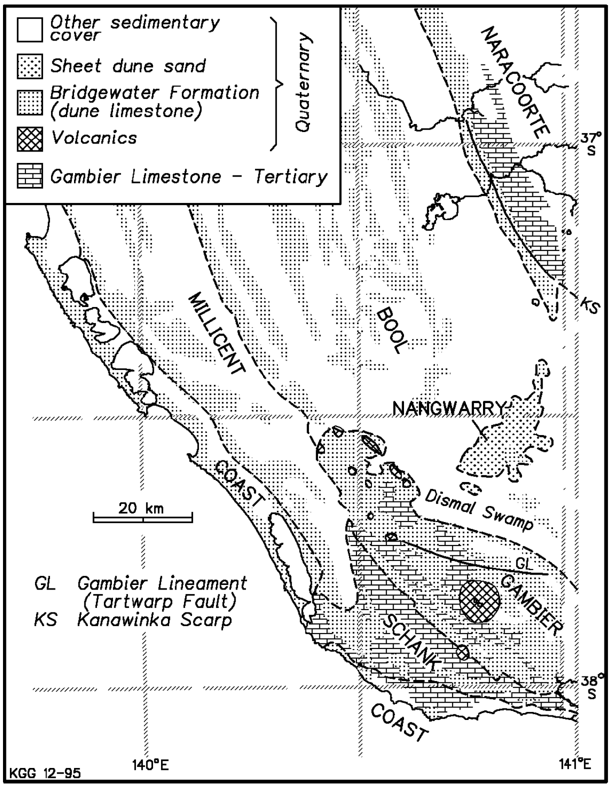


Figure 8: Karst regions and geology in South Australia.

some spectacular exceptions to that rule, and these include some extensive and very delicate forms; especially clusters of long straws and soft deposits of moonmilk. Moonmilk is composed of micro-crystalline carbonate needles with a high water content between the crystals and is generally rare in limestone areas in eastern Australia. Cave-coral is also well developed. Still pools may be partly covered by calcite rafts.

South Australian Karst Regions

Marker (1975) and later Grimes (1994) divided the South Australian part of the Gambier Karst Province into several distinctive regions (Figure 8).

The Naracoorte Plateau is an uplifted area of Tertiary limestone to the east of the Kanawinka Fault (Figure 2). Along the western margin a pair of large dune ridges are separated by the Kanawinka Escarpment. The westernmost ridge (The West Naracoorte Range) is a thick calcareous dune sand and has little karst development. The eastern ridge (The East Naracoorte Range) is perched above the old sea cliff of the Kanawinka Escarpment and has only a relatively thin dune cover over Tertiary Limestone. This is where most of the known caves occur. Most of the depressions in the ranges are dune hollows. However, on the main plateau to the east there are many well developed uvalas, dolines and dry valleys, but fewer caves.

The Bool Region comprises extensive flat swampy plains crossed by linear calcareous dune ranges. Watertables beneath the plains are very shallow – at the surface during the wet season! Caves are almost entirely restricted to the calcareous dune ridges. The flats overlie marls and limestones that have minor karst potential. They have numerous enigmatic hollows illustrated in Figure 7.

The Nangwarry Region is a low undulating sand plain, but differs from the flat sandy parts of the Bool Region in having a stronger relief and a thicker cover of quartz sand. The undulating surface is a dune sheet. Shallow dune hollows are common throughout the region, and many of them are pocketed by small subsidence dolines. Small dolines are also common on the sandy rises. No collapse dolines or caves are known in the area; probably the thick sandy soil clogs any potential entrances.

The Gambier Region is a composite area comprising several different geological and geomorphic zones. High dune ridges together with exposures of Tertiary limestone and some flatter swampy country, form the Mount Burr and Gambier Forest areas. The northern part of the Tantanoola Forest also is dune country, but the southern part is a series of low beachridges that form only a thin cover over Tertiary limestone. About Mount Gambier there is a strong 'hummocky' terrain in which rounded hills built partly of calcareous dune limestone stand above broad hollows in Tertiary limestone. Further east the hummocks become much smaller in the pine plantations of the Myora and Caroline Forests. The southern part of the Caroline Forest is a composite series of high coastal dunefields which separate into several discrete ridges further to the north-west. A major west-northwest trending structural lineament (the Gambier Lineament) is associated with the Tartwaup Fault that runs through the core of the region. A line of elongated dolines and uvalas follows the surface trace of the fault.

A variety of caves occur both in the Tertiary limestone and as syngenetic karst in the dune limestones. Many spectacular large collapse dolines occur, some of which extend below the water table to form cenotes. Swamp and saucer dolines are abundant in some localised areas, but absent in much of the region. Good examples of solutional uvalas occur to the north-west of Mount Gambier but are difficult to pick from the adjoining 'hummocky' terrain which appears to be a combination of dune and karst landforms. Dry valleys occur in the Dry Creek area in the far south-east.

The Schank Region is an area of relatively bare karst on a flat, stripped Pleistocene coastal plain to the south of the Gambier Region. The narrow Coastal Region separates it from the sea. Much of the region has thin soil or bare pavements of Tertiary limestone. Karst features include spectacular cenotes, a few uvalas, well-developed exhumed subsoil karren and caves. Many of the caves are partly or wholly submerged by the present high watertable though they would have been drained during the low sea levels of the last glacial period.

The Millicent Region is similar to but younger than the Bool Region. Unlike the older region it lacks the characteristic hollows on the flats, and caves are rare in the dune ridges.

The Coastal Region is a narrow belt of land that extends up to 6 km inland from the present coast. It consists of a low erosional coastal plain developed on Tertiary limestone, and partly covered by recent coastal dunes and beach ridges. The watertable is close to the surface. Numerous springs occur, many of them rising from submerged dolines and caves. Most of the caves can only be entered by diving. Coastal karren (lapies) are well developed on the limestone cliffs and there are some small sea caves.

Victorian Karst Regions

In Victoria the Tertiary limestones are variable in their purity, and only limited parts of the region show significant karst development.

The ***Glenelg region*** has mainly linear joint-controlled fissure caves in Tertiary limestone. The river has cut a magnificent gorge up to 35 m deep into an otherwise gently undulating limestone surface. Some of the caves are entered at the base of the river cliffs, and have out-flowing streams and vadose features. The flat country north of the Glenelg River is similar to the Bool Region, whereas that to the south is an extension of the Gambier Region.

The ***Portland region*** is a broad diverse region covering sea caves and isolated dune limestone caves, as well as the densely cavernous areas of Bats Ridge and Codrington. The low-lying plain north of Codrington (Figure 1) is analogous to the Bool Region and has similar small swampy depressions.

The ***Warrnambool*** area includes both Tertiary and Quaternary limestone karst. An active stream occurs in one cave. The caves are mainly collapse-modified phreatic systems, with some joint control. There is a well-developed field of basin-shaped dolines west of Peterborough (Site 26).

Timboon is a small area near the eastern end of the Tertiary limestone belt. The caves occur in or near the deep valley of the Curdie River which has cut through a thin basalt cover. They are small, but some are well-decorated and several contain streams.

CAVE BIOLOGY

There are two maternity sites for the Bentwing Bat (*Miniopterus schreibersii*) – one near Naracoorte and one at Warrnambool (Dwyer, 1969). Several caves along the Glenelg River host the (locally) rare Large Footed Bat (*Myotis adversus*). The cenotes and big springs contain an interesting aquatic fauna and flora – including stromatoloies and small crustaceans called syncarids (Thurgate, 1996a &b, 1999). The ***stromatolites*** are columnar or platy underwater calcareous growths formed by algae. These have been found as deep as 25 m, and also extend 2 m above the present water level – implying a higher watertable at some time in the past.

The solution pipes and collapse dolines form excellent pitfall traps and thus bone deposits of Quaternary age have been found in many caves (e.g. Wells & Pledge, 1983). The most important, and world famous, bone deposit is in the Victoria Fossil Cave at Naracoorte (Wells & others, 1984), but significant bone sites occur in both states, including some underwater bone deposits in the cenotes.

The Tertiary limestones in the Mount Gambier area have bands of flint nodules which make excellent stone tools. Evidence of aboriginal mining of flint is seen in several caves, as is also aboriginal art in the form of scratch marks and finger marks (Bednarik, 1986).

MANAGEMENT

Water Supplies

The Gambier Limestone has been referred to as one of the best aquifers in Australia (Holmes & Waterhouse, 1983). Unfortunately it has also suffered from pollution and over-exploitation (Emmit & Telfer, 1994, Stadter 1999, Schmidt, 1999, Hopton, 1999). There may be a growing problem in maintaining supplies in the face of increasing demand for private, agricultural and industrial usage. Water quality can be compromised by pollution from a variety of sources: stormwater, sewer and septic drainage in the towns, farm activities (in particular wastes from the dairies and piggeries), and some major industries such as those involved in the timber business (treatment of mill timbers, paper pulp, cellulose etc.). In the past, abattoirs have been a source of pollution with some still a cause for concern. Cheese factories also introduced major pollution plumes into the aquifer and these are still travelling through the system.

Of increasing concern is contamination of the groundwater from diffuse sources such as grazing (Harvey, 1982). In some areas, particularly in the north, increased salinity from clearance and irrigation is becoming a greater problem (Stadter, 1999).

Although regulatory controls exist under the Environment Protection Act these only cover large scale operations. Small scale operations come under a general duty of care and are usually only scrutinised when there is a direct complaint. Often a number of small, badly run, operations can cause more problems than the reasonably run large ones. Unfortunately, these small operations have more severe budgetry constraints so the owners are more reluctant to upgrade, despite programs of public education.

Surface karst management

The main problems here have to do with introduction of pollutants into the aquifer via the dolines, cave entrances and "runaway holes". Infilling and direct damage to dolines and cave entrances also occurs from forestry and agricultural activities. Many dolines and entrances have been, and still are, used as rubbish dumps. There have been major clean-ups of some dolines and caves, for example: Engelbrecht Cave in the town of Mt Gambier is now a tourist cave, and Rendelsham Cave near Millicent has recently been cleaned up and developed as a recreational area. The stromatolites that grow in the cenotes may be endangered by water pollution; either directly or indirectly by the growth of surface algal mats which block the sunlight (Thurgate, 1996). Swimmers in some of the spring ponds have caused damage to the aquatic vegetation. Ripping of limestone for increasing irrigation activity can disturb karst pavement areas and change the hydrology. Subsequent irrigation or intensified land usage will also have an impact from increased fertiliser applications.

Cave management

Management problems within the caves are mainly related to people access, and the damage that results therefrom. About a third of the known caves in South Australia are on crown land (mainly State Forests). The region has four sets of show caves: Several caves at The Naracoorte Caves, and also Tantanoola Cave, Engelbrecht Cave in Mount Gambier, and Princess Margaret Rose Cave on the Glenelg River. There are no show caves in the volcanic region, but two lava caves at Mount Eccles are open to the general public and access steps have been put into one of these. Diving in caves and cenotes is a special activity in the Mount Gambier region that is stringently controlled by a certificate and permit system (Collins, 1999). Beneath pine plantations evapotranspiration is much higher than elsewhere and this can drop the local water table by several metres, drying up cave pools and speleothems. A few caves have been intersected by quarries; one of these became a major fossil bone site - with the quarry operations continuing beside it (Barrie, 1997). A worry with syngenetic karst caves, and to a lesser extent with those in the Tertiary Limestones, is stability. "Soft-rock caves" are not as strong as the typical "hard-rock" cave of the east coast, and so roof fall is statistically more likely. This is not a major problem, but cavers have to be a bit more careful about bumping the roof, and cave managers should do regular inspections of their tour caves.

CONCLUSION

This area of 'soft rock' caves developed on youthful, weakly-consolidated porous limestones is quite different from the 'hard rock' indurated Palaeozoic limestone karsts of eastern Australia. The caves have an entirely different quality, characterised by cap rock effects, solution pipes, extensive low horizontal phreatic mazes, abundant collapse modification and extensive large flooded systems. The cenotes are unique within Australia. The karst aquifer is one of the best in Australia, but careful management will be needed to maintain that quality. Management is also required to maintain the surface karst features, the caves and their environment.

VOLCANIC CAVES AND RELATED FEATURES

The Newer Volcanics Province

The Newer Volcanic Province of western Victoria is one of the world's larger volcanic plains, and has formed by a succession of eruptions and lava flows over the last five million years. The isolated volcanoes at Mount Gambier are a western outlier of the Province (Figure 9). Eruptions have continued up to quite recent times (as little as 5,000 years ago) and further eruptions could occur in the geological future. Current isotope dating suggests that the youngest volcano may be Mount Schank, south of Mount Gambier, which erupted 5,000 years ago. 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 are in flows several million years old.

Lava tubes and other volcanic caves are scattered across the province, but the majority of them are in the western area where they are associated with two of the younger eruptions in the region (Webb & others, 1982, Grimes & Watson, 1995).

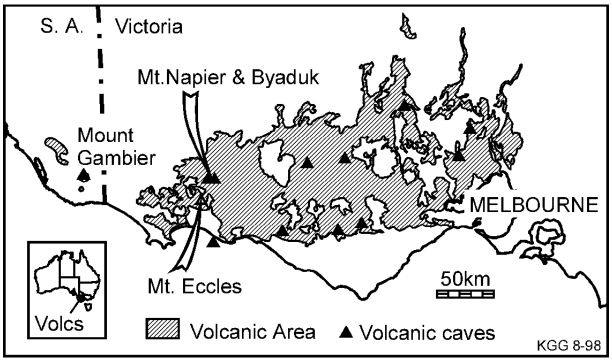


Figure 9: The Newer Volcanics Province and caves.

Surface landforms

The volcanics are dominantly built up from lava flows, but there are numerous small volcanic cones built by explosive activity, as well as larger maar lakes formed by major explosions.

The older volcanoes of the region have degraded features, and thick lateritised soils, which make their recognition difficult. By contrast, the flows from the younger eruptions have only minimal soil development and rough undulating surfaces known as *stony rises*; isotope dating suggests that these are all less than 500,000 years old.

The best modern model for the nature of vulcanism in this region is provided by the *Hawaiian volcanoes*. 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.

Local examples of lava shields are the lower slopes of Mount Napier and the lava fields surrounding Mount Eccles. However, in Victoria we also have slightly more explosive eruptions which build larger scoria cones; and the maar lakes, which are large but shallow craters formed by major steam driven explosions. At Mount Eccles a line of scoria cones running southeast from the main crater could have formed along a fissure eruption (Figure 33).

Lava flows:

Basaltic lava is a hot (1100°C) liquid that can flow readily. There are two main forms of basaltic lava flow, which grade into each other. *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 to form new lobes (Figure 11).

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.

Behind the advancing lava front solidification of stagnant areas restricts lava movement either to narrow surface *channels*, or internally in *lava tubes* beneath a surface crust. 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 (Figure 33). A number of shallow lava tubes are known in flows that have run off to the sides from these channels.

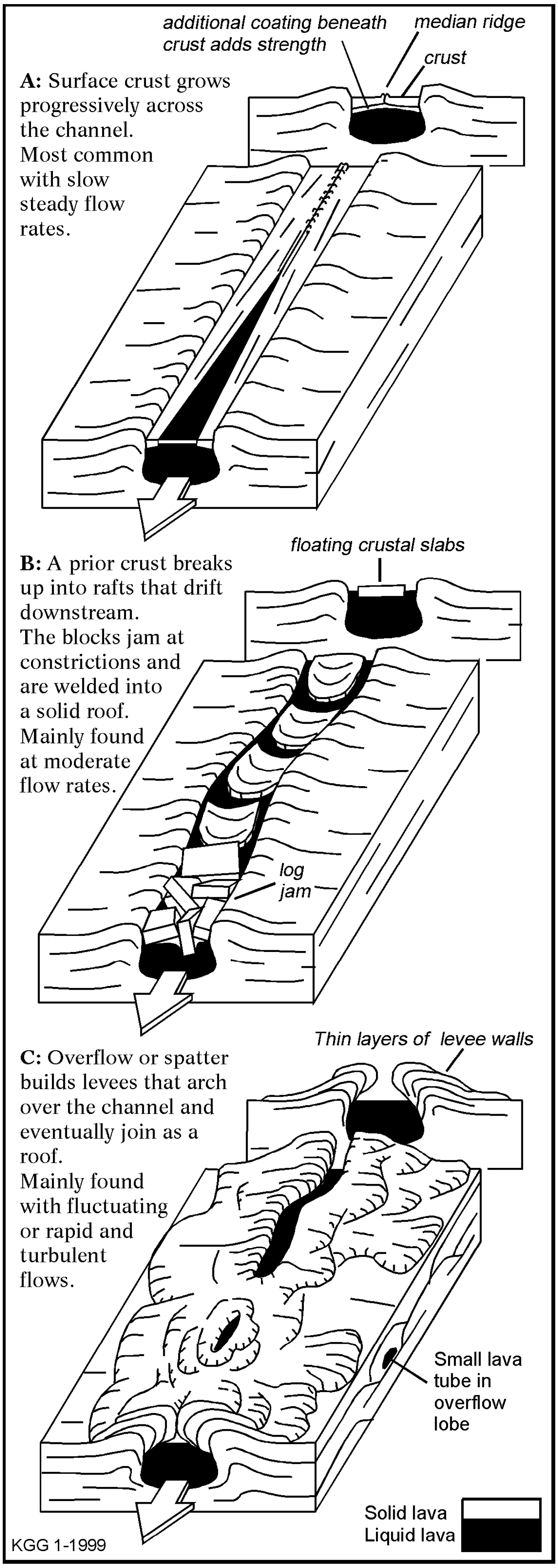


Figure 10: Three ways to make a lava tube by roofing a lava channel.

Lava tubes provide good insulation for the hot lava flowing within them. This allows the formation of very long flows such as the 50km Tyrendarra Flow from Mount Eccles, which extends offshore across the continental shelf (which was dry at the time), and the older 60km flow from Mount Rouse, which may also extend offshore (Figure 28).

When a lava flow follows a valley, as in the Tyrendarra flow from Mount Eccles, it disrupts the drainage. Twin *lateral streams* may run down each side of the original valley. *Swamps or lakes* will form where the flow enters the valley, and where tributary valleys have been dammed by the flow.

Formation of Volcanic Caves

Lava tubes form in basaltic lava flows by two main processes (Peterson & others, 1994): first by the roofing over of surface lava channels in several ways (Figure 10); and second by the draining of still

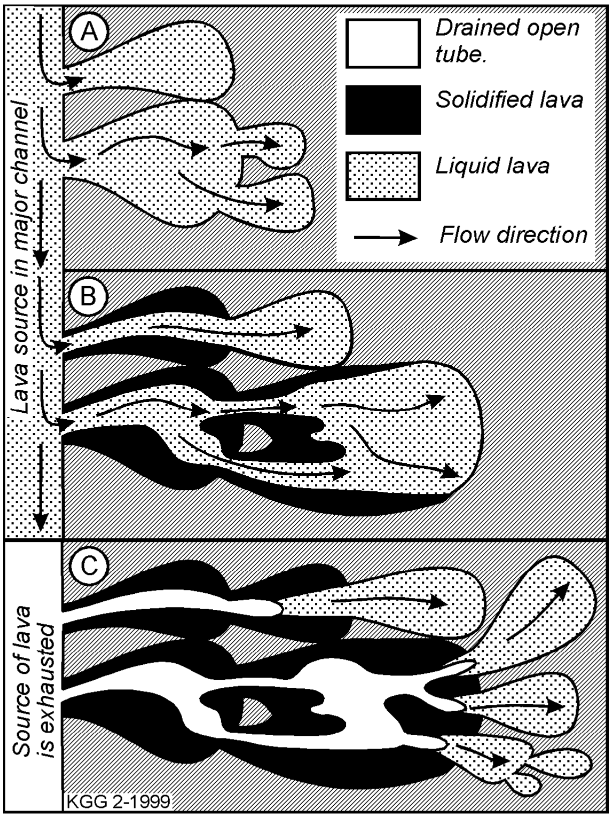


Figure 11: Stages in the formation of lava tubes by draining of lava lobes.
A: Thinly crusted lobes of lava expand by breakouts through ruptures and budding of further lobes.
B: Stagnant areas of the older lobes solidify, but flow from the source keeps the feeder conduits liquid.
C: When the source flow ceases some of the conduits may drain to form air-filled cavities.

molten material from beneath the solidified crust of a flow (Figure 11).

Tubes formed by draining of crusted lava lobes and flows are generally smaller than those formed by the roofing of a channel, but tend to have more complex forms. Lava lobes can be stacked vertically as well as advance forwards so that a complex three-dimensional pattern of branching tubes can form. The long lava flows in the region would all have been fed by large cylindrical lava tubes; but these need not have drained at the end of the eruption to form open caves.

Features found in Volcanic Caves

The lava caves contain a distinctive suite of lava structures or "decorations", some of which are illustrated in Figure 12.

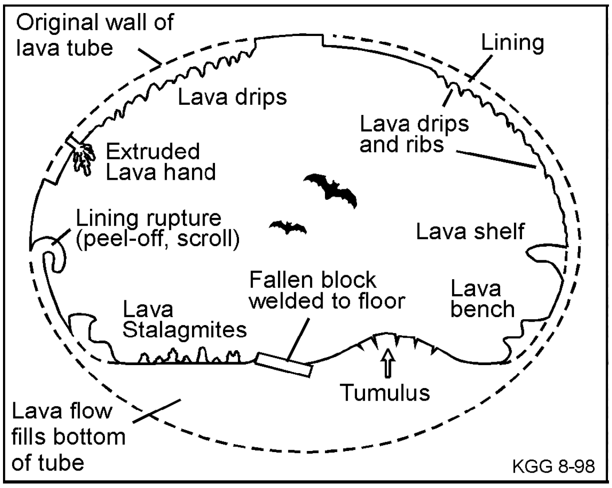


Figure 12: Formations found in lava tubes.

The level of lava within the tubes tends 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 solidified benches or shelves on the sides of the tubes. Some shelves can reach right across a passage to form a false floor.

The thin wall linings can rupture, peel back and curve over to form draperies and scrolls. Some linings are smooth, but others have a sharp hackly surface which may be due to the bursting of many small gas bubbles. Rafted slabs floating on a flow surface may leave grooves and striations on the semi-solid wall linings. Lava "hands" of semi-solid lava can be squeezed out through cracks or holes in the lining.

Small round-tipped lava stalactites, (lavacicles, lava drips) form where molten lava has dripped from the roof. Lava ribs form where lava dribbled down the walls of the cave, or where the whole lining has sagged and wrinkled. If the floor was already solid (unusual) drips of lava from the ceiling can build up lava stalagmites.

The floor of the tube is often flat or slightly arched; being the surface of the last flow of lava through it. If a lava flow within a tube forms a solid crust, and then drains away from beneath it, we get a tube-in-tube effect with a thin false-floor bridging the tunnel. Small lava mounds, or tumuli, may be heaved up by pressure from below. 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. Material falling from the roof may be rafted some distance downstream and may end up welded into the floor, or piled up in 'log jams'.

Management of Volcanic caves

The formations found in lava tubes are even less renewable than those in limestone caves. At least a broken calcite stalactite ***might*** regrow in a few thousand years, but a broken lava formation will ***never*** do so; unless someone builds one heck-of-a hot campfire in the cave!

The stony rise country of the recent lava flows is similar to karst in that surface water goes underground quickly and, if moving in lava tubes, it is unlikely to be filtered of any contaminants.

A major conflict in land use comes from the scenic and geologically interesting volcanic cones being also a source of scoria. Many have been or are still being quarried away. There are several active and abandoned quarries at both Mt Eccles and Mt Napier, and some interesting volcanic features have been destroyed while others are threatened (Guerin, 1992).

The push for tourism development in the region is putting increasing pressure on the lava caves, with the development of access steps and viewing platforms and consequent increases in visitation levels in the well-known caves. An attempt to provide a solar-powered visitor-sensing light in the self-guided Tunnel Cave at Mount Eccles was terminated by vandalism and then theft of the components.

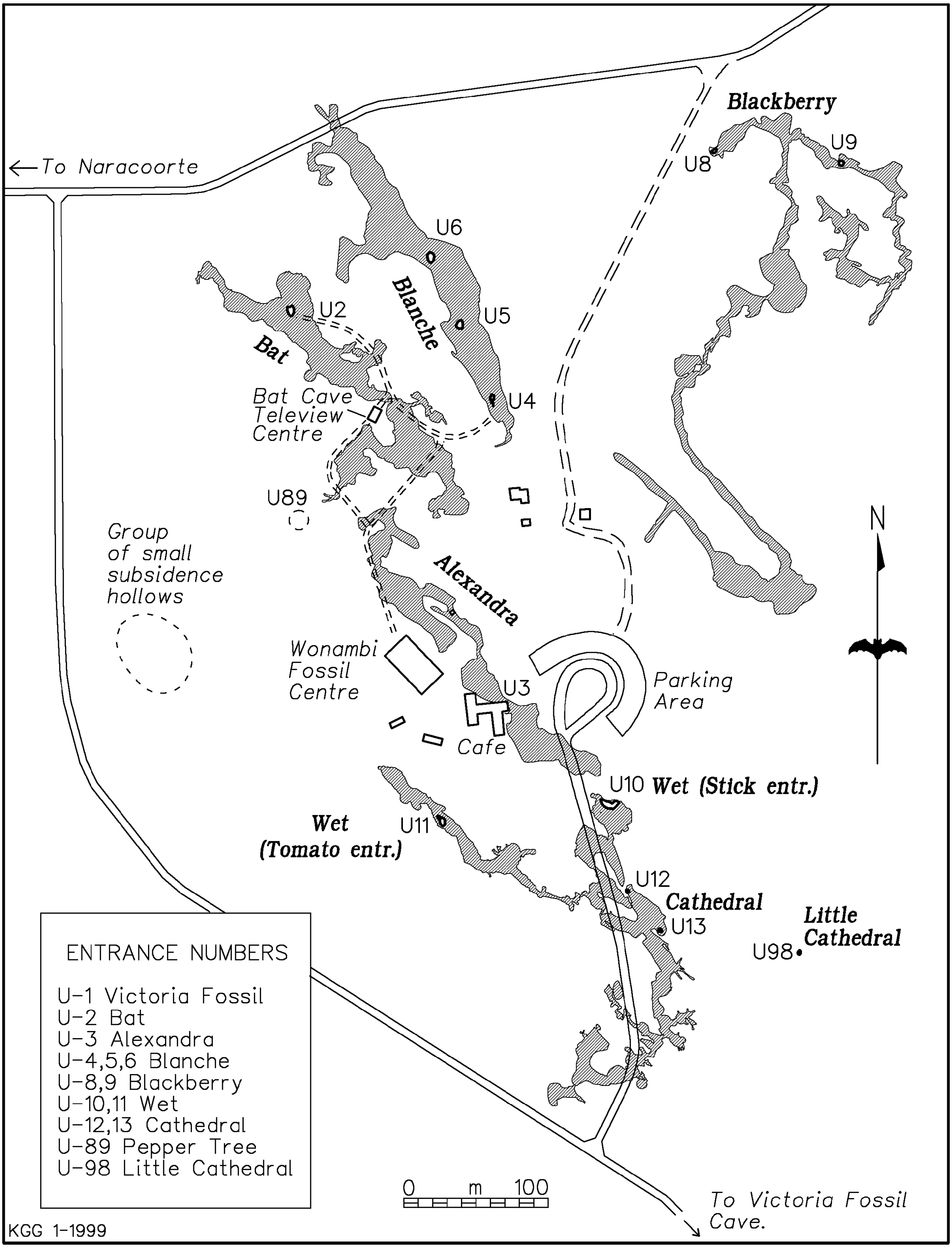


Figure 14: The main Naracoorte Caves area. See Figure 15 for Victoria Fossil Cave.

SITES IN SOUTH AUSTRALIA

NARACOORTE AREA (Site 1)

Naracoorte Caves Conservation Park overlies a series of caves in Tertiary limestone beneath a low ridge of the East Naracoorte Range (Figures 13, 14). Although the ridge has a dune topography, the dune sediments are very thin in the caves area.

Several ***surface features*** are of interest. The entrances U-9, U-12 and U-98 are solution pipes (U-98 is a pair of coalesced pipes) as is the entrance to Wombat Cave (U-58) further east. Peppertree hole (U-89) is a small undercut ledge and tunnel in the bottom of a broad shallow subsidence doline. Near the old entrance to the park is a cluster of small subsidence pits in sandy soil and calcrete. These are 1-3 m across and up to 2 m deep. They probably are subsiding into solution pipes above a possible cave. A walking trail from the camping area runs south along the western side of the road to Victoria Fossil Cave. This passes several outcrops with irregular solution tubes, and the entrance to Appledore cave (U-7) Beyond Victoria Fossil Cave the track continues south to Mosquito Creek which is an example of superimposed drainage - the creek entrenched its channel and maintained its course as the East Naracoorte Range was uplifted along the Kanawinka Fault. The cliffs beside the creek have a couple of small caves and some examples of solution pans, rain pits and horizontal solution ripples, but karren are not well developed here.

Victoria Fossil Cave (U-1)
This is an extensive, rambling, horizontal, network of collapse-dome chambers connected by low phreatic passages and flatteners (Figure 15). The tourist section is mostly collapse and the low connecting passages have been artificially enlarged. There are some extremely well decorated areas, especially in the chambers beyond the tourist section. The cave contains an important fossil bone site which is the main reason for the World Heritage status of the area.This is an extensive area of sediment beneath an old (now filled) pitfall entrance (Wells & others, 1984). The far ends of the cave are still being surveyed by CEGSA and the outline shown on Figure 15 is incomplete. Guided adventure cave trips are led into the non-tourist section.

Bat cave (U-2)
A roof window leads to a series of large high-domed chambers and collapse passages. This is the maternity site for *Miniopterus schreibersii* for South

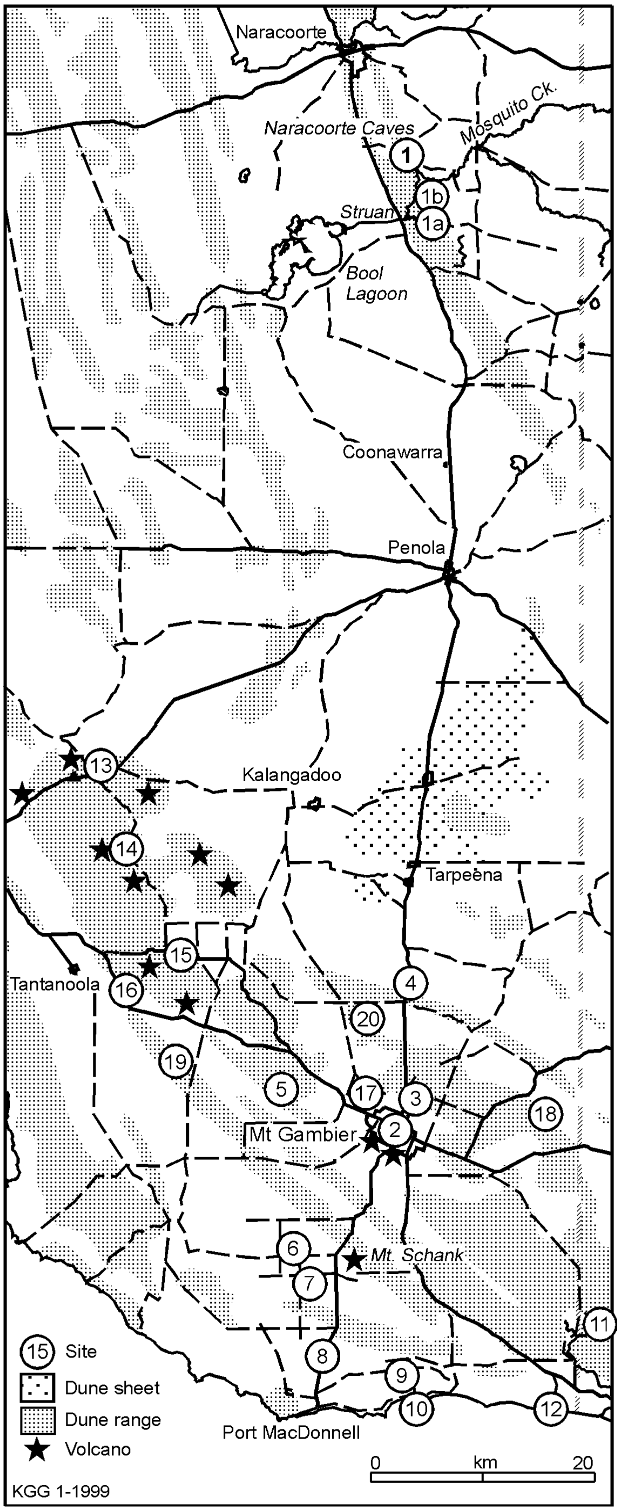


Figure 13: Conference tour sites in the Naracoorte - Mount Gambier area. See Figure 17 for location of sites 2a to 2e within the city of Mount Gambier.

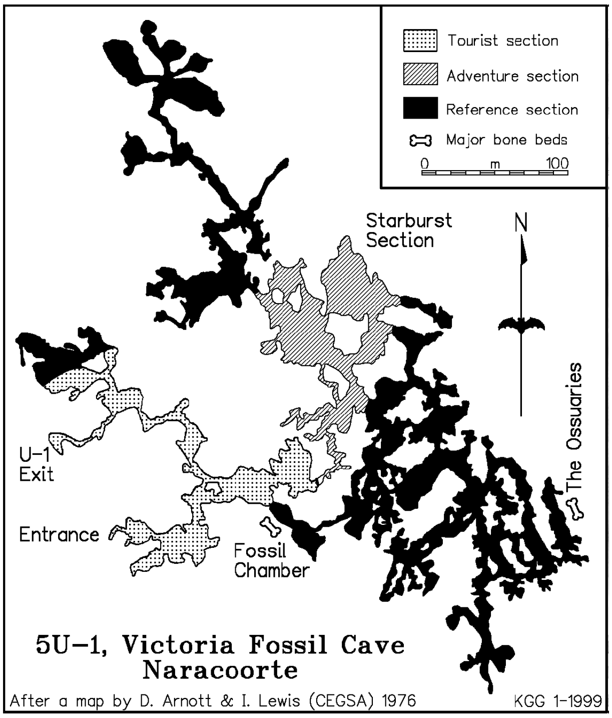


Figure 15: Victoria Fossil Cave in Tertiary limestone.

Australia and is also the type location for a number of invertebrates. Access is prohibited. In the past, extensive areas of the cave were mined for guano. Infra-red cameras have been installed in the cave, allowing visitors to the Bat Cave Teleview Centre to watch the bats interacting in the cave below.

Alexandra Cave (U-3)
This show cave is entered via a stairway within the building. It comprises several large well-decorated phreatic chambers connected by low sand-floored passages. The northern extensions were largely sand and silt-filled before they were excavated to extend the tour area. This is the type locality for the local cave weta (cricket).

Blanche Cave (U-4)
Blanche Cave is a tourist cave comprising a line of large collapse passages and chambers with several roof windows. It is a good example of collapse beneath a calcrete caprock. The formations had dried up and degraded, but since the overlying pine trees have been removed seepage has resumed and deposition recommenced.

Appledore Cave (U-7)
A small collapse entrance leads into a collapse dome and a line of rubble-filled passages and chambers. Adventure cave tours are run by Park staff.

Blackberry Cave (U-8)
This is an extensive well-decorated system of phreatic and collapse passages and domes. Entry is by prior permit only, and there is a locked gate at the start of the southern extension. Adventure cave tours are run by Park staff. A new map of the cave has recently been completed by CEGSA, but has not been incorporated in Figure 14.

Wet Cave (U-10)
Also known as Tomato-Stick Cave, the original name, Wet Cave, was reinstated when it was converted to a self-guided cave. In addition to the self-guided section, adventure cave tours are run into the western Stick Cave section (U-11) by Park staff. A large roof window leads to a group of interconnected chambers and passages showing both collapse and original phreatic character. In the final chamber of the self-guided tour there is a flat roof with well-developed avens and rock pendants. A study is currently being made of the small mammal bone deposits in this cave.

Cathedral Cave (U-12)
A solution tube (U-12) and roof window (U-13) lead to a large chamber, then alternating areas of high collapse domes and passages and smaller phreatic and collapse chambers, passages and flatteners. Sand cones occur beneath several soil-

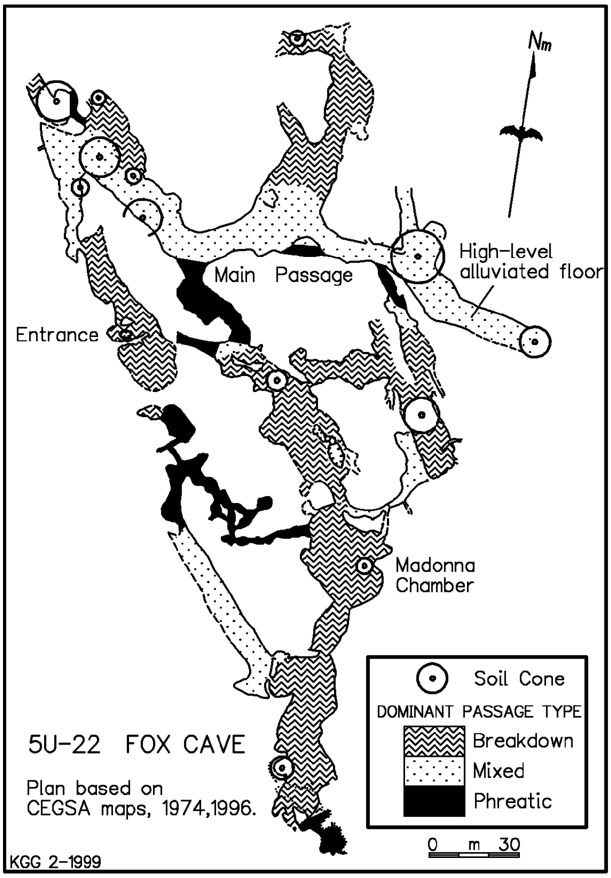


Figure 16: Fox Cave.

filled solution pipes. There are significant fossil bone deposits which are currently under study. Entry is by prior permit only.

Site 1a: Robertson Cave (U-17)
This cave is about 8 km south of the main Naracoorte Caves area. A pair of roof windows lead into a large collapse dome with some dry formations. Broken and tilted columns indicate floor subsidence in the past. Farther in a second large chamber was a bat roost prior to construction of an artificial entrance in the roof in the 1880s to allow removal of guano. This shaft was closed off in 1993 and the bats have since re-occupied the chamber.

Site 1b: Fox Cave (U-22)
Fox Cave is about four kilometres south of the Naracoorte Caves. A collapse entrance section leads via a gated tight squeeze to a series of large collapse-modified passages and chambers connected by smaller phreatic passages and low-roofed chambers (Figure 16). A feature of the cave is the large sand cones beneath soil-filled solution pipes. These had suffered from excessive foot-traffic but have now been restored, and marked trails added around them. Several chambers are well decorated and require careful movement. There is a growing problem from sand falling from cavers clothing onto the floors of the decorated areas. Adventure cave tours are run by Park staff.

Little Victoria Cave (U-44)
A small cave adjacent to Victoria Fossil, and genetically related to it. It comprises a set of collapse chambers and flatteners. Adventure cave tours are run by Park staff.

Wombat Cave (U-58)
A short solution tube leads to a line of large collapse-dominated passages. Adventure cave tours are run by Park staff; however, the cave is currently closed for the duration of an experiment in taphonomy (the processes of decay and distribution of bones within a cave).

Little Cathedral Cave (U-98)
This is little more than a pair of vertical coalescing solution pipes 7 m deep in a small subsidence pit. A small passage exists at the base.

MANAGEMENT OF THE NARACOORTE CAVES

Apart from demands by economic rationalism to regard the provision of guided tours as a profit making enterprise, the significant management concerns are the diverse scientific values and diverse scientific researchers. Providing for research and recreation access while striving to protect all values is a challenge. Key areas of most caves to which access is permitted have been track marked and reference areas are treated as exclusion zones. A research protocol to provide clear guidelines for researchers has been developed in consultation with the principle research group. Ongoing staff training also presents a challenge. As with many seasonal attractions, Naracoorte Caves has a moderate to high turnover of casual guides. As well as a good grasp of the karst and speleo aspects, guides need to be "experts" on bats and bones, the knowledge of which is ever changing.

MOUNT GAMBIER AREA

Mount Gambier City, Site 2

Elery Hamilton Smith (1993) has reviewed the somewhat chequered history of some of these caves, and the landscaping of their entrances. Figure 17 locates the sites of interest within the city.

Site 2a: Engelbrecht Cave (L-19)

This is in a park (signposted) on the southern side of the West Jubilee Highway within Mount Gambier city. This is a large linear system of phreatic and collapse passages with some large collapse domes (Figure 18). Most of it is submerged and only

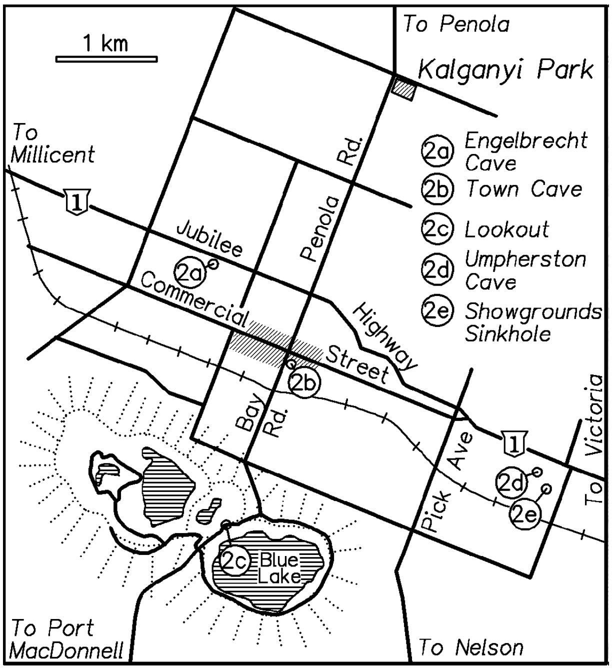


Figure 17: Sites within the city of Mount Gambier.

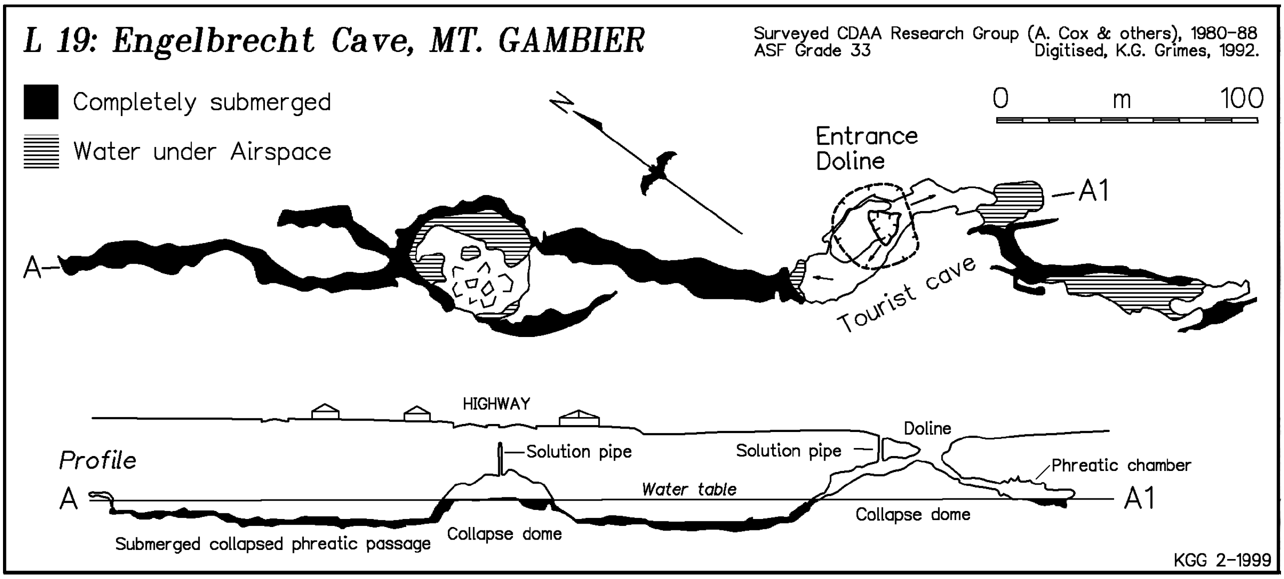


Figure 18: Engelbrecht Cave runs beneath the city of Mount Gambier.

accessible to cave divers. The collapse doline was once used as a rubbish dump. It was cleaned out by the Lions Club in 1979 and Lifeline now runs guided tours of the initial air-filled section of the cave. The display area shows videos of divers in the submerged sections. There is a large solution pipe in the roof of the western chamber. The eastern section has good examples of phreatic sculpture and roof avens in the lake chamber. The north-western submerged section leads to a large collapse chamber directly beneath the Princes Highway – drive gently!

Site 2b: Doline of Town Cave (L-4)

This small but impressive collapse doline is in a small park beside Bay Road in the centre of the city of Mount Gambier. The surface has been made into a formal garden (Hamilton-Smith, 1993). The 18 m deep doline bells out at the base into a chamber with a small lake. Note the sections of solution pipes exposed in the walls at the lowest view-point. This is the type section for the Gambier Limestone.

The cave was the original water supply for the settlers in the area. Stormwater was first directed to the cave in about 1906 and water quality has deteriorated since. In 1916 a major drainage scheme for town stormwater was constructed with the cave being the main recipient. Several clean up projects have been done in the cave. In 1914 they removed 503 cubic yards of silt. The most recent was in 1973. The water in the cave is still heavily contaminated as no screening of stormwater is currently in place.

Site 2c: Blue Lake

Take Bay Road south from the centre of town. The Mount Gambier volcano is a set of maars produced by steam-driven explosions when rising magma intersected ground water in the limestone about 28,000 years ago (Sheard, 1978, Leaney & others, 1995). The walls of Blue Lake show a sequence of grey volcanic ash over darker basaltic lava flows over white limestone. There are several small caves near the waterline and also at the basalt-limestone contact. At the main lookout one can see outcrop of dipping volcanic ash that contains numerous fragments of limestone blasted up from below.

The lake is at the level of the regional water table. Allison & Harvey (1983) discuss the blue colour which appears suddenly each November, when the lake becomes thermally stratified, and disappears in April-May when mixing occurs. The colour is thought to be due to finely-divided calcite crystals which grow when the surface water above the isocline warms up and looses CO_2. The reason for the rapidity of the colour change probably lies in some sort of seeding process as the crystals form.

Site 2d: Umpherston 'Cave' (L-6)

This large collapse doline (Figure 6) is in a park on the south side of the highway at the eastern outskirts of Mount Gambier. A set of stairs, first constructed in 1886, gives access to the floor which has been landscape gardened (Hamilton-Smith, 1993). Apparently, the floor was a lake 90 years ago (the display area has photographs of row-boats), but the ground-water levels have dropped since.

There is a small water-filled cave beneath the eastern wall, and good exposures of Tertiary limestone in the walls. Beware the large diurnal possums which prey on passing tourists! This doline has been classed as a geological monument of National significance.

Site 2e: Showgrounds Sinkhole (L-28)

This collapse doline in the timber yard adjacent to Umpherston Cave has a long history of pollution. None-the-less it has been classed, along with Umpherston Cave, as a geological monument. The sinkhole was originally used to water stock, with a ramp cut down to the water in the southern side. The state mill was established on the site in 1955. Stormwater from the mill site and blowdown water from boilers was directed to the sinkhole via drains. Several spills have occured on the site including a major one in 1983. Investigations have shown the base of the sinkhole and groundwater are contaminated with CCA and phenolic compounds. A site clean up and rehabilitation project are now underway.

Site 3: Hummocky Terrain North of Mount Gambier

The Kalganyi Caravan Park and adjoining ACKMA Conference Venue lie within one of the areas that we call *hummocky terrain*. These areas occur in several places in the Gambier Region and consist of an irregular to elongated pattern of rounded hills separated by broad basin-shaped hollows. The hills are built partly of calcareous dune limestone but the lower parts are in Tertiary limestone. The larger hummocks, close to Mount Gambier, have a vertical relief ranging from 10 to 25 m and a 'wavelength' of between 300 and 700 m. The hollows are nearly always dry – suggesting a well-developed underground drainage. This terrain may be a dune topography modified by karst processes, as the bottoms of the hollows extend below the contact between the old calcareous dunes and the underlying limestones. To the north-west of Mount Gambier the hummocks are gradational to both a high dune topography and also to true karst dolines and uvalas in Tertiary limestone.

Site 4: Dismal Swamp

North of the Mt. Gambier airport the main road drops down from a dune ridge onto the flat swampy Bool Region – an area known as the Dismal Swamp. Here is a densely-spaced set of small to moderately-large flat-floored and saucer to basin-shaped hollows and a couple of lunette lakes (Figure 19). This area has examples of all the main types of shallow depression discussed in part 1 (Figure 7).

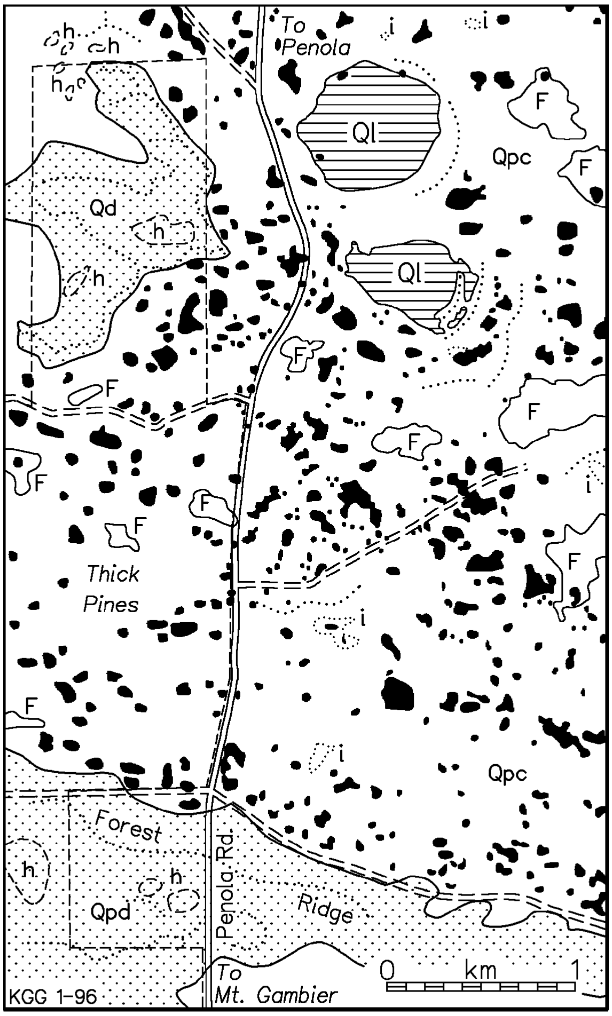


Figure 19: Part of Dismal Swamp, showing the variety of shallow hollows. See Fig. 24 for symbols.

South of Mount Gambier

Site 5: Stone Pit of Steetley Quarry

This quarry produces Gambier Stone for buildings. The stone was previously cut out of the soft limestone with wire saws, but circular saws are now used. The site also has good examples of solution pipes and other epikarstic features.

Site 6: Little Blue Lake (L-9)

A popular swimming hole, this cenote is a water-filled collapse doline about 45m across with cliffs 6m high above a water depth of 40m (Figure 6). It has been classed as a geological monument of national significance. Diving is by permit only.

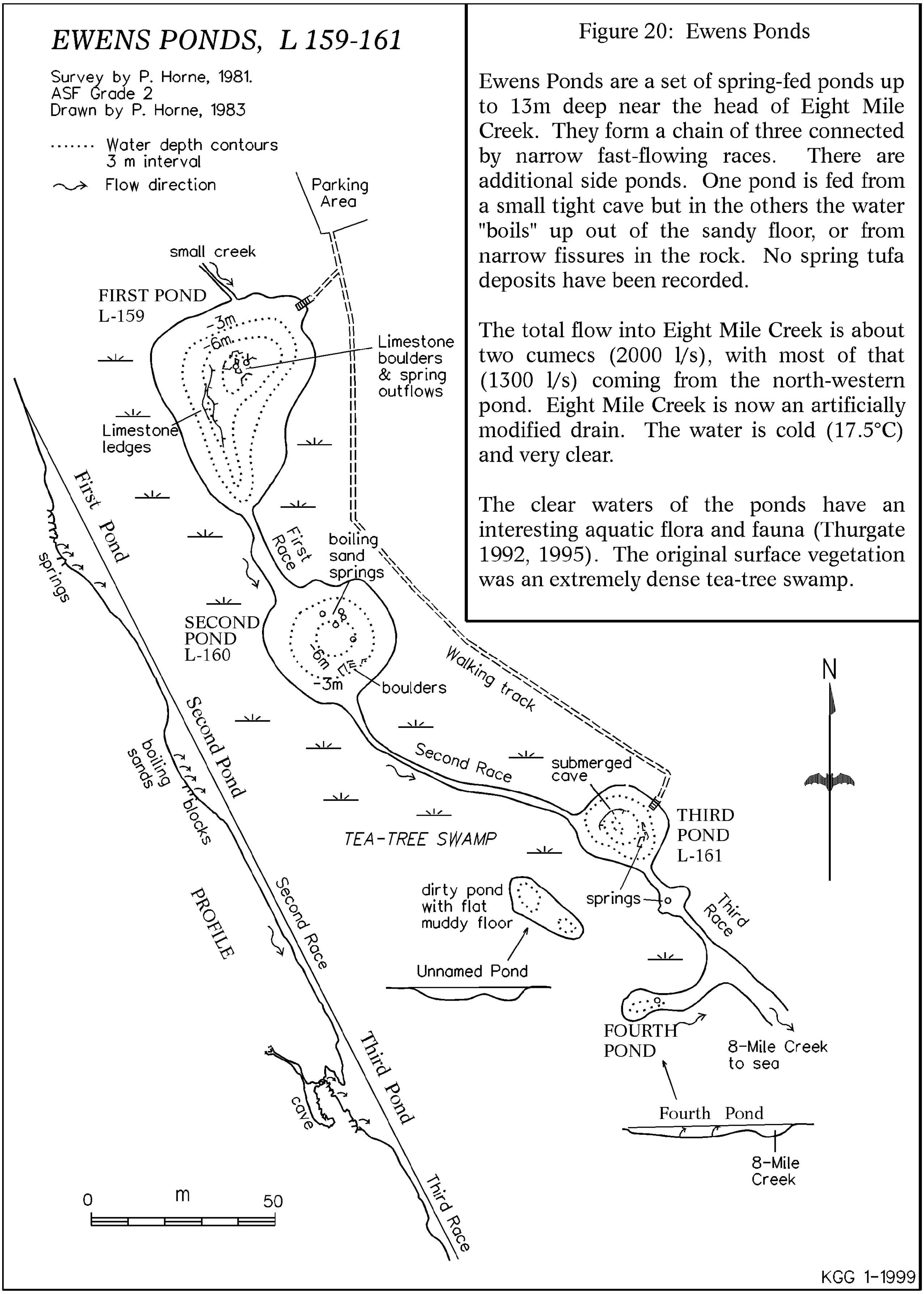


Figure 20: Ewens Ponds

Ewens Ponds are a set of spring-fed ponds up to 13m deep near the head of Eight Mile Creek. They form a chain of three connected by narrow fast-flowing races. There are additional side ponds. One pond is fed from a small tight cave but in the others the water "boils" up out of the sandy floor, or from narrow fissures in the rock. No spring tufa deposits have been recorded.

The total flow into Eight Mile Creek is about two cumecs (2000 l/s), with most of that (1300 l/s) coming from the north-western pond. Eight Mile Creek is now an artificially modified drain. The water is cold (17.5°C) and very clear.

The clear waters of the ponds have an interesting aquatic flora and fauna (Thurgate 1992, 1995). The original surface vegetation was an extremely dense tea-tree swamp.

Site 7: Goulden Hole (L-8)

Goulden Hole is not the largest of the cenotes in the region, but it shows a good range of the features typically found in them (Figure 6). It is a deep sheer-walled collapse doline containing a lake and widens out into an underwater cave that is a single large collapse chamber with a central silt-covered rubble cone (Horne, 1988). The water is 26 m deep and the cliffs rise 12 m above the lake surface. Access to the lake is by an artificial cut ramp, with a shed and water pump. The walls above the lake contain many horizontal solution tubes typically 0.5 - 1.0 m in diameter. It is worth noting that none are exposed in the cut walls of the ramp, implying that they only form in proximity to the original cliffs. The ramp walls also provide a convenient exposure of the Tertiary Gambier Limestone: a friable bryozoan limestone with bands of chert nodules. A long, dry, horizontal, cylindrical cave passage extends back beneath the ramp.

This is one of several cenotes in the region that contain live stromatolites: calcareous formations built up on the submerged walls by algae (Thurgate, 1996a,b). Active stromatolites occur in depths down to 15 m, but are most abundant in the top 10 m. Old stromatolites can also be seen as overlapping plates on the walls up to 2 m above the present water level – indicating higher water tables in the past.

The hole is an important training site for cave divers, and the wooden deck is for their access.

Site 8: Allendale Sinkhole (L-11)

The Allendale Sinkhole first appeared in the roadway at the southern end of the town of Allendale East in the mid nineteenth century. It was filled in with rubble but reopened and was refilled several times. In 1971 the road was finally diverted around the hole which remains in the central island - fenced in but triumphantly defiant! The feature is a small water-filled collapse doline (cenote) that leads to a submerged cave 28 m deep that is a simple collapse dome continuing from the doline.

Site 9: Ewens Ponds (L-159, 160, 161)

Ewens Ponds are a set of spring-fed ponds up to 13 m deep near the head of Eight Mile Creek south of Nelson Road (see Figure 20 for details).

The ponds are popular for snorkelling and SCUBA diving, but there will not be time for this during the conference visit. Persons wishing to do so at other times should collect and read the *Guidelines for Use of Ewens Ponds* available from the National Parks and Wildlife office at Mt Gambier. Note the need for a wet suit - the water is very cold and there are limited exit points if you get into trouble. Parties greater than six need to book ahead. Cave diving is prohibited. The entrance to the cave in Pond 3 has been deliberately blocked for safety reasons. This is a geological monument classified at national significance.

Site 10: Mouth of Eight Mile Creek

The flow of 2,300 l/s through the mouth of Eight Mile Creek at the coast demonstrates the large volume of water that is rising from the karst springs in this area. Most of this (2,000 l/s) comes from Ewens Ponds.

East of Mount Gambier

Site 11: Princess Margaret Rose Cave (3G-6)

This show cave is a single joint-controlled fissure passage with extensive good decoration (Figure 21). A continuation of the cave (3G-3) opens into the river cliffs to the southeast, but there is no passable connection. Other caves occur in the area. Tracks lead down to the river, and to cliff-top view points. There is a pleasant bush camping area with cabins. The operation of the tourist cave has recently been privatised, but management of the Park remains with the government.

The Glenelg River is a permanent river with its headwaters outside the limestone province. It has been incised into the limestone plain to form river cliffs up to 35 m high. The caves are joint-controlled systems found mainly in the Tertiary lime-

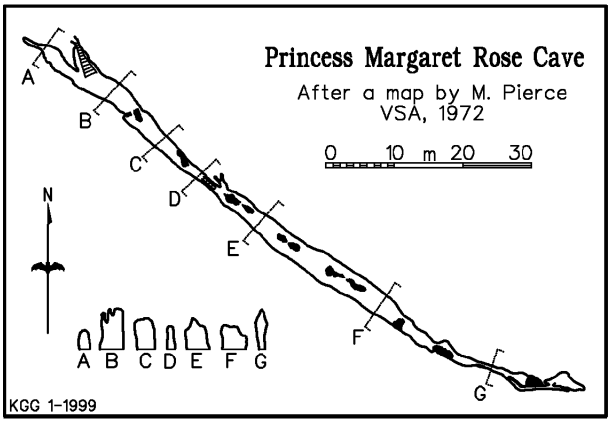


Figure 21: Princess Margaret Rose Cave.

stone; the overlying aeolianites only contain solution pipes or dolines which allow access to the underlying caves. From the river one can see cave entrances at several levels in the limestone cliffs. Some of those at river level have outflowing streams.

Site 12: Piccaninnie Ponds (L-72)

The turnoff is just west of a cutting in Punt Road, 2.5 km west of the border. Piccaninnie Ponds is one of the major springs on the coastal plain. A group of ponds occurs in an extensive area of shallow reed swamps and tea-tree thickets. The first pond is only 10 m deep, but leads to The Chasm, a flooded fissure reputedly 90 m deep. An underwater phreatic chamber known as The Cathedral connects into the side of The Chasm. A track leads to the outflow point on the beach, where one can view the total flow from the system of about 1000 l/s. A number of other smaller ponds occur in the swamp to the east and there are two springs on the beach between here and the Victorian border. The ponds contain a very interesting aquatic flora and fauna (Thurgate, 1992, 1995), and are a major attraction to skindivers. Diving is by permit only – several divers have drowned in this cave.

West of Mount Gambier

Site 13: Gran Gran Cave (L-15)

This cave is in Tertiary limestone and is a set of joint-controlled phreatic passages and collapse chambers (Figure 22). The passage going east from the main chamber has sculptured roof pendants and a pronounced zone of phreatic spongework in the lowest 1m of the wall. Extensive pools occur, but the water levels fluctuate over time. As well as being a representative example of a Tertiary limestone cave, the site has special significance in the presence of both aboriginal markings and evidence of their mining of the chert nodules that occur within the limestone – as shown by the marks of sharp sticks which they used to remove the surrounding soft matrix. The cave entrances have been gated but the matter of access has not yet been finalised.

Site 14: Mount Burr Cave (L-69)

This is an extensive, horizontal, irregular, phreatic maze system developed in dune limestone at the level of an adjoining swamp (Figure 23). Parts have been considerably modified by collapse. The entrance chamber has excellent examples of phreatic spongework sculpture and contains a lake. The levels of the lake have varied in response to the vegetation on the surface, which is an exotic pine plantation. At the peak of the plantation growth the lake practically dried out. Following bushfires in 1983 the level rose about a metre to cover most of the floor of the chamber, but has fallen again in recent years as new pine forest has grown.

Site 15: The Wombat Holes (Glencoe Area)

The Wombat Holes, 5 km west of Glencoe, are in sandy soil at the edge of the high dunes (Figure 24). They consist of numerous deep basin-shaped subsidence dolines, a few small but deep uvalas, and one long swampy hollow which has been used as a

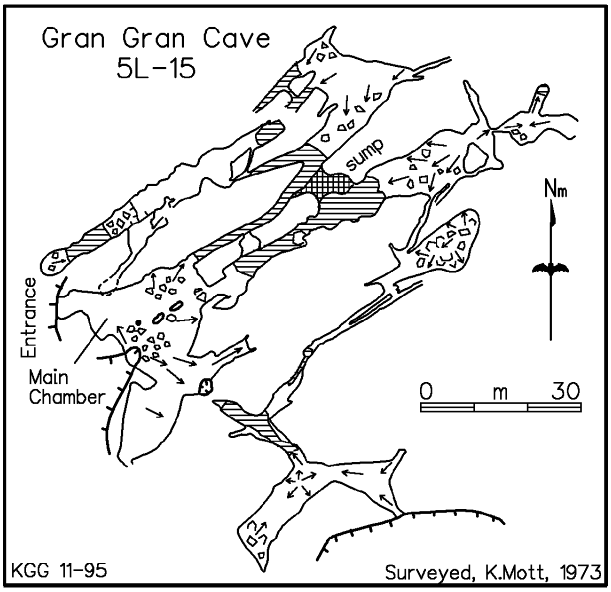


Figure 22: Gran Gran Cave is in Tertiary limestone.

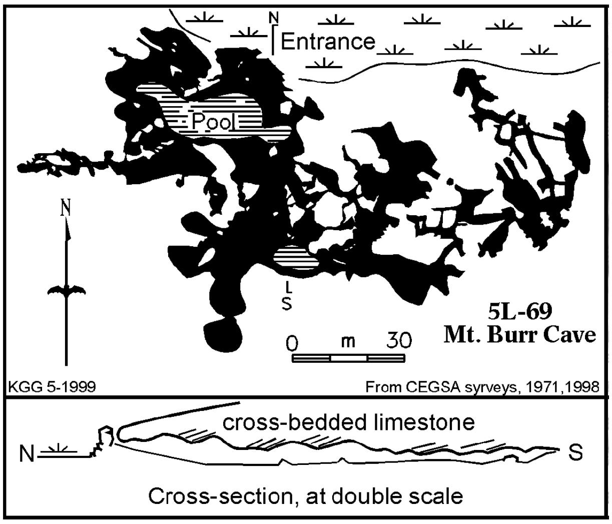


Figure 23: Mount Burr Cave is syngenetic karst in dune limestone. Pool size is that seen in 1991.

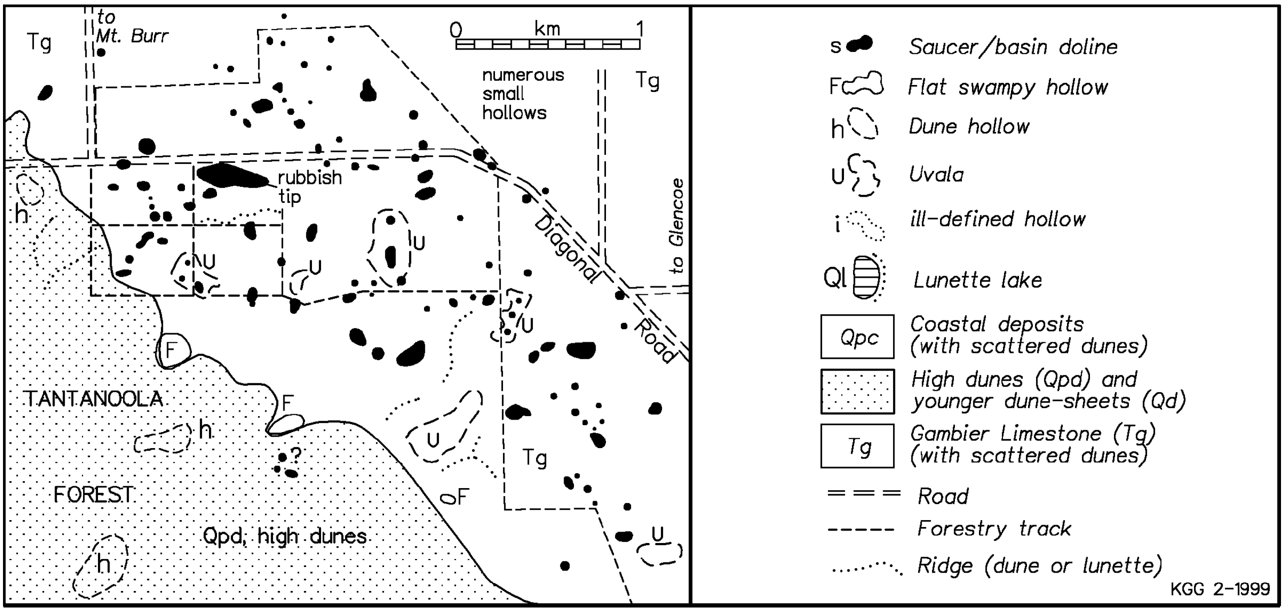


Figure 24: Wombat Holes area.

rubbish dump by the council for many years. In 1983 alternative sites were looked at but the karstic nature of these made them less suitable than the current site. The current site is in a perched swamp with about 9m of sandy clay underlying it. A waste transfer station was opened on the site in 1994.

Site 16: Tantanoola Tourist Cave (L-12) and Up-and-Down Rocks

Tantanoola Cave is a show cave beside the Princes Highway that is managed by National Parks and Wildlife, South Australia. It has a complex genesis (ASF, 1983). The cave occurs in partly dolomitised Tertiary limestone behind the Up-and-down Rocks, which are an old sea cliff. This coast existed about 300 000 years ago, and the sea broke into an earlier phreatic chamber which was then modified by wave action and partly filled with marine sediments with well rounded pebbles and some bone material, including seal bones (figure 25). These deposits were later cemented to varying degrees and then partly eroded. The final stage was one of extensive speleothem development.

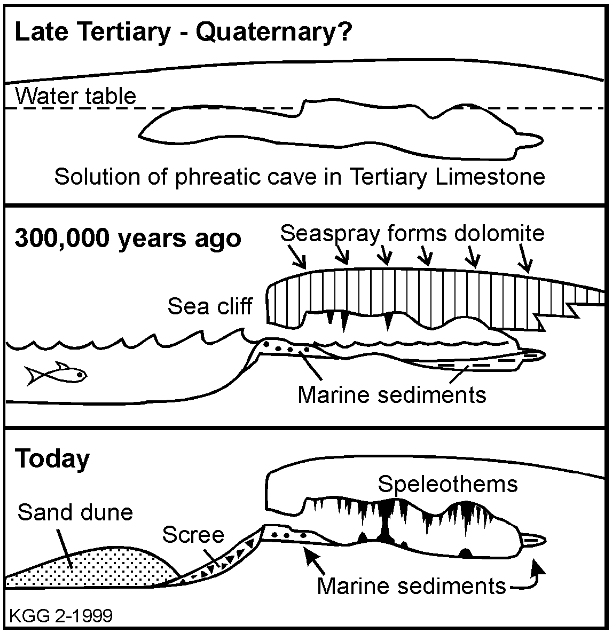


Figure 25: Stages in the development of Tantanoola cave (not to scale).

The cliff face shows well-developed solutional pitting and many small irregular tubes. Some of this could be a type of surface karren, and some might be exposures of older phreatic solutional tubes and cavities. On the ridge above the cliffs there are small, linear pavements of limestone flush with the soil which contain occasional solution pans and tubes. Apart from some grikes immediately beside the cliff there is little karren development.

Pre and Post Conference Cave Trips.

Site 17: Collins Cave (L-31)

A large degraded entrance doline connects via a locked gate and squeeze to a a pair of large rubble-choked passages in one direction and an extensive (and unmapped) maze system in the other. In the lower levels the floor has thick accumulations of calcite flakes from old ponds.

Site 18: Snake Hill Caves (L-119, 262, 263)

The main Snake Hill Cave (L-119) is formed in a dune limestone ridge and the adjoining plain. It is an extensive horizontal maze of phreatic chambers, passages and flatteners with numerous entrances and daylight holes through the calcreted caprock roof. The small scale map (Figure 26) is misleading for navigation, as much of the apparently large chambers comprises low flatteners at ankle level and these areas are not obvious as one travels through the cave. The cave has suffered badly from physical damage, marking and rubbish. The other caves in this area (L-262, L-263)are mainly smaller collapse dome chambers, but have suffered less damage.

Site 19: Morgans Cave (L-34)

Morgans Cave is a good example of a complex joint-controlled fissure system in the Tertiary limestone, albeit rather spoilt by abundant graffiti. Adventure caving tours can be arranged via the Tantanoola Tourist Cave. The entrance is a nice example of a solution pipe that leads to the main fissure. To the southeast is a single fissure choked with tree roots from the pine plantation above and a final pool. To the northwest the fissure leads to an area of mazy crawls along two intersecting joint sets. Note that the broad areas on the map (Figure 27) are not chambers, but areas of low flatteners alternating with higher fissures.

Site 20: Airport Cave (alias Sheathers Cave, L-144)

Essentially a pair of parallel, flooded, flat-roofed, joint-controlled passages; the main interest in this cave is its history of drying up of the lake in relationship to the growth of the pine forest above. When first discovered in 1963 only the small entrance chamber was air-filled and the initial exploration, which started in 1982, was by cave divers (Horn, 1988). Between 1982 and 1986 the water dropped a metre as the pine trees grow above the cave – eventually allowing exploration without scuba gear.

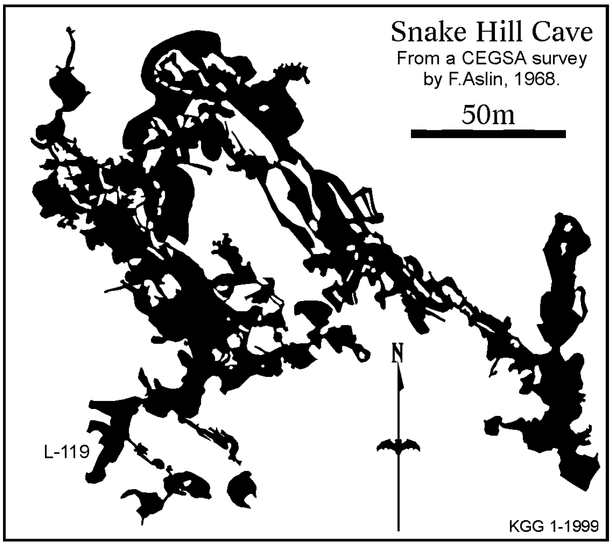
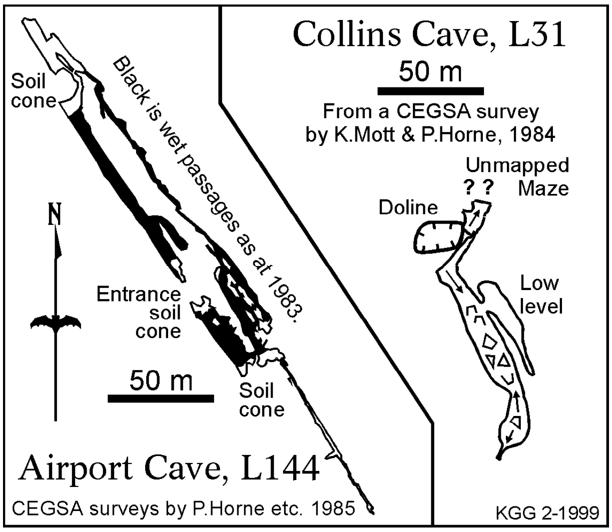


Figure 26: Snake Hill Cave is a syngenetic karst maze developed in Quaternary dune limestone.



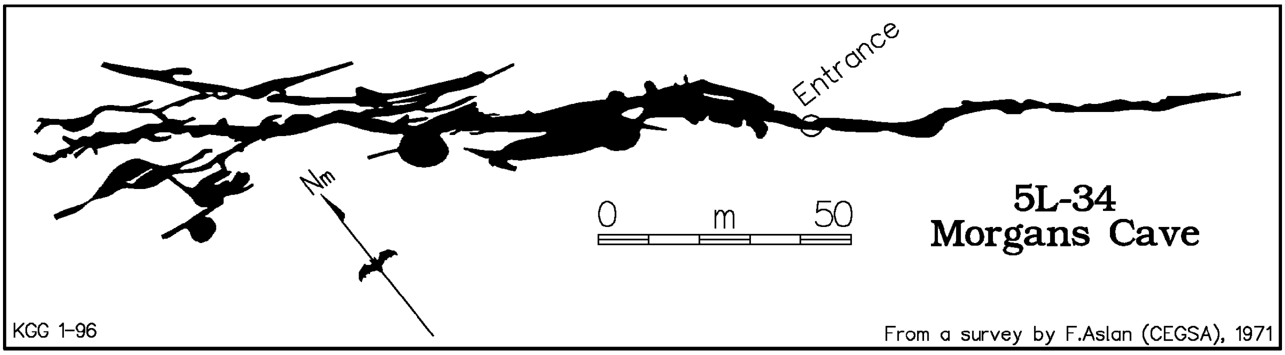


Figure 27: Morgans Cave shows strong joint control in the Tertiary limestone.

VICTORIAN SITES

Post-conference Study Tour

INTRODUCTION

This tour runs over three days, and covers the coastal soft-rock karst of western Victoria along with associated volcanics and volcanic caves.

West Victorian karst areas

In Victoria the Tertiary limestones are variable in their purity, and only limited parts of the outcrop region show significant karst development. The main areas of Tertiary caves and karst are the Glenelg River area (including Kentbruck and Drik Drik) in the west, and Warrnambool and Timboon in the east (Figures 1 & 28). Quaternary dune limestones host syngenetic karst and caves such as those at Bats Ridge and Codrington. In addition, there is the coastal scenery that is a world-famous feature of the coast east from Warrnambool. The following text is taken in part from an earlier field guide (Grimes & White, 1996) which in turn drew on the more detailed descriptions in White (1984,1989, 1995a,b)

DAY 1: Coastal and Syngenetic Karst of the Portland area.

Site 21: Bridgewater Lakes and Caves.

The best view is from the road at the top of the hill north of the lakes. The lakes resulted from drainage disruption by the coastal dune barriers. The caves are relict sea caves in an old sea cliff that may also be fault-controlled. In the Bridgewater area much of this former coastline has been obscured by younger mobile dunes.

Site 22: Cape Bridgewater and Cape Duquesne.

Cape Bridgewater has a number of sea caves in the Pliocene tuffs and basalts. The volcanics are overlain by the Pleistocene calcarenites so both the sea cliffs and the caves show tufa and other secondary calcite deposits derived from calcite saturated springs. An area on Cape Duquesne has been called a ***"Petrified Forest"*** from the tree-like features. These features are actually solution pipes which are quite common in the calcarenites of the Bridgewater

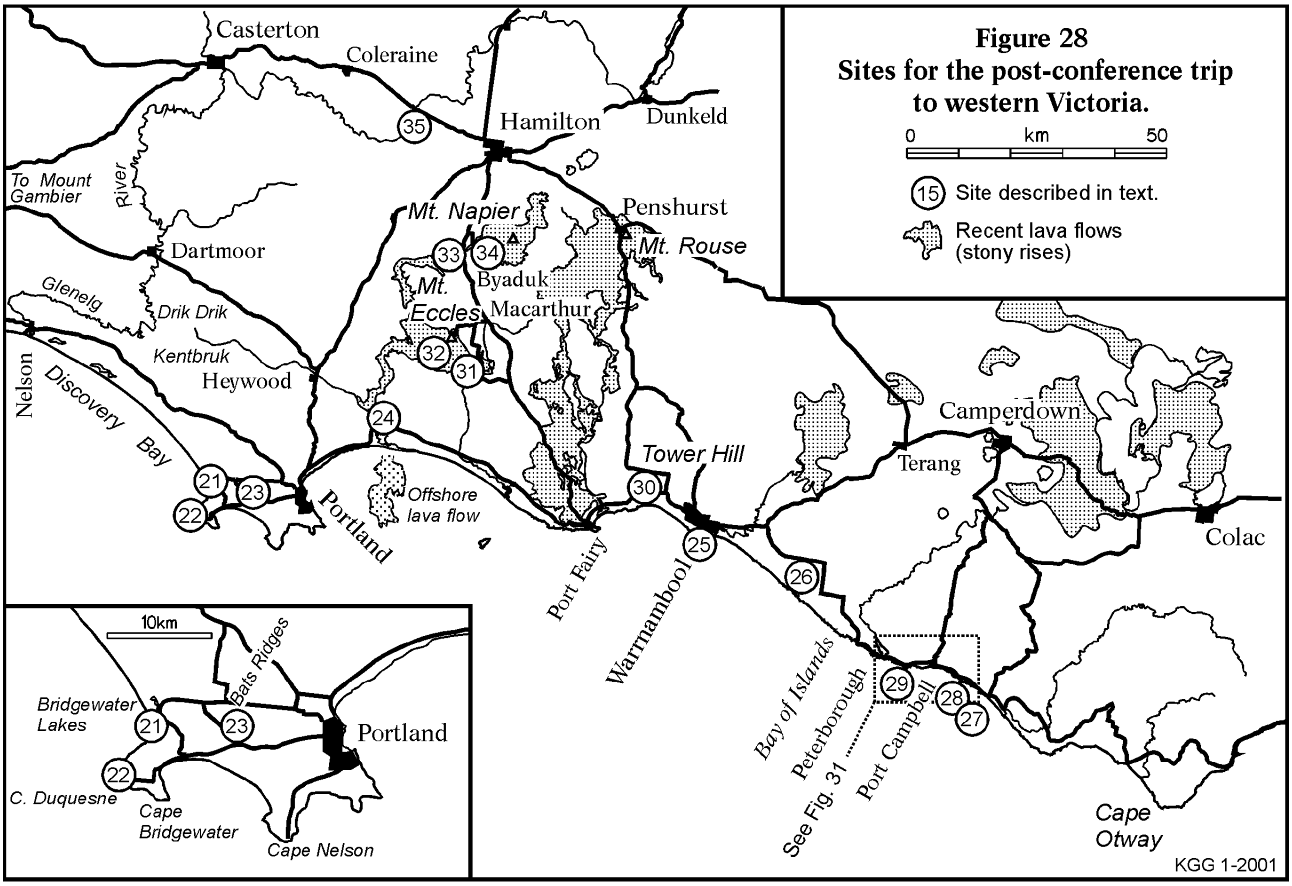


Figure 28
Sites for the post-conference trip to western Victoria.

Formation. However, the concept of the "buried forest" still lingers on. The pipes at Cape Duquesne have formed syngenetically by solution of the dune limestone. They were infilled with calcareous sand or soil which was then cemented and later exposed by further erosion. The smaller hard root-like bodies are rhizomorphs, formed by calcite cementation adjacent to plant roots that have grown down through the dune sand. The "Petrified Forest" features are subject to occasional and indiscriminate vandalism and specimen collection – how do we protect these features?

In several places you will see bare, eroded surfaces, where attempts have been made at stabilisation and re-vegetation. Surface erosion increased dramatically after the introduction of rabbits in the 19th century but present day management practices appear to have reduced it. Erosion is exacerbated by the extreme weather conditions experienced in this area

Spring tufas form extensive terraces and ponds at 'The Springs', two km north from the parking area at Cape Duquesne. Along the track you will pass areas with dune cross-bedding, calcrete bands, rhizomorphs, and solution pipes. At an unnamed lookout 1,800 m from the car park (230 m SE of the Springs Lookout), look down to see polygonal jointed basalt with some large (5-10 m) circular structures that Boutakoff (1963, p35) thought were large gas bubble vents; can you think of a better explanation?

Climb down the cliffs at a post 150 m beyond the 'Springs Lookout' and head back to the south. **Warning:** do this only when the sea is calm, several people have been washed off the platforms at the base of these cliffs by unexpected waves. Half way down you pass a palaeosoil in the cross-bedded dune limestones which includes solution pipes with a reddish soil fill. At the base of the cliffs, which is the contact between the limestone and the basalt, springs emerge and the water has built up large platforms of tufa with pools and overhung edges. Walk south around a headland to see a set of small streams cascading down a large tufa mound. This stream is fed from a small cave. In places the tufa has grown over and enclosed the channels.

Site 23 Bats Ridges

This area is best visited with a guide as many of the features are hard to find in the thick scrub. Access is via Telegraph road, then down an overgrown track to the hut. The ruins of an old lime kiln can be found hidden in the undergrowth in one place.

The Bats Ridges area is a particularly intensive example of syngenetic karst caves developed in Pleistocene dune calcarenites (White 1989, 1994, 1995b, 2000a). The dune limestone here has been

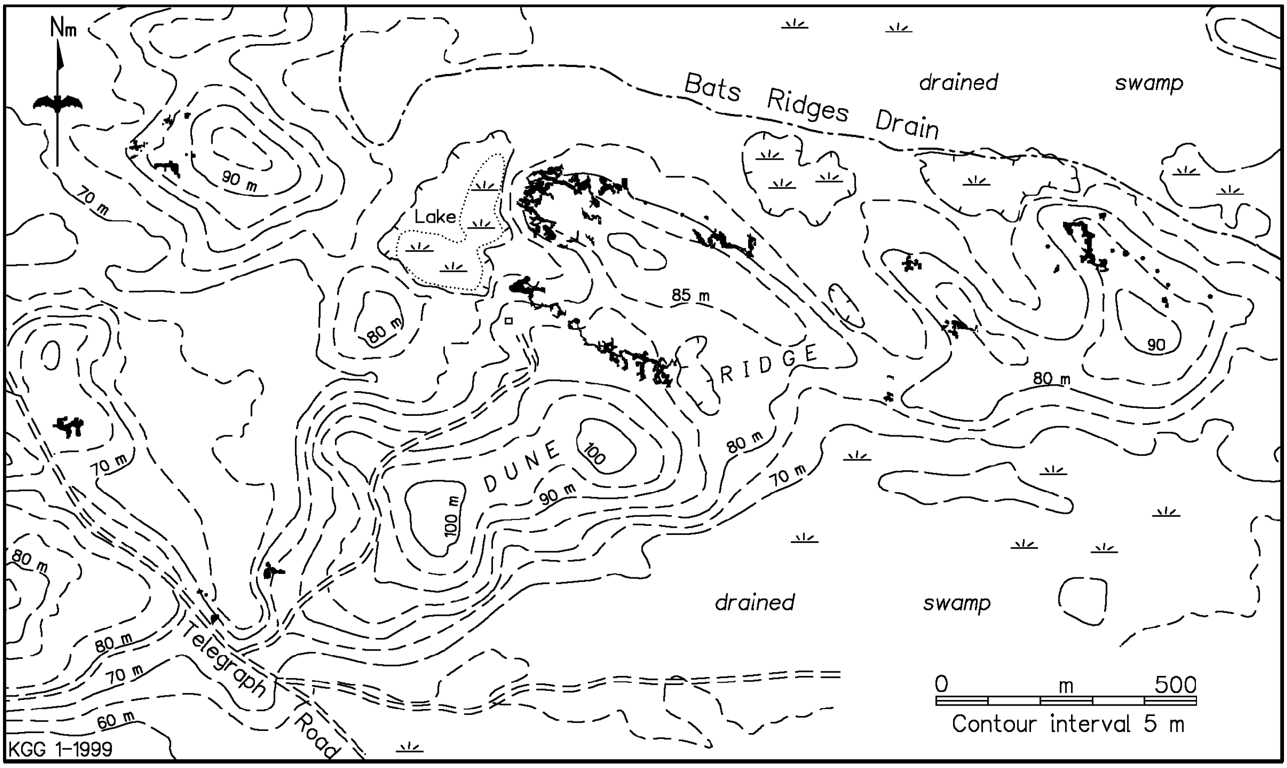


Figure 29: Bats Ridges karst area. Syngenetic caves in calcareous dunes.

dated by TL at 290,000 ±34,000 years old (White, 2000b).

There are peat swamps on both northern and southern sides of the main dune ridge. The swamps to the north are more complex and connect with swamps in the swales between the spurs (Figure 29). The ridge has the appearance of a longitudinal strandline dune which has been subjected to "blow-outs" at right angles to the dune axis during periods of sand instability. The large enclosed depressions appear to be swale lakes modified by solution.

The caves are shallow sinuous horizontal systems, often with a number of entrances. They have formed horizontally under a hardened cap rock or calcrete layer. Some solutional chambers and broad flatteners are preserved, but collapse has extensively modified the entrance, passage and chamber shapes (Figure 30). The cave floors, as well as having rock piles, are covered with clastic sediments derived predominantly from the insoluble residues of the calcarenite host rock. The caves contain a range of calcite speleothems including large expanses of moonmilk. Solution pipes, roof avens and foibes are common. However, no soil-filled pipes were found at Bats Ridge, despite their presence in other areas of Bridgewater Formation.
Syngenetic karst processes are clearly present. The caves appear to have developed on the spurs of the main ridge (Figure 29) and at the top of a previous water table, about 5 to 8 m above the present water table. This concentration may be a consequence of the influence the small swampy depressions and lakes have had on the aggressiveness of the ground water, or may be related to varying water-tables and mix-water corrosion at times in the past when the sea was nearby.

DAY 2:
Coastal Karst of The Great Ocean Road.

Site 24: Tyrendarra Flow

Between Darlot Creek and the Fitzroy River, which are twin lateral streams, the highway crosses the 20,000 year old Tyrendarra lava flow. This flow has come all the way from Mt. Eccles 25km to the north, and continues for 15 km out across the present ocean floor which was dry land at that time.

Site 25: Bat Maternity Cave, Warrnambool

Warrnambool city is built on top of dune limestone at about 50 m ASL. A major bat maternity cave (W-8) was reported by Dwyer (1969) in the actively eroding sea cliffs at Warrnambool; but the cave was

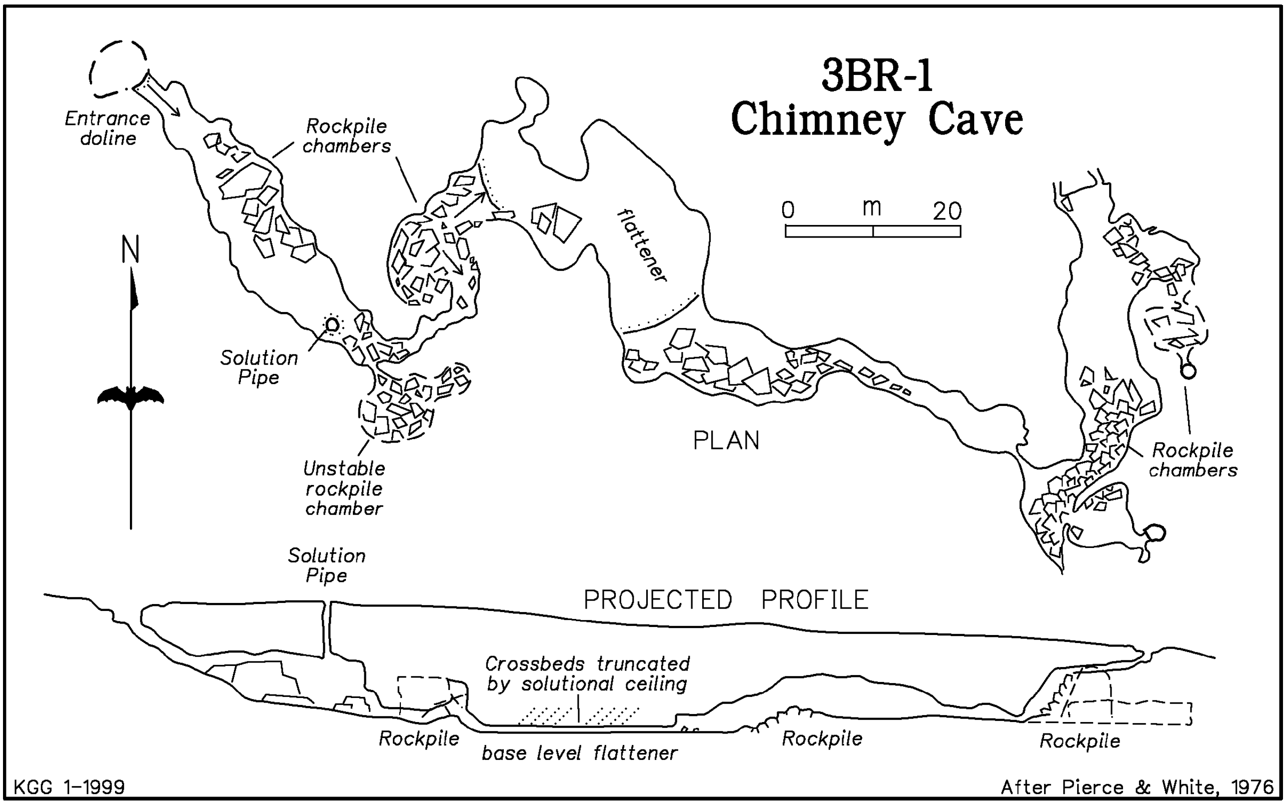


Figure 30: Chimney Cave, at Bats Ridges, shows syngenetic characters modified by collapse.

being threatened by wave erosion. In 1991 the bats were still present, but it was uncertain if they were using the site for breeding. In January 1998 the main breeding dome had been partly breached and no bats were present (Ackroyd, 1998). The bats have moved to the larger Starlight Cave (W 5) which has its entrance in a sea cliff 10 km to the southeast, but is a true karst cave modified by marine action. Starlight Cave was originally a transition site for bats on the way to the old bat maternity site. It has been suggested that concrete caps be placed on some of the pipes at the original maternity site (W-8) and that a temporary cap be tried at the daylight hole above the dome which is now being used at Starlight Cave to improve conditions there (Ackroyd, 1998).

COAST FROM WARRNAMBOOL TO TWELVE APOSTLES.

See Figure 31. The Tertiary limestone has cliffs up to 60 m high topped by calcareous and or siliceous sand in some places. The limestone plain has a number of karst features. Dolines up to 300 m in diameter have developed in an area with very little surface drainage. The Tertiary Limestone is thinly bedded and has concretions and secondary limestone deposition along the seaward-dipping beds. Prominent vertical jointing which strikes north-east controls the gorge and promontory formation; vertical and 45° jointing controls cliff development and cave formation. The area shows a wide range of spectacular features including reefs, offshore 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 present sea level.

Site 26: Doline field east from Allansford

Between Allansford and Peterborough there is an extensive field of large subsidence dolines developed in Tertiary limestone. There is an extensive limestone cave system at Childers Cove in the west section of the Bay of Islands Coastal Park.

Site 27: Twelve Apostles:

These impressive limestone stacks extend along several kilometres of coast east of Loch Ard Gorge. They are the best examples of the rock stacks along the coast and show prominent basal notches. The taller stacks are 50 m high.

Site 28: Loch Ard Gorge:

Loch Ard Gorge is developed along close jointing in the Tertiary Limestone and has a narrow entrance widening to form two small bays separated by a headland. A stairway gives access to the beach. There are two small caves, both of which have well-developed speleothems. The eastern cave receives water from an underground stream as well as from percolation through the porous limestone and it may be a karst cave that has been modified by the sea. The western cave (accessible at low tide) has 'sand stalagmites' (Grimes, 1999) formed by cementation of sand below drip points followed by the removal of the surrounding uncemented sand (the best examples are actually in the back of a small rock shelter you pass on the way to this cave). The Gorge is named after the clipper "Loch Ard" which

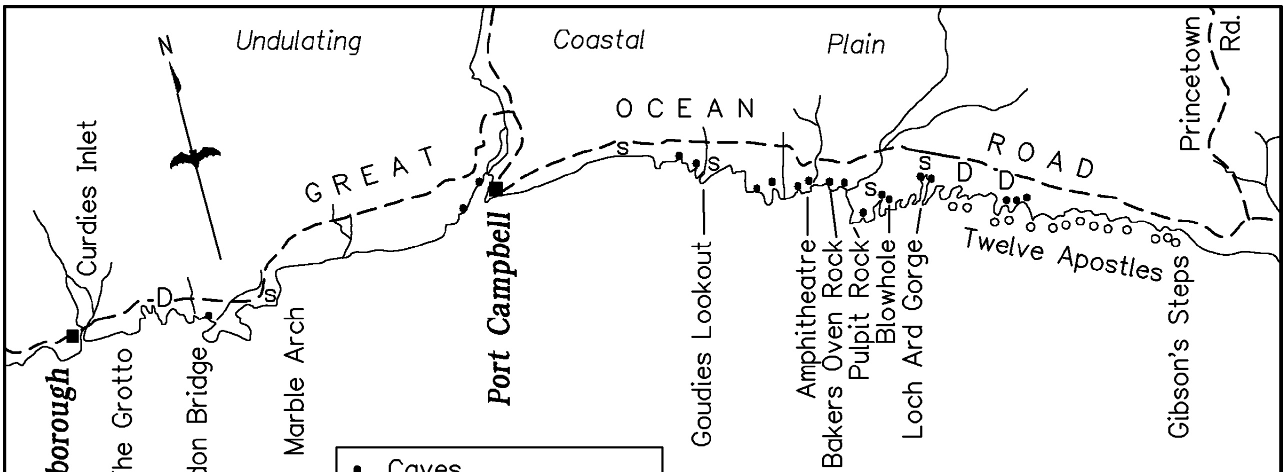


Figure 31: Features of the Port Campbell coast. After Baker (1943).

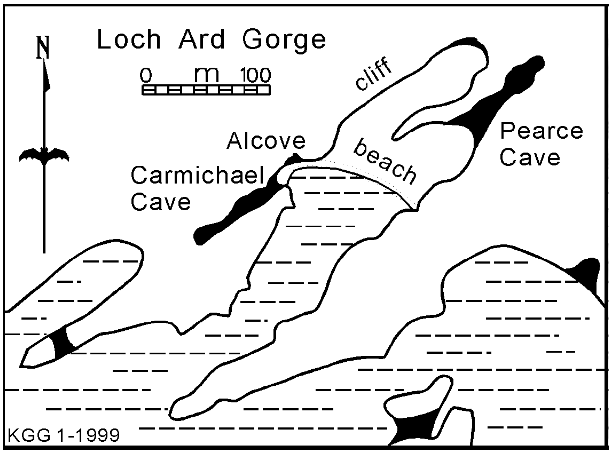


Figure 32: Loch Ard Gorge and its caves.

was wrecked in 1878 and the caves (Carmichael's Cave and Pearce's Cave) are named after the two survivors who sheltered in them.

As with most of the popular coastal sites, erosion is a continuing problem and a number of areas have had to be closed and fenced off for revegetation. The coastal cliffs are being continually cut back and unexpected rock-falls are common as at London Bridge (see below). Early reports described numerous cave pearls in the caves at Loch Ard, but these have all been removed by visitors.

The Blowhole, 600m to the west of the gorge, is an 18 m deep overhanging collapse doline above a cave which connects to the sea 100m away. The cave is incompletely explored (dangerous) but a line of hollows can be traced inland for 1000m.

Sites 29: Other coastal features:

A series of features show the interaction of marine and karst processes. From west to east some good sites are shown on Figure 31: West of Peterborough a field of basin-shaped dolines lies inland of ***the Bay of Martyrs & Bay of Islands*** which have undercut red limestone stacks and fretted limestone outcrops. In the ***Curdies Inlet*** area there is syngenetic karst and a collapse doline. East of Peterborough ***The Grotto*** is a dissected sinkhole opening onto the cliff through an archway and contains a boulder beach 13 metres above present sea level. One of the more spectacular sites is the remains of ***London Bridge*** which was once a promontory with two arches. In 1990 the larger arch collapsed leaving an arched rock stack, and stranding several tourists on the far end!. West of Port Campbell ***The (Marble) Arch*** is small but nice, with a floor 6 m above sea level. Further east ***Bakers Oven Rock*** is a rock stack with a tunnel 6 m above present sea level.

DAY 3: Volcanic Caves and other volcanic features

Site 30: Tower Hill

There is a good viewpoint right beside the highway. Although not a karst feature, this is worth a stop. A useful booklet by Orth & King (1990) can be purchased at the Information Building within the crater. About 30,000 years ago rising molten magma intersected the water-saturated Tertiary limestones and the resulting steam pressure "blew the top off" to form the crater. The central group of cinder cones built up during the waning stage of the volcanism.

Twenty years ago the cones in the centre of the crater were bare of timber, and the detailed volcanic features were much easier to see. An intensive revegetation program has hidden much that would be of geological interest. A current problem in Australia is the planting of vegetation in such a way as to obscure important geological and geomorphological sites or views. Revegetation plans should not compromise other heritage and conservation values.

Site 31: Stony Rises near Gorrie Swamp

We will drive over an area of black basaltic lava with many deep hollows which would have resulted from sagging of the still-plastic crust as liquid lava was partly drained from beneath.

Site 32: MOUNT ECCLES AREA

This will be a major stop, and we will visit several sites (Figure 33). The area is infested with Koalas, and you will notice that the foliage on many of the trees is quite sparse. A study on their effect on the vegetation, and possible control measures is being done at present. A Koala Relocation Program is presently underway, which will remove up to 1,000 animals from this site

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 channel (or "canal" as they are called locally). A line of smaller spatter and cinder cones and craters extends to the southeast from the main crater (Figure 33).

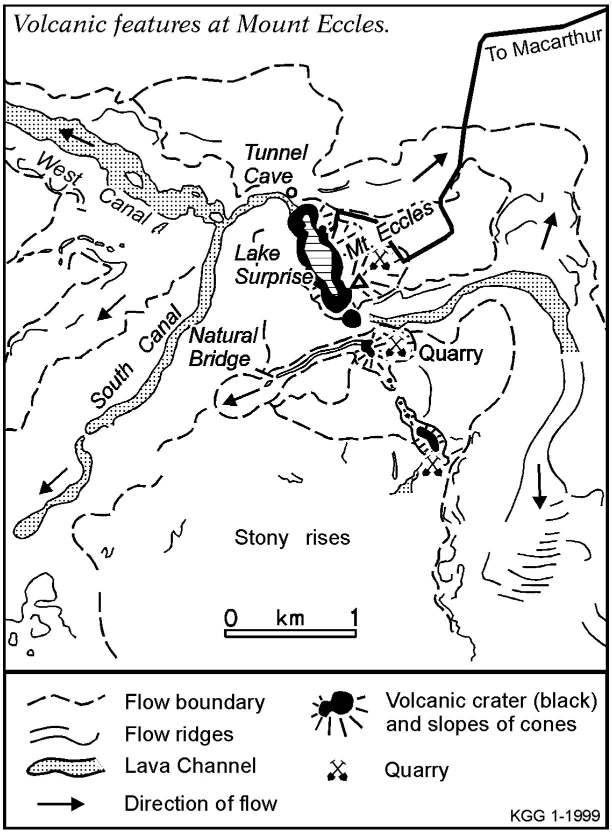


Figure 33: Mount Eccles area.

A small but well-defined lava canal runs southwards from one of these smaller cones and ends at the Natural Bridge, which is a roofed over section of the canal.

The longer and more complicated caves known at Mount Eccles are beyond the reach of a quick visit. These caves are generally formed in the levee banks on the sides of the lava canals and would have fed small lateral lava lobes or sheets when the canal overflowed. 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 (see Figure 11 and Grimes, 1995)).

Main Lookout

Below you is the crater and present lake, which is about 14 m deep. The lake is at the level of the regional groundwater, and its level fluctuates seasonally by several metres. To the left is the small peak of Mount Eccles. At the time of the eruption the crater would have been filled with a lake of liquid lava, with a large roaring fountain of lava spurting up several hundred metres into the air. The lava droplets from the fountain would have partly solidified as they fell, and were also blown to the east by a westerly wind to build up the peak, which is composed of loose or partly-welded scoria (frothy lava fragments). The cliffs below you and visible on the far side are solidified lava that overflowed from the crater lake. The main overflow point was at the north-western end where a major lava channel runs away from the crater.

Tunnel Cave, H-9

Tunnel Cave is an easily accessible cave, right next to the walking track where the big lava canal leaves the main crater. Lights are needed to see the far end of the cave. A detailed leaflet describing this cave can be obtained from the information centre.

It is a typical lava tube, with "railway tunnel" dimensions and shape. The flat floor is the top of a solidified lava pool. As you walk into the cave the roof becomes lower and eventually reaches the floor. The tube would originally have continued but is now blocked by solid lava (Figure 34). Features of interest are the lava bench on the left side near the entrance, and lava drips, a ropy lava floor and a sagged wall lining that has opened up a gap behind it. An attempt to provide a solar-powered visitor-

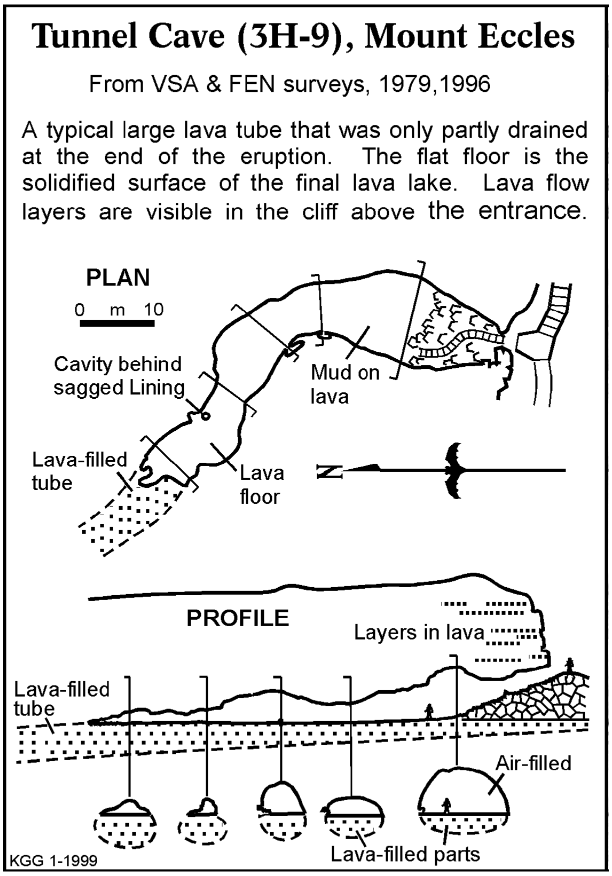


Figure 34: Tunnel Cave is open to the public.

sensing light in this cave was terminated by vandalism and then theft of the components.

Crater Rim Walk

This walk passes Tunnel Cave and circles around the far side of the main crater. It then drops down and continues past another large but dry crater which is the first of a chain of craters running off to the southeast. These may have formed along a fissure eruption. Another shallow lava channel runs off to the east from the dry crater (Figure 33).

Quarry

This scoria quarry is no longer operating, but there is a newer quarry about one kilometre to the south-east hidden behind and cut into another volcanic cone. A complete scoria cone has been removed here, what remains is just the small portion visible on the far side. Quarrying is a major problem for those who wish to preserve the volcanic landforms of the area. The scoria from the volcanic cones is a much-sought road-surfacing material. The only alternative over much of the volcanic plains is crushed basalt - which is more expensive to produce (Guerin, 1992).

Natural Bridge (Gothic Cave) H-10

From the crater near the quarry a small lava channel runs off to the south-west (Figure 33). At the end part of the lava channel has been roofed over to form a short section of cave (Figure 36). The pointed, 'gothic' roof of this cave suggests that it was roofed by levee overgrowth - and the contorted layers visible in its walls would be linings that were built up and then slumped while still hot.

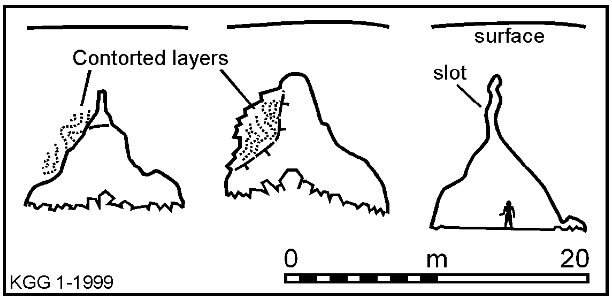


Figure 36: Cross-sections of Natural Bridge, showing the "Gothic" roof and contorted layers.

Site 33: HARMAN VALLEY VIEWPOINT

A good view point on the Hamilton - Port Fairy Road looks up the Harman Valley towards the volcano of Mount Napier. The mountain is a composite volcano with a broad, timbered, lava shield capped by a steeper, bare, scoria cone formed by explosive activity at the end of the eruption. Below the lookout one can see the lava flow (about 8,000 years old) that came down the valley from the mountain. This flow was fed by lava tubes, some of which can be entered at the Byaduk Caves (Site 34). One can see a lava channel below and to the right of the lookout.

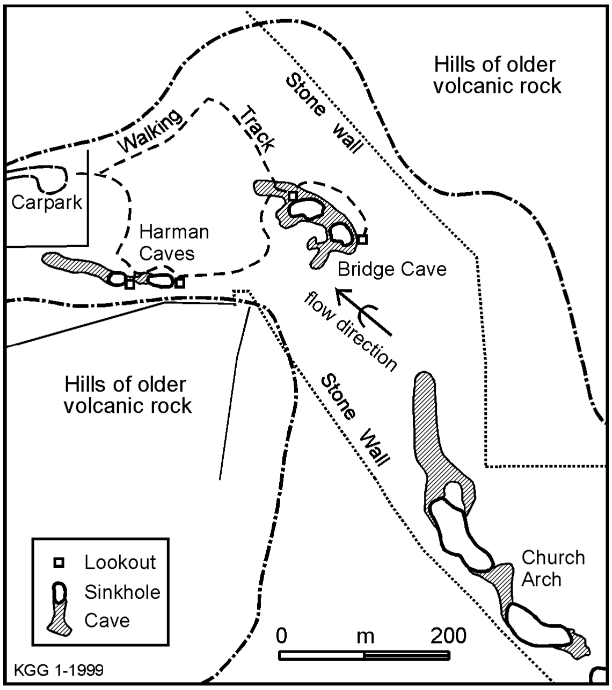


Figure 37: The Byaduk Caves are a line of large, partly-collapsed lava tubes.

Site 34: BYADUK CAVES

This lava flow, which came from Mount Napier, is the same one as that seen at Site 33. It was fed by large lava tubes which would have formed by the roofing of lava channels (c.f. Figure 10). In the Byaduk Caves area collapse of parts of the main feeder tube has exposed the largest and most spectacular lava tubes, arches and collapse dolines in the region (Ollier & Brown, 1964, Grimes & Watson, 1995). The largest tunnels are up to 18 m wide and 10 m high. There are also some smaller but more complicated caves, and a multilevel system which has a shallow surface maze, and two lower levels connected by lava cascades and chutes where the lava drained downward to the lowest level. A walking track and viewing platforms have recently been constructed; interpretation signs are being planned. Visitor access to the site is being promoted and increased visitation is inevitable. The issues involved with access to this site include: risk management, safe visitor access to selected caves,

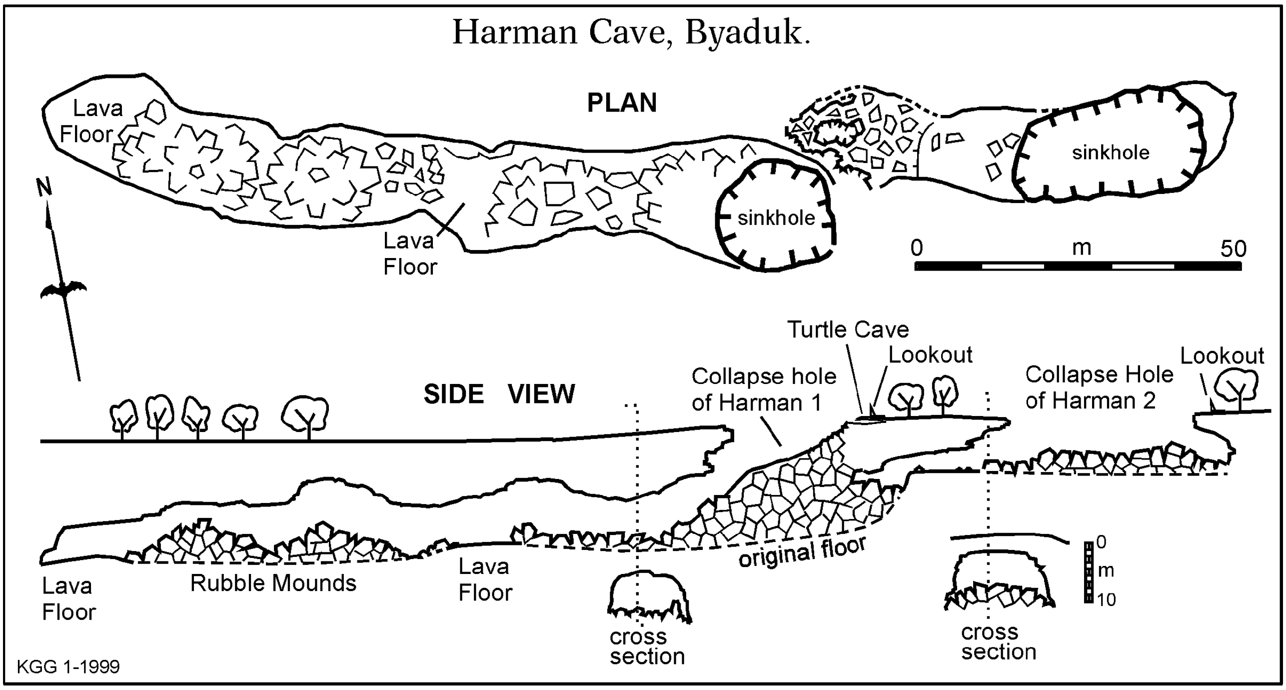


Figure 38: Harman Cave, Byaduk, is a large lava tube modified by collapse.

protection of sensitive cave sites, flora and fauna, commercialisation, and development of a permit system. Funding will be sought to develop the site in a sensitive manner, with an emphasis on protection – any suggestions would be valuable for the future management of this site.

Harman Cave, H-11

This large lava tube has been extensively modified by collapse, but some relicts of the original form can still be seen (Figure 38). In addition, the small "blister" near the western lookout, called Turtle Cave, is a shallow "drained-lobe" cave on the surface of the flow (c.f. Figure 11). Harman Cave is likely to receive increased visitation as the "volcanic trail" concept is implemented. Proposals for "improved" access to the cave include a possible circular stairway and elevated viewing platform in the middle of the big collapse doline!.

Bridge Dolines, H-13, H-14

The walking track leads to a pair of connected large collapse dolines over what would have been a large lava tube. Little of the original tube remains.

Church Arch, H-16

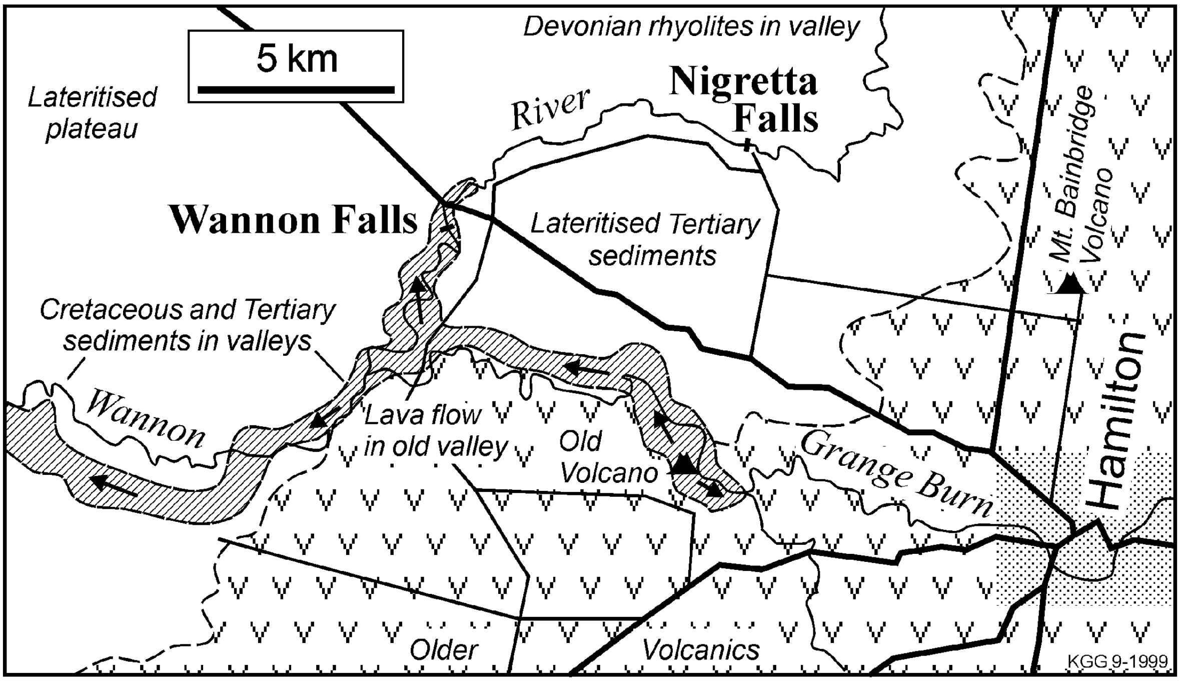
This is a spectacular arch connecting two long sections of collapsed tunnel. The tunnel is about 12m high, 25m wide and 60m long. One can see thin lava benches on the wall in places, and elsewhere the lining has broken away to reveal layers of lava that would have overflowed from the original open lava channel as the valley filled up. The cave has not been included in the walking trail at this stage as any track would have to go past another obvious cave that is potentially important for bat habitat. Should this arch be developed for increased visitor access? If so, how?

Site 35: WANNON FALLS

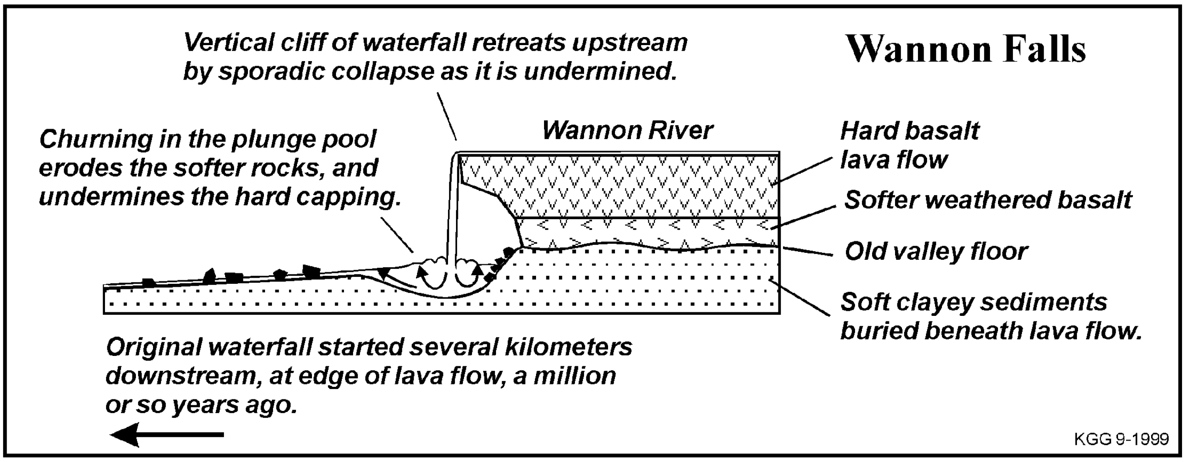
This optional stop is on the Wannon River, west of Hamilton. This is a classic hard-bed-over-soft style of waterfall. A hard, early Quaternary(?), basalt flow overlies soft Tertiary sediments. The falling water scours out a plunge pool in the soft rock and undermines the overlying hard rock to form a vertical undercut waterfall. The falls have migrated upstream for several kilometres to leave a narrow gorge.

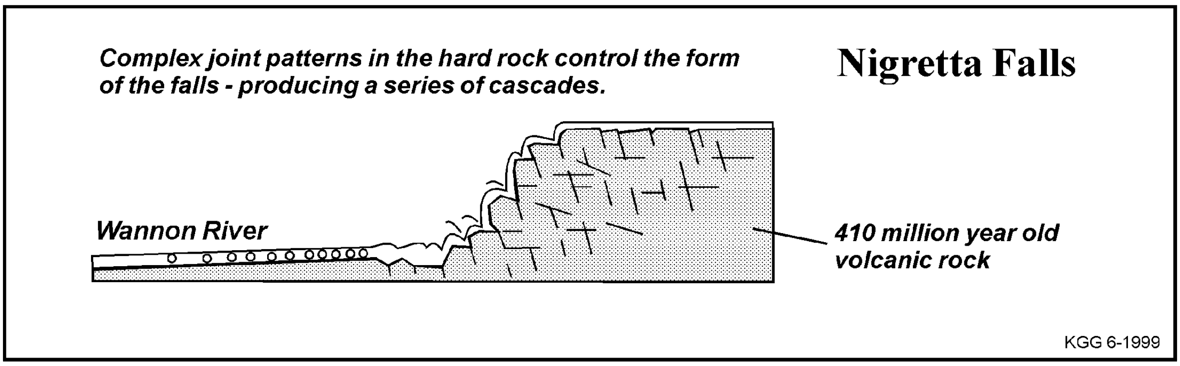
Contrast this form with the Nigretta Falls, 10km upstream, that are in an older, massive, but jointed, rock.

The lava flow appears to have run UP the river valley! It originated from a volcano to the east, and ran down a tributary valley to enter the Wannon valley 4km to the south of here. Most of the lava flow continued down the Wannon valley, but the flow was quite thick and confined by the valley so that some of the lava backed up the Wannon to this spot (see map).



Map showing older volcanic areas (V V) and the later lava flow (grey) that ran down the Grange Burn and backed up the Wannon River valley.
Arrows indicate lava flow directions.





BIBLIOGRAPHY

ACKROYD, P., 1998: Bat doings at Warrnambool. *ACKMA Journal,* **31**, 42-43.

AUSTRALIAN SPELEOLOGICAL FEDERATION (ASF), 1983: Preliminary draft management plan, Tantanoola Caves Conservation Park. Report to SA National Parks & Wildlife Service [unpublished].

BAKER, G., 1943: Features of a Victorian Coastline. *Journal of Geology.* **51**(6), 359-386.

BARRIE, J., 1997: Climatic indicators within Henschke fossil cave system, Naracoorte, South Australia. *Quaternary Australasia,* **15(2),** 45-57.

BEDNARIK, R.G., 1986: The parietal art of South Australia. *Journal, Anthropological Society, South Australia.* **24(1)** 3-21.

BOUTAKOFF, N., 1963: The geology and geomorphology of the Portland area. *Geological Survey of Victoria, Memoir* **22**

COLLINS, T., 1999: Cave diving management in South East South Australia. *in* Henderson, K. [ed] Proceedings of the Thirteenth Australasian Conference on Cave and Karst Management. ACKMA, Carlton South. 137-141

COOK, P.J., COLWELL, J.B., FIRMAN, J.B., LINDSAY, J.M., SCHWEBEL, D.A. & VON DER BORCH, C.C., 1977: The late Cainozoic sequence of south-east South Australia and Pleistocene sea-level changes. *BMR Journal of Australian Geology & Geophysics*, **2**: 81-88.

DWYER, P.D., 1969: Population ranges of *Miniopterus schreibersii* (Chiroptera) in south-eastern Australia. *Australian Journal of Zoology*, **17**: 665-686.

EMMIT, A.J., & TELFER, A.L., 1994: Influence of karst hydrology on water quality management in southeast South Australia. *Environmental Geology*, **23(2)**: 148-155.

GILL., E.D., 1948: Structure and origin of Guano Cave, near Warrnambool, Victoria. *Victorian Naturalist*, **65(8)**: 187-191.

GRIMES, K.G., 1994: The South-east Karst province of South Australia. *Environmental Geology* **23:** pp 134-148.

GRIMES, K.G., 1995: Lava caves and channels at Mount Eccles, Victoria. *in* Baddeley, G (*Ed*) *Vulcon Preceedings (20th ASF Conference)*, Victorian Speleological Association Inc., Melbourne., pp 15-22.

GRIMES, K.G., 1996: Pans, dolines and other hollows in the South-east Karst Province of South Australia. *in* HAMILTON-SMITH, E., [ed] *Abstracts of papers, Karst Studies Seminar, Naracoorte.* Regolith Mapping, Hamilton, Victoria. 3-4.

GRIMES, K.G., 1999: Sand speleothems: an Australian example. *Helictite* **36(1)** 11-16.

GRIMES, K.G., HAMILTON-SMITH, E., & SPATE, A.P., 1995: *South East Karst Province of South Australia*. Unpublished report to the South Australian National Parks and Wildlife Service. 110pp.

GRIMES, K.G., & SPATE, A.P., 1997: Andysez No. 25: Lets talk about Limestone - Part 2. *ACKMA Journal,* **29,** 33-34.

GRIMES, K.G., & WATSON, A, 1995: Volcanic caves of Western Victoria. *in* Baddeley, G (*Ed*) *Vulcon Guide Book (20th ASF Conference)*, Victorian Speleological Association Inc., Melbourne., pp 39-68.

GRIMES K.G. & WHITE, S., 1996: *Field Guide to Karst Features in Southeast South Australia and Western Victoria.* Karst Studies Seminar, Naracoorte, Regolith Mapping, Hamilton. 34pp.

GUERIN, B., 1992: Review of scoria and tuff quarrying in Victoria. *Geological Survey of Victoria report,* **96.**

HAMILTON-SMITH, E., 1993: The cave gardens of Mount Gambier. *Australian Garden History,* **5(2),** 3-6.

HARVEY, P.D., 1983: Groundwater pollution related to land use in a karst area. *International Conference on Groundwater and man.* AWRC, Sydney. 131-142.

HOLMES, J.W. & WATERHOUSE, J.D.. 1983: Hydrology. *In* TYLER M J, TWIDALE C R, LING J K, and HOLMES J W (eds) 1983 Natural History of the South East. *Royal Society of South Australia, Adelaide*, pp. 49-59.

HORNE, P., 1988: Gouldens Hole - 5L8 - Mapping project. *South Australian Underwater Speleological Society, Project Report,* **2.**

HORNE, P., 1993: *Lower South East Cave Reference Book.* Adelaide, privately published, (ISBN 0 9594383 9 4), 600pp.

JENKIN, J.J., 1991: Geomorphology. *In* COCHRANE, G.W., QUICK, G.W., & SPENCER-JONES, D., [*Eds*] *Introducing Victorian Geology.* Geological Society of Australia (Victorian Division), Melbourne. pp 57-96.

JENNINGS, J.N., 1968: Syngenetic karst in Australia. in *Contributions to the study of karst*, Australian National University, Dept of Geography Publication G/5, pp 41-110.

LEANEY, F.W.J., ALLISON, G.B., DIGHTON, J.C., & TRUMBORE, S., 1995: The age and hydrological history of Blue Lake, South Australia. *Palaeogeography, Plaaeoclimatology, Palaeoecology.* **118** 111-130.

LEWIS, I.D., 1976: South Australian Cave Reference Book. *Cave Exploration Group (South Australia), Occasional Paper* **5**.

MARKER, M.E., 1975: The lower southeast of South Australia: A Karst Province. *Department of Geography and Environmental Studies, University of Witwatersrand, Occasional Paper*, **13**.

MYLROIE, J.E., CAREW, J.L., & VACHER, H.L., 1995: Karst development in the Bahamas and Bermuda. *Geological Society of America, Special Paper* **300**, 251-267.

OLLIER, C.D., & BROWN, M.C., 1964: The Byaduk Lava Caves. *Victorian Naturalst,* **80**, 279-290

ORTH, K, & KING, R., 1990: *The geology of Tower Hill*. Geological Survey of Victoria. 17pp.

PETERSON, D.W., HOLCOMB, R.T., TILLING, R.I., & CHRISTIANSEN, R.L., 1994: Development of lava tubes in the light of observations at Mauna Ulu, Kilauea Volcano, Hawaii. *Bulletin of Vulcanology,* **56,** 343-360.

SCHMIDT, L., 1999: The history of groundwater management in the Southeast of South Australia - Towards achievable sustainability? *in* Henderson, K. [ed] Proceedings of the Thirteenth Australasian Conference on Cave and Karst Management. ACKMA, Carlton South. 32-34.

SHEARD, M.J., 1978: Geological history of the Mount Gambier Complex, southeastern South Australia. *Trans. Royal Soc. S. Aust.* **102(5)** 125-139.

SMITH, P.C., ROGERS, P.A., LINDSAY, J.M., WHITE, M.R., & KWITKO, G., 1995: Gambier Basin. *in* DREXEL, J.F. & PREISS, W.V., (*Eds*), *The Geology of South Australia, Volume 2 The Phanerozoic.* South Australia, Geological Survey, Bulletin, **54**, pp 151-157.

SPATE, A.P., 1990: Andysez No. 3: Carbonate solution made easy(ish). *ACKMA Journal,* **6,** 24-25.

STADTER, F., 1999: Groundwater resources of the south east of South Australia. *in* Henderson, K. [ed] Proceedings of the Thirteenth Australasian Conference on Cave and Karst Management. ACKMA, Carlton South. 8-11.

THURGATE, M.E., 1996a: The stromatolites of the cenote lakes of the Lower South East of South Australia. *Helictite,* **34(1)**, 17-25.

THURGATE, M.E., 1996b: Stromatolites of the karst lakes of the Mt. Gambier Region. What are they and why should we care? *ACKMA Journal*, **23**, 29-33.

THURGATE, M.E., 1999: A *Bug's Life* and *The Blob*: Tales of the groundwater ecosystems of the south east of South Australia. *in* Henderson, K. [ed] Proceedings of the Thirteenth Australasian Conference on Cave and Karst Management. ACKMA, Carlton South. 38-42.

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

WELLS, R.T., MORIARTY, K., WILLIAMS, D.L.G., 1984: The fossil vertebrate deposits of Victoria Fossil cave: an introduction to the geology and fauna. *Australian Zoologist* **21(4)**, 305-333.

WELLS, R.T., & PLEDGE, N.T., 1983: Vertebrate fossils. *in* TYLER M J, TWIDALE C R, LING J K, and HOLMES J W (eds) 1983 Natural History of the South East. *Royal Society of South Australia, Adelaide*, pp 169-176.

WHITE, S., 1984: Bats Ridge Karst Area - an annotated atlas. *Nargun*, **17**(6): pp 42-68.

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

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

WHITE, S., 1995a: Tertiary limestone areas of western Victoria. *In* BADDELEY, G., (ed) *Vulcon Guidebook*, Victorian Speleological Association, Melbourne. pp 69-80.

WHITE, S., 1995b: Quaternary limestone areas of western Victoria. *In* BADDELEY, G., (ed) *Vulcon Guidebook*, Victorian Speleological Association, Melbourne. pp 81-98.

WHITE, S., 2000a: Syngenetic karst in coastal limestone: a review. *in* KLIMCHOUK, A.B., FORD, D.C., PALMER, A.N., & DREYBRODT, W. [eds] *Speleogenesis, evolution of karst aquifers.* National Speleological Society, Huntsville, AL. 234-237.

WHITE, S., 2000b: Thermoluminescence dating of dune ridges in western Victoria. *Helictite* **32(2)** 38-40.

WHITE, S, & GRIMES, K.G., 1992: Excursion notes, Lorne (Vic) to Naracoorte (SA). *In* GILLIESON, D., (ed) *Geology, climate, hydrology and karst formation: field symposium in Australia: Guidebook.* Special Publication No 4, Department of geography and Oceanography, Australian Defence Force Academy, Canberra. Pp 101-113.