DISCOVERING CAVES

Australian Geological Survey Organisation

DEPARTMENT OF INDUSTRY, SCIENCE AND RESOURCES

AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

Chief Executive Officer:
Dr Neil Williams

ISBN: 0 642 39834 8
ISSN: 1039-0073

AGSO Record Number: 2000/17
Catalogue no. 33346

Developed and written by
Kathleen M. Kemp and
Gary B. Lewis

Discovering Caves was prepared while Kathleen Kemp was on research/study leave from the Department of Geology, University of Toronto, Canada.

Scientific advice and editing:
Andy Spate, Jo Ingarfield
Cindy Hann, Cindy Trewin
Julie Wissmann, Heather Wallace

Design and Cartography:
Karin Weiss
Shawn Stanley
Leanne McMahon
Gayle Young

Product information:

AGSO Sales Centre
GPO Box 378
CANBERRA ACT 2601
AUSTRALIA

tel. +61 2 6249 9519 or
+61 2 6249 9642

fax +61 2 6249 9982

e-mail sales@agso.gov.au

web www.agso.gov.au/information/bookshop.html

Discovering Caves consists of:

***Discovering Caves in Australia* poster complied by Kathleen M. Kemp and Gary B. Lewis**

***Discovering Caves Activities* by Gary B. Lewis**

***Fact Sheets* by Kathleen M. Kemp and the following:**

- *Caves in Australia* - Andy Spate
- *Australian Cave Facts* - Andy Spate, Mia Thurgate, Jane Gough
- *Dissolving Limestone to Form Caves*
- *Nature's Way of Decorating Caves*
- *Making Limestone Caves* - Armstrong Osborne and Susan White
- *Stalactites, Stalagmites and Other "Cave Things"* - Andy Spate
- *Karst Landscapes and the Movement of Water* - David Gillieson
- *Using Land and Caring for Caves* - Elery Hamilton-Smith and David Gillieson
- *Determining the Age of Cave Deposits* - John Webb
- *How Caves Tell Us about Past Climates*
- *Bats, Birds and Other Vertebrates that Live in Caves* - Les Hall
- *Creepy Crawly Invertebrates that Live in the Dark* - Bill Humphreys
- *Human Use of Caves* - Elery Hamilton-Smith and David Gillieson
- *The Effects of Tourism* - Elery Hamilton-Smith, David Gillieson
- *Cave Fossils*
- *Karst and Caves in Rock other than Limestone* - Susan White
- *Finding out More about Caves and Caving* - John Dunkley

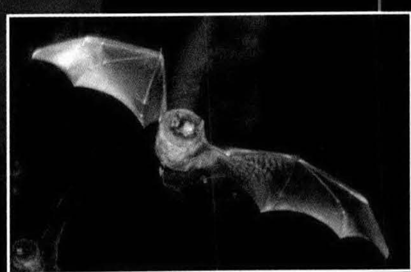
Images used on this folder

Cave Interior © Stephen Babka
Bat © Stefan Eberhard
Caver © Andy Spate
Bats used throughout the kit © Stefan Eberhard

Reproduction of the fact sheets and pages from the Caves Activities booklet is authorised for educational purposes.

DISCOVERING CAVES *activities*

By Gary B. Lewis



Australian Geological Survey Organisation

DEPARTMENT OF INDUSTRY, SCIENCE AND RESOURCES

AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

Chief Executive Officer:
Dr Neil Williams

ISBN: 0 642 39834 8
ISSN: 1039-0073

AGSO Record Number: 2000/17
Catalogue no. 33346

This booklet is part of the Discovering Caves Kit.

Developed and written by
Gary B. Lewis

Educational cave model:

Tau Rho Alpha, John P Galloway and John C. Tinsley III, USGS Open-file Report 97-536-A

Scientific advice and editing:

Kathleen Kemp, Andy Spate, Cindy Trewin, Cindy Hann

Cover design:

Karin Weiss

Product information:

AGSO Sales Centre
GPO Box 378 CANBERRA ACT 2601
AUSTRALIA

tel.	+61 2 6249 9519 or +61 2 6249 9642
fax	+61 2 6249 9982
e-mail	sales@agso.gov.au
web	www.agso.gov.au/ information/bookshop.html

Other Education Titles in this series include

Earthquakes (1995/20)	Student Activities
Volcanoes (1995/24)	Teacher Notes and Student Activities
Time and Life (1995/14)	Teacher Notes and Student Activities
Climate Change (1995/21)	Teacher Notes and Student Activities
Plate Tectonics (1995/8)	Teacher Notes and Student Activities
Silicate Chemistry (1995/19)	Teacher Notes and Student Activities
Gas: Energy and Change	Teacher Notes and Student Activities
Australian Earthquakes (1995/25)	Slide Set
Australian Volcanoes	Slide Set
Volcanic Hazards	Slide Set
Australian Landslides	Slide Set
Mt Todd Map Kit (1996/10) Student Activities and maps	Teacher Notes and
Topographic Map Kit	(1997/2) Teacher Notes and Student Activities and maps
Discovering Remote Sensing (1999/30A)	Teacher Notes and Student Activities

Teachers Guide

CURRICULUM LINKS

This kit contains information and activities which are closely linked to the Science and SOSE/HSIE – Geography curricula. On the next page is a curriculum links matrix for most states as well as those for the National Profiles.

ACTIVITIES

This activity booklet contains seven activities that you can use to introduce and explore issues about caves. Suggested answers to these activities can be found at the back of this booklet. The activities are:

Solution — an activity about the solution of limestone by carbonic acid. This activity involves students plotting data on a graph them using the graph to extrapolate information.

Make Your Own Speleothems — an activity involving growing speleothems using saturated Epsom salt solutions. This is a hands-on activity.

Growth Chart — an activity about the rate of growth of a real stalagmite. Students calculate growth rates, compare and contrast growth rates and use possible error values.

Cave Mapping — an activity about the use of symbols to represent features on cave maps. Students learn to recognise the use of symbols then are asked to draw a long section through a cave using cave map data. Students are also asked to design symbols for some other cave features.

Living in a Dark World — an activity about troglobites. Students are asked to describe an animal from a diagram then to sketch an animal from a description.

Make a Model Cave and Sinkhole — Students construct a 3D model showing many cave features.

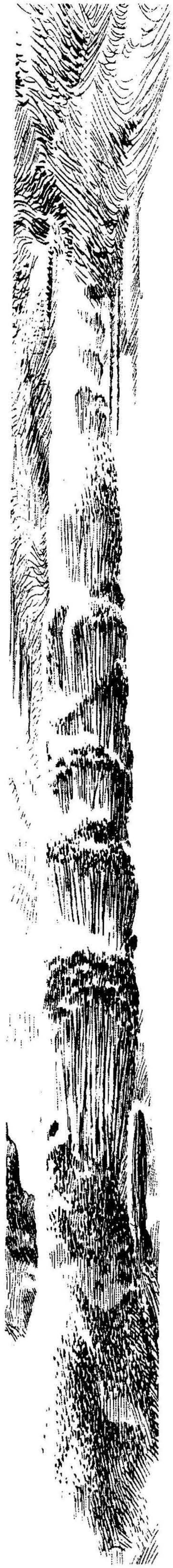
Let's Role Play — an activity about conflicting uses of land in a cave area. Students take on the roles of people within a community and debate the pros and cons of cave development in an area with working quarries and endangered animals.

Other Activity Ideas — some suggested extension activities.

Discovering Caves: Curriculum Links

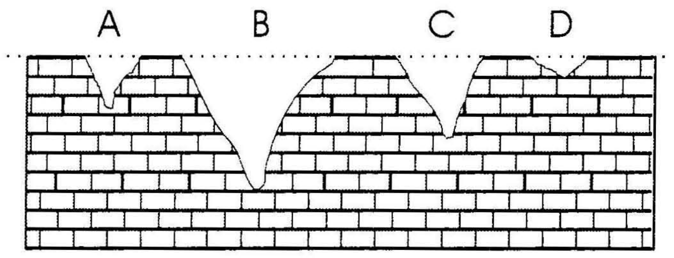
Curriculum links		AGSO resource
		Discovering Caves
National		
Science		
	working scientifically	3, 4, 5
	earth and beyond	3, 5,
	life and living	3
	energy and change	
	Natural and processed materials	4
SOSE		
	Investigation, communication & participation	3, 4, 5
	Place and space	3, 4, 5, 6
	Resources	
	Time, continuity and change	3,
	Natural and social systems	4, 5
VIC		
Science		
	Biological science	3, 4
	Chemical science	2,
	Earth and space science	3, 4, 5
	Physical science	
	Skills, processes and procedures	2, 3, 4, 5
SOSE		
	Society and environment	3,
	History	
	Geography	4, 5
	Economy and society	
Geography		
	VCE Unit 1 & 4	Unit 1
QLD		
Science		
	Science and Society	
	Earth and Beyond	2, 3, 4
	Energy and Change	
	Natural and processed materials	2, 3
	Life and Living	3
SOSE		
	Time Continuity and change	
	Place and space	2, 3, 4, 5
	Culture and identity	
	Systems, resources and power	
WA		
Science		
	Working scientifically	✔
	Earth and beyond	✔
	Energy and Change	
	Natural and processed materials	✔
	Life and Living	✔
SOSE		
	Investigation, communication & participation	✔
	Place and space	✔
	Resources	
	Time, continuity and change	
	Natural and social systems	✔
NSW		
Science		
	Science and technology K-6	2, 3
	Stage 4	4.9, 4.10, 4.16, 4.19
	Stage 5	5.9, 5.16, 5.19
	Stage 6 Earth and Environmental Science	✔
Geography		
	Human Society and its Environment K-6	2.2, 2.5, 3.5, 2.6
	Stage 4	4.2, 4.3, 4.5, 4.6, 4.7
	Stage 5	5.2, 5.5,
	Stage 6	✔

(by outcome level or ✔= present in outcome statement, or syllabus, but no levels are given)



Solution

A block of limestone was set up in a laboratory underneath a container of dilute carbonic acid. The carbonic acid was allowed to drip onto the limestone block in four locations (A, B, C & D) slowly dissolving the block to form a small pit. At each location the solution was allowed to drip for varying periods of time so that each pit is a different size.



Complete the following table by measuring the maximum depth of each pit in millimetres (mm) and recording in the correct column.

Location	Time period of dripping	Maximum depth of pit (mm)
A	28 days	
B	68 days	
C	44 days	
D	12 days	

On the graph paper, plot the depth of the pit (y axis) against the number of days (x axis). Make your x axis extend up to 120 days.

Use your graph to find out how many days would it take for a drip of the same acid to dissolve a pit through the entire block of limestone? ___________days

Use your graph to find out how long it takes for a drip of acid to dissolve through 1 cm of limestone? ________ days

The deepest cave in Australia is about 375 metres deep. How many days would it take for a cave this deep to be dissolved using the acid in this experiment? ___________

What could you change in this experiment to increase the rate at which limestone is dissolved?

____

____

Make Your Own Speleothems

What you need

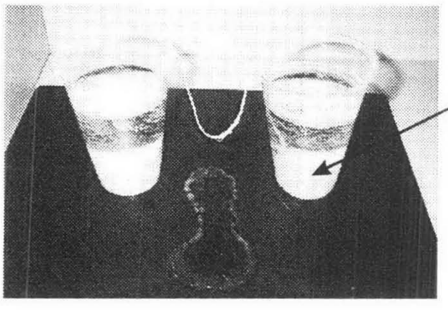
two disposable cups
spoon
one cup of Epsom salts
20 cm thick cotton string
aluminium foil or plastic
two paper clips

What to do

Find a place to set up this experiment where it will be away from drafts and not be disturbed.

Put half the Epsom salts into each of the disposable cups and then fill each cup with hot water. Stir the mixture so that the water becomes saturated with dissolved Epsom salts. Most of the Epsom salts will not dissolve but remain at the bottom of the cups.

Tie a paper clip to each end of the thick string. Wet the string well with tap water then place the ends of the string into the two cups as shown below in the photograph. Place the cups so that the string sags in the middle. Place a piece of aluminium foil or plastic beneath the string where it is sagging.



What do you see?

Write down your observations after 5 mins, 10 minutes and the next day?

What do you see happening both to the string and below the sag?

What to do next?

Use your observations from this experiment to describe the development of speleothems in limestone caves?

What could you do to change the rate of growth?

How is this experiment similar to the way speleothems form in caves?

How is it different from the way speleothems form in caves?

Growth Chart

A stalagmite was collected at Jersey Cave, Yarrangobilly NSW, for dating. The stalagmite was cut lengthwise and four samples (A, B, C & D) were taken which were sent to a dating laboratory. The laboratory provided an age in years for each of the samples as well as the possible error in each of the ages in years.

Sample	Age (years)	Possible error (+/-) (years)
A	2 840	240
B	3 980	320
C	35 000	2 200
D	38 800	2 500

Using these ages we can calculate the growth rate of the stalagmite for three different periods of time as well as the average rate for the whole stalagmite.

Step 1.
On the image of the speleothem, measure the distance between each sample site in millimetres and record the distance on the table below.

Time Period	Distance (mm)	Difference in Age (yr)	Growth rate (mm/yr)
A-B			
B-C			
C-D			
A-D (average)			

Step 2.
Calculate the difference in age between the sample sites and record on the table.

Step 3.
Calculate the growth rates of the stalagmite by dividing the distance between sample sites by the difference in age. Write the results in the table.

Questions

1. Between which dates did the stalagmite grow the fastest?
2. Between which dates did the stalagmite grow the slowest?
3. What factors in the environment may have changed the growth rate of the stalagmite?
4. How long would it take for this stalagmite to grow an additional metre in length (use the average rate of growth)?
5. What is the youngest possible age and oldest possible age of Sample A? (use the error figure provided in the chart)
6. What happened around 18,000 years ago that may have changed the rate of growth for speleothems in eastern Australia?

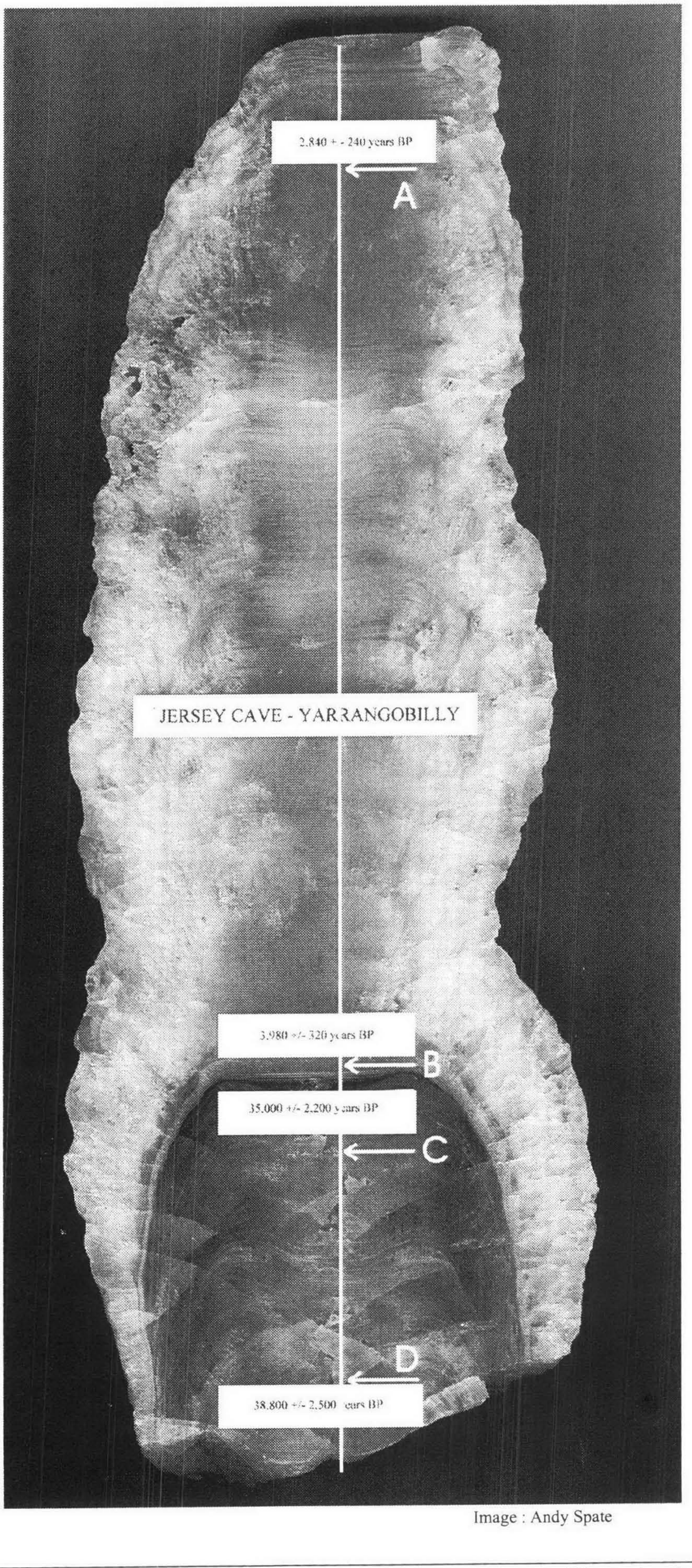


Image : Andy Spate

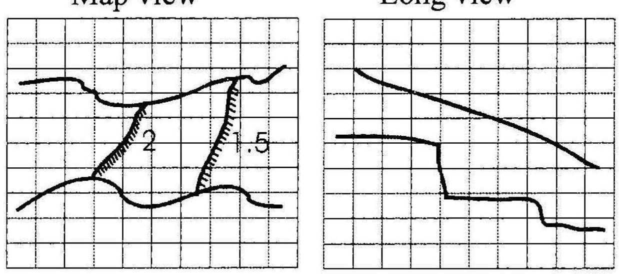
Cave Mapping

Mapping the shape of the Earths surface can be a complex task. Imagine then how much more difficult it is to map a cave which twists and turns in three dimensions as well as recording roof and floor features — and then do it by torch light!

Even the simplest cave maps require the use of symbols which indicate changes to the level of the floor and roof. A few of these symbols are summarised below. The numbers refer to the change in height of either the roof or floor in metres. The ***map view*** shows a map of the cave seen from above. The ***long view*** shows what it would look like if we made a vertical cut through the cave and looked at it sideways.

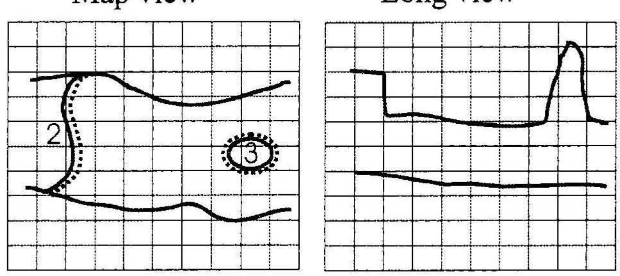
Floor changes.

Map view Long view

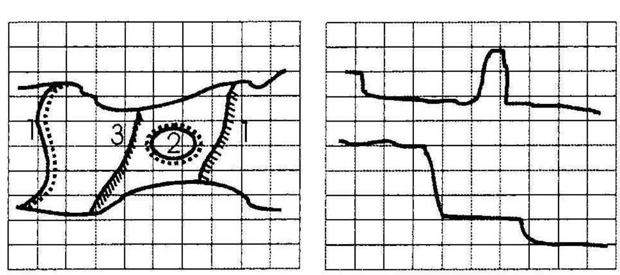


Roof changes.

Map view Long view



If we combine these two types of symbols, we can draw a cross section of a cave showing changes in both the heights of the floor and roof:



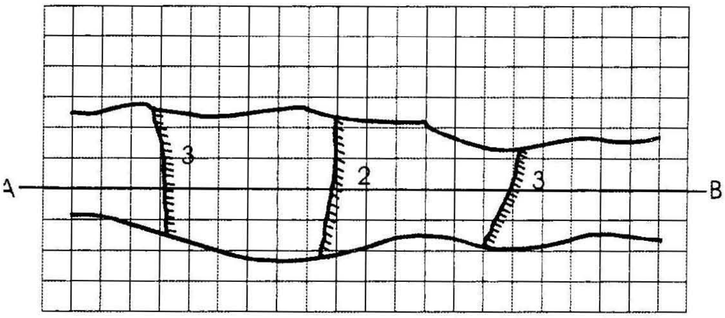
Use these diagrams to complete the next mapping problems.

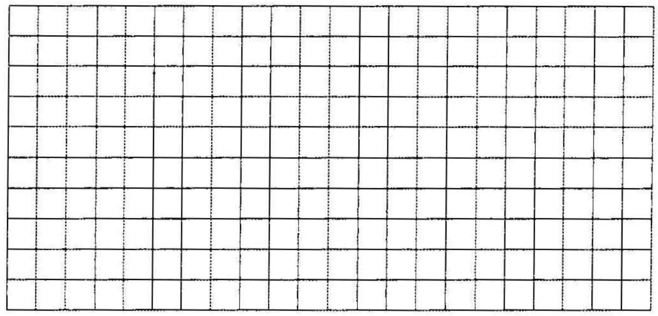
Complete the following maps and long sections

Each small square is one metre by one metre

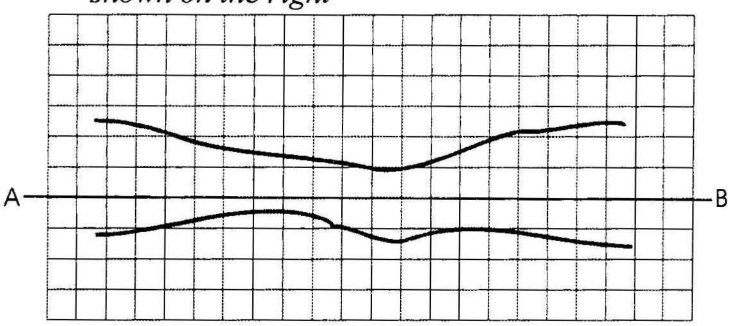
1. Floor changes

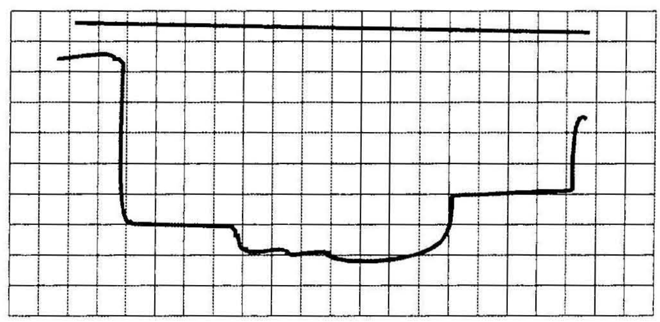
a. Complete the long section using the plan view to the left.





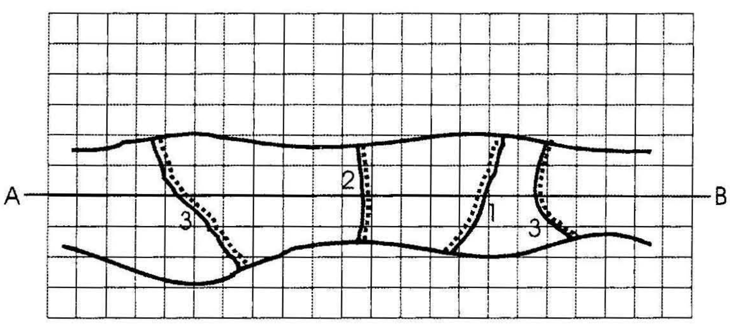
b. Complete the map using the long section shown on the right

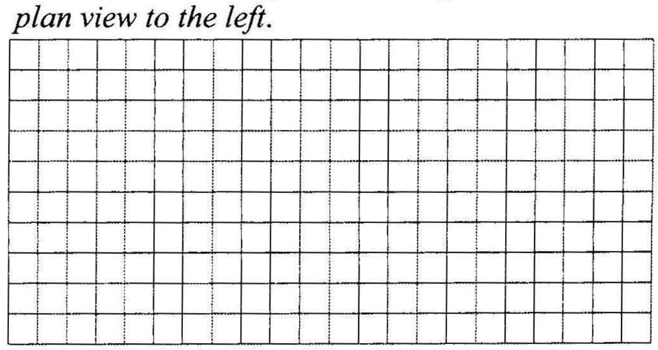




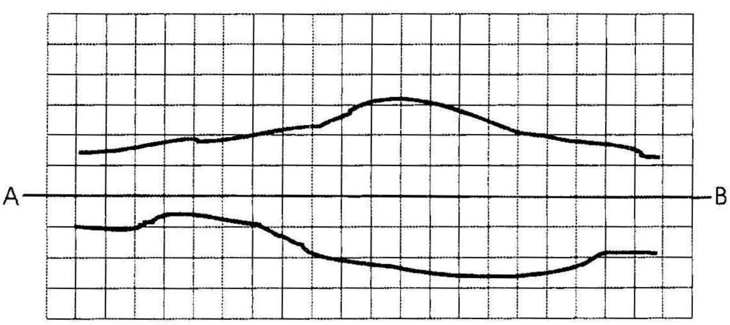
2. Roof changes

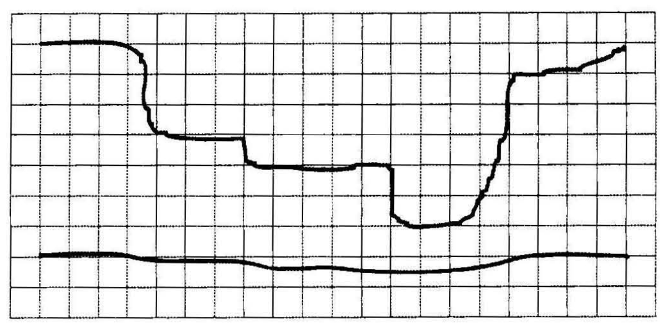
a. Complete the long section using the plan view to the left.



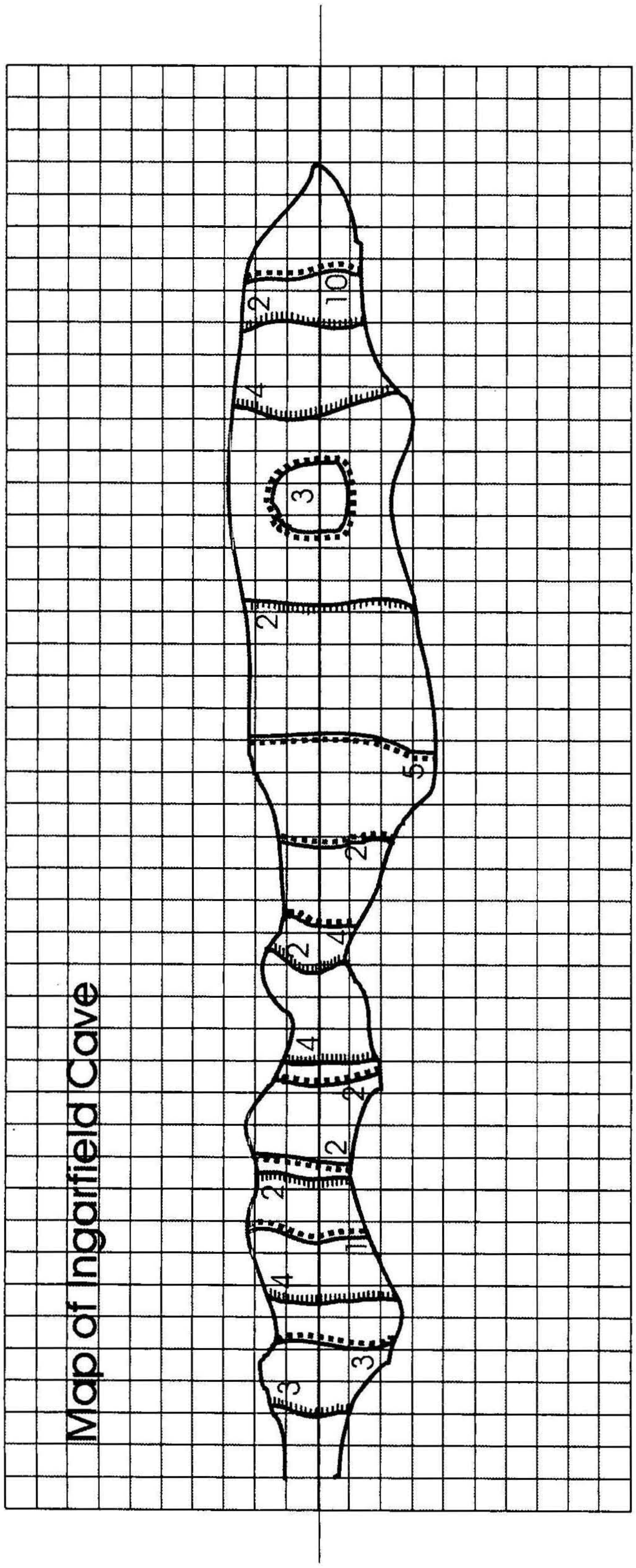


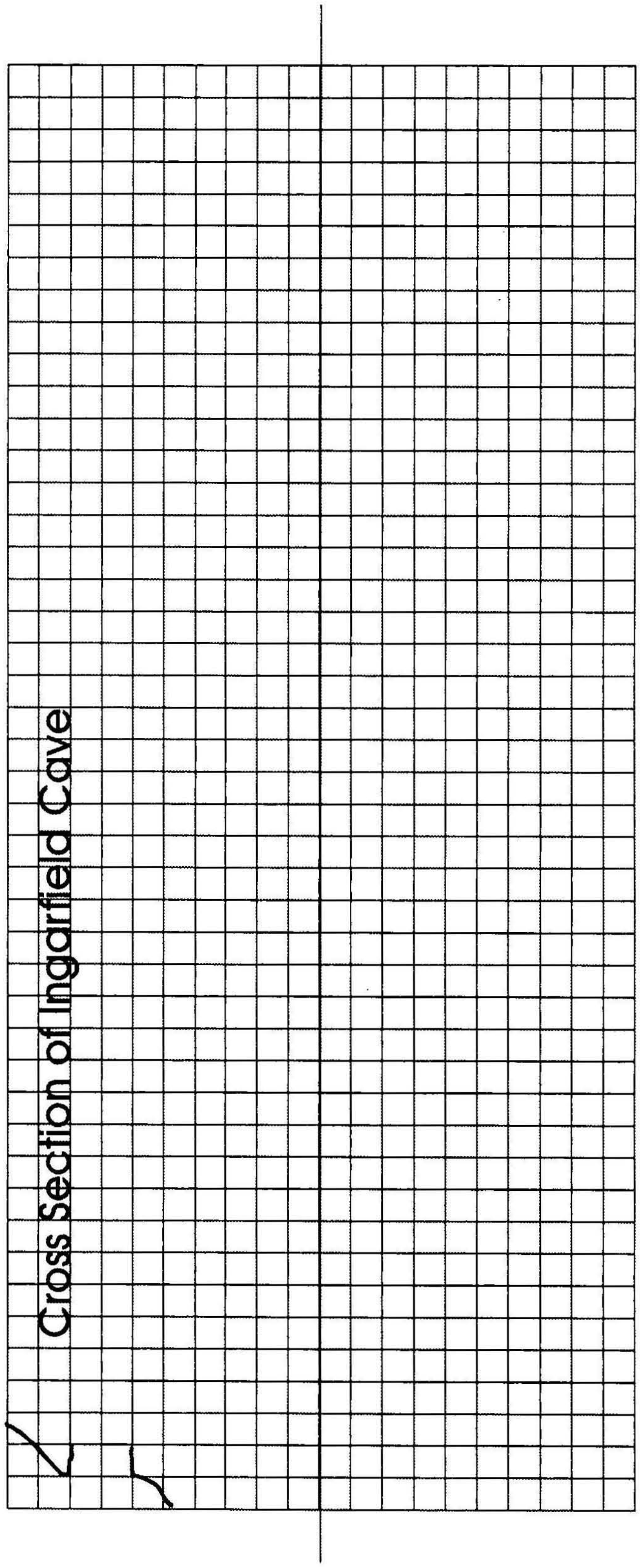
b. Complete the map





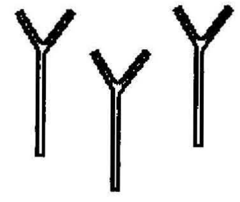
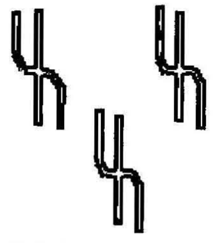
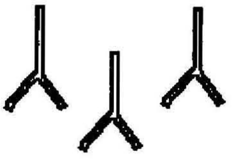
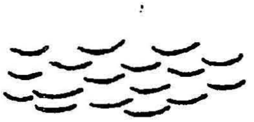
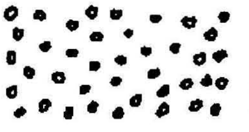
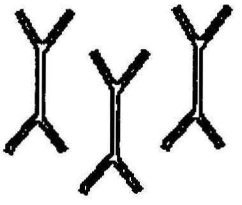
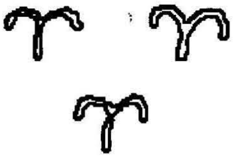
Using your understanding of these symbols draw a long section through Ingarfield Cave in the space provided below the cave map. Each small square is one metre by one metre. The opening of the cave has been drawn for you.





People use many other symbols to show features found in caves. Some of these symbols are shown below.

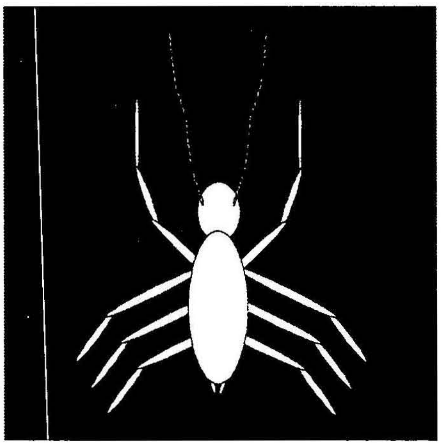
Complete the table by making up your own symbols for some of the other features that are found in caves.

Stalactites	**Helictites**	**Limit of daylight**
		
Stalagmites	**Flowstone**	**Pebbles or gravel**
		
Columns	**Guano**	**Rockfall**
		
River	**Sand**	**Bat colony**
Stairs	**Light fitting**	**Bridge**

Living in a Dark World

Animals that are adapted to live their whole life in the dark areas of caves are called troglobites. These creatures have evolved in an environment very different from other animals, as they can't rely on sight to find their way, hunt or collect food.

What senses could these animals use to navigate, detect predators and find food in caves?



During a survey of a cave, a new troglobite species was discovered. The cave manager sketched the new animal. Using this sketch, write a detailed description of this new animal giving details including the shape and size of each body part.

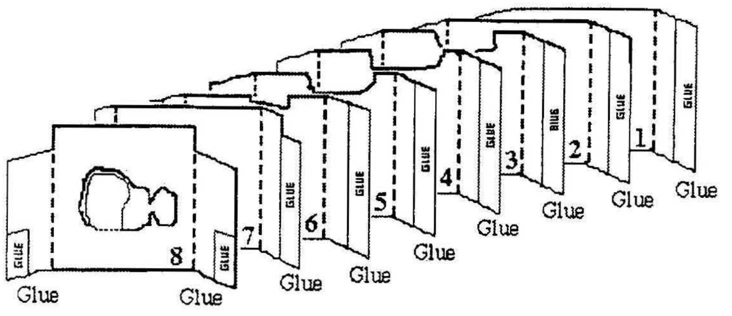
The following description was written about a troglobite found in the same cave over fifty years ago. Use this description to draw the creature in the box below.

"The animal's body was 32 mm long and was made up of 8 segments. Each segment was identical and only 8 mm wide. Each segment has four legs, two from each side. The legs are 24 mm long. The legs on the end segments have small claws that are 2 mm long. From the final segment, two fury feelers extend for 50 mm. The whole animal is white in colour"

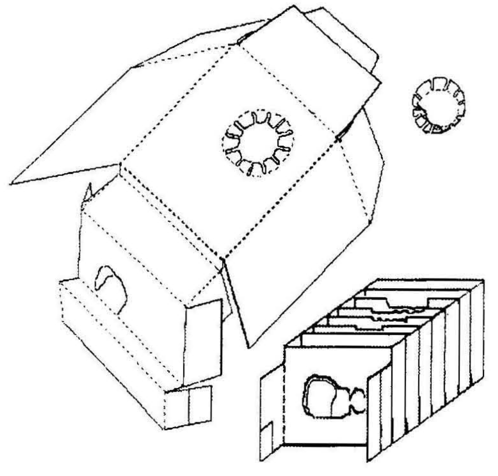
What further information would you like to have to complete your diagram? What animals that live on the Earth's surface do each of these animals resemble?

Make a Model Cave and Sinkhole

1. Colour the dotted areas blue. They represent water. You can also colour in the limestone (light grey), stalactites and stalagmites (cream).

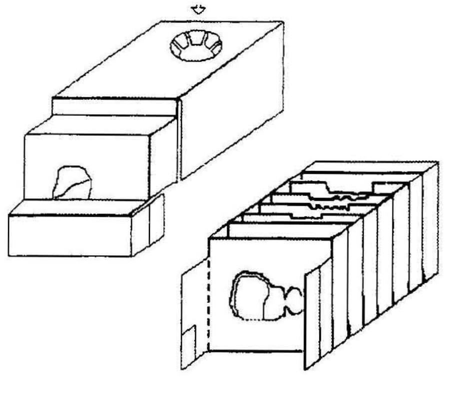


2. Cut out the main model body and the eight cave sections. In each part you will have to cut out some internal pieces. You also need to cut out the small sinkhole piece.



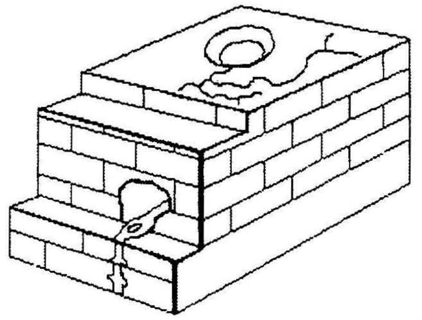
3. Fold the eight cave sections along the dotted lines then glue the eight cave sections togther as shown. (Each piece glues to the piece in front of it).

4. Fold the main model body using this diagram as a guide. Glue the tabs marked so that it forms a rigid box.



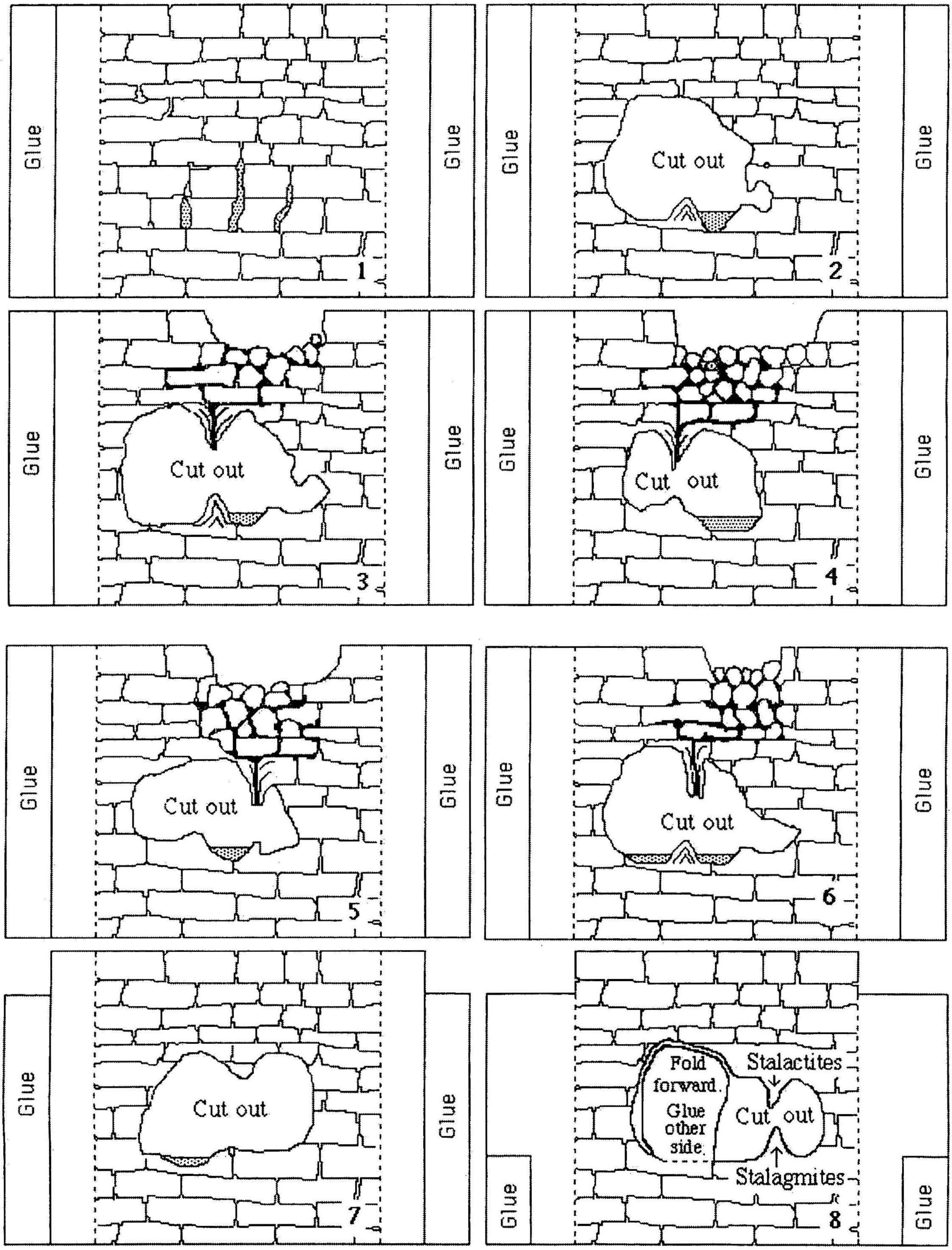
5. Cut out the pieces between the 'petals' of the sinkhole then glue the sinkhole piece into the space on the top of the box.

6. Glue the internal cave sections inside the box where shown. You will be able to lift the box off the internal sections when you pull on the tab at the back.



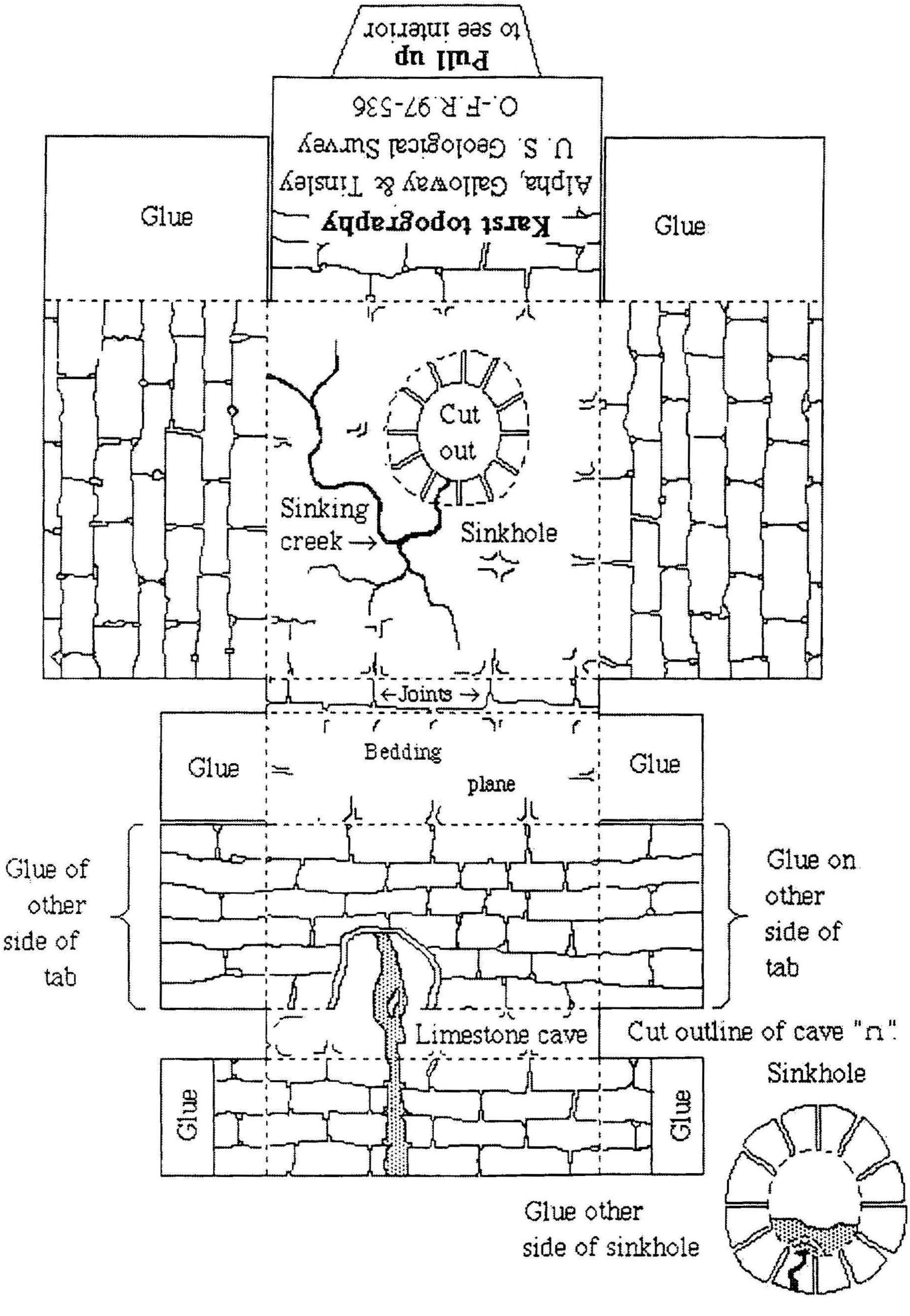
Discovering Caves Activities
Australian Geological Survey Organisation
(with Permission - USGS)

Eight cave sections



Discovering Caves Activities
Australian Geological Survey Organisation
(with Permission - USGS)

Main Model Body



Let's Role Play . .

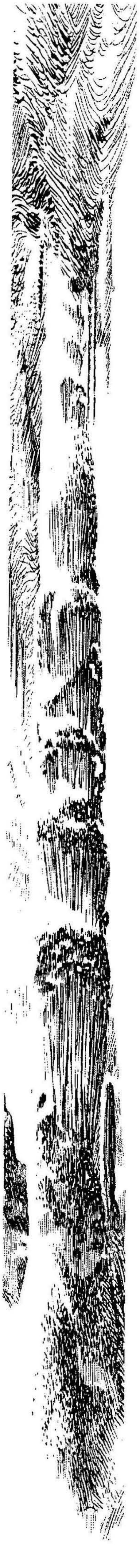
An area of limestone near the town of Kempville has both an operating quarry and a series of small caves. A local group wants to open one of the caves for tourists and they are concerned that the quarry operations might damage the cave. The quarry operators are concerned that they will be denied access to some of the limestone they had planned to quarry because of the caves. The quarry employs 30 Kempville residents. If the tourist cave opens it will employ five people, but it will bring hundreds of tourists to Kempville each week. A local biologist thinks that the caves might also be home to an endangered spider.

The local Kempville Council has decided to hold a meeting of all the parties to make a decision on if the caves should be opened to tourists.

Select people to take on the following roles — Kempville Mayor, Kempville Limestone Quarry Owner, Tourist Cave Group, Local Biologist, President of the Save Our Spiders Group, President of Kempville Tourist Association and the Limestone Workers Association. Have each person prepare a five minute speech to the Council outlining their position. The rest of the class can be the Council members and at the end, vote on whether the tourist cave should go ahead (remember – you are all citizens of Kempville).

Other Activities Ideas

- Research the number of species of bats in Australia. How many species of bats use caves? How can human activity affect bats?
- Get the geological map for your area and see where limestone can be found.
- Design a mask that stops 100% of light to simulate conditions in a cave.
- Research caves in other countries.
- See if limestone or marble is used in buildings in your local town (look inside buildings as well as on the walls outside).
- Survey a local cemetery to find the proportion of headstones that are made of marble or limestone. Compare the condition of old limestone or marble headstones to new ones.



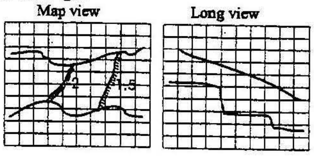
Suggested Answers

Cave Mapping

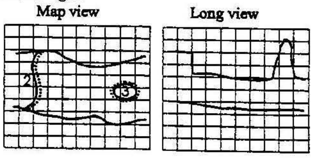
Mapping the shape of the Earths surface can be a complex task. Imagine then how much more difficult it is to map a cave which twists and turns in three dimensions as well as recording roof and floor features — and then do it by torch light!

Even the simplest cave maps require the use of symbols which indicate changes to the level of the floor and roof. A few of these symbols are summarised below. The numbers refer to the change in height of either the roof or floor in metres. The ***map view*** shows a map of the cave seen from above. The ***long view*** shows what it would look like if we made a vertical cut through the cave and looked at it sideways.

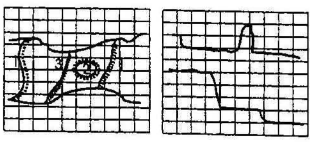
Floor changes.



Roof changes.



If we combine these two types of symbols, we can draw a cross section of a cave showing changes in both the heights of the floor and roof:



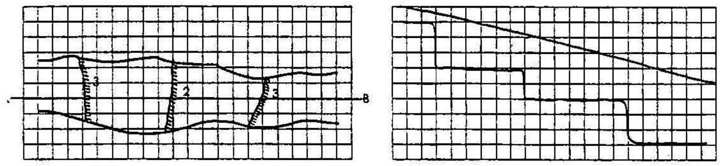
Use these diagrams to complete the next mapping problems.

Complete the following maps and long sections

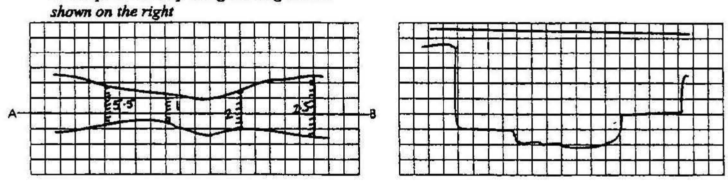
Each small square is one metre by one metre

1. Floor changes

a. Complete the long section using the plan view to the left.

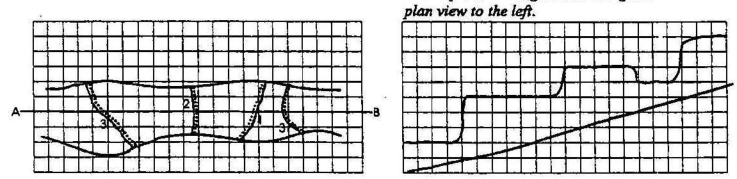


b. Complete the map using the long section shown on the right

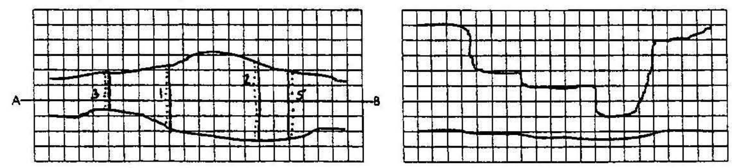


2. Roof changes

a. Complete the long section using the plan view to the left.

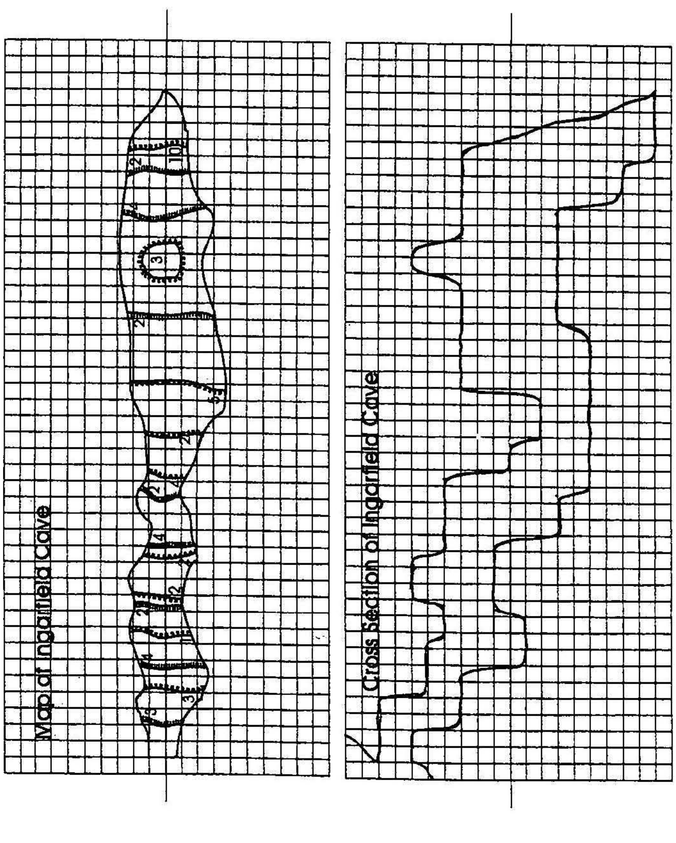


b. Complete the map



Discovering Caves Activities
© *Australian Geological Survey Organisation*, 2000

Using your understanding of these symbols draw a long section through Ingarfield Cave in the space provided below the cave map. Each small square is one metre by one metre. The opening of the cave has been drawn for you.

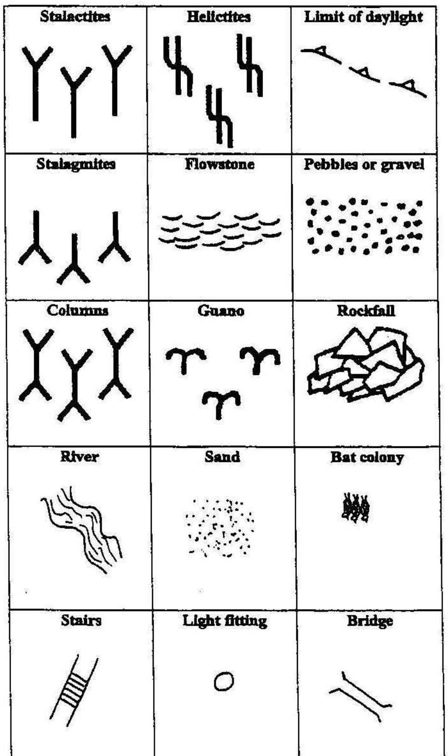


Discovering Caves Activities
© *Australian Geological Survey Organisation*, 2000

People use many other symbols to show features found in caves. Some of these symbols are shown below.

Complete the table by making up your own symbols for some of the other features that are found in caves.

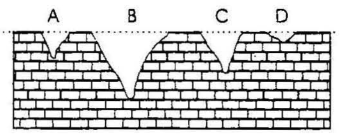
Stalactites	**Helictites**	**Limit of daylight**
Stalagmites	**Flowstone**	**Pebbles or gravel**
Columns	**Guano**	**Rockfall**
River	**Sand**	**Bat colony**
Stairs	**Light fitting**	**Bridge**



Discovering Caves Activities
© *Australian Geological Survey Organisation*, 2000

Solution

A block of limestone was set up in a laboratory underneath a container of dilute carbonic acid. The carbonic acid was allowed to drip onto the limestone block in four locations (A, B, C & D) slowly dissolving the block to form a small pit. At each location the solution was allowed to drip for varying periods of time so that each pit is a different size.



Complete the following table by measuring the maximum depth of each pit in millimetres (mm) and recording in the correct column.

Location	Time period of dripping	Maximum depth of pit (mm)
A	28 days	7 mm
B	68 days	18 mm
C	44 days	11 mm
D	12 days	2·5 mm

On the graph paper, plot the depth of the pit (y axis) against the number of days (x axis). Make your x axis extend up to 120 days.

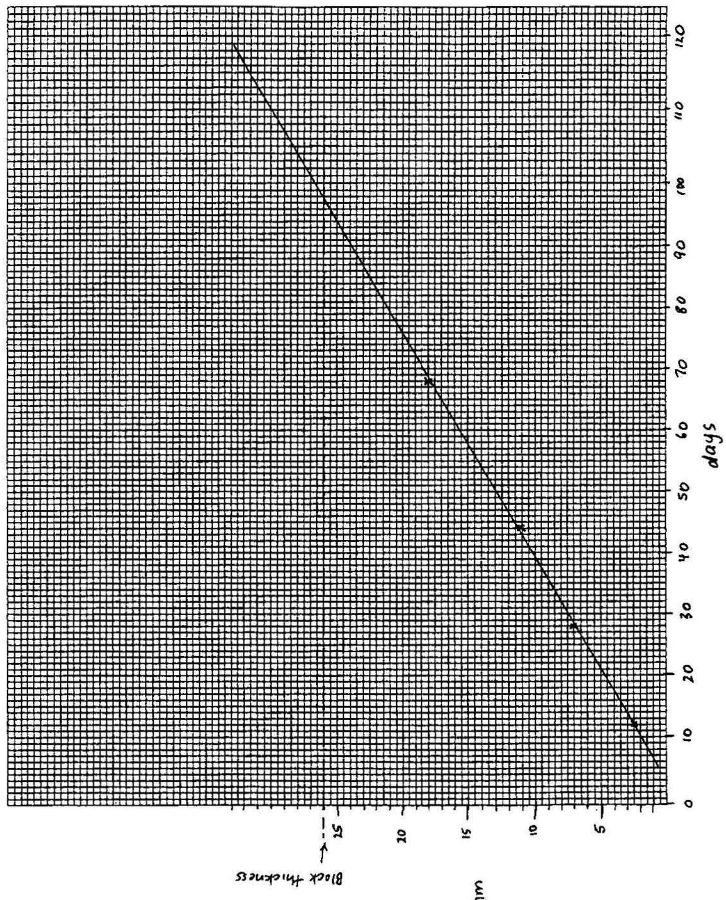
Use your graph to find out how many days would it take for a drip of the same acid to dissolve a pit through the entire block of limestone? 98 days

Use your graph to find out how long it takes for a drip of acid to dissolve through 1 cm of limestone? 39 days

The deepest cave in Australia is about 375 metres deep. How many days would it take for a cave this deep to be dissolved using the acid in this experiment? 1 462 500 days

What could you change in this experiment to increase the rate at which limestone is dissolved?

Concentration of the acid; the rate the acid dripped onto the limestone; purity of the limestone



Make Your Own Speleothems

What you need

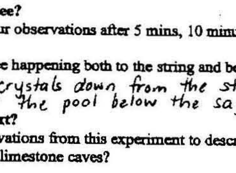
two disposable cups
spoon
one cup of Epsom salts
20 cm thick cotton string
aluminium foil or plastic
two paper clips

What to do

Find a place to set up this experiment where it will be away from drafts and not be disturbed.

Put half the Epsom salts into each of the disposable cups and then fill each cup with hot water. Stir the mixture so that the water becomes saturated with dissolved Epsom salts. Most of the Epsom salts will not dissolve but remain at the bottom of the cups.

Tie a paper clip to each end of the thick string. Wet the string well with tap water then place the ends of the string into the two cups as shown below in the photograph. Place the cups so that the string sags in the middle. Place a piece of aluminium foil or plastic beneath the string where it is sagging.



Crystals in cup

What do you see?

Write down your observations after 5 mins, 10 minutes and the next day?

What do you see happening both to the string and below the sag?
Growth of crystals down from the string and around the edges of the pool below the sag.

What to do next?

Use your observations from this experiment to describe the development of speleothems in limestone caves?

What could you do to change the rate of growth? Change the amount of Epson Salts in the cups or place in a warmer/colder room.
How is this experiment similar to the way speleothems form in caves?
Crystals forming from droplets of saturated water.
How is it different from the way speleothems form in caves?
Speleothems grow due to changes in CO_2 inside a cave.

Growth Chart

A stalagmite was collected at Jersey Cave, Yarrangobilly NSW, for dating. The stalagmite was cut lengthwise and four samples (A, B, C & D) were taken which were sent to a dating laboratory. The laboratory provided an age in years for each of the samples as well as the possible error in each of the ages in years.

Sample	Age (years)	Possible error (+/-) (years)
A	2 840	240
B	3 980	320
C	35 000	2 200
D	38 800	2 500

Using these ages we can calculate the growth rate of the stalagmite for three different periods of time as well as the average rate for the whole stalagmite.

Step 1.
On the image of the speleothem, measure the distance between each sample site in millimetres and record the distance on the table below.

Time Period	Distance (mm)	Difference in Age (yr)	Growth rate (mm/yr)
A-B	149 mm	1140 yr	0·1307 mm/yr
B-C	19 mm	31 020 yr	0·0006 mm/yr
C-D	37 mm	3800 yr	0·0097 mm/yr
A-D (average)	195 mm	35 960 yr	0·0054 mm/yr

Step 2.
Calculate the difference in age between the sample sites and record on the table.

Step 3.
Calculate the growth rates of the stalagmite by dividing the distance between sample sites by the difference in age. Write the results in the table.

Questions

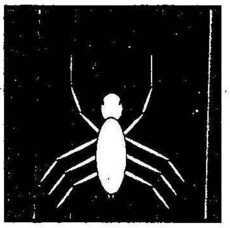
1. Between which dates did the stalagmite grow the fastest? A-B
2. Between which dates did the stalagmite grow the slowest? B-C
3. What factors in the environment may have changed the growth rate of the stalagmite? Change in climate - colder/dryer
4. How long would it take for this stalagmite to grow an additional metre in length (use the average rate of growth)? 185,185 yrs
5. What is the youngest possible age and oldest possible age of Sample A? (use the error figure provided in the chart) 2 600 yrs - youngest 3,080 - oldest
6. What happened around 18,000 years ago that may have changed the rate of growth for speleothems in eastern Australia?
   End of the last Ice Age (glacial maximum decline)

Living in a Dark World

Animals that are adapted to live their whole life in the dark areas of caves are called troglobites. These creatures have evolved in an environment very different from other animals, as they can't rely on sight to find their way, hunt or collect food.

What senses could these animals use to navigate, detect predators and find food in caves?

touch, hearing, smell, taste

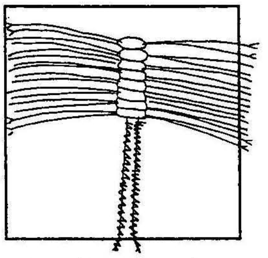


During a survey of a cave, a new troglobite species was discovered. The cave manager sketched the new animal. Using this sketch, write a detailed description of this new animal giving details including the shape and size of each body part.

The animal's body is 20mm long oval. From the body come 8 legs - 4 on each side. The legs are jointed and are 19mm long. The front legs extend forward. All others extend backwards. The head is 7mm long. Two feelers extend.....

The following description was written about a troglobite found in the same cave over fifty years ago. Use this description to draw the creature in the box below.

"The animal's body was 32 mm long and was made up of 8 segments. Each segment was identical and only 8 mm wide. Each segment has four legs, two from each side. The legs are 24 mm long. The legs on the end segments have small claws that are 2 mm long. From the final segment, two fury feelers extend for 50 mm. The whole animal is white in colour"



What further information would you like to have to complete your diagram?
What animals that live on the Earth's surface do each of these animals resemble?

DISCOVERING CAVES

Contents

Images on front cover:

Cave interior © Stephen Babka
Large Bent-wing Bat © Stefan Eberhard
Cave spider in her web © Norman Poulter OAM
The Giant Shawl © Stephen Babka

AGSO
AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

Discovering Caves

THE IAN POTTER FOUNDATION

Caves in Australia

The "chimneys" allow sunlight and cave explorers to enter the cave.

Dune limestones are easily dissolved. The roof of this cave is full of tube-like "chimneys" that can be seen on the surface.

Australia has about 10 000 known caves. This is a small number for such a large country. Although we have few caves — and most are small — each is unique.

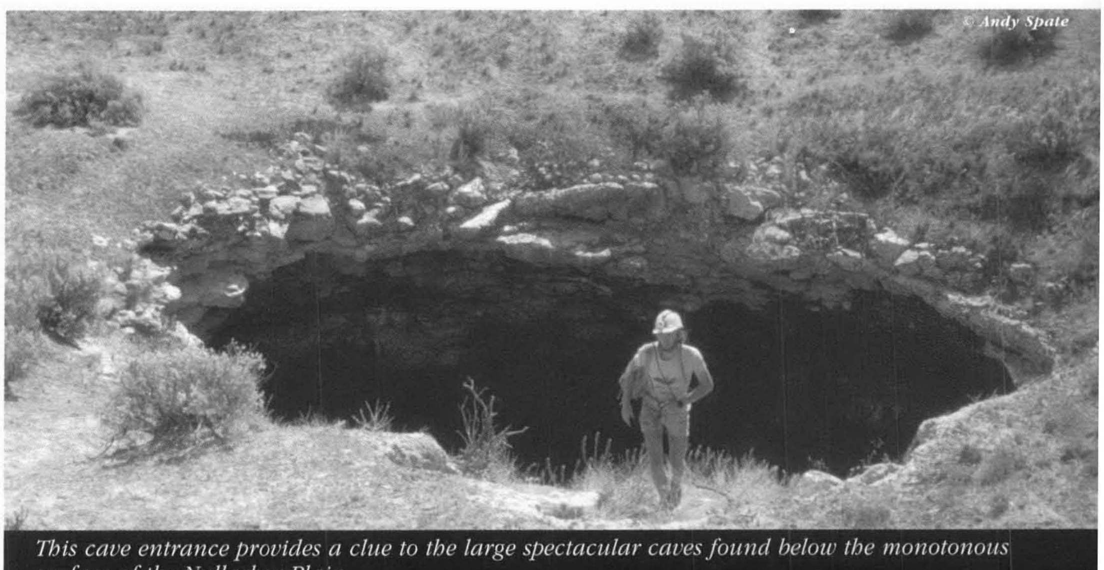
Caves are important to Australians for many reasons. Caves can be amazing places to explore. They provide homes to unusual and often rare creatures that can teach us about evolution. For example, the fossils of giant extinct animals that lived in Australia were first found in caves. Caves also preserve Aboriginal rock art and help us understand past climates. The rocks in which caves occur are sources of water and the rock itself is used to make many items we use in our everyday lives, from window glass to roads and medicines.

Australia has some unique cave landscapes. The Nullarbor Plain is the Earth's largest dry limestone area. In spite of the dry climate that has existed there for millions of years, it contains large and complex cave systems. The Limestone Ranges of the Kimberley in the north of Western Australia are made of rock that is similar to the limestone being formed at the Great Barrier Reef (limestone is often made of coral). However, the Limestone Ranges are ancient and stand up from the surrounding land — just as the Great Barrier Reef would today if we drained away the Pacific Ocean. Special cave systems also occur in very young limestone, mainly in Western Australia. This limestone is made of shell and coral fragments blown off the exposed sea floor to form sand dunes. The sea floor was exposed during the Ice Age when water was locked up in glaciers and sea level was low.

Caves are found along the entire length of the Great Dividing Range, in Eastern Australia. In addition, many deep caves occur throughout Tasmania while those of Naracoorte and Mount Gambier in South Australia are quite shallow.

- *Andy Spate*

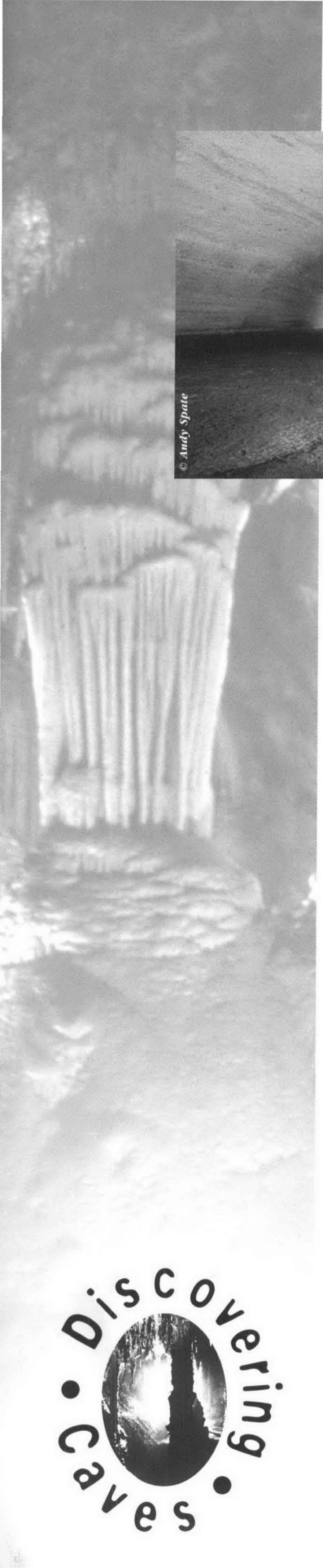
An aerial view of the Kimberley, WA. Many caves are found in the ancient reef limestones that make up these ridges.

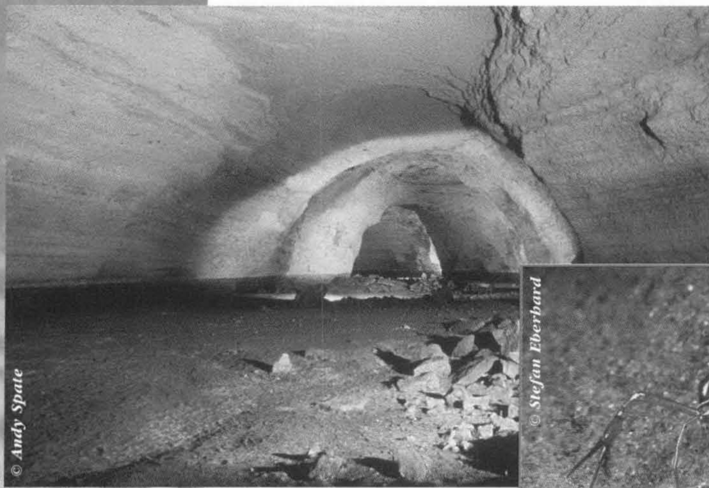


This cave entrance provides a clue to the large spectacular caves found below the monotonous surface of the Nullarbor Plain.

Discovering • Caves •

Australian Cave Facts



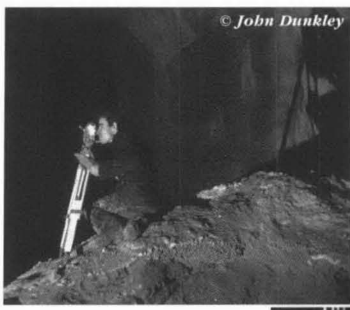


This chamber in Abrakurrie Cave, WA is the largest in Australia. It is 470 metres long by 35 metres wide and up to 30 metres high. Its floor would provide parking for almost 1000 cars.

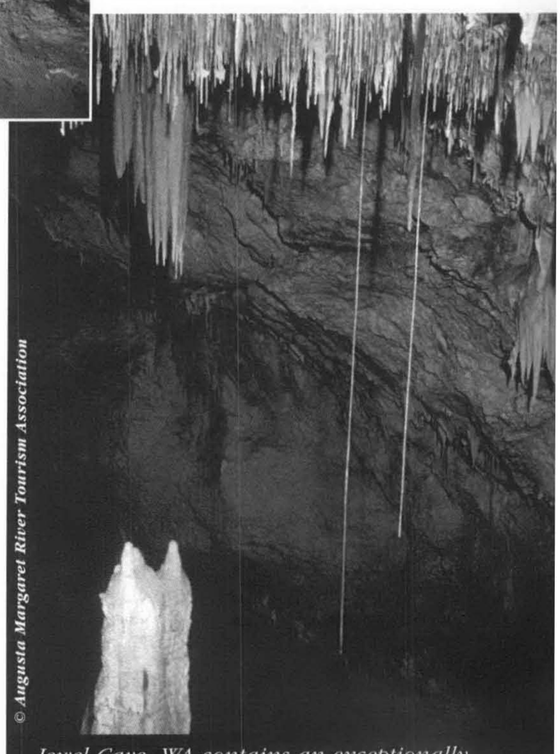
This cave pseudoscorpion is only found in the caves at Mole Creek, Tasmania. It is well adapted for living underground. The species may become threatened if the water or food supply in the cave dried up or became contaminated.

- The longest straw stalactite recorded in the Guinness Book of Records is found in Strongs Cave in Western Australia. It reaches 6.37 metres down from the ceiling. This is the length of about 31 drinking straws put end to end.
- The world's biggest salt stalactites and stalagmites are found in Nullarbor caves in Western Australia. One stalagmite made of salt reached 2.78 metres from the cave floor before it fell over. This is taller than the tallest basketball player.
- The deepest cave recorded in Australia is Niggly, Tasmania. Its highest and lowest points are 375 metres apart. This difference in depth is greater than the height of the 300 metre high Sydney Centrepoint Tower.
- The Bullita Cave system in the Northern Territory is the longest in Australia. By the year 2000, about 70 kilometres of passages had been surveyed and when surveying is complete the entire system will be nearly 100 kilometres in length. A cave explorer would take many weeks to visit all parts of the cave.
- During the last Ice Age some Aboriginal people were living in Tasmanian caves within sight of glaciers.
- Fossils of Mountain Pygmy Possums were first discovered at Wombeyan Caves, New South Wales in 1895. They were believed to be extinct but then were found alive at a ski lodge in Victoria in 1966.
- A mummified thylacine (Tasmanian Tiger) found in a cave in the Nullarbor, Western Australia was first thought to have died only a few years previously because the body was not badly decomposed. Radiometric dating revealed that it was 4650 years old.
- The longest lava tube cave in Australia is at Undara, Queensland, which is 1350 metres in length. This is 27 times as long as an Olympic pool.

\- *Andy Spate, Mia Thurgate, Jane Gough and Kathleen Kemp*



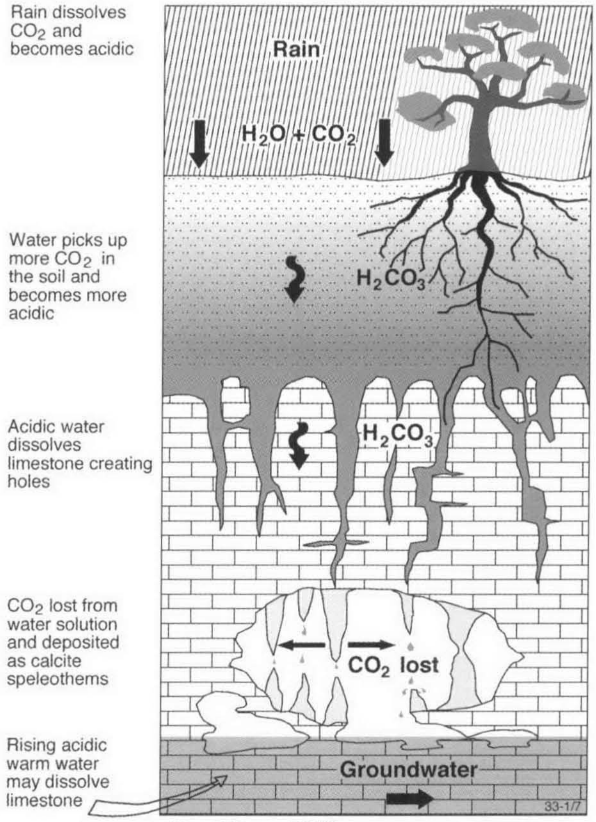
Cave surveys require special equipment, careful work and some ingenuity to get into awkward corners. Changes in the height of the roof and floor are recorded on the map as well as the shape of the chambers.



Jewel Cave, WA contains an exceptionally long straw stalactite that reaches for nearly six metres from the ceiling .

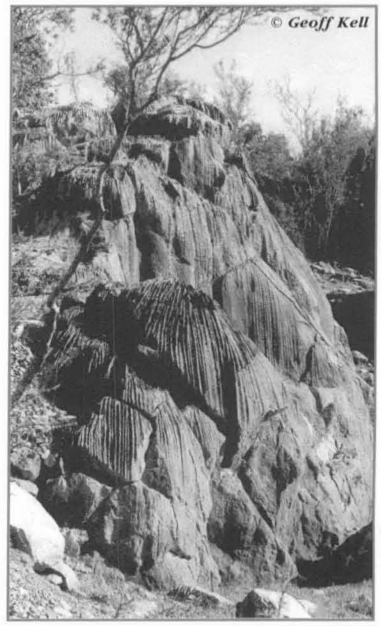
Discovering Caves

Dissolving Limestone to Form Caves



After Gillieson (1996)

The grooves in this limestone are formed by acidic rain running down the rock and dissolving it.



Caves usually form in carbonate rocks because they can be dissolved in water. Calcite ($CaCO_3$) is the most common carbonate mineral. The sedimentary rock limestone is made of the mineral calcite. When limestone is put under pressure and heated it becomes the metamorphic rock marble. A less common carbonate mineral is dolomite.

Acidic water is necessary to form caves. Only a small amount of carbonate can dissolve in pure water but carbonates dissolve more quickly in acidic water. When rainwater dissolves (or combines with) carbon dioxide from the atmosphere it becomes slightly acidic. The rainwater becomes dilute carbonic acid.

H^2O	+	CO^2	=	H^2CO^3
Rainwater		carbon dioxide		carbonic acid

As water soaks through the soil it can become more acidic by dissolving carbon dioxide gas released by roots and decaying plants and animals. When the carbonic acid reacts with calcite it dissolves the calcite. The dissolved calcite components remain in the water.

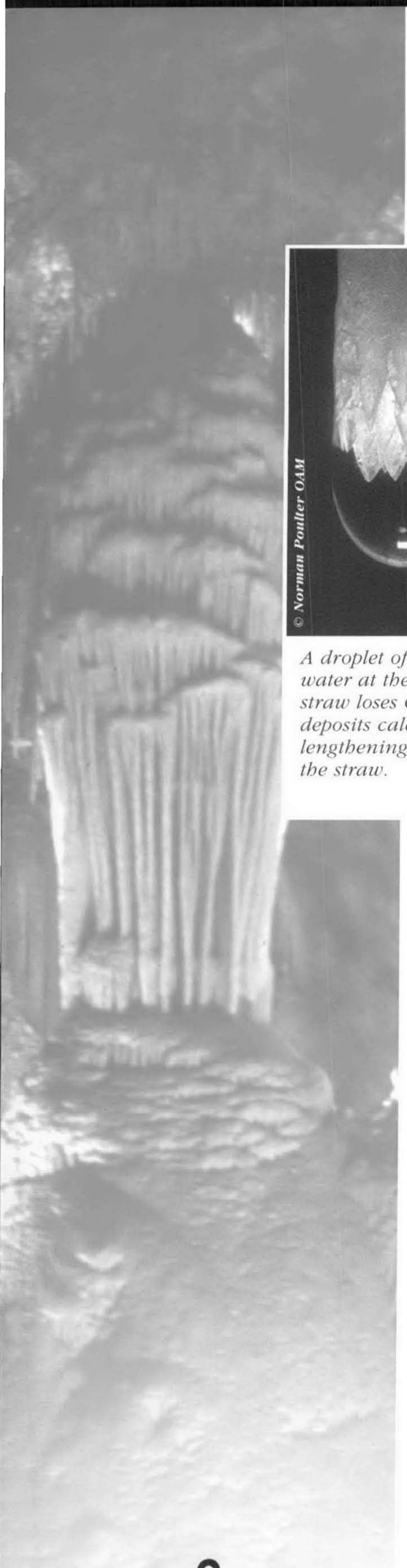
H^2CO^3	+	$CaCO^3$	=
carbonic acid		calcite	
Ca^{++}	+	$2\ HCO^{3-}$	
calcium ion		hydrogen-carbonate ions	

The water will continue to dissolve calcite until it is saturated with dissolved calcite components. An example of a saturated solution is when so much sugar is added to tea that the sugar no longer dissolves in it and it leaves undissolved sugar in the cup. Over time a large volume of acidic water can dissolve enough limestone to produce caves. Acidic water can also be produced deep in the ground by sulfur released from petroleum and mineral deposits or by gases released by molten rock.

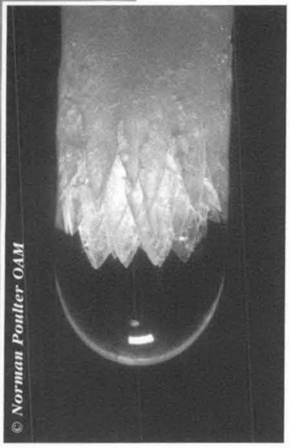
- *Kathleen Kemp*

Discovering Caves

Solution pans or hollows form by the dissolution of limestone. JN Jennings, who did research on Australian caves for many decades, is testing the water to determine its composition.



Nature's Way of Decorating Caves

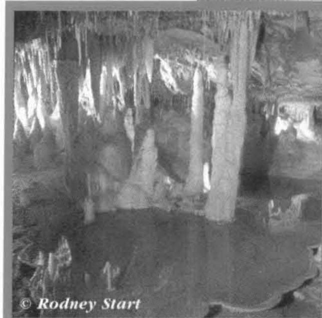


A droplet of saturated water at the end of a straw loses CO^2 gas and deposits calcite crystals lengthening the straw.

Australian caves are often well-decorated, containing many speleothems such as stalactites and stalagmites. This is because chemical conditions allow a lot of calcite to dissolve in the water that eventually reaches the caves. The chemistry of the cave air then allows the calcite to be redeposited from the water. Sometimes bacteria play a role in creating speleothems as well.

Speleothems grow at vary different rates. One person found that some stalactites grew 7 cm in 10 000 years while in other places they can grow 4 cm in one year. Growth stops if water stops flowing into a cave. A common misconception is that evaporation is the main process that forms speleothems.

Acidic water becomes saturated with calcite components while it moves through tiny gaps in limestone. When the saturated water seeps into an open cave it encounters air that has a lower content of CO_2. The saturated water releases CO_2 gas into the air. This is similar to the way that lemonade produces bubbles of CO_2 when you lower the pressure inside a bottle by removing the cap. When CO_2 gas is released from the saturated water it decreases the amount of these chemicals that the water can keep dissolved. The excess components are then deposited as calcite speleothems. This process is the reverse of that which produced caves by dissolving limestone.



Calcite crystals form at the edge of a pool of cave water and create small walls.

$$Ca^{++} + 2\,HCO^{3-} =$$

Calcium ion; Hydrogen carbonate ions

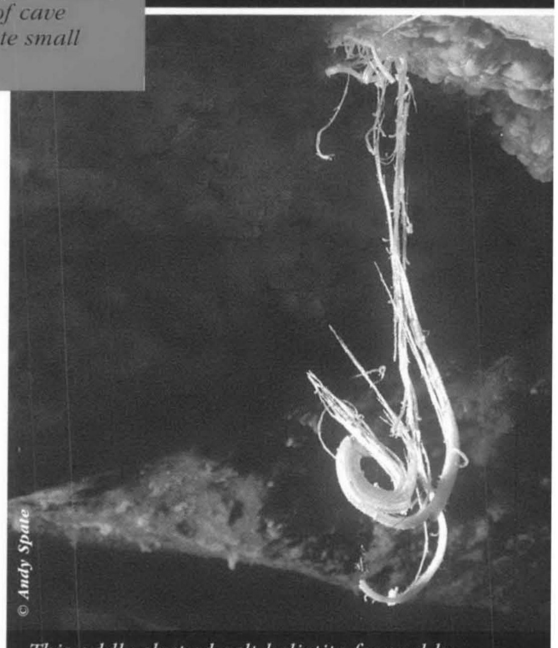
$$CO^2 + CaCO^3 + H^2O$$

carbon dioxide gas; calcite; water

Minerals other than calcite, such as table salt (NaCl), can be dissolved in water. These minerals are also deposited when the water in which they are dissolved is exposed to different chemical conditions and can no longer hold the chemicals in solution. Many salt and gypsum speleothems form by evaporation in caves in the Nullarbor, southern West Australia and South Australia.

- *Kathleen Kemp*

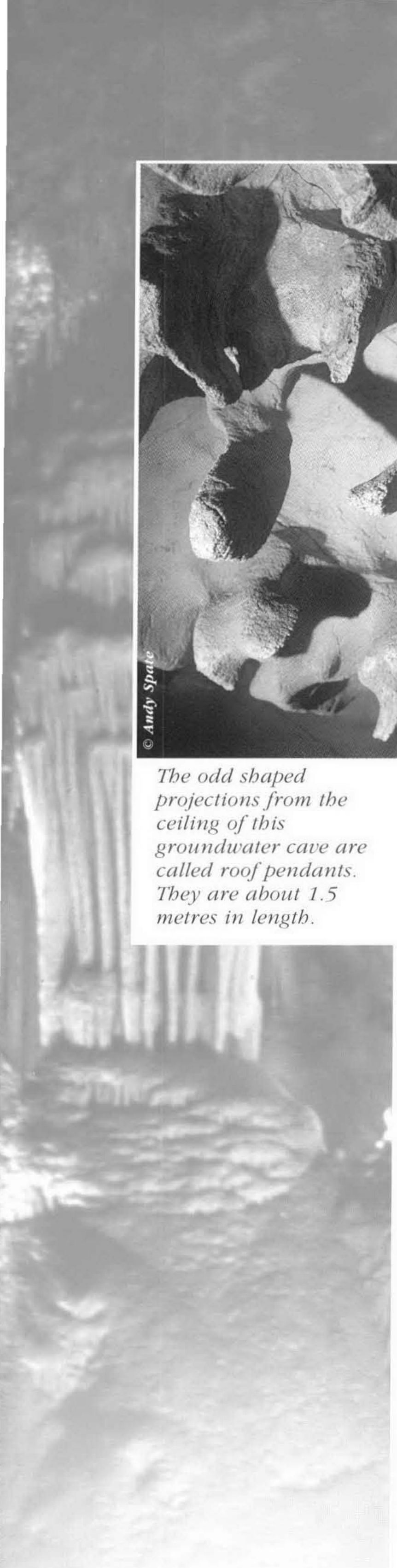
Speleothems need water saturated in dissolved calcite components to continue to grow.



This oddly shaped salt helictite formed by evaporation in a Nullarbor cave because the arid climate has concentrated chemicals in cave water. Unlike calcite speleothems, these salt helictites grow from their bases.

Discovering Caves

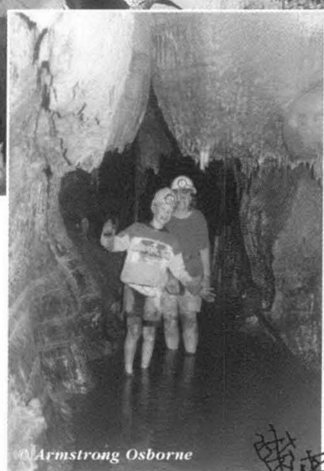
Making Limestone Caves

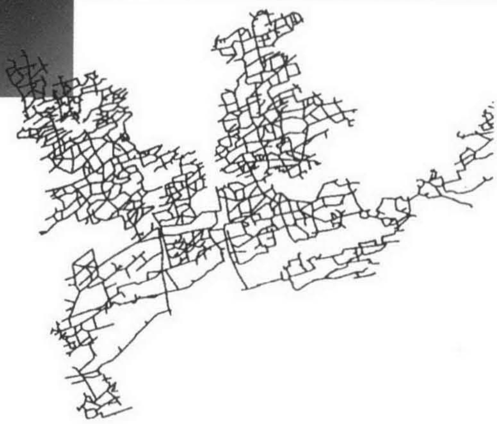


The odd shaped projections from the ceiling of this groundwater cave are called roof pendants. They are about 1.5 metres in length.

Limestone often contains cracks that cross one another. Water travels through the cracks and dissolves the limestone widening the fractures. Eventually these openings may become a cave.

This stream is dissolving limestone and extending the cave downward.





A map of a maze cave shows how the cave has developed along two sets of fractures like those in the photograph above. (Canberra Speleological Society and Don Glasco)

Caves begin to form along particular cracks or layers in limestone as water moves through the rock. This occurs below the level in the ground where cracks are completely filled with water (known as groundwater). Water dissolves the surrounding rock. Most groundwater is rainwater that has come from the surface and soaked through soil. Some groundwater is warm water rising from deeper in the Earth, as in the Great Artesian Basin.

Groundwater caves have rounded walls, high domed ceilings and strangely sculptured pieces of rock projecting from the floor, walls and ceiling. These features result from rock being dissolved in three dimensions (3-D). These caves closely follow cracks and layers in the rock. Flowing water in these caves behaves as if it is in a pipe and can even flow uphill. Examples of groundwater caves include Nullarbor caves and the flooded caves of Mount Gambier.

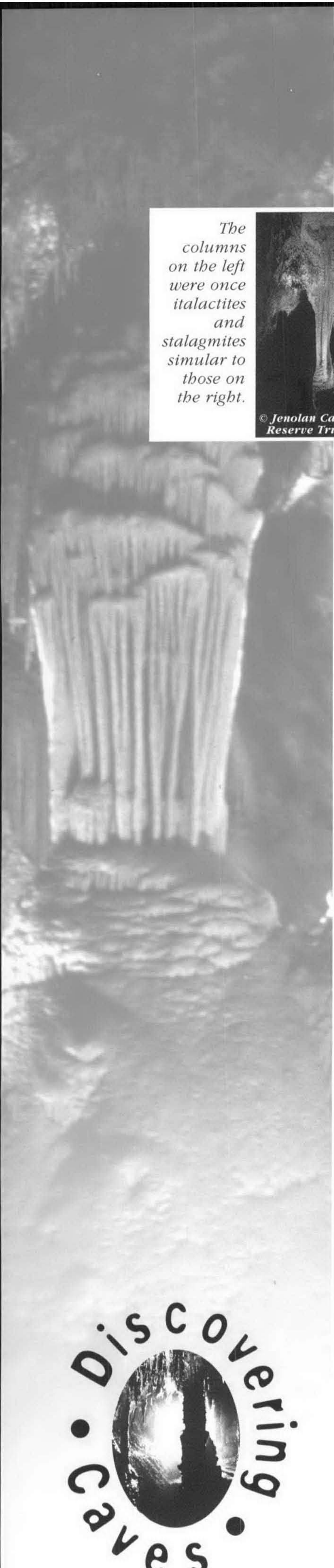
Erosion of the surrounding landscape can allow the water to drain from the cave. The cave then becomes filled with air and the water in the cave behaves like a normal stream. Water then erodes downward, forming canyons with streams and waterfalls flowing through them. Caves that are modified in this way are called stream caves. Examples are Royal Cave, Buchan (Victoria) and Jersey Cave, Yarrangobilly (New South Wales).

Maze systems occur when solution along cracks over long periods of time results in complex cave maze systems. Dune caves form in geologically young (from 10,000 to 6,000,000 years ago) limestone dunes found on the coast from Bass Strait into Western Australia. These are irregular maze systems that may have underground streams. Kelly Hill Caves on Kangaroo Island off South Australia are good examples.

- *Armstrong Osborne and Susan White*

Discovering Caves

Stalactites, Stalagmites and Other "Cave Things"

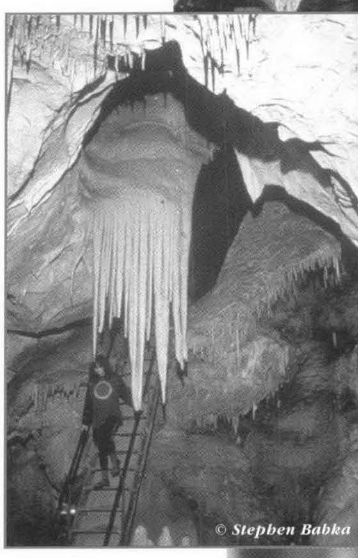


The columns on the left were once italactites and stalagmites simular to those on the right.

© Jenolan Caves Reserve Trust

Speleothems (or "cave things") are rocks made from chemicals that were dissolved in the water dripping through the roof of a cave or flowing through a cave. Straws, stalactites, stalagmites and flowstone are all types of speleothems. Most speleothems consist of the mineral calcite (calcium carbonate). Calcite forms when the gas, carbon dioxide (CO_2), is released from cave water.

A straw forms when a water drop on the cave roof loses CO_2. A ring of calcite crystals forms around the drop. Water keeps flowing through the hollow centre of the ring, depositing calcite and forming a straw. If a straw is blocked, water will flow over the outside and deposit calcite creating a stalactite. Stala**c**tites hold tightly to the **c**eiling of a cave. Water drops falling from stalactites hit the floor, lose more CO_2 and deposit stala**g**mites on the **g**round. Columns form when stalactites growing down from the cave ceiling join with stalagmites growing upward from the cave floor. Water drops can also meander along the sloping roof and sides of a cave, depositing calcite in a wavy ridge that can grow into a shawl or a folded curtain. Helictites are speleothems growing from the roof that twist and curl.



© Stephen Babka

This large canopy consists of flowstone with a fringe of stalactites.

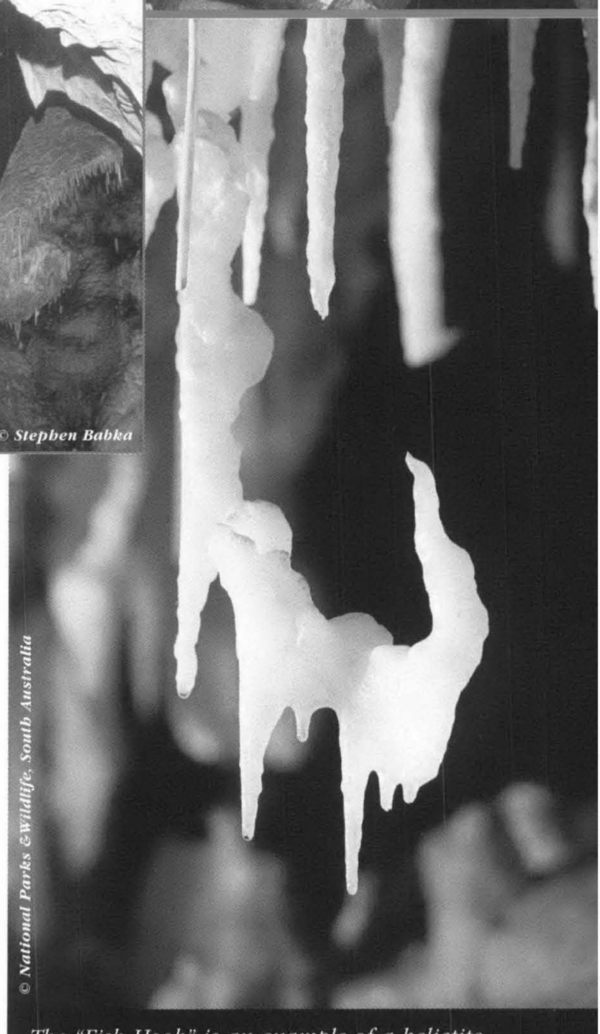
When water flows down cave walls or along floors, sheets of calcite are deposited as flowstone. Sometimes flowstone forms over pebbles that are later washed away leaving a flowstone ledge with nothing beneath it.

Speleothems with colours such as yellow, brown, orange and red are made of calcite stained by iron and organic material (from dead plants and animals) that were dissolved in the cave water. Unusual colours such as black, blue and pink may be due to manganese, copper and organic materials. White calcite is free of impurities that cause colour. Large pure crystals are transparent.

- *Kathleen Kemp and Andy Spate*

This shawl is lit from behind to bring out the stripes of various colours that were caused by iron impurities.

© Stephen Babka

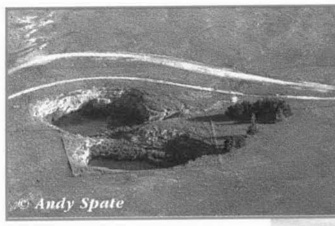


© National Parks &Wildlife, South Australia

The "Fish Hook" is an example of a helictite.

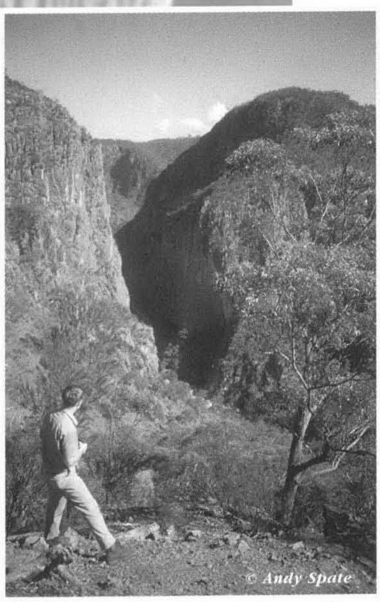
Discovering Caves

Karst Landscapes and the Movement of Water



These water-filled depressions formed by the collapse of the ground into the caves. The road provides a clue to the size of the collapse depressions.

Karst landscapes have unusual features such as pits, caves, springs, grooved rock, steep hills, gorges and streams that seem to disappear into the ground. Karst forms because carbonate rocks such as limestone dissolve easily in naturally acidic water. This dissolution creates holes such as caves, but it can also leave behind undissolved towers and ridges of rock. Not all karst areas are rugged; the Nullarbor Plain, which contains spectacular karst caves, is flat. Old landscapes, such as Arnhem Land, Northern Territory also develop karst features in resistant rocks such as quartzite and sandstone by dissolving gradually over very long periods of time.

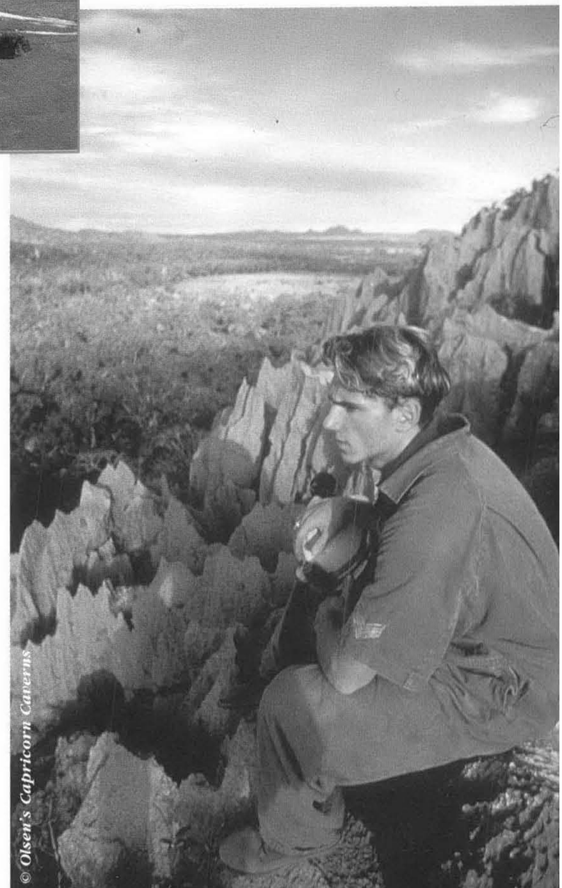


Limestone dissolves fairly easily so it erodes more quickly than the surrounding rock types, forming this steep-sided gorge.

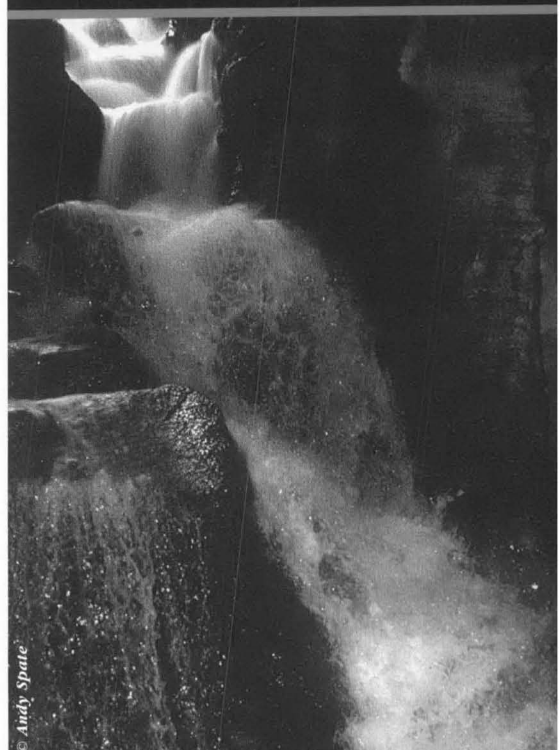
Solution depressions are hollows on the Earth's surface which form when limestone beneath is dissolved. They have gentle slopes and are usually shallow. Collapse depressions have steep sides and form by the (sometimes sudden) collapse of the ground's surface into a cave creating a new cave entrance.

The water from streams that suddenly disappear below the surface continues to flow underground. It is difficult to know the route this underground water takes. In karst areas, water flow is often controlled by folds and faults in rock. They can produce passages that allow water flow in directions that cannot be determined using the shape of the hills and valleys on the surface. Even though some valleys are separated by hills on the surface, water can flow between the valleys through caves. Water may even flow uphill under pressure. One way to test where water is going is by putting harmless fluorescent dye into water where it goes underground and later finding it at surface springs when the water re-appears. An important issue is that waste dumped in karst areas may contaminate underground water and affect surrounding areas.

- *David Gillieson and Kathleen Kemp*



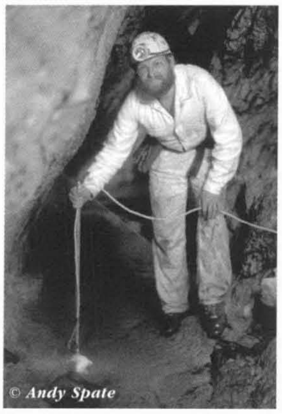
This spiky karst landscape was produced when naturally acidic rainwater dissolved limestone and left more resistant rock behind.



Water in the ground usually seeps through tiny gaps in rocks. In contrast, caves may have rivers flowing through them. These waterfalls occur in a cave in Tasmania.

Discovering Caves

Using Land and Caring for Caves



Measuring water flow and chemistry can show how changes in land use are effecting the cave and its inhabitants.

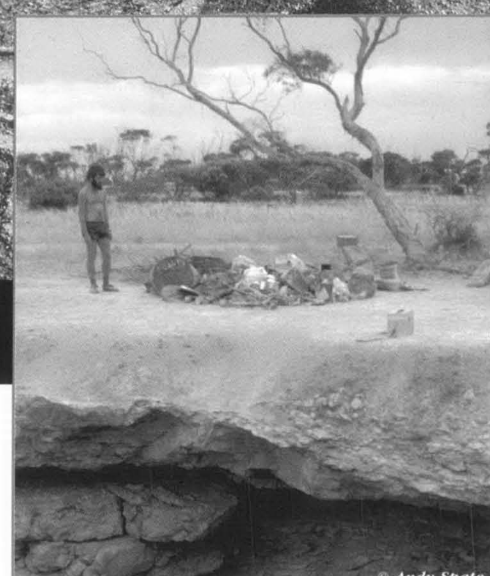
Cave conservation depends mainly on managing the land in which caves are located. Human activity occurring many kilometres from a cave can affect it, so the entire water system connected to a cave must be protected. Some caves and unique fossils have been removed by mining for limestone and phosphate.

The rock in which caves occur is full of holes and water travels through it quickly. Polluted surface water does not have time to be purified and arrives in caves still polluted. For example, sewage, cheese factory wastes and timber treatment liquids dumped into caves polluted underground water in parts of South Australia. This water eventually provides the towns above the caves with drinking water, so the dumping has been stopped.

Cave areas have often been the focus of land use conflicts. Mount Etna in Queensland is an example of reconciliation between a company that mines limestone and people who value caves. Limestone is needed to make cement that is used to build houses and roads as well as for manufacturing paper a flux in smelting and many other uses. The caves at Mt Etna are home to large colonies of bats that help control moths on nearby vegetable and fruit farms. After many years of dispute the company agreed not to mine their leases near these caves. The mining company also helped buy additional land for Mount Etna Caves National Park and will return areas that have been quarried to a more natural state. Today limestone is being quarried in a way that preserves the beautiful caves and protects the Little Bent-winged Bats raising their young in the caves.

- *Elery Hamilton-Smith and David Gillieson*

Redirecting and filtering water in this quarry rehabilitation project has decreased the amount of sediment being carried into caves.



Surface depressions and caves have often been used as rubbish pits. Cavers remove garbage to stop pollution and provide access to caves once again.

Caves can be destroyed by altering the volume of water entering the cave. Caves have been flooded following the construction of dams. Irrigation, soil compaction, climate change and exotic vegetation can change water levels and water chemistry in caves. Without water with the correct chemistry, caves and speleothems stop forming and cave creatures die.

Discovering Caves

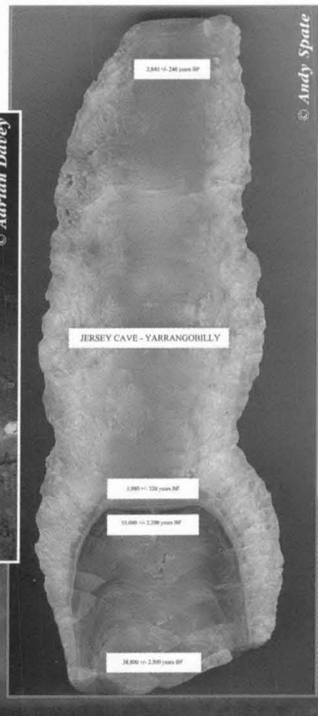
Determining the Age of Cave Deposits

Stalactites and stalagmites (speleothems) are usually dated using radiometric dating that gives an estimate in years. Mud and sand (sediments) that collect in caves are usually dated by palaeomagnetism. This identifies whether sediment is older or younger than one of Earth's natural magnetic reversals. The age of some stalagmites can be determined using bands caused by changes in composition. It may be possible to see each layer in a stalagmite as another year's growth, much like counting tree rings.

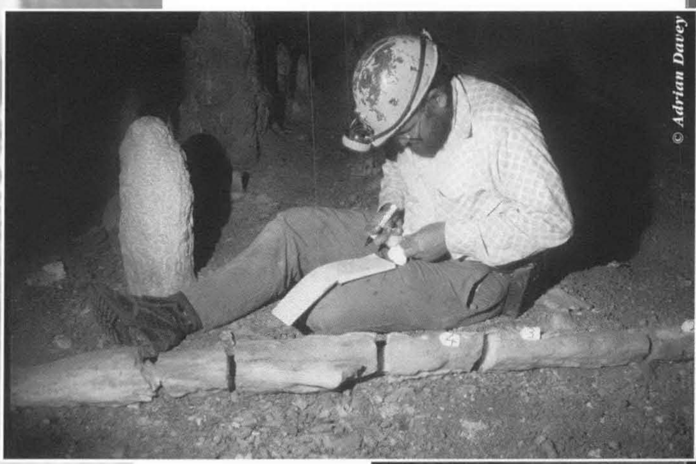
Radiometric dating depends on the fact that most water at the Earth's surface contains tiny amounts of dissolved uranium. This uranium is included in calcite deposited in caves as speleothems. Uranium is radioactive or unstable, and decays to form other elements, thorium and lead; these "daughter elements" remain within the speleothems. In older speleothems, more of the uranium will have decayed to thorium (and lead) than in younger speleothems. By measuring the ratio of the original uranium to daughter thorium, it is possible to calculate the age of the calcite. This technique can accurately date rocks that are up to 400 000 years old.

Palaeomagnetic dating uses the tiny grains of magnetic minerals (magnetite and haematite) that were washed by rain or rivers into caves with the surrounding sediment. Each magnetic grain acts like a tiny compass needle and points to magnetic north and retains, to some extent, this position. The Earth's magnetic field reverses every so often, so that for periods of time the south magnetic pole becomes the north magnetic pole. The Earth's magnetic field last reversed 780 000 years ago. This means if the magnetic grains within a layer of cave sediment point to the south pole, this sediment must have been deposited more than 780 000 years ago.

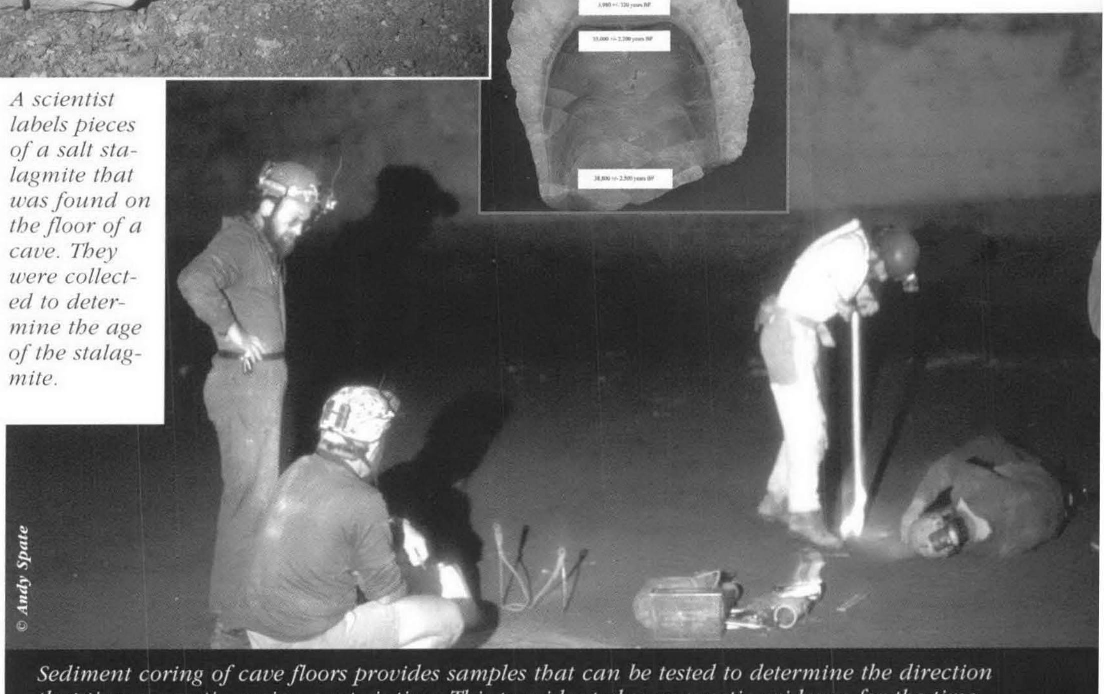
\- *John Webb*



This stalagmite has been sawed in half and polished. Tiny calcite samples were taken to measure uranium and thorium contents and to determine their ages.



A scientist labels pieces of a salt stalagmite that was found on the floor of a cave. They were collected to determine the age of the stalagmite.



Sediment coring of cave floors provides samples that can be tested to determine the direction that tiny magnetic grains are pointing. This provides palaeomagnetic evidence for the time when the sediments were deposited.

Discovering Caves

How Caves Tell Us about Past Climates

Water falling from the roof of the cave is collected and its composition is compared with the chemistry of rainwater collected above the cave. This shows scientists how climate changes are reflected in the chemistry of cave water and in the speleothems they produce.

Caves may preserve evidence of past climates (the average weather over many decades or centuries), particularly the temperature and rainfall of an area. This information is recorded in the mineral calcite that makes up speleothems (stalactites and stalagmites). Caves can provide information on climatic change across Australia because they are found in a wide range of environments. We use radiometric dating or bands of the calcite to determine when these climate changes occurred.

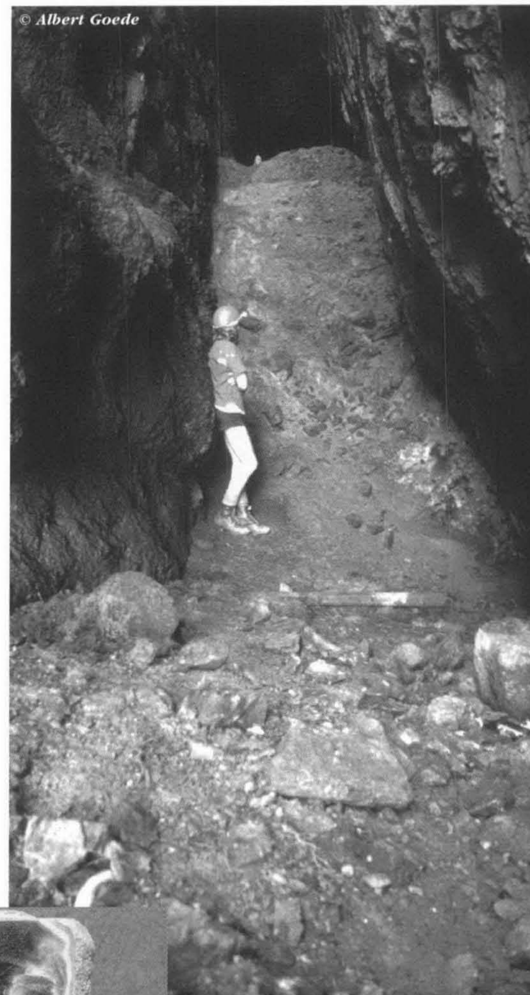
Speleothems grow quickly when rainfall is high. Slow growth suggests cool or dry conditions. Growth stops when there is no flow of water through the ground. This can occur when the climate is cold and water freezes or when the climate is very dry.

Dense calcite without holes is deposited by water in air-filled caves. In caves filled with seawater, calcite can still be deposited but is full of holes. This means that we can determine whether an old coastal cave was once flooded by seawater or whether sea level was low and the cave was filled with air. Sea level was low during the Ice Age when water was locked up in glaciers.

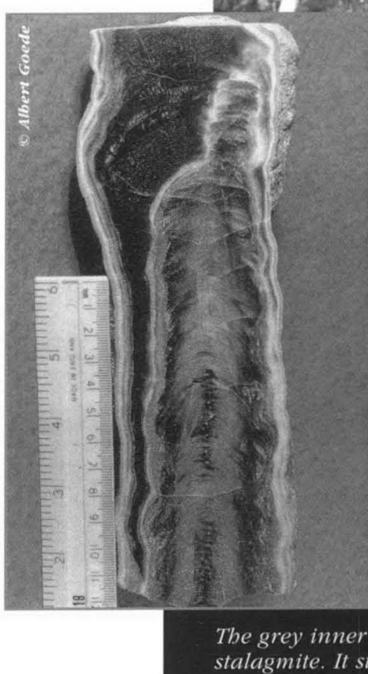
Most caves have air temperatures close to the annual average that occurs on the surface. In some parts of the world the proportion and version of oxygen included in calcite changes with the air temperature. At higher temperatures a higher proportion of ^{16}O (called "oxygen 16" because it has a mass of 16 atomic units) as opposed to the heavier version of oxygen, ^{18}O, will be included in the calcite speleothems. In tropical areas, however, the proportion of different versions of oxygen is influenced by the amount of rainfall rather than temperature.

Animal and plant remains found in caves also tell us about the climates that existed when they were alive. Remains of a tropical plant indicate the climate was tropical when the plant was alive.

- *Kathleen Kemp*

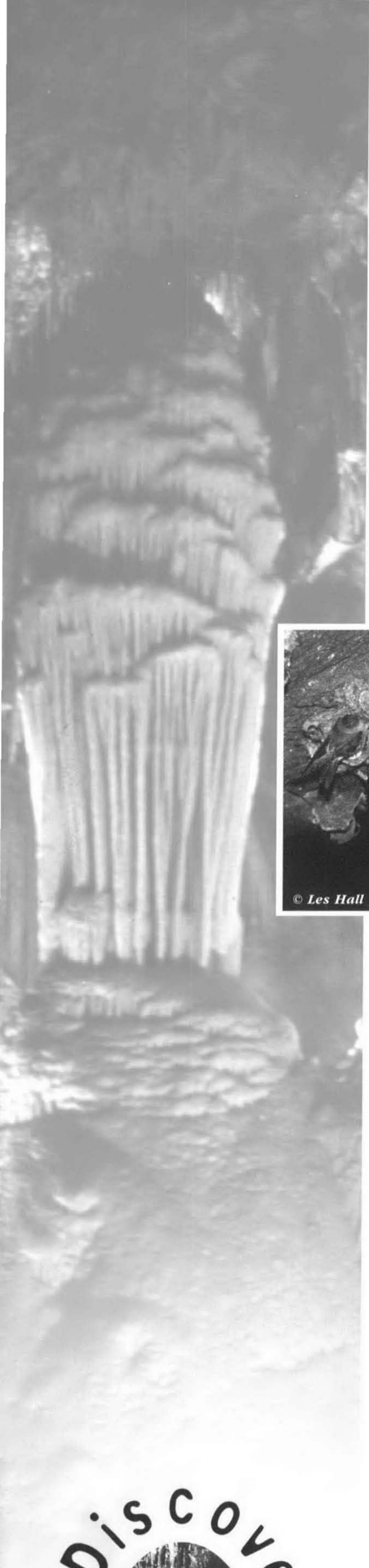


This sea cave in Tasmania originally formed when sea levels were low. Most of the entrance of the cave was later filled with broken rock during the last Ice Age. This broken rock was moved around afterward by waves during higher sea levels, caused partly by the melting glaciers.



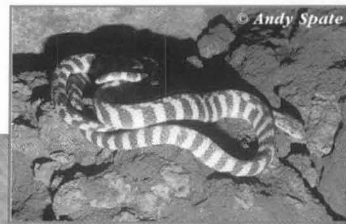
The grey inner area is the oldest part of this stalagmite. It stopped growing and started to dissolve when the climate changed. A later climate change resulted in the deposition of a white layer followed by the black coloured calcite.

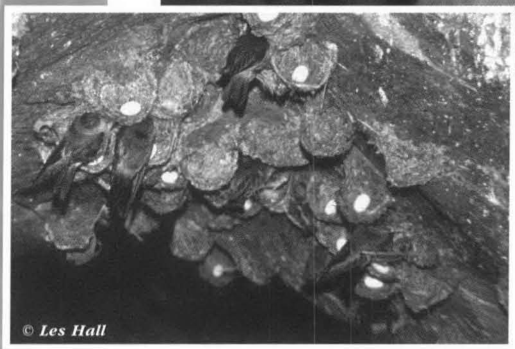
Discovering Caves



Bats, Birds and Other Vertebrates that Live in Caves

This snake lives in caves in the Northern Territory. It eats bats that also live in the cave.





These Little Bent-winged Bats have been disturbed by humans who entered their cave roosting site. The bats use echo location to avoid crashing into each other and cave walls.

In the breeding season these swiftlets build nests for their eggs high on the walls of caves. At night they sleep in caves and during the day they leave the cave to feed on forest insects.

A wide variety of animals with backbones (vertebrates) live in caves. Most are taking advantage of the even temperature and humidity in caves. Caves also provide a safe retreat from predators.

Birds such as swallows and hawks tend to roost and nest near the cave entrance on cliffs or ledges. In north Queensland, swiftlets attach their nests to the walls deep inside caves. There are blind, white fish that live permanently in the dark waters of caves where they have no need of body pigment or sight.

Accidental visitors that may fall into caves or be washed into them include animals such as fish, frogs, snakes, lizards and wallabies.

Bats are trogloxenes (TROG-lox-zenes) because they live in caves but also leave them to find food. Bats can live far from the cave entrance in total darkness. They find their way in the dark using echo-location. When a bat squeaks the echo tells it what is nearby. Bats allow the temperature of their bodies to match the air temperature; therefore they choose caves that are warm or cool depending on the time of year. In early summer, female bats choose maternity caves (places to give birth and raise their young) that are warm and have domed ceilings that trap heat. The mothers and their young also crowd together to raise the temperature of the top of the cave. In winter some bats "sleep" in cool caves to save their energy. These bats drop their body temperature, heart and breathing rates and "sleep" for many days at a time. Bat guano (droppings) and bodies of dead bats provide food for the creatures that live on the cave floor.

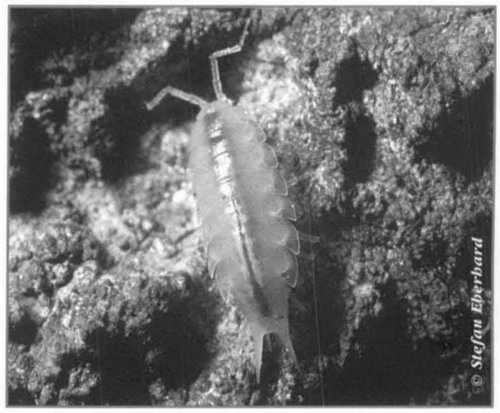
- *Les Hall*

The blind gudgeon is a cave fish from Cape Range, WA. This species is one of only two troglobitic vertebrates known in Australia.

Discovering Caves

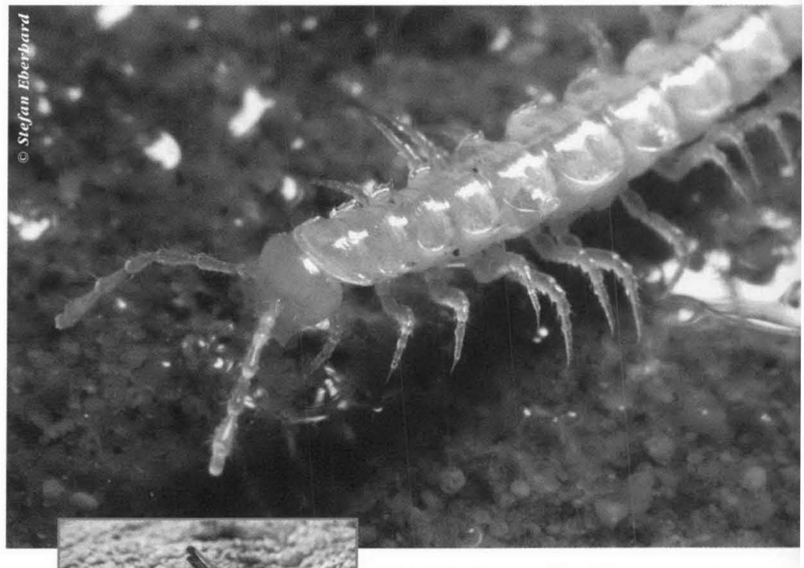
Creepy Crawly Invertebrates that Live in the Dark

Many invertebrates (animals without backbones) live in caves. Troglobites (TROG-low-bites) live in total darkness. They are blind and delicate and some have bodies that allow light to pass through them, and cannot exist outside caves. To compensate for their blindness they have longer antennae, legs and pincers than their relatives living on the Earth's surface. Typically they grow slowly, live for a long time and produce few young; therefore, troglobites are easily hurt by human activity. Troglobites depend on food entering the cave from the outside, either brought in by other animals (for example, the bodies and droppings of cave crickets) or leaves and animal bodies carried into the cave by water. Deep in caves there is no light so plants that need light to grow cannot survive.



This troglobitic slater has no eyes. Its gut can be seen beneath its thin and fragile exterior skeleton.

Cave millipedes are troglobites that live in dry areas of caves. They resemble millipedes that live on the surface but have no eyes or body pigment.



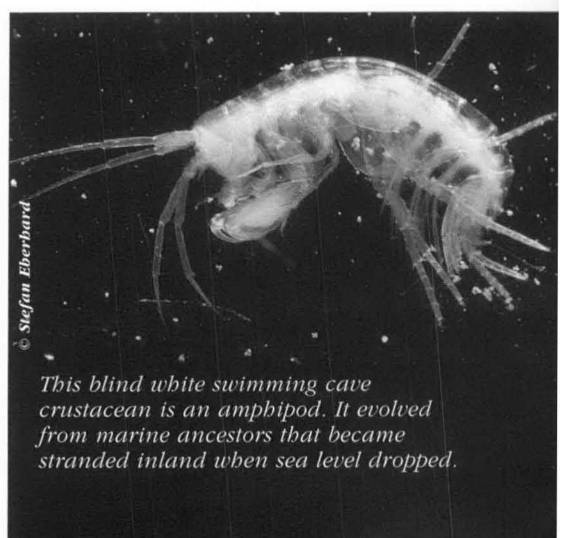
In the dry parts of caves, troglobites include arachnids (spiders, mites) and insects (beetles, cockroaches), millipedes, centipedes and slaters. They are usually related to animals that live in the dead leaves on the ground of forests where the dark, damp conditions are similar to those found in caves. Glow worms are gnat larvae (the young form of flies) which produce light using chemicals to attract prey. They can put on spectacular 'light shows'.

Cave-loving crickets live in caves and similar moist, sheltered surface habitats. The long antennae help the crickets navigate and detect food and enemies in the dark.

The troglobites that swim in cave waters have evolved from freshwater animals that live on the Earth's surface, or from sea creatures that entered caves long ago when the sea level was higher than it is today. Crustaceans are the most common animals in cave waters; they include amphipods, slaters, and shrimps. Various worms also live in cave waters, but swimming insects are rare.

Many caves in the world have unique troglobites so new cave animals are always being discovered.

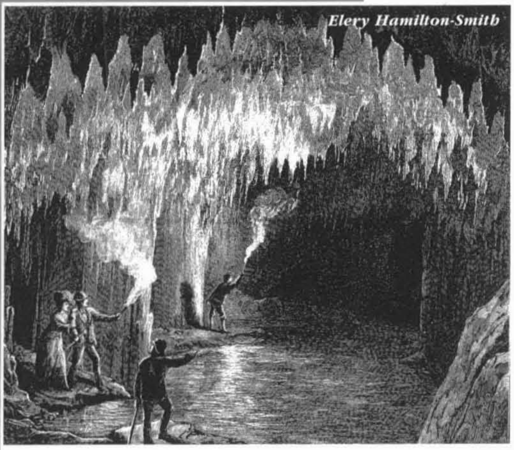
- *Bill Humphreys*



This blind white swimming cave crustacean is an amphipod. It evolved from marine ancestors that became stranded inland when sea level dropped.

Discovering Caves

Human Use of Caves



Early tourists in Oakden's Cave, Tasmania, from the Illustrated Sydney News, 15 September 1877.

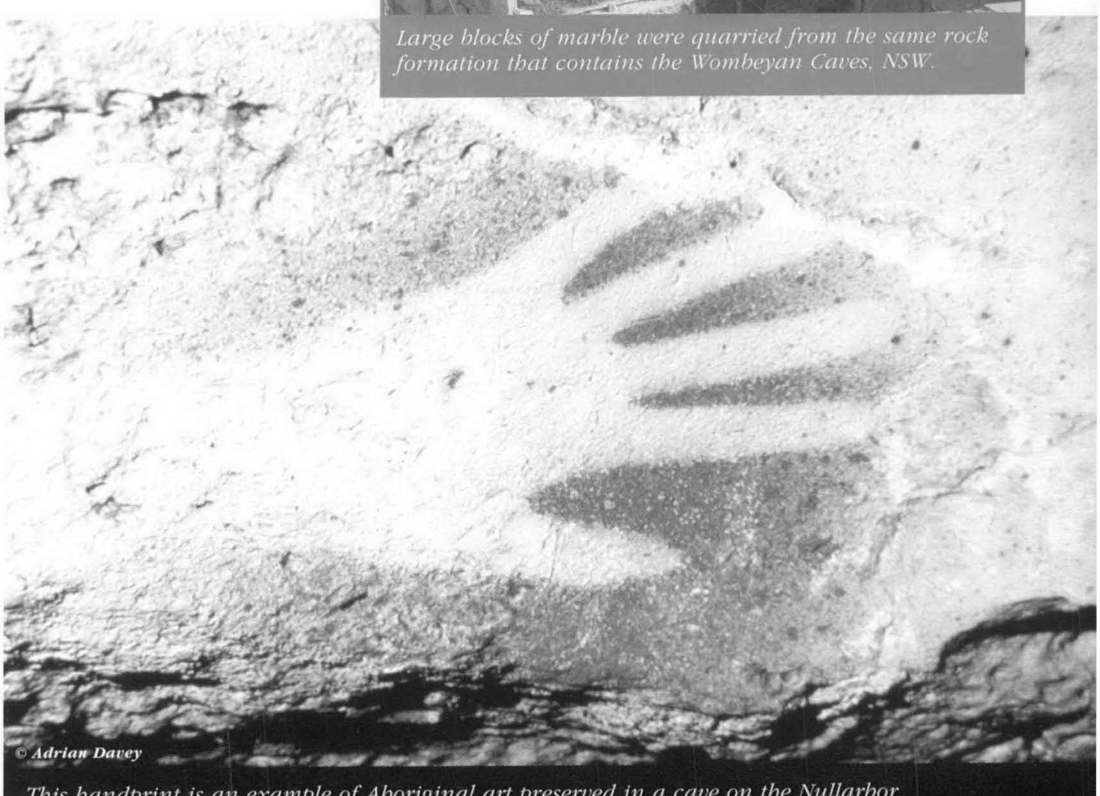
The cave site of Zhoukoudian, China, home of the Peking Man, shows that people have used caves for at least 1.5 million years. Indigenous Australians used caves as their homes, cooking places, burial sites, workshops for making stone tools, and places to decorate with symbols and pictures. Since tourism began, long before the birth of Christ, caves have been visited, and today many millions of people around the world visit tourist caves annually. Caves are also used as sources of water for irrigation and hydro-electricity, hiding places during war and they provide unique conditions for cheese-making (including Roquefort blue). The droppings of cave-dwelling bats and birds can be used for fertiliser, and the limestone in which caves form is excavated for agriculture and construction.

Early Europeans in Australia explored caves. In 1838 Sir Thomas Mitchell found fossils belonging to giant extinct animals in the Wellington Caves, NSW. These fossils became famous, capturing the interest of Charles Darwin and other scientists. The story of Wellington and its fossils also appeared in Australia's first children's book. Around 1841 the spectacular Jenolan Caves were discovered. The first curators at Jenolan Caves, Jeremiah Wilson and his brother Frederick, were men of remarkable enthusiasm and vision. They ensured the protection of the caves, and used the best technology available at the time to show the caves to visitors. Jenolan Caves were the first in the world lit by electricity, and the site of the first hydro-electric plant in Australia. For many years Jenolan was the most popular tourist area in Australia.

Researchers find valuable information about human history, past climates and the evolution of life in caves.

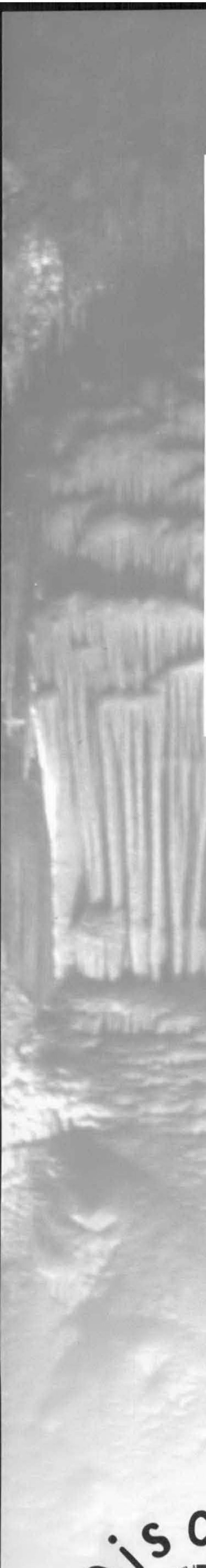
- *David Gillieson and Elery Hamilton Smith*

Large blocks of marble were quarried from the same rock formation that contains the Wombeyan Caves, NSW.

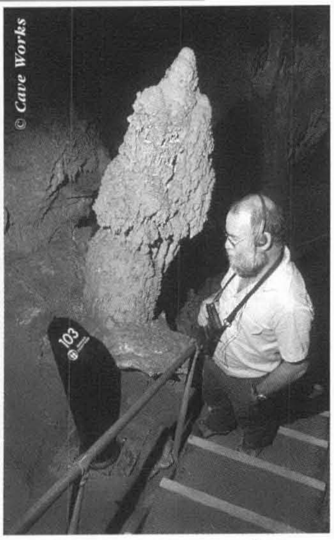


This handprint is an example of Aboriginal art preserved in a cave on the Nullarbor.

Discovering • Caves •

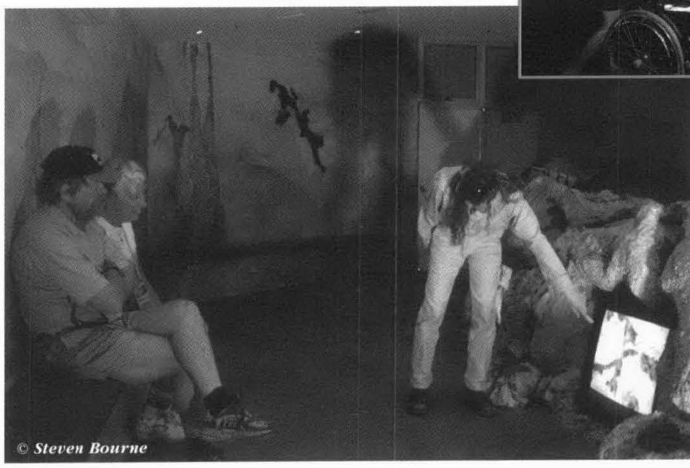


The Effects of Cave Tourism



Visitor tours a cave at his own pace guided by an audio CD that explains features.

Thousands of tourists of all ages visit caves each year. Cave managers go to great efforts to make their caves accessible. Raised pathways can protect the floor.



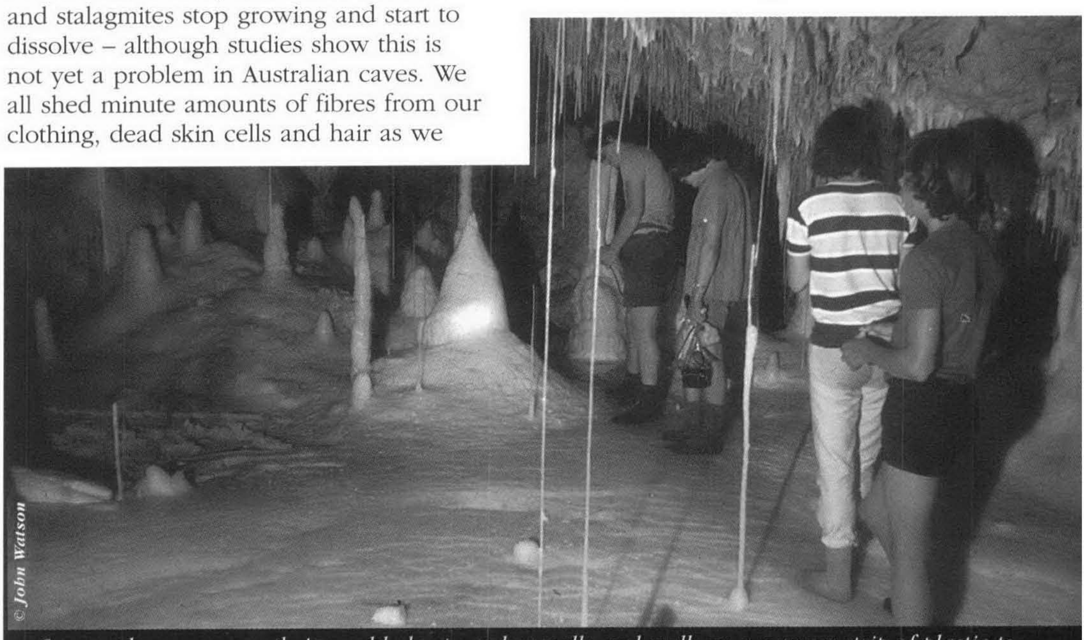
A guide shows visitors the secret world of bats in real-time video. The Teleview Centre was set up because bats will abandon caves if they are frequently disturbed.

Human entry into caves always causes change. Many caves have been damaged by graffiti and by people breaking off stalactites. Cave floors preserve the record of past climates and environments in the mud and sand layers that form the floor. The floor also contains fossils, and provides a home for living insects and other cave creatures. Trampling and digging can destroy these features.

Even visitors in carefully managed tourist caves leave an impact. Continuous electric lighting of caves encourages growth of green algae and other plants that are not found naturally in caves. Cave lights give out heat, but so do people. A party of 80 people in Lucas Cave, Jenolan, can raise the air temperature by 2°C. Carbon dioxide gas exhaled by visitors may raise carbon dioxide levels to a point where stalactites and stalagmites stop growing and start to dissolve – although studies show this is not yet a problem in Australian caves. We all shed minute amounts of fibres from our clothing, dead skin cells and hair as we walk through a cave. These provide different food supplies for cave animals from those that occur naturally, and can change the types of animals that live in a cave. We can also introduce foreign bacteria and fungi into caves on our shoes and clothing. We don't yet know enough about the results of all these changes.

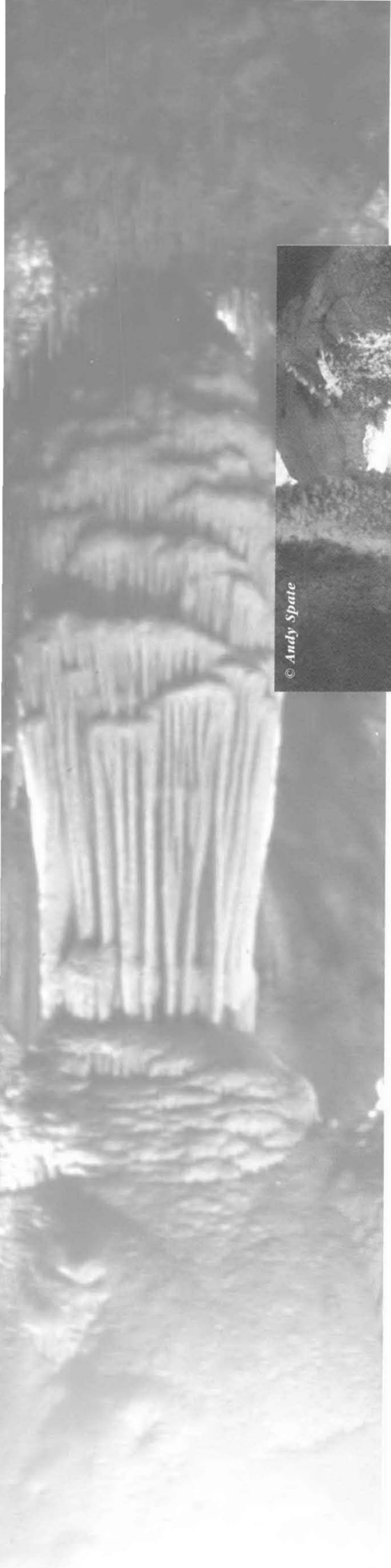
Managers can minimise damage to caves in a variety of ways. They can use timers to light only the section of the cave currently being visited, limit the number of visitors and remove algae and the dust that visitors inevitably leave behind. Raised pathways protect the cave floor. Doors on entrances prevent vandalism and help maintain each cave's natural humidity and temperature.

- *Elery Hamilton-Smith, David Gillieson and Kathleen Kemp*



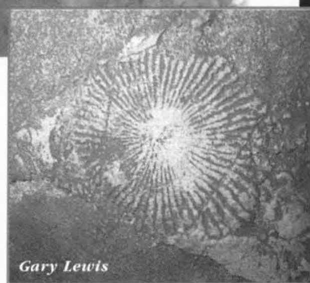
Cave explorers remove their muddy boots and overalls and walk on a narrow strip of plastic to prevent damage to the floor of this cave.

Discovering Caves

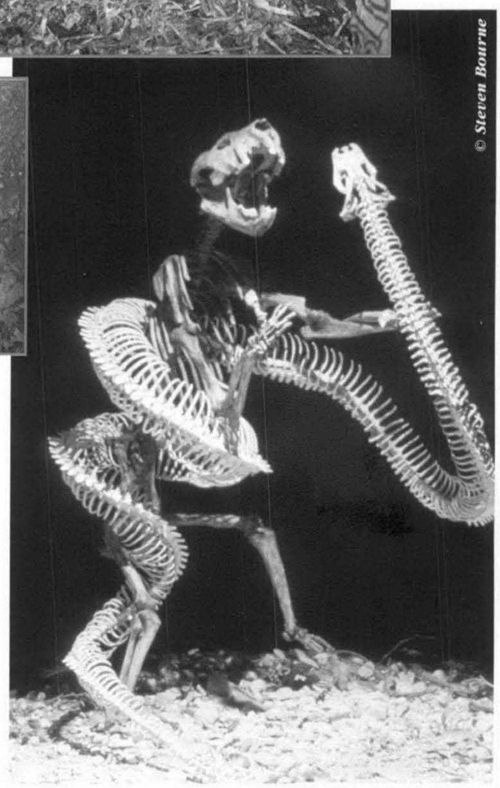


Cave Fossils

Many generations of sooty owls have brought their prey into this cave. The pile includes bones of animals that are now extinct.



A section through a coral seen in a cave wall. It has been preserved in limestone which formed in ancient ocean



Skeletons of extinct animals, including pythons and marsupial lions, have been found in the Victoria Fossil Cave, SA.

Ancient oceans visible in cave walls

Fossils (evidence of ancient life) such as snails, coral, nautiloids and sea feathers can be seen in the walls of some caves. These animals lived in ancient oceans and were included in limestone when it formed at the bottom of the ocean.

Animal remains found inside caves

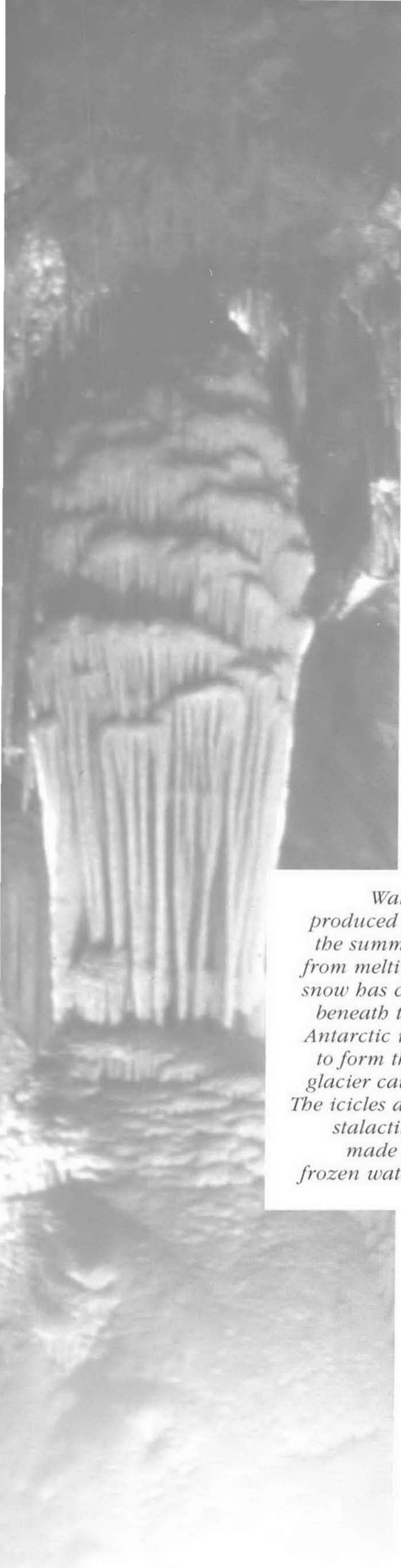
The first discovery of megafauna (gigantic extinct animals) in Australia took place in Wellington Caves, New South Wales, in 1838. Mr. Ranken tied his rope " to what seemed a projecting portion of rock . . . where he discovered, on the fragment giving way, that the rope had been fastened to a very large bone" (Thomas Mitchell). The bone belonged to *Genyornis* (jen-ee-OR-nis) a huge bird that grew up to 2.5 metres tall but had wings too small to fly.

Not all fossils found inside caves belong to animals that once lived in the cave. Some fossils are of animals like *Genyornis* that fell through the roof of the cave or were washed into it. Remains that are deposited in caves have a better chance of being preserved than those left on the Earth's surface, because they are sheltered from rain, sun, temperature changes and scavengers. Also cave water does not dissolve bone quickly. Strong teeth and large bones such as leg bones are more likely to be preserved than fine bones such as finger bones. Fossils of extinct animals that are unique to Australia such as *Sthenurus* (sten-YOU-rus), a short-faced kangaroo that has similarities to kangaroos living today, support the theory of evolution. This theory was being debated in the 1800s when megafauna fossils were first found in Australia. These discoveries helped to convince people that animal species evolved over time.

- *Kathleen Kemp*

Discovering • Caves •

Karst and Caves in Rocks Other than Limestone



Karst refers to the distinctive features such as caves, gorges and spiky or grooved surfaces resulting from the dissolution of some rock while other rock is left behind. Karst features usually form in limestone because it dissolves fairly easily. More resistant rocks such as sandstone and granite can develop karst features, given sufficient time.

This empty passage in Barker's Cave in Queensland formed by a lava river that flowed through the lava tube.

Water produced in the summer from melting snow has cut beneath the Antarctic ice to form this glacier cave. The icicles are stalactites made of frozen water.

An aerial view of karst developed in the Abner Sandstone, Northern Territory. Sandstone dissolves very slowly so it has taken a long time for this sharp pinnacle karst to develop.

Sea caves are small caves found in rocks around the rugged coastlines of Australia. They form by a combination of processes. Rock may be dissolved by seawater, as well as being ground away by sand and pebbles carried in waves and blasted apart by air that is compressed by the waves that pound coasts. The rock above the sea cave will eventually be worn away and may produce sea stacks such as the Twelve Apostles in Victoria.

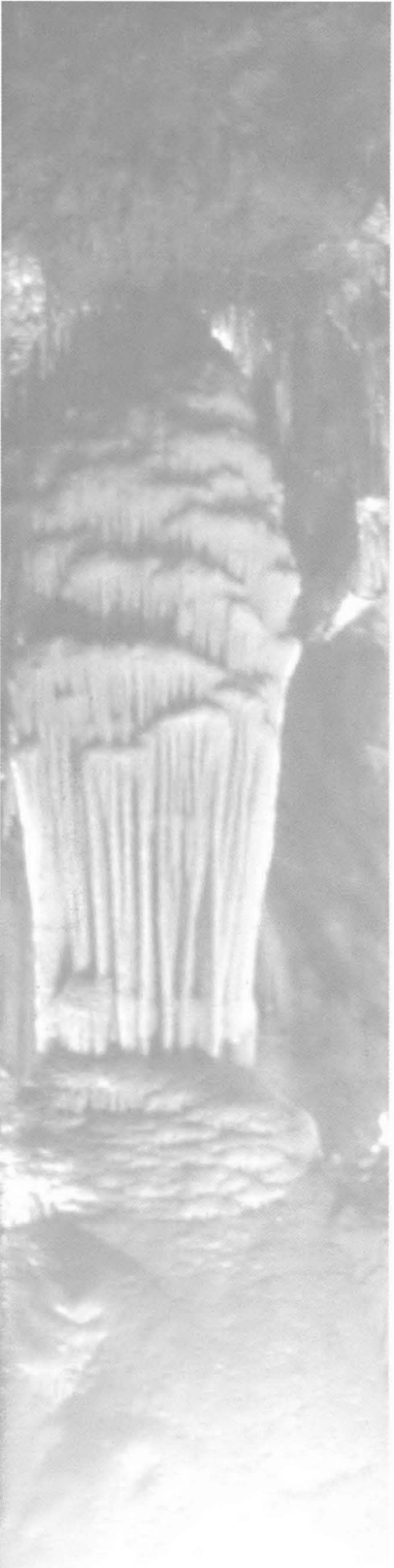
Granite caves are generally in boulder piles that have had the smaller pieces and soil removed from the pile by streams — for example, Britannia Creek Victoria.

Glacier caves form where ice has melted and formed a river that flows out of a glacier, melting ice and creating a cave. Glacier caves may only exist for a short time before the ice collapses or melts. There are no glaciers in Australia, but Australians study glacier caves in Antarctica and New Zealand.

Lava caves form when the top and edges of molten lava rivers cool and harden to form rock tubes. The molten lava in the centre continues to flow through the tube and gradually drains out of it, leaving the tube hollow. The inside walls of the tube may be thickened by later lava flows moving through the tube. Lava tubes occur in the volcanic rocks at Mt Eccles, Victoria and Undara, Queensland.

- *Susan White and Kathleen Kemp*

Discovering Caves



Finding Out More about Caves and Caving

Why do people explore caves? Some admire their natural beauty or seek adventure by testing their physical endurance. Others are curious and search for answers to scientific questions. Many cavers have spent years helping to save caves from damage and destruction. All over Australia, organised groups of people explore caves.

The Australasian Cave and Karst Management Association **(www.netserv.net.au/cwork/ackma99/index.html)** encourages standards of good management for caves and karst by providing a network for the exchange of information between cave managers, researchers and general interest groups.

The Australian Speleological Federation **(www.caves.org.au)** is the national body representing those interested in the exploration, scientific study and conservation of caves. ASF coordinates standards for safety, rescue, surveying, diving and conservation and keeps Australian cavers in contact with cavers throughout the world.

Websites

www.caves.org.au
The Australian Speleological Federation, has links to many fascinating aspects of caves and contains addresses of groups that you can contact to learn more about the caves in your area.

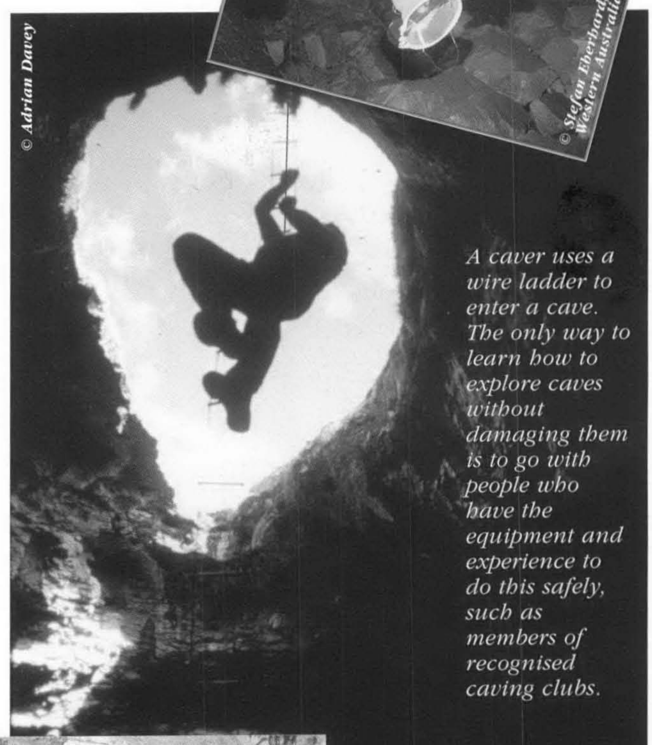
www.batbox.org/
The Buzbee bat box has links to almost everything to do with bats.

www.netserv.net.au/cwork/
CaveWorks, is an educational, research and visitor service centre for the Augusta-Margaret River area.

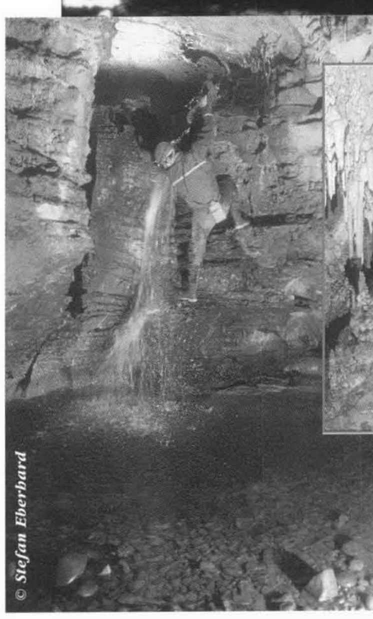
wasg.iinet.net.au/
The Western Australia Speleology Page includes many links including: The Cave Life Page, The Cave Bone Page and a Glossary of Caving Terms.

www.agso.gov.au/education/
The Australian Geological Survey Organisation's Education page describes educational resources and services.

Many caves are filled with water and special diving equipment and skills are needed to explore them. This cave diver is collecting tiny animals with a fine-meshed net.



A caver uses a wire ladder to enter a cave. The only way to learn how to explore caves without damaging them is to go with people who have the equipment and experience to do this safely, such as members of recognised caving clubs.

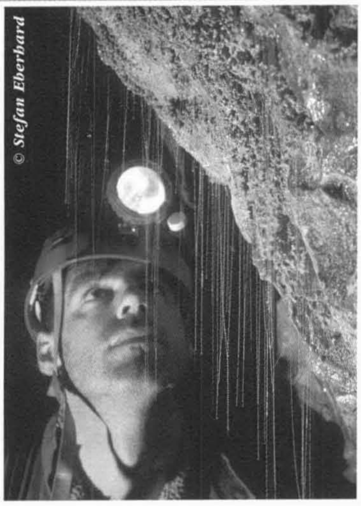


Caver admiring delicate formations in a Tasmanian cave.

Caver climbing a waterfall in a cave in Tasmania.

Discovering Caves

Finding Out More about Caves and Caving



A cave biologist studies the long sticky threads which glowworms use to capture their prey.

Magazines and Books

Australian Caver is the Journal of the Australian Speleological Federation, PO Box 388, Broadway NSW 2007.

Helictite is the Journal of Australasian Cave Research, 123 Manningham Street, Parkville, Victoria, 3052.

Journal of the Australasian Cave and Karst Management Association, PO Box 36, Carlton South, Victoria 3053

Australian Bats. S. Churchill, 1998. Sydney: Reed New Holland

Australian Quaternary Caves. In: Wildlife of Gondwana. P Vickers-Rich and TH Rich, 1993. Sydney: REED,.186-193

Caves and Cave Life. P Chapman, 1993. London: Harper Collins.

Caves - facts, stories, games. J. Wood. 1990. Two-Can Publishing Ltd.

Cave Life - a close-up look at the natural world of a cave. F. Greenaway and C. Gunzi, 1993. Harper & Collins

Cave Minerals of the World. C Hill and P Forti, 1997. Edn 2. Huntsville(Al): National Speleological Society.

Caves: Processes, development and management. D Gillieson, 1996. Oxford: Blackwell.

Mysterious McCavity. In: *Australian Geographic*. M Spencer, 1997. Jan-Mar; 45: 48-63.

The Life of the Cave. CE Mohr and TL Poulson, 1966. Time Life Science Books. McGraw - Hill.

Speleology. GW Moore and N Sullivan, 1997. St Louis (Mo): Cave Books.

Tuglow Caves. I Cooper, M Scott and K Vaughan-Taylor, 1998. Sydney University Speleology Society, ISBN 1 86451 373X.

Undara Volcano and Its Lava Tubes, A and V Atkinson, 1995. . PO Box 505, Ravenshoe, QLD, 4872.

Under Bungonia. J and P Bauer, 1998. Life on Paper, PO Box 115, Oak Flats, NSW, 2529.

Underground Australia. E Hamilton-Smith and B Finlayson, [in preparation] Sydney: University of New South Wales Press.

Wombeyan Caves. HJ Dyson, R Ellis, and J James, 1982. Sydney University Speleological Society, ISBN 095 99608 48.

- *Kathleen Kemp and John Dunkley*

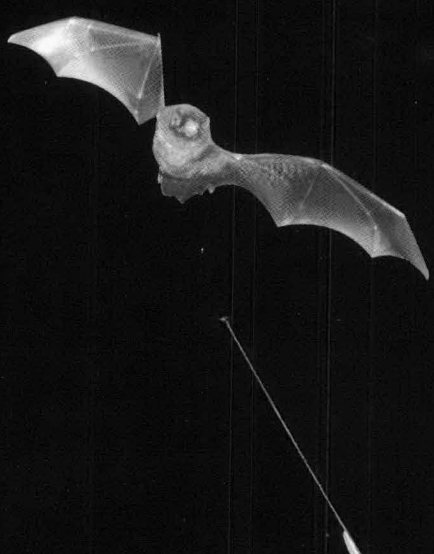
A biologist searches for tiny animals on a tree root that reaches down into a cave.

A young caver admires delicate stalactites that have formed on the ceiling of this cave in the Kimberley, WA.

A helium-filled balloon is released in a cave to measure its height. The string tied to the balloon has measurements marked on it.

Contributors

Anne Atkinson, Thomas Atkinson, Vern Atkinson, Ausgusta-Margaret River Tourism Association, Anne Augusteyn, Australian Speleological Federation Inc., Australasian Cave and Karst Management Association Inc, Stephen Babka, Peter Berrill, Steven Bourne, Phil Bradley, Terry Brown, Parks & Wildlife Commission, Northern Territory, Canberra Speleological Society Inc., Dale Calnin, Michael Chalker, Faye Christopher, Brian Clark, Cliff Collier, Michele Cooper, Adrian Davey, Jol Desmarchelier, John Dunkley, Ross Dunstan, Stefan Eberhard, Brett Ellis, David Gillieson, Albert Goede, Jane Gough, Ken Grimes, Peter Haines, Les Hall, Elery Hamilton-Smith, Jody Hammat, Michael Hansford, Wendy Haylock, Kent Henderson, Rod Hillman, Julie Hiscott, Hannelore Hoch, Ernst Holland, Ian Houshold, Bill Humphries, Cameron James, Julia James, Lana Little, Lin Kay, Geoff Kell, John Kennard, Sarah Kerin, Liam Kinsella, Julie Mail, Peter Mathews, Robyn McBeath, Tracey McClelland, Greg McNamara, Jenny Micucki, Kevin Mott, National Parks and Wildlife Service, NSW, National Parks and Wildlife Service, SA, Armstrong Osbourne, Wendy Payne, Vivien Peters, Glenda Pollard, Stephen Reilly, H. Rimmer, Chester Shaw, Jacqui Skinner, Rodney Start, Jackie Taylor, Mia Thurgate, Pauline Treble, Keith van der Staay, Dianne Vavryn, Josef Vavryn, John Watson, John Webb, Rauleigh Webb, Chris White, Susan White, L. T. Wilcox, Dave Wurst, The Australian Caving Community



DISCOVERING CAVES

Discovering Caves in Australia Poster

Find the location of caves in Australia and see spectacular features found in tourist cave areas.

Fact Sheets

- Caves in Australia
- Australian Cave Facts
- Dissolving Limestone to Form Caves
- Nature's Way of Decorating Caves
- Making Limestone Caves
- Stalactites, Stalagmites and Other "Cave Things"
- Karst Landscapes and the Movement of Water
- Using Land and Caring for Caves
- Determining the Age of Cave Deposits
- How Caves Tell Us about Past Climates
- Bats, Birds and Other Vertebrates that Live in Caves
- Creepy Crawly Invertebrates that Live in the Dark
- Human Use of Caves
- The Effects of Tourism
- Cave Fossils
- Karst and Caves in Rock other than Limestone
- Finding out More about Caves and Caving

Discovering Caves Activities

Reproducible activities to explore caves with your children or students. Make a cave model, sketch an animal, plot solution rates and many more.

Suggested answers provided.

AGSO Australian Geological Survey Organisation
The Ian Potter Foundation
Australasian Cave and Karst Management Association Inc.
Australian Speleological Federation · Established 1956
University of Toronto 1848 Geology 1998 150 Years

Discovering Caves in Australia

Australia boasts some 10 000 caves - this is a small number for the size of our continent. This map shows the locations of most cave areas with some symbols representing up to 300 individual caves. New caves continue to be discovered. Some areas of Australia are rich in caves while others appear to have no caves at all. This is due to the lack of suitable rock types and the aridity of the Australian climate.

Most caves in Australia are found in limestone or its close relatives marble and dolostone. Of these caves, 22 cave systems are open to the public as tourist caves. Australia also has some unusual caves. These are caves found in other rock types, such as granite, sandstone and volcanic rocks. One of these cave systems is also open to the public. The tourist caves have been identified on this map in orange. Photos provide a glimpse of features that can be seen in these cave areas.

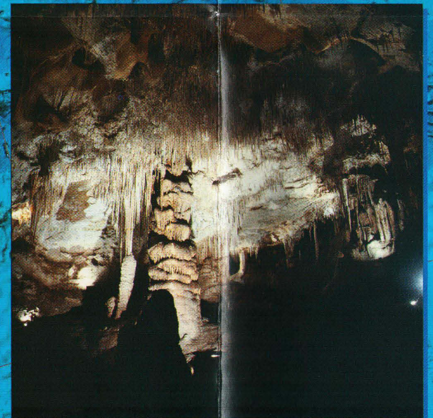
Caves are fragile environments. Human entry always causes changes to these unique places. Careful management will continue to ensure that the beauty and value of Australia's cave heritage is preserved. For more information about caves, see the *Discovering Caves Kit*

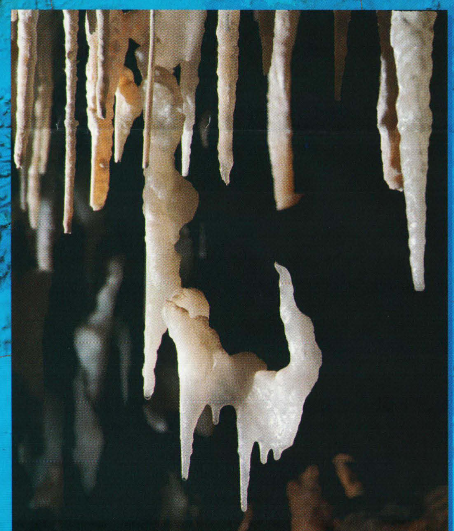

Cutta Cutta. *Pinnacle karst forms when acidic rainwater dissolves limestone in tropical environments*
© Andy Spate


Yanchep. *Many white stalagmites grow up from the floor of Crystal Cave*
© Yanchep National Park

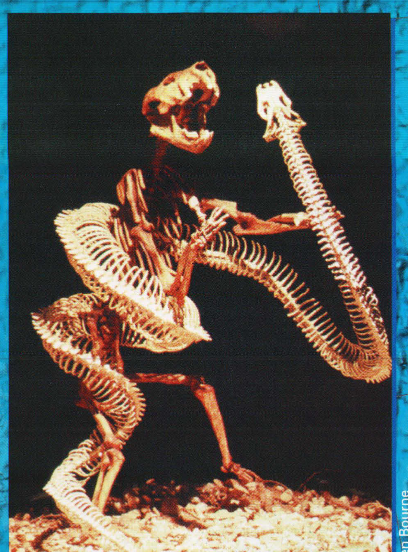

Ngilgi. *The mineral calcite makes up most of the crystal found in caves*
© Ngilgi Caves


Augusta-Margaret River. *Jewel Cave contains an exceptionally long straw stalactite that reaches down from the ceiling for nearly six metres*
© Augusta Margaret River Tourism Association

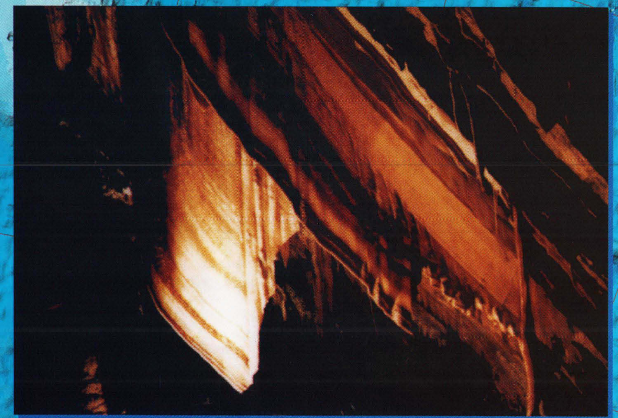

Tantanoola. *This magnificently decorated cave has formed in dolomite while most Australian caves occur in limestone*
© Armstrong Osborne


Kelly Hill Caves. *The "Fish Hook" is an example of a helictite*


Engelbrecht. *This display shows the special equipment that cave divers need to explore flooded caves*


Naracoorte. *Skeletons of extinct animals including pythons and marsupial lions were found in the Victoria Fossil Cave*

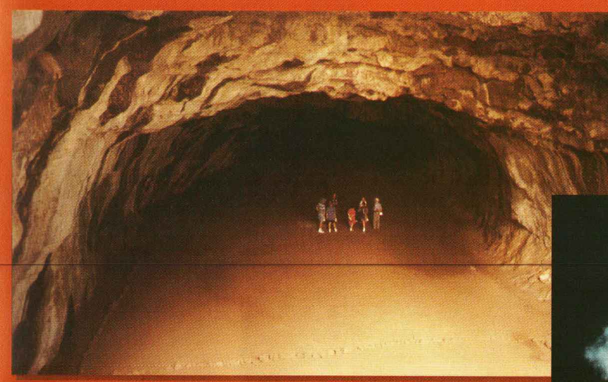

Princess Margaret Rose. *The cave was part of the river system that formed this spectacular flooded gorge*


Gunns Plains. *This colourful shawl is lit from behind to bring out the stripes of various colours that are caused by impurities in the calcite*


Hastings. *Lighting and paths allow visitors to experience the wonders of caves*

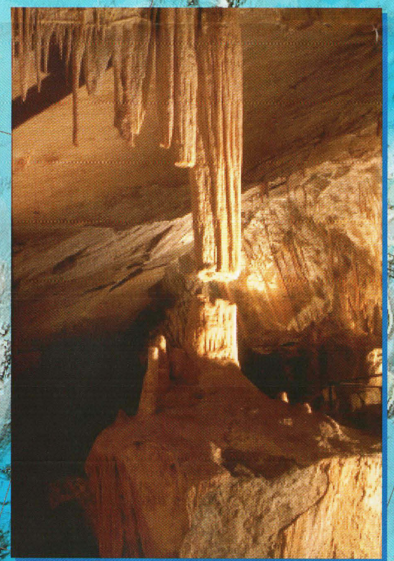

Buchan. *"Font of the Gods" consists of spectacular minerals that have been deposited around the rims of pools of cave water*


Chillagoe. *These tower karst bluffs are riddled with caves*
© Mia Thurgate

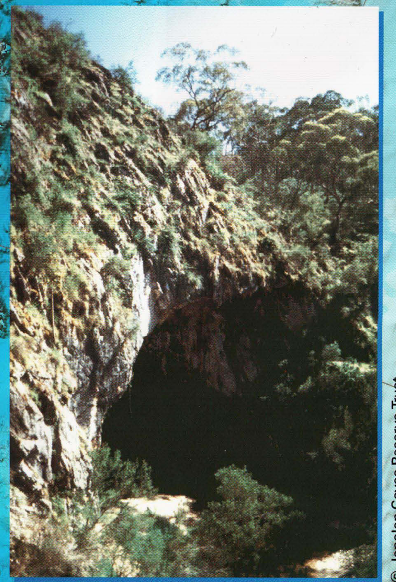

Undara Lava Tubes. *Flowing lava formed these unusual caves*
© Thomas Atkinson


Tiny blind colourless butterflies live on roots that have reached into the lava tubes
© Hannelore Hoch

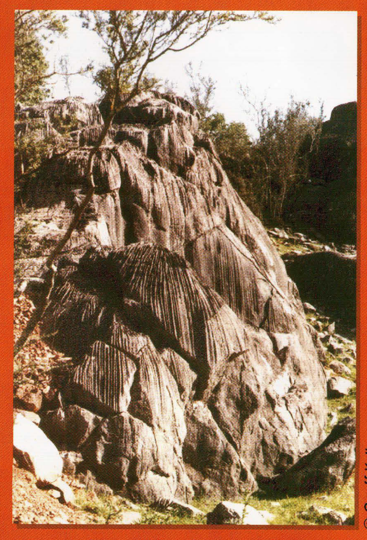

Mount Etna Caves National Park. *Over 100,000 Little Bent-wing Bats emerge from Bat Cleft nightly in summer. Brown tree snakes feast on these bats*
© Josef Vavryn


Jenolan. *Columns form when stalactites and stalagmites meet. This column broke as the floor beneath it settled*
© Jenolan Caves Reserve Trust

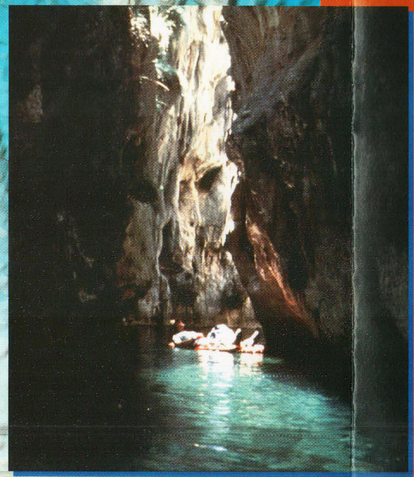

Olsen's Capricorn Caverns. *Cathedral Cave is a natural setting for church services and concerts*
© Doug Steley


Abercrombie. *The "Grand Arch" is the entrance to several caves open to visitors*
© Jenolan Caves Reserve Trust


Wellington. *Visitors can experience a restored section of a phosphate mine within this cave*
© Armstrong Osborne


Carey's Cave, Wee Jasper. *Grooves in the rock outside the cave entrance show how rainwater dissolves limestone*
© Geoff Kell


Mole Creek. *This pseudoscorpion is only found in these caves. It is well adapted for living underground*
© Stefan Eberhard


Wombeyan. *Exploring this sheer-sided limestone gorge in the summertime*
© Jenolan Caves Reserve Trust


Yarrangobilly. *Thousands of tourists of all ages visit caves each year. Cave managers try to make their caves as accessible as possible*
© Ross Dunstan

Caves are fragile. Do not enter any cave unless accompanied by a trained guide. To learn more about caving, contact your local caving (speleological) club

The background terrain model is courtesy of AGSO's Australian Ocean Territory Mapping Program. The image has been derived from the digital elevation model of Australia onshore, from ship survey data around Australia (Buchanan, AGSO), and from the predicted bathymetry derived from satellite altimeter data (Smith and Sandwell 1997, Science 277, 1956-62) in the more remote areas offshore

Compiled by: KM Kemp, GB Lewis and SP Stanley with assistance from AP Spate and J Ingarfield

Cave location data: Australian Speleological Federation Inc
Karst area data: KG Grimes

Copies of this poster may be obtained from:
AGSO Sales Centre
GPO Box 378
CANBERRA ACT 2601
Ph +61 2 6249 9519 Fax + 61 2 6249 9982
http://www.agso.gov.au

Catalogue no: 33849
The poster is also available as part of the *Discovering Caves Kit*
Catalogue no. 33346 ISBN: 0 642 39834 8

LEGEND

- Tourist cave location
- Cave location
- Volcano karst
- Young dune karst
- Buried karst

THE IAN POTTER FOUNDATION · AUSTRALIAN SPELEOLOGICAL FEDERATION ESTABLISHED 1956 · Australasian Cave and Karst Management Association Inc. · AGSO AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION