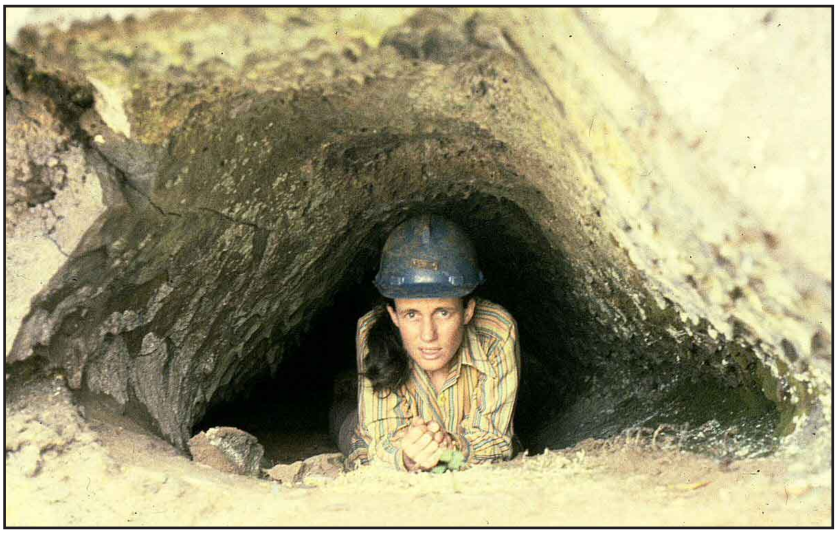
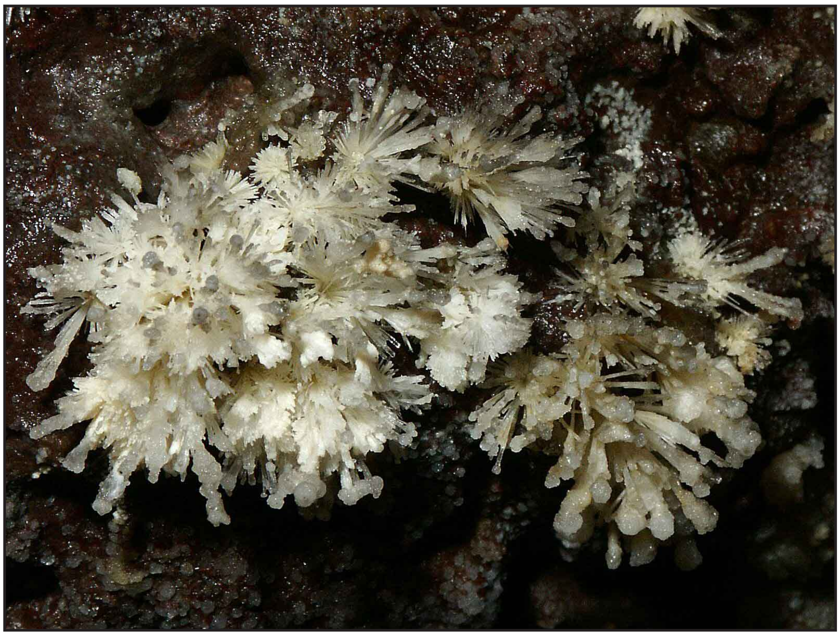
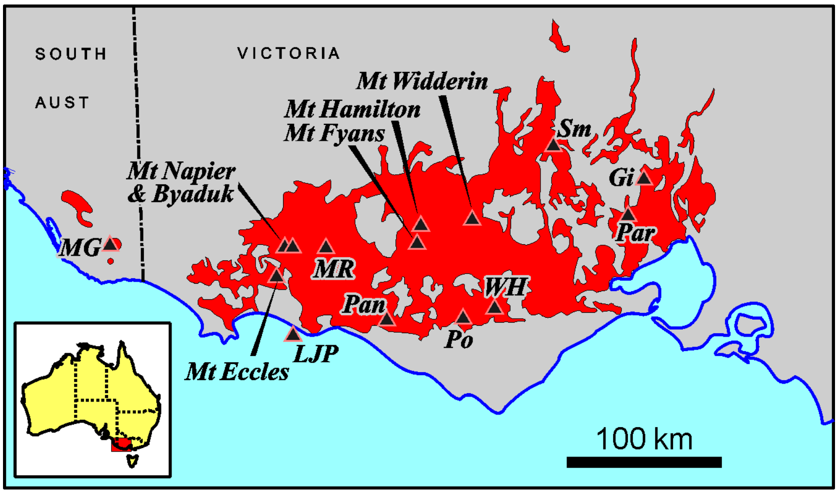
Field Guide

to the Volcanic Caves of Western Victoria

Small is Beautiful







INTERNATIONAL SYMPOSIUM ON
VULCANOSPELEOLOGY
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XIV

Field Guide

to the Volcanic Caves of

Western Victoria

Edited by

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with contributions by

Ken Grimes, Elery Hamilton-Smith and Susan White

14th International Symposium on Vulcanospeleology.

August 2010

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Field Guide toVolcanic Caves of Western Victoria.

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1 Caves - Victoria - Guidebooks. **2** Volcanoes - Victoria - Guidebooks.
3 Victoria - Guidebooks.

I Grimes, Ken (Kenneth George), 1944 - . **II** International Union of Speleology Commission on Volcanic Caves, Victoria, Australia. **III** Title.

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Cover Photographs:
Top: A small lava tube (H-52) opening from a lava channel at Mt. Eccles.
Middle: Radiating spikes of Opal-A in Mt. Hamilton lava cave (H-2).
Both photos by K.G. Grimes.

CONTENTS

Acknowledgements

I must especially acknowledge my predecessors who conceived most of the ideas expressed here: In particular Don Peterson, Ken Hon, Bill Halliday, and many other speleo-geologists.

This report draws on the exploration and mapping efforts of numerous speleologists from the Victorian Speleological Association and other groups over the last 50 years (see Chapter 3 for a brief history of cave exploration).

Photographs are by Ken Grimes (KGG), Reto Zollinger (RZ), and Lionel Elmore (LE).

Introduction

Ken Grimes & Susan White

The Western District Volcanic Province extends from Melbourne across to the Mount Gambier area, in South Australia, and has been erupting basalt lavas for at least the last 5 million years (Chapter 2). Lava caves have formed in 15 areas across the region, but the best concentrations are in the ~30,000 year-old lavas from Mt. Eccles and Mt. Napier.

Some of the younger eruptions were seen by the Aboriginal people, who made some use of the caves and sinkholes, but more of the surface landforms and associated swamps and lakes (Chapter 3). Europeans have viewed, used and explored the caves over the last 170 years.

Lava tubes form in two main ways (Chapter 4). The first is by the roofing of narrow surface lava channels, which happens in several ways. This type tends to form linear and simply-branched or anastomosing tubes. The second way is by draining from beneath the crust of a set of spreading lava lobes near the leading edge of a lava flow – this tends to form smaller, but more complex mazes of shallow, low-roofed chambers and passages. Over time these may evolve by solidification of the more stagnant areas and erosional enlargement of the fastest moving routes to form simpler linear tubes that are difficult to distinguish from the roofed channels.

Both types of tube contain liquid lava flowing beneath a solid crust. At the end of the eruption some of that lava drains out to leave empty caves, but most tubes remain filled with solidified lava. Many lava caves end at solid undrained lava sumps.

There are a variety of volcanic caves in the region (Chapter 5), including large feeder tubes that are responsible for the long lava flows, but also smaller but more complex shallow subcrustal lava caves. There are also a few unusual volcanic caves: for example still-open volcanic vents or hornitos, and a cave in a basalt dyke.

It is the "Small but Beautiful" subcrustal caves that we will emphasise during this field trip.

Note that the cave numbers used in this field guide are from the 3H series (volcanic region) in the Australian Karst Index (Matthews, 1985).

The Excursion

The 14th International Symposium on Vulcano-speleology will have a pre-symposium excursion to the lava caves and related features of Western Victoria. This will comprise four days from 7th August to 10th August, 2010.

The itinerary will be provided on a separate sheet, with road map. The next section describes some volcanic sites that will be passed by the bus while travelling to and from Melbourne.

Window Views while travelling

Melbourne-Ballarat

In this section we will travel across an area of Pliocene and Quaternary volcanic plains. Schleiger (1995) has published a useful field guide to the exposures along the highway. The area has been block faulted and, starting at Bacchus Marsh, the valleys in the uplifted blocks cut through the lavas to expose older rocks:

- Tertiary sediments and older volcanics near Bacchus Marsh;
- Permian glacial sediments between Bacchus Marsh and Ballan; and then
- Paleozoic metasediments and granites further west.

Many of the exposures of the older rocks have been deeply weathered during the Tertiary.

Basalt plains of western Melbourne: The plains north and west of the city of Melbourne consist largely of lava flows of Late-Tertiary and Quaternary age which have been extensively quarried as major sources of building and road material, known locally as bluestone". Resistant older rocks such as the You Yangs granite and Mt Macedon Devonian volcanics rise above the lava plains. Well-preserved scoria cones such as Mt Fraser and Mt Kororoit, and lava shields such as Mt Cotteril rise above the relatively flat plain and the drainage has cut deep valleys, e.g Deep Creek, Jackson's Creek. A number of the last phase lava and scoria eruption points can be seen.

Mount Cottrell (also spelled Mount Cotteril) is a late Cainozoic lava shield, the outline of which can be seen clearly as we drive. A crater is absent, however, a small circular summit outcrop of basalt is probably the remnants of a crater lake. The hawaiitic basalt flows that emanated from Mount Cottrell were probably of low viscosity and extended for tens of kilometres symmetrically around the vent. As a result, a shield of considerable bulk, about 100 m in height, and of great extent was produced. Dating of basaltic rocks from this area indicates that the hawaiitic volcanic domain is ~1.4 Ma. This is one of the largest shield volcanoes in Victoria and is significant due to the unusual inward dipping basalt structures at the bluff and the extent of the radial flows. No caves are known. It has State geological significance.

Anthonys Cutting: As the highway descends into the large valleys of the Werribee and Lerderderg Rivers at Bacchus Marsh the road cutting exposes Upper

Pliocene non-marine sediments overlying a Pliocene (3-5 Ma) basalt flow that fills an earlier valley cut into the Miocene non-marine (fluvial) sediments of the Werribee Formation. Sedimentary structures are generally absent from the Werribee Formation which consists of clay, sand and minor gravel. Both scoria and basalt are present in the volcanics. The overlying Pleistocene sediments are typical of an alluvial environment and show cross-bedding, cut-and-fill structures and channelling. The site provides a valuable section through the Tertiary sequence and shows basalt thickness and sedimentary features, but has serious safety problems for access.

Parwan Cave H 4: This small lava cave is south of Bacchus Marsh (see page 6).

Pykes Creek Permian glacial features: The highway cuttings expose Permian glacial tillites at Pykes Creek Reservoir. At several localities, the angular unconformity of the Permian with the underlying Ordovician sediments is visible. The contact surface on the Ordovician varies from uneven to smooth and in places there are small striations. On the southwest side of the lake, Permian fluvioglacial beds faulted against steeply dipping Ordovician, are exposed in the north face of the road cutting. On the southeast, the cuttings expose Permian and Tertiary sequences. The glacial sediments consist of very complex subaqueous outwash and lacustrine sediments with slump deposits, rippled sandstone and other sandstone. Overlying the Permian are Tertiary gravels displaying excellent large-scale cross-bedding. The sequence of sediments and stratigraphic relationships exposed are important in understanding the Permian of southeastern Australia (northeastern Gondwana).

Volcanic features between Bacchus Marsh and Ballarat: From the highway we should see several basalt and scoria eruption points. These include Mt Darriwill (composite scoria cone), Mt Gorong (lava hill), Mt Hydewell (lava shield), O'Donnell Hill (scoria cone with crater), Poverty Point (lava cone with crater) and Black Hill (scoria cone with crater), to name a few. These give an indication of the variety of volcanic features.

Ballarat is a large regional centre originally famous for its gold mines and the Eureka Stockade uprising. It was very wealthy in the 19th century and many of the large buildings were constructed then. There is a tourist area, Sovereign Hill, which has exhibits and re-enactments of the goldmining history of the area.

Ballarat-Hamilton

Beyond Ballarat, the bus will follow the Hamilton Highway to the west. The initial hilly country is mainly in Palaeozoic metasediments, but there are also areas of Tertiary "deep leads" which are gold-bearing valley-fills that were buried by the Pliocene lavas. These are only obvious where we see mullock heaps left by the gold miners in paddocks beside the roads, as at Smythesdale and Linton.

Further west, beyond Skipton, we come out into rolling volcanic plains again, with scattered volcanic cones and shields visible. These include ***Mt. Widderin***, a broad low lava shield immediately to the south, and several others to the north. Some of the younger lava flows are obvious as rocky ridges (the "stony rises") which have followed old stream-lines. On Saturday, we will detour south from the highway to visit the caves at ***Mt. Hamilton*** and ***Mt. Fyans***, both of which are relatively young volcanoes with stony rise lava flows. The "stony rises" around Mt. Fyans have some particularly elegant and distinctive dry-stone walls that were constructed by early British settlers (photo 2.7). Towards the end of the day we will pass ***Mt. Rouse***, the source of a long lava flow, with stony rises and dated at about 350 ka, that ran for 60 km to the coast at Port Fairy (Figure 2.2).

On the way east from Hamilton on Tuesday we will pass the ***Grampians Ranges*** (Gariwerd); an impressive array of Siluro-Devonian sandstone scarps.

Figure 1.1: *Stony rises* near Lake Condah, on a 30,000 year old lava flow from Mt. Eccles. [KGG]

The Western District Volcanic Region

Ken Grimes & Susan White

The Western District Volcanic Province.

The basaltic Western District Volcanic Province (also known as the Newer Volcanic Province) of western Victoria is one of the world's larger volcanic plains. The isolated volcanoes at Mount Gambier form a western outlier of the province (Figure 2.1). The province has over 400 identified eruptive points and it ranges in age back to the Pliocene (about 5 Million years), though there are some volcanoes as old as 7 Ma (Joyce, 1988; Joyce & Webb, 2003; Price & others, 2003). Eruptions have continued up to quite recent times and further eruptions could occur in the geological future. Current dating suggests that the youngest volcano may be Mount Schank, south of Mount Gambier, which erupted 5,000 years ago. The lava flows associated with these younger eruptions show better lava caves and surface features than those of the older volcanics. None-the-less, a few of the caves are in flows several million years old (e.g. Parwan Cave is in a 2.5 to 2.7 Ma lava flow). The younger lava flows have surfaces ranging from strongly undulating ("stony rises") to flat.

Recent summaries of the volcanic caves and associated surface features of the province appear in Grimes (1995, 2007, 2008) and Grimes & Watson (1995). The earlier literature on lava caves of the region by Ollier, Joyce and others is reviewed in Webb & others (1982) and Grimes & Watson (1995) and in the History chapter of this field guide (page 7).

Surface landforms

The volcanic plains are dominantly built up from basalt lava flows, but there are numerous small volcanic cones built by explosive activity, as well as larger maar lakes formed by major explosions (Price & others, 2003; Joyce & Webb, 2003).

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 (e.g. Figure 2.2) have only minimal soil development and rough undulating surfaces known locally as *stony rises* (Photo 1.1); 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 (Macdonald & others, 1983, Peterson & others, 1994, and see Chapter 4). 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.

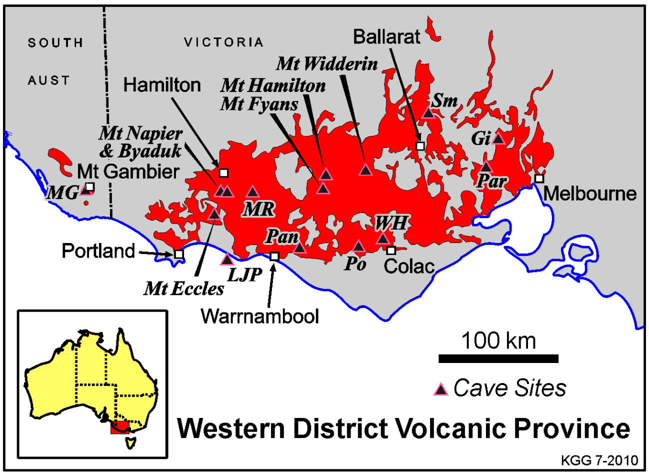


Figure 2.1: The Western District (or Newer) Volcanic Province of Victoria and South Australia. Volcanic cave areas marked by triangles: **Gi**, Gisborne; **LJP**, Lady Julia Percy Island; **MG**, Mt. Gambier; **MR**, Mt. Rouse; **Pan**, Panmure; **Par**, Parwan; **Po**, Porndon; **Sm**. Smeaton; **WH**, Warrion Hill.

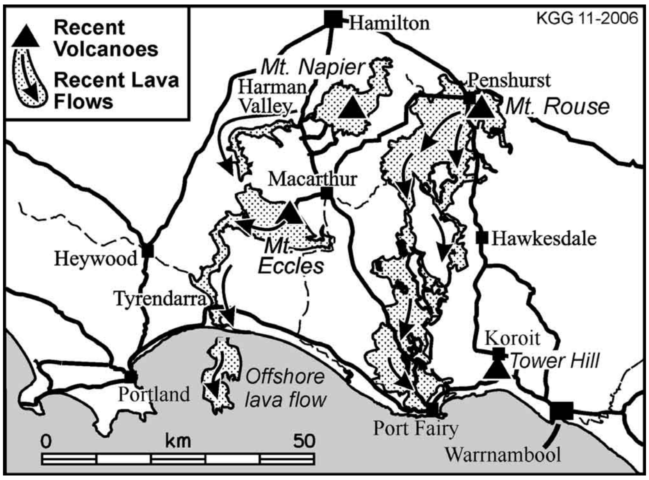


Figure 2.2: Recent lava flows in western Victoria.

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 built larger *scoria cones*; as well as the *maar* lakes (eg. Tower Hill), which are large but shallow craters formed by major steam-driven explosions where rising magma intersected water-saturated limestone. At Mount Eccles a line of scoria cones running south-east from the main crater could have formed along a *fissure eruption* (Figures 2.3, 2.4).

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 lava advances 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 4.11).

As pahoehoe loses gas and cools it becomes frothy and stiffer. 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 channels builds up *levee* banks of thin sheets or spatter. Larger flows across a 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 occur at Mount Eccles (Figure 2.3). A number of shallow lava tubes are known in overflows that have run off to the sides from these channels (Grimes, 1995 & 2008; Figure 4.3).

Lava tubes provide good insulation for the hot lava flowing within them. This allows the formation of very long flows such as the 50 km Tyrendarra Flow from Mount Eccles and the older 60 km flow from Mount Rouse (Figure 2.2); but the large feeder tubes that must have formed the Mt. Rouse flow seem not to have drained and only one small cave is known.

Drainage modifications

When a lava flow enters or follows a valley, as in the Harman Valley flow from Mt. Napier and the Tyrendarra flow from Mount Eccles, it disrupts the drainage. Twin *lateral streams* may run down each side of the original valley. In some areas streams were diverted repeatedly by successive lava flows to end up many miles from their original position. *Swamps or lakes* will form where the flow enters the valley, and where tributary valleys have been dammed by the flow. Lake Condah and other wetlands provided an opportunity for Koori (Aboriginal) engineering to make a complex pattern of fish traps (see History section, page 7). The volcanoes, especially the scoria cones, are significant recharge points for the regional groundwater.

Overview of the Lava Cave areas and their Volcanoes

Lava tubes and other volcanic caves are scattered across the province (Figure 2.1), but the majority of them are in the western area where they are associated with two of the younger eruptions in the region – Mt. Eccles and Mt. Napier (Figure 2.2; Webb & others, 1982; Grimes & Watson, 1995; Grimes, 2008). Brief summaries are given below. See Chapter 4 for discussion of the genesis of the different types of tube and cave, and Chapter 5 for detailed descriptions of caves to be visited during the ISV excursion.

At **Mount Eccles** the main volcano is a deep steep-walled elongated crater which contains Lake Surprise (Photo 2.4). At the north-western end, the crater wall has been breached by a lava channel that flows west and then branches into two main channels (referred to locally as "lava canals") running to the west-northwest and to the south-southwest (Figure 2.3; Grimes, 1995). Extending to the southeast from the main crater there is a line of

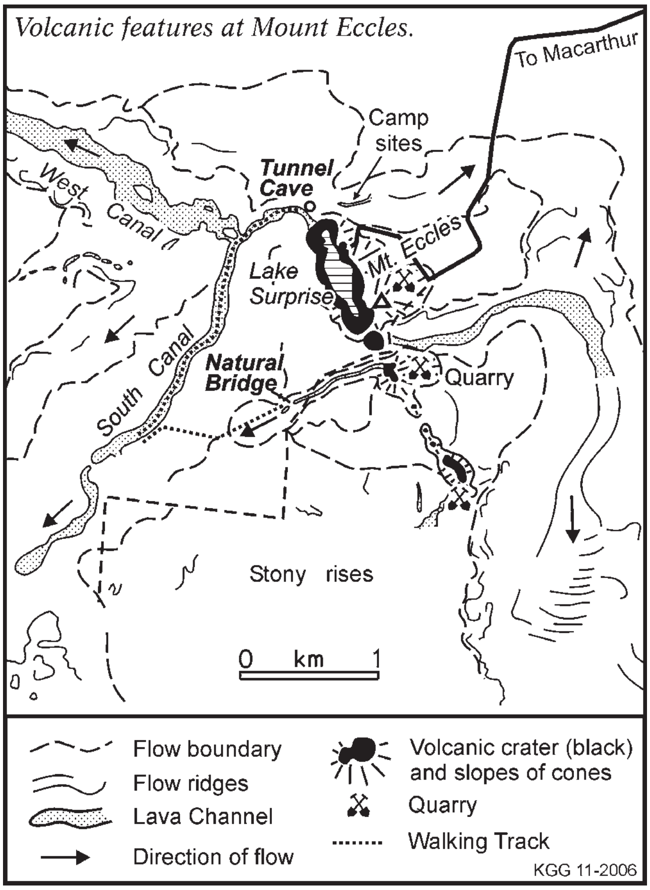


Figure 2.3: The Mt. Eccles (Budj Bim) Fissure Volcano, with its lava channels.

Figure 2.4: Lake Surprise, Mt. Eccles, and the line of smaller craters, looking east. [LE]

smaller spatter and scoria cones and craters which may have been initiated as a fissure eruption. Two of these smaller craters have lava channels running out from them. Lava caves occur here in a variety of settings:

- many small subcrustal systems ranging from isolated small chambers ("lava blisters") under mounds in the stony rises to complex mazes in overflow sheets from the larger surface lava channels;
- one large developed tube (Tunnel Cave);
- one cave formed by the overgrowth of levees across a surface channel (Natural Bridge); and
- one small open volcanic shaft (The Shaft, see page 23 for details).

Beyond this central area of explosive activity, basalt flows form a lava field about 16 km long and 8 km across. From the western end of this lava field a long flow, the Tyrendarra Flow, runs 30 km southwards to the present coast and continues offshore for a further 15 km (Figure 2.2); sea level was lower at the time of the eruption, 30,000 years ago (Builth & others, 2008). This long flow must have had a major feeder tube, but no drained sections have been discovered to date.

Mount Napier and the Harman Valley flow: Mt. Napier, about 20 km northeast of Mt. Eccles, is a steep cinder cone capping a broad lava shield 10 km in diameter (Whitehead, 1991; Figures 2.5, 2.6). The lava spilled into the pre-existing Harman Valley, dammed up Buckley Swamp and flowed downstream for at least 20 km to the west. Some lava caves occur on the lower slopes of the steep scoria cone, and on the lava shield, but the main cluster is at the **Byaduk Caves** (Figure 5.19) where there are both large feeder tubes at depth and shallow subcrustal caves, including one stacked multi-

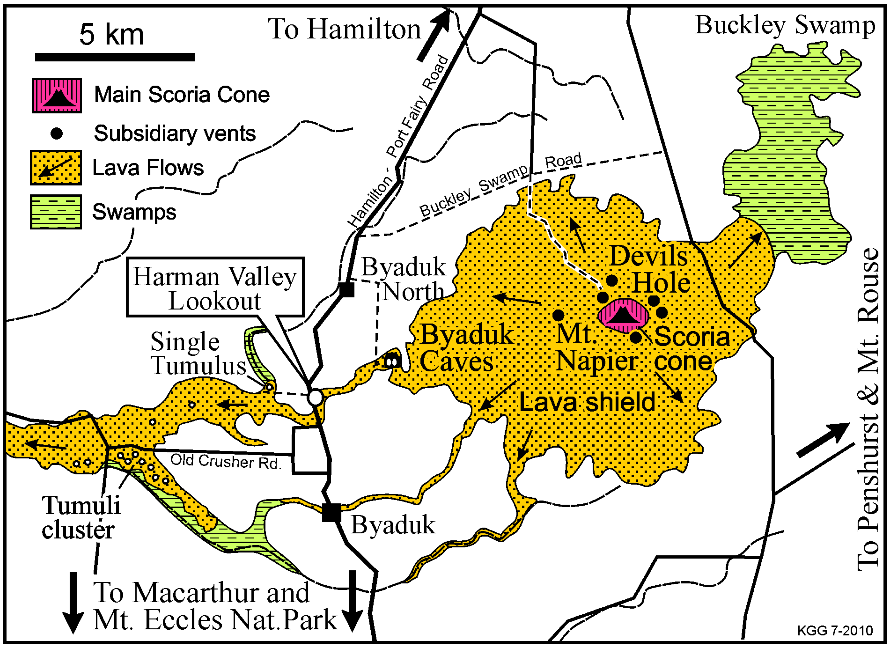


Figure 2.5: The Mt. Napier volcano, lava shield and valley flows; with dammed swamps. Photo 2.6 is taken looking east from the Harman Valley Lookout.

Figure 2.6: View to east from the Harman Valley Lookout (Figure 2.5), showing the scoria cone and lava shield of Mt Napier, and the lava flow running down the valley in the foreground [KGG].

level system (see pages 31-37 for details). Other lava caves (large and small) occur further down the valley, as do an excellent set of sharply-defined tumuli (see page 31; Ollier, 1964b). It was at the Byaduk Caves that Ollier & Brown (1965) derived their "layered lava" model of tube formation.

Mount Fyans, further to the east (Figure 2.1), is a broad lava shield with a small scoria cone. The cone has been badly defaced by a quarry; however, one benefit of this is that it has exposed an unusual small cave (3H-105) in a large basalt dyke that intrudes the scoria; and several smaller partly-drained lava bodies (see page 21 and Grimes, 2006). The surrounding stony rises have some particularly elegant and distinctive dry-stone walls that were constructed by early British settlers (photo 2.7).

Mount Hamilton is a lava shield surrounded by stony rise lava flows. There is a large lava crater at the summit 350m across and 40m deep. One group of complex lava tubes occurs on the slopes of the shield (3H-2 etc; see page 20; Ollier, 1963a).

Mount Widderin (near Skipton) is a broad, low lava shield with extensive stony rise lava flows running to the south and west. The Mt. Widderin Cave (3H-1, also known as the Skipton Cave) is on the NW flank, near the homestead. It has two large chambers and a shorter, partly collapsed, passage with small lake ((Ollier, 1963b; see page 19).

Other caves and cave areas:

Other caves in the province are listed below, but will not be visited during the ISV excursion. More detailed descriptions of many of these are given in Webb & others (1982) and in the reports cited below. See Figure 2.1 for locations.

Gisborne Bone Cave (3H-27) is a small cave in weathered tuff near Mt. Macedon (Selwyn, 1859) that appears to be erosional pseudokarst, or perhaps even dug by "fossorial animals" (Gill, 1964).

Mt. Gambier: There are two small erosional caves in the scoria of the western crater (5L-256 and 257; Horne, 1993)

Mt. Rouse: Huttons Cave (3H-81) is a collapse doline with a small cave in rubble, and a pond that possibly connects to an underwater tube (VSA Records). A few small lava dribbles down the fractured doline wall indicate that the collapse occurred during the eruption.

Panmure (3H-5) is a single branching lava cave with 100 m of passage length. See map in Ollier & Joyce (1968).

Parwan (3H-4) is a 300 m tube in a relatively old lava flow (2.4 to 2.7 Ma). It is a small irregular lava tunnel which has been modified by a rockfall. There are lava stalactites and phosphate minerals (taranakite (hydrated alkali iron-aluminum phosphate) and parwanite (hydrated Na-Mg-Al-phosphate)) described by Birch & Henry (1993). There is a map in Rees & Gill (1959).

Porndon: An unusual volcano with a lava "disk" surrounding the central cones. There are two well-formed lava caves up to 100 m long (3H-6 & 7). See maps and descriptions in Ollier & Joyce (1968) and Webb & others (1982).

Skipton: (see Mt. Widderin, above and page 19)

Smeaton: Armchair Shaft (3H-47) is a small, 10 m deep, open hornito (map by D.Smith in Webb & others, 1982). There is a second, mostly plugged, hornito nearby.

Warrion Hill: This area has five small caves (3H-34 to 38) up to 50 m long.

Figure 2.7: Dry-stone wall and gateway beside the Woorndoo-Dundonnel Road, Mt. Fyans area [KGG].

The Background Stories

Elery Hamilton-Smith & Ken Grimes

The Aboriginal perspective and actions

The Indigenous people would have seen eruptions of the more recent volcanoes, including both Mt. Napier and the associated lava flows through the Byaduk Caves; and Mt. Eccles (known by the indigenous Gunditjmara people as Budj Bim) with the associated damming of Lake Condah. Regrettably, the slaughter by early white settlers and unfamiliar illnesses mean that we have little record of the way in which they used the volcanic narrative in their stories of the dreaming. However, Builth (2004) reports that *in 1870 the Portland Guardian published a Gunditjmara local oral history that revealed witness of volcanic activity and the associated tsunami that was said to have drowned most of the people*.

At Lake Condah, and elsewhere along the lava flows of Mt. Eccles and Mt. Napier, there are remarkable examples of hydrological engineering (Coutts & others. 1978; Builth 2004; Wettenhall, & others, 2010; Figure 3.1). The water flow through the Lake Condah system was supplemented by excavated canals each up to a metre deep and 300 metres in length linking the Darlot Creek area to the lake. A complex system of stone fish traps were then built to capture the large eels and other fish. The lake overflows into the adjoining lava flows and sinks into natural hollows. Some hollows have been walled off to prevent water loss through them. This water flows along both natural and artificial channels with fish traps.

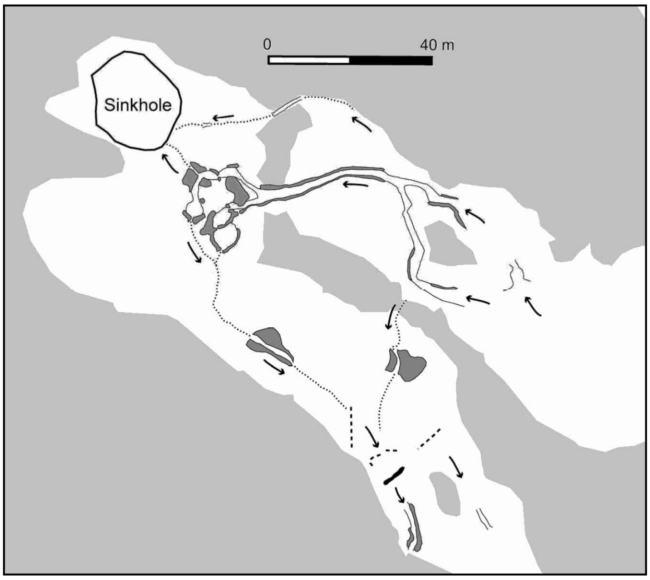


Figure 3.1: Map of fish traps and artificial channels leading to a natural sinkhole in the stony rises near Lake Condah. Light grey and white areas are the natural rises and hollows. Dark grey is artificial rock constructions. Arrows indicate water flow. From McNiven (2009).

In turn this led to the construction of permanent stone-based houses. Some 175 sites have been identified, with 146 of these clustered into a village. It is estimated that some 700 people lived on site, and doubtless many more visited in season. Regrettably, the pioneer Whitefellas demolished the houses, and even a number of fish traps, to use the stone in building their own homes.

It is no surprise that they used some of the caves for shelter. Both the Tunnel (H-9) at Mount Eccles and Church Cave at Byaduk have evidence of extensive use in erosion and some markings of the walls with occupational debris buried in the floor at common gathering sites. Some of the evidence which Hamilton-Smith and Tindale identified in the 1950s has been damaged by more recent visitor impacts. A systematic search would doubtless find evidence in other lava caves or overhangs.

Clark (2007) reports unpublished papers by Mathews (c. 1890) that refer to harming practices that used the sinkholes at the Byaduk caves. Huttons Cave (H-81), in the Mt. Rouse lava flow, appears to have special significance as its European owner reports that there was an Aboriginal burial there in the late 1930s (Tim Hutton, pers. comm., 1995). In the H-87 cave, at the north edge of the Mt. Eccles lava field, there is a small stone wall at the back of the entrance shelter which gives protection from a cold breeze arriving through a side tunnel (Grimes, 1997). Was this an Aboriginal or European construction? It is hard to tell.

White Fella settlement

Early permanent European settlements were established in the early 1830s at both Portland and Melbourne. Their impact upon the indigenous people was almost universally disastrous.

The beginning settlement was extended following Major Thomas Mitchell's glowing accounts of the potential grazing capacity of the Western Plains as squatters settled along the route of Mitchell's return journey. The region was largely grassy woodland but with some more heavily timbered areas. This meant that not only were many of the volcanic sites self-evident, but the entrances to both lava tubes and karst caves were easy to see. In 1843, George Augustus Robinson was led into Mt. Widderin Cave (H-1) near Skipton and drew what is probably Victoria's first cave map (reproduced in Clark, 2007 and here as Figure 3.2)

An indicative overview is provided by James Bonwick's 1857 narrative of his horseback journey across Western Victoria. He saw various cave sites from his saddle, and was directed to others by his hosts,

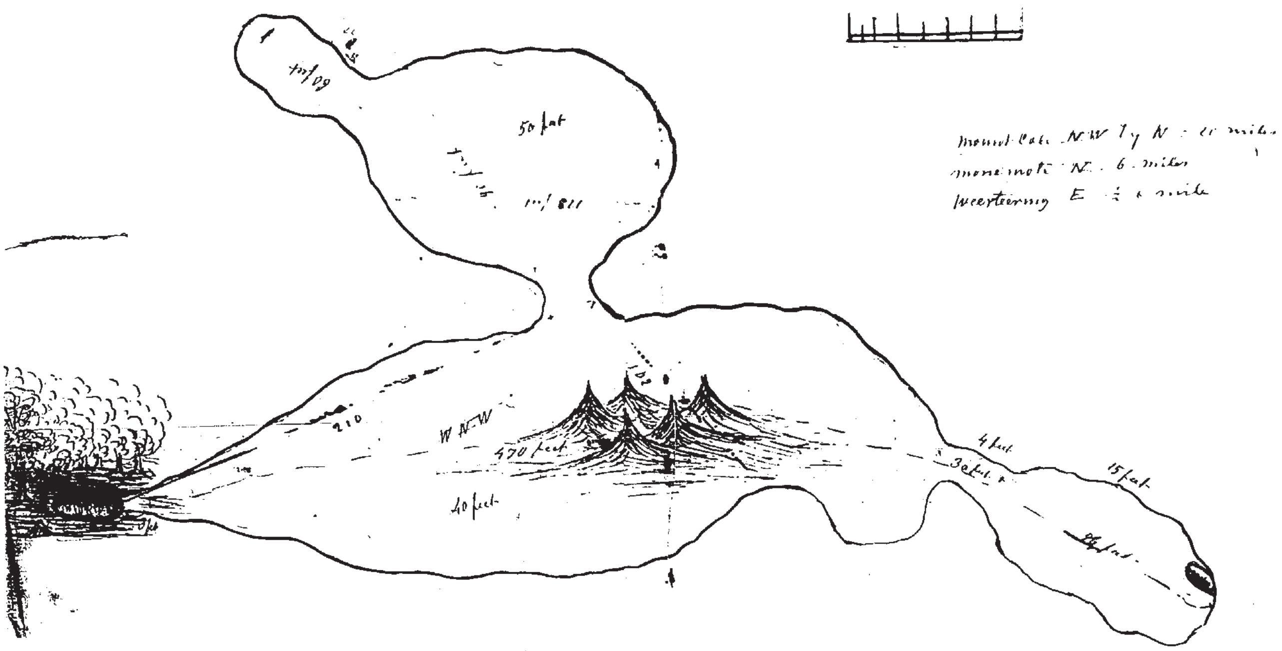


Figure 3.2: Robinson's 1843 map of the cave at Mt. Widderin, near Skipton. Note his depiction of the guano piles, since removed. From Clark (2007).

several of whom were indeed personally interested in and proud of the caves on their own properties.

He refers to various lava caves (and other sites) in the volcanic areas:

- The Stony Rises to the West of Colac
- Porndon Arch caves, where he gave due emphasis to the presence of the bats, and found that some settlers were using the guano as garden fertilizer.
- Groundwater springs at Mt. Noorat
- Various caves, in both lava and limestone of the Warrnambool area. There was already considerable quarrying for building stone in this area.
- Numerous unidentified caves in the Mt. Eccles – Darlot Creek volcanics
- Portland and the Limestone coast area, including the volcanic peaks but without any reference to lava caves.
- The Wannon Falls with an undercut cave, behind the foot of the falls.
- Both Mt. Eccles (using Mitchell's original name of Mt. Eeles) and Mt. Napier are briefly discussed, but regrettably, Bonwick did not visit them.

Over the years, other sites were recognised by landowners and/or others, including Gisborne, Panmure, Parwan, Skipton, Smeaton and Warrion Hill (Figure 2.1). Scientific investigations commenced with descriptive accounts by Alfred Selwyn, Director of the Geological Survey of Victoria and his staff. Of the further caves, the only one that attracted significant interest and visitation was Mt. Widderin Cave at Skipton (Selwyn & Ulrich 1866). The complex phosphate minerals of this Cave attracted great attention from mineralogists in both Victoria and in Europe (see review in Webb, 1997).

Bat guano was harvested from Skipton and Porndon as a fertilizer for farms and domestic gardens. The large flat-floored chambers at Mt. Widderin (Skipton) and Tunnel Cave (Mt. Eccles) were used for parties and balls up till quite recent times. Mt. Widderin Cave has graffiti dating back to 1856. The pools in Mt. Widderin and Huttons caves have been tapped for farm water supplies. H-57 cave in the Harman Valley was used as a cellar and has meat hooks and a drip shield within it (VSA records).

Modern Times

The volcanoes of the region attracted quarrying of basalt and scoria, but apart from at Mt. Eccles and Mt. Fyans there appears to have been little significant damage to caves or other features of speleological interest. Regrettably, the worst impacts adjoin and also occur to the South of Mt. Eccles where quarrying and agricultural activities have left unsightly views and destroyed two small caves including what was possibly a second volcanic shaft (The Pit, H-29, Ollier, 1964a).

The second half of the 20th century saw an immense increase in exploration, research and (often informal) tourism. This was in three phases: the 1960s were a time of scientific studies and small-scale mapping by Cliff Ollier and others; the 1970-80s saw further exploration and more detailed mapping by members of the Victorian Speleological Association (VSA) and by Lionel Elmore of the Hamilton Field Naturalists; and in the 1990s activity was focused on the Mt. Eccles and Mt. Napier areas, and involved the VSA and the Friends of Eccles and Napier (FEN).

In the 1960s, probably one of the most interesting discoveries was the complex network of small tunnels of over 1,000 metres in total length in the relatively shallow cave at Mt. Hamilton (H-2; Ollier, 1963a). Many new (often small) caves were discovered and surveyed by speleologists, while earth scientists, particularly Ollier, Brown and Joyce, described the caves in detail, making significant contributions (even though partly superseded since) to understanding of the processes which contributed to lava tube structures (see bibliography in Webb & others 1982).

Hamilton-Smith (1968, 1972) and Simpson & Smith (1964) studied the bat populations and the invertebrate fauna, primarily in Skipton Cave and some of the Byaduk Caves. There is also an interesting study of the ecology of Tunnel Cave by a group of students (Johnson and others, 1968). Wakefield (1963, 1964a,b) studied bone deposits in several of the caves.

In the 1970-80s VSA was working in most of the volcanic sub-areas, and produced some good cave maps (e.g. by Tom Whitehouse, Dave Smith, Miles Pierce, Peter Robinson, and Peter Matthews), but there was limited publication of these. Lionel Elmore (Hamilton Field Naturalists) described many caves on the slopes of Mt. Napier (Gill & Elmore, 1974), and many of these were surveyed by Dave Smith & others in 1983, but never published. Webb & others (1982) included the west Victorian volcanic region in their comprehensive review of the lava caves of eastern Australia.

In the 1990s, stimulated by a conference of the Australian Speleological Federation at Hamilton in 1995, exploration and detailed mapping with geological interpretations was focused in the Mt. Eccles and Mt. Napier areas, and involved both the VSA and the Friends of Eccles and Napier (which was active from 1994 to 2001). As well as mapping of new caves, there was fair-drawing and publication of many earlier VSA maps with addition of extra detail, sections etc by Ken Grimes. Several of Ollier's small-scale maps were also upgraded or completely resurveyed. The Friends Group produced and erected interpretation signs at the Byaduk Caves and published leaflets on Tunnel Cave and Natural Bridge at Mt. Eccles. Grimes published new views on the formation of the smaller shallow lava caves (Grimes, 1995, 2008). Elsewhere, Bridge (1971) and Birch both carried out further studies on the phosphate mineralogy of Skipton and Parwan and an excellent summary of knowledge is provided in Birch and Henry (1993, pp.121-149).

The re-birth of Budj Bim

For an excellent detailed overview of this theme see Wettenhall, & others (2010). The new century saw the indigenous Gunditjmara people come together and establish a Traditional Owners Aboriginal Corporation (Gunditj Mirring) to work together with the state government and establish a co-managed National Park. This includes the former Mt. Eccles National Park, Lake Condah, the Tyrendarra lava flow and other traditional tribal lands.

This co-operative development led in turn to a strong commitment to the proper recognition of the ***Budj Bim National Heritage Landscape***. In 2007, the Federal Court of Australia handed down the Gunditjmara Native Title Consent Determination. Then in 2008, Lake Condah was also formally returned to the Gunditjmara people by the State of Victoria. A program of blocking the European drains and reflooding Lake Condah is nearing completion (Wettenhall, & others, 2010).

Alan Gould: Park Ranger Extraordinaire

In 1964, the Mt Eccles National Park was expanded by the addition of farmland formerly owned by Alan Gould, and Alan remained in residence as the first on-site ranger at Mount Eccles.

Alan had a remarkable style of operation. Each morning he would go to the campground and talk with visitors, often sharing their morning coffee.

He would then call out to describe his work for the day and invite anyone interested to join with him. Thus, at the one time, he achieved a high level of park improvement or maintenance while fostering the interest and understanding of visitors.

He always particularly welcomed people from within the region, and many of them became frequent visitors with a genuine personal commitment to the Park. I particularly remember his retirement. Some of us arranged a day with Alan for a farewell party and then printed and scattered invitation posters for a BYO-everything throughout the region. On the appointed day, an incredible crowd appeared, and cars were parked alongside the roads for miles!

It was truly a great tribute and thank you to Alan for his great and very infectious enthusiasm.

Allan was followed by two other dedicated rangers, Andy Carmichael and Geoff Sharrock, who both continued his policy of close personal involvement with visitors to the park. Andy Carmichael unfortunately died suddenly in 1993; his popularity was indicated by the 500 people who attended his funeral.

The Genesis of the Volcanic Caves – Large and Small

Ken Grimes

Introduction

Most documented lava caves around the world are large, linear or anastomosing, tubes. However, increasing numbers of small shallow caves are being recorded that have complex patterns of interconnected low-roofed chambers and small passages. These "subcrustal" lava caves appear to form at shallow depth in broad lava lobes, or smaller lava mounds or tumuli, by a process of drainage from beneath thin crusts.

Somewhat larger lava tubes can form by roofing of lava channels. These tend to be less complex than the subcrustal systems.

In long-lasting lava-flow systems, continuing evolution of both the roofed channels and the subcrustal systems in the upstream parts of the flow can produce simpler linear tubes and eventually large "feeder-tubes". A continuum of cave forms results: ranging from simple "lava blister" chambers, through irregular networks of chambers and connecting passages to large linear conduits. Modifications in the later stages can obliterate the evidence of the original genesis.

The ISV field trip will visit examples in the Western District Volcanic Province of Victoria that cover the full range of sizes and types.

Terminology

The terminology of surface lava flow features and their caves has become rather complex and confusing in recent years, so I will list here some terms, and my intended usage. See also discussion in Grimes (2008)

Surface lava features

The local usage of *stony rises* for the fields of chaotic mounds and hollows found on our younger lava flows (Photo 1.1) seems to correspond to the *hummocky pahoehoe* of Hon & others (1994), but some flows have relatively flat surfaces that correspond to their *sheet flows* and there are also transitional forms. In Walker's (1991) terminology the Victorian *stony rises* represent a mix of his *tumuli* (*sensu lato*), *pressure ridges*, *lava rises* and *lava rise pits*.

In Victoria, the usage of *tumulus* has always been restricted to the distinctive, steep-sided, roughly-circular mounds described by Ollier (1964b) in the Harman Valley. Walker's (1991) broader, but genetic, definition is difficult to apply in the relatively old (20-40,000 year) lava flows in Victoria, where weathering and tree roots have reduced much of the surface to a cracked and jumbled rubble, making Walker's definitive axial clefts difficult to identify (Grimes, 2008).

Caves

In any discussion of lava tubes and lava caves and their genesis, it is important to distinguish between active (lava-filled) cavities and the drained tubes and chambers (i.e. caves) which appear at the end of the eruption.

As discussed below, the term *subcrustal lava caves* is used here as a broad term for all the small shallow caves that form by drainage from beneath a broadly-crusted lava flow. These include the *surface tubes* of Nieuwenhuis (1992) and Larson (1993).

Proto-tube is a term introduced by Grimes (2008) for the very small tubes that seem to be the earliest stage in subcrustal drainage (page 11).

In Victoria, speleologists have used the term *blister cave* for the small, simple, isolated chambers found under the stony rises (Figure 4.2). However, care is needed to avoid confusion with another usage of that term for small chambers formed by gas pressure (Gibson, 1974, and Larson, 1993). Grimes (2008) suggested usage of *lava blister* for those inflated by liquid lava and later drained, and *gas blister* for those generated by gas pressure.

Halliday (1998a & b) described two types of small lava cave: *sheet flow caves* and *hollow volcanic tumulus caves,* which he regarded as being distinct. Grimes (2008) argued that these are probably just two of several possible members of a continuum of forms which have been referred to as *subcrustal lava caves*.

Types of Lava Cave found in the Western District Volcanic Province

Overview

In the late Quaternary lava flows of Mount Eccles and Mount Napier, and elsewhere in the Western District Volcanic Province, we find a range of cave types. The simplest and smallest type are the isolated lava blister caves. More interesting are the small subcrustal systems of shallow low-roofed chambers and small connecting passages that in places can form complex three-dimensional networks.

The larger branching and anastomosing lava cave system at Mount Hamilton appears to be a further-evolved "feeder" system. The big feeder tubes at Byaduk and elsewhere may have evolved still further.

The following is based on the descriptions in Grimes (2008).

The subcrustal lava caves.

The shallow lava caves of western Victoria involve a broad array of styles ranging from simple single chambers to multi-level, complexly-interconnecting systems of tubes and chambers. All gradations occur between these extremes, but the group has in common the dominance of shallow, low-roofed, irregular chambers and small-diameter tubes. They also grade into larger and more-linear tubes. Thus, while we can identify several distinctive types, there are many transitional forms that are hard to classify. Their genesis is discussed in more detail below (page 15)

Small Proto-tubes

In the walls of some lava caves, and exposed in thin lava flows in cliffs, there are occasional, very small, vertically compressed, and partly-drained tubes. These are typically less than half a metre wide and only a decimetre or so high (photo 4.1, and see also figure 9 in Halliday, 2002). They seem to be the earliest stage in the appearance of an organised tube drainage within a new lava flow lobe or sheet.

In some flow units, these proto-tubes can be confused with gas pockets where vesicles have coalesced. The latter can be distinguished as they typically have hackly (burst bubble) walls and no lining, whereas the proto-tubes commonly have a lining 10-20 cm thick, with smooth walls or lava drips and other structures typical of larger lava tubes.

Proto-tubes are generally too small to enter, so technically are not “caves”. The small cave 3H-52 (Photo 4.6), could be considered to lie near the boundary between a proto-tube and a true lava tube.

Simple lava blister caves

Scattered through the stony rises there are small, shallow, low-roofed chambers; typically only a metre high with a roof a metre or less thick. These can be circular, elongate or irregular in plan; up to 10m or more across but grading down to small cavities only suitable for rabbits. These caves generally are found beneath low lava mounds, although in some cases the surface relief may only rise half a metre. Some Victorian examples are shown in Figure 4.2, and include Turtle Cave (which looks like an empty turtle shell) illustrated in Figure 5.30. In section, the outer edges of the chambers may be smoothly rounded or form a sharp angle with a flat lava floor. The ceiling may be arched or nearly flat, with lava drips, and sometimes has a central “soft” sag that would have formed while the crust was still plastic. Commonly, the thin central part of the roof has collapsed and we find only a “peripheral remnant” hidden behind rubble at the edge of a shallow collapse doline, or circling a sagged centre (e.g. H-78, Figure 4.2, and see map of Christmas Cave, Hawaii, in Halliday, 2002).

Figure 4.1: A small *proto-tube*, with 20 cm thick lining, exposed in the wall of a larger, more-evolved, tunnel in the Mt. Hamilton lava cave. Scale bar is 10 cm [KGG].

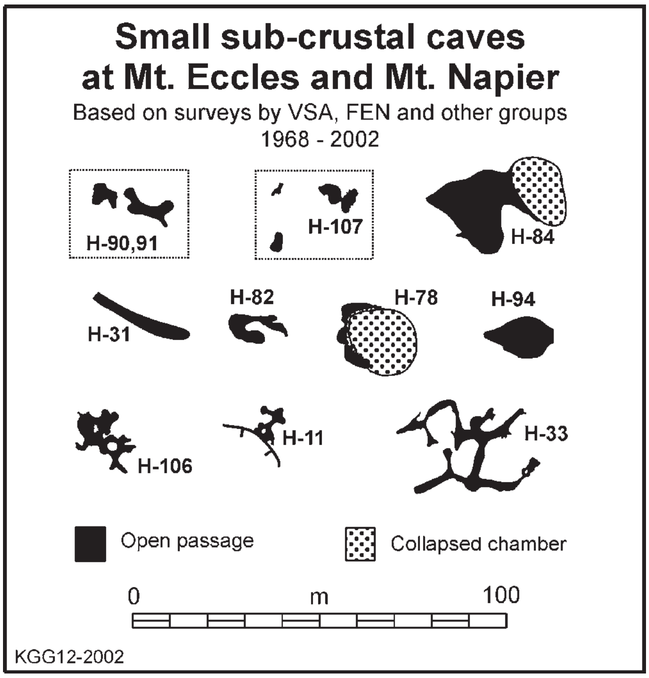


Figure 4.2: Examples of small, simple, subcrustal caves; mostly associated with low lava mounds. H90, 91 and 107 would be called “lava blisters”; H-82 and 78 are “peripheral remnants” left by the sag or collapse of the roof of shallow chamber; H-31 is approaching a linear “tube” form; H-11, 33 and 106 are grading to the more complex forms.

The more elongate versions of these simple caves grade into short tubes; for example, Shallow Cave (H-31, Figure 4.2) described by Ollier & Joyce (1968, p.70).

Complex systems in lava lobes and sheets.

More complex caves associated with the lava channels at Mt. Eccles are generally shallow systems formed in the levee banks on each side of the channels and would have fed small lateral lava lobes or sheets when the channel overflowed or breached through the levee (Grimes, 1995, 2008). Figure 4.3 shows the lateral caves associated with the South Canal at Mt. Eccles, and

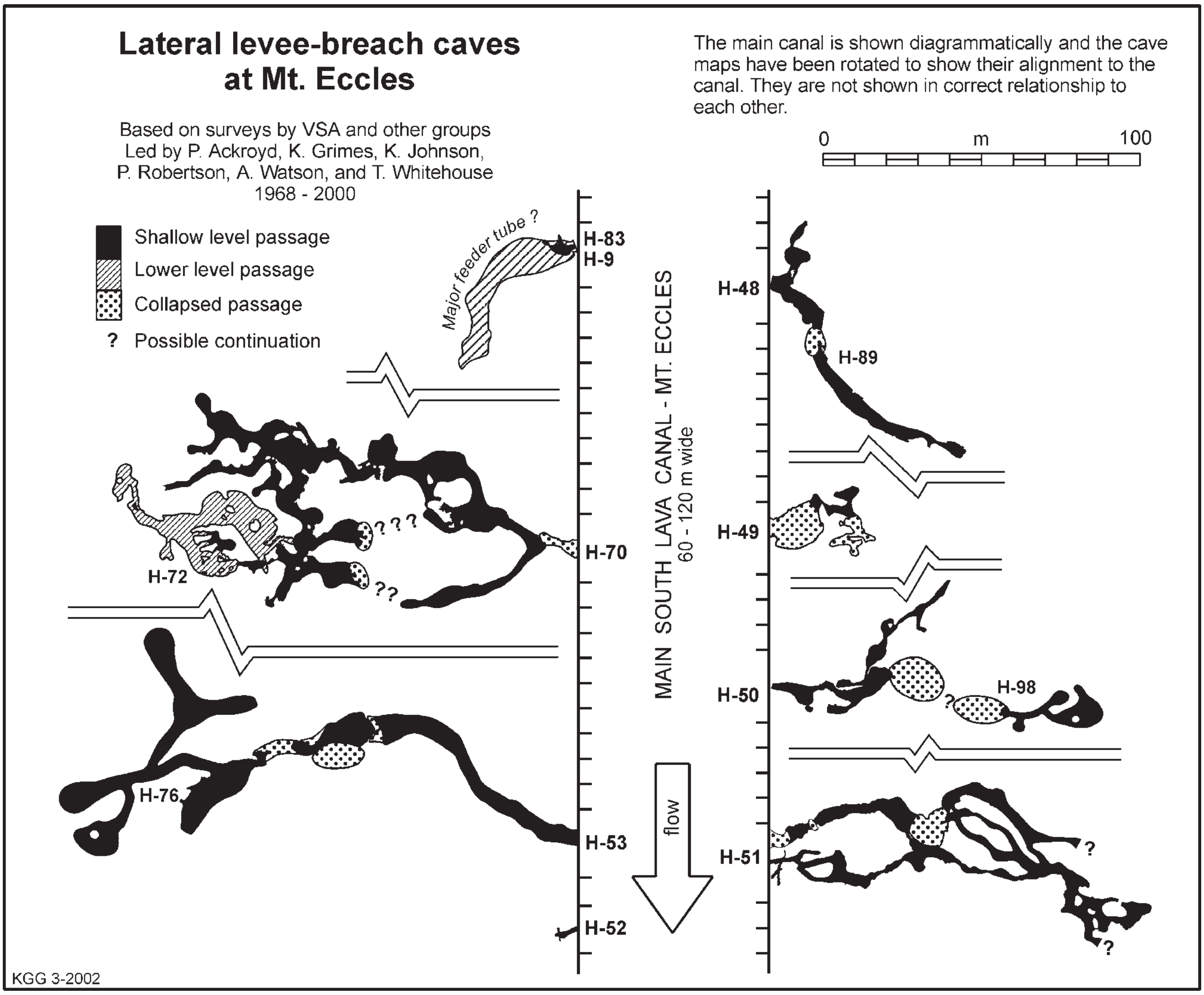


Figure 4.3: Examples of more complex subcrustal caves formed in thin overflows from a lava channel at Mt. Eccles. See Maps 5.13, 5.15, 5.18 for details of H-51, 52, 53, 70/72.

Figure 4.4 shows a group of shallow caves adjacent to a large collapsed feeder tube at Byaduk.

Some of these caves are simple linear tubes (e.g. H-48, 89, and the proximal part of H-53), but mostly they are branching systems with complexes of low passages that bifurcate and rejoin, or open out into broad low chambers. The shape suggests draining from beneath the thin solidified roof of a series of coalesced flow lobes. Only a few of the passages are large enough to stand in, typically (but not always) those nearest the proximal end – the channel entrance (e.g. H-48, H-53, H-70). Most passages are crawl-ways about a metre high with low arched roofs and flat lava floors (Photos 4.5, 4.13). Some of the smallest passages have smoothly-rounded cross-sections (Photo 4.6). The ceiling is generally only a metre or so below the present surface, and in places breakdown has exposed the base of overlying pahoehoe flows, indicating that the original roof was less than a metre thick. In some chambers the roof has sagged down in a smooth curve to reach the floor (Photo 4.7). Where not covered with introduced soil or breakdown, the floors are generally pahoehoe, with smooth, platy or ropy surfaces; but sharp aa lava floors occur in several places (e.g. H-51 and H-70). Some of these are late-stage invasions; running over an earlier pahoehoe floor.

Where not disrupted by breakdown, the walls and roof typically have thin (2 - 20 cm) linings. These conceal the original wall, but in a few places fallen linings have exposed layered lava comprising thin sheets with ropy or hackly surfaces (eg the proximal end of H-70). Most caves are at a single level, but some show evidence of several levels (only a metre or so apart vertically) that either have coalesced vertically into a single passage or chamber or are joined by short lava falls (e.g. H-48, H-70 (Map 5.18, photo 5.17) and H-108).

At Byaduk, three caves occur in a stacked set of thin, 1-3 m, lava flows exposed in the wall of a large collapse doline (H-74, 106 & 108; Figure 4.4). The elongated doline formed over a deeper large feeder tube (up to 25 m wide and 15 m high) and the thin flows may have been fed by overflows from the feeder tube, through roof windows. The three shallow caves comprise low-roofed branching passages and chambers very similar to those

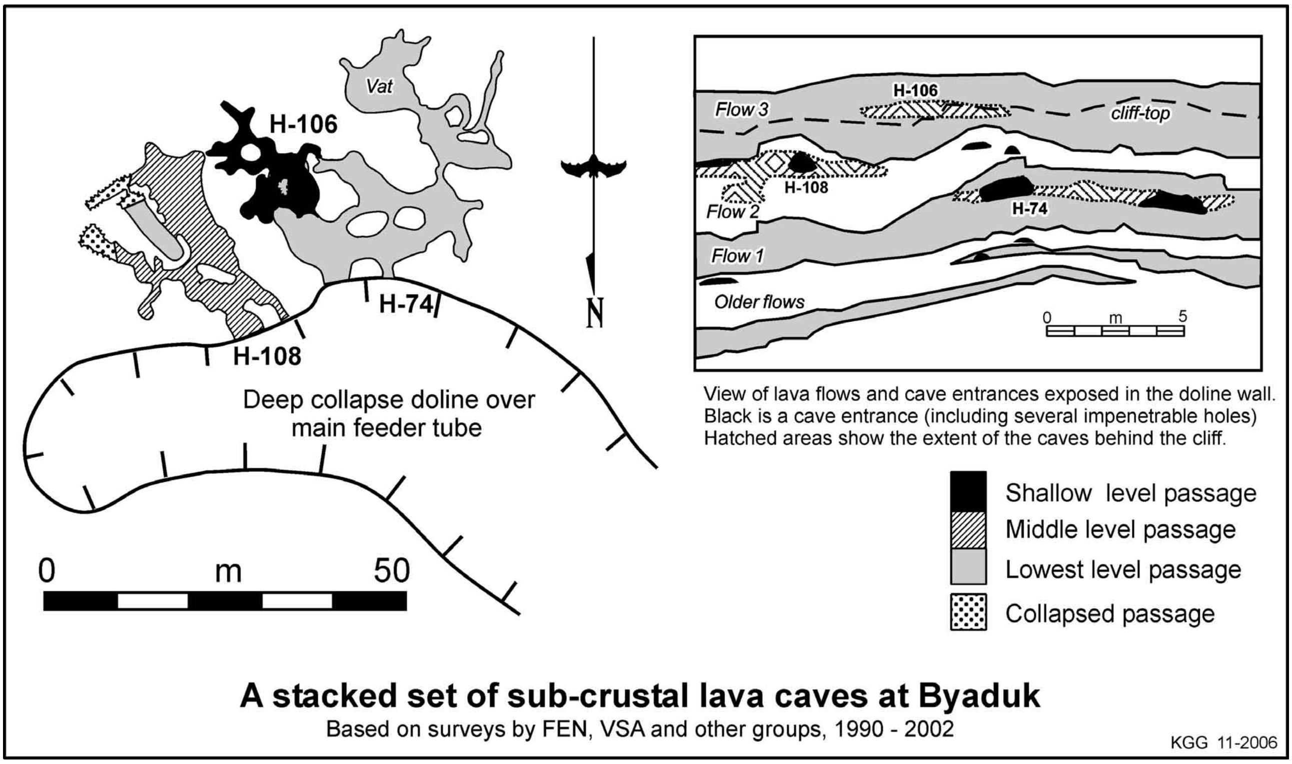


Figure 4.4: A set of three small subcrustal caves formed in separate stacked lava flows at Byaduk.

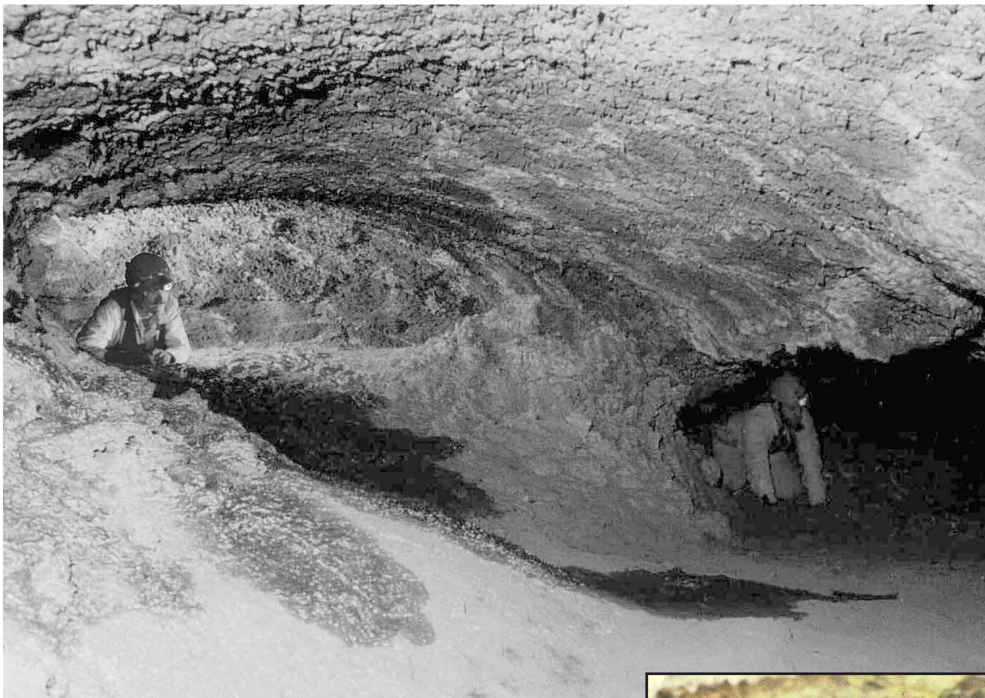
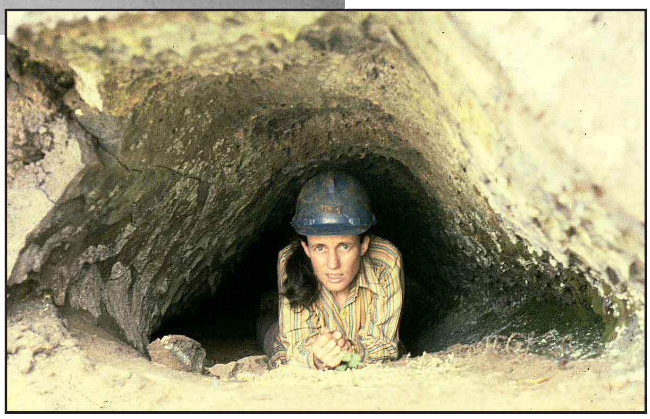


Figure 4.5: Caves formed by draining of lava lobes tend to have low broad chambers and passages. Photo in 3H-70, looking south from section X22 of Map 5.18. Note the "window" over a mound on the left which might be the remains of a partition between two lava lobes [KGG].

Figure 4.6: Small sub-crustal tube, H-52 at Mt. Eccles [KGG].



found beside the channel at Mount Eccles (Figure 4.3). In all three caves there are intrusive lava lobes that may have entered through roof holes from the overlying lava flow. In the middle-level cave (H-108) a lava fall drops a metre to a short section of lower-level passage that might be in the same flow as H-74, but does not connect to it.

Multi-level Systems

More complex stacked systems also occur. These can be fed from below, through a skylight in a major feeder tube, or laterally from a remote source.

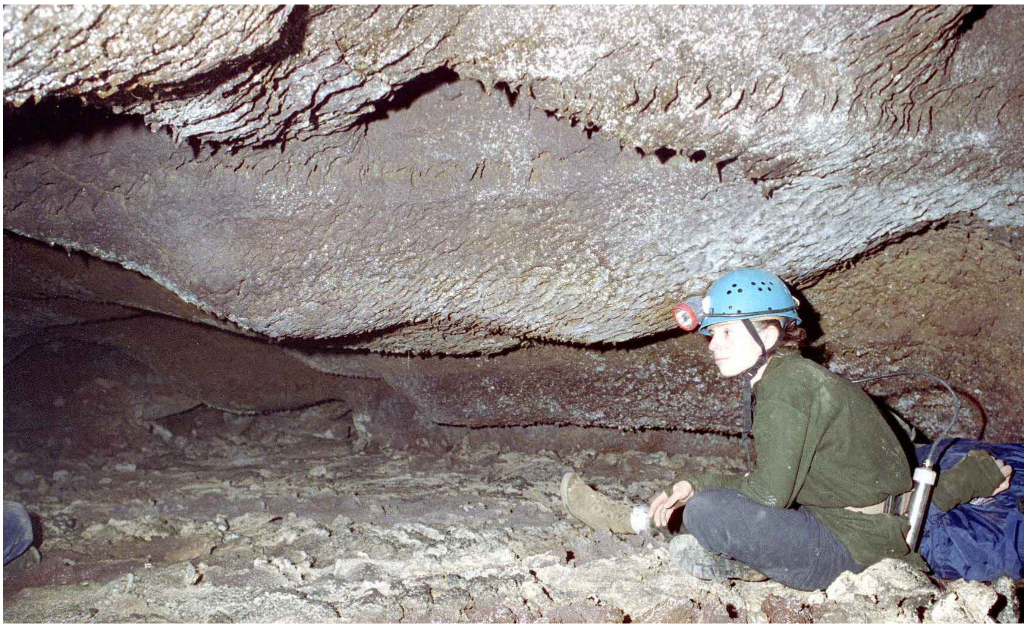


Figure 4.7: Chamber in H-74, showing sagged parts of roof. [KGG]

The upper level of The Theatre (H-33, Figure 4.8, 5.25) is a small subcrustal cave system obviously fed from below as the shallow branching tubes occupy an isolated raised mound and a drain-back tube allows access to lower levels of low-roofed chambers and eventually to a large feeder tube at depth (Photo 5.29). Lava would have welled up from this lower level and formed the surface rise in several stages (the different "levels"), then drained back to leave the small tubes and chambers.

Fern Cave (H-23, Figure 4.8) comprises a large feeder tube at depth, but there is a higher level of low-ceilinged irregular chambers and passages which appears to be in a younger flow that ran over the prior-roofed tube. This upper flow seems to have been fed from a large collapsed tube to the south, which might have been an open channel at that time. The present connections between the upper and lower levels of Fern Cave are later accidents of collapse of the lower tube roof.

More evolved systems

The Mount Hamilton Cave (H-2) is a complex system of moderately large (up to 6 x 5 m) bifurcating tubes at several levels (Figure 5.2; Ollier 1963a; Webb & others, 1982). It is dominated by linear tubes rather than the broad low chambers typical of the many smaller caves described above which may indicate a more evolved style of larger subcrustal lava cave (see below). Small proto-tubes are exposed in the walls and ceiling of the

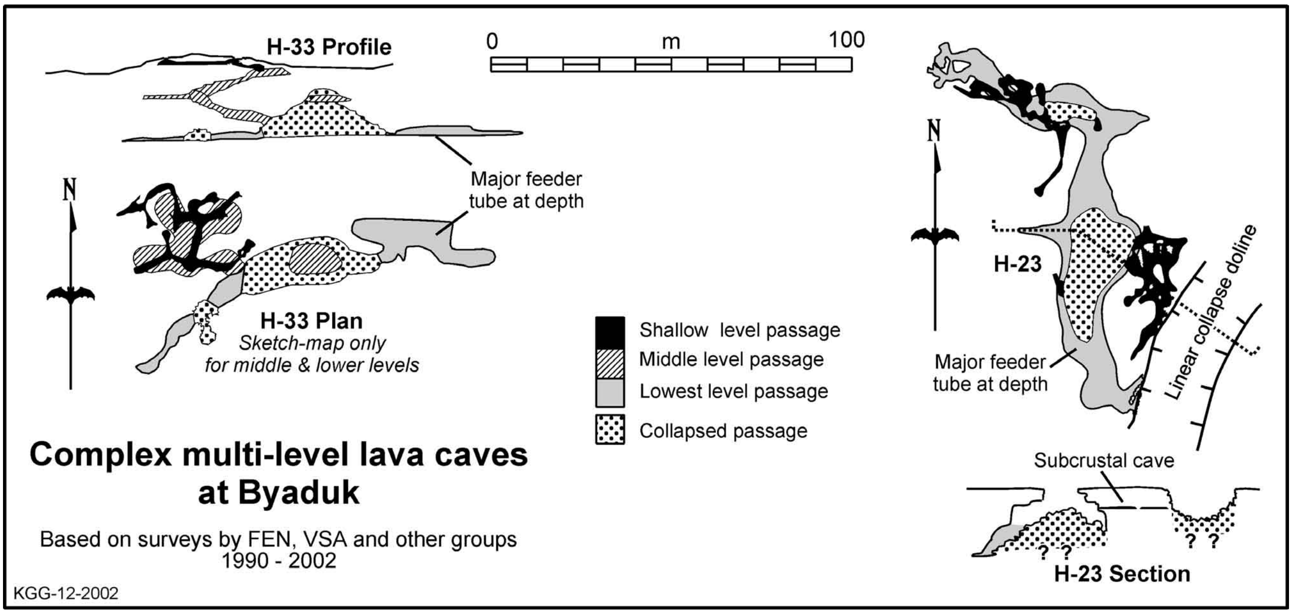


Figure 4.8: Two multi-level systems at Byaduk. H-33 (The Theatre) has its upper levels fed from below (Figure 5.25 is a more detailed map). In H-23 (Fern Cave) the upper levels are in thin flows fed from an adjoining lava channel.

larger tubes, possibly indicating remnants of the initial subcrustal system (Photo 4.1).

Large feeder tubes:

The large lava caves at Byaduk are up to 25 m wide and 18 m high, with their floors 20 m beneath the surface of the lava flow. They form a chain 1.3 km long (Figure 5.19), but the individual caves are less than 200 m long with abrupt endings at vertical faces above lava sumps (Figures 5.21, 5.22). The associated collapse dolines expose lava flow units 1-3 m thick. The higher flow units probably are younger than the caves, but the lower ones could predate the caves, which may have incised into them, or have formed contemporaneously as the banks of a surface channel grew upwards from overflows before roofing over to make a cave. Tunnel Cave at Mt. Eccles is also of large diameter (up to 12 m wide and 6 m high), but only 60 m long to a termination where the present roof slopes gently down to meet a horizontal lava floor (Figure 4.9). Mt. Widderin Cave (Figure 5.1) might also be part of a pair of large feeder tubes, but is difficult to interpret.

Other unusual caves:

In addition to the lava tubes there are some volcanic caves formed in special ways. The Mount Fyans Cave is a small drained passage within a dyke that is remarkably similar in appearance to a lava tube (see page 21 for detail). The Shaft (page 23), the Pit and Armchair are all vertical shafts or pits that are open volcanic vents or hornitos. Natural Bridge (page 25) is a lava tube, but with a distinctive angular "gothic" ceiling. There are also some small erosional caves in volcanic tuff or scoria.

Genesis

For a more detailed description of the observed processes in active lava flows, and models deduced from these, see Peterson & Swanson (1974), Wood (1977), Greeley (1987), Peterson & others (1994), Hon & others (1994) and Kauahikaua & others (1998). The models used here and in Grimes (2008) are essentially those described in the last three of those papers (Figures 4.10 & 4.11).

When discussing genesis one must keep in mind the distinction between active tubes (lava-filled) and drained tubes (caves), as discussed by Halliday (2002, 2004). Only some active tubes will be drained and become accessible at the end of an eruption; most will remain filled and solidify. Tunnel Cave (Figure 4.9) is an example of a partly drained tube.

As long as a tube or cavity remains active, its form can evolve by, firstly, solidification of its stagnant parts including linings; secondly, mechanical and thermal erosion of its edges; and thirdly, partial drainage to form

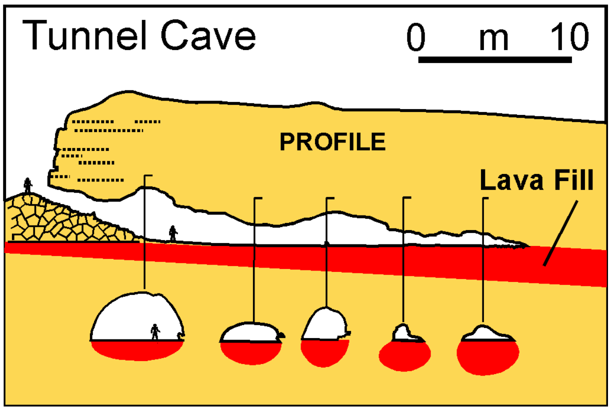


Figure 4.9: Tunnel Cave (3H-9) is a large feeder tube that only partly drained at the end of the eruption. See also Figure 5.9).

an open cave. Collapse of the roof can occur while the tube is active, as well as after it is drained.

Lava tubes form in basaltic lava flows by two main processes: roofing of an open surface lava channel, and by subcrustal drainage within a flow. Both types can evolve further to form larger, but simpler "master" or "feeder" tubes.

Roofed channels

A surface lava channel can be roofed in three ways (Figure 4.10).

1: The simple progressive growth of a crust across the surface of the lava stream (Figure 4.10a) is the most common, and is typical of slow steady flow rates.

2: In the "log-jam" process (Figure 4.10b), fragments of broken crust are rafted down the channel and accumulate at constrictions. This is less common, and no definite examples have been recognised in this area.

3: The overgrowth of levees (Figure 4.10c) occurs in faster, more turbulent flows that involve much splashing, or where fluctuations in discharge cause regular overflows of the banks. The levees build up as multiple thin sheets or spatter layers and grow upward and inward until they meet to form a roof. This commonly results in a distinctive angular or "gothic" ceiling cross-section (Photo 4.12). This form is also uncommon, but we have two examples in western Victoria: Natural Bridge, 3H-10, at Mt. Eccles (see page 25, Map 5.12), and Fiery Cave, 3H-66, on the upper slopes of Mt. Napier (see figure 13.10 in Joyce, 1976) .

In all three cases, lava flowing beneath the roof can thicken it from below, and later overflows through sky-lights may thicken the roof from above. In many cases linings plastered on the tube walls, or collapse modifications, make it hard to distinguish the three modes of formation.

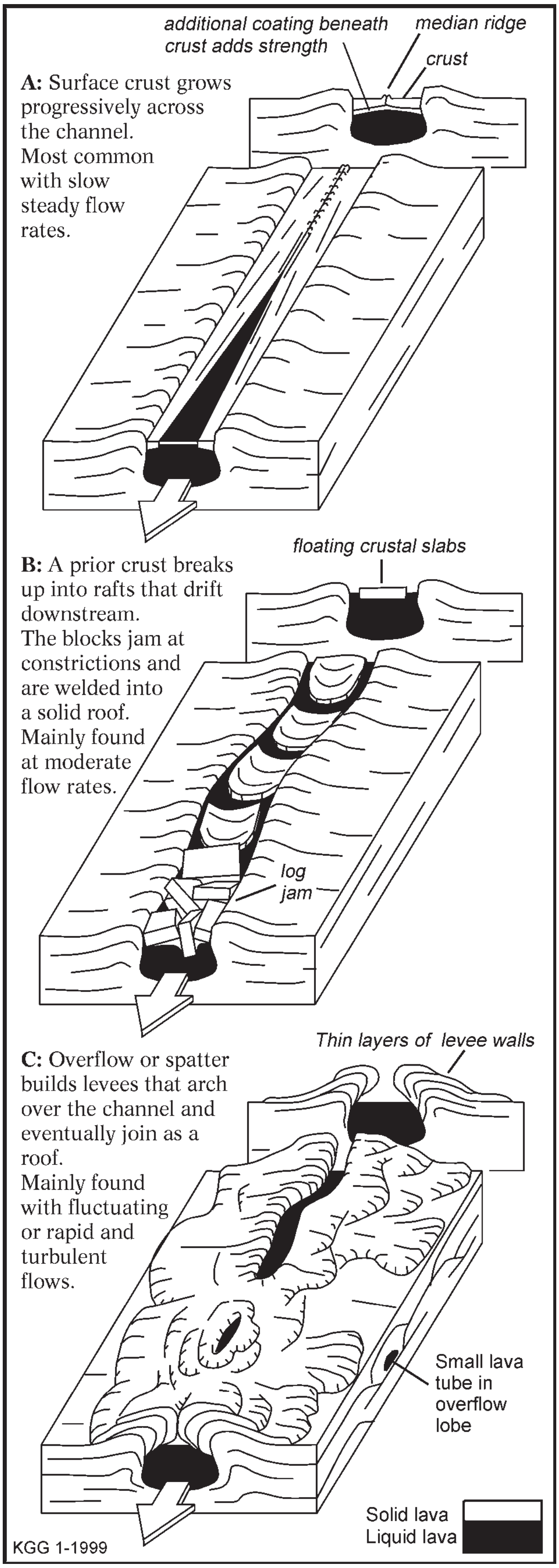


Figure 4.10: Three ways to make a lava tube by roofing a lava channel.

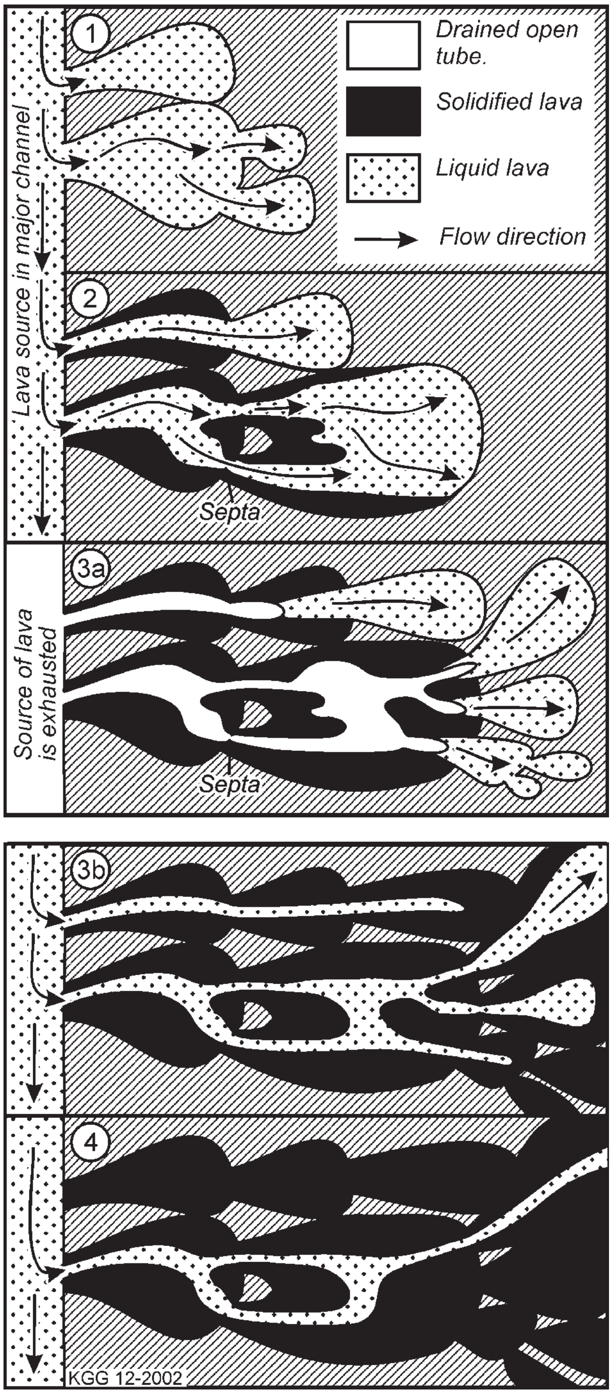


Figure 4.11: Stages in the formation of lava tubes by draining of lava lobes.

Step 1: Thinly crusted lobes of lava expand by breakouts through ruptures and budding of further lobes.

Step 2: Stagnant areas of the older lobes solidify, but flow from the source keeps the feeder conduits liquid.

Step 3a: If the source flow ceases some of the conduits may drain to form air-filled cavities.

Steps 3b and 4 indicate the further evolution into more linear feeder tubes as lava continues to flow through the system.

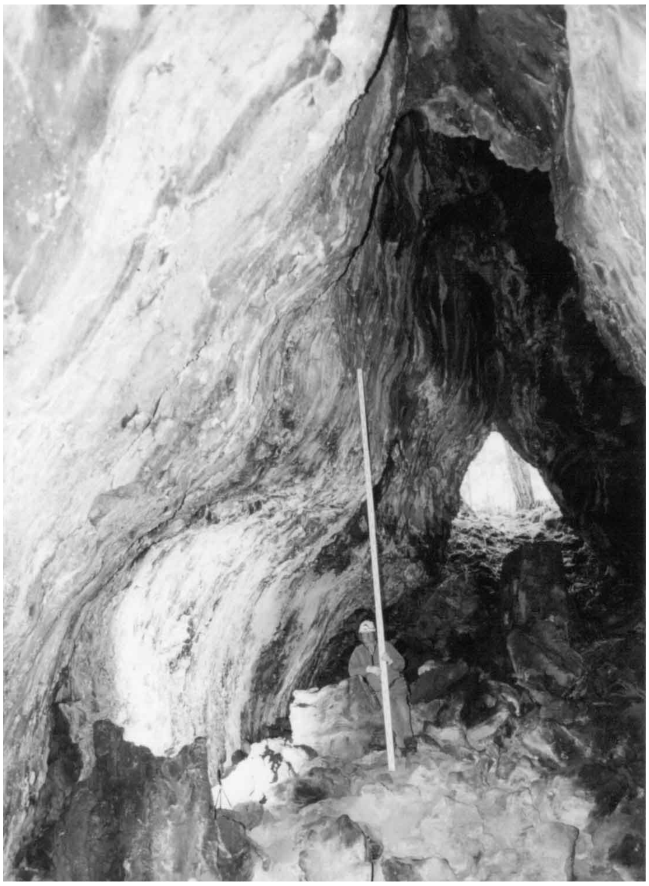


Figure 4.12: The ceiling of Natural Bridge (3H-10), Mt. Eccles, has a "Gothic" shape that suggests it formed by levee overgrowth, as shown in Figure 4.10c, [KGG] See also Map 5.12.

Subcrustal drainage systems

Simple lava blisters:

The isolated small lava blister caves found beneath low mounds in the stony rises have formed by irregular draining of cavities beneath the thin solidified crust of a broad lava flow. The process is similar to that which forms other subcrustal drainage tubes (see below), but less organised so that only isolated low-roofed chambers result beneath the high points of the undulating surface. This type includes the "hollow volcanic tumulus caves" of Halliday (1998a), but that term is complicated by differences in the usage of "tumulus", as discussed in Grimes 2008 and page 10. All gradations occur between the "tumulus caves" and "sheet flow caves" of Halliday (1998a, 1998b) and the terminology should not be based on the surface morphology (Grimes, 2008). Commonly the unsupported central part of the chamber roof sags (while hot) or later collapses so that only a crescentic "peripheral remnant" survives, as at H-78 (Figure 4.2), and see also the "circumferential" passages shown in figures 16 and 17 of Halliday (2002).

Complex subcrustal systems:

Figure 4.11 illustrates the formation of more complex tubes and cavities by subcrustal draining from beneath a crusted flow. The figure shows the situation where a channel has overflowed, as along the Southern Canal at Mount Eccles, but similar effects occur at the front of an advancing pahoehoe lava flow where the lava is delivered by a surface channel or major feeder tube, but then spreads out into a series of lobes. These lobes grow by a process of 'budding' in which a small lobe develops a skin, and is inflated by the lava pressure until the skin ruptures in one or more places. Lava escaping through the rupture develops new lobes and so on (Figure 4.11-1, -2, -3). Lobes can stack vertically as well as spreading horizontally. If the supply of fresh lava is cut off, the still-liquid parts of a lobe may be drained to form a broad but low-roofed chamber (Figure 4.11-3a, Photos 4.5, 4.7, 4.13). However, if fresh hot lava continues to be delivered from the volcano it may become progressively concentrated into linear tubes that feed the advancing lobes, while the remaining stagnant areas solidify (Figure 4.11-3b, -4).

Tubes that are formed by draining of lava lobes and flows are generally smaller than those formed by the roofing of a channel. The earliest proto-tubes are typically less than half a metre diameter (photos 4.1, 4.6). However, inflation of the crusted flow by pressure of the lava within (Hon & others, 1994) can provide a thickness of ten metres or more in which larger subcrustal drainage tubes can form. If flow through them continues after they are formed, several small tubes within a lobe complex may coalesce by breakdown of their thin walls or floors (the "partitions" or "septa" of Hon & others, 1994, and Halliday, 1998b) to form a larger feeder tube. These partitions can sometimes be deduced from constrictions along passages or between chambers (eg photo 4.5). Also, a continuing flow of hot lava through a small feeder tube can enlarge it by mechanical and thermal erosion of the walls or floor. Destruction of the crust above the active tube can form skylights or local surface channels, and overflow from these can form secondary flow lobes. Thus, pahoehoe lobes can be stacked vertically as well as advance forwards so that a complex three-dimensional pattern of branching tubes and chambers can form – as seen in Carmichael Cave (Map 5.18, Photos 4.5, 5.17).

Pudding Cave, (H-53 & 76, Map 5.15) may show a transition from the low-ceilinged branching and chambered systems at the (younger) distal end, to the more linear and slightly larger unbranching tube systems at the proximal end that would develop in time as flow became more localised and organised to feed an extensive overflow sheet.

Evolved systems

As the front of a lava flow advances the lava drainage patterns left behind continue to evolve. This happens in three ways. Firstly, inflation of the flow units creates a greater thickness and this, together with the fusing of separate lobes by the breakdown of their partitions,

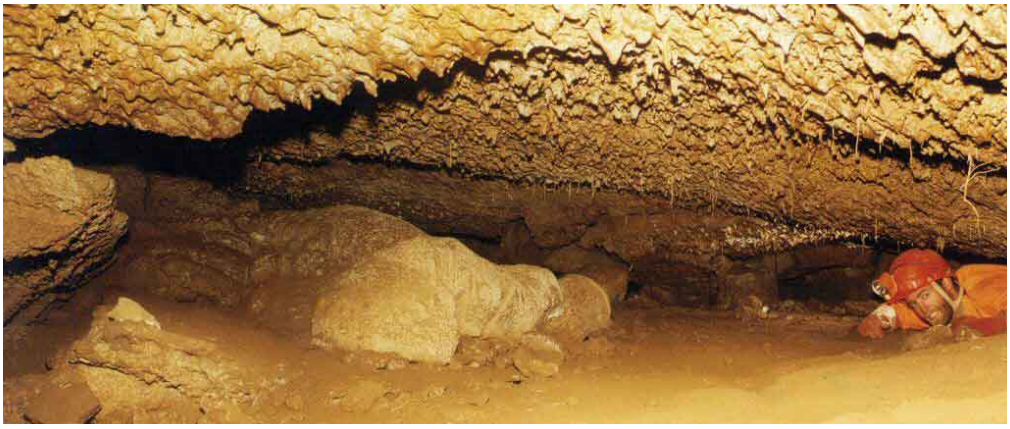


Figure 4.13: Broad, low-roofed subcrustal chamber, in H-106, Byaduk. Note the invasive lava lobe at left. [KGG]

permits easier development of bigger-diameter tubes. Secondly, the initial pattern of multiple anastomosing tubes becomes simplified as some tubes capture the bulk of the lava flow and grow, while the remainder stagnate and then solidify (as shown in Figure 4.11-4). Thirdly, the still-active tubes, now in a simplified, more-linear pattern, enlarge by thermal and mechanical erosion of their walls, and tend to cut down below the level of the original lava flow, invading earlier flows and perhaps earlier tubes (Peterson & Swanson, 1974; Greeley, 1987; Kempe, 1997).

This transition from an initial high-level braided system to a simpler linear pattern of larger and deeper master or feeder tubes has been well documented in Kazumura Cave, Hawaii (Allred & Allred, 1997). These feeder tubes provide insulation and allow the development of very long lava flows (Cashman & others, 1998, and other papers in that issue) – for example the Mt. Rouse and Tyrendarra flows (Figure 2.2).

The Mount Hamilton Cave (H-2, Map 5.2) may be a good local example of a partly evolved system in which the original irregular chambers and small passages of subcrustal drainage caves in several stacked flows have combined and evolved into a more linear, but still multi-branched, system of moderate-sized feeder tubes (Photo 5.3) as lava flow continued through the conduit system on its way to the lava field below. This suggestion is supported by the presence of small proto-tubes, 20-60 cm in diameter, that are exposed by breakdown in the walls and ceiling of the larger tubes in several parts of the cave (Photo 4.1).

Several of the levee overflow cave systems at Mt. Eccles have multiple thin flow units exposed in the walls, suggesting erosional enlargement across several flow units.

Tunnel Cave, Mt. Eccles, is a large diameter feeder tube, that also has multiple thin flow units exposed behind the cave lining. The canal wall outside Tunnel Cave shows many thin lava flows with small proto-tubes and one slightly larger subcrustal tube in a flow unit above the main cave (The Loft, see Figure 5.9a).

Many of the large feeder tubes at Byaduk also show thinner lava units exposed in their walls, and they probably enlarged by thermal erosion. However, the subcrustal caves seen there are all at higher levels and may be in younger flow units that overflowed through skylights in the big tubes, eg. at Fern Cave and The Theatre (Figure 4.8).

Conclusion

Small subcrustal lava caves form by drainage of lava from beneath a thin crust developed on a lava surface. In its simplest form, drainage of lava from beneath high areas on the crusted surface will form simple isolated chambers – lava blisters. Complex nests of advancing lava lobes create equally complex patterns of active tubes and chambers which can later drain to form open caves. This can include three-dimensional patterns in stacked lobes, with vertical as well as horizontal connections between the lobes. Tube systems formed by roofing of surface channels tend to be less complex and larger, but can overlap on size and pattern with the subcrustal systems. Both types evolve further during the time of the eruption.

As lava continues to flow through these complex systems they will evolve by erosion and solidification to form larger, more streamlined, linear tube systems that act as feeder tubes to carry hot lava to the advancing lava front. These feeder tubes can enlarge further by eroding the surrounding lava or underlying material. The remaining parts of the initial network of small tubes will generally stagnate and solidify, but some proto-tubes adjacent to the larger, evolved, tubes may drain out into those when the latter drain.

Note that although roofed-channel tubes tend to be larger and simpler than the initial subcrustal tubes, the two types overlap in size and pattern. Determining the origin of simple large lava tubes can be difficult as much of the evidence may have been removed by erosional enlargement of the original tube, or be hidden behind wall linings.

Cave Descriptions

Ken Grimes

Overview

Lava caves are known across the whole of the Western District Volcanic Province (Figure 2.1), but are most common in the younger flows associated with Mount Eccles and Mount Napier.

In these younger flows we find a range of cave types: isolated small lava blister caves, shallow complex subcrustal caves, evolved subcrustal caves where the flow has been concentrated into a few larger passages, and big feeder tubes (Chapter 4). There are also some unusual types: Natural Bridge (H-10) was formed by overgrowth of the levees of a lava channel; The Mt. Fyans Cave (H-105) is in a basalt dyke; The Shaft (H-8) is an open volcanic vent; and Armchair Shaft (H-47, near Smeaton) is a smaller hornito. There are also some weathering caves in tuff and scoria deposits.

Caves in the areas to be visited by the ISV excursion are listed below. Other areas are summarised in the regional description (Chapter 2, page 6) and details of some of those are given in Webb & others (1982). Note that the ISV excursion may not visit all the caves described below.

Eastern Areas

(Skipton, Mt. Hamilton & Mt. Fyans)

3H-1: Mount Widderin (Skipton)

Note: This cave is frequently referred to as the Skipton Cave (eg. Ollier 1963b), but the Widderin name is preferred by the owners.

Access & time: Private land. An access fee is charged. 1-2 hours.

Gear & Hazards: Standard horizontal.

Description: A broad collapse doline has two hollows. The southern one leads to the cave (Figure 5.1, Ollier, 1963b). The main cave comprises two large mud-floored chambers (Main and Ballroom) connected by a small arch. A climb up a mud slope to the south leads to an upper-level passage, and then drops down into a breakdown section that leads to the small lake chamber.

The Main Chamber now has a smooth flat mud floor with some rubble on the south side. It originally had large mounds of guano, described by Robinson in 1843, who also drew what may be the first cave map in Victoria (Figure 3.2, and see Clark, 2007) but most of the

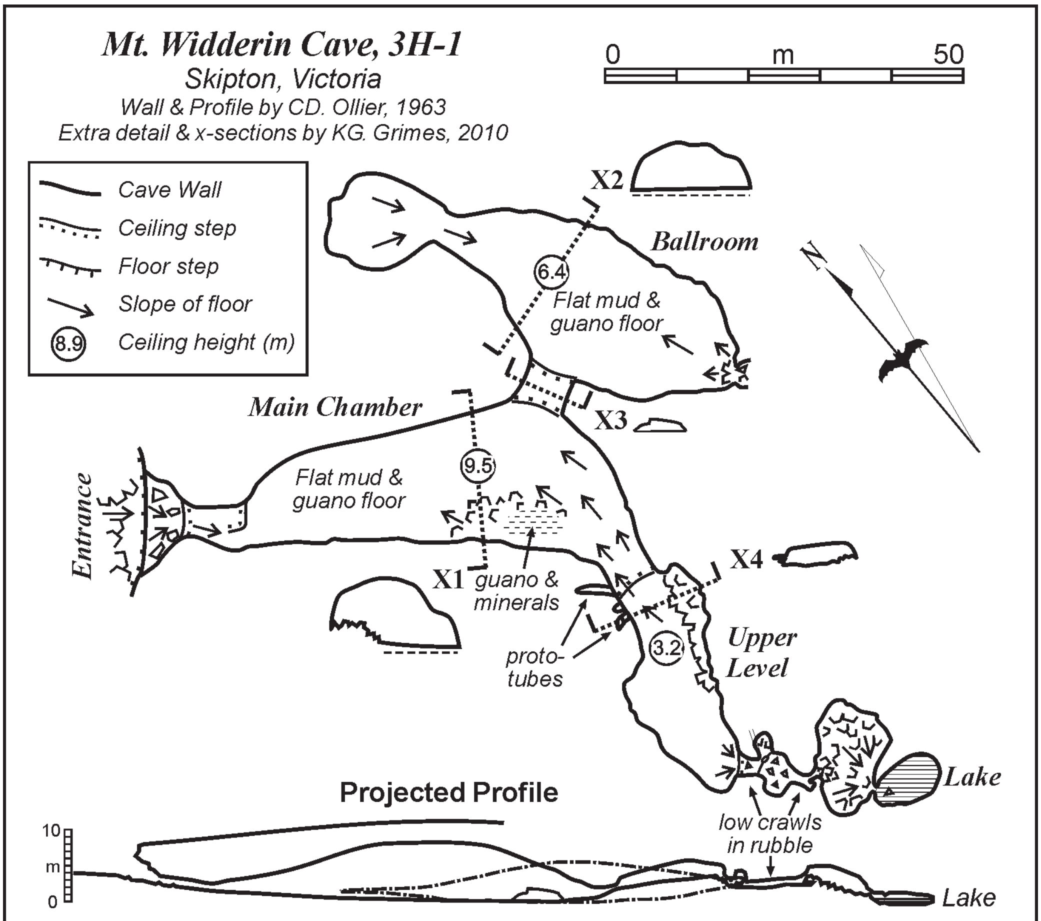


Figure 5.1

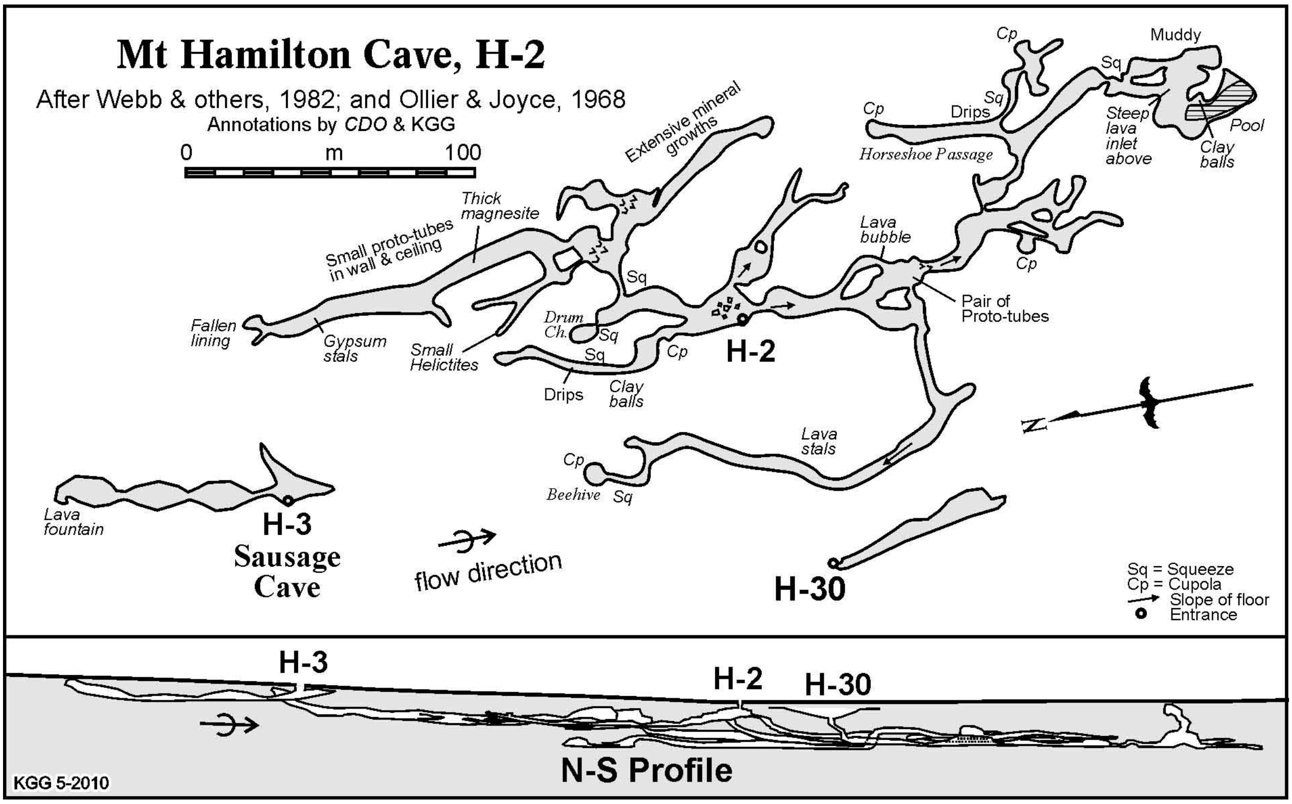


Figure 5.2: Mt. Hamilton Cave is a partly evolved system of moderately-sized passages.

guano was mined in the mid 1800s. The guano hosted an array of phosphate minerals, described by Vince & Hall (1993) and Webb (1997). It is the type location for struvite, hannayite, newberyite, schertelite, and dittmarite. The mining activities may have contributed to the disappearance of the large bat colony (reported by Robinson, and by Selwyn in 1875, but gone by the time the cave was visited by Fletcher in 1895). The Ballroom is reached from the Main Chamber by a short arch and is similar in style.

The walls and ceiling of both chambers are largely a broken surface, but still fairly smooth, not jagged. Only in a few places are there preserved lava linings with small drips and dribbles. As well as the lava formations the walls have some small areas of paler brown to cream speleothems (coralloids and small flowstone areas of uncertain composition).

The Upper Level passage has several small proto-tubes in the west wall near its start. The passage then drops into a complicated rockpile area to end eventually at the low lake chamber. A windmill on the surface pumps from this lake.

Proto-tubes: Several small tubes with linings occur in the west wall of the upper level passage. These are typically 0.6-1.5 m wide and 20 to 50 cm high. They generally extend only a metre or two into the wall, but one continues (very tight) into darkness after about 3m. Most have a lining about 10-20 cm thick and some showed ropy structures and lava drips. One of the proto-tubes is blocked by a plug of ropy lava.

Graffiti: The wall of the entrance area (twilight) has some old names with dates going back to 1899 and the early 1900s (when the cave was used for balls and other social gatherings). The oldest graffiti, with a date of 1856, is carved into the north wall of The Ballroom.

3H-2, 3, 30: Mount Hamilton

Access & time: Private land, a 2 km walk from bus. 2-3 hours in cave.

Gear & Hazards: Standard horizontal, some short squeezes, including the entrance (metal ladder).

Description: The Mount Hamilton Cave (H-2), at 1200 m of passage, is the longest lava cave in Victoria. Together with the nearby Sausage Cave (H-3) and Insect Cave (H-30), it forms a complex system of moderately

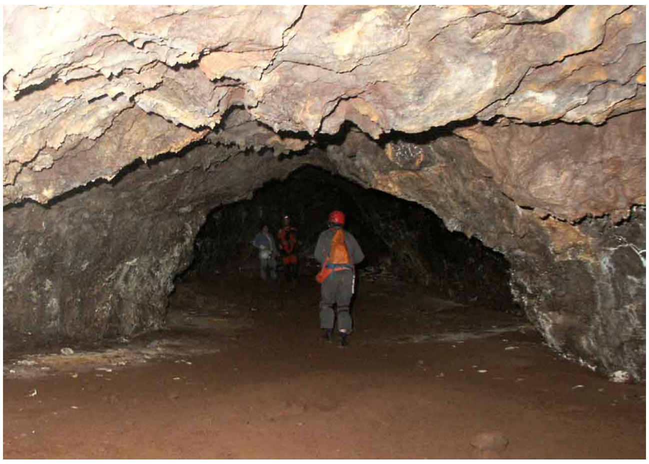


Figure 5.3: A typical tunnel in the Mt. Hamilton cave [KGG].

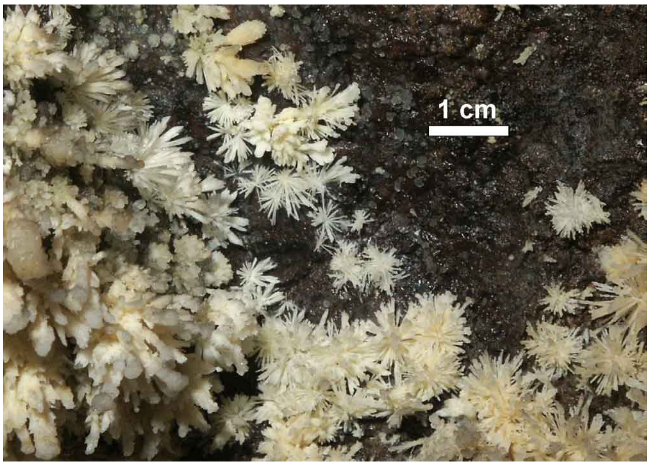


Figure 5.4: opaline needles in the Mt. Hamilton Cave [KGG] See also cover photo.

large branching tubes at several levels (Figure 5.2; Ollier 1963a, Webb & others, 1982). There are partly-drained remnants of earlier proto-tubes exposed in the walls of the larger passages (Photo 4.1), which suggest that this is an evolved system, in which a few of the original small subcrustal tubes have grown at the expense of their neighbours and pirated most of the lava flow. The main passages have some nicely arched cross-sections (Photo 5.3) and occasional cupolas, alternating with constrictions that require belly crawls. There is a small, muddy, pool at the downflow end.

3H-105: Mount Fyans Dyke Cave

Access & time: Wildlife Reserve. 30 minutes.

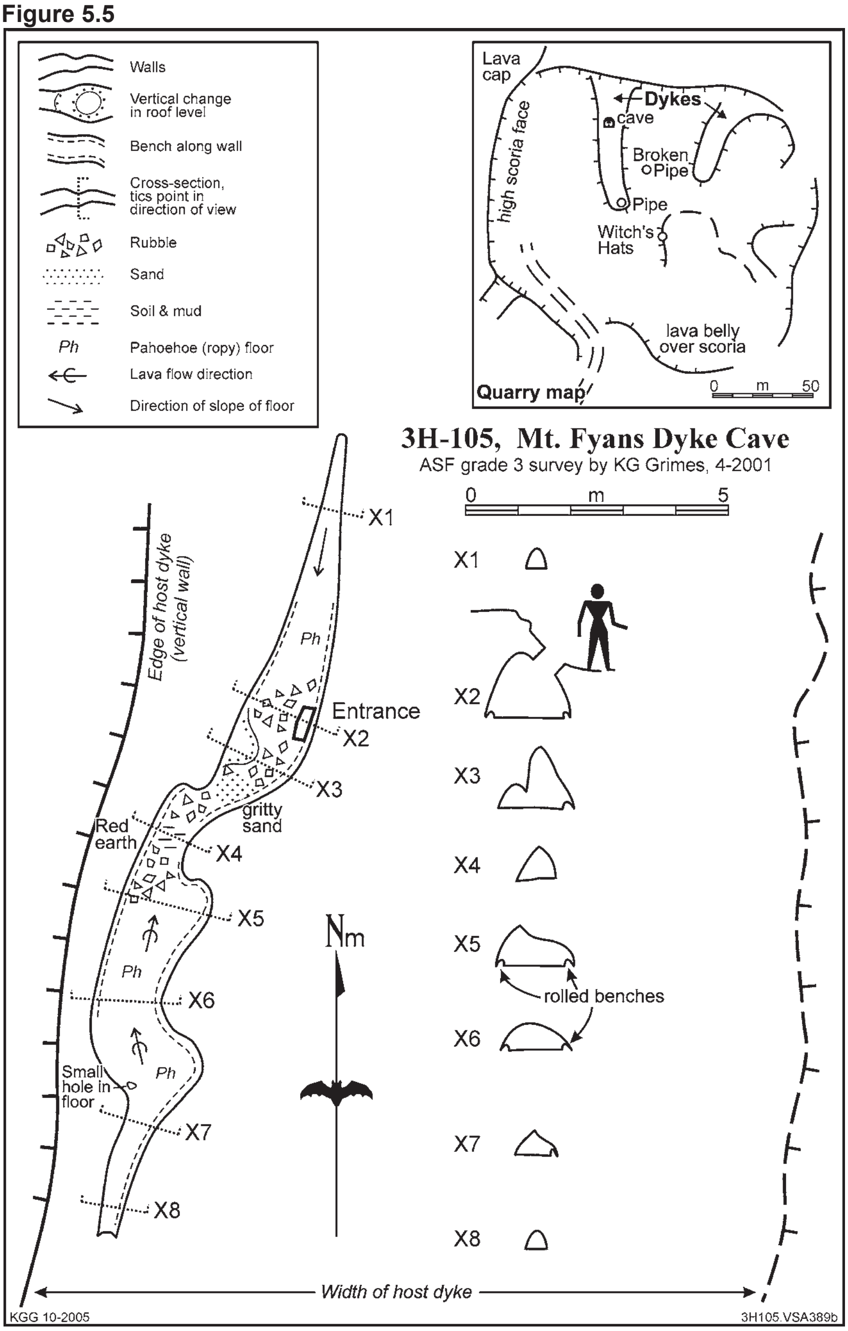
Gear & Hazards: Standard horizontal. Beware of possible collapse of scoria triggered by your activity near steep quarry faces.

Description: The quarry in the summit cone has exposed an unusual small cave (H-105) in a large basalt dyke that intrudes the scoria (Figure 5.5; Grimes, 2006). The cave is about 17 m long and generally less than one metre high. Features within the cave mimic those of conventional lava caves. The roof and walls have numerous lava drips and the floor is a horizontal ropy pahoehoe surface. There are well-developed rolled benches (10 cm diameter) along the edges of the floor that suggest that the lava levels oscillated within the cave. Elsewhere in the quarry there are several smaller

As well as good examples of drips and other lava structures, the cave contains a variety of secondary minerals and speleothems, including gypsum crusts and small helictites (Ollier, 1963a; but the helictites were not found on a recent trip) and Webb (1985) reports clusters of radiating needles (anthodites) that are composed of opal-A and probably represent pseudomorphs after a fibrous zeolite (Photo 5.4). There are also clay sediments and loose hard clay balls.

Wakefield (1963) described bone material from several parts of the cave. His species list includes three extinct forms, two currently known only in Tasmania, and ten no longer in Victoria. The distribution of some large species and vegetable matter suggested that there was a prior entrance near the northern end of the cave.

Figure 5.5



pipe or finger-like basalt bodies, some of which have been partly drained to leave small cavities (the "witches hats", Grimes, 2006).

Mount Eccles (Budj Bim) Area

The main volcano has a deep steep-walled elongate crater which contains Lake Surprise. This is actually three coalescing craters (Figure 5.6). 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 scoria cones and craters extends to the southeast from the main crater, suggesting a fissure eruption (Figure 5.6, Photo 2.4). Smaller lava channels run away from two of these craters. Recent studies on sediments within the crater lake suggest an age of about 30,000 years for the Mt. Eccles eruption (Builth & others, 2008).

Main Lookout

Below you is the crater and present lake, with a water depth of about 14 m. The lake is at the level of the regional groundwater, and its level fluctuates 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 at the south-east end spurting up several hundred metres into the air. The lava droplets from the fountain would have frothed and 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 quieter part of the crater lake. The main overflow point was at the north-western end where a major lava channel runs away from the crater. Koalas are commonly seen in the trees here.

The Lava Canals

There is a 5 km circle walk that follows the main South Canal, and returns via Natural Bridge and its smaller canal, then back to Lake Surprise via several of the smaller craters (Figure 5.6). One half-day excursion will follow part of this route, with a side trip to The Shaft.

Shortly after leaving the main crater (Lake Surprise) the South Canal branches as a result of a breach on its western side, and the West Canal runs off for about 4 km. The South Canal has several complex subcrustal caves on either side of it that formed in sheets of lava that overflowed from the canal (Figure 4.3). The canal ends abruptly, but must have continued as an underground tube to feed the lava field to the south-west, including the long Tyrendarra flow.

A small shallow canal starts within the camping area, north of Lake Surprise. This may have been fed from

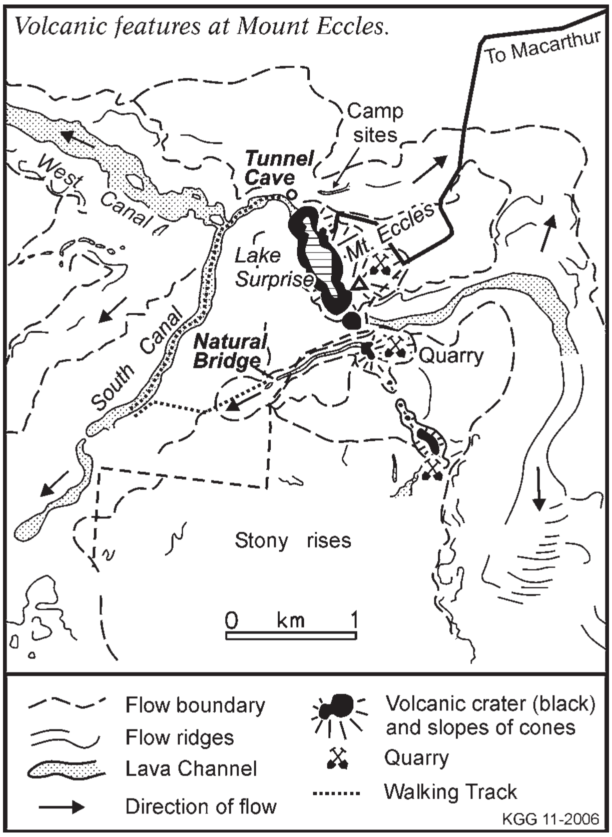


Figure 5.6: The Mt. Eccles volcano and canals.

a continuation of the Tunnel Cave tube, but there is no accessible cave.

Two small canals run away from smaller craters in the south-east line; one broad but shallow channel to the east and a narrow but well-defined channel that runs southwest and ends at the Natural Bridge (H-10), which is a roofed-over section of the canal.

Further out

Beyond the area of craters, the lava channels fed a broad lava shield about 10 km across which has diverted several streams and eventually narrows to run south to the coast as the long Tyrendarra flow (Figure 2.2; Gill, 1979). That flow continues offshore – the continental shelf was dry at the time as it was near the peak of the last glacial period (Boutakoff, 1963). A few small caves are known within the lava shield and on the Tyrendarra flow but much of that remains unexplored.

Where the lava met Darlot Creek to the west it dammed it up to form Lake Condah and the Condah Swamp. This was an area of extensive wetlands that was developed by the Aboriginal people into a complex system of fish-traps and stone-based houses (see history Chapter 3, page 7). It was drained by the Europeans, but a weir has recently been built across the drain to re-flood the system and reactivate the fish-traps.

The Caves

Most of the longer caves known at Mount Eccles are in or adjacent to the lava channels, but there are smaller caves scattered throughout the area, and the known distribution may simply reflect the more intensive exploration along the main canals. There are several types of lava cave in the area. Roofed channels include Natural Bridge (H-10), which has the distinctive "gothic" ceiling of tubes formed by overgrowth of a levee bank (Figure 4.10c), and also possibly Tunnel Cave (H-9), which might have started as an open branch of the main South Canal. The remainder are shallow, low-roofed subcrustal caves that fall into two types: complex, levee-overflow systems on the sides of the major lava channels, e.g. H-51 & H-70 (Figure 4.3); and small, isolated, drained chambers (lava blisters) within the stony rises (e.g. H-78; Figure 4.2).

The levee-overflow systems 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 4.3 and Grimes, 1995, 2008).

3H-8: The Shaft.

Access & time: National Park. Short walk from a track. Half hour to rig. 10 minutes each on bottom is enough! Avoid the congestion created by large parties.

Gear & Hazards: 23 m ladder or SRT, with an extra 20 m of slings to tie back to a large boulder hidden in bracken on outer SE slope – this is the preferred rigging point as the rope/ladder then hangs free and avoids damage to ferns in the narrow part of the shaft. Danger: keep children away from this site, and take care around the edges and on the slippery inner slopes or you may reach the bottom faster than you intended!

Description: The still-open vent of a small volcano (Ollier 1964a). A shaft in the bottom of a funnel shaped crater in a small spatter cone opens up below into a single large elongated chamber with rubble floor. Contains moss-covered lava stalactites. See Map 5.7, Photo 5.8.

3H-9: Tunnel Cave

Access & time: National Park (public access). Right beside Crater Rim walking track. Half an hour to visit.

Gear & Hazards: Lights only. Stone steps inside entrance are uneven and may be slippery.

Description: This cave is a typical lava feeder tube, 60 m long, 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 (Map 5.9, and see also 4.9). Features of interest are the hollow lava bench on the left side near the entrance (cross-section A), and further in there are lava drips, a sagged wall lining that has opened up a gap behind it (section G, Photo 5.11), and a ropy lava floor at the end. In two places on the left wall (sections C & D on the map) the lining has fallen away, revealing stacked lava layers behind it. These suggest either that the tube was enlarged by thermal erosion, cutting across multiple small flows; or that that the layers were built by overflows from a surface channel that later roofed over.

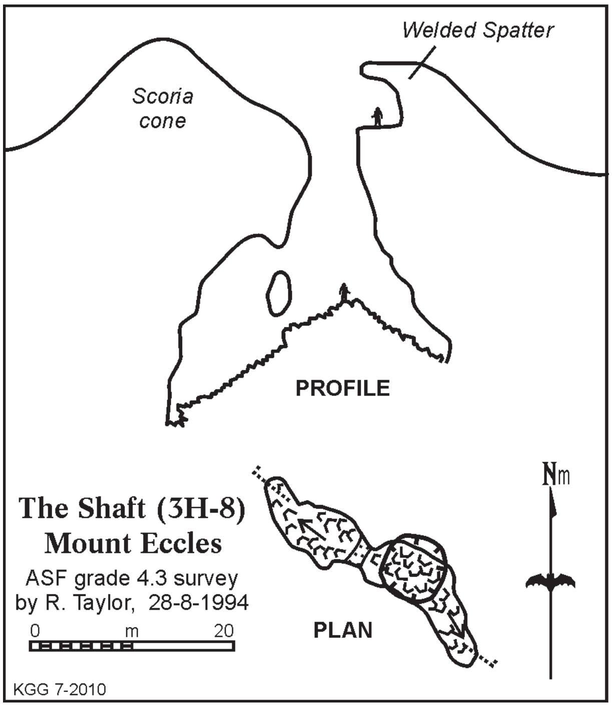


Figure 5.7: The Shaft, an open volcanic vent.

Figure 5.8: Looking up The Shaft [KGG].

Figure C.9a

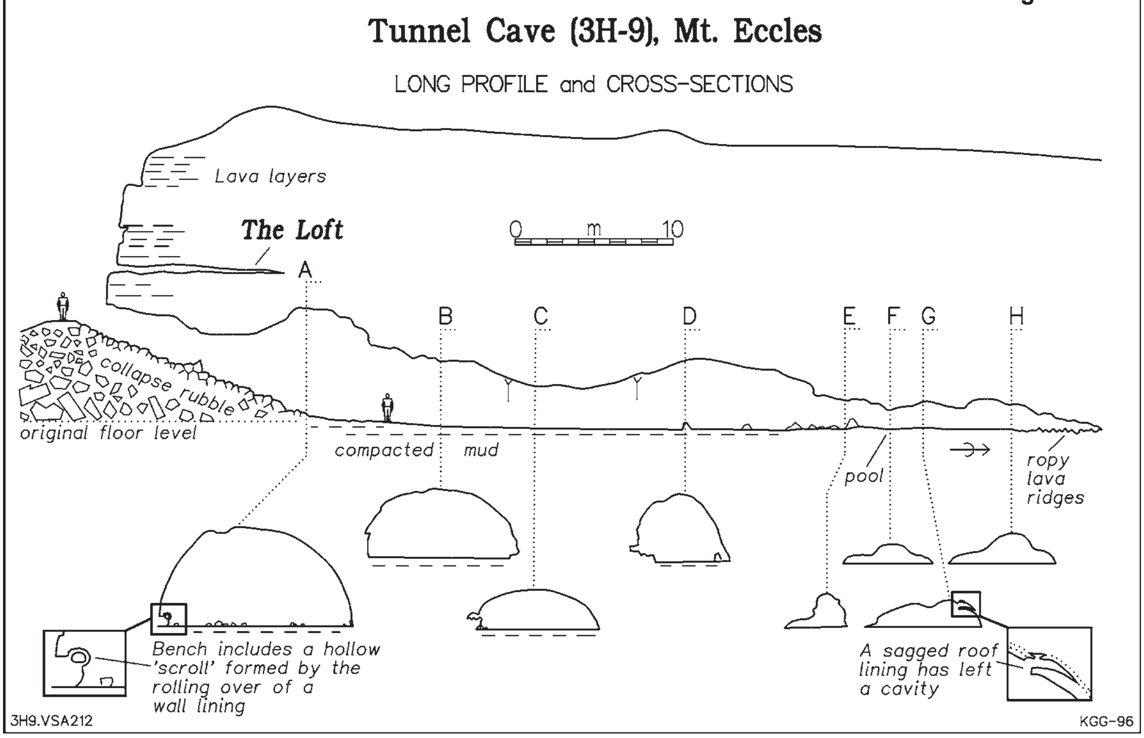
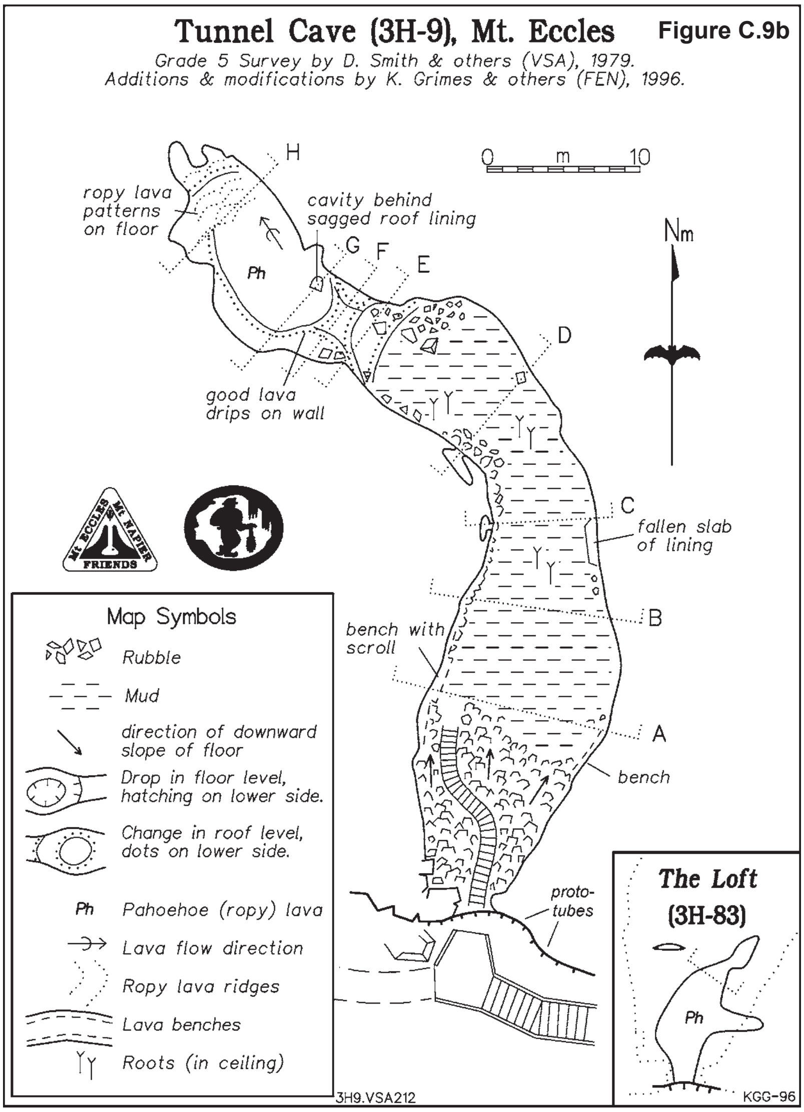


Figure C.9b



Figures 5.9a & b (above and left): Tunnel Cave is a feeder tube running away from the start of the South Canal, Mt. Eccles.

Figure 5.10 (below): The roof of Natural Bridge has a narrow "gothic" shape, and contorted layers that slumped while hot [KGG].

Figure 5.11: Cavity behind sagged lining in Tunnel Cave. [KGG]

Outside the cave, look at the cliff beside the platform and stairway. This has many irregular thin lava sheets that would have overflowed from the main lava channel behind you. Within these are many small proto-tubes and also smaller cavities that may just be coalesced gas pockets. Above the main entrance a larger subcrustal tube extends in for about 10m (The Loft, see map), but we do not recommend trying to climb into this; there is nothing of interest inside and you may drop things (including yourself) onto other visitors!.

References: Ollier 1964a; Johnson & others, 1968 (biology & ecology). Grimes 1998a.

3H-10: Natural Bridge (Gothic Cave)

Access & time: National park (public acess). 5 minutes walk from local carpark. 10 minutes drive from campground. Stairs at NE end are reached via the track along the canal floor. Half hour in cave.

Gear & Hazards: Hand torches. If you look at the surface hole above the cave, do not climb into it – fallen leaves can hide a dangerous drop into the main cave.

Description: From the crater near the south-east quarry a small lava channel runs off to the south-west (Figure 5.6). In its final section the channel becomes more narrow and deeper and eventually is roofed over with lava to form a short 36 m section of cave (Figure 5.12). Beyond the cave the channel widens out and disappears.

Near the base of the new stairway into the cave (not shown on map) the south wall has scrape

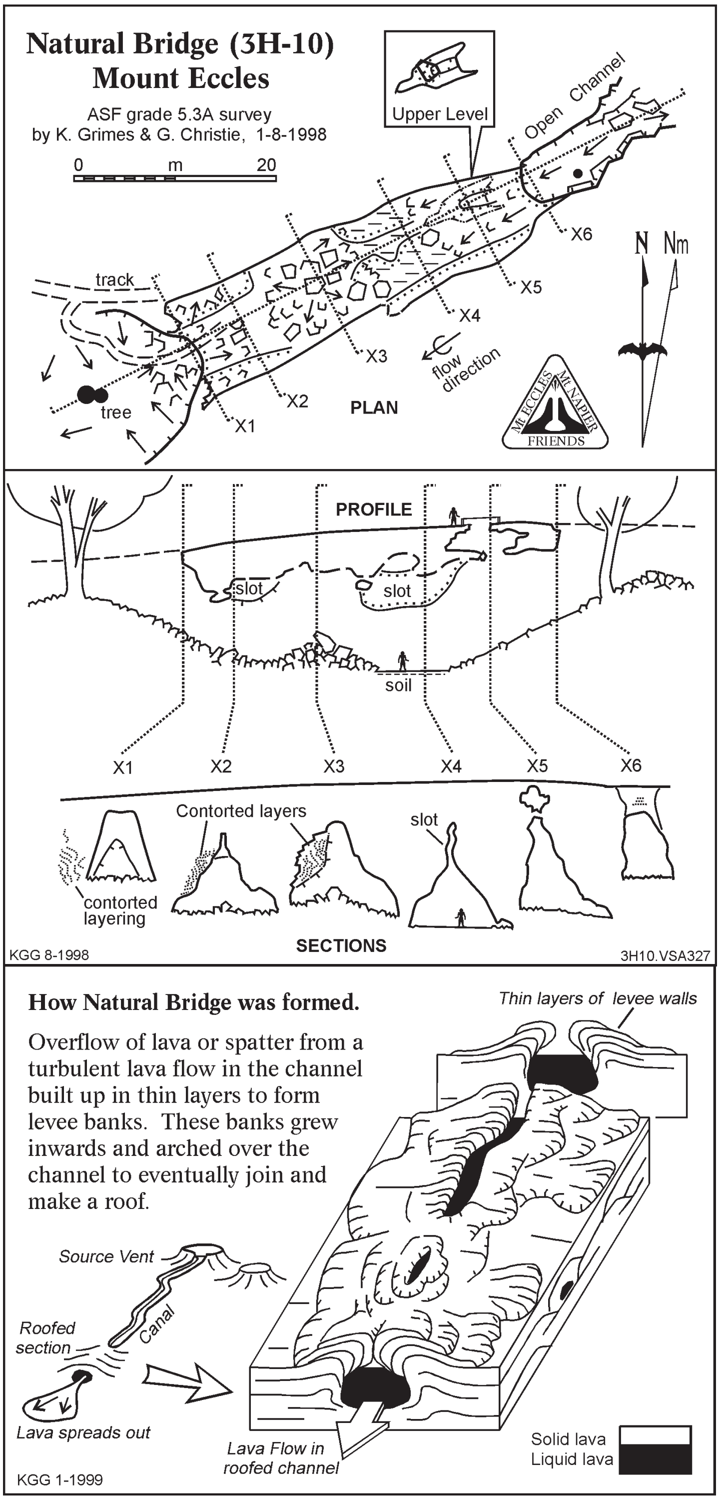


Figure 5.12: Natural Bridge Cave is a roofed channel.

marks formed when the lining was still soft. Look up at the roof (Sections X4, X5); the walls come together at a sharp angle and in places they leave a narrow slot. It is this angular arched roof that gives the cave its other name, Gothic Cave, and suggests that it was roofed by levee overgrowth (Figure 5.12, Photos 4.12 & 5.10, and see Chapter 4, page 15-16). From the base of the stairs go onwards and climb over the rubble pile, then look back at the broken wall (cross section X3) to see convoluted folding in the thin linings. This is the result of slumping of the layers while they were still hot and soft.

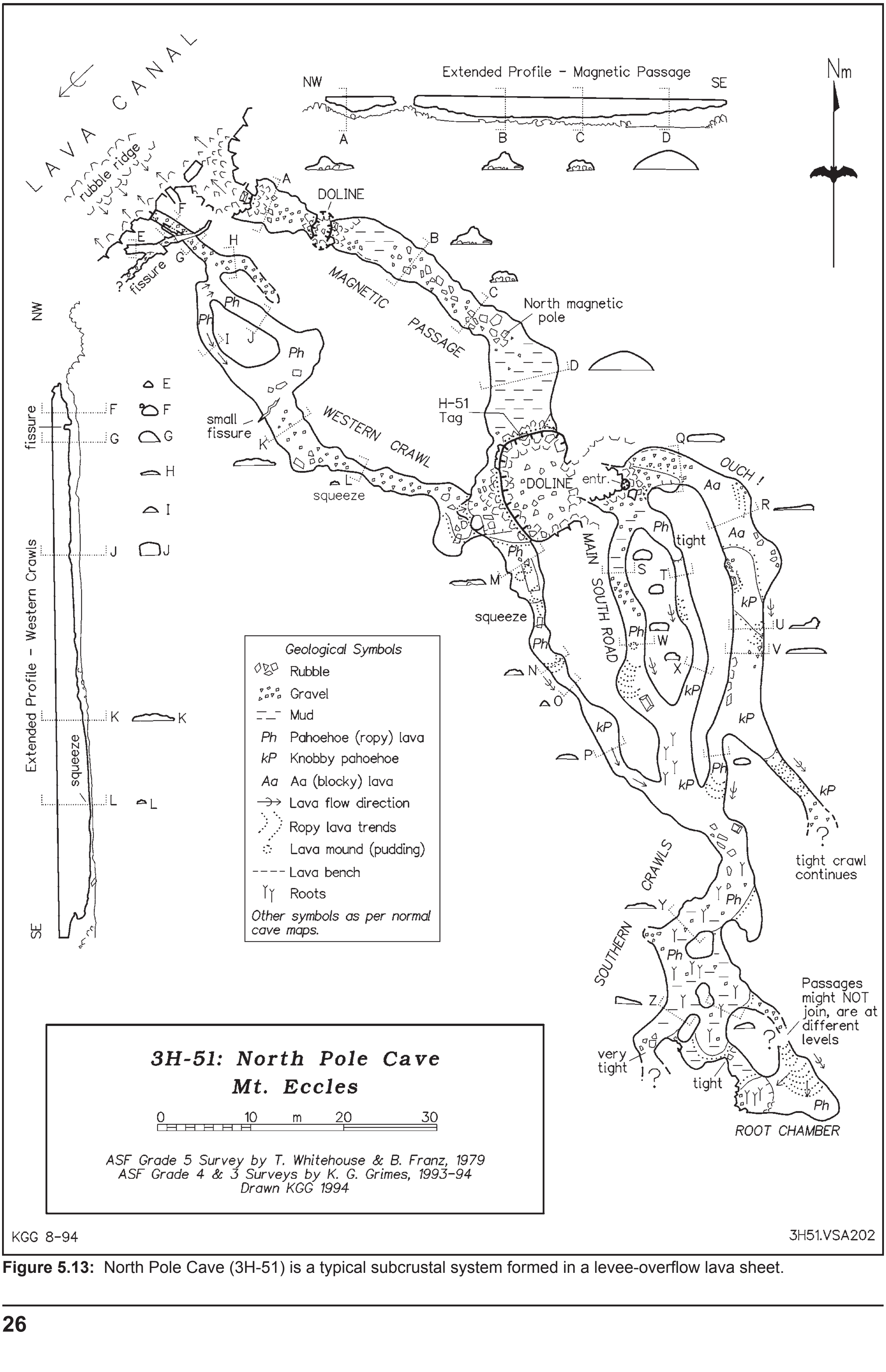


Figure 5.13: North Pole Cave (3H-51) is a typical subcrustal system formed in a levee-overflow lava sheet.

You can exit the cave at the SW end and come back to look down the daylight hole, and also view the lava channel from above.

Reference: Ollier,1964a; Joyce 1976; Grimes 2002b.

3H-51: North Pole Cave

Access & time: National Park. 20 minute drive on rough road then 10 minute track walk. 1-2 hours.

Gear & Hazards: Standard horizontal, old overalls, Mostly 1 m or less headroom.

Description: A set of small anastomosing subcrustal lava tubes running away from the canal (Map 5.13). The name refers to a pointed magnetic rock found at an obvious survey point; one can imagination the consternation of the surveyor when all his sightings gave an identical reading of 000°. There are good lava features throughout the cave, including sharp aa floors, and some sporty squeezes. Next to the canal, a cambering fissure cuts the cave. This has exposed sections of small tubes, including one with a lava plug which can be seen by standing up within the fissure at sections E & F of Map 5.13. Fine tree roots hang from the ceiling in the downflow section of the cave, and there is a photogenic root chamber at far end, beyond a tight squeeze (Photo 5.14).

3H-52.

Access & time: National Park. 20 minute drive on rough road then 10 minute track walk and 5 minutes scrub-bash along base of canal wall. 10 minutes in cave.

Gear & Hazards: Minimal.

Description: H-52 is a neat little tube opening in the canal wall (Photo 4.6, Map 5.15). It has a rounded-triangular cross-section (60 cm high and 1.4 m wide) and has some good lava drips on the roof. In the canal wall at the entrance, one can make out the boundary of the flow unit that contained the tube. This unit is thinner than the tube, its upper surface arches up over the roof of the tube, indicating local inflation before the tube was drained. The tube runs in for about 6 m to a vertical cambering cross-fissure which has opened up about 40 cm, and then ends two metres further on at a sloping lava plug.

Also in the canal wall, about 14 m south-west of H-52, is a really dinky little proto-tube that has not been given a number. It goes about 3 m into the wall of the canal and is only 0.6 m wide and 0.5 m high. None the less, it shows some good lava drips on the roof and a nice pair of sagged inwardly-curved wall linings, which partly block the tube so one cannot get inside.

3H-53,76: Pudding Cave

Access & time: National Park. 20 minute drive on rough road then 15 minute track walk. 1-2 hours.

Gear & Hazards: Standard horizontal, significant crawling.

Description: H-53 has two entrances: one in the canal wall and one in a collapse doline beside the walking track. A medium-sized linear tube leads away from the canal becoming smaller, and after a squeeze past a group of small tumuli (the puddings) reaches the collapse doline (Map 5.15). A second cave (H-76) further downflow is separated underground from H-53 by tight breakdown. This downflow section has several branching low-roofed crawls with ropy lava floors. There are some good lava formations. The downflow cave is a typical subcrustal system of low chambers and passages, but the upflow cave is more evolved and is a slightly larger arched tube.

3H-54: Footes Cave

Access & time: National Park. 25 minute drive on rough road then 5 minute track walk. 1 hour.

Gear & Hazards: Standard horizontal.

Description: A large entrance chamber has a slightly domed ropy lava floor partly buried under rubble (Grimes, 1994). This connects to a short tunnel which has a high-level flattener on one side. This could be an example of an initial broad low-roofed subcrustal chamber, part of which was later deepened by thermal erosion by the ongoing concentrated flow. A lava-fall connects the two levels. At the end of the tunnel the lava floor has sagged to make a shallow pit.

Figure 5.14: Root chamber in North Pole Cave. [KGG & RZ].

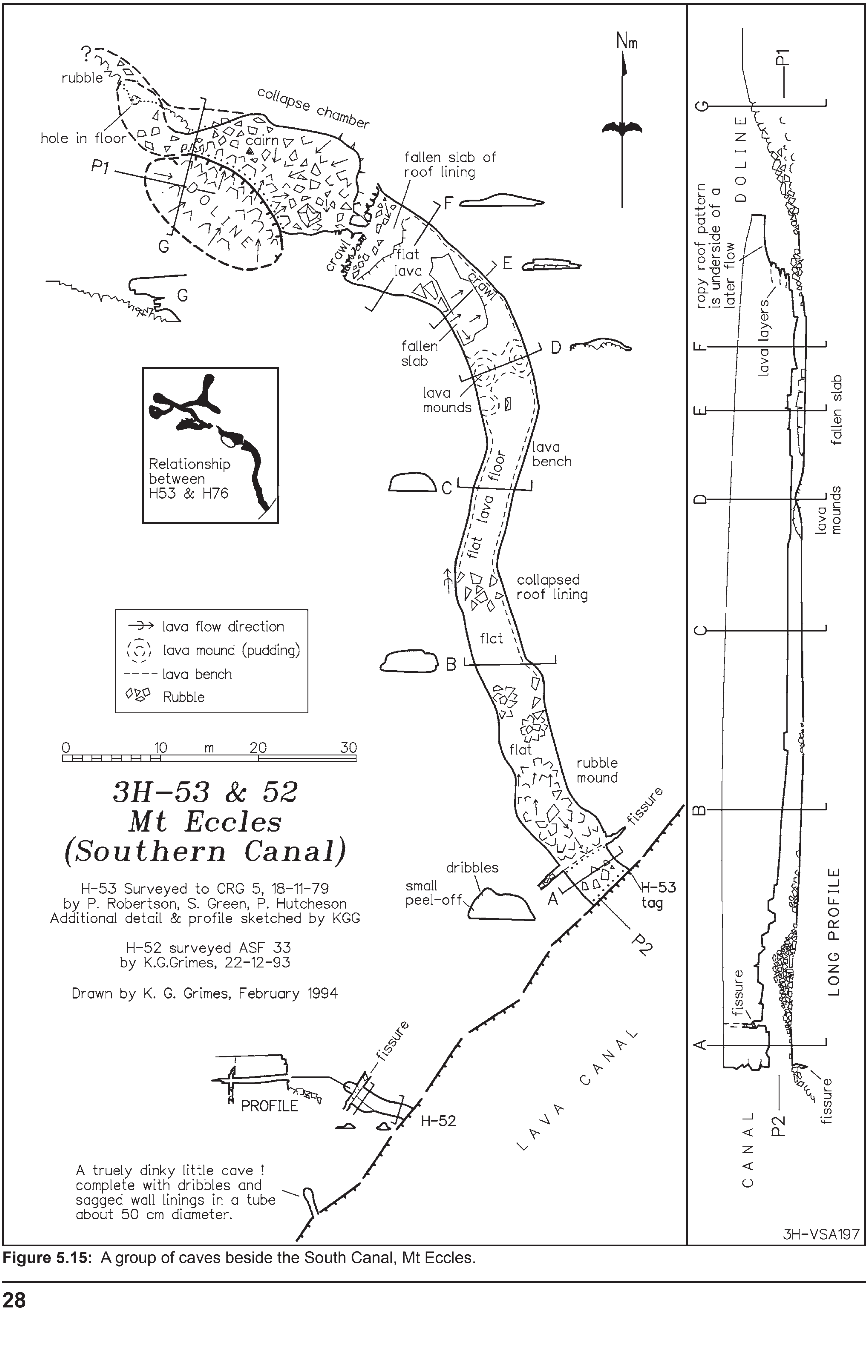


Figure 5.15: A group of caves beside the South Canal, Mt Eccles.

Figure 5.16: A lava "turd" extruded through a hole in the lining [KGG].

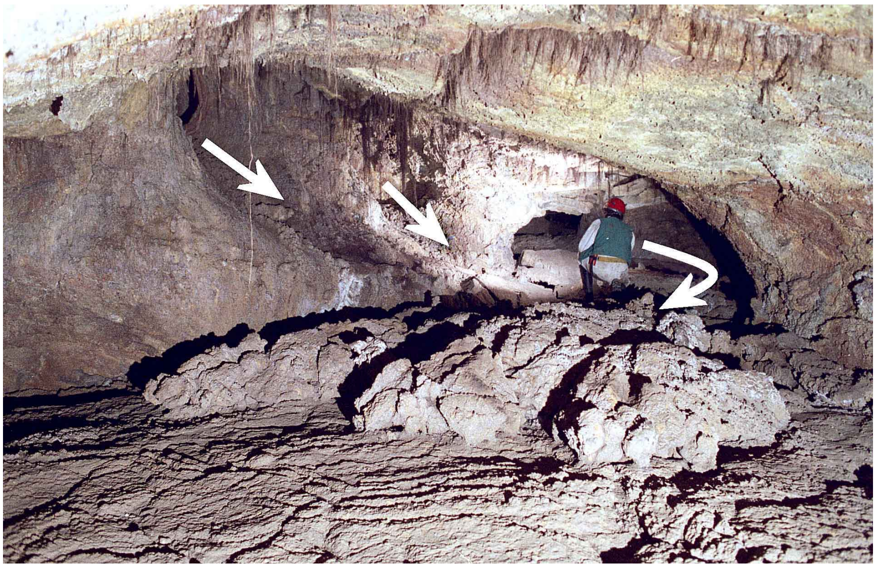


Figure 5.17: An aa lava flow has invaded the lower level of Carmichael Cave. Arrows indicate its entry points from a higher level. [KGG]

3H-70, 71, 79: Carmichael Cave

Access & time: National Park. 20 minute drive on rough road then 20 minute track walk. 2-4 hours.

Gear & Hazards: Standard horizontal. Significant crawling and a few tight squeezes.

Description: A complex 605 m anastomosing subcrustal system formed in several thin sheets of lava that breached or overflowed the levee banks on the side of the South Canal. It has many small tunnels alternating with low broad chambers (Grimes 2002a; Map 5.18). The low but complexly-branching form suggests formation by progressive growth and draining of a series of stacked lava lobes. A lower level at the far end has a larger, partly collapsed, chamber. See Grimes (2002a) for a detailed description.

There are many good lava formations. At cross-section X6 (Map 5.18) the ceiling has nice lava drips and a small burst lining; the western wall has a group of extruded lava "turds" and small agglutinated lava-mites on the shelf below (Photo 5.16). Nearby, the wall lining has broken away to reveal the original lava bedding behind – the tube seems to have expanded and cut through several thin flows.

The eastern end of section X31 is a broad low-roofed chamber in which the roof has sagged, while hot, till it touched the flat lava floor.

Just inside the H-79E entrance, the two chambers of sections X21 and X22 are separated by a low mound which might be the eroded remains of a "partition" (of the type postulated by Hon & others, 1994) that originally separated two flow lobes (see Photo 4.5).

The Big Chamber (Entrance H-71E, section X28) probably resulted from the collapse of a thin floor between two levels. At the northern end of this chamber there is a good range of lava formations. The floor there is a domed pahoehoe flow and in one place there is a squeeze-up where lava has oozed up and spread out from a crack in the floor. On the north wall there is a lining with lava drips and small lava "turds" emerging from holes. On the facing wall (to the SW) there are good examples of burst bubbles in the lining. However, one needs a strong light to spot some of these features.

The mazes to the west of the Big Chamber are a set of small sloping passages, which seem to have connected a higher-level lava flow with the main-level cave. They all feed out into a single passage to the north to form a small lobate aa flow running across the earlier pahoehoe floor (Photo 5.17).

This is an excellent example of a complex subcrustal style of lava cave with several interconnected levels formed in stacked lava lobes.

Mt. Napier & the Harman Valley

Mt. Napier

Mount Napier 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 (Whitehead, 1991; Figure 2.5, Photo 2.6). There are a few small lava caves on the shield. The lava shield flooded the pre-existing Harman Valley, damming the creek to form a major swamp on the upstream (north-eastern) side, and flowing down the valley as a long linear flow that finally is lost beneath the Condah Swamp (which was dammed up by a lava flow from Mt. Eccles). This long flow was fed by lava tubes, drained remnants of which can be entered at the Byaduk Caves (Figure 5.19), near the head of the valley, and elsewhere. Lava also flowed down several other, smaller, valleys; such as Scotts Creek at Byaduk township, where the original stream was diverted underground through a limestone cave (Grimes, 1998c).

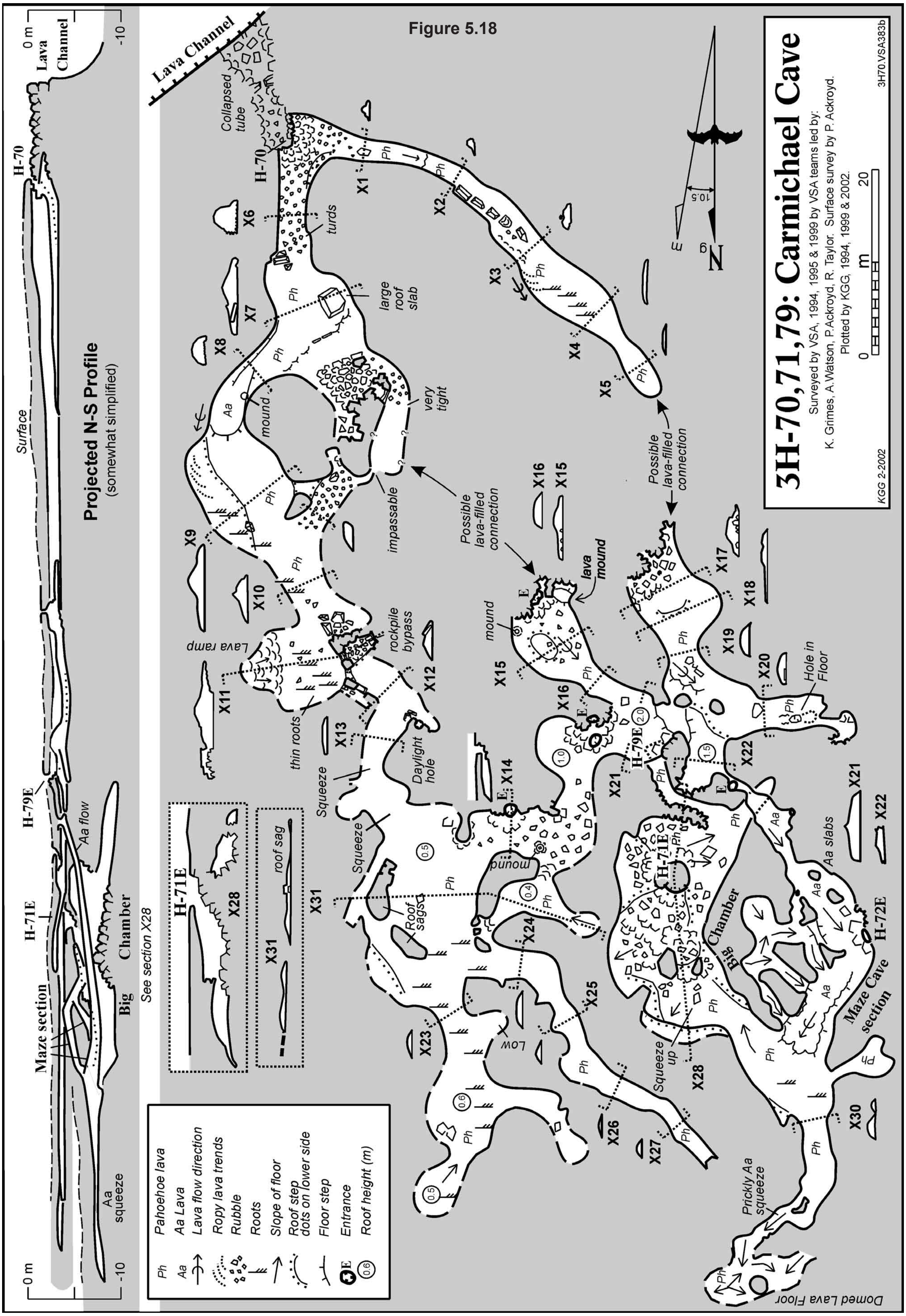


Figure 5.18
3H-70,71,79: Carmichael Cave
Surveyed by VSA, 1994, 1995 & 1999 by VSA teams led by:
K. Grimes, A.Watson, P.Ackroyd, R. Taylor. Surface survey by P. Ackroyd.
Plotted by KGG, 1994, 1999 & 2002.
KGG 2-2002
3H70.VSA383b
Projected N-S Profile
(somewhat simplified)
Lava Channel
Collapsed tube
Big Chamber
Maze section
Maze Cave section
See section X28
Possible lava-filled connection
Domed Lava Floor
Ph Pahoehoe lava
Aa Aa Lava
Lava flow direction
Ropy lava trends
Rubble
Roots
Slope of floor
Roof step dots on lower side
Floor step
Entrance
Roof height (m)

For a long time the eruption was thought to have been a bit over 8,000 years old, based on a "minimum age" radiocarbon date from peat material in the swamp dammed by the flow. However, Stone and others (1997) used isotopes generated by cosmic radiation hitting the lava surface at the Byaduk caves to deduce an age of 32,000 years.

Harman Valley Viewpoint

This is a good viewpoint on the Hamilton–Port Fairy Road that looks up the Harman Valley towards the volcano of Mount Napier (Photo 2.6). There is a parking area with interpretation signs.

The volcano can be seen in the distance, and is described on page 5. Below the lookout one can see the lava flow that came down the valley from the mountain. This flow was fed mainly by lava tubes, but some surface channels were also present. One can see a lava channel, with levees, below and to the right of the lookout.

Wallacedale Tumuli.

A large cluster of well-defined tumuli occur in the western part of the Harman Valley (Ollier, 1964b, Figure 2.5). In the narrow sense used in Victoria, a *tumulus* is a discrete steep-sided mound of lava crust that has been pushed up above the lava surface. Elsewhere, the solidified crust above the liquid core of a lava flow generally forms irregular mounded surfaces known as *stony rises*. However, the movement was localised to small "soft spots" in the crust which are pushed up to form mounds the size of a house rising above a relatively flat surface. A close look shows tilted remnants of the original crust's surface split apart by gaping cracks on the sides and top of the mounds and in places small tongues of liquid lava have been squeezed out through the cracks. Even more rarely one finds that the liquid core has drained back down to leave a central subsided hollow and a "donut" ring, or perhaps a small cave within the tumulus.

While stony rises are a common feature, steep-sided tumuli are rare, and the tumuli seen in the Harman Valley flow are the best examples in Australia (Ollier, 1964b).

The Byaduk Caves

This lava flow, which came from Mount Napier, is the same one as that seen from the Harman Valley Lookout. It was fed by large lava tubes. 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, 1965; Grimes & Watson, 1995; Figures 5.19, 5.20). There is a walking track and viewing platforms with interpretation signs at several of the sinkholes.

Here we find both very large feeder tubes at depth and many small shallow subcrustal caves.

The large feeder tube caves include Harmans (H-11 & 12, Map 5.22), Bridge (H-13, Map 5.24), Church and Church Arch (H15 & 16) and others in that line. The

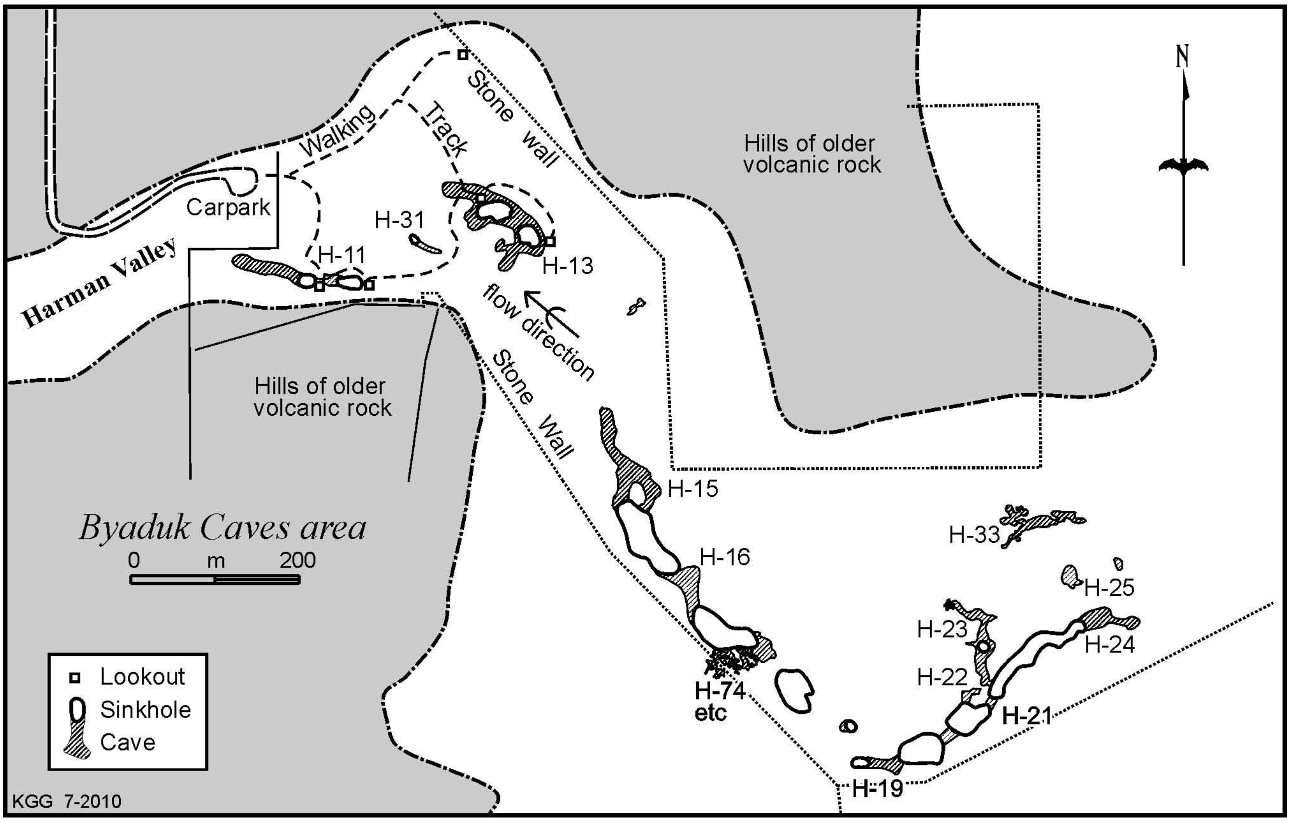


Figure 5.19: Byaduk caves - location map.

largest tunnels have their floors at depths of 20 m beneath the surface, and are up to 18 m wide and 10 m high, but not very long (maximum 200 m) as they terminate abruptly at steep faces above a lava sump. In places within the caves we see multiple lava flows exposed in the walls which suggests that the tubes enlarged by thermal and mechanical erosion after they were initiated. Or perhaps they started as surface channels that built up multiple overflows before they became roofed over. After roofing and enlargement of the big feeder tubes, overflows through skylights thickened the roof, and small subcrustal tube systems developed in many of these shallow flows.

Some of the small subcrustal caves are exposed, along with their containing lava flows, at various levels in the walls of collapse dolines formed above the large tubes; for example, the upper level of Fern Cave (H-23, Figure 4.8) and H-74 and H-108 (Figure 4.4). Others are shallow isolated lava blisters and more complex caves on the flow surface (H-31, 90, 91 and 106; Figures 4.4, & 5.30). One shallow cave has an open feeder from below that connects to a larger feeder tube at depth, forming a multi-level system (The Theatre, H-33, Map 5.25).

3H-11, 12: Harman Caves

Access & time: National Park. 5 minutes walk from car park. 1-2 hours.

Gear & Hazards: Standard horizontal, handline for Harman 2 sinkhole. Much scrambling over large slippery blocks. Please stick to a single route at start to avoid damage to ferns.

Description: This large feeder tube has been extensively modified by collapse, and is separated into two parts (Harman 1 and 2) by a large collapse doline (Map 5.22). However, some relicts of the original form, including ropy lava floors, can still be seen (Photo 5.21). The connection from H-11 to H-12 is hard to find and initially a tight squeeze through rubble.

Harman 1 is a large passage with a dominantly rubble floor, but there are two sections of lava floor exposed. At section X6, lava linings have sagged outwards to form benches with hollows beneath, and a steep lava slope on the southern side suggests subsidence of a crust. At the end (X1) the lava floor is slightly domed by pressure from below and would have been a sump, as the end wall is near-vertical (Photo 5.21). There are some good ropy lava ridges here, and the walls have many close-spaced horizontal lines that seem to be marks from old water levels, though there is no historic record of a lake within the cave.

The walls have linings and primary (lava) and secondary coralloid growths, as well as some unusual mineral speleothems that have mushroom-like forms, with a short stem, then spreading out sideways as a thin transparent cap up to 1cm across (see Photo 5.23a and a possible explanation in Figure 5.23b). Samples of broken coralloids were analysed by John Webb (pers. comm., 2010) as opal-A. Towards the back of the cave there is also a soft brown organic(?) slime on the walls and as vermiculation patterns on the ceiling. There are also numerous patches of white, water-repellant, microbial colonies.

Bats frequently hang in the dome above the middle rubble pile, which has guano-mud.

Harman 2 is reached via a rockpile squeeze. It has a large chamber adjacent to the second doline, but the floor here is higher and ends in a lava wall (see profile in Figure 5.22). It seems that the eastern doline may have been an open skylight towards the end of the eruption and the lava flow within the big tube crusted beneath this to form a high-level floor. Attempts to get into possible drained chambers beneath this have failed. The "washbasin" shown on the map is an overturned fragment of the ceiling that has a hemispherical hollow with lava drips. No taps have been fitted yet.

Both collapse dolines expose multiple lava flows in their walls; the highest ones may be overflows via

Figure 5.20: A partly collapsed section (H-21) of the large feeder tube at Byaduk. [KGG]

Figure 5.21: Lava sump and vertical wall at downflow end of Harman 1 Cave (H-11). [KGG]

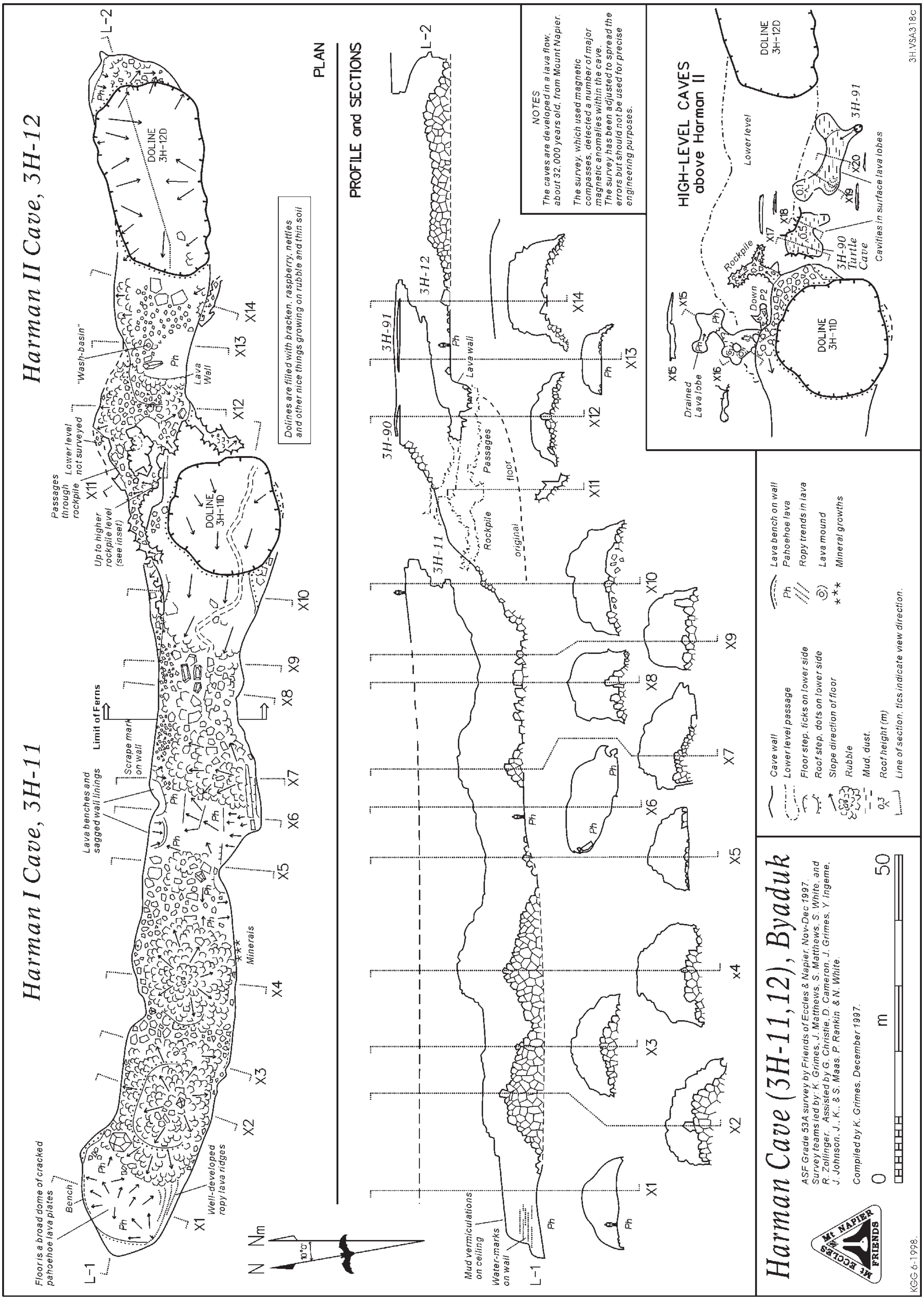
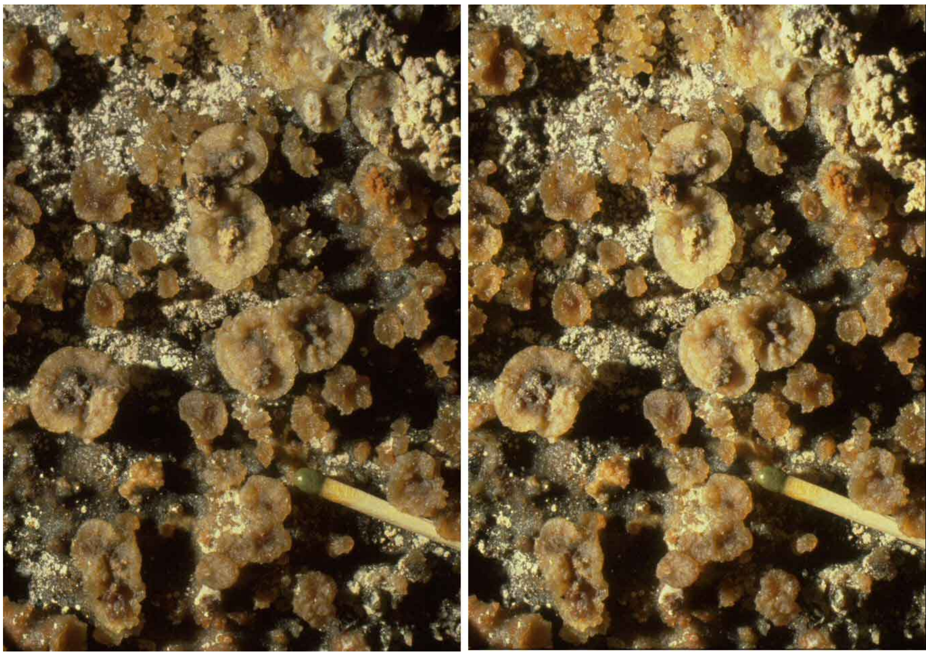


Figure 5.22: Harmans Caves (H-11 & 12), Byaduk, is a large feeder tube. Inset shows high-level subcrustal caves (including Turtle Cave, H-90) formed in later lava flows.



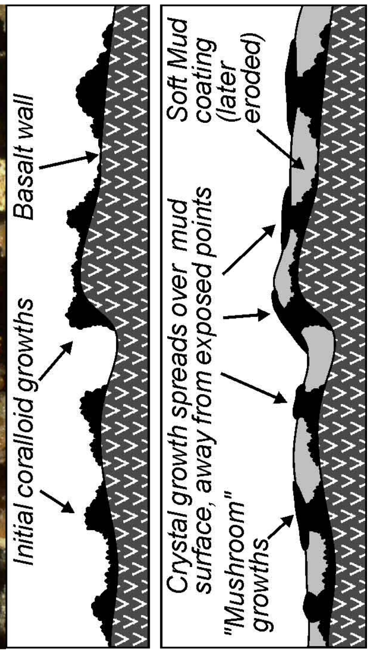


Figure 5.23a (left): Mushroom-like mineral growths on the wall of Harman 1 Cave (H-11). Match-stick for scale. Stereopair, [KGG].

Figure 5.23b (right): A possible method of formation, involving crystal growth across a soft mud film.

the postulated skylight. The western sinkhole has intersected a small subcrustal cave in a thin flow (see inset "high-level" map in Figure 5.22). This comprises a set of small interconnected low chambers with ropy lava floor and solid lava walls and roof. The roof and walls have a hackly surface of secondary coralloid deposits superimposed on lava bursts and drips. The floor has several small lava mounds, one of which shows evidence of having been pushed up from below as a tumulus. This cave would have formed later than the main tube, by draining of the core of a small lava flow that was originally above the roof of the big tube.

The small surface lava blister beside the track to the western lookout, called Turtle Cave (3H-90), is a shallow subcrustal cave on the surface of the flow (c.f. Figure 5.30). Poke your head in (but watch for snakes), it has some nice lava drips on the ceiling.

Reference: Grimes 1998b, Wakefield, 1964b (bones from H-12).

3H-13, 14D: Bridge Cave and Dolines

Access & time: National Park. 10 minutes walk from car park. One hour underground.

Gear & Hazards: Standard horizontal. Use handline for climb down the south wall of the western doline.

Description: The walking track leads to a pair of large collapse dolines over what would have been a large branching lava tube. Beneath is a complexly branched tube system that comprises a bridge between two big collapse dolines and several short passages at both east and west ends (Map 5.24). It is all considerably modified by collapse but with some original wall, floor and roof structures preserved in places. The exposed lava floors are all irregularly contorted and fractured pahoehoe – this was a turbulent flow with pressure heaving of a slabby crust, not a smooth lava lake. At the north-western end (Section X1) the roof is low (1-2m) and cuspate with some lava drips, and has well developed vermiculations of a brown organic(?) slime forming anastomosing ridges up to 30 mm across and 5 mm thick. Some of the lava floor here has coatings of a hard white powdery material. The eastern end of this section goes back under a false-floor (with collapse rubble above).

Reference: Ollier & Brown 1964, Wakefield, 1964b (bones).

3H-15: Church Cave

Note: We will avoid this cave on the excursion as it is frequently used as a bat shelter in winter.

Access & time: National Park. 20 minutes walk from car park, over sharp stony ground. One hour underground.

Gear & Hazards: Standard horizontal. Much scrambling over large slippery blocks. Please do not enter in winter (bats sheltering).

Description: Similar in style to Harmans (west) Cave, but on a bigger scale. See small scale map in Figure 5.19. It is mostly rubble floored, but lava floors occur in the side passage and half way along the main passage. The latter floor has large tilted slabs suggesting subsidence after crusting of the final flow through the cave. As at Harmans, the cave ends abruptly at a vertical wall at the downflow end. A small hole leads down to a lower chamber, but mainly in rockpile. Ollier & Brown

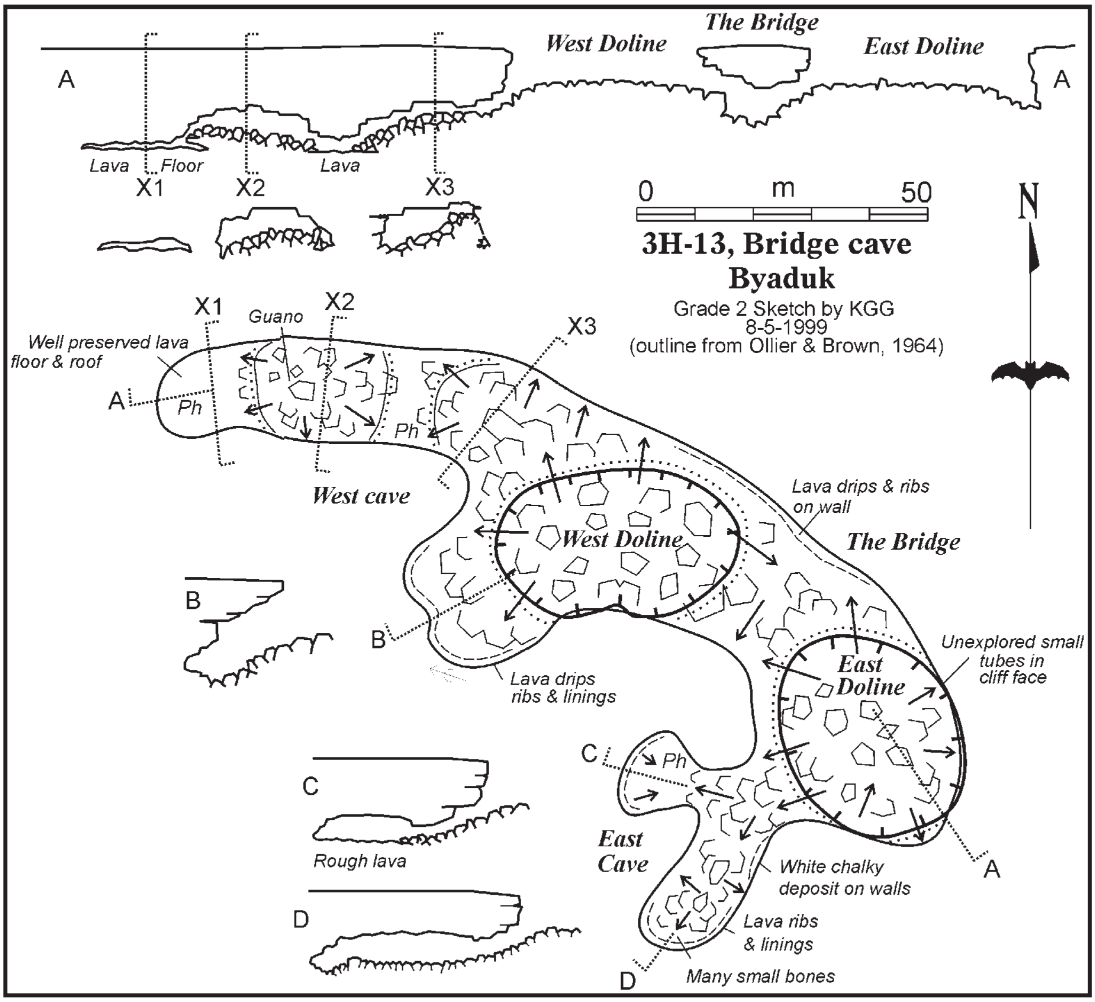


Figure 5.24: Bridge Cave

(1964) record a "small high-level lava conduit" in the end wall that has only partly drained, dribbling down the wall. Finlayson & Webb (1985), show a photograph of an allophane stalactite from Church Cave, but give no details.

3H-16: Church Arch

Access & time: National Park. 20 minutes walk from car park, over sharp stony ground. Half hour underground.

Gear & Hazards: Minimal gear, daylight from both ends.

Description: This is a spectacular twilight arch connecting two long sections of collapsed tunnel. The tunnel is about 12 m high, 25 m wide and 60 m long with an uneven rubble floor. One can see thin lava benches on the wall in places, and elsewhere the lining has broken away to reveal layers of lava that could have overflowed from the original open lava channel.

3H-24: The Turk

Access & time: National Park. 40 minutes walk from car park over sharp stony ground. Half hour underground.

Gear & Hazards: Standard horizontal.

Description: The Turk is the easternmost cave in the long line of partly collapsed feeder tubes (Figure 5.19; Ollier & Brown, 1964). The entrance chamber is mainly breakdown, but has some nice examples of sagged and dribbled lava lining on the south wall. A short crawl, over a false floor, leads to the inner chamber which has well-preserved tube features. A lava floor is composed of slabs that have slightly raised rims, suggesting jostling on a lava lake while they were still soft. There are small lava benches. The walls and ceiling have lava drips and extruded(?) lava coralloids with paler secondary coralloids of uncertain composition superimposed. Many of these have a film of brown organic slime and white microbial patches.

3H-25: Staircase Cave

Access & time: National Park. 40 minutes walk from car park over sharp stony ground. Half hour underground.

Gear & Hazards: Standard horizontal.

Description: A single large chamber has a series of lava benches that form the "staircase". The walls and ceiling have a variety of linings, lava drips, lava coralloids and extruded lava "hands" up to 20 cm long (Ollier & Brown, 1964).

3H-33: The Theatre

Access & time: National Park. 40 minutes walk from car park over sharp stony ground. 2-3 hours underground.

Gear & Hazards: Short ladder or handline for first drop (short people will need a leg-up on exit), 10 m ladder or SRT for second drop (a piton or 1" chock is handy for tie-off). There is a connection to 3H-25 but via a dangerous unstable rubble pile. Use old overalls that you don't mind ripping.

Description: The most interesting and complex cave at Byaduk (Map 5.25). The upper level comprises branching crawlways in a surface lava mound. The middle level has several descending chambers connected by lava cascades that leads to "The Stage". This faces into a large collapse dome, "The Theatre", which is part of the main, lowest, level.

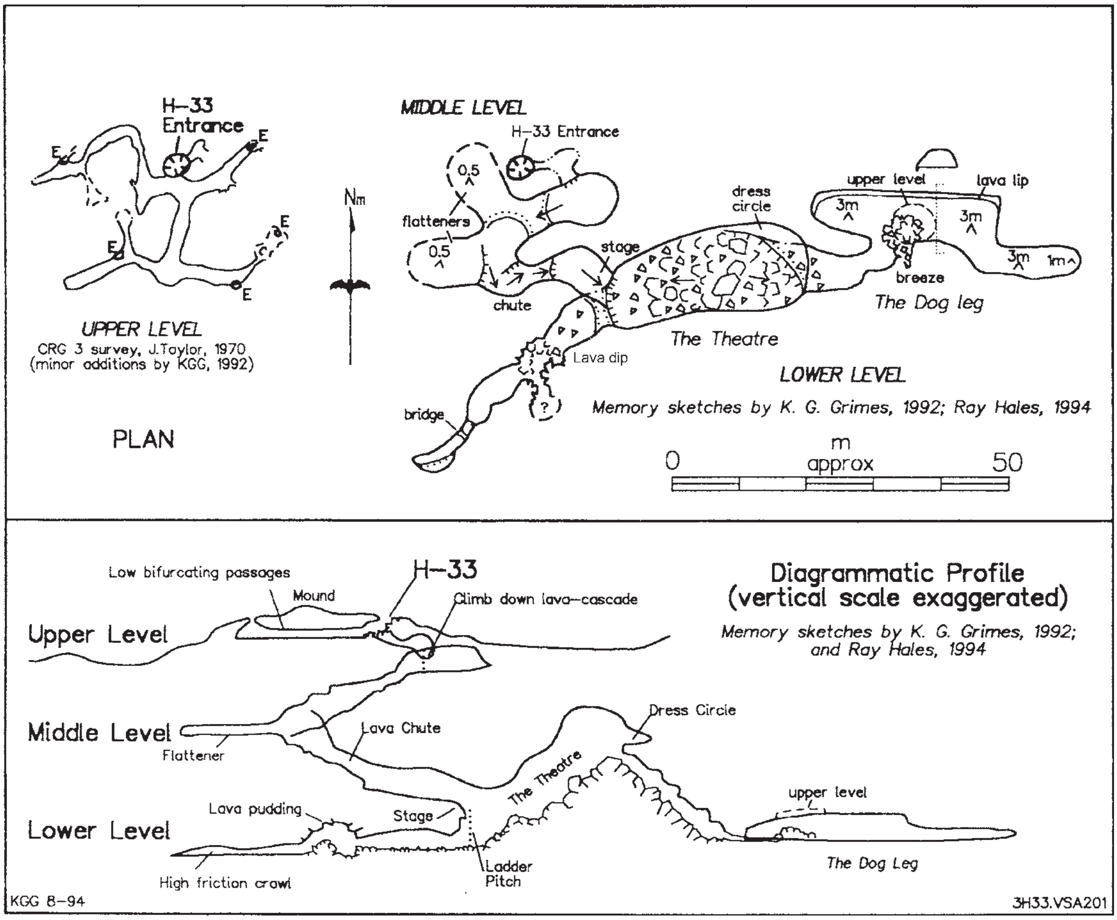


Figure 5.25: The Theatre, a multi-level system.

Figure 5.26: Lava Stalagmite, The Theatre. [KGG]

Figure 5.27: Lava dip (tide-mark) on a roof pendant. The Theatre [KGG]

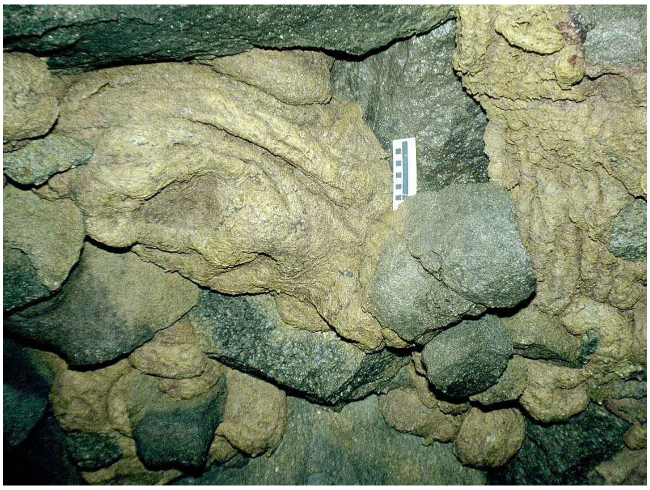


Figure 5.28: Breakdown rubble, welded by intrusive lava lobes. Lower level of The Theatre [KGG].

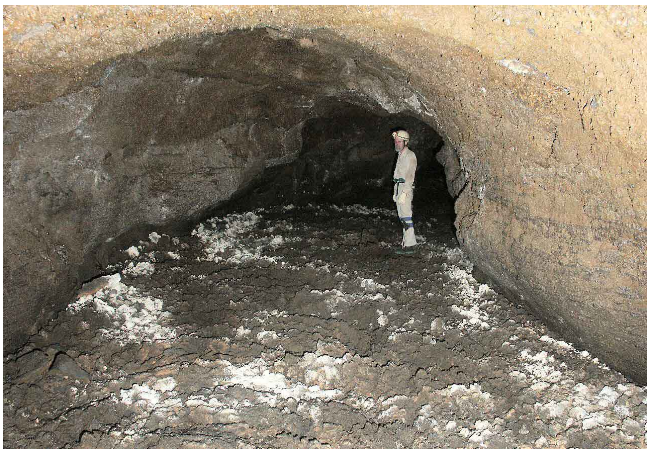


Figure 5.29: Feeder tube at lowest level, east end of The Theatre [KGG]

The top of the dome of The Theatre is in a natural lava chamber at the same level as the middle entrance series. At the base of the far wall there is a well-formed lava stalagmite (photo 5.26) and some small squeeze-up rosettes on the floor. Beyond this chamber a rough-floored crawl and sharp squeeze opens into a short section of large feeder tube with a rough ropy lava floor (Photo 5.29). A hole in the ceiling leads through a false floor to a low-roofed chamber with a curved cross-section (a tube-in-tube effect; not shown on sketch map).

The western passage, running back beneath The Stage, has nice examples of lava-tidemarks (Photo 5.27) and lava-cemented rubble in the ceiling (Photo 5.28). It ends in a small passage with triangular section that seems to be the edge of a sagged chamber – there is a surface depression above this.

The cave has formed by lava rising from the lowest feeder tube to build a surface mound that partly solidified, and then drained back to the lower level to leave the multi-level upper passages.

3H-74, 106, 108: Chocolate Surprise Cave (and neighbours).

Access & time: National Park. 30 minutes walk from car park over sharp stony ground. 2-3 hours to explore the group

Gear & Hazards: SRT or ladders to reach the separate cliff entrances of H-74 & H-108. Long tie-offs involved for each. The caves are low crawly things, locally sharp.

Description: A group of three lava caves in separate flow layers stacked on top of each other, but without open connections between the levels (Map 4.4 shows the group and their relationships). The entrances to H-74 and H-108 are exposed in the cliff of a large collapse doline. H-106 has a small entrance in a mound behind the cliff.

All three are low-roofed crawls with alternating small passages and broad low chambers (Photo 4.13). There are some good lava formations in all three caves, including intrusive lava tongues (Photo 4.13), drips, sagged ceilings (Photo 4.7) and lava floors. There are some very good primary and secondary coralloid growths on the walls of H-74. The "Chocolate Vat" in H-74 is a lava floor.

3H-90, 91: Turtle Cave.

Access & time: National Park. 5 minutes walk from car park. 5 minutes underground.

Gear & Hazards: Minimal gear, Snakes.

Description: Turtle Cave is the obvious small cavity, like an empty turtle shell, right beside the walking track to Harman 1. This, and the nearby H-91, are both *lava blisters*: low chambers developed by the draining of small surface lava mounds (see maps below, and in inset to Figure 5.22). Turtle Cave has some nice lava drips in its ceiling.

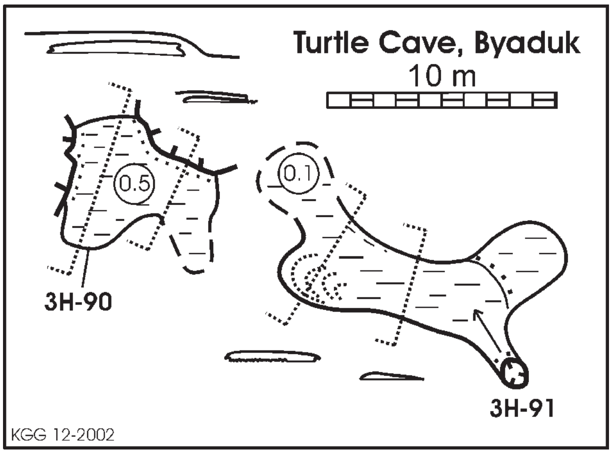


Figure 5.30: A pair of lava blisters formed by local draining of small lava mounds. Above 3H-11, Byaduk,

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