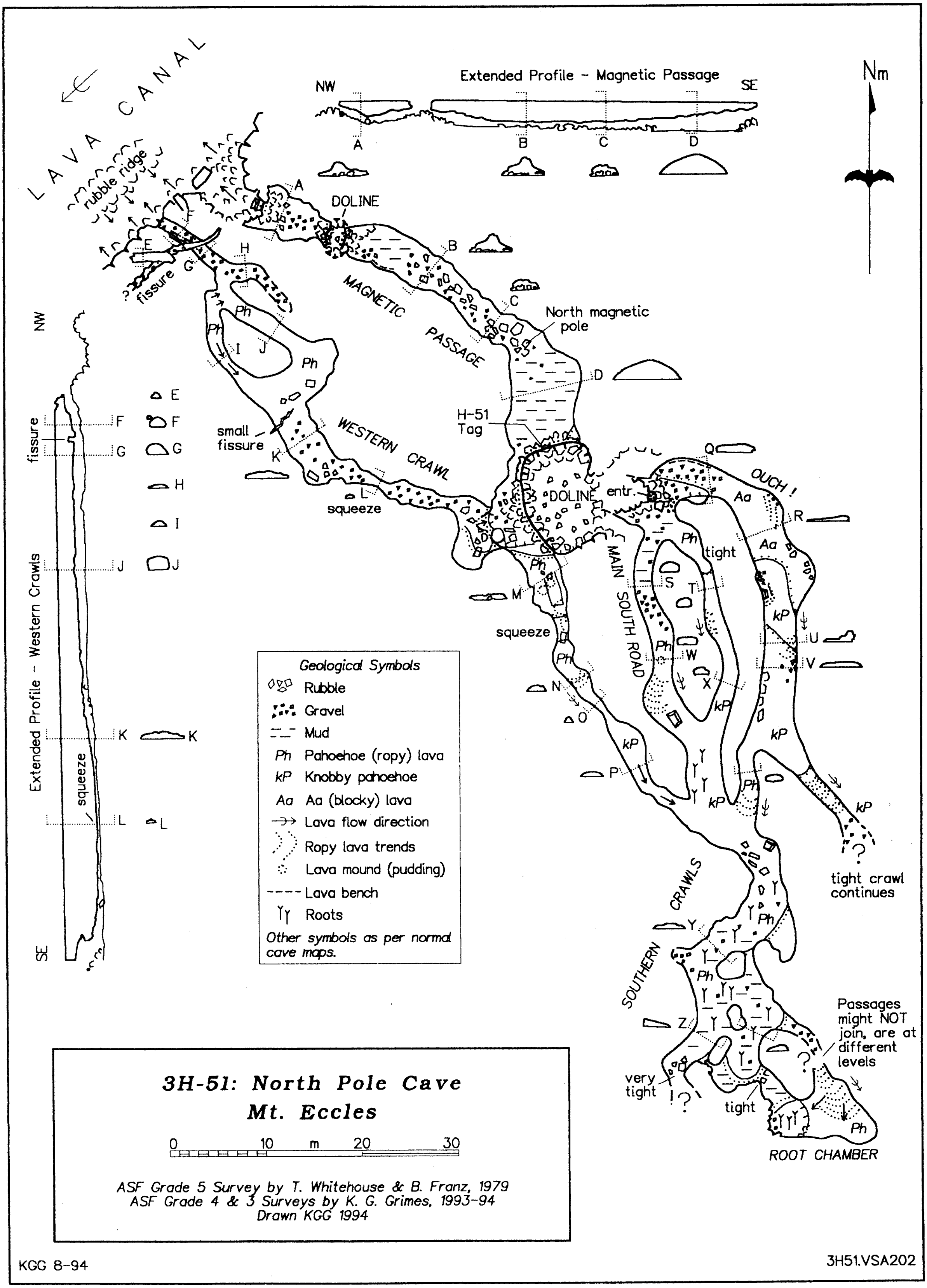
SUPPLEMENTARY MATERIAL ON THE CD
INCLUDED IN THE BOOK
PROCEEDINGS OF THE X, XI, AND XII
INTERNATIONAL SYMPOSIA ON VULCANOSPELEOLOGY

The CD contains, in addition to the PDF file for this proceedings volume, some material to supplement some of the articles. In some cases there are additional photographs or maps. In others, I have judged that a higher-resolution graphic of a map would be significantly more legible than the printed version. Australian Ken Grimes has provided PDF files of some of the papers referred to in an article and also a couple of nice color educational posters. Page numbers in red are the page numbers in this PDF file; other page references are to the book. Note that the page size is highly variable in this PDF.—Bill Mixon, AMCS Editor



Extended Profile - Magnetic Passage
NW
SE
A
B
C
D
Nm
LAVA CANAL
rubble ridge
DOLINE
fissure
MAGNETIC PASSAGE
North magnetic pole
WESTERN CRAWL
small fissure
squeeze
H-51 Tag
DOLINE
entr.
OUCH !
tight
MAIN SOUTH ROAD
Extended Profile - Western Crawls
tight crawl continues
SOUTHERN CRAWLS
Passages might NOT join, are at different levels
very tight
tight
ROOT CHAMBER
Geological Symbols
Rubble
Gravel
Mud
Ph Pahoehoe (ropy) lava
kP Knobby pahoehoe
Aa Aa (blocky) lava
Lava flow direction
Ropy lava trends
Lava mound (pudding)
Lava bench
Roots
Other symbols as per normal cave maps.
3H-51: North Pole Cave
Mt. Eccles
0 10 m 20 30
ASF Grade 5 Survey by T. Whitehouse & B. Franz, 1979
ASF Grade 4 & 3 Surveys by K. G. Grimes, 1993-94
Drawn KGG 1994
KGG 8-94
3H51.VSA202

Ref:	Report Date	Club:	Hours:	Name of Cave / Feature:	Visit Date:	Cave No:
	21-3-2002	*FEN*	*2*	*.*	*3-3-2002*	***3H-106***

Names in Party (Author, Leader):
Ken Grimes, Reto Zollinger.

If no number, tick reason
New Cave [X]
Unidentified Old Cave [ ]
Can't tell which: [ ]

Purpose and result of visit:
Inspection & survey of a cave discovered by Mark Somers on a CCV/CEGSA trip on 10-6-2000. The cave was completely surveyed and tied to the cliff above H-74. Some photos were taken. A new cave (H-108) was found nearby and surveyed and tied to H-106 (see map).

Area Name:
Volcanics (Byaduk)

Type of feature (if not Cave):

Comments/recommendations (if any):
Together with H-74 and H-108, this forms a useful reference site for a set of three shallow sub-crustal lava caves that are stacked in three separate flows. See also report on H-108.
We also looked quickly at H-74 and sketched the eastern part which was missing from its existing map. H-74 runs under H-106, but it needs a proper survey as we had trouble relating our sketch to the existing one.

Description:
A shallow "sub-crustal" system of several low interconnected chambers. There are two entrances but only the eastern one is comfortable. It consists of several interconnected, broad, but low-roofed chambers that run just beneath the surface. Some sections are very tight and dusty. The floor is mainly earth and some rubble, but with one area of flat pahoehoe lava at section X2. In the second chamber (southern end of section X-1) there is an invasive mound of pahoehoe lava lobes that has squeezed in from a rupture in the wall (photo C0204.10+11). This is the main feature of interest in the cave. The two chambers shown in section X1 are separated by a line of blocks that have fallen out of a roof slot. This fracture is in a sagged section of roof that actually touches the floor in one place (see section X1). In the north-west chamber we found a lower jaw bone of a wombat in reasonable condition (we left it there). This must be fairly old as no wombats have been recorded in the area for at least fifty years.
The cave overlaps with the eastern part of H-74, but that cave is about three metres lower and in a separate lava flow. H-108 to the northeast also comes close, but is 2m lower and in a flow lying between those that host H-74 and H-106 (see map)..

Topo Sheet:	Scale:	Best Grid co-ords:	Parish/Hundred:	Allotment:
Byaduk, 7222-2-2:	1:25,000	*0586061 m E, 5803263 m N (GPS, projection not known)*		

How to get there:
About 11m SSE of the cliff above Chocolate Surprise (H-74), a small hole at the edge of a surface mound.

Equipment:
Standard horizontal.

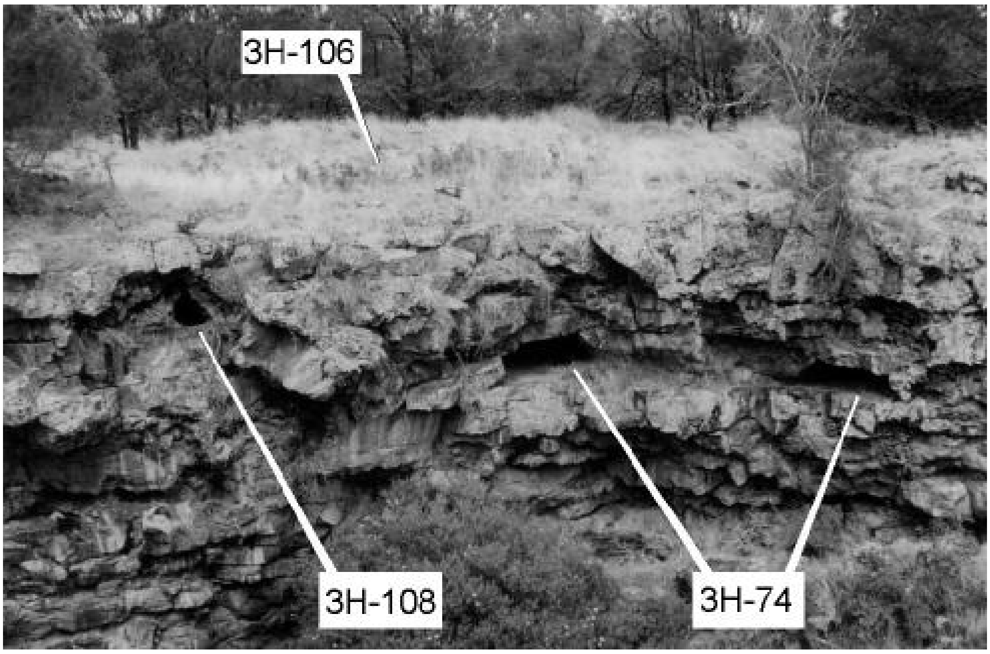
Tick the boxes for selected headings, then write about each in sequence, using the correct numbers and headings.

4 Cave type	[X]	24 Hazards	[ ]	38 Air temperature	[ ]	Geol. Strata names	[ ]
5 Rock type	[X]	25 Difficulties	[X]	39 Humidity	[ ]	Dip & Strike	[ ]
6 Other entr numbers	[ ]	26 Degree explored	[X]	40 Moisture level	[X]	Main stream flow	[ ]
7 Total entrs	[X]	27 Prospects	[X]	41 Discoverer & date	[X]	Inflow & Outflow points	[ ]
8 Entr type	[X]	28 Owner category	[X]	42 Extension discov.	[ ]	Water composition	[ ]
9 Development	[X]	29 Present Cave Use	[X]	44 Contents	[X]	Gases	[ ]
10 Decoration	[X]	30 Present surface use	[X]	45 Species	[X]	Likely archeol. Site?	[ ]
11,12 Length & method	[X]	31 Damage	[X]	46 Important for	[X]	Age of archeol. material	[ ]
13-14 Vert Range/method	[X]	32 Management class	[ ]	47 References	[ ]	Age of paleontol. Material	[ ]
15 Largest chamber	[X]	33 Protection	[ ]	Entr Doline size	[ ]	Peak tourist count / day	[ ]
16 Pitches	[ ]	34 Permission from	[ ]	Watersheds	[ ]	Yearly tourist count	[ ]
17 Horizontal Extent	[ ]	35 % mapped	[X]	No. Of levels	[ ]	Conservation rating	[ ]
18,19 Latitude & Longitude	[ ]	36 Widest Map	[X]	Accidents	[ ]	Best area map	[ ]
23 Entr elevation	[ ]	37 Entrance Marker	[ ]	Rescue comments	[ ]	2 bearings & distances	[ ]

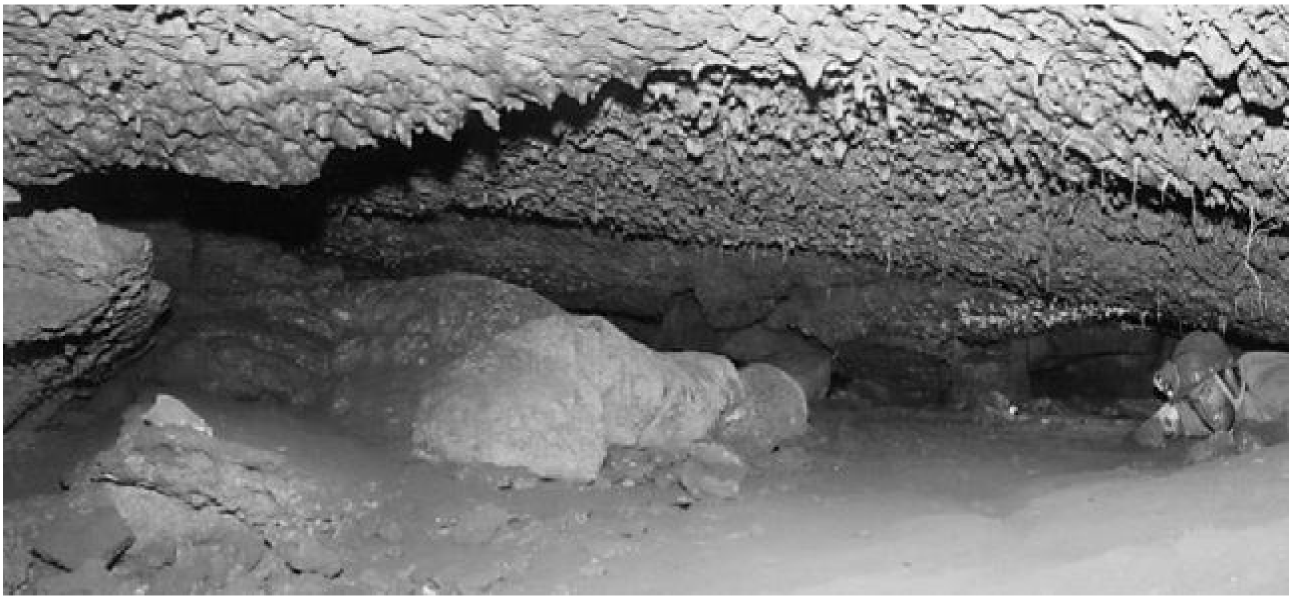
4: Type: *= Lava cave (shallow sub-crustal type)*
5: Rock *= Basalt*
7: TotEntr *= 2*
8: Entr *= Cave type, dry*
9: Dev *= A shallow "subcrustal" system of several low interconnected chambers.*
10: Decs *= Some Unusual decs*
11: Length *= 40m, surveyed*
13: Depth *= 1m, surveyed*
15: Chamber *= 6mL, 4mW, 0.7mH.*
25: Diff *= Extensive crawling*
26: Deg Exp *= Fully explored, some difficult leads*
27: Prosp *= nearby features*
28: Ownr *= Govt (State Park)*
29: CUse *= nill*
30: SUse *= State Park*
31: Dmg *= no damage*
35: %map *= 100% mapped*
36: Map *= herewith, VSA 390*
40: Moist *= dry (dusty) env.*
41: Disc *= Mark Somers, CCV, 10-6-2000.*
44: Cont *= bone*
45: Spec *= Vombatus sp.*
46: Sig *= geomorphology*

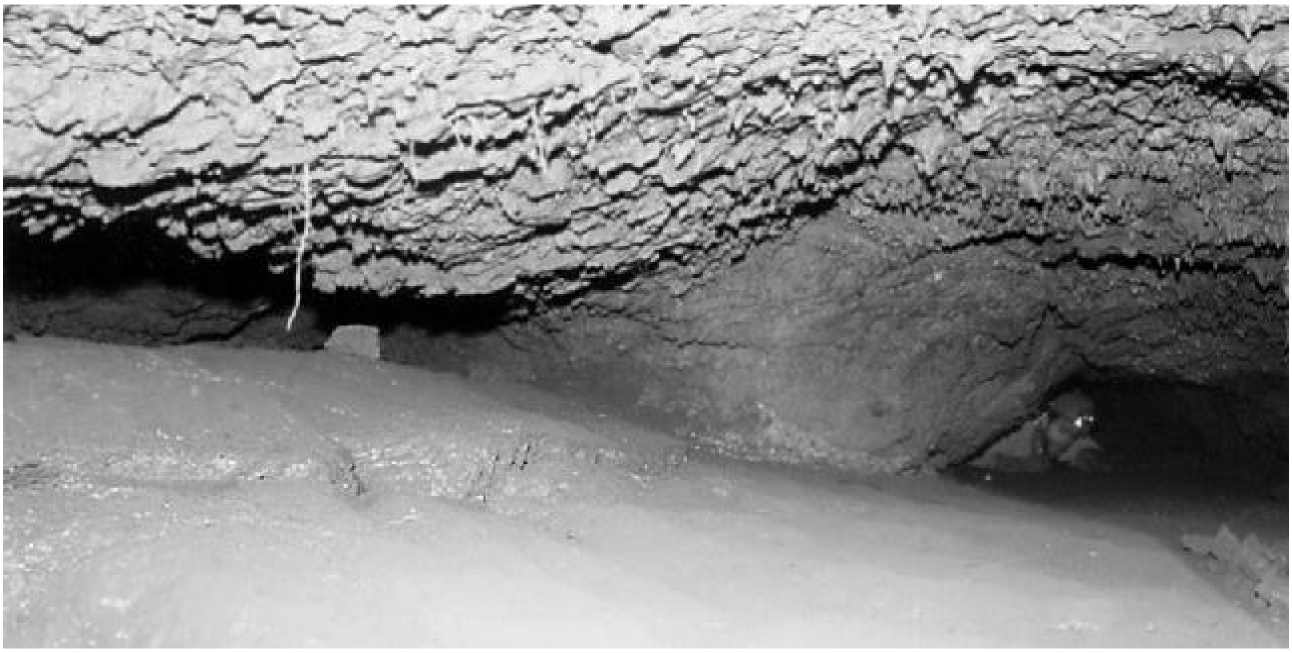
.

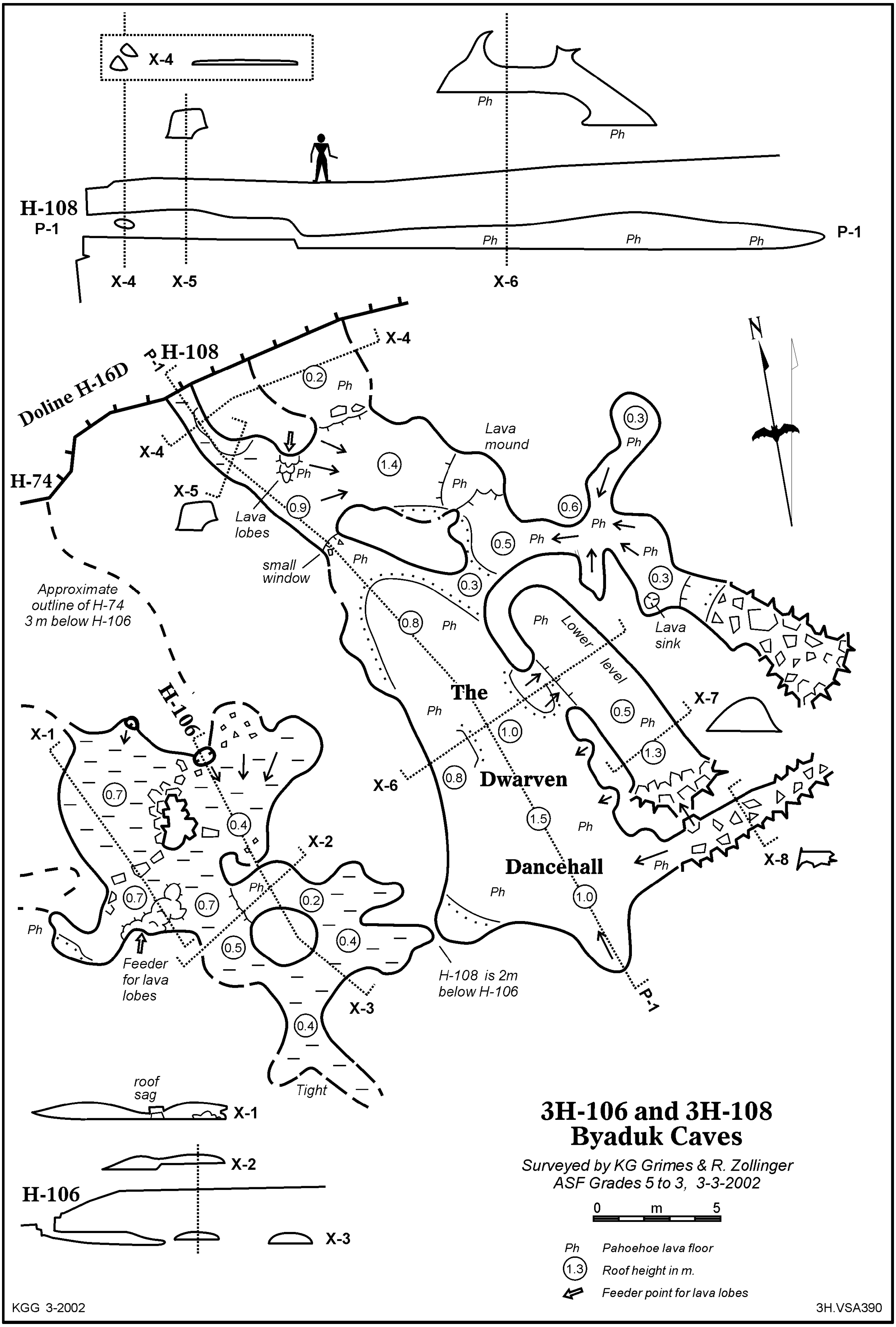
 Tick when transferred to Cave Summary [ ]



Location of cave, on surface behind the doline cliff. (C0204.24)


Invasive lava lobe (from left) in second chamber, looking NW. (C0204.10+11))


Looking south-east past section X-2. Note rise of floor to pahoehoe flow on left. (C0204.12)


X-4
X-5
X-6
Ph
H-108
P-1
Doline H-16D
H-74
Lava mound
Lava lobes
small window
Approximate outline of H-74 3 m below H-106
H-106
Lower level
Lava sink
X-7
X-8
X-1
X-2
X-3
The Dwarven Dancehall
Feeder for lava lobes
H-108 is 2m below H-106
Tight
roof sag
N
3H-106 and 3H-108
Byaduk Caves
Surveyed by KG Grimes & R. Zollinger
ASF Grades 5 to 3, 3-3-2002
0 m 5
Ph Pahoehoe lava floor
1.3 Roof height in m.
Feeder point for lava lobes
KGG 3-2002
3H.VSA390

Ref:	Report Date	Club:	Hours:	Name of Cave / Feature:	Visit Date:	Cave No:
	21-3-2002	*FEN*	*2*	*.*	*3-3-2002*	***3H-108***

Names in Party (Author, Leader):
Ken Grimes, Reto Zollinger.

If no number, tick reason
New Cave [X]
Unidentified Old Cave [ ]
Can't tell which: [ ]

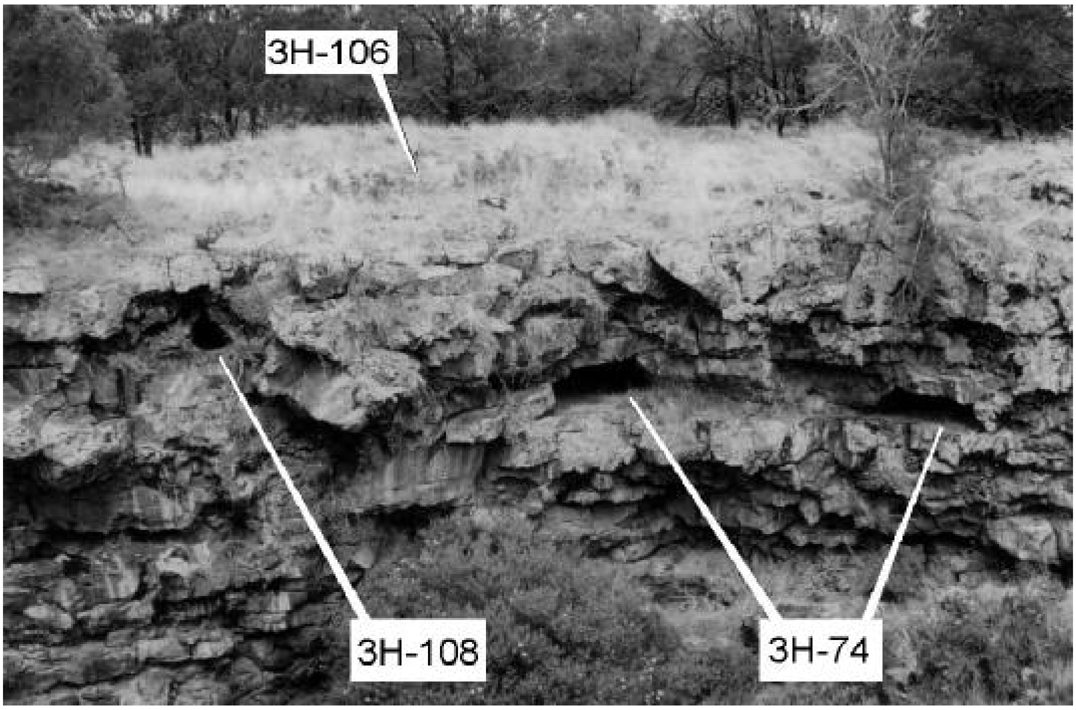
Purpose and result of visit:
Exploration & survey of a new cave near Chocolate Surprise (H-74).
A small entrance was noticed in the cliff east of H-74 and explored. The cave was completely surveyed and tied to the cliff above H-74, and to H-106 (see map).

Area Name:
Volcanics (Byaduk)

Type of feature (if not Cave):

Comments/recommendations (if any):
Together with H-74 and H-106, this forms a useful reference site for a set of three shallow sub-crustal lava caves, that are stacked in three separate flows. See also report on H-106.

Description:
A shallow horizontal "sub-crustal" system of passages and broad, low-roofed chambers. Drops to a lower level in one place.
A small entrance, partly blocked by a 'tube-in-tube' effect(section X-4) leads to a small chamber. A very low (10-20cm high) horizontal slot leads back to daylight from this chamber (section X-4). Climb over a lava mound to a junction. Left (east) is a set of small lava-floored passages that rise and fall. The main one ends at a rockpile area. Right from the junction a squeeze lead into a broad (20 x 8m), but low-roofed chamber with flat (plus small knobs) pahoehoe floor (called the "Dwarven Dancehall", 'cause only a dwarf could dance in it). There are a couple of interesting roof 'avens' in the hall (section X-6). At the east side of the hall it drops to a short lower level passage that ends at rockpile. At far end of main hall a rockpile passage leads east, and one can shine a light through a small hole to the lower level.
The cave has extensive pahoehoe floors that are smooth to knobbly. There is a lava mound at one room junction - possibly a 'partition' or 'septa'? The small window connecting the entrance chamber to the dancehall might also be through a 'septa'?, There is an invasive set of pahoehoe lobes in the entrance chamber. The "lava sink" shown on the map in the eastern section is a small pit where lava has been pouring down into a lower level, but is now blocked. There are some interesting roof avens in the main hall. I am not yet sure how to interpret these.
The cave comes close to H-106 to the southwest, but is 2m below H-106 and in a separate lava flow. The lower level comes close to that of H-74, and may indicate invasion from the H-108 flow down into a prior cave in the flow below.



Topo Sheet:	Scale:	Best Grid co-ords:	Parish/Hundred:	Allotment:
Byaduk, 7222-2-2:	1:25,000	586080 m E, 5803270 m N (map)		

How to get there:
A small triangular entrance in the doline wall about 6 m NE of H-74. Drop a ladder from above, getting off ladder and into tight entrance is a bit awkward!

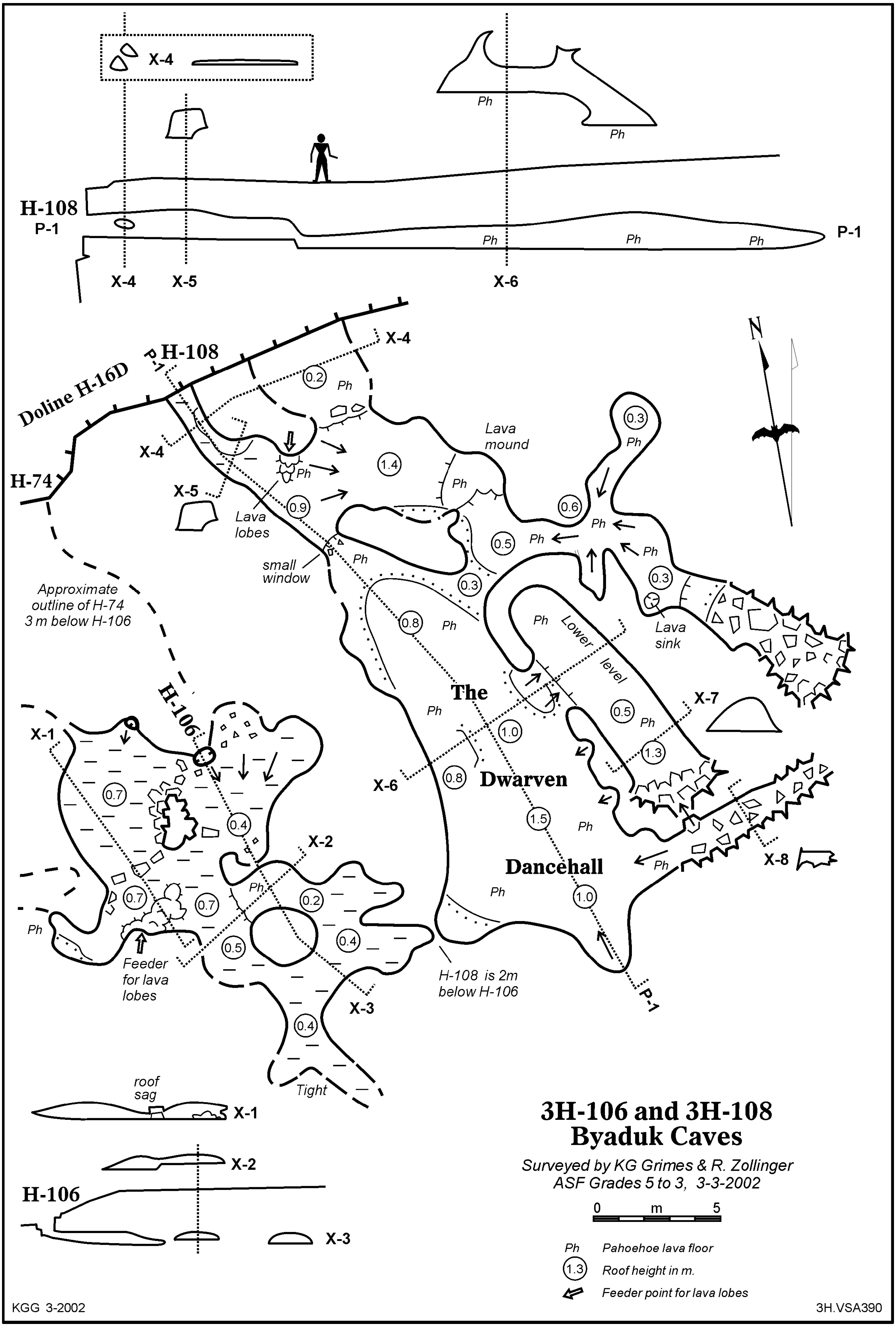
Equipment:
Ladder (awkward to rig, need extra ropes) and belay for entrance, Standard horizontal inside.

 Tick when transferred to Cave Summary [ ]

Tick the boxes for selected headings, then write about each in sequence, using the correct numbers and headings.

4 Cave type	**[X]**	**24 Hazards**	**[ ]**	**38 Air temperature**	**[ ]**	**Geol. Strata names**	**[ ]**
5 Rock type	**[X]**	**25 Difficulties**	**[X]**	**39 Humidity**	**[ ]**	**Dip & Strike**	**[ ]**
6 Other entr numbers	**[ ]**	**26 Degree explored**	**[X]**	**40 Moisture level**	**[ ]**	**Main stream flow**	**[ ]**
7 Total entrs	**[X]**	**27 Prospects**	**[X]**	**41 Discoverer & date**	**[X]**	**Inflow & Outflow points**	**[ ]**
8 Entr type	**[X]**	**28 Owner category**	**[X]**	**42 Extension discov.**	**[ ]**	**Water composition**	**[ ]**
9 Development	**[X]**	**29 Present Cave Use**	**[X]**	**44 Contents**	**[ ]**	**Gases**	**[ ]**
10 Decoration	**[X]**	**30 Present surface use**	**[X]**	**45 Species**	**[ ]**	**Likely archeol. Site?**	**[ ]**
11,12 Length & method	**[X]**	**31 Damage**	**[X]**	**46 Important for**	**[X]**	**Age of archeol. material**	**[ ]**
13-14 Vert Range/method	**[X]**	**32 Management class**	**[ ]**	**47 References**	**[ ]**	**Age of paleontol. Material**	**[ ]**
15 Largest chamber	**[X]**	**33 Protection**	**[ ]**	**Entr Doline size**	**[ ]**	**Peak tourist count / day**	**[ ]**
16 Pitches	**[ ]**	**34 Permission from**	**[ ]**	**Watersheds**	**[ ]**	**Yearly tourist count**	**[ ]**
17 Horizontal Extent	**[ ]**	**35 % mapped**	**[X]**	**No. Of levels**	**[ ]**	**Conservation rating**	**[ ]**
18,19 Latitude & Longitude	**[ ]**	**36 Widest Map**	**[X]**	**Accidents**	**[ ]**	**Best area map**	**[ ]**
23 Entr elevation	**[ ]**	**37 Entrance Marker**	**[ ]**	**Rescue comments**	**[ ]**	**2 bearings & distances**	**[ ]**

4: Type: *= Lava cave (shallow sub-crustal type)*
5: Rock *= Basalt*
7: TotEntr *= 1*
8: Entr *= Cave type, dry*
9: Dev *= A shallow "subcrustal" system of several low interconnected chambers and passages, and one lower level.*
10: Decs *= Some Unusual decs*
11: Length *= 83m, surveyed*
13: Depth *= 2.5m, surveyed*
15: Chamber *= 20mL, 8mW, 1.5mH.*
25: Diff *= Extensive crawling*
26: Deg Exp *= Fully explored, some difficult leads*
27: Prosp *= nearby features*
28: Ownr *= Govt (State Park)*
29: CUse *= nill*
30: SUse *= State Park*
31: Dmg *= no damage*
35: %map *= 100% mapped*
36: Map *= herewith, VSA 390*
41: Disc *= Reto Zollinger & KG.Grimes, 3-3-2002*
46: Sig *= geomorphology.*


X-4
Ph
Ph
H-108
P-1
Ph
Ph
Ph
P-1
X-4
X-5
X-6
H-108
P-1
X-4
Doline H-16D
(0.2)
Ph
X-4
H-74
X-5
Lava lobes
(0.9)
Ph
(1.4)
Lava mound
Ph
(0.3)
Ph
(0.6)
Ph
(0.5)
Ph
Ph
(0.3)
small window
Ph
(0.3)
Approximate outline of H-74 3 m below H-106
(0.8)
Ph
Ph
Lower level
Lava sink
H-106
The
Ph
(1.0)
(0.5)
Ph
X-7
(1.3)
X-1
X-6
(0.8)
Dwarven
(0.7)
(0.4)
(1.5)
Ph
X-2
Dancehall
Ph
X-8
Ph
(0.7)
(0.7)
(0.2)
Ph
(1.0)
Ph
(0.5)
(0.4)
Feeder for lava lobes
H-108 is 2m below H-106
X-3
P-1
(0.4)
roof sag
X-1
Tight
X-2
H-106
X-3
3H-106 and 3H-108
Byaduk Caves
Surveyed by KG Grimes & R. Zollinger
ASF Grades 5 to 3, 3-3-2002
0 m 5
Ph Pahoehoe lava floor
(1.3) Roof height in m.
Feeder point for lava lobes
KGG 3-2002
3H.VSA390

Text and diagrams of a paper *in* Baddeley, G (Ed) *Vulcon Precedings (20th Australian Speleological Federation Conference, 1995)* , Victorian Speleological Association Inc., Melbourne., pp 15-22. (1995)

Lava caves and channels at Mount Eccles, Victoria.

Ken Grimes

PO Box 362, Hamilton, Victoria, 3300.

Introduction

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

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

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

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

Lava Channels

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

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

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

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

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

Lava Caves

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

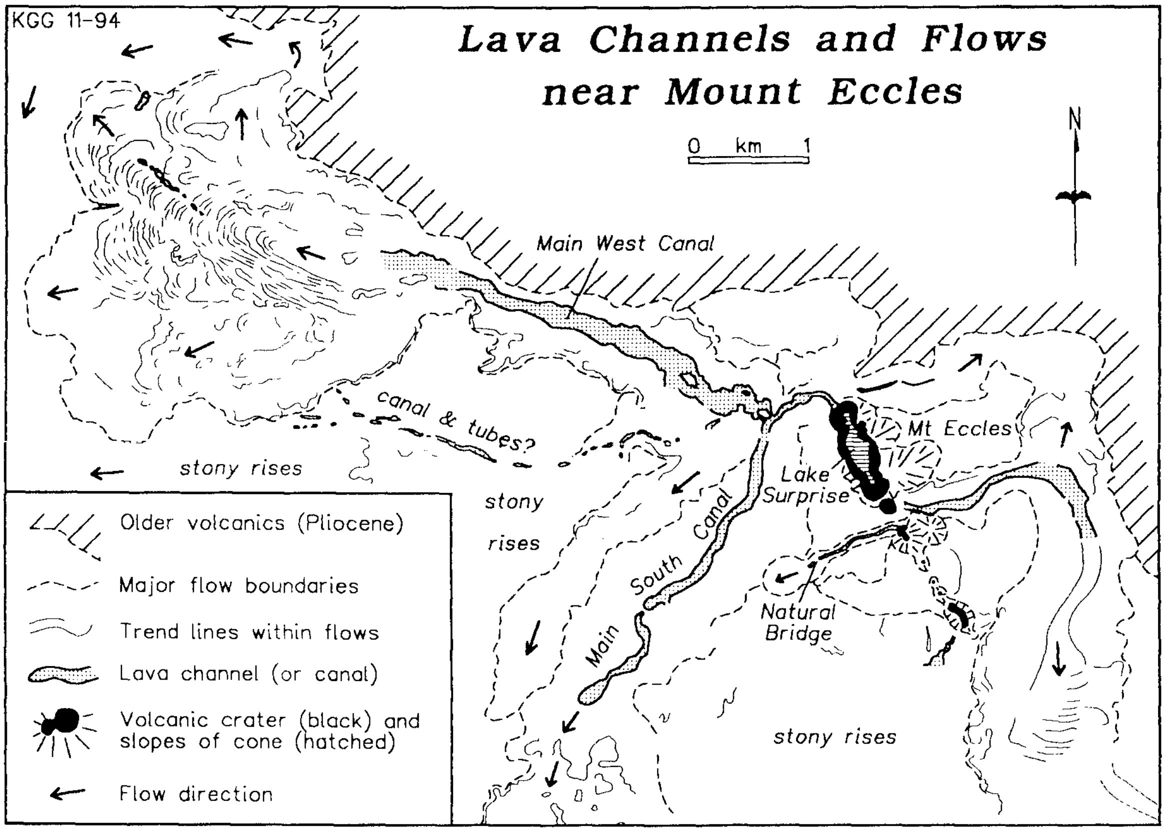


Figure 1: Lava Channels and Flows near Mount Eccles

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

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

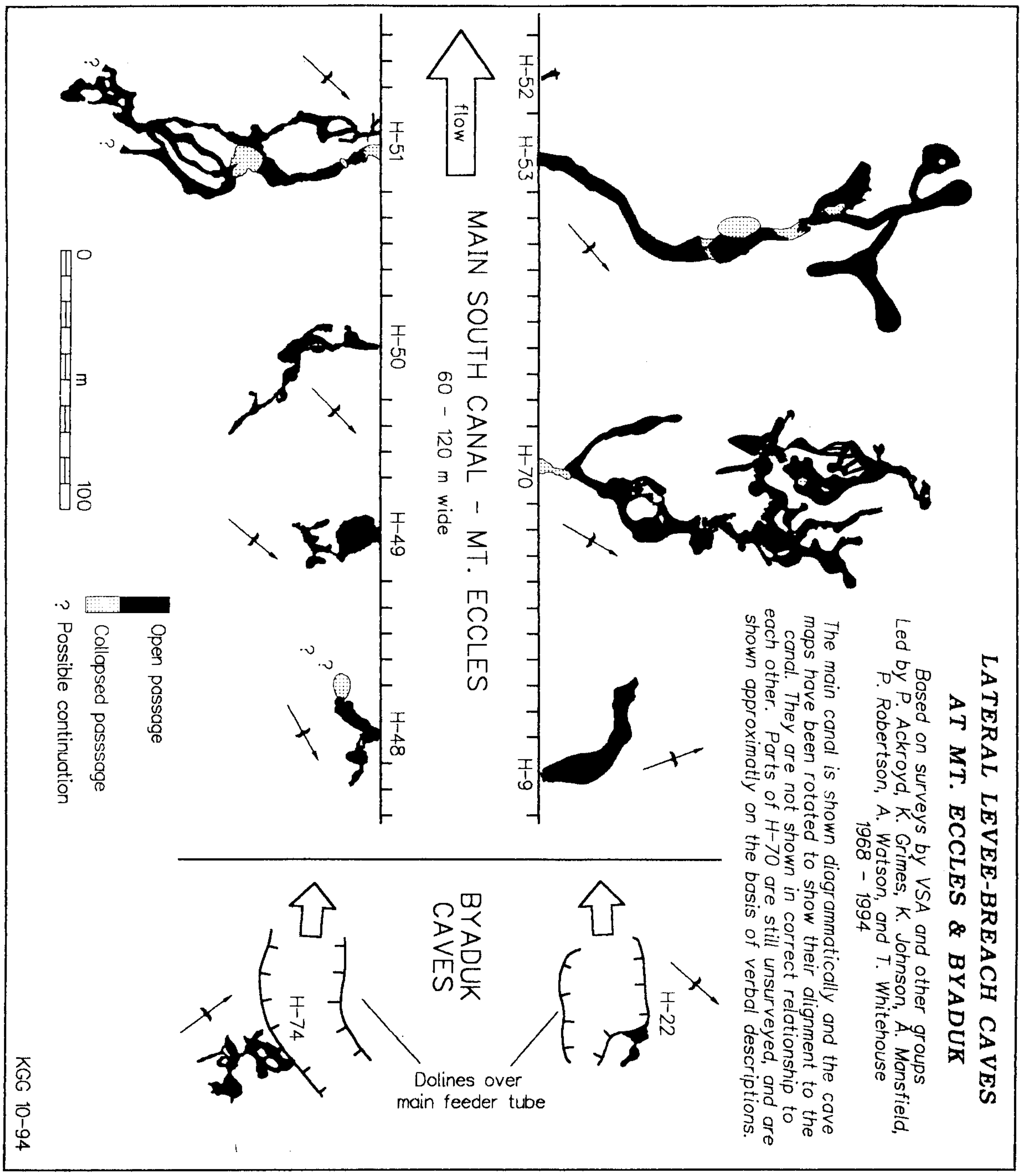


Figure 2: Lateral levee-breach caves at Mt. Eccles and Byaduk

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

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

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

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

The Byaduk Caves

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

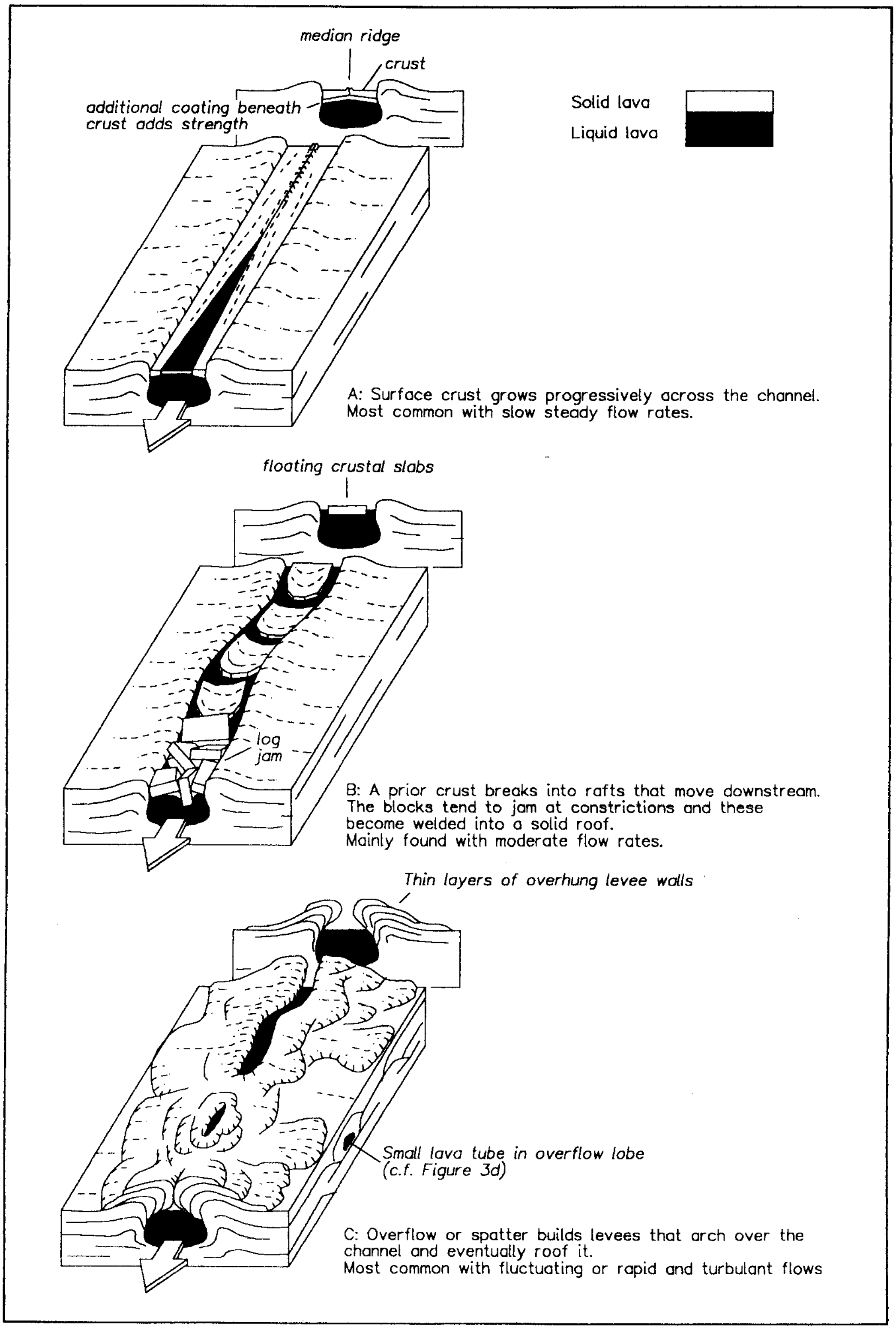


Figure 3: Formation of lava tubes, by roofing over of a lava channel (A-C), or by drainage from beneath crusted lava lobes (D, next page)

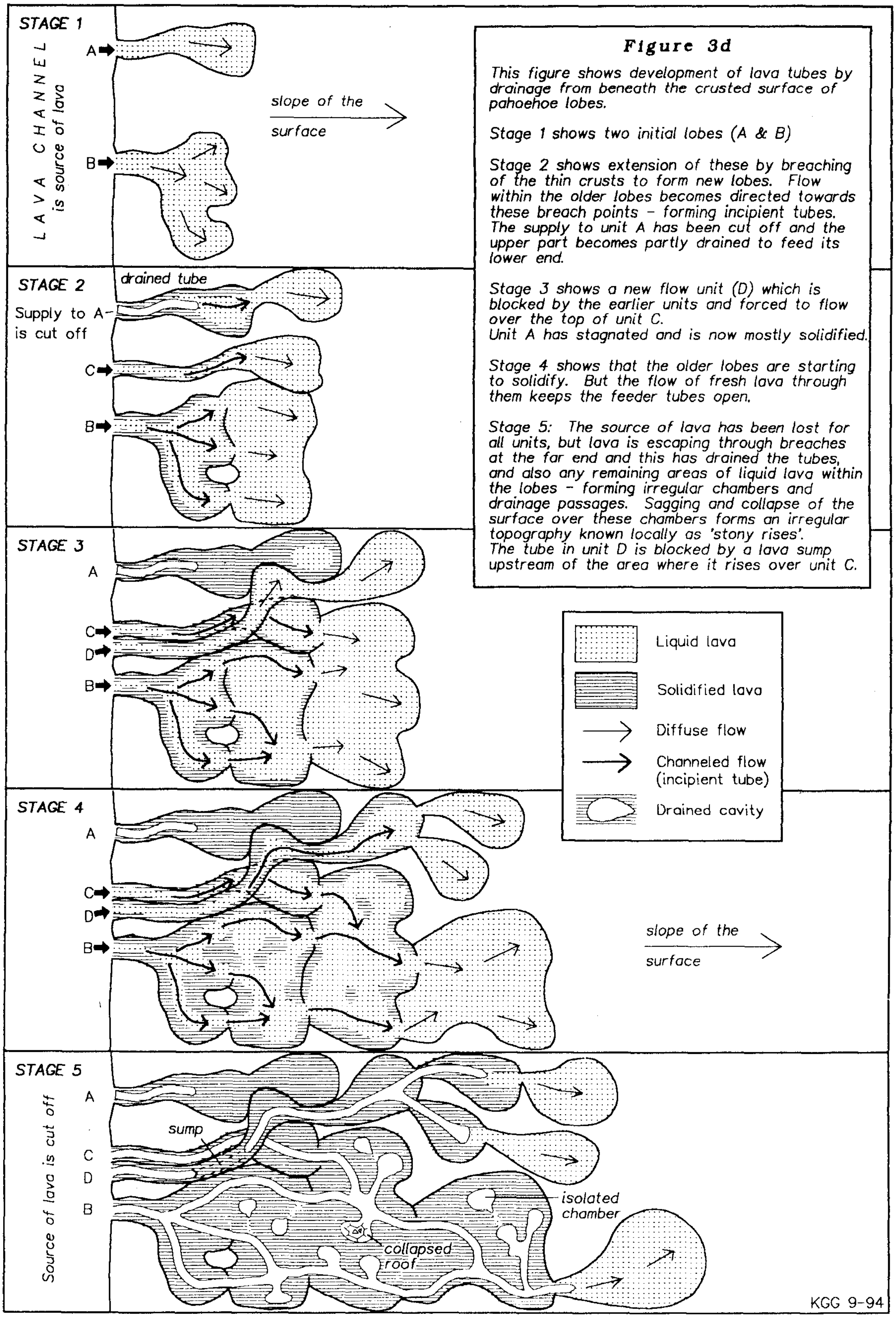


Figure 3d

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

Stage 1 shows two initial lobes (A & B)

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

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

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

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

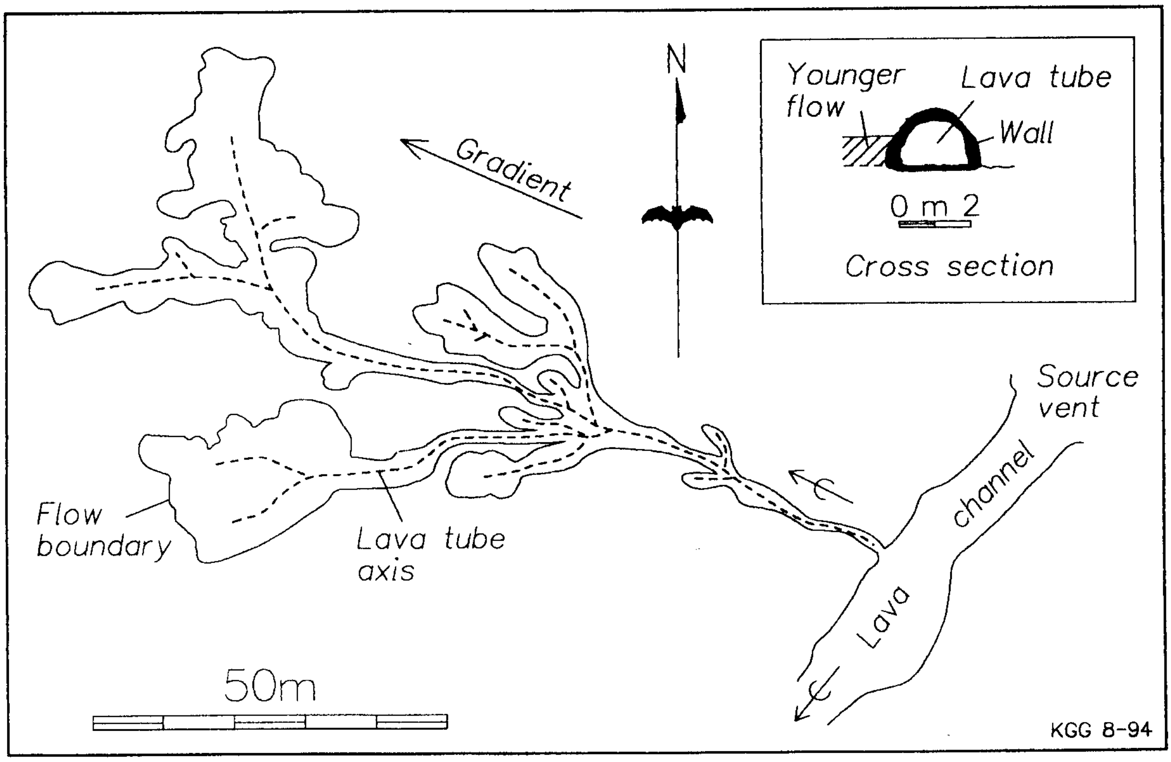


Figure 4: Example of a distributary system of small lava tubes feeding pahoehoe lobes. From near Bend, Oregon. (after Greeley, 1987)

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Carmichael Cave (3H–70): A complex, shallow, "sub–crustal" lava cave at Mount Eccles, Victoria.

Ken Grimes

Carmichael Cave (3H–70) is a shallow lava tube system that starts at the edge of the main southern lava canal at Mt. Eccles and runs north as a series of branching, interconnected low–roofed tunnels and chambers.

Of the known lava caves at Mt. Eccles, this is currently the most interesting. It is a complex system showing a variety of development styles and having a wide range of well–preserved lava features within it. This cave is a critical reference site in the region for the understanding of the development of the shallow "sub–crustal" or "drained lobe" lava tubes. It has had little damage—so far. Its current protection relies on the lack of signposting and location information.

This report compiles observations from many trips by a variety of clubs and individuals (1991 – 1999) and presents the (finally) completed map.

Carmichael's Cave is named after Andy Carmichael, ranger at Mt. Eccles, who died suddenly in early 1993. Several people appear to have discovered and rediscovered its various parts over the last 20 years or so. Peter Matthews tells me that its first VSA record was by a VSA team led by Tom Whitehouse on 12th May 1979, but it wasn't numbered and tagged until 1990. I was first shown the H–71 entrance by Rob Young, a local farmer and field naturalist with a keen interest in the caves, in 1991. He had known of it for some time. On the VSA trip of 25th – 26th June 1994, when mapping commenced in earnest, the H–70 area was connected through to the previously unexplored H–79 entrance, which in turn was found to connect through an impassable squeeze to part of the H–71 section (previously called *Maze Cave*). Most of the cave was surveyed in two weekends in 1994, with teams led by Ken Grimes (H–70, and eastern part of H–79), Tony Watson

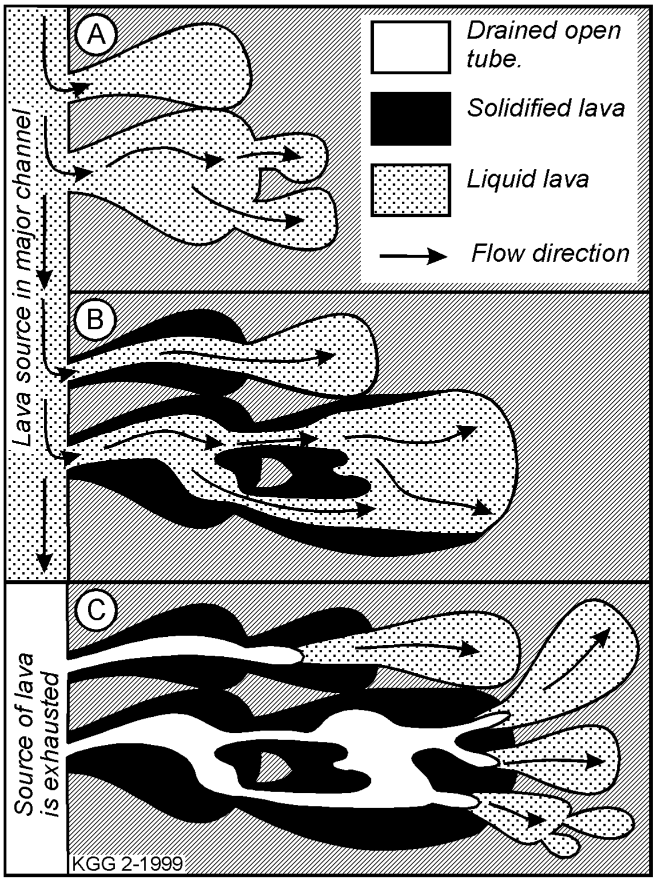


Figure 1: Stages in the formation of sub–crustal lava tubes by draining of thin lava lobes (from Grimes, 1999).

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

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

C: When the source flow ceases some of the conduits may drain to form air–filled cavities.

(H–71, *Maze* and part of the *Big Chamber* area), Peter Ackroyd (surface survey and west from H–79) and Roger Taylor (H–71, part of the *Big Chamber* and the southern passage from the *Maze* area). Ferret (Brett Wakeman) provided a sketch map of the northernmost area beyond the "sharp" aa squeeze—to the best of my knowledge he is the only person to have entered that area! It took a while to get everyone's field notes together, and a few gaps remained, mainly the two passages running south from the H–79 entrance, and for that reason the map in the Vulcon field guidebook has only a preliminary silhouette. The final tidy–up survey was not done until 1999.

Description

The H–70, 71 and 79 segments are all part of the same system formed in a thin sheet of lava that breached or overflowed the levee banks on the side of the South Canal. The tunnels would have fed a lateral lava flow that ran down the levee slopes to the west and their low but complexly–branching form suggests formation by progressive growth and draining of a series of lava lobes (Figure 1). The *Big Chamber* below the H–71 entrance is a somewhat deeper system, possibly in an older lava sheet, and the H–79 segment has breached into its roof via the *Maze section*.

H–70 Segment

The H–70 entrance is at the southern end of the cave, between the track and the edge of the canal. There is a shallow hollow linking it to the canal that would be due to collapse of that part of the tunnel. Inside the entrance there is a rubble cone and two branches. The northern tunnel leads to the main system (see below). The western branch is a 46m long tunnel, typically 3–4m wide and 1m high initially, but becomes wider and lower towards the end, where the roof finally drops to the level of the lava floor. In one place (see cross section X3) the roof lining has sagged enough to leave a gap above it. There are a few poorly developed lava "benches" and some tree roots, but little else of interest was seen in this passage. Bones of a small dog (or fox?) and a probable brushtail possum were found in this passage.

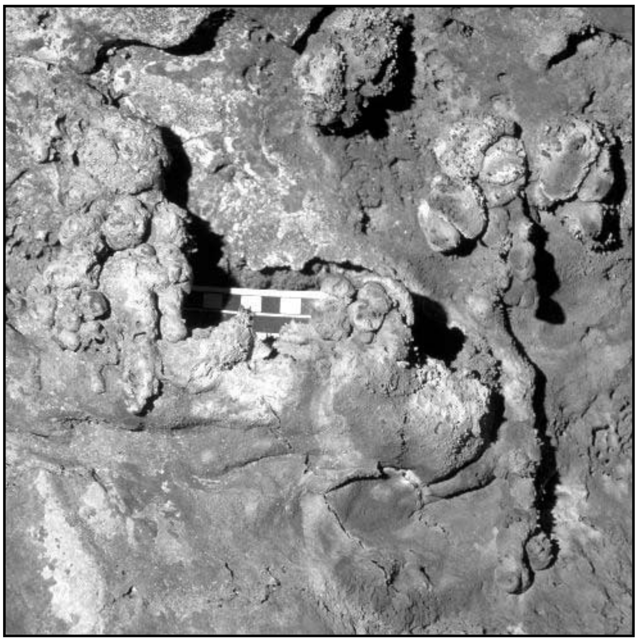


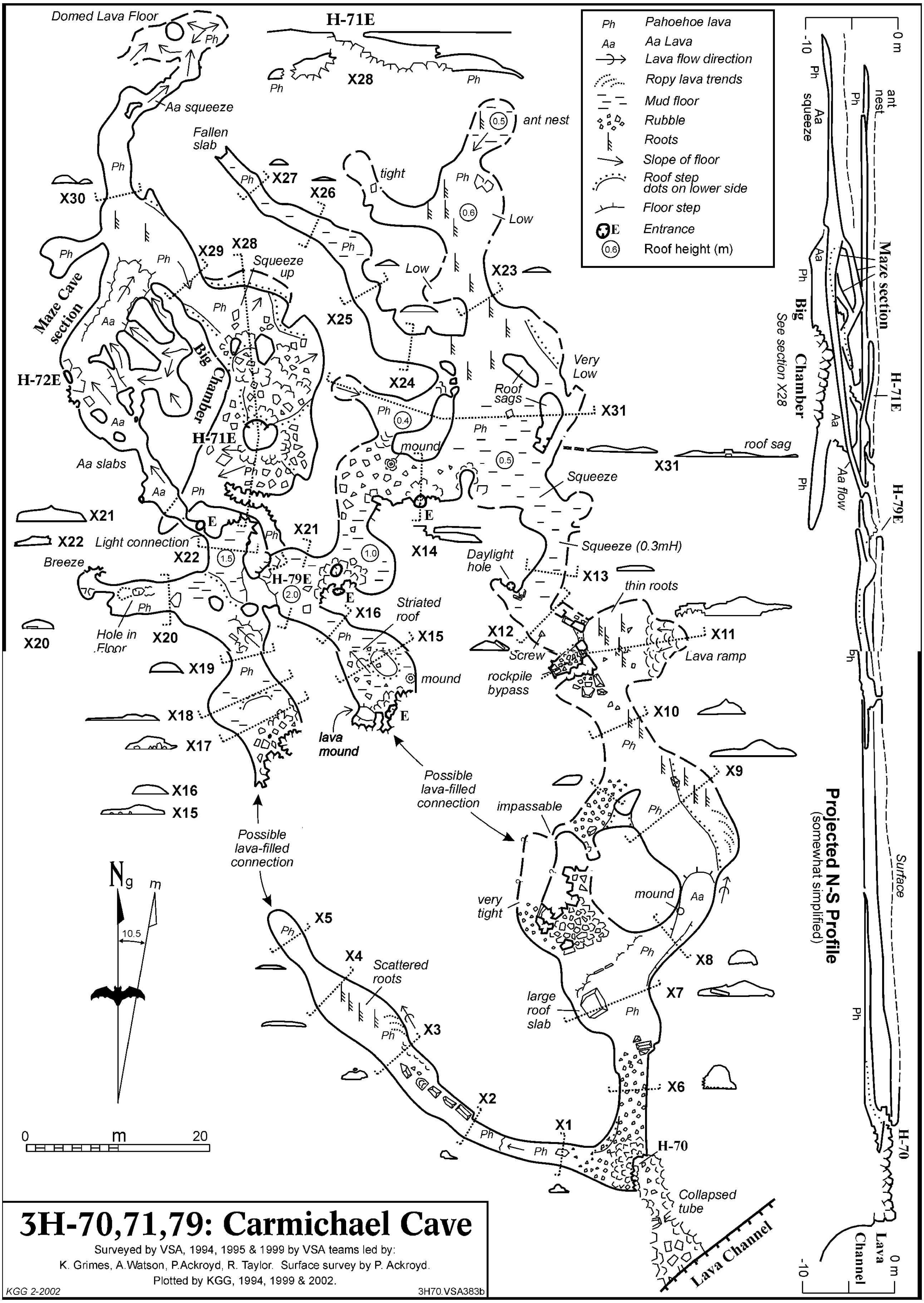
Figure 2: Lava "turds" extruded through small holes in wall lining. Scale is marked in centimetres.

The northern tunnel starts off as a typical "tunnel" shape about 3m wide and up to 3m high in places. Near the entrance on the right hand (east) side some lava dribbles on the wall slope away from the entrance, suggesting an inward flow of hot gases when they formed. On the left wall and a bit further in look for a small ledge at eye height. This has formed where a thin lining has sagged. Here, lava with a pasty consistency has oozed out through several holes in the remaining lining to form lava "hands" and built up small agglutinated lava–mites on the shelf below. There are also some interesting "dog turd" shaped lava deposits here (see Figure 2). Lower down the lining has fallen off to expose some layered lava. All along this section there are good lava drips and ribs on the ceiling.

The tunnel widens to form a chamber (cross–section X7) then heads off to the NE. On the floor on the left hand side of the chamber one can see the edge of a thin final flow, along with some vertical slabs that would be tilted fragments of lava crust. The largest slab may be a fallen piece of thick roof lining. The rubble pile is collapsed roof material, but you can crawl and squeeze along the southern side to where I could look north into a low chamber, but I was too thick to get into it.

Following the main tunnel the pahoehoe lava floor becomes rougher for a while and approaches an aa style before ending abruptly. The passage then turns to the NW and widens. The floor in this area (X9) is pahoehoe again, with a mosaic pattern that suggests that crustal fragments were cracking and jostling each other on the surface of a stationary flow. The roof has a more hackly surface with secondary cave–coral deposits, in contrast to the smooth linings with drips seen to the south, but there are still some sections with drips in this area.

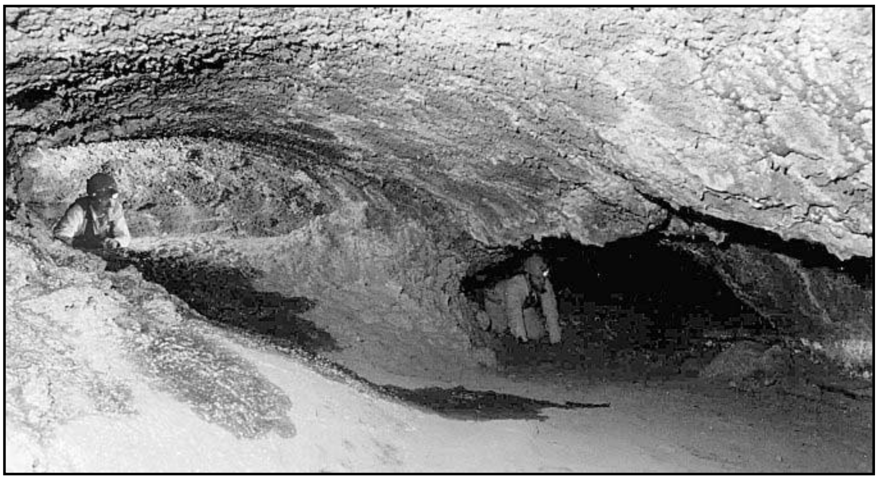
A side branch to the south–west is blocked at the end by a massive roof sag, but has two very tight 'impossible' continuations on each side: one of which might connect back to the unreachable void I saw from the south.



Panorama of the broad chamber of cross–section X31 would be a drained lava lobe.
Box is 30cm wide—the roof is nowhere more than 1m high.

Incorrect Caption!
the photo this refers to is missing

The main passage continues to what was originally thought to be the 'final' chamber (section X11). This is a moderately sized chamber, up to 1.7m high, with thin tree roots. It has a mound of ropy lava rising up the eastern side. Possibly this was an inward flow from above or from a blocked passage? A couple of very small holes at the base of the west wall give a view into the H–79 section. The way through is by a squeeze up into a rockpile chamber to the west and then back down on the other side.



Western part of the H–79 segment, looking south from cross–section X22. High area to left is a lava mound separating two sub–tubes. Could this be a remnant of a partition separating two lava lobes?

H–79 Segment

This central segment is the largest part of Carmichael Cave and can be divided into a more extensive, but simpler, eastern part, and a more complex western part—with the change in character at section X14 (see map). As well as the numbered entrance there are several others which carry unofficial PJA tags placed during the survey.

The eastern part is essentially a set of low broad rooms and low passages. Roof height is less than a metre throughout and the ceilings are flat to broadly arched, with local sags (photo). The floors are flat pahoehoe lava with mud coatings in places. Breakdown is rare, being confined to a few isolated blocks that have fallen out of slots in the roof. Tree roots are locally common. In the northeastern chamber the floor is slightly higher. There is an ants nest here. A tight (0.3m high) squeeze at section X13 has stopped some thicker–than–normal people. A small chamber at the western end of section X31 is at a slightly higher level. A pahoehoe flow appears to have entered into this chamber from the northwest and exits via shallow ramps down the southern and northeast connections to the rest of the cave.

The western part has some larger passages, up to 2m high, and more breakdown. The floor is mostly pahoehoe plus rubble and some local patches of aa lava. The numbered H–79 entrance is in the centre of this portion and leads to a relatively large, 2m high, domed chamber. The two low, wide, passages south of it both end in rubble blockages. Pahoehoe patterns in these indicate a flow to the north, so these passages may once have been connected to the H–70 area via passages that are now lava–filled or choked by rubble. The arched roofs show striations in several places—possibly formed by gas blasts?

Going west from the entrance chamber of H–79 one climbs over a lava mound into another roomy chamber (1.5m high—see photo). This mound might be a partly remelted partition between two lava lobes; of the type postulated by Hon & others, (1994). A similar, smaller mound occurs south of section X15. From the bigger mound one can continue west to a low–roofed area where an aa flow drops into a floor–hole with a short cavity continuing beneath the thin floor crust. There is a slight breeze at the far end of this area. The map shows that the northern part of the H–79 segment overlies the southern passages of H–71 which are 5m lower, but there is no direct connection. Instead an impenetrable squeeze (light connection) leads to a sloping tube that runs NW into the H–72 maze area.

H–71 Segment (Big Chamber)

The H–71 entrance leads to a large rubble pile that partly blocks and segments what would originally have been a single large chamber with a pahoehoe floor (cross–section X28). This is at a lower level than the rest of the system and may have formed in an earlier lava flow. 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 "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. At the northwest end of this chamber the floor rises to the junction with the Maze Section.

H–72 Segment (Maze Cave section)

This complex area is the connection between the higher levels of the H–70 and H–79 sections and the Big Chamber of H–71. A small (un–numbered) entrance just beyond the light connection with H–79 leads down a sloping passage with a floor of rugged aa and tilted slabs to the maze area. The mazes are a set of small sloping passages, which seem to have connected the two levels. They all feed out into a single passage to the north with an aa flow on the floor that just reaches the connection with the H–71 chamber (photo). The cave then continues north as a low passage that narrows to a painful aa squeeze then drops to a final chamber with a domed pahoehoe floor.

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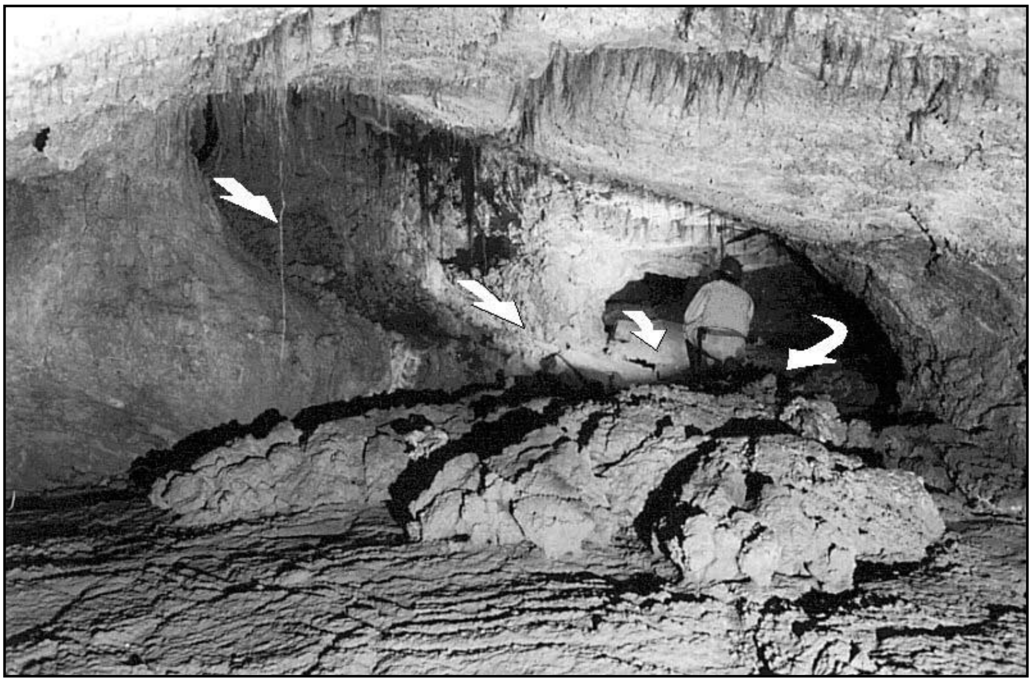


Looking SW into the H–72 maze section. Pahoehoe flow in foreground with a tongue of aa flow invading from higher level. Arrows indicate entry points from maze section.

Natural Bridge (3H–10), Mount Eccles: a special type of lava tube.

Ken Grimes

Natural Bridge is a small but interesting cave found at the far end of a small lava channel (or canal) south of Mount Eccles. The lava channel originated as an overflow from a small crater—one in the line of craters that runs southeast from Mount Eccles. These craters may have erupted from a fissure, or may be "hornitos" fed through skylights in a lava tube that was running southeast from the main crater of Mount Eccles. The geologists are still undecided as to which story they believe.

In its final section the channel becomes more narrow and deeper and eventually is roofed over with lava to form the cave. Beyond the cave the channel widens out and disappears.

A walking track follows the channel from its source vent down to the cave, and this is the most interesting approach. Alternatively, you can drive along a dirt road and park 100m from the cave, just before the track drops down and crosses the lava channel. From the far side of the cave the walking track continues across stony rises to the South Canal and one can return to Mount Eccles by that route, possibly visiting other caves on the way (Figure 1).

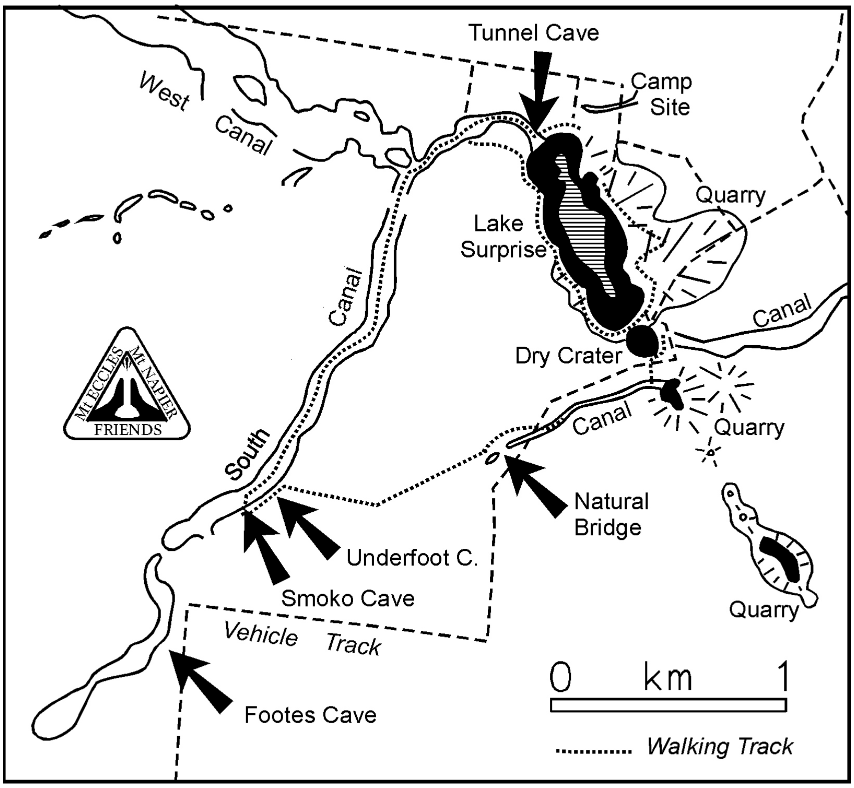


Figure 1: Mt. Eccles and its craters, lava channels, and those caves which are commonly visited by the general public.

Features of the cave

As you approach the main, south, entrance note the contorted lava layering on the wall of the cliff to the left. This is the result of slumping of the layers while they were still hot and soft. Look up at the roof of the entrance (Figure 2). The walls come together at a sharp angle and in places inside the cave they leave a narrow slot. It is this angular arched roof that gives the cave its other name, *Gothic Cave*, and which gives it its special interest—as we shall see later. The cave is a simple short tunnel, with a roof hole in one place (see cave map, Figure 3). Total passage length is only 36m, and the depth is 15m. A lot of material has fallen from the roof and walls and the floor is mostly rubble–covered apart from one flat soil–covered section—a lava surface probably underlies this. The roof has a distinctive angular "gothic" shape (Front Cover Photo). The main passage has a narrow roof slot, where the walls almost meet. A small high–level chamber and daylight hole occur above the roof slot at section X5. At one point (between sections X3 and X4) there is another small high–level chamber visible above the slot. Lower down the cave is wider, and partly modified by collapse. Collapsed sections reveal the contorted layering in the walls (Figure 4). The floor within the cave is much lower than the open sections of the channel outside, those have been partly filled by rubble from collapse of a former roof and walls. Upstream

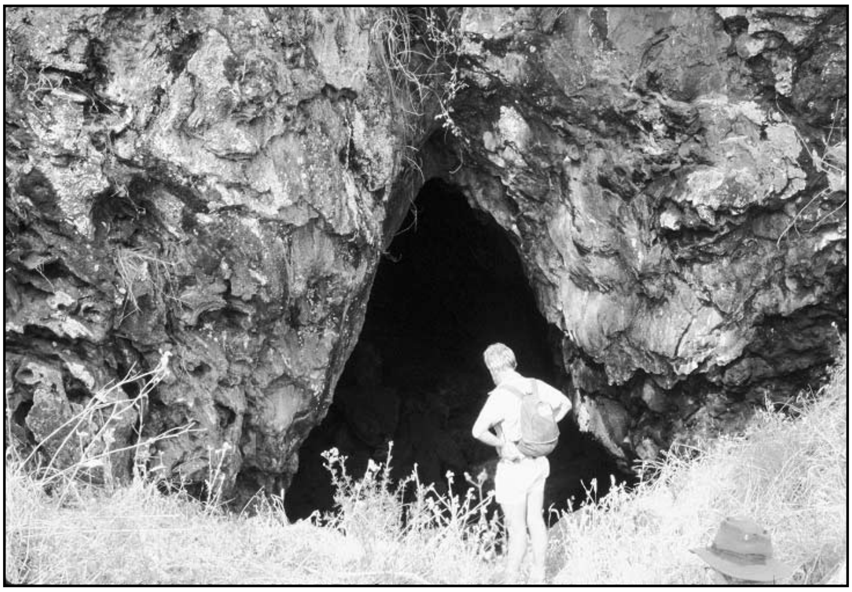


Figure 2: Southwest entrance to Natural Bridge. Note the “Gothic” roof outline.

(northeast) the open channel is quite narrow, and a roofed tube may have once extended some distance this way. Downstream, the channel widens and loses its character quickly.

The cave has a few lava drips and dribbles, but nothing special in the way of lava decorations. However, near cross section X4 the south wall has a smooth surface with scattered sub–horizontal grooves. These formed where slabs of crust, floating on a past lava stream, have scraped against the soft lava lining on the wall (Figure 5).

The cave environment

Cave environments are characterised by darkness, dampness and a stable temperature with little air movement. This cave generally has a pool of cool air, most noticeable in summer; however, in a small cave such as this the light from both entrances prevents complete darkness.

As your eyes adapt to the twilight you will notice a greenish tinge to the rocks. A range of small plants are managing to survive on the limited light that comes through the entrance. These include small ferns, mosses, liverworts and algae. You will see that there is a marked change in colour from green on the sides facing the entrance to black on the shaded side. The cave is quite colourful if you have a bright light (floodlight)—a mix of greens and rich browns.

The origin of the cave

There are two main ways in which lava caves form: by the roofing of a surface lava stream running in an open lava channel or by draining out from beneath a crusted lava lobe within a lava flow. The processes have been observed in active lava flows in Hawaii and elsewhere (Peterson & others, 1994) and I have illustrated examples of these processes in Grimes (1995 & 1999)

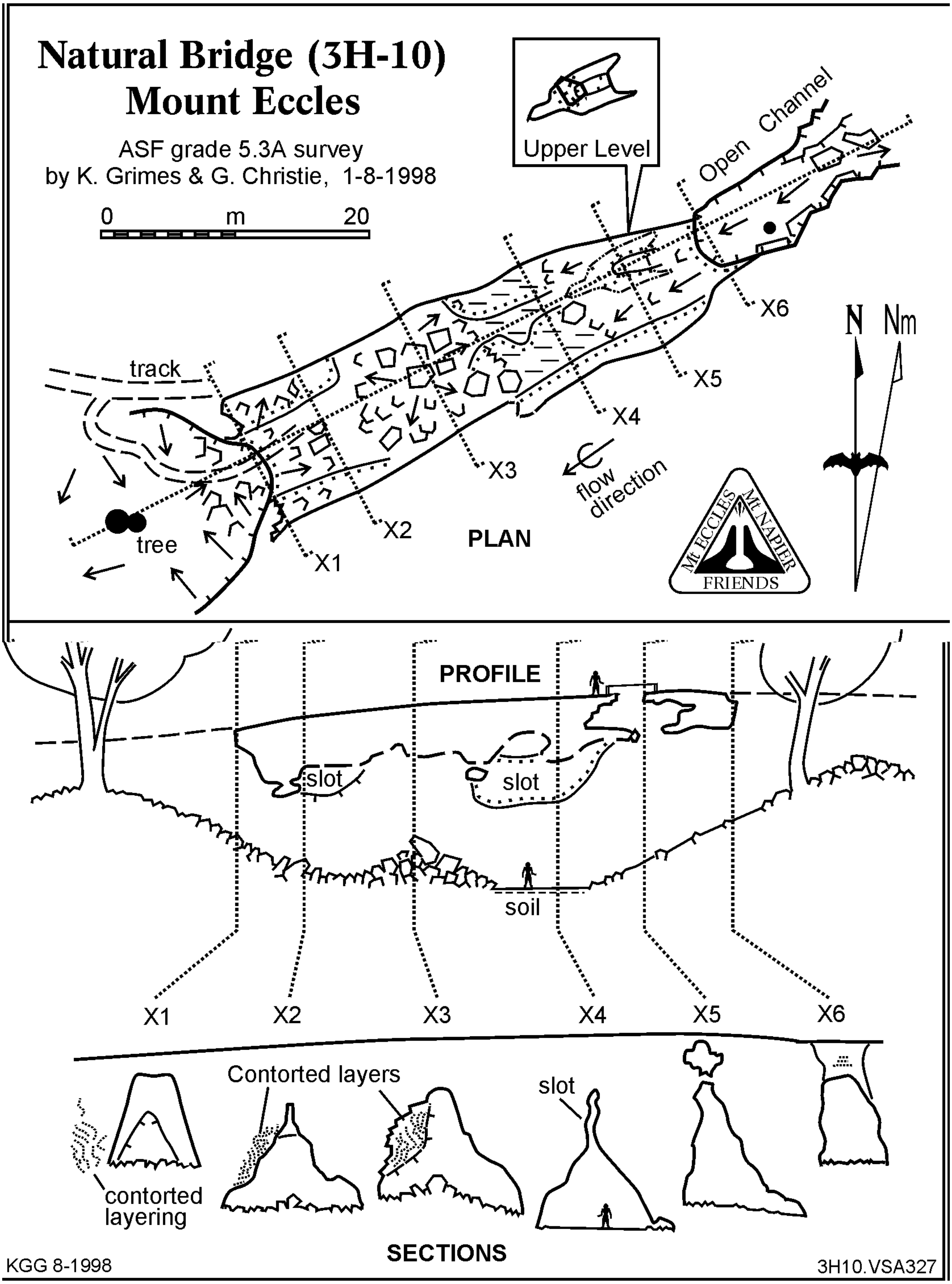
At Mt. Eccles, Natural Bridge and Tunnel Cave both formed by roofing of open lava channels. There are three ways this can happen (see above references). At Tunnel Cave (Grimes, 1998) there is no definite evidence of which of these operated. However, at Natural Bridge good evidence for the mode of formation is provided by the “gothic” shape of the walls and in the thin contorted layers exposed in the walls (Joyce, 1976).

At Natural Bridge the channel is steeper than other channels at Mt. Eccles, and the lava flow appears to have been more turbulent and variable in height. So we had a lot of splashing and periodic brief overflows of the channel. These built up levee banks composed of successive thin sheets of lava. As the sheets accumulated they not only built upward but also grew inwards from the edges until they eventually met to form a roof over the lava stream (see diagram, Figure 6). The sharply angled roof is a consequence of this linking of the two banks. While the layers were still hot and soft they sagged downward into the cave and we can see these wrinkled layers exposed where parts of the cave walls have fallen away. Molten lava continued to flow in a tunnel left beneath the crust; and solid bits of floating crust scraped against the lining in places. At the end of the eruption, that liquid partly drained away from the end of the channel to leave the cave we now see. Thin linings were left stuck to the walls and partly conceal the evidence, but fortunately enough has fallen away to expose this.

Management

This seems to be a fairly robust cave capable of standing up to the visitor traffic it gets, which is

Figure 4: “Edge enhanced” detail of contorted wall linings near section X3. Staff is about 2m long.


Natural Bridge (3H-10)
Mount Eccles
ASF grade 5.3A survey
by K. Grimes & G. Christie, 1-8-1998
0 m 20
Upper Level
Open Channel
track
tree
X1
X2
X3
X4
X5
X6
flow direction
PLAN
N Nm
Mt ECCLES Mt NAPIER FRIENDS
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slot
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X2
X3
X4
X5
X6
Contorted layers
slot
contorted layering
SECTIONS
KGG 8-1998
3H10.VSA327

Figure 3

mostly non–cavers. However, there are hazards for careless visitors: the rough rubble floor can be slippery and without a light it is hard to see where to step. If visitation by the public continues (as it will), Parks Victoria will probably have to install steps and some sort of smooth path over the rubble section.

Take special care if you decide to visit the high–level chamber and roof hole. This is dangerous in that there is a hole with a 10m drop down into the main cave. The floor of this chamber frequently has branches and leaves that conceal the extent of this hole—tread in the wrong place and you might descend faster than you intended! The daylight hole has been railed off for this reason and it would be best to not enter here if any members of the general public are watching (especially kids—it may give them wicked ideas!).

Figure 5: Scrape marks made by bits of floating lava crust that bumped against the soft wall lining.

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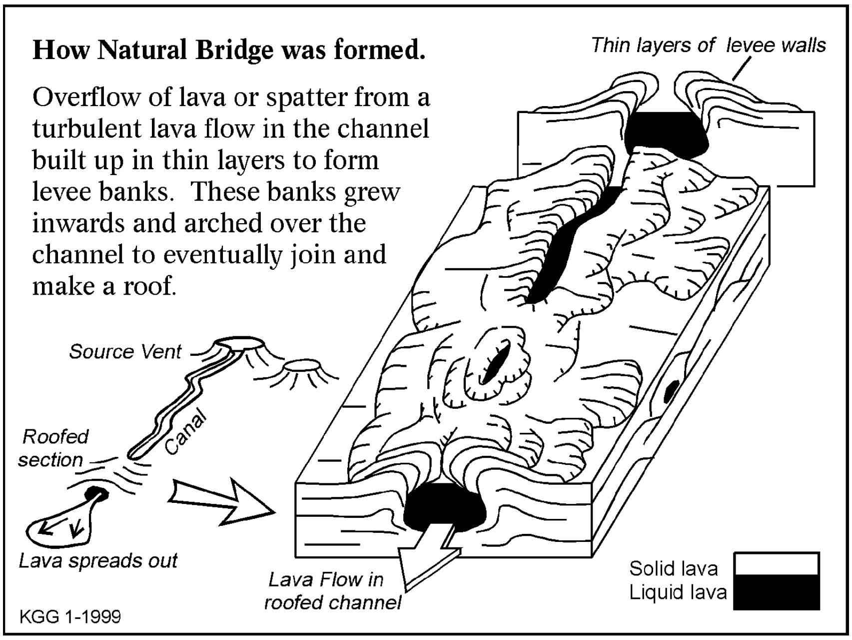

Figure 6

Helictite, (2006) **39(1):** 17-20

A small cave in a basalt dyke, Mt. Fyans, Victoria, Australia

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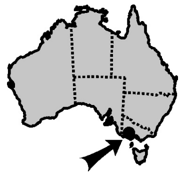


Abstract

A small but unusual cave has formed within a large dyke that intrudes a scoria cone at the summit of Mount Fyans, western Victoria. Draining of a still-liquid area, after most of the dyke had solidified, left an open cavity. Features within the cave mimic those of conventional lava caves, and suggest that the lava levels oscillated within the cave. Some smaller fingers of lava that intruded the scoria also have hollow, drained, cores.

Keywords: pseudokarst, volcanic caves, dyke.

The Volcano

Mount Fyans is a volcano within the Western District Province of western Victoria, Australia (Figure1. Price & others, 2003, Joyce & Webb, 2003). The age of the province dates back at least 5 million years, but Mount Fyans is a relatively youthful eruption, undated, but possibly less than 500,000 years old – judging by the well preserved "stony rises" (remnants of the original hummocky lava surface) and minimum soil development (Joyce, 1998; MacInnes, 1985). The volcano is a broad gently-sloping shield of basaltic lava with a low scoria cone at the summit and possibly once had a small crater – though an extensive quarry in the scoria makes the original form difficult to deduce!

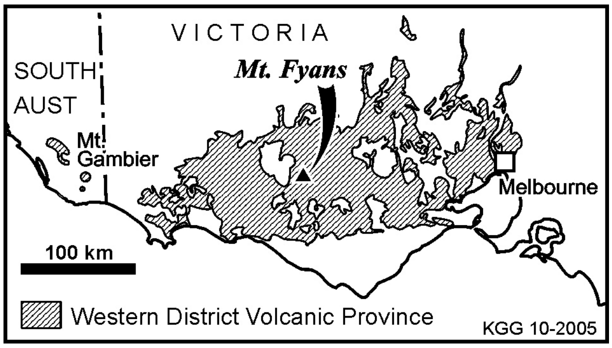


Figure 1: Location of Mt Fyans within the Western District Volcanic Province of Victoria, Australia.

The scoria at the summit has a thin cap of basaltic lava, and ropy patterns on the underside of this are well-exposed on the southern margin of the quarry. The loose scoria has been intruded by two large basalt dykes up to 12 m across (which would have fed the lava cap) and a number of smaller pipe or finger-like basalt bodies, some of which have been partly drained to leave small cavities. Figure 2 is a view of the quarry and the main

Figure 2: View of Mt. Fyans Quarry, looking north towards the large dyke. C = cave, P = pipe, W = witch's hats.

dyke. An inset map in Figure 3 shows the location of the various features described here. The quarry operations have worked around the large dykes, but damaged the smaller intrusive features (which is how we know they are hollow!). Minor quarrying activity appears to be continuing.

Mount Fyans Cave, 3H-105

A small horizontal cave occurs within the largest dyke. It lies close to the west edge of the dyke and runs parallel to the dyke wall (Figure 3). Entry is via a small hole broken into the roof by the quarry operation. The cave is about 17 m long and generally less than one metre high. The roof and walls have numerous lava drips (Figure 4). The floor is a horizontal ropy pahoehoe surface which rises gently towards the northern end – but the ropy structures suggest a final flow direction from south to north. The drainage points for the lava are not obvious; but there is a very small hole in the floor at the southern end. Both roof and floor have common patches of pale-cream coatings over the basalt – possibly fumerolic alteration? There are well-developed rolled benches (10 cm diameter) along the edges of the floor (Figure 5). These suggest that the lava rose and fell within the cavity at least once after its initial draining. One small hole in the ceiling, near the entrance, opened into broken scoriaceous material.

Related features

As well as the cave, the main dyke also has a drained hollow vertical pipe at its southern end – this has been broken into by the quarry operation and we found the upper part lying on its side 20 m to the NE (see inset map, Figure 3). This pipe had spatter and dribble patterns on its inside walls (Figure 6). Elsewhere in the quarry there are intrusive pipes and smaller fingers of basalt that have pushed up through the loose scoria. Several of these have drained back after the outside had solidified so as to leave a hollow core, some with lava drips. Probably the most distinctive are conical "witch's hat" structures (Figure 7).

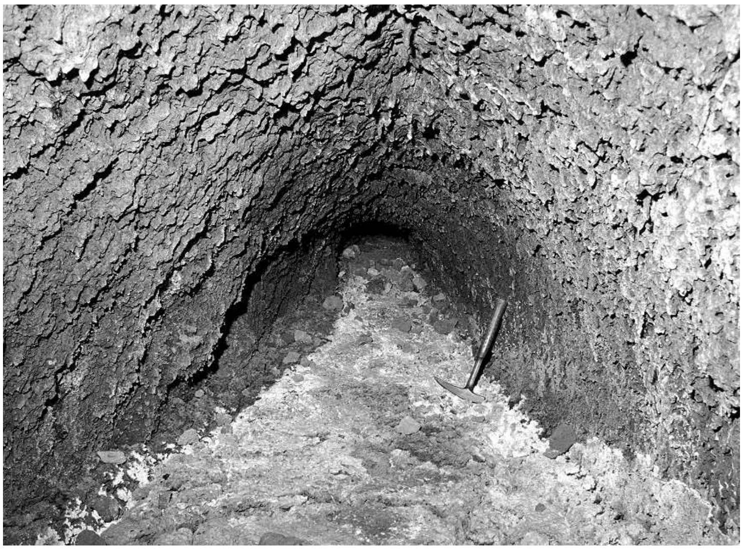


Figure 4: View looking north from the cave entrance.

Figure 5: Looking south from section X4. Note the small rolled bench against the foot of the wall and the pale patches on the wall. Notebook is 18 cm long.

Figure 6: Spatter and drips in a vertical pipe.

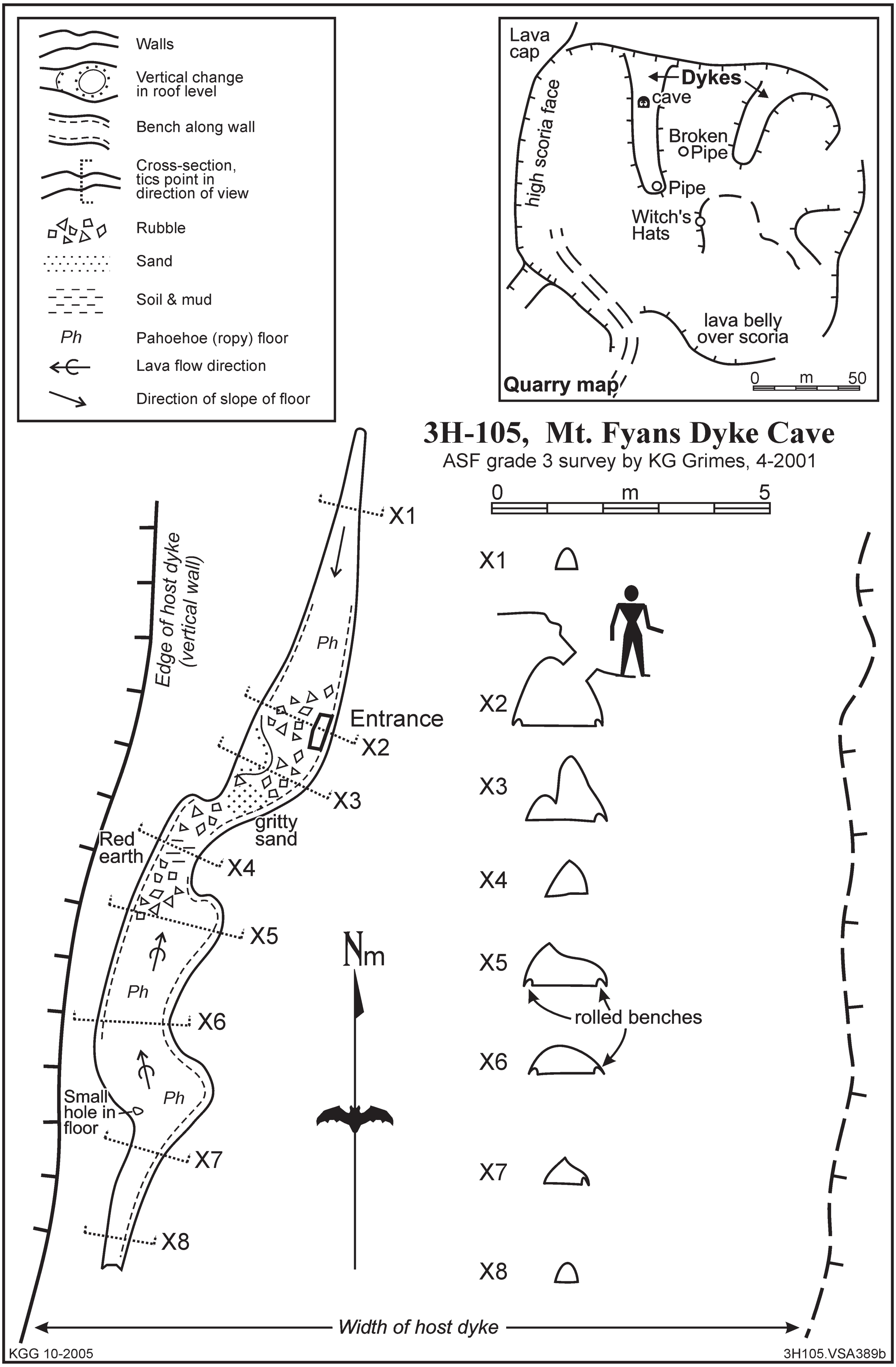


Figure 3: Map of Mt Fyans Cave, 3H-105. The inset map shows the volcanic structures within the quarry.

SUPPLEMENTARY MATERIAL ON THE CD
INCLUDED IN THE BOOK
PROCEEDINGS OF THE X, XI, AND XII
INTERNATIONAL SYMPOSIA ON VULCANOSPELEOLOGY

The CD contains, in addition to the PDF file for this proceedings volume, some material to supplement some of the articles. In some cases there are additional photographs or maps. In others, I have judged that a higher-resolution graphic of a map would be significantly more legible than the printed version. Australian Ken Grimes has provided PDF files of some of the papers referred to in an article and also a couple of nice color educational posters. Page numbers in red are the page numbers in this PDF file; other page references are to the book. Note that the page size is highly variable in this PDF.—Bill Mixon, AMCS Editor

Lava Tube Formation

Lava Flows and their Caves

Lava Flows and Caves

- ➤Long lava flows are invariably fed by tubes which insulate the lava travelling within them.
- ➤The leading edge of a flow is an advancing wall of pahoehoe lobes or aa rubble.
- ➤Behind the edge, flow is concentrated into surface channels, or hidden tubes beneath the crust. Stagnant areas solidify.
- ➤When the lava drains out an open cave is left.

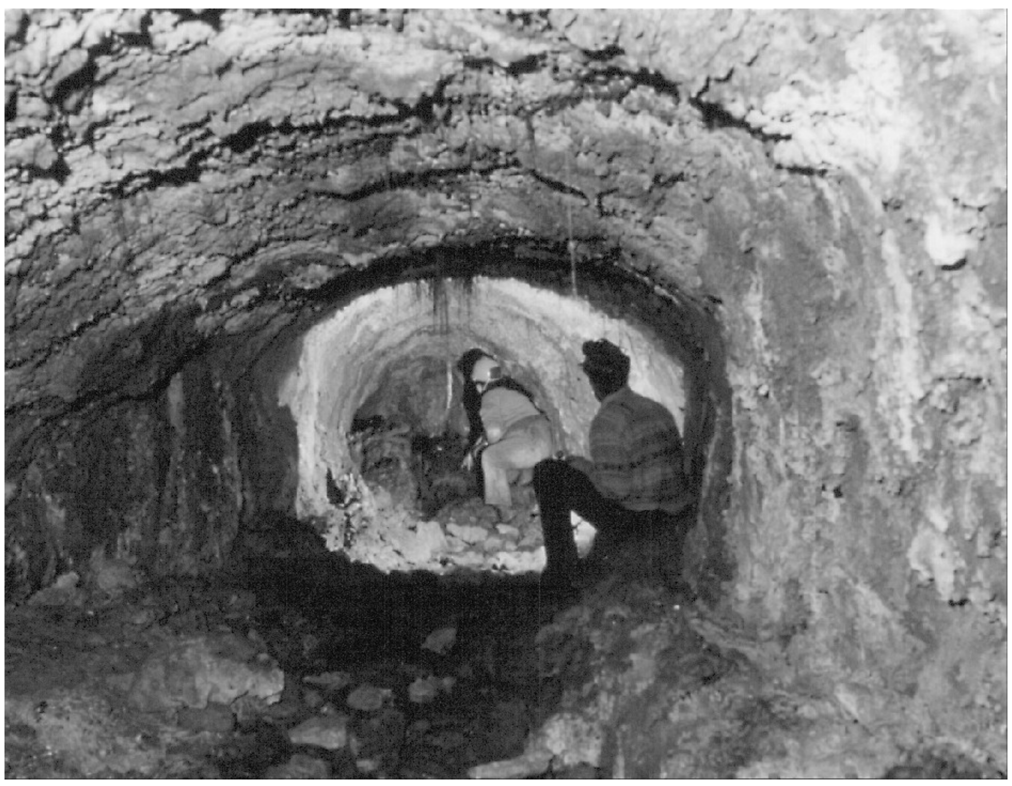
Lava Flows

Liquid lava spreads out from a vent but quickly crusts over. The crust can be smooth and wrinkly (Pahoehoe or Ropy lava) or if the lava is stiffer it may break into jagged fragments (Aa lava).

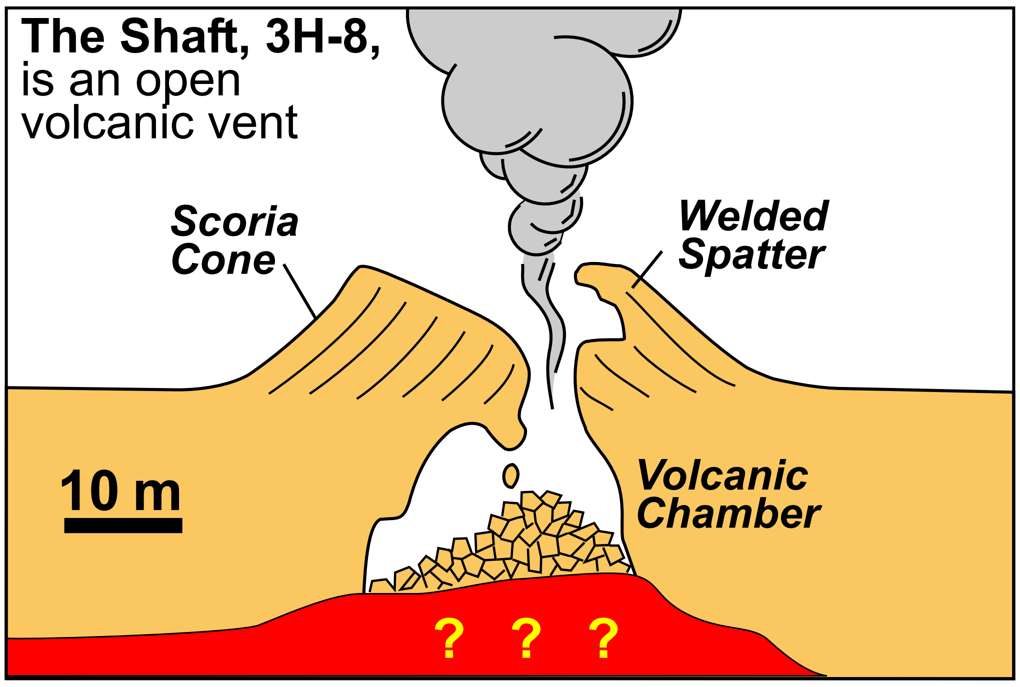
Liquid lava continues to flow beneath the crusted surface, inflating it and pushing out in front as lobes of pahoehoe or walls of rubbley aa.

Behind the advancing front the liquid flow becomes concentrated into linear streams: either surface channels or in tubes and chambers beneath the crust. The surface channels may later crust over to form tubes.

Draining of the liquid lava from these tubes will leave open caves. Most tubes never drain and become blocked with solid basalt.



A typical small, cylindrical, lava tube.



Overview of lava cave formation

Observations of active lava flows has shown that there are two distinct ways in which lava tubes or caves form:

Roofing of surface lava channels. This can happen in three ways (e.g. Peterson et al, 1994), see panel 2.

Sub-crustal drainage within thin lava lobes or sheets. (e.g. Hon et al, 1994), see panel 3 .

Open Volcanic Vents are a rare type of cave formed by the draining of the lava back into the source vent (figure above). Caves can also form in tectonic fissures.

Weathering of ash and lava can also form secondary caves.

References

Hon, K., Kauahikaua, J., Denlinger, R., & Mackay K., 1994: Emplacement and inflation of pahoehoe sheet flows: Observations and measurements of active lava flows on Kilauea Volcano, Hawaii. *Geological Society of America, Bulletin.* **106:** 351-370.

Peterson, D.W., Holcomb, R.T., Tilling, R.I., & Christiansen, R.L., 1994: Development of lava tubes in the light of observations at Mauna Ulu, Kilauea Volcano, Hawaii. *Bulletin of Volcanology,* **56:** 343-360.

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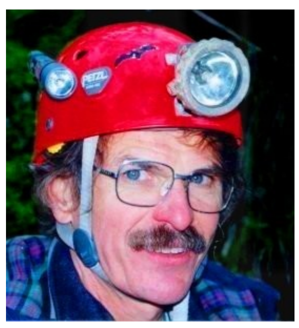


Lava Tube Formation

Roofing of Lava Channels

Roofing a Channel

Surface lava channels can be roofed over to form tubes.

This has been seen to happen in three ways.

A: Simple crust growth.

Surface crust grows progressively across the channel. It may then be thickened from below.

This is most common with slow steady flow rates.

B: Log jam of floating slabs

A prior crust breaks up into rafts that drift down-stream. The slabs may form "log jams" at constrictions and are then welded into a solid roof.

Mainly found at moderate flow rates.

C: Levee overgrowth

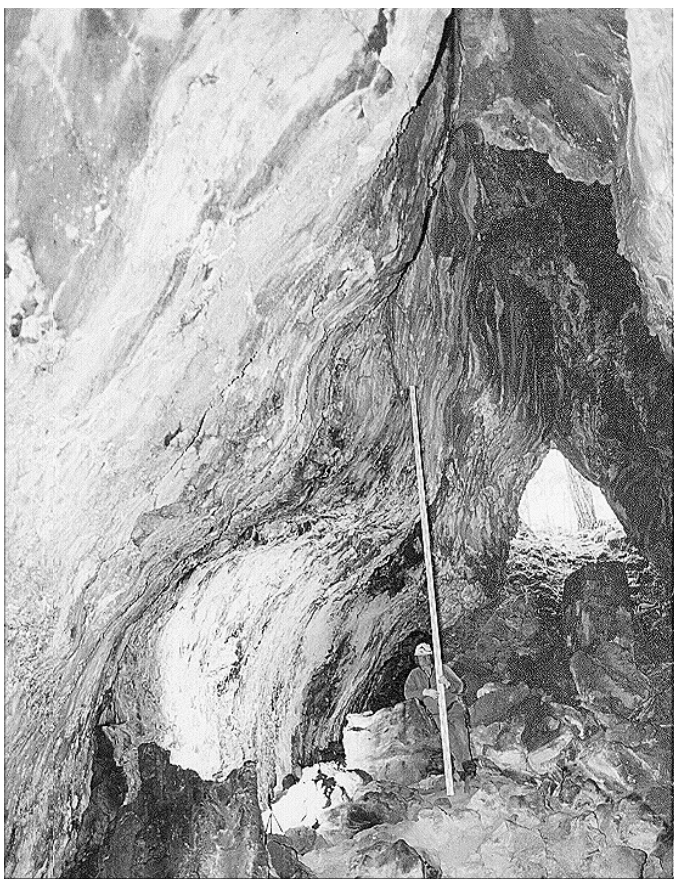
Overflow or spatter builds levees that arch over the channel and eventually join as a roof.

Mainly found with fluctuating or rapid and turbulent flows.

Subsequent evolution.

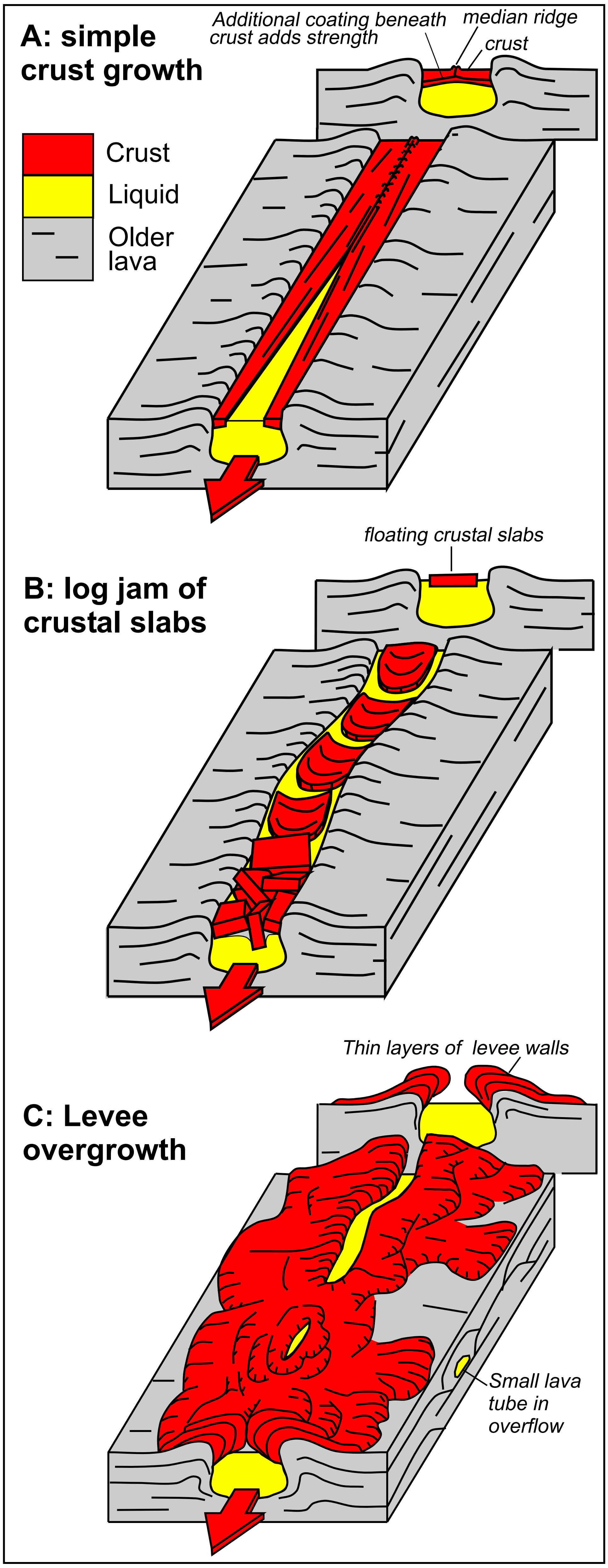
In all three cases, later overflows through sky-lights may thicken the roof from above.

On many cases linings plastered on the walls, or collapse modifications, make it hard to distinguish the three modes.



The angular, "gothic", roof of this tube is typical of ones formed by levee overgrowth. (c.f. Figure C ➔)

5 m staff.



Lava Tube Formation

Sub-crustal Drainage

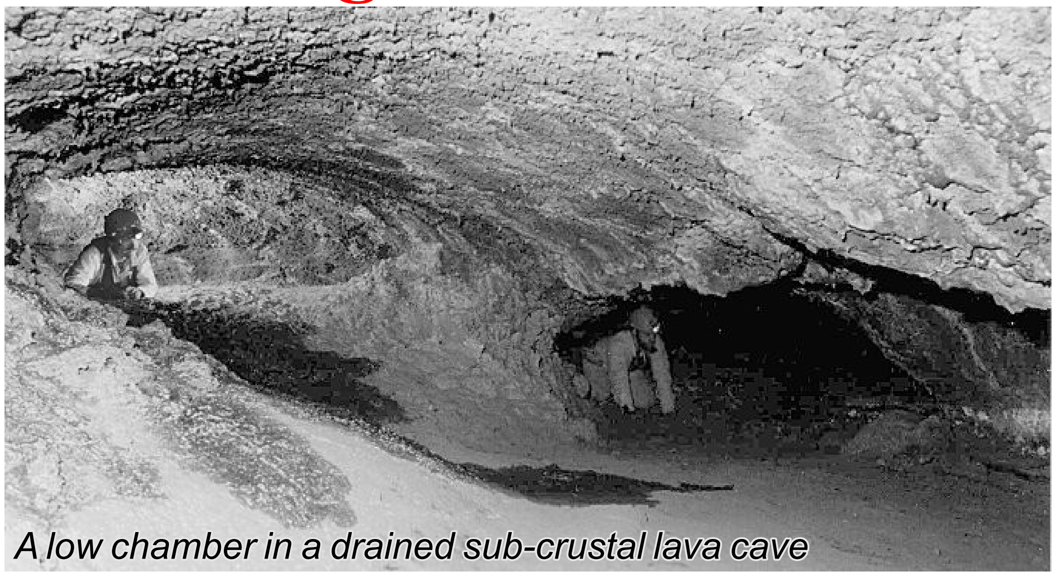
Sub-crustal Lava Caves

A newly-formed lava flow quickly develops a crust, which may be inflated upwards.

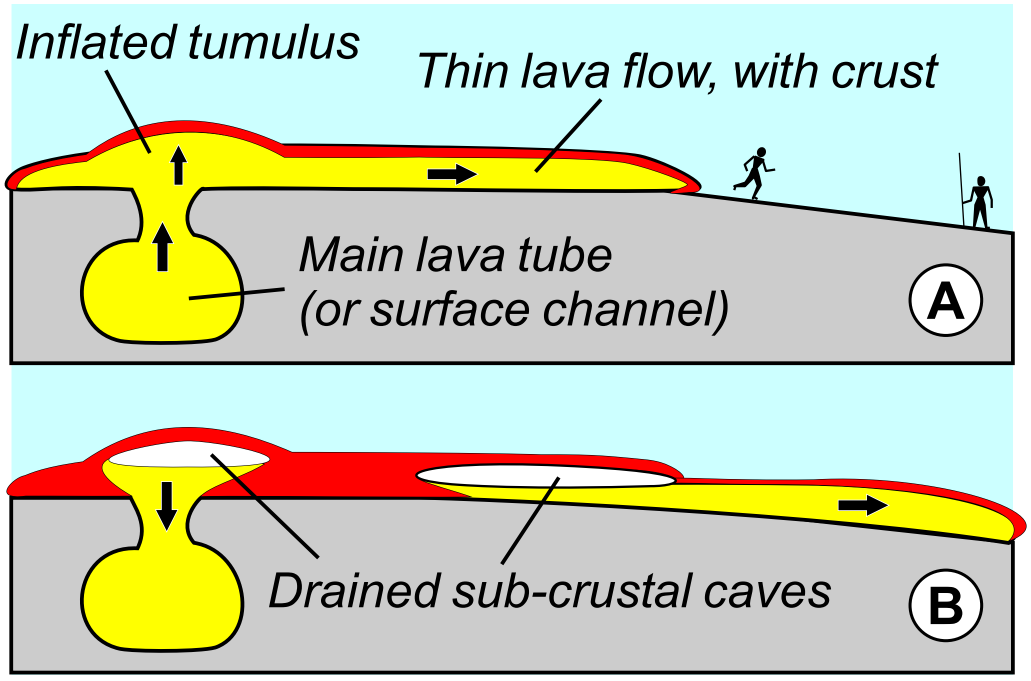
Later drainage of liquid lava from beneath the crust can form small shallow caves.

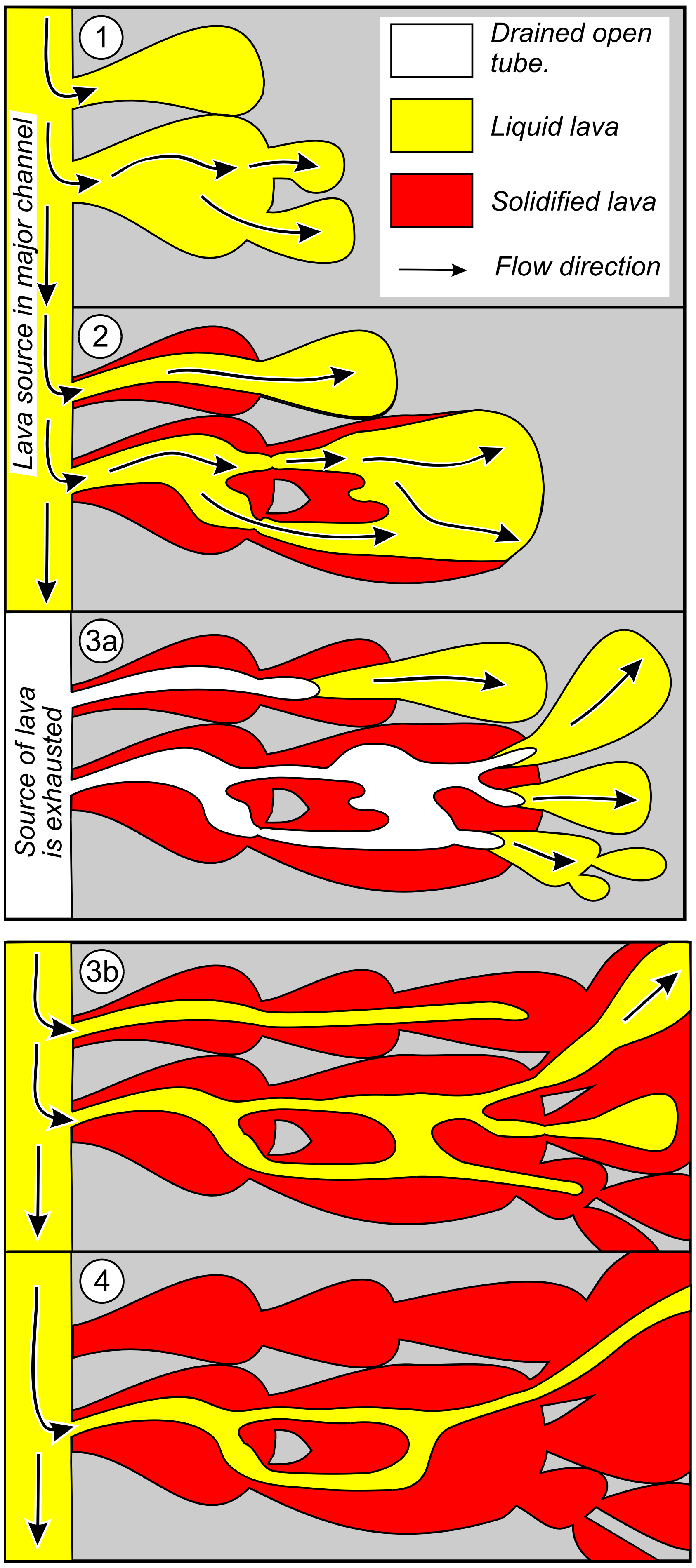
As the flow advances and expands, complex sub-crustal drainage systems can form.

Ongoing flow becomes concentrated into a few "master" tubes.



A low chamber in a drained sub-crustal lava cave





Development of sub-crustal caves

- Lava spreads from a skylight above a tube(A ↑), or by overflow from a crater or a lava channel (1, ➔) .
- The spreading 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 (B ↑, and 1 & 2 ➔).
- If the supply of fresh lava is cut off, the liquid parts of the lobes may be drained to form a set of broad but low-roofed chambers and passages (3a ➔).
- However, if fresh hot lava continues to be delivered from the volcano (3b ➔) the sub-crustal flow may become concentrated into linear tubes that feed the advancing lobes, while the surrounding stagnant areas slowly solidify (4 ➔).
- The evolving "master" tube can enlarge by erosion of its walls - destroying evidence of its initial mode of formation.

Lava Tube Formation

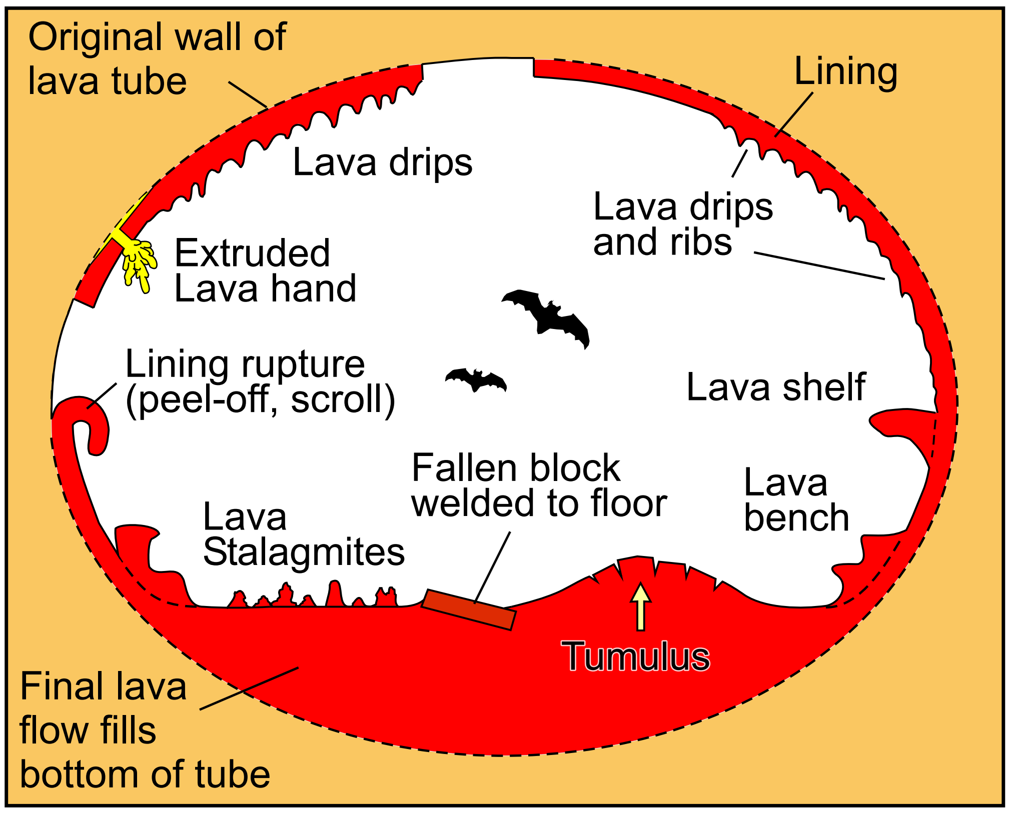
Formations within Lava Tubes

Contents of Tubes

- Lava caves have a distinctive suite of lava structures.
- As lava drains from the tube it leaves linings on the walls which can drip, run or peal to form other formations.
- The fluctuating lava flows through the tube may leave "tide-marks" on the walls.
- Various flow structures can form on the lava floor.

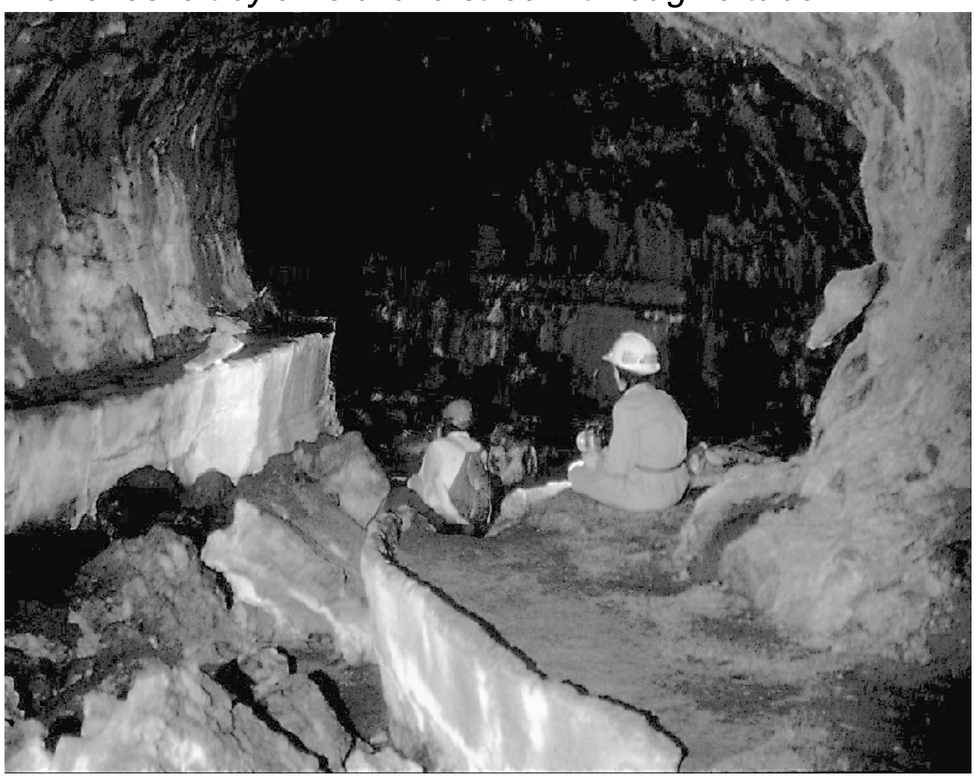
A burst lining, sagged away from the wall

Extruded lava hands and fingers with a stalagmite below.



Lava drips & ribs on a wall

Benches left by an old lava stream through a tube



Some Lava Formations

- Most tubes have linings on the walls. These may drip or run down the walls. Or burst to leave pockets, or peal off to form scrolls.
- Burst bubbles may form a sharp hackly surface.
- Benches & shelves may form at old lava "tide marks" on the base of the walls. Some may reach across the tube to form a false floor or "tube-in-tube".
- Liquid lava trapped behind the linings may ooze out through holes to form lava "hands", "turds" or "straws".
- If the floor is already solid (unusual) then drips from above may form stalagmites.

Sub-crustal Lava Caves

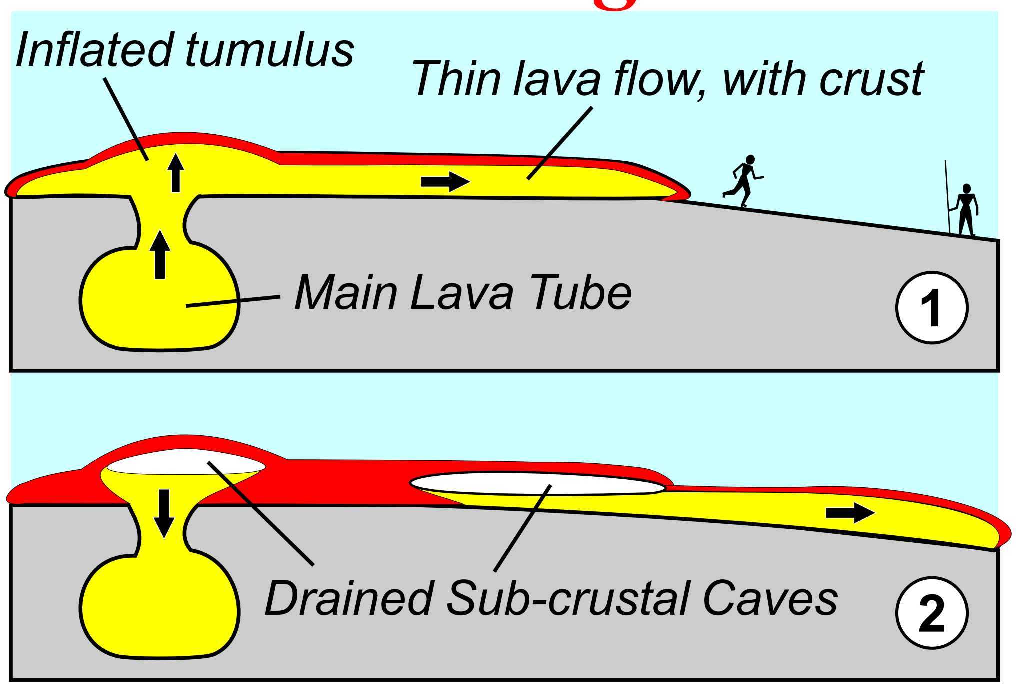
The Process of sub-crustal Drainage

Sub-crustal Lava Caves

A newly-formed lava flow quickly develops a crust, which may be inflated upwards.

Later drainage of liquid lava from beneath the crust can form small shallow caves.

As the flow expands, complex sub-crustal drainage systems can form.



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Observations of active lava flows has shown that there are two distinct ways in which lava tubes or caves form:

Roofing of surface lava channels (e.g. Peterson et al, 1994) - not discussed here.

Sub-crustal drainage within thin lava lobes. (e.g. Hon et al, 1994) - the subject of this poster.

Development of sub-crustal caves

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The spreading 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.

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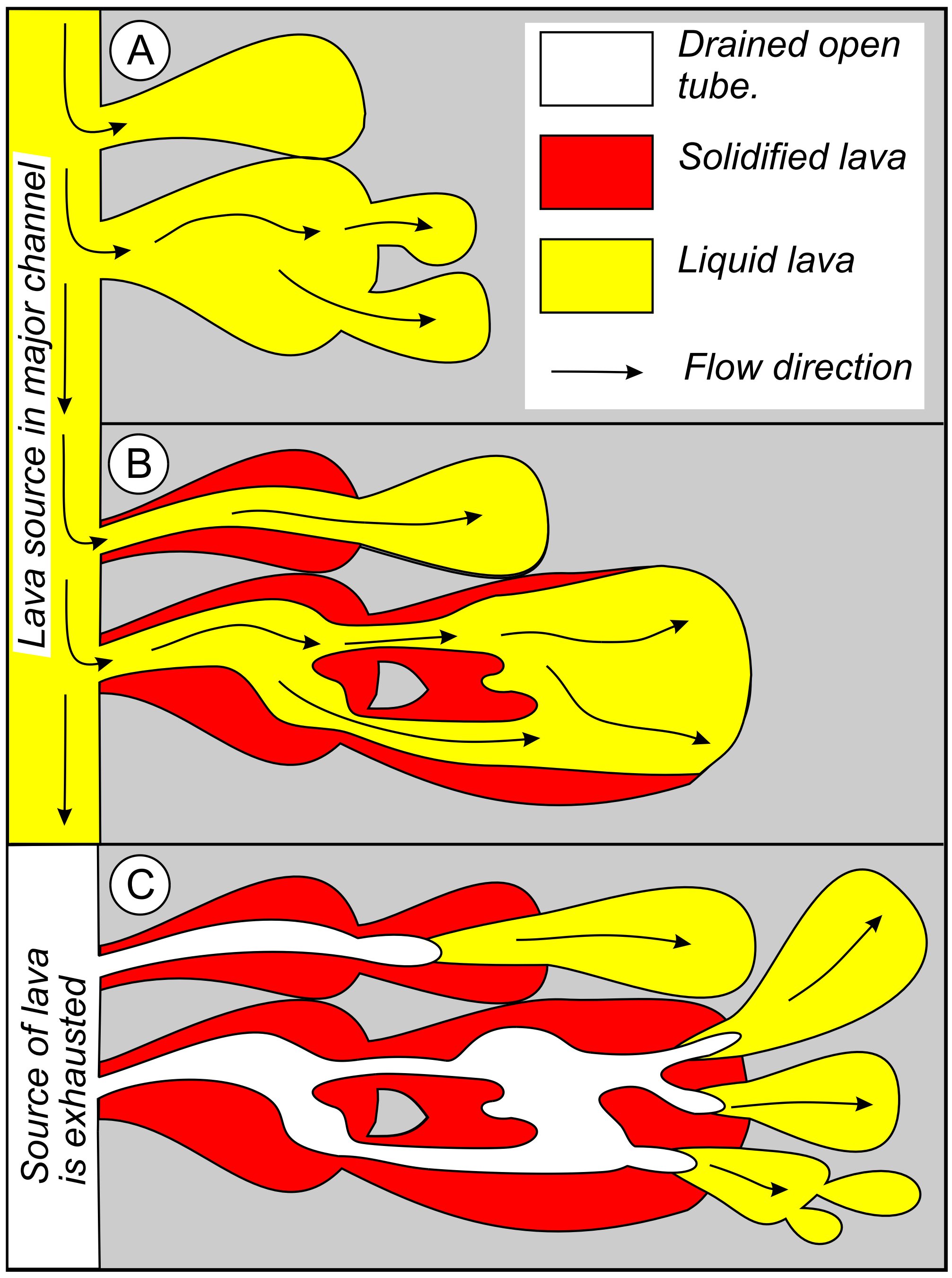

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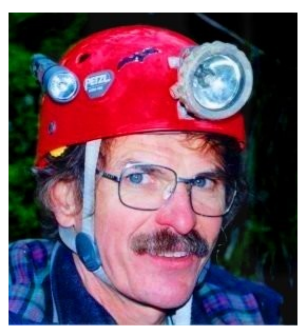


Sub-crustal Lava Caves

Small sub-crustal lava caves

Small isolated caves

Small isolated chambers occur scattered through the undulating lava fields.

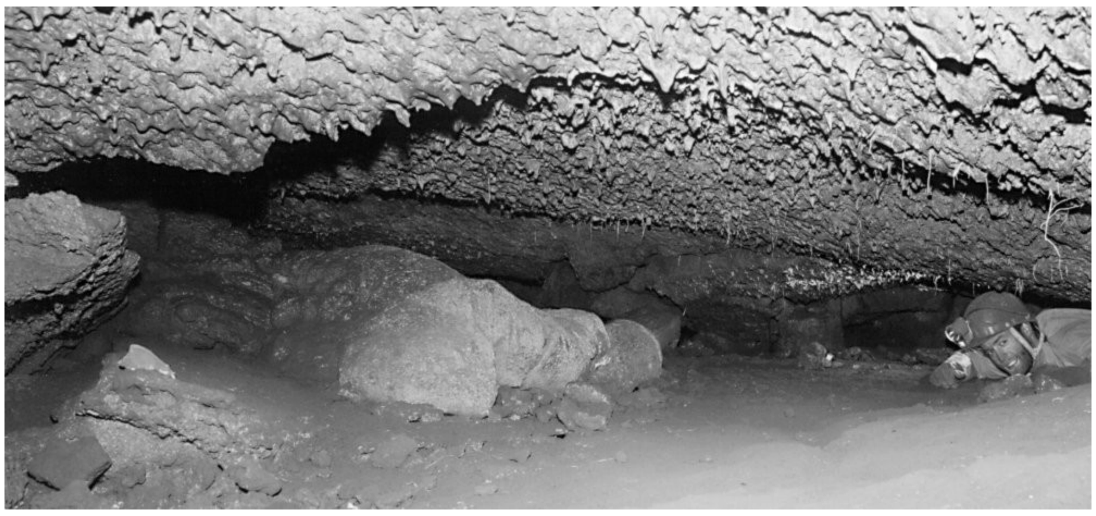
The simplest caves are small chambers (typically only 1m high with a roof about 1m or less thick) which occur scattered through the lava fields. These have been called "blister caves" in Victoria. They generally are found beneath low rises, though some have no surface relief at all.

They can be circular, elongate or irregular in plan; up to 20m or more across but grading down to small cavities only suitable for rabbits.

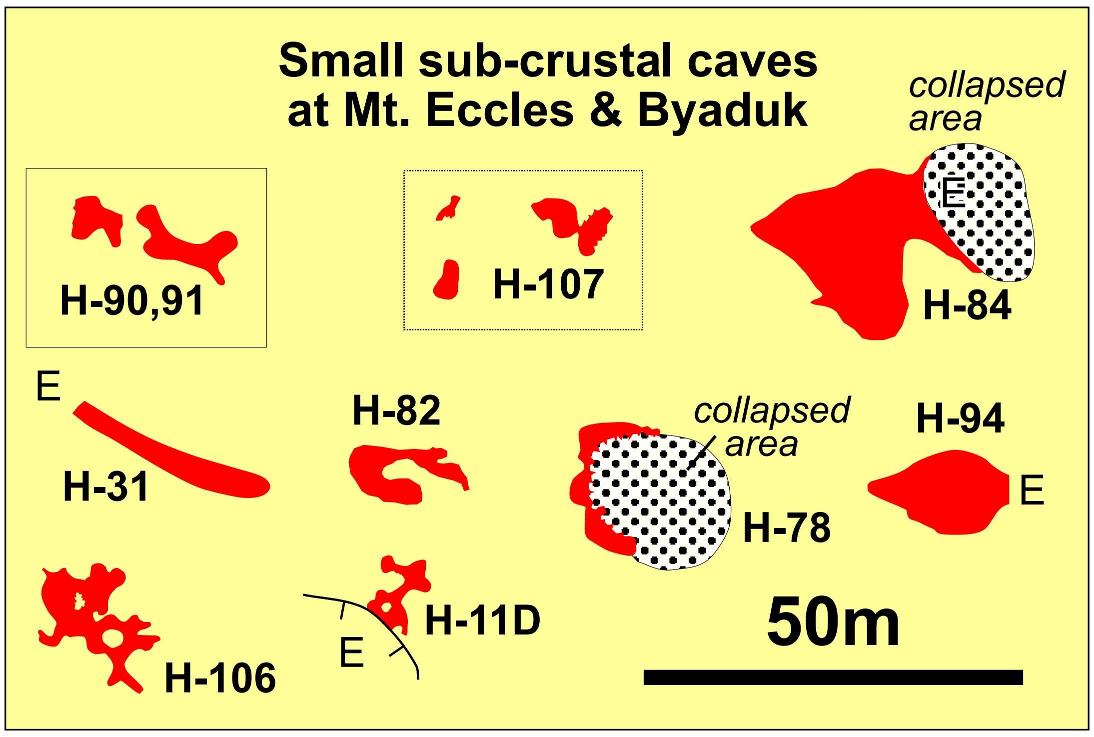
In cross-section, the outer edges of the chamber may be smoothly rounded or form a sharp angle with a flat lava floor.

The ceiling may be arched or nearly flat, and can have a central "soft" sag that would have formed while the crust was still plastic. Alternatively, the thin central part of the roof has collapsed and we find only a peripheral remnant around the edge of a shallow collapse doline (e.g. H-78).

The more elongate versions grade into small "tubes" (e.g. H-31).

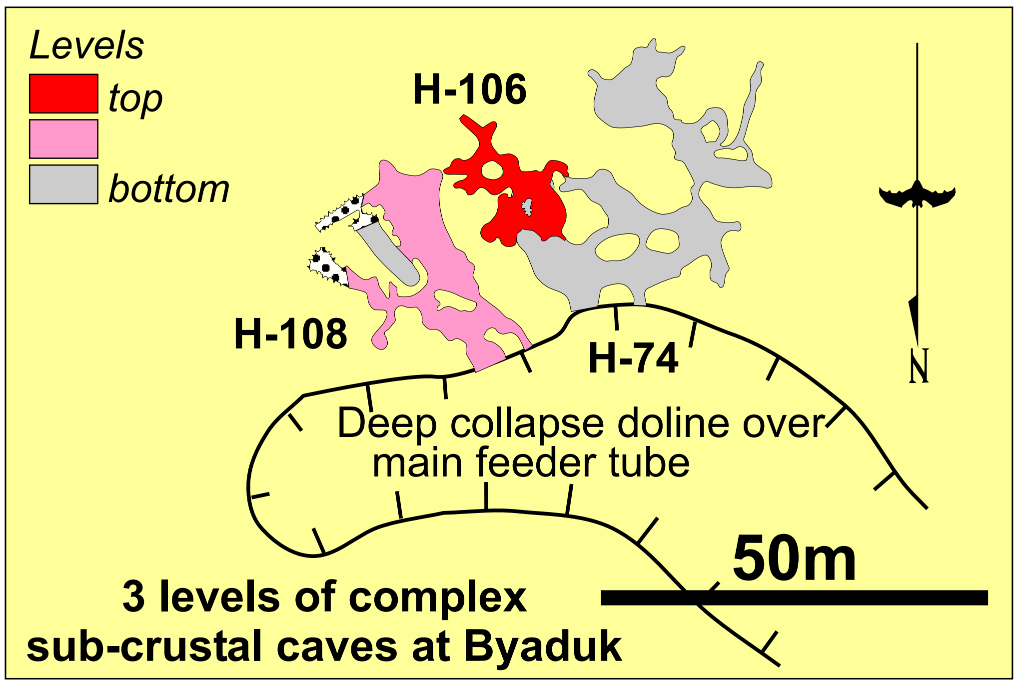


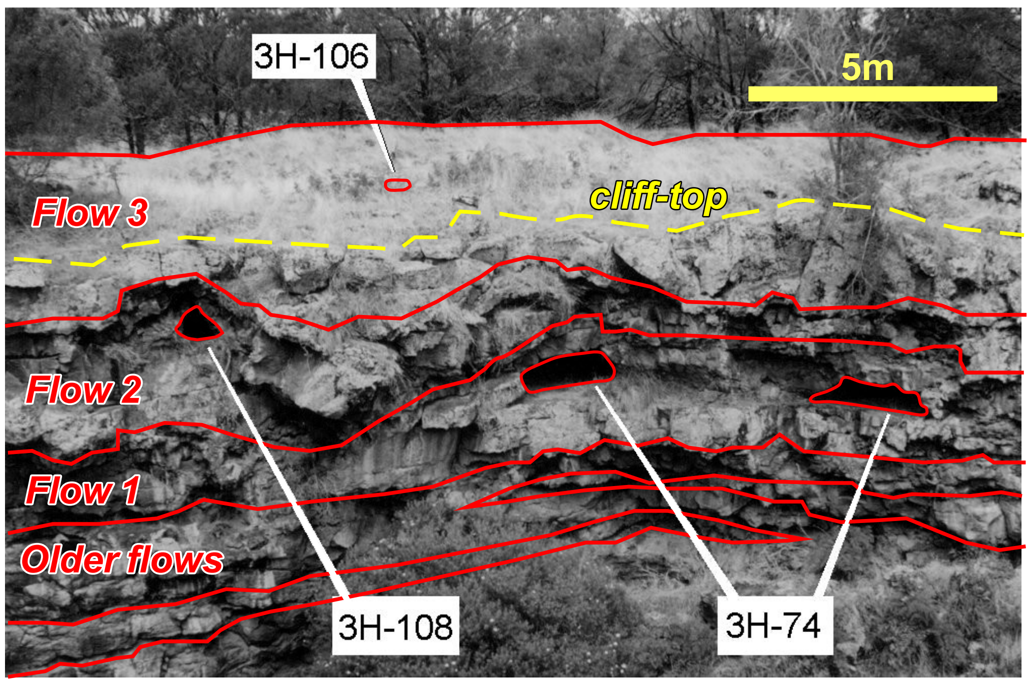
Broad low chamber in H-106. A mound of invasive lava lobes enters from the left.



A stacked system at Byaduk, Victoria.

Three distinct sub-crustal caves have developed; each in a separate lava flow, 1-3 m thick. The flows and cave entrances are exposed in the cliff of a collapse doline developed over a large feeder tube at greater depth. The thin lava flows may have been fed by overflow from this major tube - either through a skylight, or when it was an open channel



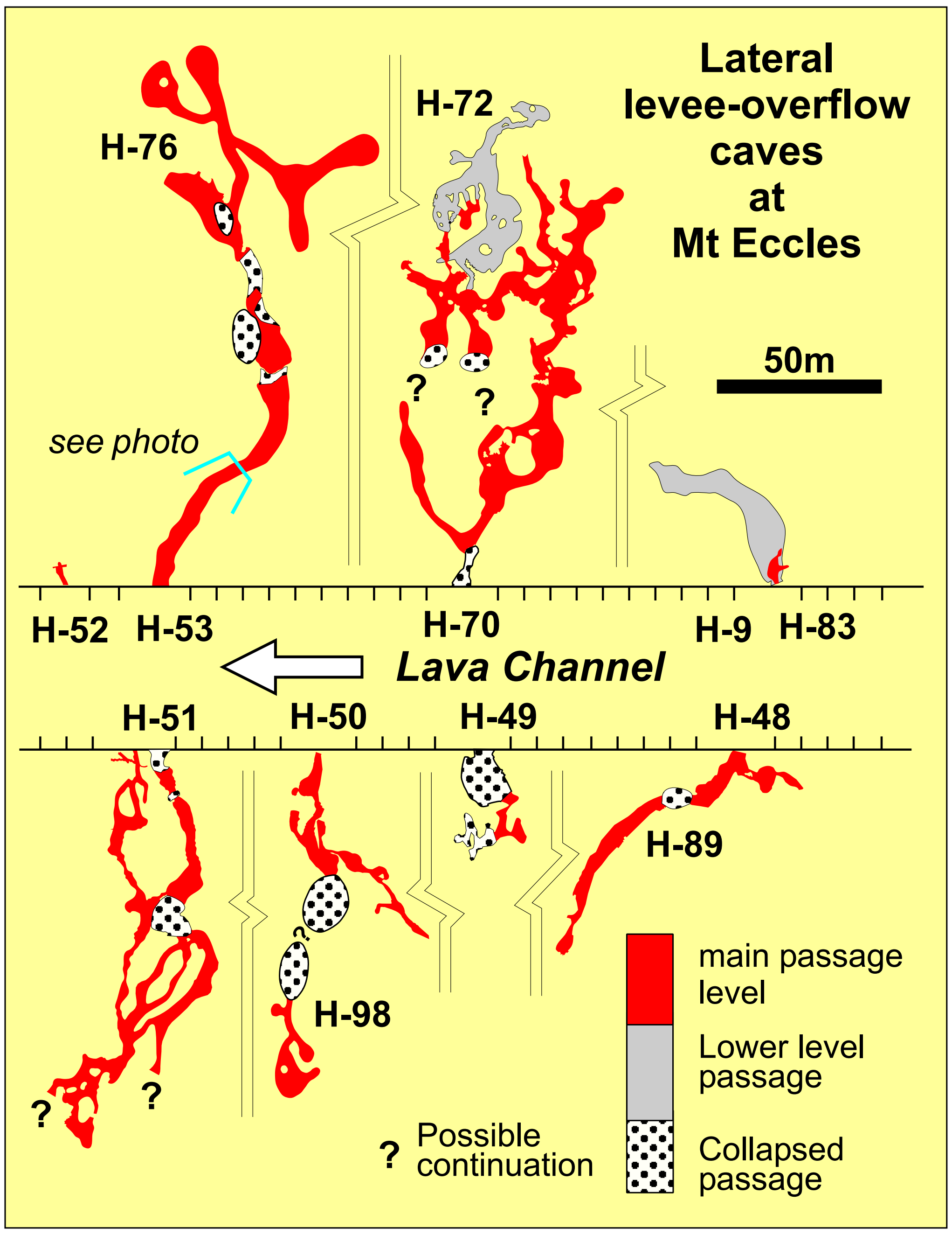


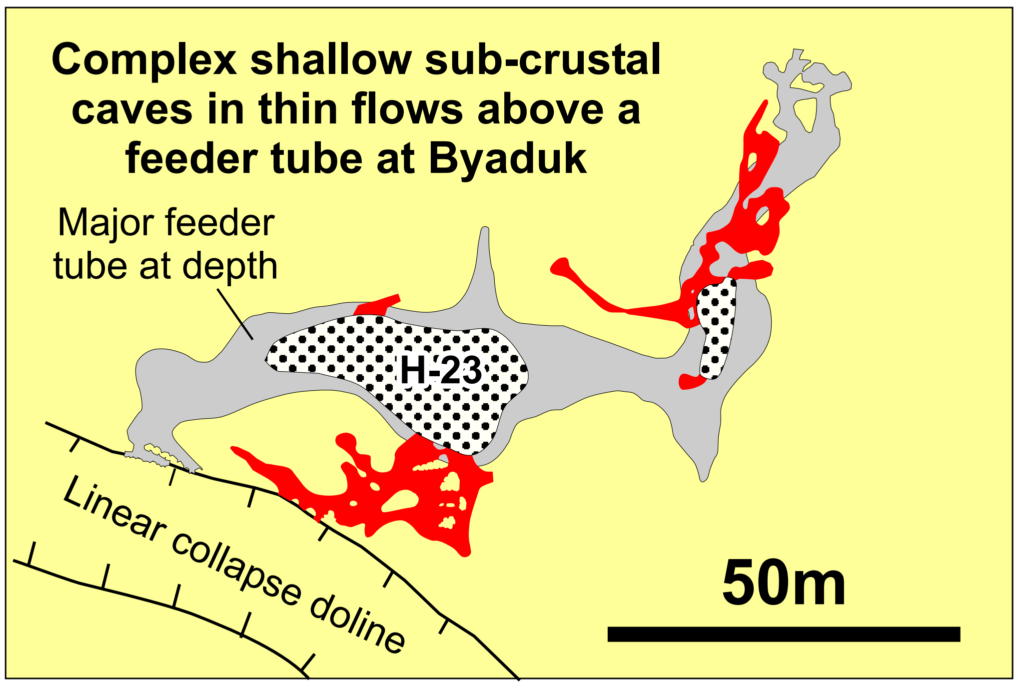
Sub-crustal Lava Caves

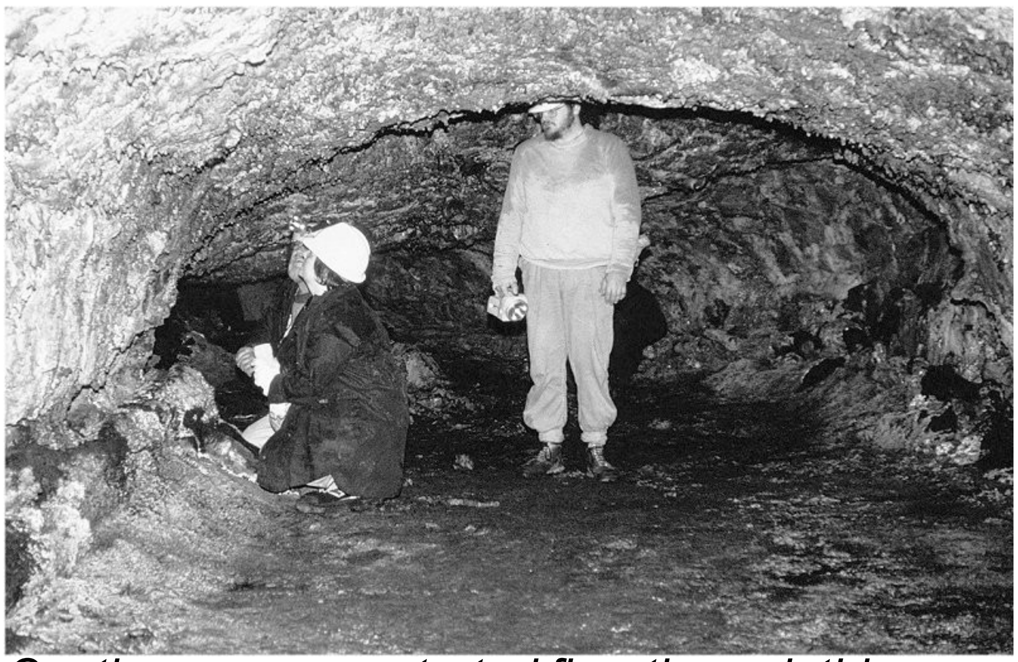
Complex sub-crustal lava caves

Complex Caves

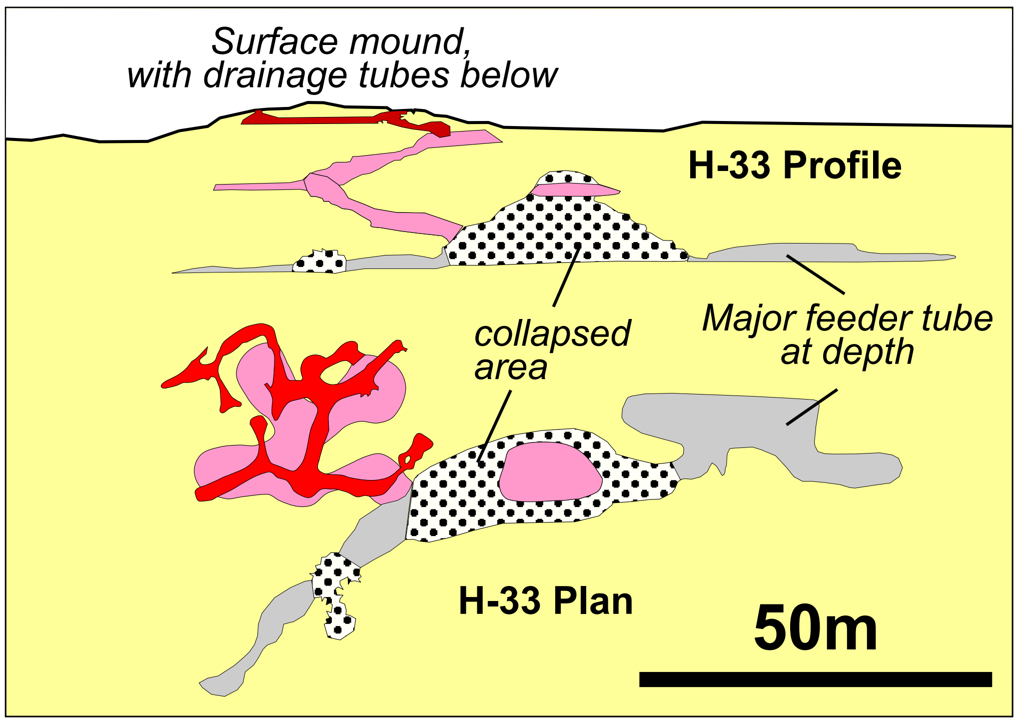
In larger flow systems the original simple "drained-lobe" forms evolve into branching systems of low passages that bifurcate and rejoin, or open out into broad, low chambers.







Continuous concentrated flow through this section of H-53 has produced a linear cylindrical form typical of major feeder tubes.



Overflow to the surface from a major feeder tube formed a domed mound with a branching tube pattern. Draining back to the lower level left several low-roofed chambers and tubes.

Developed Systems

More complex systems evolve where lava continues to flow beneath the crust for an extended time and over a greater distance.

Complex networks can evolve, with cylindrical "Feeder" tubes being maintained in areas of rapid flow, while slow moving areas solidify.

These linear tubes may extend radially from a central source (e.g. the upper level of H-33, see map to right) or laterally from the breached levee of a lava channel (maps above). At the downflow end the feeder tubes may split into a maze of smaller tubes and chambers.

Sub-crustal Lava Caves

Example: Carmichael Cave, 3H-70, Mt. Eccles

A complex sub-crustal cave

H-70 comprises alternating linear tubes, mazes and broad low-roofed chambers. It was formed by over-flow from a lava channel. The lower level may be an earlier system invaded by the later one.

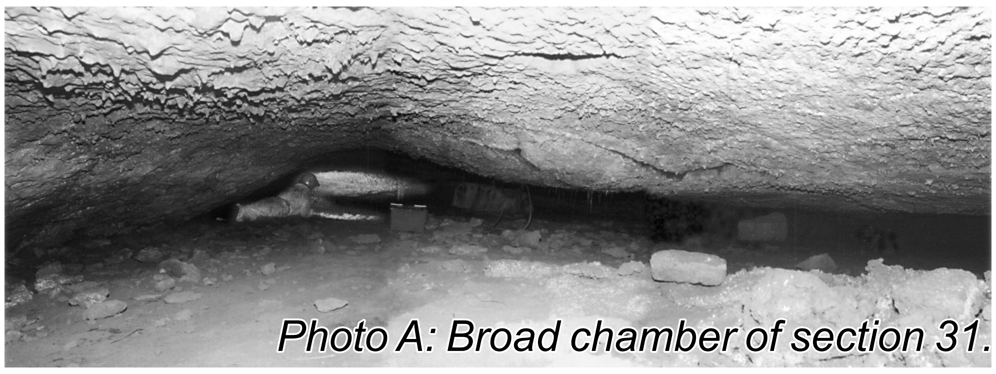
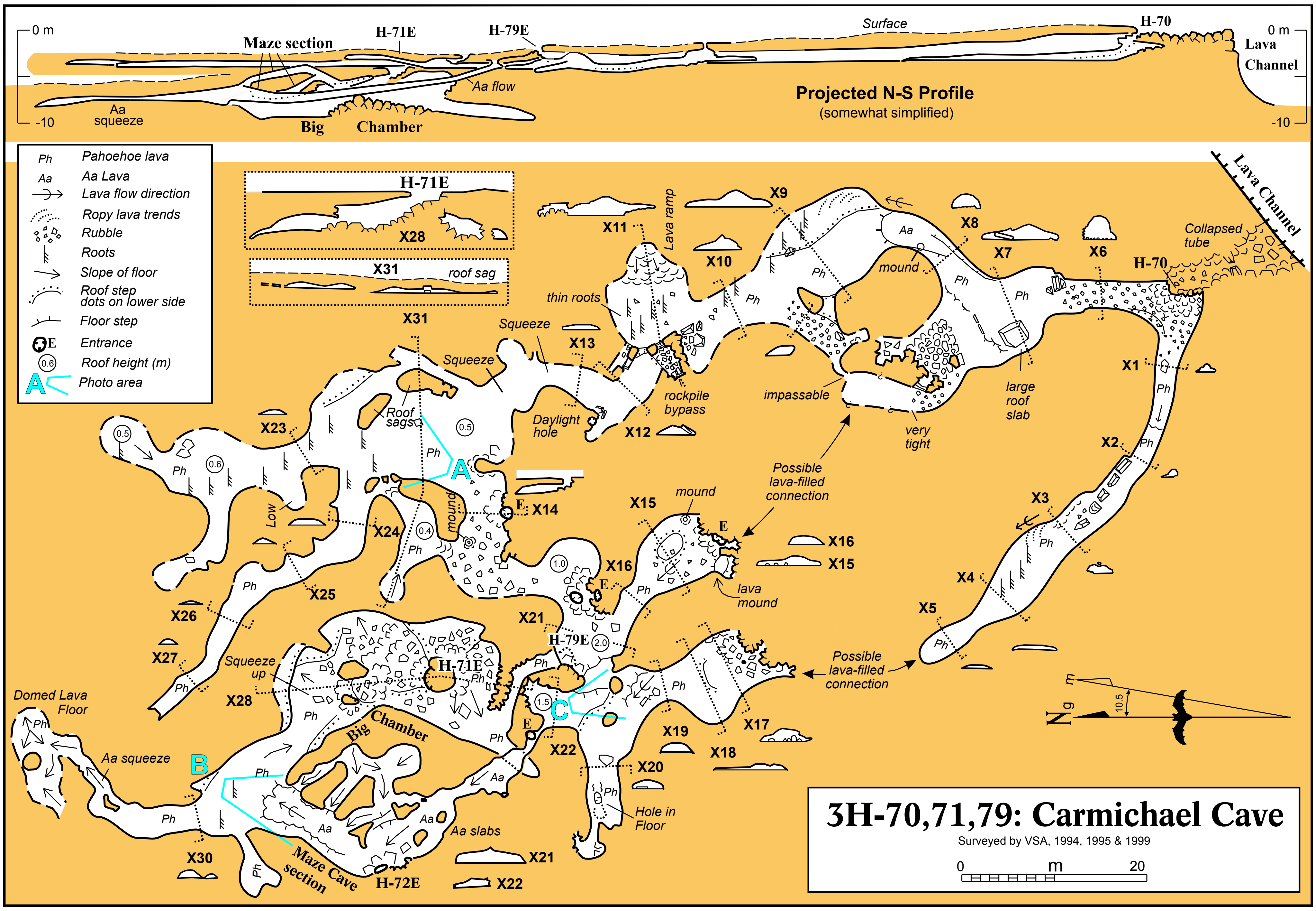


Photo A: Broad chamber of section 31.



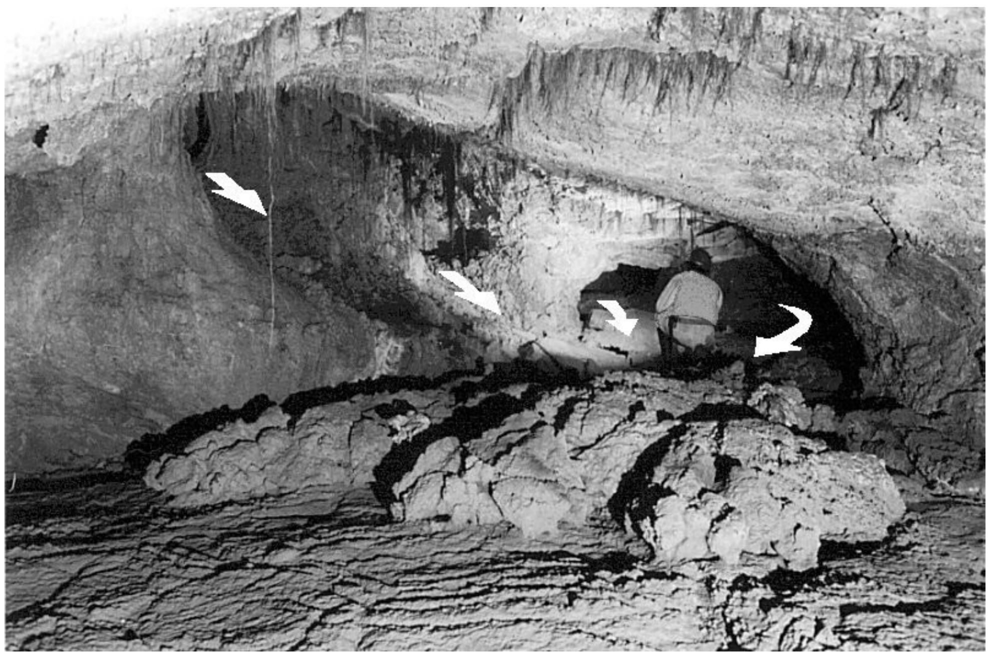


Photo B: Maze section: Aa flow invading from higher levels (arrows)

Photo C: Mound at left separates two chambers - is this a partition between two lobes?