AUSTRALASIAN CAVE & KARST MANAGEMENT ASSOCIATION INC.

Eighteenth Australasian Conference on Cave and Karst Management

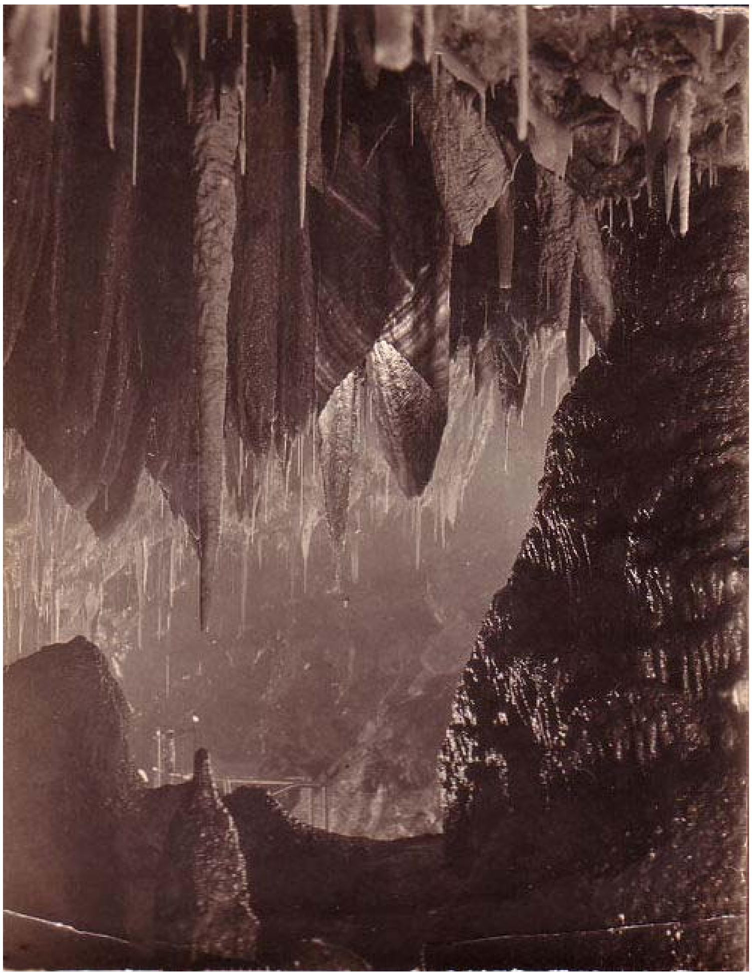
Margaret River, Western Australia, Australia

3rd May – 9th May 2009

Field Guide

to the

Leeuwin-Naturaliste Karst



"The Shawl Shop" Ngilgi Cave (6Ya-1) photo by JHA Macdougall (early 1910's)

Conference supported by:

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Field Guide prepared by Rauleigh J. Webb and Ken G. Grimes

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Acknowledgments

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List of Abbreviations

Augusta Margaret River Tourism Association	AMRTA
Australian Speleological Federation	ASF
Cavers Leeuwin (Inc)	CLINC
Caves Access Committee	CAC
Department of Conservation and Land Management (now DEC)	CALM
Department of Environment and Conservation	DEC
Geographe Bay Tourism Association	GBTA
Köppen Climate Classification (Mediterranean)	Csb
Speleological Research Group of Western Australia	SRGWA
Western Australian Speleological Group	WASG
University of WA Outdoor Club	WROK

Production of the guide was partly sponsored by the organisations listed below.

The Leeuwin-Naturaliste Karst

Introduction

The Leeuwin-Naturaliste Ridge, in SW Western Australia, is a narrow strip of coastal dune limestone about 90 km long, but never more than 6km wide, running between Cape Leeuwin in the south and Cape Naturaliste in the north (Figure 1).

The area has many show caves & self-guided tourist caves, as well as "restricted access" caves, which have excellent and varied decorations (including, several long calcite straws) that are reflected by underground lakes to produce picturesque views. There are spectacular large collapsed holes connecting to the caves, and creeks that disappear mysteriously into the ground. There is coastal scenery with springs and tufa terraces draped over rocky shores and cliffs. The limestone dunes are clothed by tall karri forests and by coastal heath with wildflowers. The main karst areas are included within the Leeuwin-Naturaliste National Park, which is a chain of discontinuous blocks, but some karst areas are in State Forest, or private land, including urban residential areas west of Margaret River. There are several special reserves for cave tourism. The Australian Karst Index divides the region into several cave areas, from north to south (Figure 1): Yallingup (6Ya), Cowaramup (6Co), Margaret River (6MR), Witchcliffe area (6Wi), and Augusta (6Au); see WASG (1995) for additional information.

Reports of the caves date back to 1848, and tourist development began in 1901 (WASG, 1995). The earliest scientific work leading to the concept of syngenetic karst was done in this area (eg Bain, 1962a,b and Bastian, 1962, 1964). The historic Leeuwin water wheel was fed from a karst spring, and is now cemented by calcareous tufa deposits.(See Plate 1).

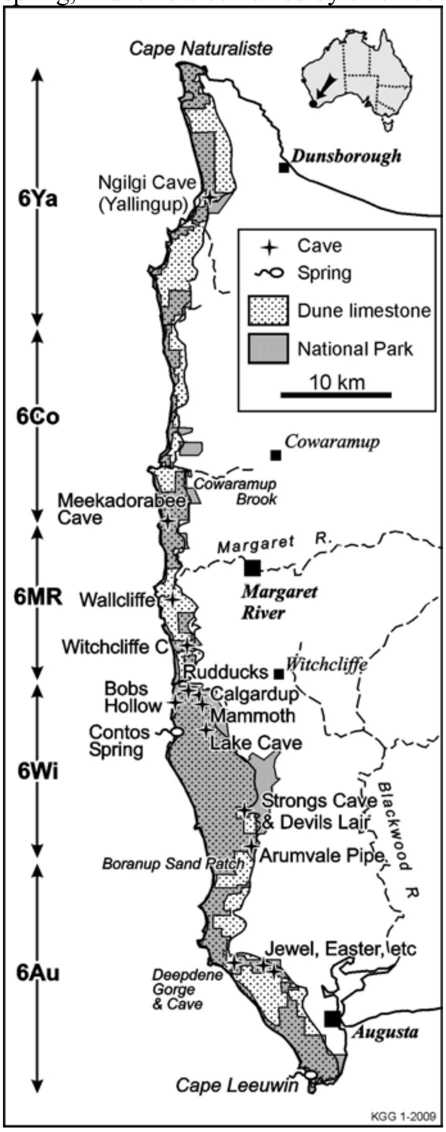

Figure 1: Location of the Leeuwin-Naturaliste karst, showing the areas of dune limestone and that part covered by National Park. The extent of the ASF areas are also shown by their letter codes on the left side of the figure.

Plate 1: Carolyn Hewlett by the Cape Leeuwin water wheel 1972. Photograph by Paul Caffyn.

Climate

The Margaret River region between Cape Naturaliste and Cape Leeuwin has a Mediterranean climate with warm dry summers and cool wet winters. There is a significant winter maximum in rainfall with mean summer temperature maxima resulting in low rainfall (16-28mm) in the summer months. The average monthly maximum & minimum temperatures and rainfall figures for Cape Naturaliste and Cape Leeuwin, are shown in Figure 2, indicating small temperature variations with higher rainfall at Cape Leeuwin for the Leeuwin-Naturaliste ridge

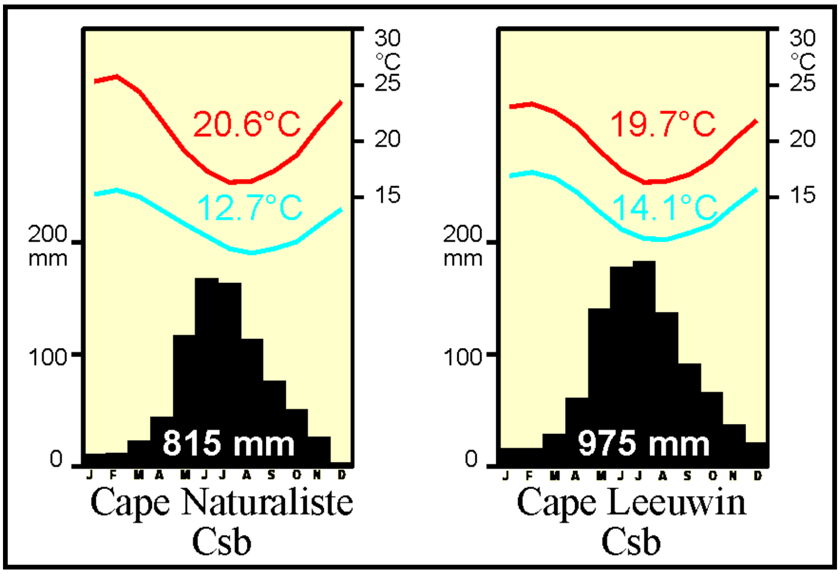

Figure 2: Monthly and annual temperatures and rainfall for Cape Leeuwin and Cape Naturaliste.

Flooding at cave inflows, such as Mammoth cave, does occur during heavy rainfall events. These flood events are covered in more detail in the site description section of Mammoth Cave.

Vegetation

The vegetation shows an interesting zonation that corresponds to the age of the dune beneath it: ranging from tall Karri forest (*Eucalyptus diversicolor*) on the oldest inland dunes, through peppermint (*Agonis flexuosa*) and Jarrah (*E. marginata*) woodland to low coastal heath and wattle thicket on the youngest dunes (Beard, 1990). The currently active dunes (eg the 3km long Boranup Sandpatch) are bare or have sparse pioneer vegetation.

Some areas of karst such as portions of the Cowaramup area have been cleared for farming.

Land Use

The major land uses in the Augusta-Margaret River shire (covering the majority of the Leeuwin-Naturaliste ridge) according to the CSIRO (2005) are:-

> "In 2000 – 2001 mineral extraction and processing made up the majority of the economic contribution for the South West Region. Coal, mineral sands and alumina processing comprise over 90% of the value of mineral production in the region (South West ACC Inc, 2000)."
>
> "There are 2405 agricultural establishments covering an estimated area of 1,129,879 hectares (SWDC 2001) and these include beef and dairy cattle, vegetables, fruit (mainly apples), viticulture and wool production."
> (Note the Reference (SWDC 2001) was not supplied in the CSIRO (2005) report.)

The major tourist caves of the region provide significant economic contributions to the region's tourist associations: the Augusta-Margaret River Tourism Association (AMRTA) and the Geographe Bay Tourism Association (GBTA).

Geology and Geomorphology

The coastal dune limestones (calcarenite) of the Leeuwin-Naturaliste ridge comprise the Quaternary Tamala Limestone formation (Playford et al, 1976) which is the dune limestone shown in Figure 1. This formed in several stages over the last 600,000 years, with the youngest dunes near the coast and older ones inland. The dunes overlie a late Proterozoic basement of hard, impermeable, banded granite gneiss; the Leeuwin Complex (Myers, 1990). Inland from the dune belt, the granitic rocks have been deeply weathered and a laterite, with associated sandy soils and other regolith, has formed on them (Hall & Marnham, 2002, Marnham et al., 2000). Further east again, a fault separates the granites from Mesozoic sediments of the Perth Basin (Playford et al, 1976).
Alluvial and swampy deposits also occur behind the dunes which have blocked or diverted some of the streams which originally flowed west to the sea. However, many of the streams have managed to either break through the dune barrier, or else maintained their course as the dune ridges built up beside them – the "gorges of construction" of Jennings (1980). The blocked streams now disappear into the dune sands or flow into cave entrances and continue as linear stream caves (see below).

Since their deposition, the calcareous dunes have been weathered to varying degrees according to their age. Rainwater dissolves the surface sands but reprecipitates much of the lime to form a hard cemented band just below the surface – known as "caprock" or "calcrete". With time, the deeper sands are also cemented and solution pipes and caves are dissolved simultaneously with this induration to form "syngenetic karst" (Jennings, 1968; Grimes et al, 1999, Grimes, 2006, and see discussion below). It was early work by speleologists in the Leeuwin-Naturaliste area that led to the concept of syngenetic karst (eg Bain, 1962a,b and Bastian, 1962, 1964).

Drainage

The major surface drainage systems of the region are shown as dashed lines in Figure 1– they include Cowaramup Brook (near Gracetown), the Margaret River and the Blackwood River (near Augusta). The known major inflows into the Leeuwin-Naturaliste karst include the Nindup plain swampy inflow into Mammoth Cave (6WI-38), Calgardup Brook which overflows into Calgardup Cave (6WI-49) via the 6WI-50 inflow, Rudducks Cave (6Wi-51) and Swamp Inflow (6Wi-87) and 6Wi-102. Further south the inflow 6Wi-83 is thought to be the source of the underground stream that formed Tight Entrance Cave (6Wi-101) and 6Wi-187 (see Figure 6).

Also the unnumbered inflow Forest Grove sink near Lake Cave (6Wi-30) is thought to be one of the sources for the Conto Spring (6Wi-90). See Plate 2 for the 1973 photo of Conto Spring resurging on the beach west of Lake Cave. Strongs Cave (6Wi-63) is fed from a blind valley, and the Arumvale system from Breakneck Gully (6Wi-54). There is also an inflow (6Wi-88) near Boranup. The Jewel Cave system at Augusta seems to have mainly vertical diffuse inputs from rainwater.

Plate 2: Conto Spring (6Wi-90) resurging on the coast, 1973. Photograph by Paul Caffyn

The Karst

The Leeuwin-Naturaliste Karst Region has several distinctive geological features, which contribute to the special character of the cave and karst development.

It is a syngenetic karst (where caves and associated karst features formed at the same time as the original sediment was being cemented into a soft rock, Jennings, 1968; Grimes, 2006) that is developed on geologically young, porous, calcareous sand dunes. The porous nature of the partly cemented sand means that the groundwater moves both rapidly through linear solutional conduits and by slower diffuse flow through the sand's porosity. The different flow types produce different cave types and the diffuse downward seepage of rain water forms the extensive speleothem formations (stalactites etc) that make these caves some of the best decorated in Australia.

There is a shallow impermeable basement, which can guide the water flow in the dunes above. Linear stream caves follow buried valleys.

Much of the groundwater enters the dunes laterally via creeks from the country to the east and disappears into the dune sands or into cave entrances at the ends of blind valleys. This foreign water is aggressive, i.e. capable of dissolving limestone, and so we find a concentration of caves at the inner margin of the dunes.

The region has a variety of cave types, of which the linear stream caves (Figure 3), the watertable maze caves (Figure 4) and the breakdown caves (Figure 5) form three major groups (Bastian, 1964; Williamson, 1980; Williamson & Bell, 1980; Eberhard, 2002, 2004; Grimes, 2006).

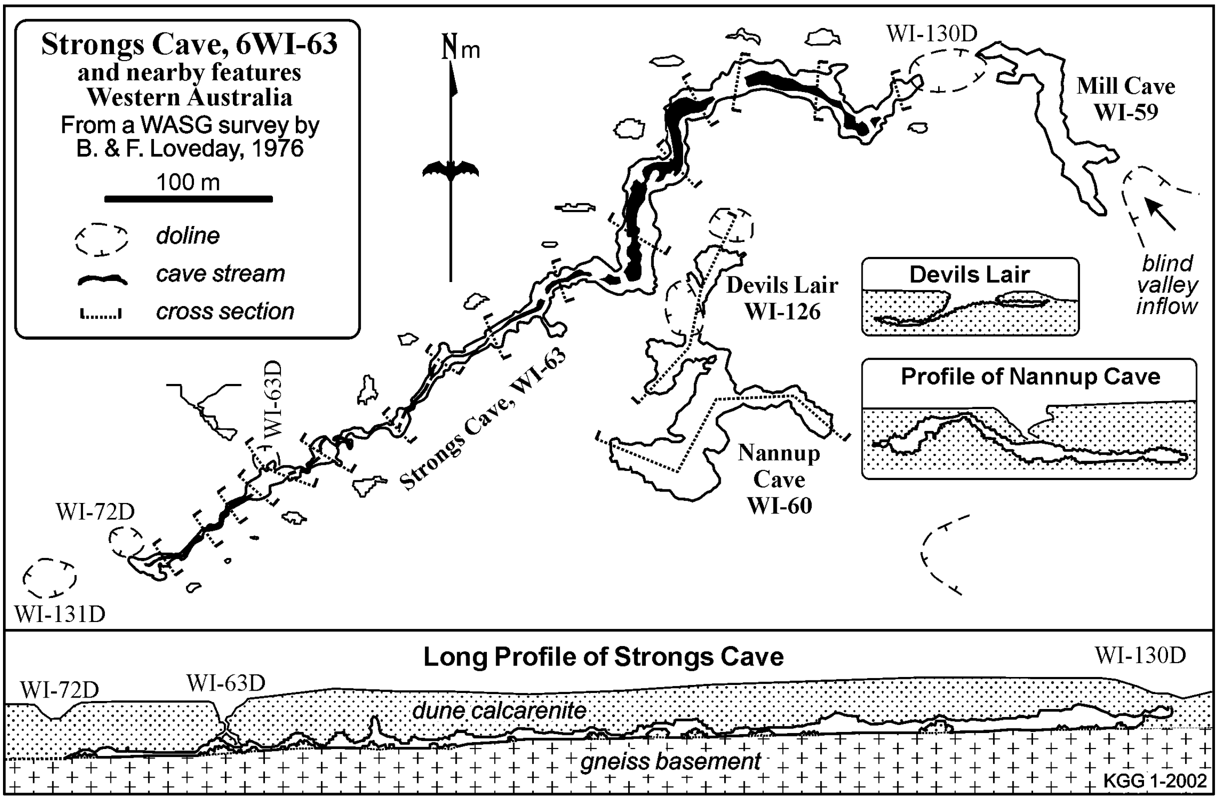

Figure 3: Map and sections of Strongs Cave (6Wi-63), and nearby features. This is a stream cave fed by an external creek that enters the dune from the east (after B & F Loveday 1976).

The *linear stream cave* systems include *inflow caves*, where surface streams moving into the dunes from the east enter caves and continue to flow underground (such as Calgardup Cave (6Wi-49), Rudducks Cave (6Wi-51) and Mammoth Cave (6Wi-38); see Figure 6); some mid-stream caves, such as Strongs Cave (Figure 3) and Connelly[1] Cave (6Wi-48), that allow access from above to underground streams which are following old basement valleys that were buried by the advancing dune sand; and *outflow caves* which are found where the underground stream re-emerges to feed springs at the coast (eg Bobs Hollow Resurgence, 6Wi-82) . Note that the surveys of Connelly Cave and Bobs Hollow Resurgence caves suggest that they are only separated by 7m ± 5 horizontally underground and the stream clearly flows from Connelly Cave into the Bobs Hollow Resurgence cave.

The *maze caves* (or lake caves) are restricted to the Jewel Cave Karst System in the southern end of the region (eg 6Au-13, 14; Eberhard, 2002, Figure 4). They differ from the stream caves in that the underground water flow was diffuse and moved slowly through the sand as a broad sheet rather than concentrated into a stream – this is an unusual situation in most limestones. This diffuse flow dissolved irregular horizontal passages and low-roofed chambers at the old water table (Figure 4). As the sandy limestone was only weakly cemented it tended to collapse so that higher "breakdown" chambers formed and in some cases reached the surface to form large sinkhole entrances. Many of these chambers had placid lakes which reflected the abundant speleothem decorations in a beautiful manner eg Jewel Cave (6Au-13). Within the region, this cave type is restricted to the Jewel Cave Karst System in the southern end (eg 6Au-13, 14; Eberhard, 2002, Figure 4), but it also occurs north of Perth, eg at Yanchep. See Plate 27 and Plate 28 for photographs of the Flat Roof chamber in Jewel Cave as an example of passage development in these maze caves.

[1] There are several spellings of this cave name but it should be the one provided here.

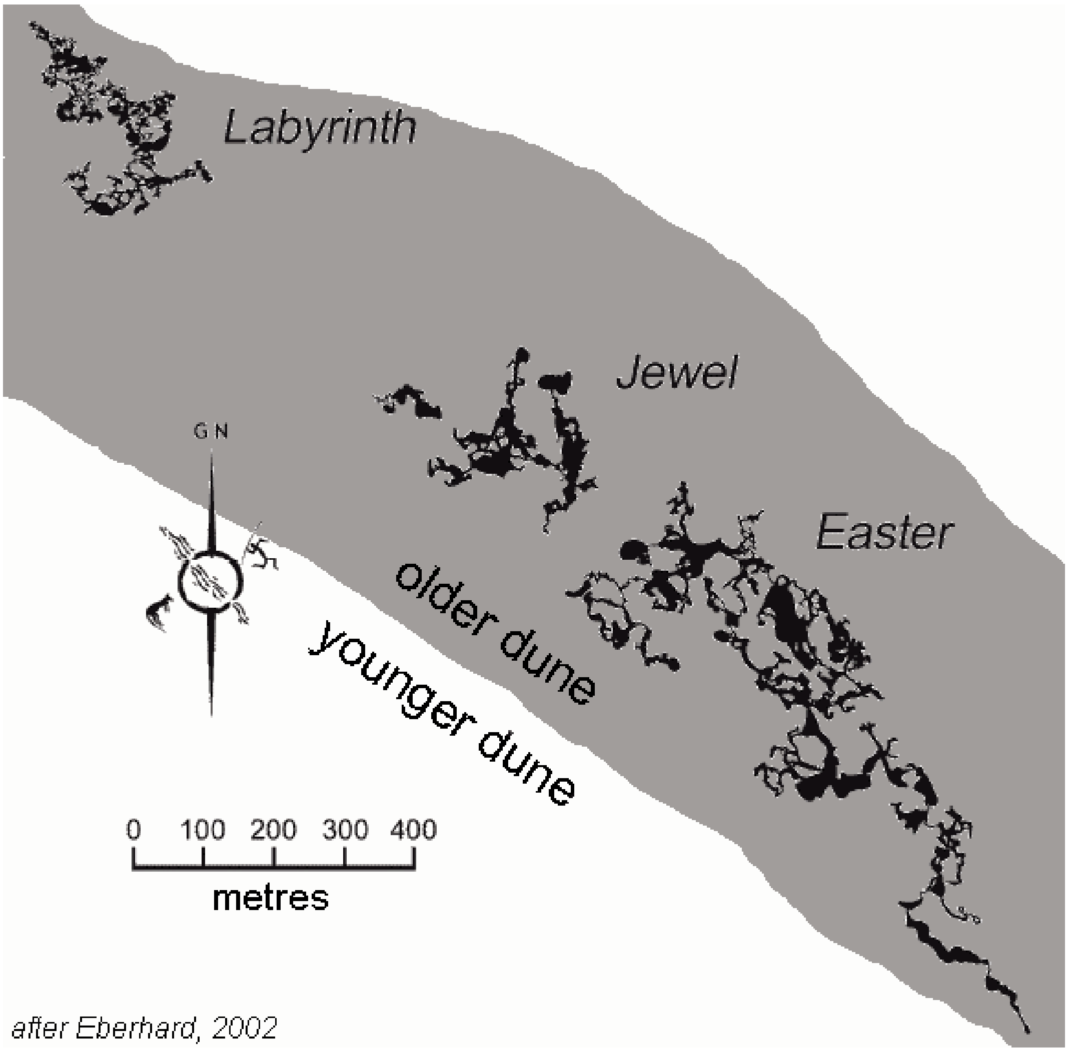

Figure 4: Map of the maze caves of the Jewel Cave Karst System (JCKS).

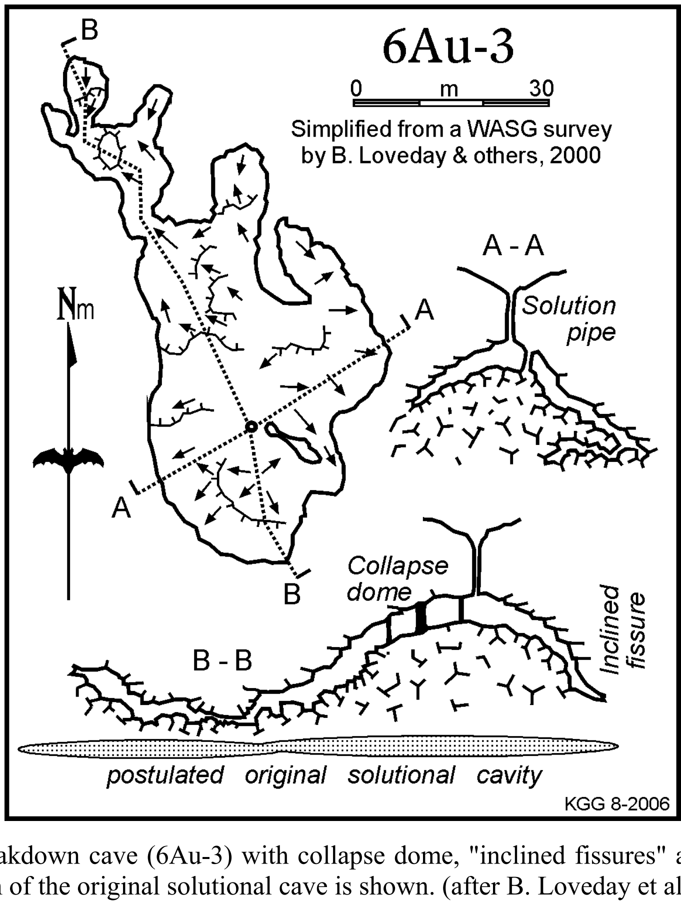

Figure 5: Map of a typical breakdown cave (6Au-3) with collapse dome, "inclined fissures" at the edges and a solution pipe entrance. The deduced position of the original solutional cave is shown. (after B. Loveday et al 2000)

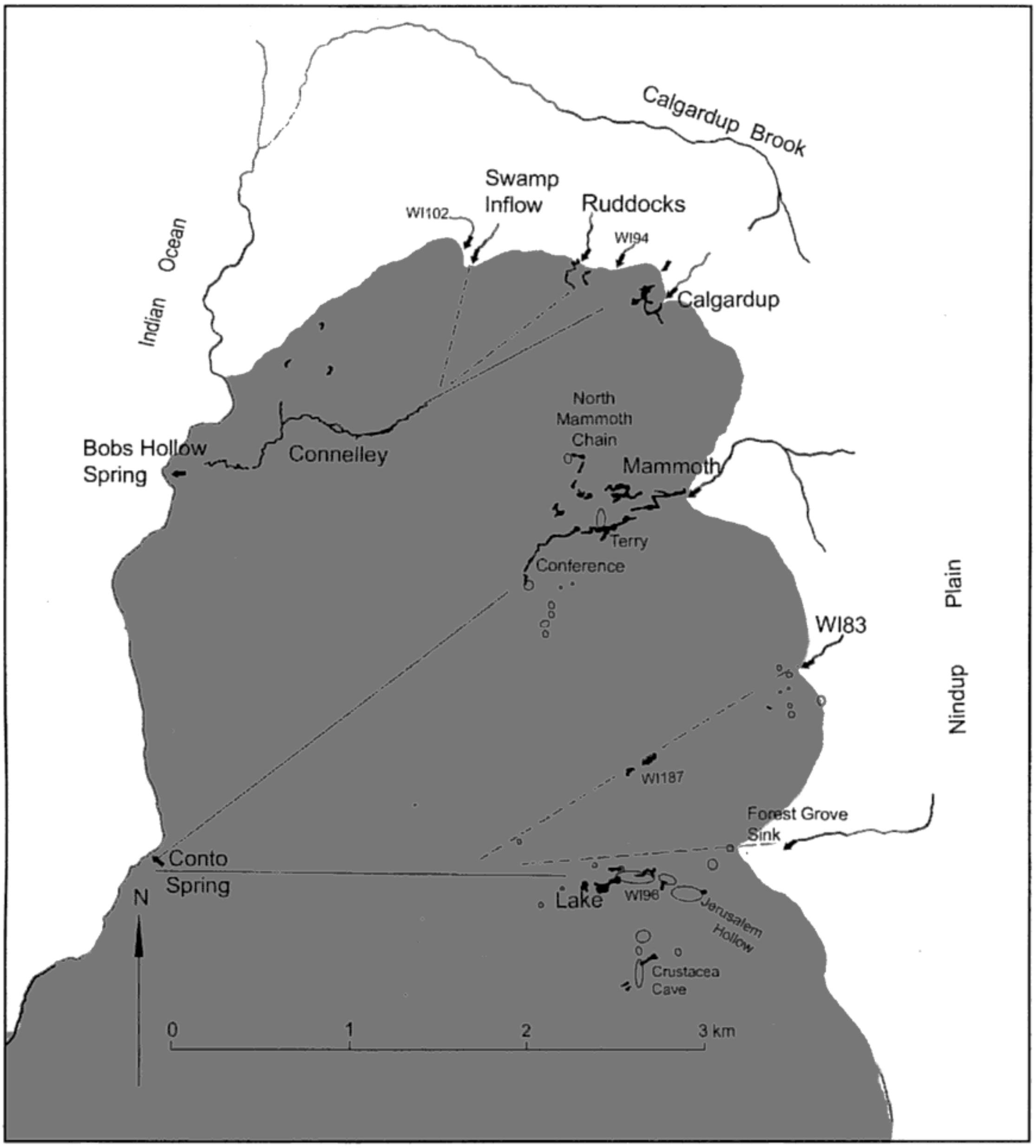

Figure 6: The North Witchcliffe karst area showing limestone (grey), mapped caves (black silhouette), dolines (open circles and ellipses), streamsinks (short arrow), traced flow (solid line), inferred sub surface flow (dashed line). Adapted by R. McBeath (2005) from S. Eberhard and B. Loveday.

The *breakdown caves* (also referred to as *inclined fissure caves*) originated as linear or maze types, but the original solutional passages and chambers have been strongly modified by collapse of the roof so that they now form irregular, rubble-filled dome chambers (Figure 5). The "inclined fissures" occur at the edges of the collapse domes, where the rubble floor and sloping roof rise parallel to each other – this is commonly the only accessible part of the cave. These are less interesting to the geomorphologist, but can have extensive speleothem decorations, and some of the tourist caves are partly or wholly of this type (e.g. Ngilgi Cave (6Ya-1) in the north of the region, and Mammoth Cave (6Wi-38) in the Witchcliffe area). Other breakdown caves such as 6WI-113 Winjan Cave (See map in Figure 17), 6WI-112 Labour Cave and 6WI-114 Kudjal Dar have formed above the original solutional passages but do not provide entry to these original passages. See the photo in Plate 3 of an “inclined fissure” passage in Winjan Cave which contains heavy speleothem decorations.

A special type of cave which does not fit into any of the above groups is 6Co-8 (Meekadorabee Cave) which cuts across a meander bend of a surface creek – an example of "underground stream capture". An added complexity comes from a smaller stream, fed by a spring uphill from the cave, which enters the cave via a waterfall above its upstream entrance (see map in Figure 10 and photograph in Plate 15). This stream is saturated with lime and is forming extensive tufa deposits (soft porous lime) over the entrance and through the cave (see Plate 15).

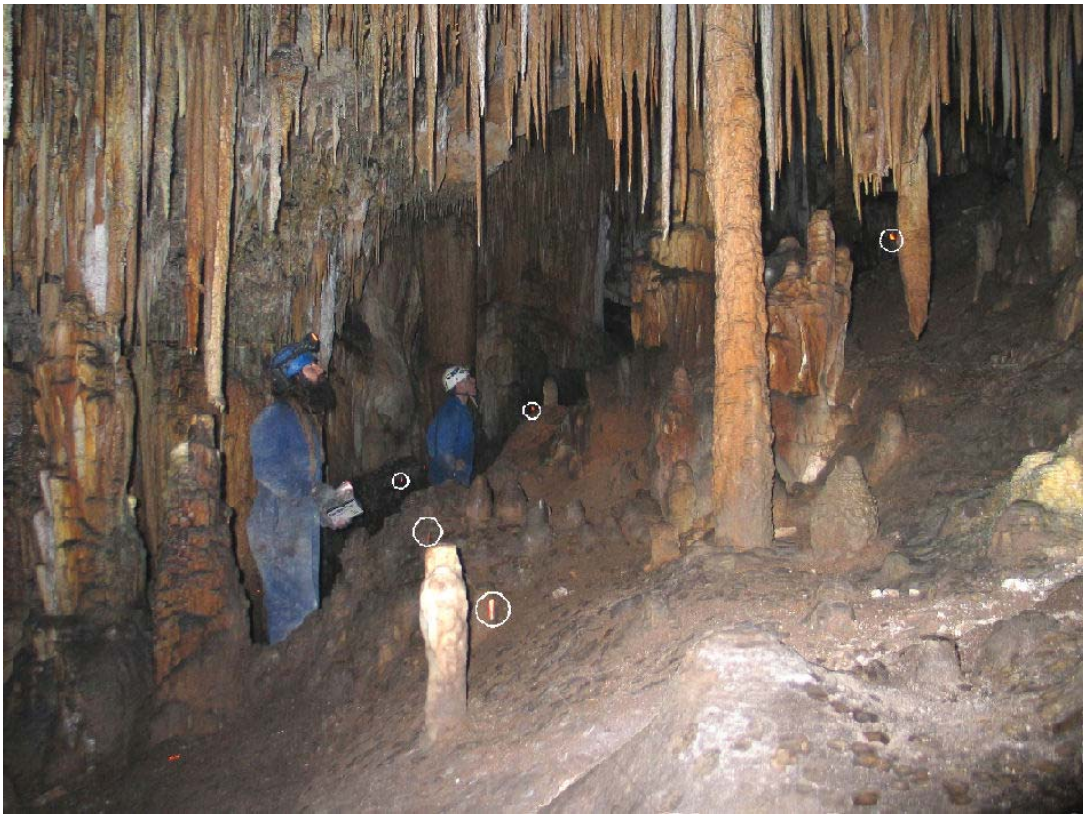

Plate 3: An “inclined fissure” passage in Winjan Cave. Photo by Ross Anderson.

There are a variety of *surface karst features* such as blind valleys (where a valley entering the dunefield ends abruptly at a cliff or steep sandy slope), stream sinks (where water from a creek disappears into the limestone, typically at the end of a blind valley), springs (some with picturesque tufa terraces, Scott, 2003), and large sinkholes (closed depressions formed above caves) such as the entrance to Lake Cave which is 70m across and has its own Karri forest on the floor (Yates, 1982). The gorge at Deepdene, see Plate 4, cuts across the dune limestone ridge – its origin is controversial, with several possibilities having been suggested (see discussion in Eberhard, 2004, pp 75-77). The dune surfaces often have a soil hardpan which may contain vertical cylindrical tubes, with cemented rims, known as solution pipes, some of which may connect to caves (eg 6Wi-56, Arumvale Pipe). Some younger dunes contain calcified root structures (rhyzomorphs) which, in conjunction with the cemented solution pipes give the impression of buried "petrified forests".

Plate 4: Deepdene Gorge aerial photo showing surrounding bush and farmland. Photograph by Brian Combley.

Fauna

The permanent streams and lakes in the region's caves support a significant and diverse stygofauna (groundwater ecosystem) which has been described by Eberhard (2004) & English & Blyth (2000). In particular, the root mats (see Plate 5) within some pools provide a constant and abundant primary food source, and sustain some of the richest faunal communities known from groundwater in caves anywhere in the world (English & Blyth, 2000). However, Eberhard (2004) emphasised that conservation strategies need to be aimed at the groundwater environment as a whole, not individual root mats. That groundwater environment is threatened by dropping water tables at the regional scale, as well as by localised pollution.

Plate 5: Root mat communities in stream pools, Strongs Cave, 2003. These are now completely dry. Photograph by Ken Grimes.

Some of the species recorded in these pools are relicts from when Australia was part of the supercontinent of Gondwana about 350 to 100 million years ago, or possibly even the earlier Pangaean period (English & Blyth, 2000). There is significant variation in species composition between the caves.

Significant collections of cave fauna have occurred in the caves of the south-west since the 1980's and particularly after professionals such as Dr Bill Humphreys joined the WASG. With WASG members such as Brian Vine, Darren Brooks, Rob Foulds, Stefan Eberhard, Tim Moulds, Rob Susac, Jay and Ross Anderson becoming avid collectors of cave fauna, which has been provided to the WA Museum, the overall knowledge and distribution of cave fauna in caves in Western Australia increased dramatically. Other speleologists such as Norm Poulter, SRGWA, were also adding to the cave fauna knowledgebase.

A permit is required from DEC to collect cave fauna in Western Australia regardless of land tenure. It should be noted that the speleologists mentioned above are collecting state wide and not specifically on the Leeuwin-Naturaliste ridge. They also generally collect different species. The WA Museum has a fauna database which contains details of cave fauna collected in caves.

Four root mat communities from Calgardup Cave, Easter Cave, Kudjal Yolgah and Strongs Cave have been listed as being critically endangered. Eberhard (2004) indicated that these communities were more widespread after finding them in Jewel Cave (6Au-13), The Labyrinth (6Au-16)and Budjur Mar (6Wi-144). Stygofauna was also collected from aquatic habitats in Crystal Cave (6Wi-62) and Green Cave (6Wi-2) where tree roots were absent. Several of the root mat communities have dried up in recent years.

The significant increase in the number of speleologists collecting cave fauna also leads to the management problem of possible over-collection and re-collection of the same specimens by different collectors. The development of a Karst Management database, which would hold all of the details of specimens collected in each cave, would allow researchers to take current lists of species collected from a cave whenever they are collecting. Such a central online database would avoid this duplication of effort and any unnecessary collection of fauna.

Palaeontology and Archaeology

Since the discovery of caves in the Leeuwin-Naturaliste ridge at least 18 digs have been performed in 18 different caves of the Leeuwin-Naturaliste ridge. These have been performed by professional palaeontologists and archaeologists as well as amateur speleologists. The major palaeontological digs are those performed in Mammoth Cave in the 1900's and more recently in Tight Entrance Cave (6Wi-101) in the 1990's and again in 2008. Some of the results of the Mammoth Cave excavation are listed in the site description section for Mammoth Cave. The most significant dig performed by a speleologist is the Skull Cave (6Au-8) dig, by Roger Howlett, which has been ongoing since at least 1961 when it was first recorded. Roger still continues to excavate material from Skull Cave.

Ayliffe et al, 2008 indicate that 37 vertebrate species were retrieved from excavations in Tight Entrance Cave from 1996-1999. The majority of these species were kangaroos and 12 extinct megafauna species were identified. Plate 6 shows the lower jaw of *Simosthenurus occidentalis,* an extinct browsing kangaroo which was located in sediments with an estimated age of 47±2 ka. The major conclusion of this research was that of the 12 megafauna present in the deposit, 10 of them were located in a single unit (D) which was deposited in the penultimate glacial maximum and/or during the last interglacial with dates ranging from 119±4 to 137±3 ka. However two sthenurine kangaroos, one from Tight Entrance Cave and another from Kudjal Yolgah (6Wi-9), were dated to < 50 ka indicating that megafauna was still present at that time.

Plate 6: Lower jaw of a large extinct browsing kangaroo (*Simosthenurus occidentalis*) during laboratory preparation. Photograph by Grant Gully

An example of a dig performed by a speleologist is outlined in the Deepdene Cave site description section of this guide.

Devils Lair (6Wi-61) is a significant archaeological and palaeontological site. The first study, from a single pit dug in the 1950s, was reported by Lundelius (1966) who interpreted the bone material as being the den of a Tasmanian Devil; hence the present name Devils Lair (Lundelius referred to his dig as being part of the adjoining Nannup Cave, see Figure 2). Following the discovery of a human tooth in material from the first pit, the main excavations were done by the Western Australian Museum during the 1970s (Dortch, 1984). Their main pit was 6.6m deep, bottoming on a flowstone, and had over 100 distinct stratigraphic layers. Charcoal, charred bone, scattered artefacts and several heaths record discontinuous Aboriginal occupation commencing about 30,000 years ago (at a depth of 3.6m), and continuing to about 12,000-6000 BP when the original entrance closed. The modern entrance seems to have been open for only a few hundred years. The pits also sampled a diverse fossil bone fauna which included several specimens of the megafauna (*Protemnodon* and *Sthenurus*). The megafauna were mostly found below the layers of human material, but one broken metatarsal of *Protemnodon* in the lowest occupation layer was considered by Dortch (1984, p.62) to be a *"probable" artefact*. – this was the first suggestion of a narrow overlap between humans and the megafauna; which continues to be debated today.

Paleoclimate Research

In recent years researchers have taken a strong interest in paleoclimate information stored in speleothems. Pauline Treble has studied the speleothems from caves of the Leeuwin-Naturaliste ridge. Treble el al (2003) used a stalagmite from Moondyne Cave, which was collected from a boardwalk where it grew between 1911 and 1992, to provide the first confident comparison between the instrumental climate record and speleothem trace element content. The annual speleothem Mg and P concentrations were found to clearly record the rainfall decrease from 1970.

The same stalagmite was used by Treble et al (2005) to record the seasonal and inter-annual oxygen ($\delta^{18}O$) and carbon ($\delta^{13}C$) isotope ratios. Seasonal variations in calcite $\delta^{18}O$ were measured in situ by high spatial resolution ion microprobe, whilst inter-annual variations of $\delta^{18}O$ and $\delta^{13}C$ were measured by conventional gas-source mass spectrometry. This work concluded that small changes in the relative masses of calcite deposited in winter and summer could produce significant shifts in mean $\delta^{18}O$ and $\delta^{13}C$ that have a complex relation to climate.

Drip water studies were then undertaken in Golgotha Cave (6Wi13) by Treble et al (2008) where they found that drip water Mg/Ca ratios are in fact higher in the wet winter months than summer, and tracing with O isotopes did not suggest that this was due to a seasonal lag. Also at Golgotha Cave they noted that the highest Mg/Ca ratios were reached in 2006, which was the driest year on record.

Fisher & Treble (2008) describe how they devised a new regression model, which provided a consistent picture of ^{18}O variability over a range of timescales, which had not been the case with any previous climate-isotope regression model.

Geological Heritage

The geological setting is unusual – having porous dune limestone overlying a granitic basement, which has controlled the hydrology of the area, with groundwater flowing both diffusely through the sand and in streams within linear caves. The geomorphology includes coastal cliffs and bays, dune systems and karst landforms. The karst has excellent examples of syngenetic karst features and processes, contact zone effects, basement guidance, caprocks, solution pipes, dolines, springs with tufa deposits, and a diversity of cave types. Some caves host palaeontological and archaeological values (Devils Lair, 6Wi-61, is particularly significant for both; Dortch, 1984). The surface vegetation provides an excellent example of progressive development controlled by the age of the dunes and the dune soils – reaching a climax vegetation of tall karri forest on the oldest dunes (Beard, 1990).

Management/Conservation Issues

The Leeuwin-Naturaliste National Park and related reserves cover most of the significant karst areas. Land uses elsewhere on the dune ridge include forestry, agriculture and residential. Several small pine and eucalypt plantations had been placed in the catchment of caves such as the Strongs/Mill cave stream. The loss of water in Strongs and Mill caves prompted CALM to remove some of these plantations from the catchment areas of these caves.

The effects of tourism on caves & surface karst are mixed. On one hand, the visitor experience and publicity assists in broadening the public understanding of karst and its problems. On the other hand, visitor numbers impact directly on the caves and surface, and the associated infrastructure (buildings, carparks, cave trails and lighting) can also cause local damage and generate pollution problems.

Prior to the Cave and Abseiling permit system implemented in 1992, the majority of caves of the Leeuwin-Naturaliste ridge had uncontrolled visitor access. Caves such as Giants Cave (6Wi-21) had visitor numbers as high as 18,000 per annum (Webb, 1989). Recreational caving causes some wear and tear in all caves, particularly the most popular ones. The permit system controlled the numbers and the experience of those entering the caves (Wood, 2001) and it significantly reduced visitor numbers to caves on DEC land. The number of registered cave leaders fell from over 500 in 1992 to approximately 50 qualified leaders in 2008. This has clearly reduced the visitation to caves significantly over this period.

One of the best examples of cave conservation by speleologists on the Leeuwin-Naturaliste ridge is the Christmas Star Extension of Crystal Cave (6Wi-62). This extension was found by WASG at Christmas in 1968 (Bridge, 1968). In January 1969 Bridge (1970) describes how he had brought “a several thousand foot roll of 20 inch wide plastic sheet” which was “cut into sections of varying length , and laid on the flowstone”. Poulter, 1972 recommended several improvements in the extension including the replacement of the light plastic used by Bridge, that helmets should not be taken into the extension and that a change of clothes should be taken into the extension. All of these and more were implemented, resulting in a well conserved area of cave despite some formations being accidentally destroyed by speleologists. See Plate 7 for a photograph of the plastic paths in the extension in ~1972.

Plate 7: Donna Summers on plastic path in Crystal Cave (6Wi62) in 1972-3. Photo by Paul Caffyn

This early "track marking" was replaced in the 1990's by track markers such as those in Strongs Cave – See Plate 8. Other forms of track marking using track tags were implemented in delicate cave areas throughout the Leeuwin-Naturaliste ridge. An example of track tags is shown in Plate 9 where they were used in the Flat Roof area of Jewel cave to minimise caver impacts on now dry floors and to stop speleologists from muddying cave formations. See the inset of the column in the Plate 9 to show the mud on the formation which occurred before the track marking was put in place.

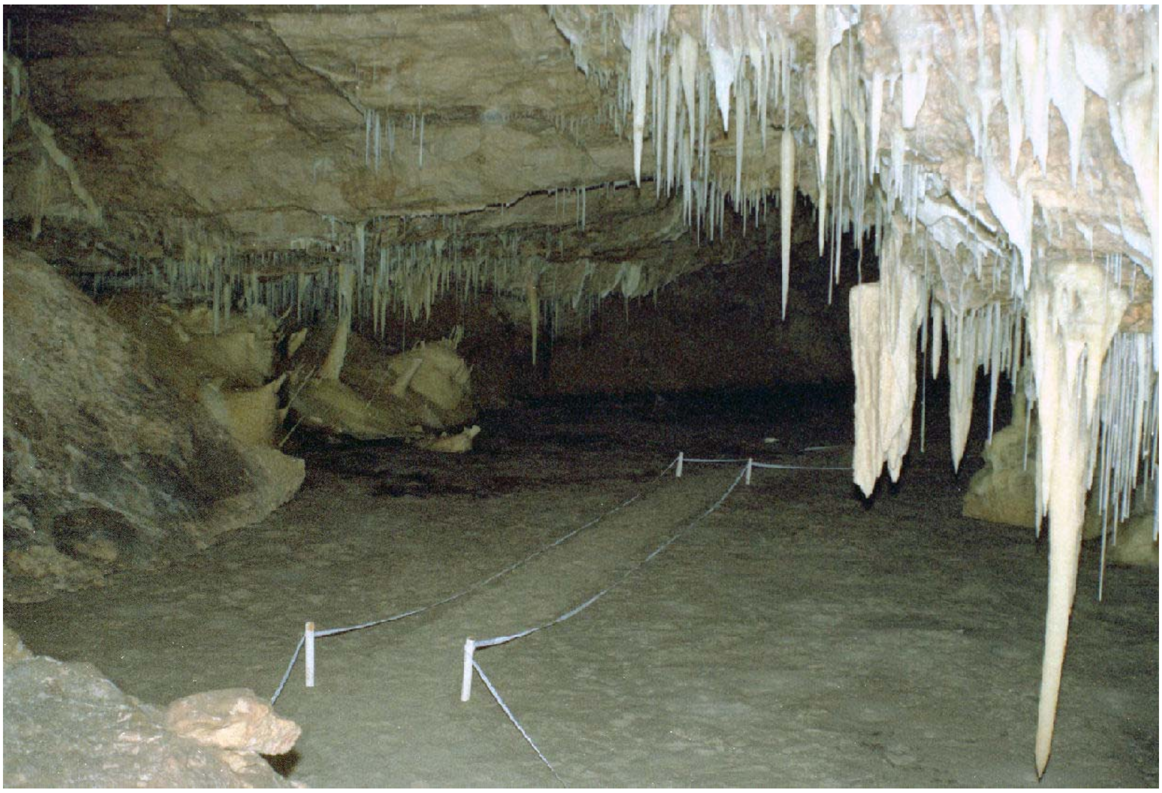

Plate 8: Track Marking and Rotated Collapsed blocks. Strongs Cave (6Wi-63). Photograph by Ken Grimes.

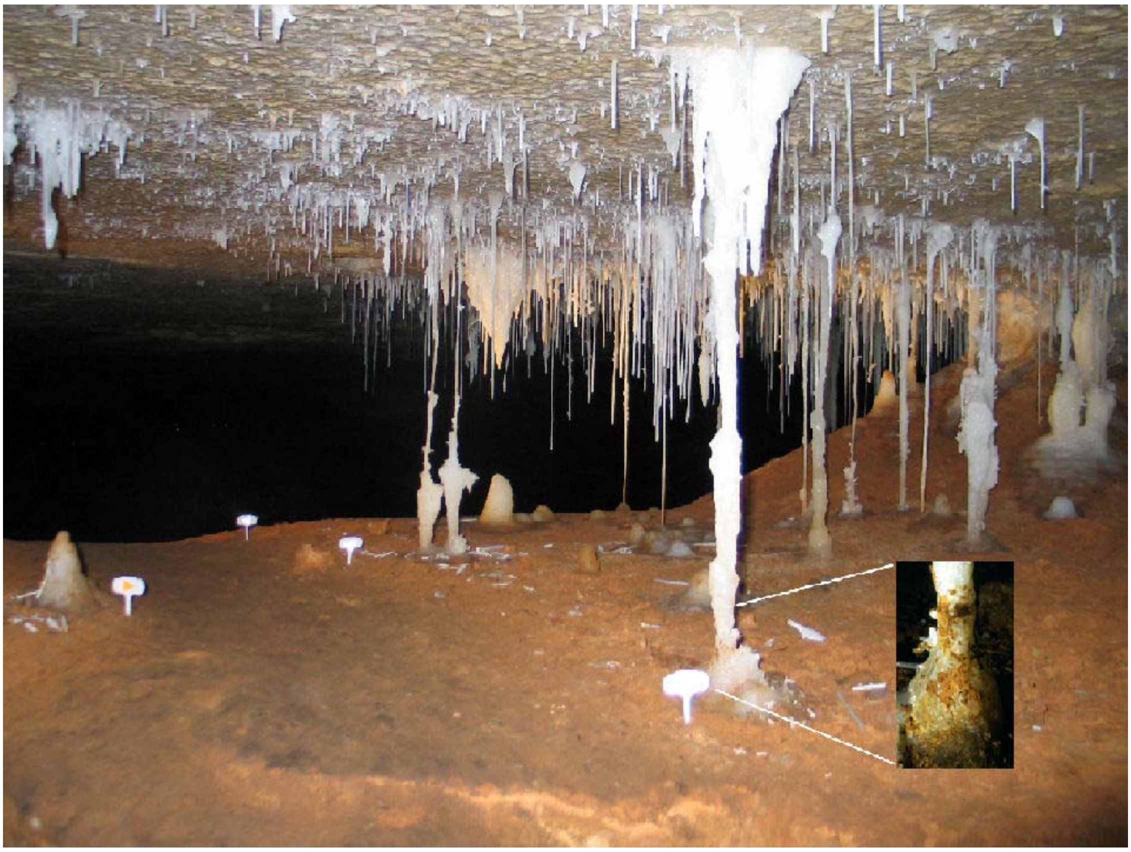

Plate 9: Track Tags on crawlway into Flat Roof Chamber, Jewel Cave. Photograph by Ross Anderson. Inset of muddied column by Rauleigh Webb.

Some early track marking and placement of signage efforts were inappropriate, such as those shown in Plate 10, but these were soon corrected without gluing track markers to cave formations or leaving unattached signs on flowstone.

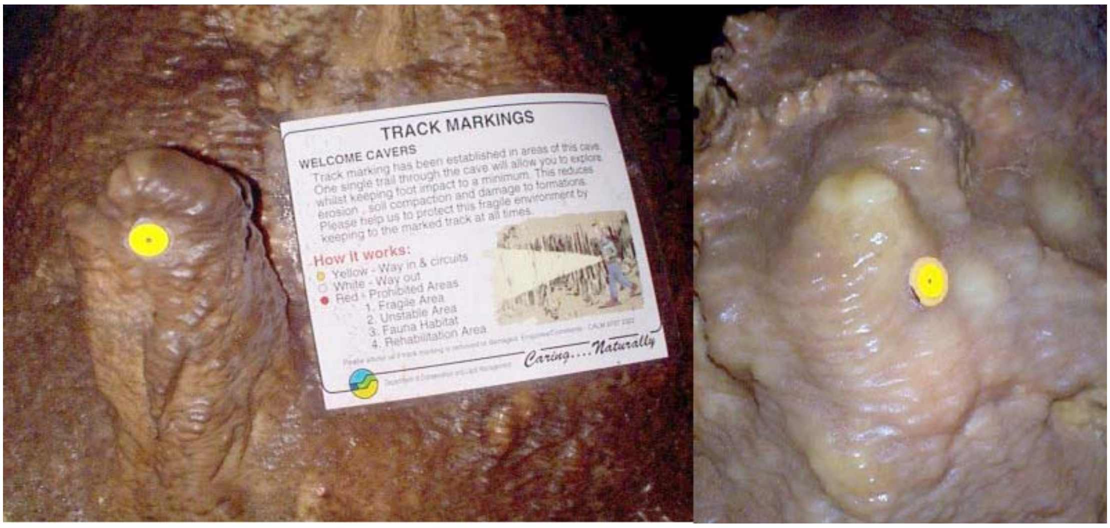

Plate 10: Inappropriate placement of track markers and signs, Nannup Cave, 1999. Photographs by Rauleigh Webb.

In the areas outside the reserves, land clearing and construction of buildings, roads etc has had an impact in the past and this will continue. Several large areas of native vegetation are still unreserved and their survival will be subject to the vagaries of politics and local government decisions.

The hydrology of each karst area in the Leeuwin-Naturaliste ridge is clearly different. Water levels in the caves, and in the karst aquifer in general, have dropped significantly in the last 50 years. The photographs in Plate 27 and Plate 28 show the complete loss of water from the 1980's to 2007, in the JCKS. A further drop of only 0.5m would drain most of the ponds and cave streams which support the root mats and aquatic ecosystem. The scenic value of the lakes in the tourist caves has already been lost except for Lake Cave which is in decline. Various causes of the drop have been suggested, including a decrease in fire frequency in the overlying forests (Eberhard, 2002, 2004). Some localised pollution of the cave waters has occurred in the past. One of the largest challenges for cave managers in the Leeuwin-Naturaliste ridge is ensuring the integrity of the water catchment of the karst they are trying to manage. Given that in most cases the catchments for karst areas generally lie outside of the boundaries of the land management agencies, they must rely on maintaining close ties with surrounding land managers to protect the karst they are managing.

The photograph in Plate 11 shows the mining of sand east of the karst within the karst catchment. This is a typical example of the issues facing karst managers in the region.

Plate 11: Dave London adjacent to a sand mine on land in the catchment of karst in the Leeuwin-Naturaliste ridge. Photograph by Rauleigh Webb

Another cave impact issue has been the use of pine logs treated with chromated copper arsenate (CCA) which were used as steps in caves where heavy traffic was occurring or in the stabilising of sand slopes. The research by Swabey & Roest (2005) and Weis et al (1992) clearly demonstrated the significant potential impacts of the use of CCA treated material in caves on cave fauna. Therefore a significant quantity of the treated pine logs, that were likely to be affected by drip water, were removed from caves on the Leeuwin-Naturaliste ridge by DEC (A. Wood, Pers. Comm.). Some material still remains in areas that are not likely to come into contact with water. Further work is required to find a suitable material (recycled plastic?) to place in heavy traffic areas such as "Adventure" caves.

Another issue still facing some cave managers is Lampenflora in lit tourist caves. The majority of the tourist caves of the Leeuwin-Naturaliste ridge have this problem under control but Ngligi Cave does have a bad lampenflora problem. An example of the lampenflora is shown in Plate 12. The lampenflora on the stalactites is outlined in the white boxes on the photograph as it is hard to see the green lampenflora in black and white images.

Other issues facing cave managers include the inability to collect and collate cave management data relating to all of the diverse aspects that relate to the management of caves. In general cave managers suffer from lack of resources and time to adequately prepare and implement management plans. A vital requirement for the long-term management of all the caves is the development of a Karst Management database to store this information and retrieve it, in order to develop cave management prescriptions and larger scale cave management plans. The development and adoption of such a database should be one of the major goals for all cave management agencies and also organisations such as ACKMA.

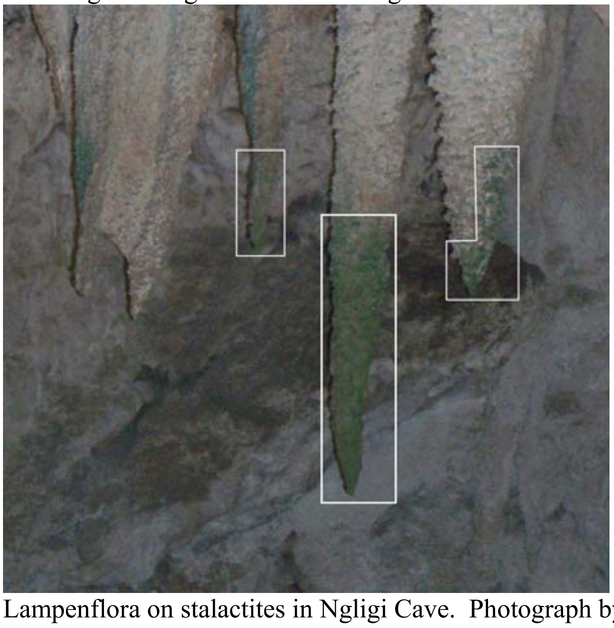

Plate 12 Lampenflora on stalactites in Ngligi Cave. Photograph by Rauleigh Webb

Site Descriptions

This section of the field guide gives descriptions of a number of the caves and karst features from the five areas that comprise the karst of the Leeuwin-Naturaliste ridge (Figure 1). The caves have been chosen because they are interesting or significant within their area.

The Yallingup Area

The karst of this area is somewhat hidden except for the spectacular cliffs and sea caves at Cape Naturaliste. Unfortunately, these are difficult to view except from an aircraft or boat.

The Yallingup area has some of the thickest limestone (up to 200m ASL at Mt Duckworth) of the Leeuwin-Naturaliste Ridge, but despite the thickness of the limestone very few large caves or extensive cave systems have been found. The deepest cave in the area is Lost Pearl Cave (6Ya-51) at 75.9m (see description below) while the longest cave is Ngligi Cave ,also know as Yallingup Cave (6Ya-1), at 740m.

In general, the karst is overlain with sand with few limestone outcrops. However, on the coast, limestone cliffs and white sandy beaches are a feature. Other significant features are Yallingup Brook and lagoon and historic Caves House (see http://www.caveshousehotel.com.au/).

Ngligi Cave (also known as Yallingup Cave)

Ngligi cave (6Ya-1) is located off Caves Road between Dunsborough and Yallingup. It is a public self guided tourist cave. It also offers “Adventure Cave“ tours. The cave was formed by roof collapse onto a once active cave stream. The breakdown chambers so formed provide good examples of the "inclined fissure" style. They are well decorated, with shawls and helictites being key features.

Some History of Ngligi Cave, quoting from Kinsella, 1994.

> “It is believed that while out looking for stray horses Edward Dawson came upon the present entrance, the date was the 11th of October 1899. Dawson returned some time later with two friends, Seymour and Curtis, who assisted the initial exploration.
>
> Edward Dawson began conducting tours through the cave in 1900 and served as its head guide until 1937. The popularity of the tours conducted by Edward Dawson resulted in the establishment of Caves Hotel in 1901.
>
> Management of the cave and the reserve has been the responsibility of a number of bodies over the years with the cave eventually being vested with the Busselton Tourist Bureau in 1966. The Busselton Tourist Bureau then became the Cape Naturaliste Tourism Association (and is now the Geographe Bay Tourism Association, *Ed*.).
>
> In 1903, Yallingup Cave was the first cave in Western Australia to have electric lights installed “

Another first for Western Australian tourist caves was the installation of recycled plastic platforms and handrails in Ngligi cave. Recycled plastic wears well and is more resistant to attack by insects and fungi. This type of plastic is claimed to significantly reduce the leaching of chemicals from the plastic, and hence it is useful in cave environments where cave fauna are likely to be effected by such chemicals. Weis et al (1992) is the definitive study on recycled plastic and they showed that 100% recycled plastic containing no polystyrene produced very low levels of leachates (all with relative abundances less than 10E6). The majority of the leachates were long chain alkanes which were considered to have low toxicity. Only two chemicals required further testing to determine their toxicity and they were 1,2-Benzisothiazole and Butylated Hydroxy Toluene (BHT) which is used as an antioxidant food additive.

The Aboriginal legend of Ngligi is also courtesy of Kinsella, 1994.

> "Yallingup Cave is associated with a rich Aboriginal legend describing a battle between a good and an evil spirit.
>
> Ngligi, a good spirit, lived in the sea and Wolgine, an evil spirit, lived in the cave. At the time the opening to the cave was near the sea and Wolgine had been taking the people's children.
>
> Concerned for the welfare of his people, Ngilgi gathered the sea spirits together and attacked Wolgine. Gradually, Wolgine was driven back through the cave and so fierce was the battle that a tunnel collapsed, cutting the cave off from the sea.
>
> The collapsed tunnel can still be seen today as a deep gully a short distance from the cave. Eventually Wolgine was driven up through the earth creating the present entrance.
>
> Wolgine was banished from the cave and Ngilgi claimed it as his own thus the cave became known as Ngilgi's Nurilem (cave)."

Some excellent historic stereograph photographs taken by JHA Macdougall, probably between 1912 and 1916 when he lived in Fremantle, WA, document many of the caves features. A number of these images can be viewed at:

http://home.websolutionswa.com/Caves/Macdougalls Stereographs/album/index.html

One of these stereographs is of "The Shawl Shop" in Yallingup Cave (see cover photograph) Macdougall was one the first photographers to use side lighting in caves to produce excellent depth and texture in his images as shown in the cover photograph. Another image entitled "Crystal Loops and Knots" highlights the helictites in the cave – See Plate 13.

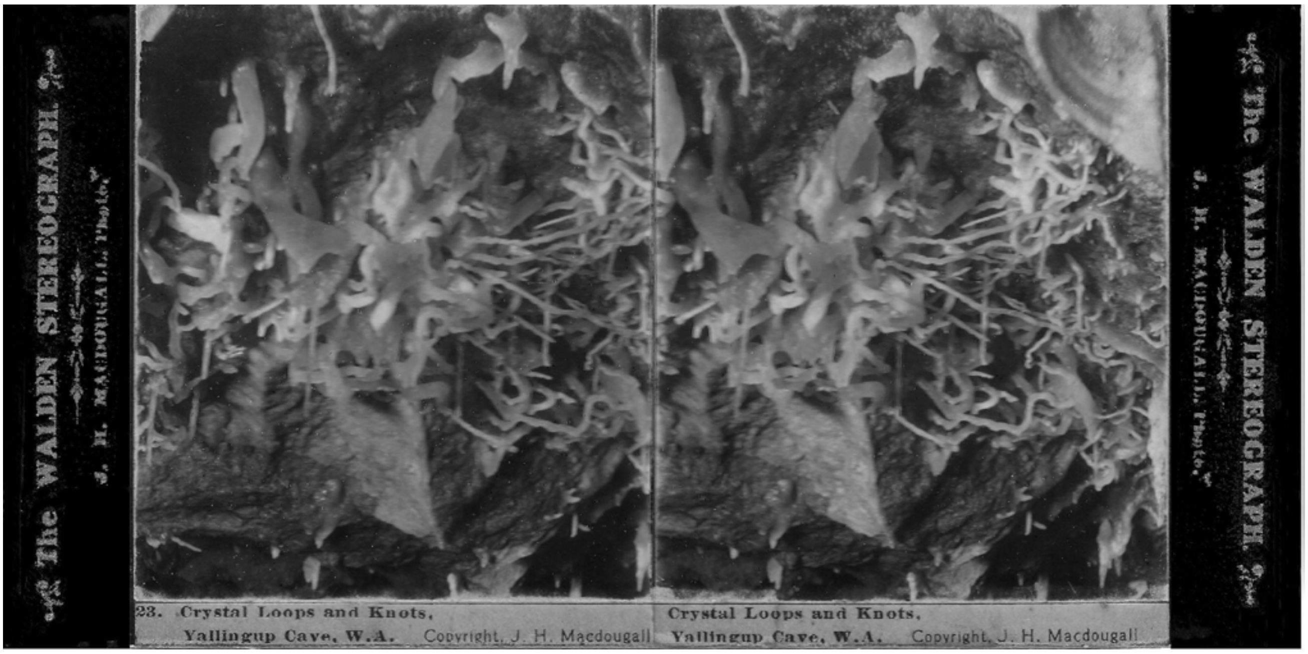

Plate 13: Crystal Loops and Knots - Yallingup Cave. by JHA Macdougall

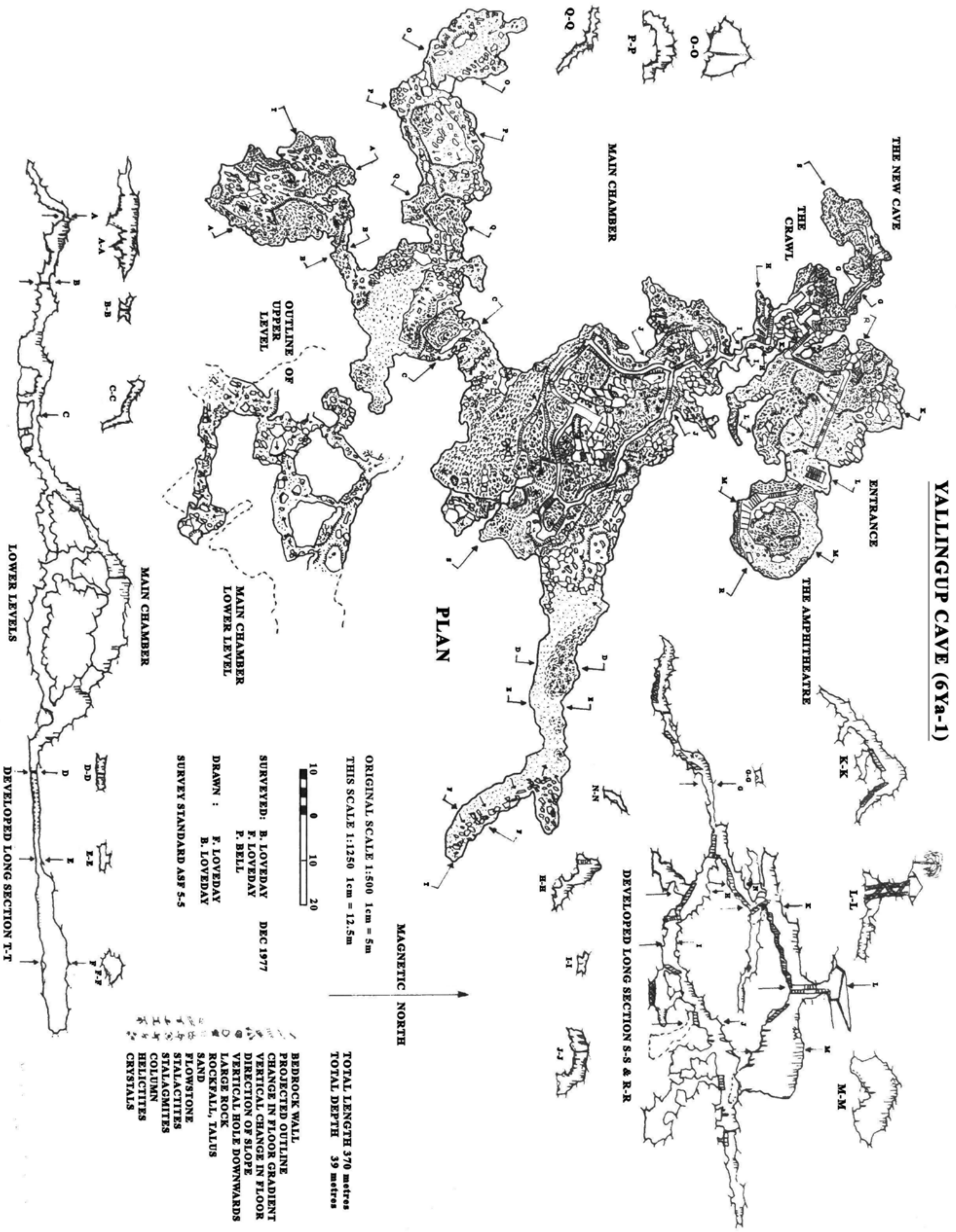

Figure 7: Map of Ngligi Cave (then Yallingup Cave). by F & R Loveday

Northcote Grotto

Northcote Grotto (6Ya-2) was officially opened as a tourist cave by the then Governor Northcote in September 1905 and named after him. It was later fitted with electric lights but suffered the fate of many of the old tourist caves and was eventually closed to the public (Loveday, 1976).

The cave is located very close to Caves Road in the Yallingup Area. This proximity did attract a lot of visitors who did not obtain the necessary permit to visit the cave. Significant vandalism to speleothems has occurred in the cave (See Plate 14). The cave was once locked, but the gate was breached and not repaired for many years. The major management issue for the cave was the unauthorised access to the cave by the general public, so in the last two years, the cave's manager, DEC have replaced the gate, reducing visitation by non-permitted visitors. Another issue was the rickety wooden ladder that provided access to the stream level in the cave. This and other introduced wood in the cave has been removed by cavers and DEC. Access to the cave is via permit from DEC.

The map of Northcote Grotto (Figure 8) shows the short entrance climb with collapse chambers leading to the lower level which contains the active stream passage. This cave is only one of two caves in the area in which a stream is visible. This stream is sluggish and possibly diffusely fed (Williamson, 1975). It contains root mat communities (Jasinska 1997) and stygofauna (Eberhard,2004). The cave does still contains some areas of decoration although they have been damaged by visitors – See Plate 14 for a photograph of a flowstone and stalactite area in the upper levels.

Plate 14: Flowstone and vandalised Stalactites in Northcote Grotto (6Ya-2). Photograph by Ross Anderson

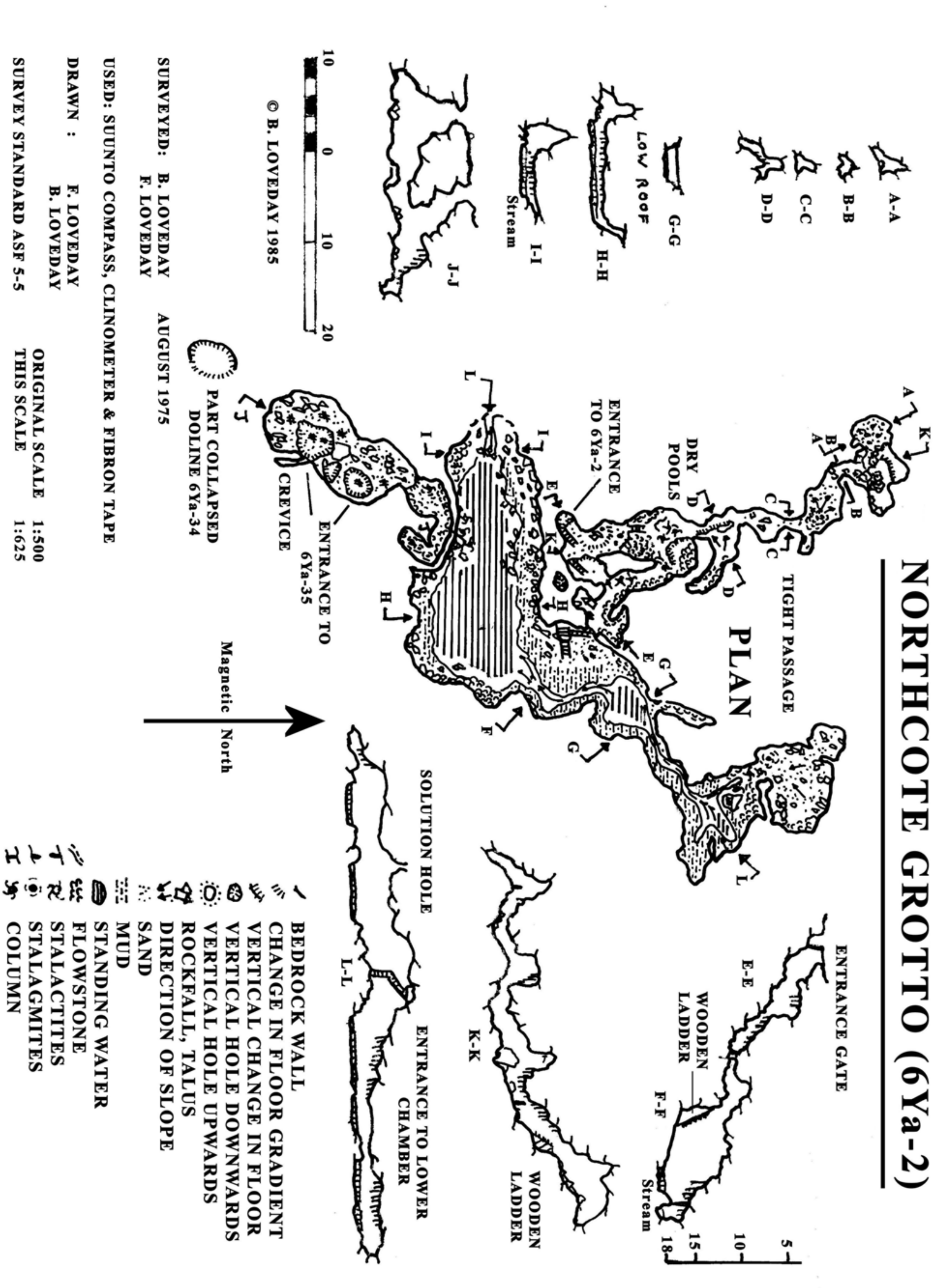

Figure 8: Map of Northcote Grotto (6Ya-2) and 6Ya-33 - Survey by and © B & F Loveday 1985

Lost Pearl Cave

Lost Pearl Cave (6Ya-51) was located by a bulldozer driver who almost drove into the doline of the cave. Bell (1983) does describe how cavers had located the cave entrance previously but had not entered the cave. The cave is located in the southern portion of the Yallingup karst region on DEC land. A permit is required from DEC to access the cave. On the ground the cave is reached via a walk though bush from nearby 4WD tracks.

A short, solution pipe, entrance pitch of 10m leads to a large rockfall chamber sloping down at about 30 degrees. The roof of the first part of the descending chamber, which is about 35m wide, is well decorated with stalactites. A flat sandy floor is reached at the bottom of the cave at a depth of 77m making this cave the deepest in the Yallingup area. The cave entrance is close to a 180m ASL contour suggesting the original stream is well below the existing known cave. The sand floor in the cave is unlikely to be an old stream level but purely sand and organic material washed into the cave by heavy rainfall events.

This cave is typical of the *breakdown caves* described in The Karst section of this guide.

The Cowaramup Area

The Cowaramup area ranges from Quinninup brook in the north to Ellensbrook in the south. Significant areas of coastal blocks have been cleared for farming around Moses Rock Rd in the north of this area as well as an area north of Cullen Rd. In addition to the caves described below, Quinniup Lake Cave (6Co-1) is also significant. It contains a small stream that resurges into a lake within the dunes near the beach. This cave is the only cave in the southwest that contains a small bat population.

Cowaramup Cave

The cave is located on private property adjacent to Cullen Road, which is north of Gracetown, and is infrequently visited by speleologists. Permission from the land owner, Cullen Wines, is required to visit the cave. In conjunction with the land owner the development of a conservation plan for the cave would be appropriate; given the biodynamic approach that Cullen Wines adopt in their wine making they are likely to appreciate such an approach from suitably qualified karst managers.

The cave is found in a valley within which a dune has built up and formed limestone over the flowing stream. Subsequent collapse of the limestone into the streamway has formed this interesting, multi-entrance stream cave, which contains a small waterfall, which is very rare for caves in the Leeuwin-Naturaliste region. Over the length of the cave, which is about 100m, the stream falls about 14m. The stream exits the limestone and flows across a beach into the Indian Ocean about one kilometre west of the cave.

Meekadorabee Cave

[2]Meekadorabee Cave (6Co-8) is located about 9km north west of Margaret River. From Caves Rd take Ellensbrook Rd to Ellensbrook House. Entry to the cave is currently not permitted by the management authority, DEC. The cave name is an aboriginal word whose meaning is "bathing place of the Moon" (DEC, 2008). Here is the aboriginal story relating to the name of the cave (DEC, 2001):

> "According to local Aboriginal people a girl called Mitanne spent her time exploring caves and other strange places. Sometimes a boy named Nobel would accompany her. One evening Mitanne returned back to camp and told her mother she had found Meekadarabee, the moon's bathing place.
>
> Her grandmother was angry, as to gaze upon Meekadarabee in the water brings death and sorrow.
>
> Mitanne had been promised to a tribal elder but eloped with Nobel. They lived happily at Meekadarabee, hunting at night to avoid being found.
>
> The elder sent warriors to find Nobel and kill him. One night he stayed hunting much longer than usual and Mitanne found him speared through his body. He died in her arms. She was taken back to the elder and forced to do all the hard work around camp until she collapsed and died. After Mitanne died, the spirit of Nobel was waiting for her in the peppermint trees. They made their way to Meekadarabee and it is said their spirits still reside there."

Meekadorabee Cave is only a short walk from the nearby Ellensbrook house, which was built in 1857 by Alfred and Ellen Bussell: it was home to their family of 12 children. The cave is a short stream cave on the Ellensbrook Stream. The entrance is well endowed with tufa and calcified rushes (see Plate 15). A waterfall also flows over the entrance, seeping through the roof and forming an excellent display of cave pearls on the flowstone below. A trip through the cave is very wet, but short as the cave is approximately 100 m long. The walkways have somewhat reduced the aesthetics of the area, particularly as the stairs go very close to the stream and eastern entrance of the cave. However, to the uninitiated the area still has a lot of charm

[2] Please note several spellings of this name occur but the official cave name is spelt Meekadorabee.

with its groves of peppermint trees (***Agonis flexuosa***) and the 'feral' Arum Lilies (***Zantedeschia aethiopica***) that have heavily infested the area.. It is worth looking at the early historic property built by the Bussell's, which is now part of the Leeuwin-Naturaliste National Park. Note that the Ellensbrook House is managed by the National Trust and is only open at weekends, please call the National Trust Headquarters' in Perth to confirm that the house is open ((08) 9755 5173) if you wish to visit.

In order to protect the major waterfall entrance to the cave, the then Department of Conservation and Land Management (CALM), now DEC, requested that cavers did not enter or leave the cave via the waterfall entrance but rather via the less sensitive outflow entrance. If access were to be permitted to the cave this restriction should still apply to reduce caver impact on the fragile main entrance area.

Plate 15 Tufa and waterfall at entrance to Meekadorabee Cave (6Co-8). Photograph by Rauleigh Webb

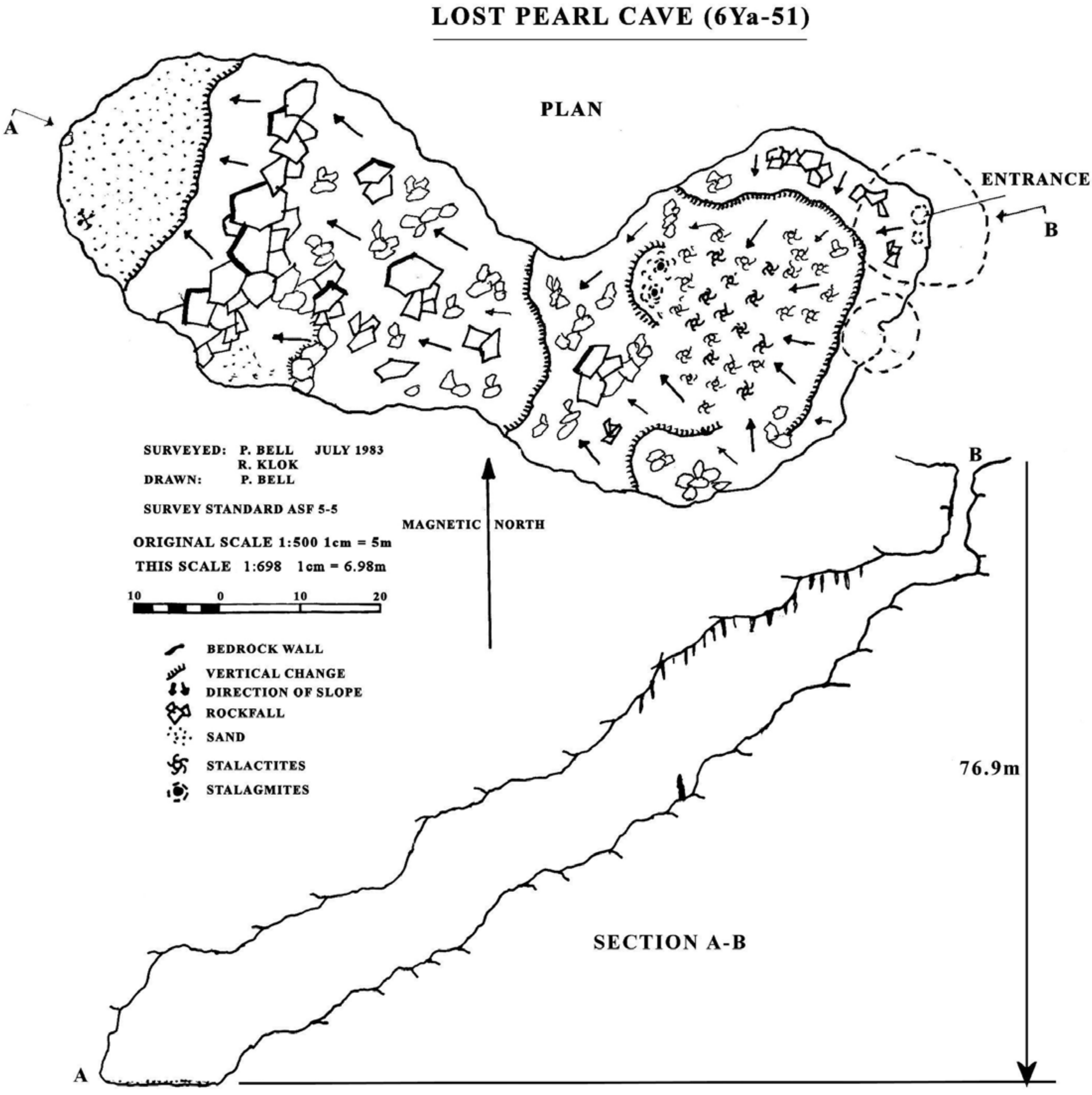

Figure 9: Map of Lost Pearl Cave (6Ya-51) - © P Bell 1983 – This version of the map was redrawn by B. Loveday 1985.

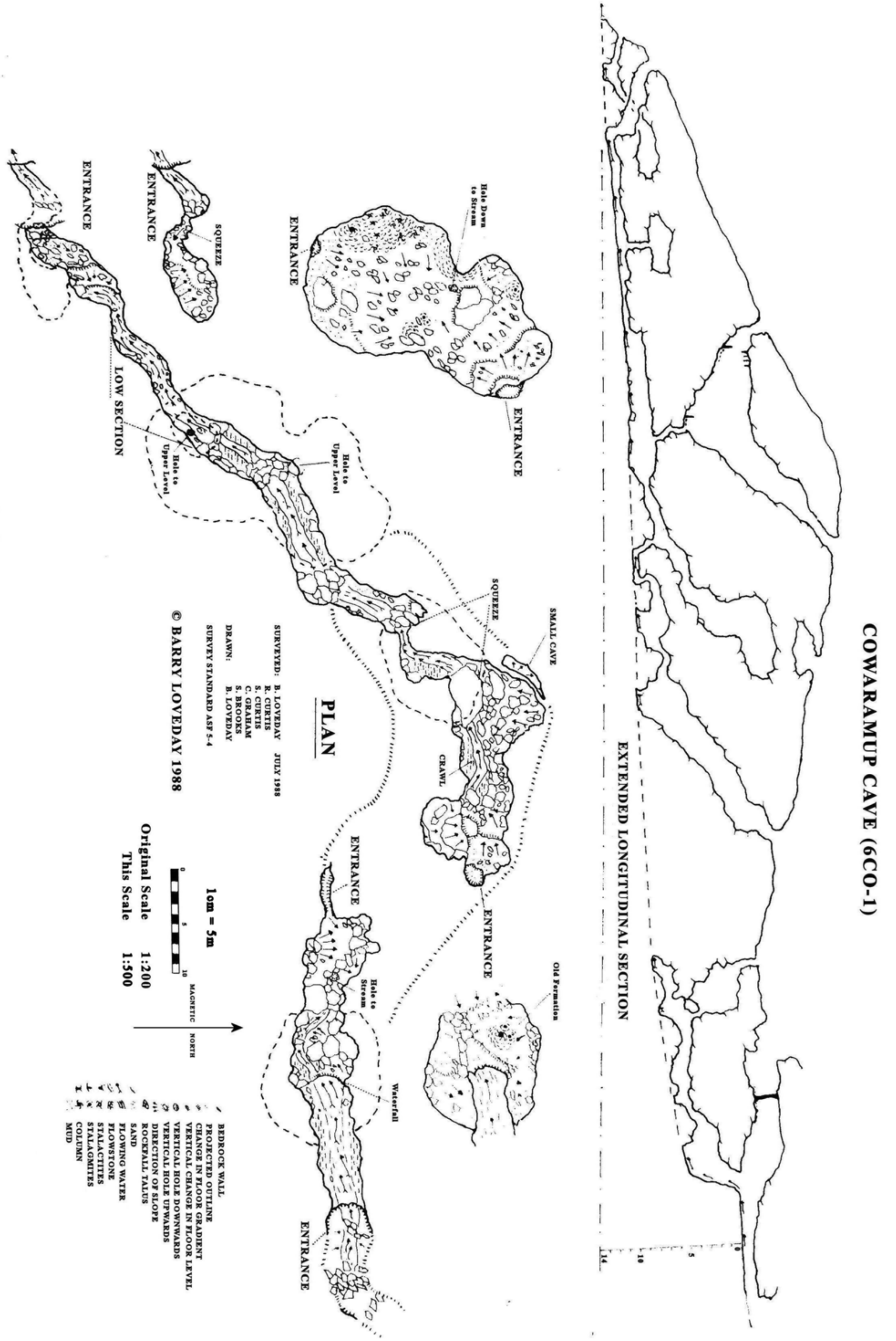

Figure 10: Map of Cowaramup Cave (6Co-7) - Survey by and © B. Loveday 1988

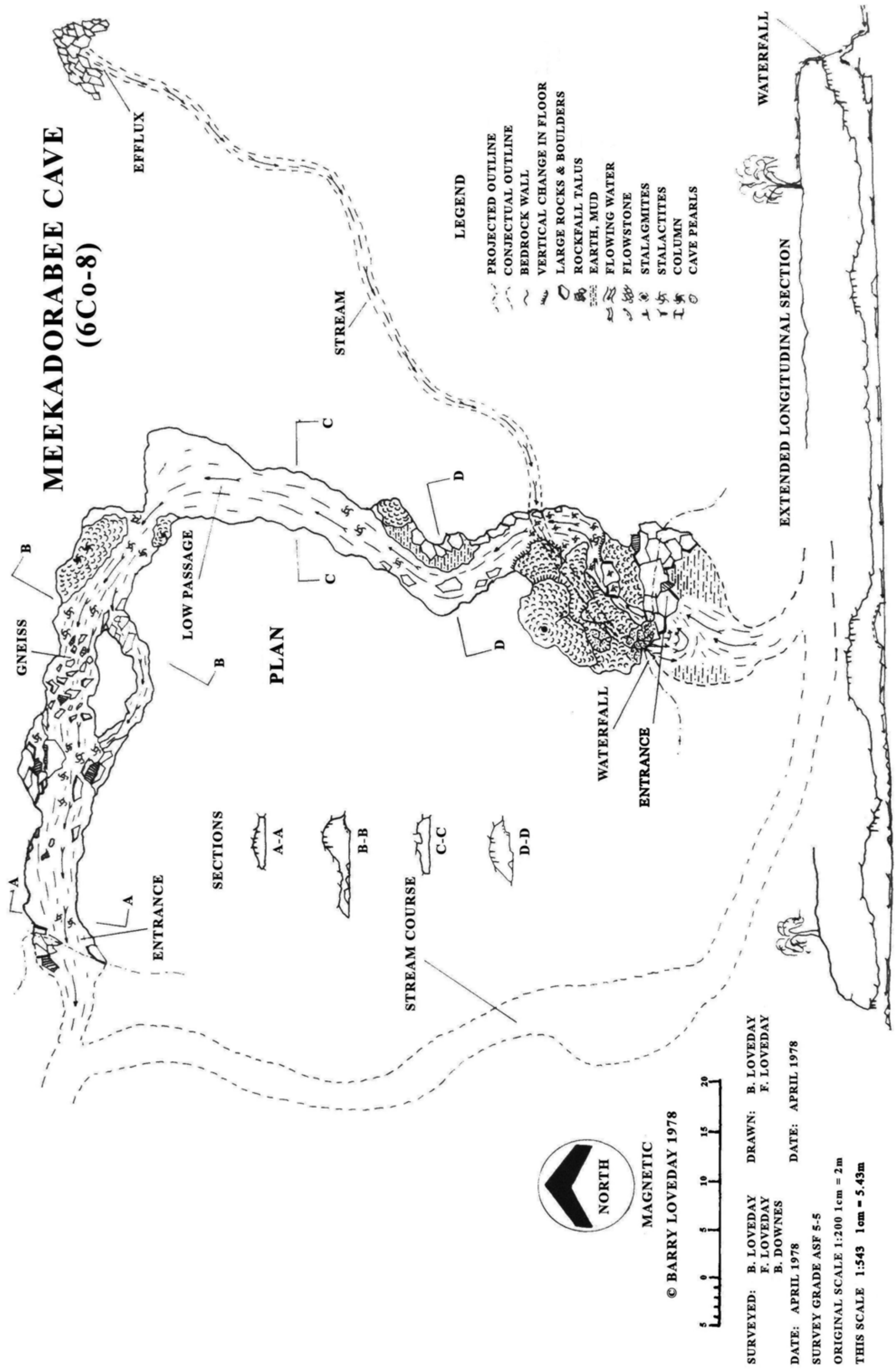

Figure 11: Map of Meekadorabee Cave (6Co-8). Survey by and © B. Loveday 1978

The Margaret River Area

The Margaret River karst area is contained between Calgardup Brook in the south and Ellensbrook in the north and is bisected by the Margaret River. The majority of the coastal strip between Ellensbrook and Calgardup Brook remains forested with areas developed for Prevelly Park near the mouth of the Margaret River.

Blackboy Hollow Cave (6Mr-2) is the largest of the caves in the area and is an ex tourist cave discovered by John Bussell about 1895. It is not covered in the site descriptions but is a Restricted Access cave permitted by DEC who can be contacted if more information is required.

Foxhole Cave

Foxhole Cave (6Mr-9) was discovered by Marmaduke Terry in 1900. Fortunately, probably due to its location, it has suffered little due to the small number of visitors. The cave is located near Kilkarnup Road about 12km from Margaret River. Access to the cave is via permit from DEC. The cave does contain some speleothem development. The underground stream that formed this cave is never reached as the cave entrances in the Foxhole Cave area are about 60m ASL, with the terrain dropping 60m vertically over less than 500m before reaching the coast. Dallip spring on the beach is probably where the underground stream that formed the caves in this region resurges.

The cave is known to contain cave fauna including the spider *Baiami tegenariodes* , a troglophile, shown in Plate 16 and is know to be a very active biological site (J. Anderson Pers. Comm.).

Plate 16: Photograph of *Baiami tegenariodes* taken in Foxhole Cave (6Mr-9) by Bert De Waele

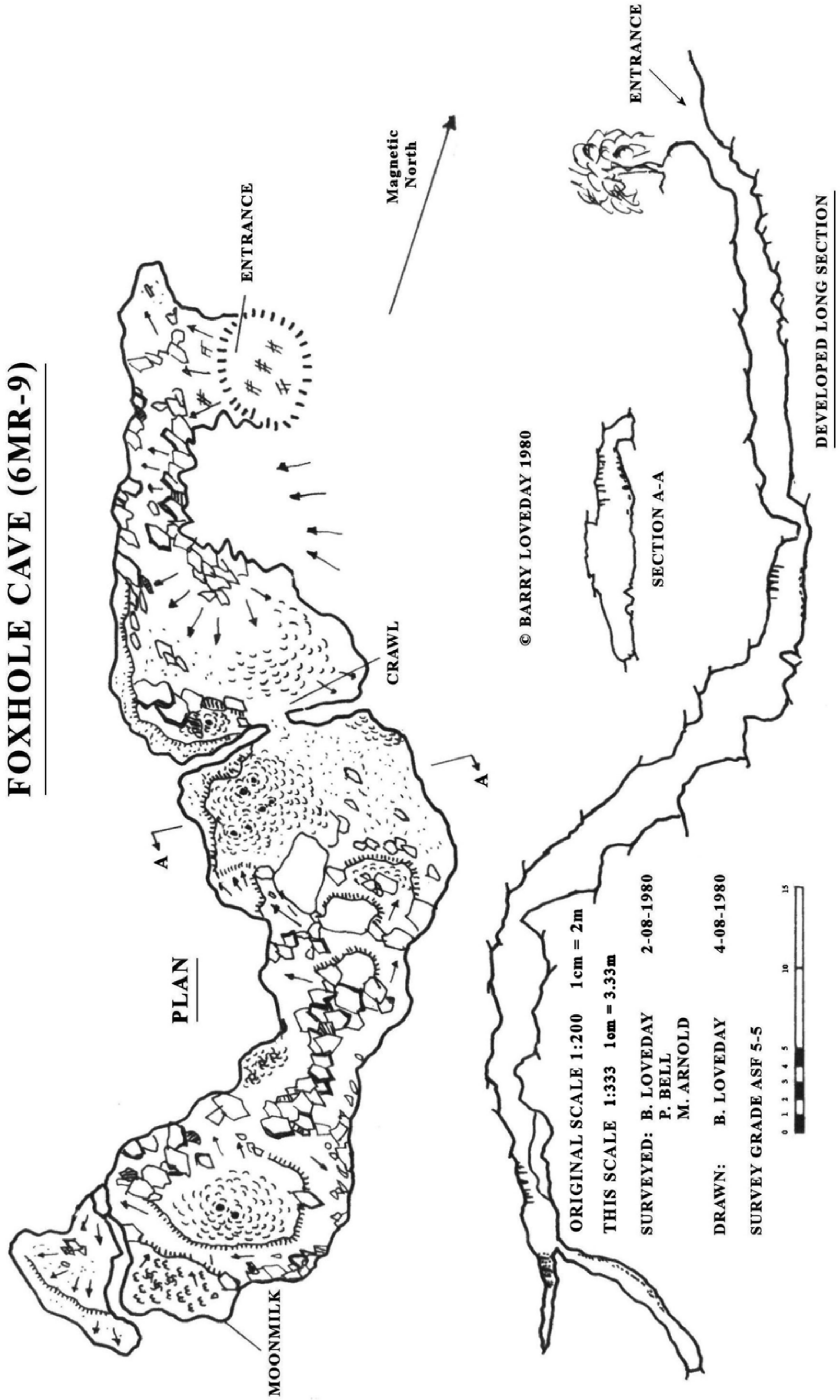

Figure 12: Map of Foxhole Cave (6Mr-9). Survey by and © B. Loveday 1980

Wallcliffe Cave

Wallcliffe Cave (6Mr-4) is near the mouth of the Margaret River. It is an ex-tourist cave found by Grace Bussell in 1870. This cave is situated at the back of Wallcliffe House. The famous Wallcliffe House, nestled on the banks of the Margaret River, was built by Arthur Bussell. The house can be seen from the entrance to Wallcliffe Cave (see Plate 17). This was home to Grace Bussell who with stockman Sam Isaacs rescued crew and passengers from the Georgette, a 211 ton steam and sail vessel, on 1 December 1876.

The cave has two entrances about 7m apart (See map in Figure 13). The main entrance has rough cut steps in limestone which leads down a tunnel into the main chamber. The cave has been heavily vandalised and many old names can be seen written into and on the formation in the cave. The cave is a pair of breakdown domes. The entrance chamber has a central rubble cone covered with flowstone and other speleothems and a marginal flat floor of sand and soil (Loveday, 1975).

This cave was used as a formal tourist cave in the early 1900's, but throughout the 1990's and into the present decade the commercial operator, Bush Tucker Tours, conducted "adventure" tours of Wallcliffe Cave. A Wallcliffe Cave management plan was prepared by Stefan Eberhard (2002a) for the Shire of Augusta Margaret River who are the land managers. The lack of appropriate track marking in this small cave and inappropriate guiding of visitors has resulted in even more damage to the cave. A rock marked track does occur in the main chamber and the path is very clear in the smaller area due to visitor impact. Fortunately Bush Tucker Tours have currently stopped using the cave for "adventure" tours.

Plate 17 View of Wallcliffe House from near the entrance to Wallcliffe Cave. Photograph by Jeff Murray.

Figure 13: Map of Wallcliffe Cave (6Mr-1). Survey by and © B. Loveday 1975

Witchcliffe Cave

Witchcliffe Cave (6Mr-1) was discovered by Grace Bussell about 1884. It was also known as “Pearl of the Diadem” or by its aboriginal name of Doodjijup. It was one of the many tourist caves used in the early 1900’s.

The cave was described in glowing terms by May Vivienne in “Travels in Western Australia” published in May 1901 (Vivienne, 1901). Here is an excerpt describing Witchcliffe Cave.

> “While all the caves we saw are worth many times the journey, the most beautiful is, in my opinion, that known as Doodjijup, a mile south of Blackboy Hollow, and 100 feet above the slanderously entitled "Devil's Pool." A lady could go through this cave without soiling her dress. You enter this lovely "bower" from the side of a high limestone ridge and the commanding situation allows a pretty prospect of water and lea, with the shimmering streak of the Doodjijup brook in the foreground. The access to the cave is rather steep and somewhat rugged, but when once the inlet is gained the labour is rewarded, and the visitor can move at ease and admire the terraces, the columns like the pipes of a cathedral organ, and the pendants that glow like the stars of night in the three chambers of this wondrous arcade.”

The speleothems throughout the cave contains a considerable quantity of “old” graffiti.

This abandoned outflow cave, perched scenically above Devil's Pool on Boodjidup Brook, has a pair of broad, flat-floored chambers that are separated by a row of columns (see Plate 18 for a view of some of the columns in the cave, and the cave map in Figure 14). Williamson (1980) cited various types of solutional sculpturing as evidence that the chamber was a high-level phreatic predecessor or flood bypass of the present stream (2m below the floor). An active spring is known to flow from beneath rockfall down slope of the cave entrance into Devil’s Pool.

This site is almost certainly an aboriginal site as the cave would provide good protection from the weather and has an excellent water source in Devil’s Pool and the springs that feed it. Access to the cave is via permit from DEC.

Plate 18: Main chamber Witchcliffe Cave (6Mr-1) showing columns which are the main feature of the cave.
Photograph by Ross Anderson

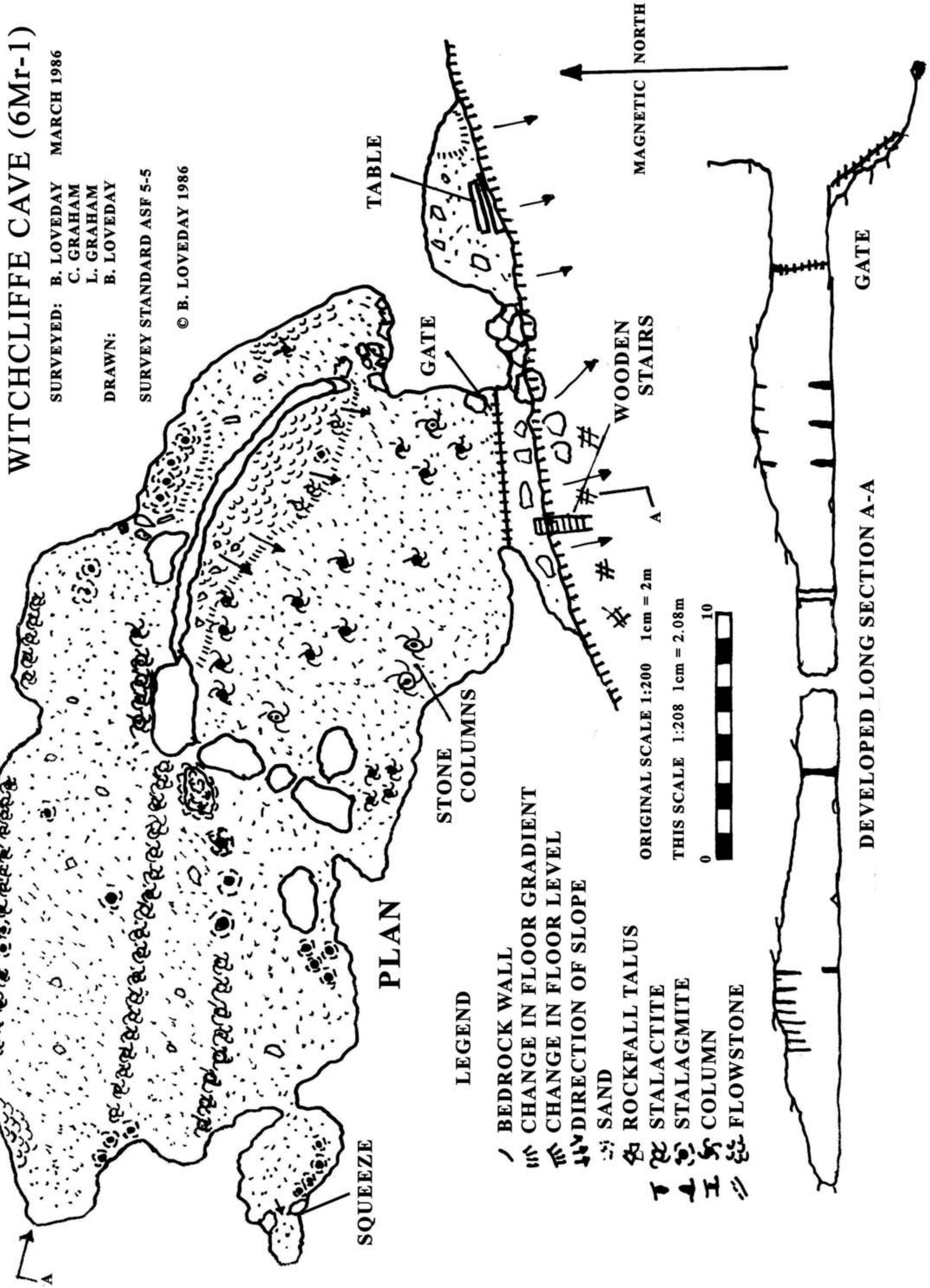

Figure 14: Map of Witchcliffe Cave (6Mr-1). Survey by and © B Loveday 1986

The Witchcliffe Area

This section of karst is wider than the other karst areas, and has numerous caves and surface karst features, including most of the important stream cave systems in the region (Williamson, 1980; McBeath, 2005).

The karst drainage comprises linear stream caves fed by aggressive winter-flowing external streams that enter the eastern margin of the limestone and sink underground to flow west at the contact between the dune limestone and the impermeable basement. There is also local input from rainwater seeping down through the dune sands. The waters rise in coastal springs or disappear offshore. Roof collapse has blocked and diverted the underground streams in many places.

Figure 6 shows the relationships between major caves in the northern Witchcliffe area, including traced or inferred underground drainage lines (Eberhard, 2001, McBeath, 2005). There are two separate underground drainage systems here: The northern Bobs Hollow system and the Conto's Spring system. Other systems further south (e.g. Strongs Cave) are less extensively known (see Williamson, 1980) and their outflow points are unknown.

The Bobs Hollow drainage system comprises allogenic inflows at Rudducks Cave, Calgardup Inflow and other points on the north-eastern edge of the dune; the through-flowing Connelly Cave; and the Bobs Hollow Resurgence (Figure 5, McBeath, 2005; Williamson, 1980).

The Conto's drainage system has its main allogenic stream inflows at Mammoth Cave, Wi-83 and Forest Grove sink. Through flow streams are observed in Mammoth, Terry and Conference caves in the north and Lake Cave in the south. These have been traced to the Conto's Spring on the coast (Figure 6). Other caves in the rather complex Mammoth area may be abandoned contributory and/or distributary sections resulting from diversion of drainage by successive collapse of the passages (McBeath, 2005).

It should be noted that two of the most heavily visited tourist caves in this region Calgardup Cave and Lake Cave are not covered by this guide, but both have interesting and long histories as tourist caves.

Mammoth Cave

Mammoth Cave (6Wi-48) was officially recorded in 1900 when surveyor Marmaduke Terry found the cave and explored it with Tim Connelly and Ned Dawson (Mitchell & Wood, 2009). Tim was appointed caretaker and guide of the cave and he conducted lamplight tours of the cave until 1904 when electric lighting was installed and it was officially opened as a tourist cave. The early stereograph, probably taken between 1912 and 1916, in Plate 19 shows the original Rotunda outside the Mammoth Cave as well as the "caving" attire for visitors of the period.

The cave is located about 20km south of Margaret River on Caves Road. It is managed by the AMRTA and is now a self-guided tourist cave. Visitors are provided with MP3 audio headsets and these "guide" you through the cave.

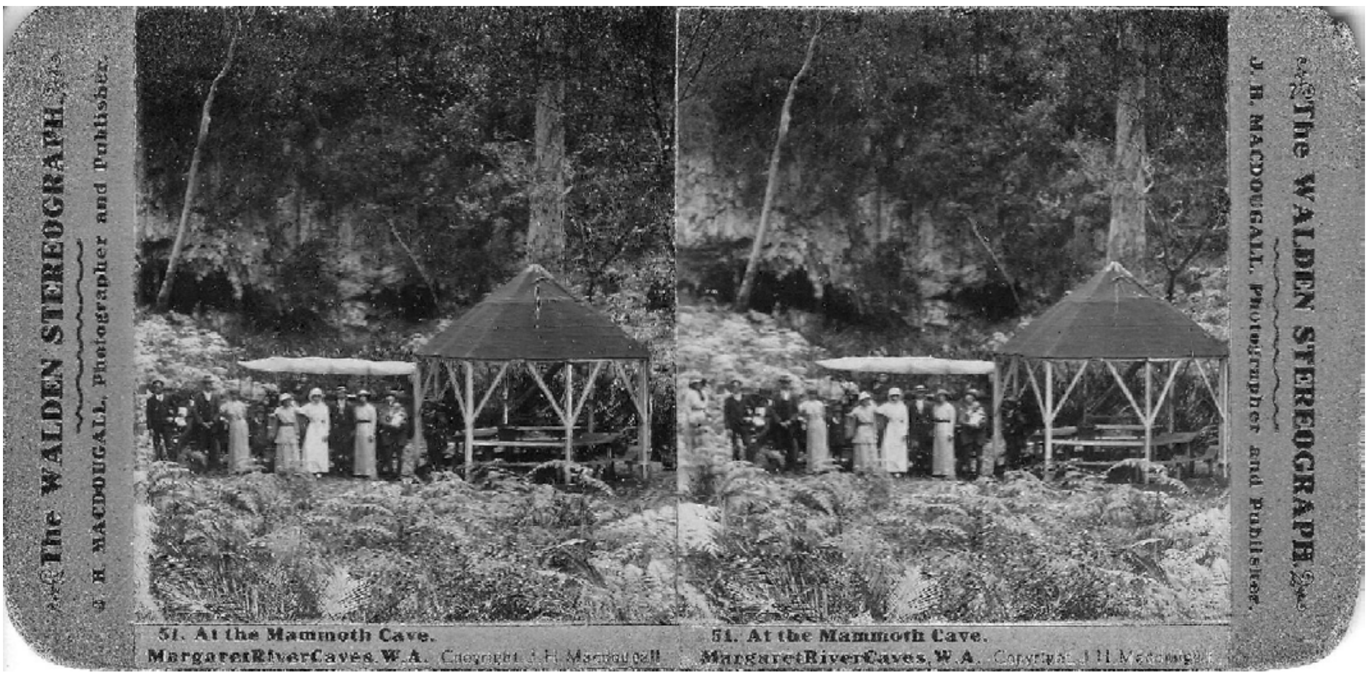

Plate 19: Early 1910's Stereograph of the first Rotunda at Mammoth Cave. Photograph by JHA Macdougall. Reproduced with permission from Anne Pollitt, MacDougall's granddaughter.

A surface stream, which drains the Nindup plain to the east, flows freely into a large cave entrance. Flood pulses are not uncommon, as noted by Yates, 1973 who described several flood pulses in 1972-73 including what he call a real "Lu-Lu" on the 7th September, 1973. After 24 hours of rain 1 inch (25mm)was received in 2½ hours. When he attended the cave three hours after the rainfall peak, a seat in the car park was in water and inside the whole floor was awash and several cave lights were under water.

The photographs in Plate 20 shows the main tourist entrance to the cave and internal walkways inundated by flood waters in the 1999 flood.

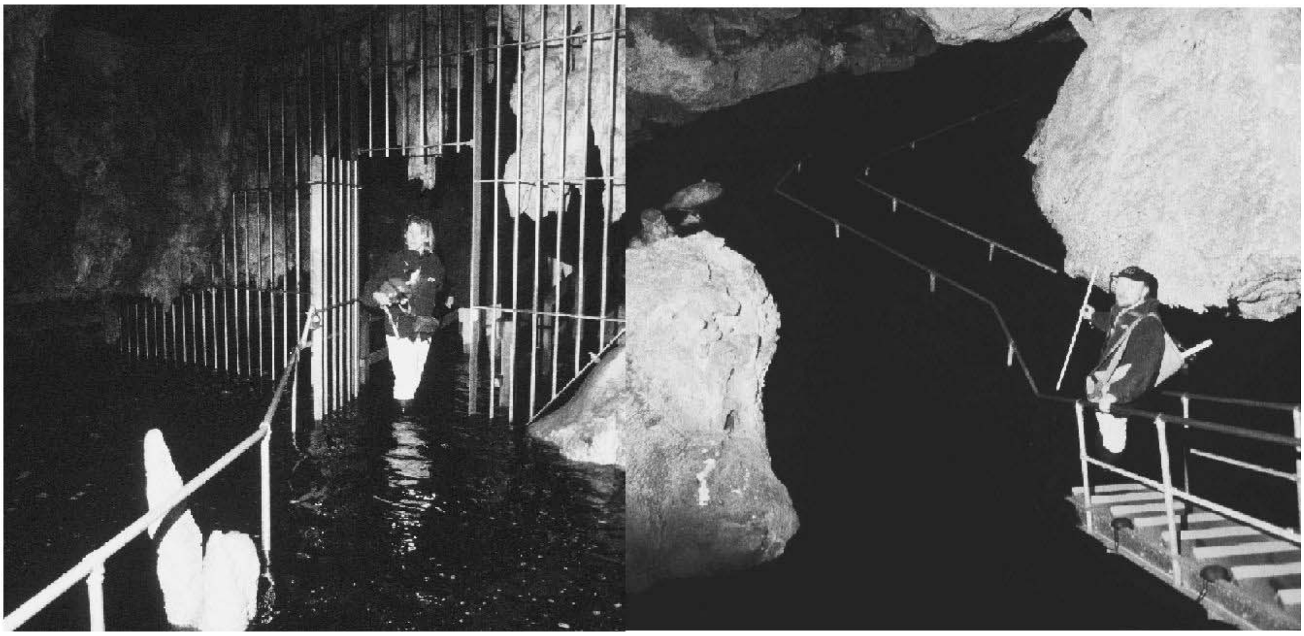

Plate 20: Mammoth Cave Entrance and walkways in flood 1999. Photographs by Stefan Eberhard.

McBeath (2005) suggests that the large chamber in Mammoth cave may be the result of water mixing at the junction of two underground streams. The junction of the underground streams can clearly be seen on the map of the cave which is shown in Figure 15. The northern arm of the cave is blocked by rockfall and no active stream is located in this passage. It does however trend towards the northern Mammoth chain of "inclined fissure caves" mentioned in the Winjan Cave description below and was probably the stream that formed this chain of caves.

Mammoth Cave is also well know for its fossil deposits which were excavated by the WA Museum between 1909 and 1915. A fossil collection of about 10,000 specimens was collected from about 30 cubic metres of soil. Some of the important finds were the giant echidna (*Zaglossus hacketti*), extinct wombat (*Vombatus hacketti*), wallaby (*Wallabia kitcheneri*), the giant wombat (*Zygomaturus trilobus*), extinct browsing kangaroos (*Simosthenurus occidentalis* and *Sthenurus brownei*), the marsupial lion (*Thylaceleo carnifex*) and the extinct Tasmanian Tiger (*Thylacinus cynocephalus*) Dating of flowstone adjacent to a jawbone of *Zygomaturus trilobus* indicated dates between 44,000 and 55,000 years old. (Mitchell and Wood, 2009)

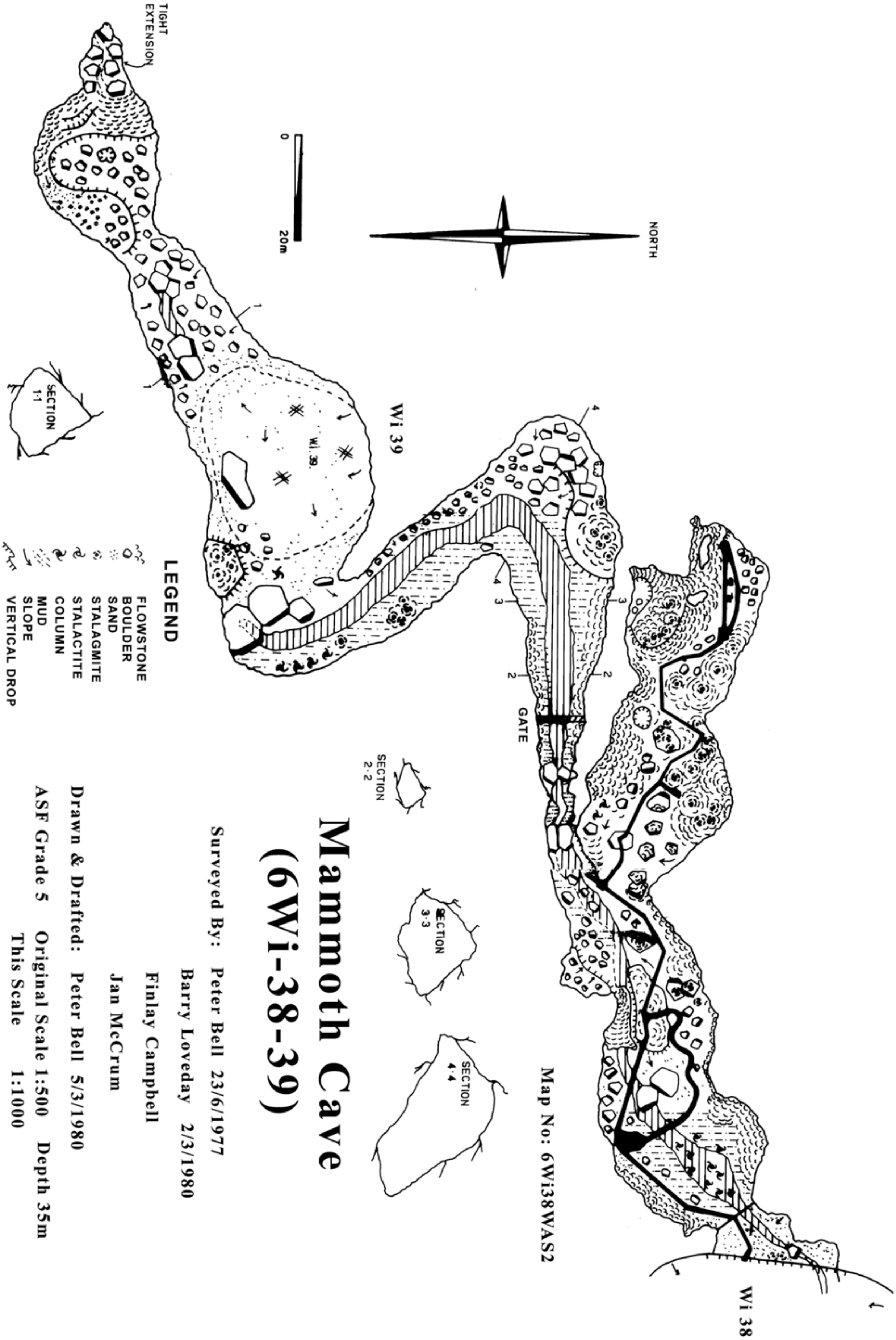

Figure 15: Map of Mammoth Cave. Survey by Pete Bell

Kudjal Yolgah

The cave 6Wi-9 was known to speleologists from the 1960's but it was Gary Pick who first found water in the cave. Williamson (1974) returned to the cave with Gary Pick and they explored the major portion of the cave. It was not until later that year that they were able to confirm that the cave they were exploring was 6Wi-9. The second stream in the cave was first noted by Hart, 1975a. It was Williamson (1976a) who finally named 6Wi-9 "Kudjal Yolgah" in an article suggesting that aboriginal names should be used for some caves and Kudjal Yolgah was the first. The name means "two streams".

The early explorations of Kudjal Yolgah revealed significant levels of CO_2 in the cave and those high levels, up to 6%, continue to be recorded in the cave. One of the reasons for these high CO_2 levels is the significant quantity of tree roots in the cave. A good example of these fibrous tree roots can be seen in Plate 21.

This is one of the four threatened ecological community sites and the stream stopped flowing in 2007. The stream did recover somewhat in 2008. J. Anderson (Pers. Comm.)

Plate 21: Fibrous tree roots in the roof of Kudjal Yolgah. Photograph by Ross Anderson

The cave is located on one of the most photographed bends in Caves Road just south of Lake Cave. The karst valley that contains its entrance supports a large stand of regrowth karri that was logged near the turn of the century – see Plate 22. The cave was gated by the manager, DEC, in the 1990's. Access to the cave is via permit from DEC and authorisation by the CAC.

Plate 22: Regrowth Karri forest in a massive collapse doline that contains multiple cave entrances including Kudjal Yolgah. Photograph by Rauleigh Webb.

The cave has been surveyed three times. Originally by R. Hart, then R. Capon and finally by B. Loveday. The map by R. Capon is the only coloured map in the WASG map library with CO_2 areas coloured to indicate elevated levels. It is reproduced in Figure 16 with the coloured CO_2 areas in the extended long sections grey scaled.

The southern end of the cave (see Figure 16) is extensive flowstone over the boulders that have collapsed into the stream below. This area of cave was damaged by visitors, but restoration work and plastic paths (Wood, 1992) have reduced the impacts of cavers on this area of cave. Plastic paths in caves can provide good protection to delicate floors (see discussion on Crystal cave in the section on Management/Conservation Issues) but they can become slippery and they do degrade with wear and need ongoing replacement.

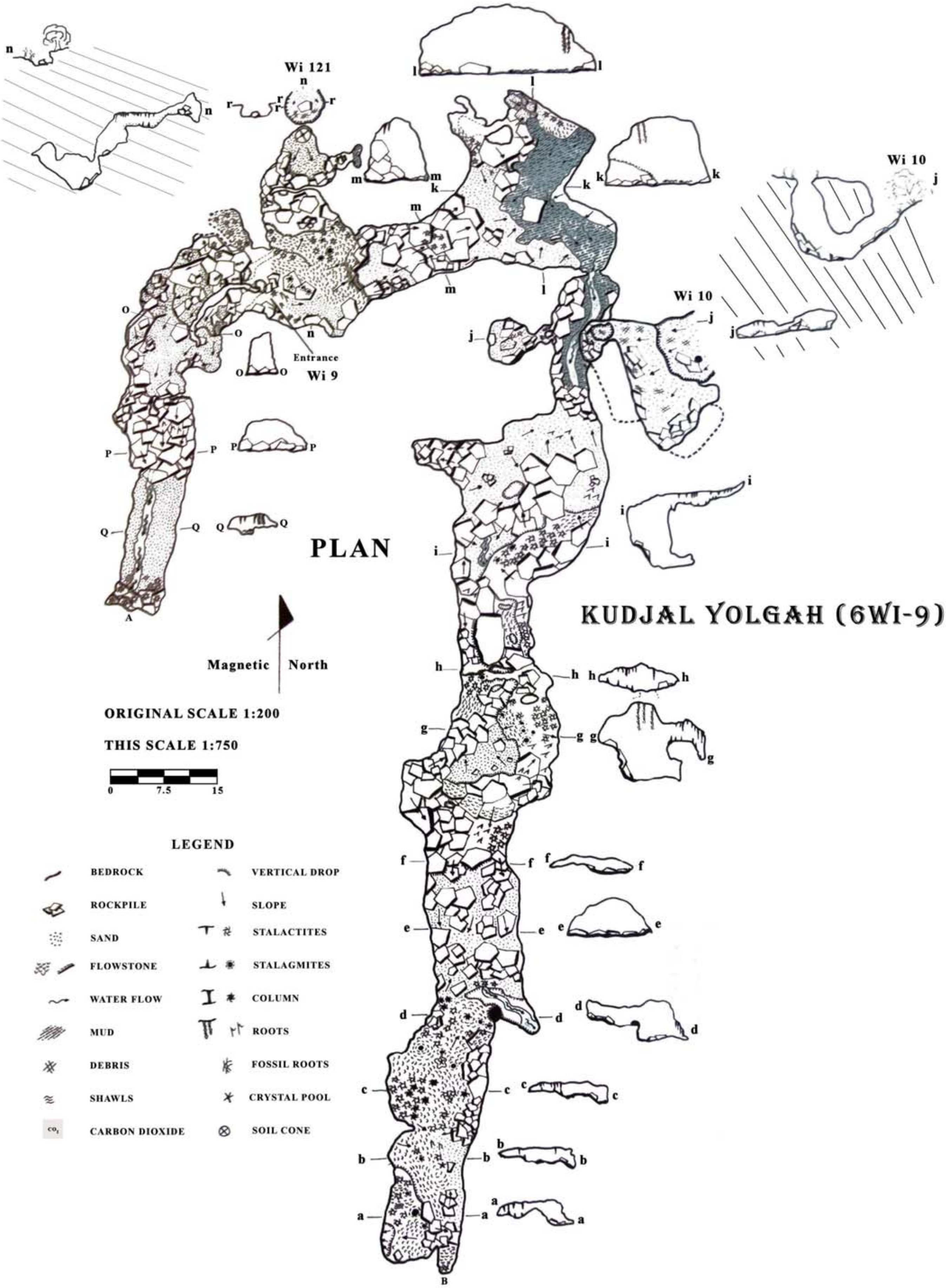

Figure 16: Map of Kudjal Yolgah showing areas of CO_2 distribution in cave in grey. Survey by Rob Capon.

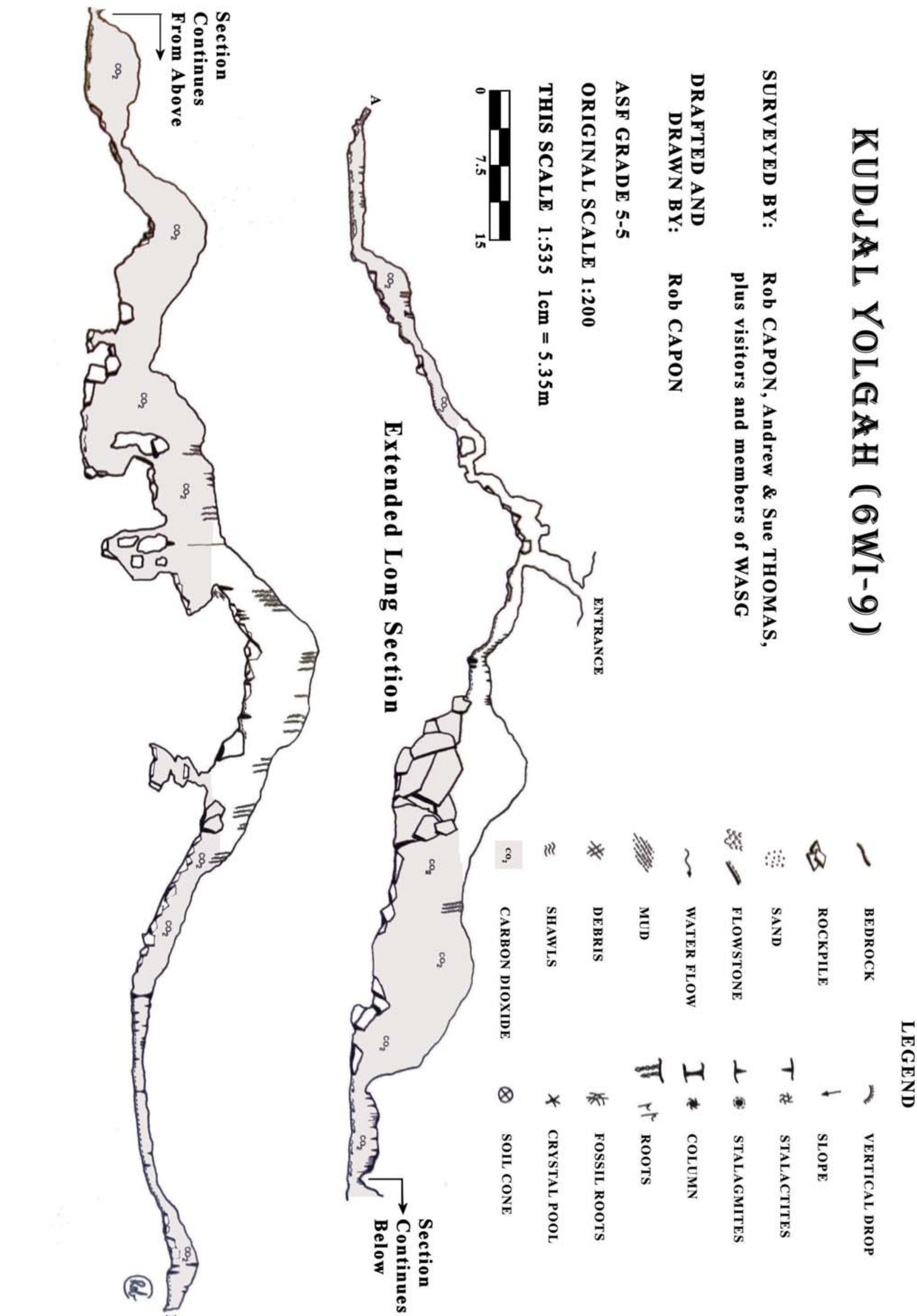

Figure 16: Map of Kudjal Yolgah showing areas of CO_2 distribution in cave in grey. Survey by Rob Capon.

Winjan Cave

Winjan Cave (6Wi-113) was discovered by Mark Dwyer and Geoff Oxley, who found the entrance while returning from another cave at night. Other caves, Kudjal Dar (6Wi-114) and Labour Cave (6Wi-112), were found the next day by a party of cavers mainly from the WROK club (Hart, 1975). The cave is located to the north of Mammoth cave in what is locally called the northern Mammoth chain of caves. These caves are all *inclined fissure caves* forming above an underground streamway that is never reached.

Access to the cave is via permit from DEC with approval from the Caves Access Committee (CAC) as it is a locked cave.

The cave is heavily decorated with speleothems over the rockfall collapses that originally formed the cave. The photograph in Plate 3 shows this heavy speleothem development as well as the inclined nature of the cave. Reflective track markers have been placed in the cave to reduce and confine caver impacts and some of these are circled in Plate 3

Some areas of the cave contain friable rock falls and significant extensions to the cave were made via these rock fall areas, such as the Evening Star Extension.

Bobs Hollow Resurgence – Connelly cave

Both the Bobs Hollow Resurgence (6Wi-82) and Connelly Cave (6Wi-48) are found on the coast south-west of Calgardup Cave which is located on Caves Road about 13km by road from Margaret River.

The Bobs Hollow Resurgence was known to speleologists for many years before 1971 when Gary Pick and friends dug in sand at the base of the limestone cliff where water was emerging at two places. They were able to enter a low tight stream passage which had enough air space to allow passage. This initial exploration yielded over 200 feet of cave (Caffyn, 1972).

The Bobs Hollow resurgence, at the base of an abandoned sea cliff, (see Plate 23) is fed from a long, low, narrow stream passage with well developed solutional sculpturing. The passage terminates upstream in stream passage where the stream flows out from under a rock shelf at water level. Only about 7m away is the end of Connelly Cave where the water flows in under a similar rock shelf at water level. The strong sculpturing of the passage walls might indicate increased aggression from the mixing of stream water with the top of an underlying wedge of sea water – perhaps at a time of slightly higher sea level. However, Williamson (1980) suggested that there was evidence for an addition of stream water between Bobs Hollow and Connelly which might also account for mix-water aggression. This was proven to be correct once the major portion of the downstream section of Connelly Cave was discovered; a second stream was found to flow into Connelly Cave from the north. This is the small northern passage entering the main Connelly streamway in the cave survey shown in Figure 15.

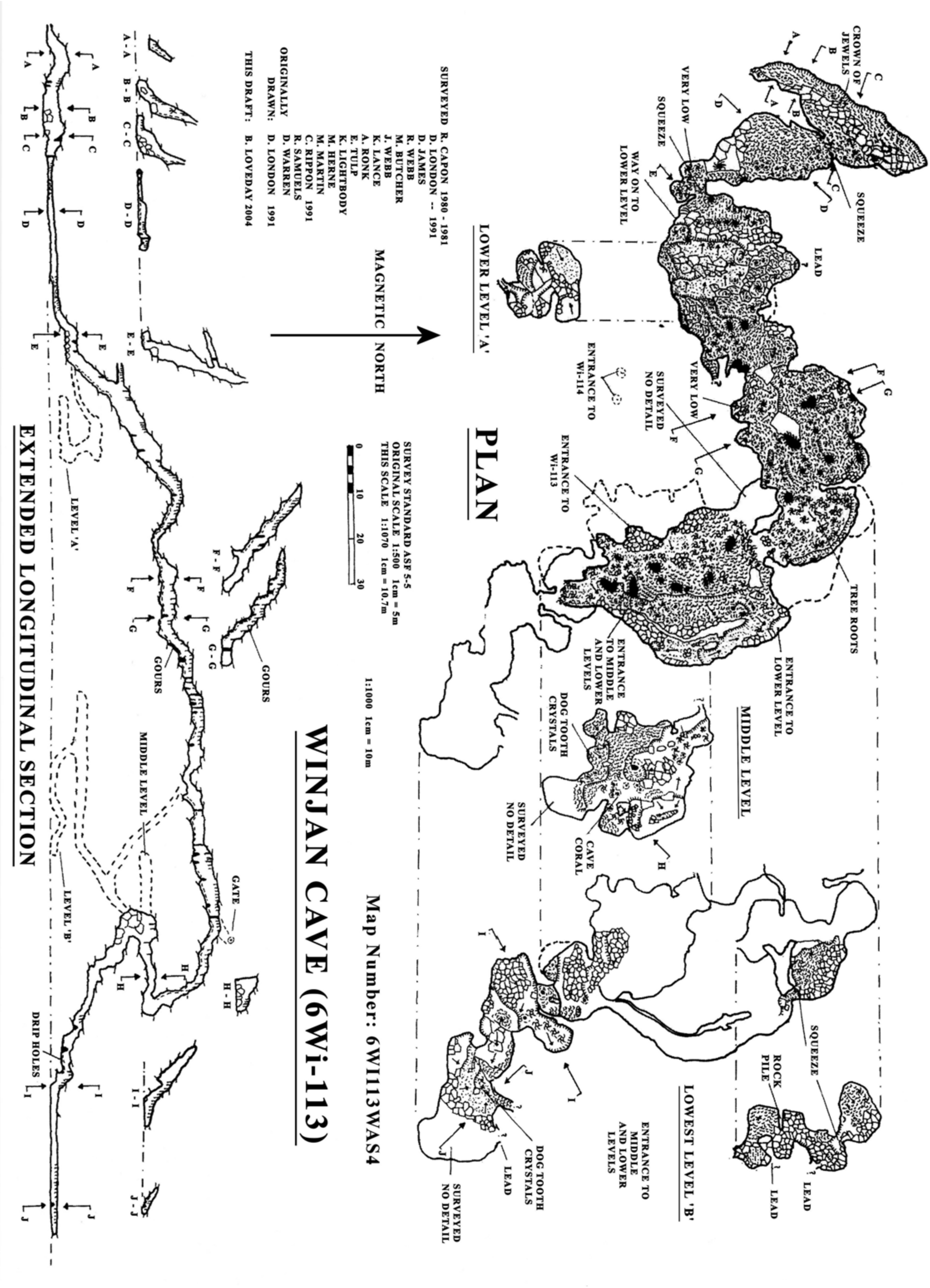

Figure 17: Map of Winjan Cave (6Wi-113). Surveyed by D. London el al. Drawn and © B. Loveday 2004

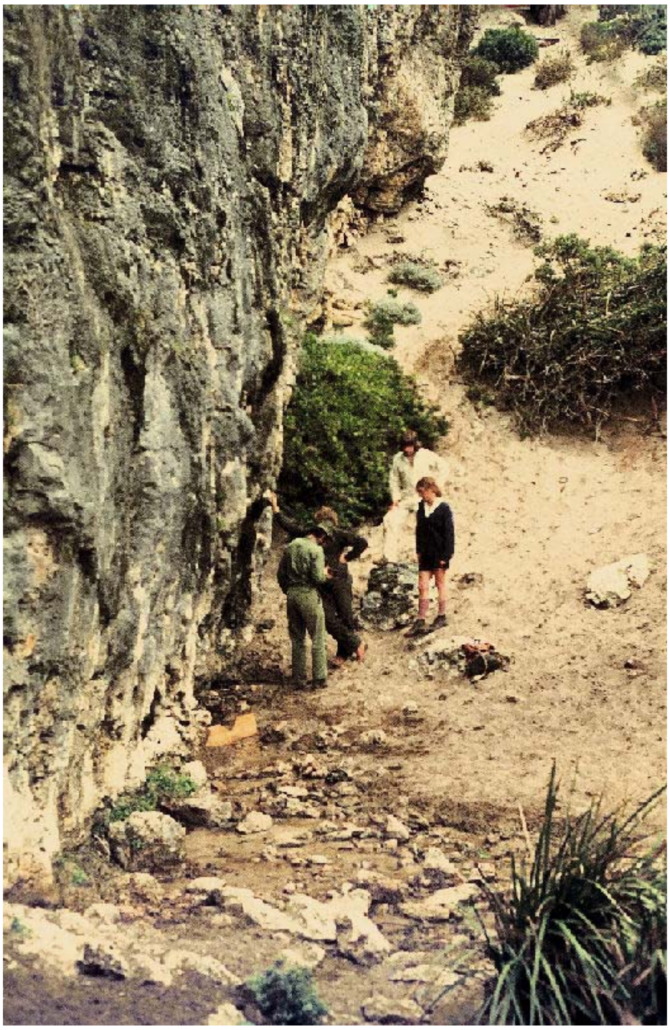

Plate 23: Bobs Hollow Resurgence (6Wi-82). 1972 Photograph by Paul Caffyn

Connelly Cave was probably discovered by Marmaduke Terry who included the cave location on his 1901 Sussex Plans. Bastian (1973) describes his original exploration of the cave, in 1959, and the recommendation that the cave should be named Connelly Cave after Tim Connelly, the late guide at Margaret River, who with Rudduck's father was the first to enter the cave about 1902.

The first high grade survey of the cave was completed by B. and F. Loveday in 1977. At that time the cave was 1km of surveyed passage. In 1984 R. Webb lead a party of cavers looking for the way on in the downstream section of the cave and Peter Downes successfully found the way over the then terminal rockfall. Loveday, 1984 describes how a further 1km of downstream passage was surveyed with the cave becoming the longest stream cave on the Leeuwin-Naturaliste ridge at 2km of surveyed passage.

The cave contains a number of rockfall collapses onto the active streamway as well as significant speleothem development over these collapses as shown in Plate 24.

Plate 24: Heavy speleothem development Anita Eckberg Chamber, Connelly Cave 1972. Photograph by Paul Caffyn.

Strongs Cave

Strongs Cave (6Wi-63) is located in the Boranup forest about 15km south of Witchcliffe. The cave was marked on Marmaduke Terry's traverses of 1909-10 but may have been known to timbercutters earlier than this (Williamson et al, 1976). It was named after Aubury Strong who showed members of the WA Speleological Group the location of the cave. Access to the cave is via permit from DEC and approval by the CAC.

This is the best documented example of a linear stream cave in dune limestone which was guided by the topography of the underlying impermeable basement (Williamson et al., 1976; Williamson, 1980). Mill, Strongs and Dingo caves are all related to the same underground stream. Nearby Nannup Cave and Devils Lair may be collapsed parts of a tributary drainage system (see Figure 3).

Strongs Cave is a linear system, partly modified by collapse, that contains a stream partly incised into the gneiss basement. This cave is one of the few caves where the gneiss contact with the limestone is readily observed. Other features of interest are a long straw stalactite which was the "world's longest straw" (6.25m) for a number of years, and rotated speleothems (including upside-down straws) that indicate slow undermining of rubble blocks by the stream.(See photographs in Plate 25 and Plate 8).

Aggressive waters enter the dunefield from the east, forming marginal swamps and sinking in a blind valley immediately to the east of Mill Cave. Some of this water reappears as a stream within the caves and is responsible for their formation. The cave passages become progressively smaller to the west – a result of increasing saturation of the stream water, which reduces its ability to dissolve the limestone.

The cave has delicate root mat communities in the stream pools (see Plate 5), and large tree roots form columns stretching from the ceiling to the floor.

The root mat community in the cave is one of the four listed as threatened in the Leeuwin-Naturaliste ridge but the stream passage in the cave has now been dry for more than 5 years. Measurements in nearby Crystal Cave show that the water is now absent up to 1m below its streambed (J. Anderson. Pers. Comm.). This level of water loss, if translated to Strongs Cave, will almost certainly result in the loss of the threatened root mat community.

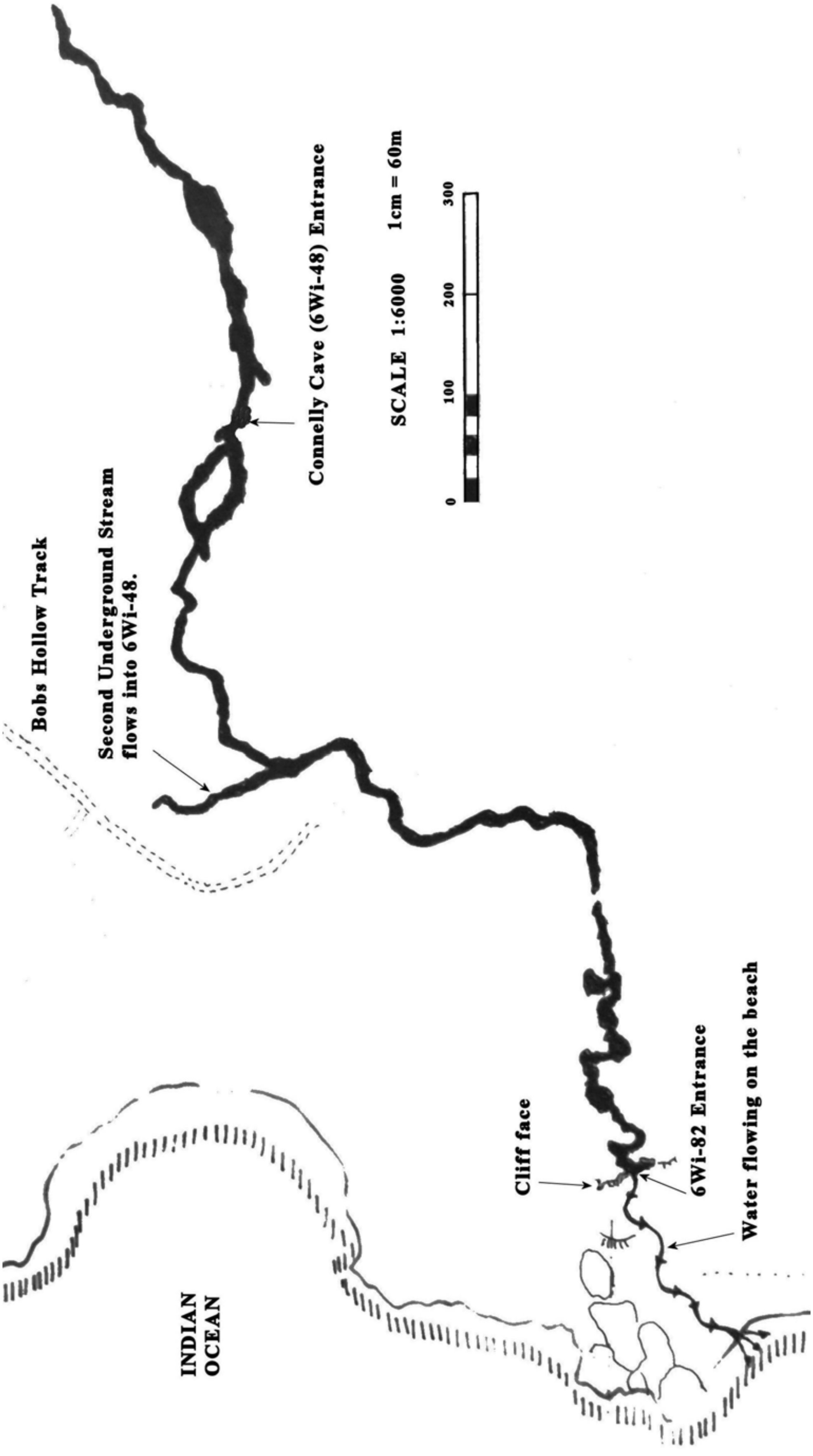

Figure 18: Connelly Cave and Bobs Hollow Resurgence Maps. Survey by and © B. Loveday 1985

Plate 25: Rotated collapsed blocks in Strongs Cave. Photograph by Ken Grimes

The cave is managed by DEC although the land surrounding the entrance is vested with the WA Museum. The cave was heavily track marked and older marking repaired in 1994 (Ryan, 1994). The track marking was too late to save the “snowflake” passage, which had been totally crushed before track marking was in place.

The unique fauna in the cave also provides management with challenges. The management strategy must clearly be aimed at ensuring the integrity of the overall groundwater environment but Eberhard (2004) clearly indicates that:

> “Populations (of *Perthia* sp. 1) in Calgardup Cave, Strongs Cave, and the Jewel Cave karst system are geographically, hydrologically and genetically isolated from each other, as they are also isolated from populations in springs and surface waters belonging to separate catchments.”

Which clearly makes these populations unique and an important focus of management.

The Augusta Area

The Augusta area extends from the Blackwood river estuary to the southern edge of the Boranup Sand Patch, taking in the old Hamelin area. It has the longest and best decorated caves in the region. The length is a consequence of their maze character – quite different from the linear stream caves found further north. Springs with associated tufa deposits occur along the southwestern coast and in Deepdene Gorge, but none are definitely associated with the maze cave drainage. The Leeuwin Water Wheel, now completely encrusted in calcareous tufa , was originally fed from a spring (6Au-26) (see Plate 1 for a photograph of the Water Wheel). The karst aquifer which feeds the water is also being used to water facilities at the Leeuwin Lighthouse.

Jewel Cave Karst System

The Jewel Cave Karst System (JCKS) is located about 8.8km north west of Augusta by road. A small reserve surrounds the Jewel Cave which is vested with the AMRTA and they manage the Jewel Cave, Moondyne Cave and Easter Cave which are all located on the reserve. The land surrounding the reserve is mainly part of the Leeuwin-Naturaliste National Park, managed by DEC. The Labyrinth (6Au-16) is managed by DEC and requires a permit and authorisation from the CAC to enter.

The Jewel Cave Karst System (JCKS) comprises a group of adjoining maze caves, Jewel, Easter and The Labyrinth (Eberhard, 2002, 2004; Figure 4). These lie in a narrow belt, less than 500m wide and about 5km long under the inland side of the dune range and adjacent to a swampy valley that might have provided aggressive acidic water in the past, although present inputs seem to be mainly local rainwater from above.

The impermeable granitic basement is exposed in several places in the floor of the caves but instead of producing linear stream caves, as has happened elsewhere in the region (c.f. Strongs Cave), there were slow moving "lakes" as shown by Webb (1988) and these slow moving perched groundwater lakes resulted in the maze caves. Plate 26 shows a flow experiment of two submerged bottles with reflective tape on their tops moving across the Epstein Lake in Easter Cave – this experiment was undertaken in 1978-79. The photograph was taken with an electronic timer setting off a flash every 15 minutes. The water was recorded as having a surface velocity of 1m/hour. Soon after this experiment was undertaken the "lakes" stopped flowing.

Subsidence dolines and solution pipes lead to extensive horizontal cave systems with an irregular spongework maze pattern that has partly collapsed to form higher-level rubble domes. The four main caves total over 10km of passage length. There are excellent examples of various speleogens (phreatic spongework, flat water-table roofs, and flow scallops (both slow & fast)) and solutional sculpting of fallen blocks. Speleothems are well developed and have combined with reflections in the lakes to make an excellent tourist display – unfortunately the lakes in Jewel Cave have dried up.

Some speleothem dating work has been undertaken on the Leeuwin-Naturaliste ridge with the oldest date being obtained from a flowstone speleothem in Moondyne Cave which dated back to 627ka (Eberhard, 2002, 2004).

Plate 26: Multi-exposure photograph of submerged bottles moving in the Epstein Lake, Easter Cave 1978-79. Photograph by Rauleigh Webb

The caves once held spectacular groundwater lakes, but many of these have dried up following recent drops in the watertable. The history of changing watertable levels goes well back into the Quaternary – with both higher and lower levels recognisable (Eberhard, 2002, 2004). The recent drop in water levels may be a result of reduced fire frequency – which caused greater vegetation cover and therefore less infiltration (Eberhard, 2002). Plate 27 and Plate 28 show the significant drop in the watertable with Plate 27 showing the lake level in the Flat Roof Chamber of Jewel Cave in the 1980's while Plate 25 is a recent image, 2007, that shows the same chamber completely dry. Note the extensive track marking in the 2007 image to reduce caver impacts in this area of the cave.

Plate 27: Pete Bell in the lake in Flat Roof Chamber lake, Jewel Cave – 1980's. Photograph by Rauleigh Webb

Plate 28: Jay Anderson in the dry Flat Roof Chamber, Jewel Cave 2007. Photograph by Ross Anderson

Eberhard, 2004 detailed the importance of the root mat communities that have been found in the JCKS and in other caves of the Leeuwin-Naturaliste ridge. He also recommended that the conservation status of the four root mat communities that are listed as "Endangered – Critical" may need to be revised, given that his work shows that the extent of occurrence is much greater than previously suggested.

Deepdene Cave

Deepdene Cave (6Au-1) was used as a tourist cave around 1901 (see Vivienne, 1901). Historical information relating to Deepdene Cave could not be obtained in time for publication.

The cave is located in the Leeuwin-Naturaliste National Park and is managed by DEC. Access is via permit from DEC.

A dig was performed by Lowry and Lowry (1968) in the lowest part of a large old rimstone pool which is marked on the cave map as “OLD DIG” – See Figure 19. They reported that between 7 and 11 inches deep the deposit was about 90% bone material and consisted of small macropods, a few rats and ?possum. Their conclusion was that given the high concentration of bones the material was not transported by water and they proposed that it was either an animal lair, a human midden or animals had drowned while drinking at the pool. It is assumed that the bone material was lodged with the WA Museum.

The cave is essentially a conjunction of two collapsed domes, but with abundant speleothems. The original solutional level would be deeper, and may be exposed in small caves in the cliff of nearby Deepdene Gorge (Eberhard, 2004). Deepdene Gorge might be a gorge of construction (Jennings, 1980), or might be a collapsed stream cave following underground capture of Turner Brook (Eberhard, 2004).

This very well decorated cave has suffered heavily at the hands of vandals. Even in her 1901 description of Deepdene Cave Vivienne refers to vandals and broken stalactites:

> “The first large gallery once had a number of fine stalactites, but some vandals have torn them away.”

Also in the early years, 1900’s, visitors were encouraged to write their names on the formations (see Plate 29 for a graphic example) which has resulted in significant graffiti in the cave.

Plate 29: Graffiti on speleothems. Deepdene Cave (6Au-1). Photograph by Jay Anderson

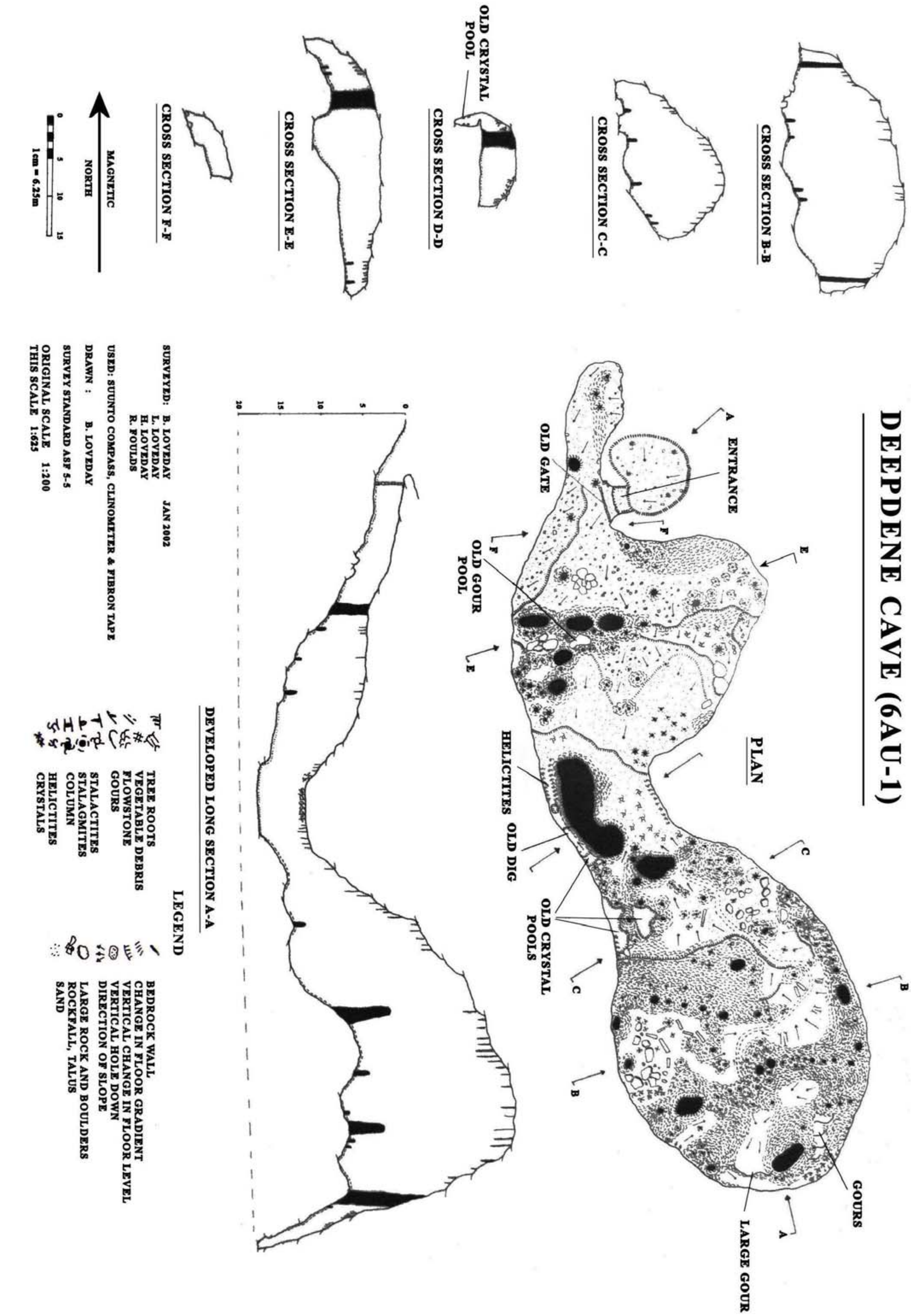

Figure 19: Map of Deepdene Cave (6Au-1). Survey by and © B. Loveday 2002

Moondyne Cave

Moondyne Cave (6Au-11) was originally called Coronation Cave, but this name was changed to Moondyne Cave in honour of Moondyne Joe, a Western Australian bushranger of local fame and fable. Elliot (1978) suggested that Moondyne Joe found the cave but that it is unlikely that he used it as a hideout.

The cave is located near Jewel Cave at Augusta and access to the cave is obtained via the AMRTA and the CAC.

The cave was used as a tourist cave, and Webb (1980) describes how Matt Brennan, a long time guide, used a "tilly" lamp and flares to light the cave for tourists. The cave closed to tourists in December 1959. In 1978 Ray Hart (Hart, 1978) co-ordinated an extensive cleanup of the cave. Significant track marking was installed and many formations washed clean. This was the first track marking introduced into a then "wild cave" in Western Australia. Plastic paths had been used previously in Christmas Star Extension in Crystal Cave but no track markers were used.

The cave is managed by the AMRTA and it was used for some time as an "adventure" cave after being restored by AMRTA under the leadership of Peter Bell (Bell, 1993). Unfortunately high levels of CO_2.and other insurance issues resulted in tours being abandoned. CO_2 levels in the cave were regularly at 3% in the lower areas.

Although a part of the JCKS, Moondyne Cave does not reach to the water table and is entirely a system of breakdown chambers – presumably there was once a maze system at depth. The largest chamber in the cave contains the massive column and adjacent long straw stalactites shown in Plate 30. As well, the cave contains an interesting area known as the "Snowflake extension" which is filled with "snowflakes" and "volcanoes" (see Hill and Forti, 1997, for explanation of the formation of these speleothems). This area appears to have been a massive gour pool at one time when the "snowflakes" and "volcanoes" formed, but then the gour wall broke draining the pool (see map in Figure 20 showing the extent of the "snowflake" area). This area of the cave may contain high levels of CO_2 (1-6%).

Plate 30: Ev Tulp adjacent to the Large Column in Moondyne Cave. Photograph by Rauleigh Webb.

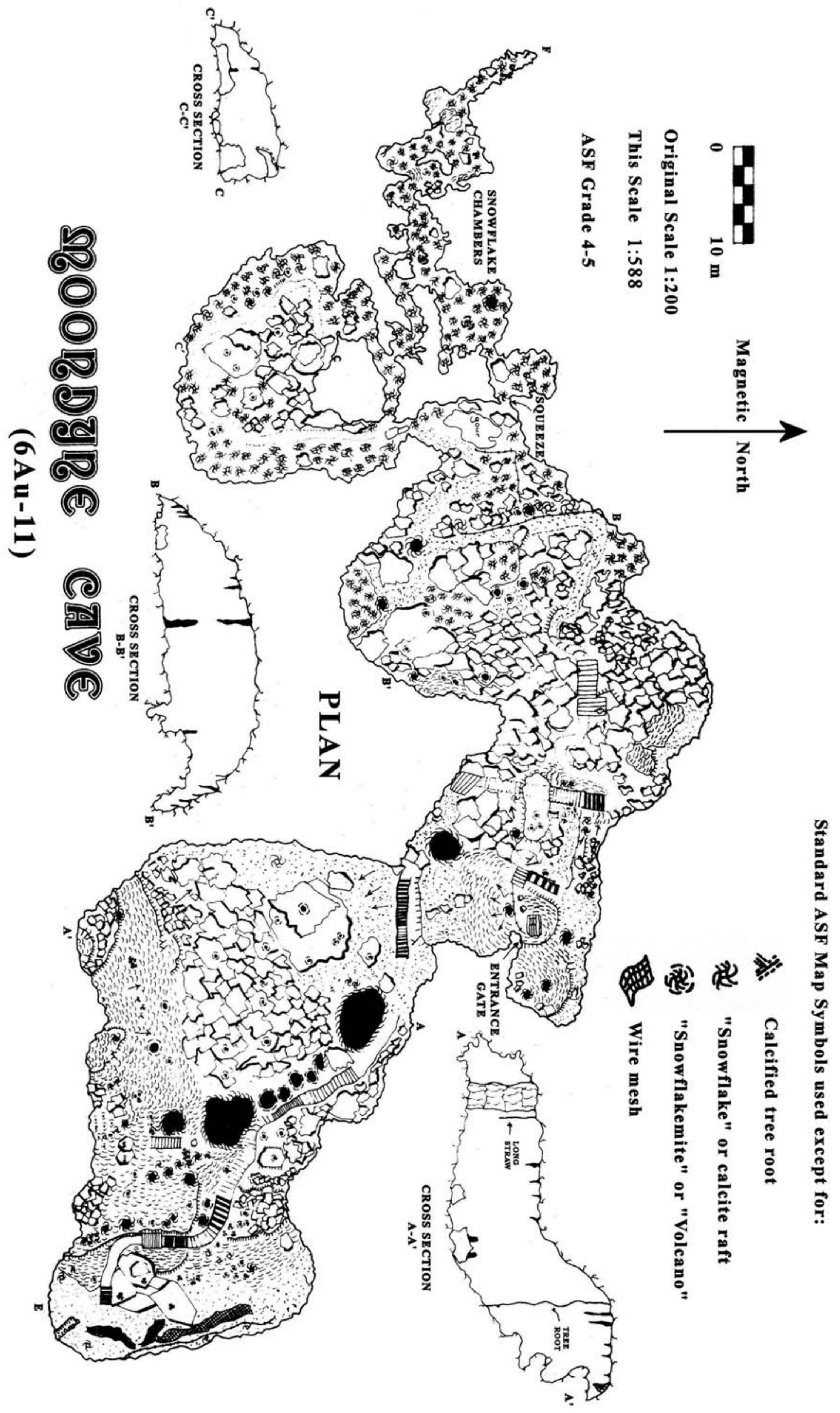

Figure 20: Map of Moondyne Cave (6Au-11). Survey by R. Webb 1978

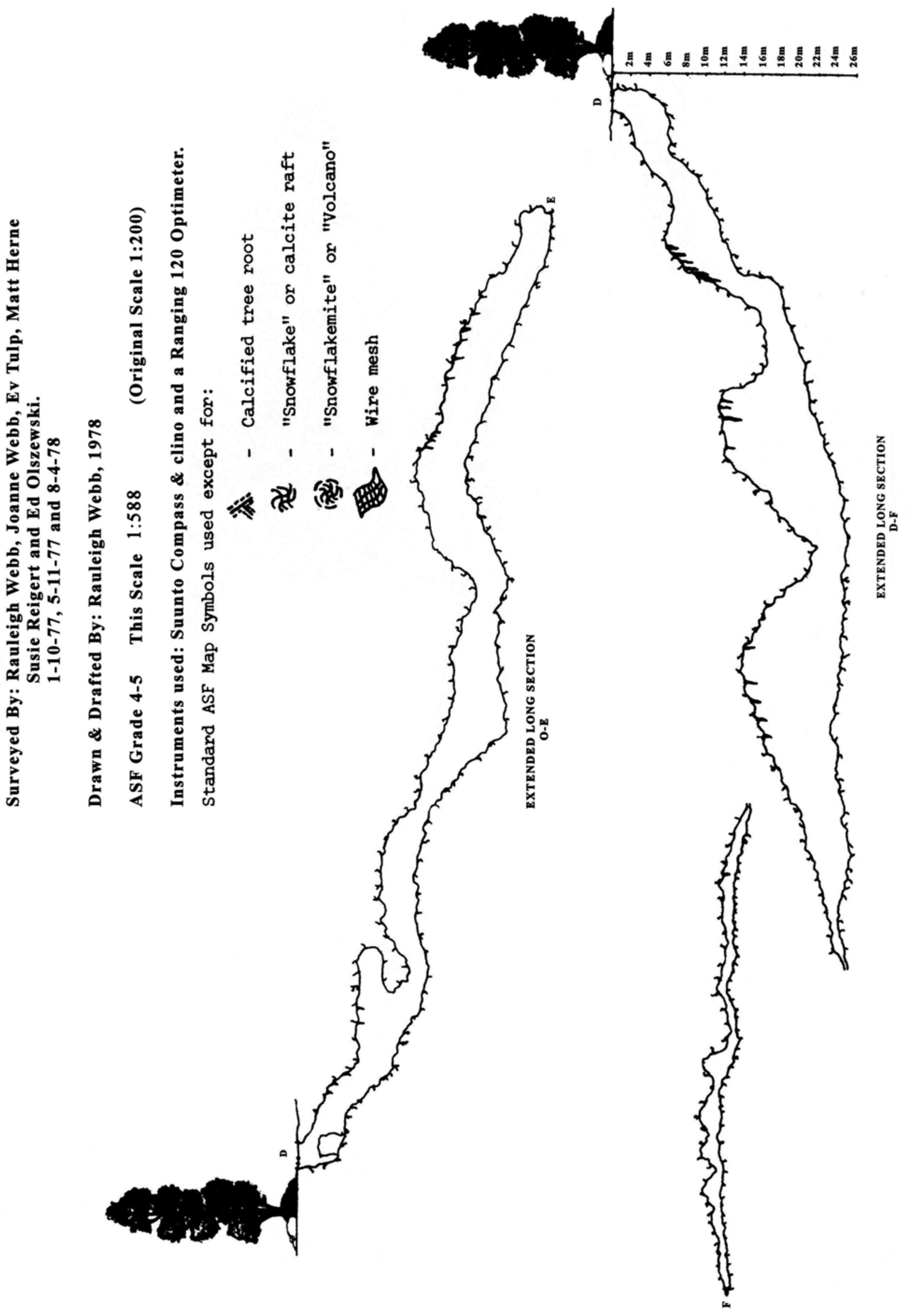

Figure 20: Map of Moondyne Cave (6Au-11). Survey by R. Webb 1978

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