VOLUME 33 (2) 1995

Helictite

Journal of Australasian Speleological Research

DGillieson Gunung Tempurung

HELICTITE

Journal of Australasian Cave Research
ISSN : 0017-9973

Helictite was founded by Edward A. Lane and Aola M. Richards in 1962. It is intended to be wide ranging in scope from the scientific study of caves and their contents, to the history of caves and cave areas and the technical aspects of cave study and exploration. The territory covered is Australasia - Australia, New Zealand, the near Pacific Islands, Papua New Guinea and surrounding areas, Indonesia and Borneo.
In 1974 the Speleological Research Council Limited agreed to support the Journal with financial assistance and in 1976 took over full responsibility for its production.

The Speleological Research Council Limited, the publisher and owner of Helictite, is a non-profit limited liability company incorporated in May 1964.

The aims of the Speleological Research Council Limited are:

- To organise and promote the exploration and charting of caves and cave systems.
- To promote, support and assist in the scientific investigation of caves and to foster speleology as a science and a sport.
- The promotion of speleology and speleological societies and to assist with grants of money and otherwise.

Other publications by SRC Ltd:

- **The Exploration and Speleogeography of Mammoth Cave, Jenolan**. J.R. Dunkley, 1972.
  -a detailed history and description.
- **Papua New Guinea Speleological Expedition, NSRE** 1973. J.M. James, 1974.
  -report of the 1973 Niugini Speleological Research Expedition to the Muller Range.
- **A Bibliography of The Jenolan Caves. Part One: Speleological Literature**. J.R. Dunkley, 1976.
  -a detailed reference list.
- **The Caves of Jenolan, 2: The Northern Limestone**. B.R. Welch (ed), 1976.
  -a detailed description.
- **Caves and Karst of The Muller Range**. J.M. James and H. Jane Dyson (eds), 1980.
  -report of the 1978 speleological expedition to the Atea Kananda.
- **Vertical**. Alan Warild, 1994.
  -vertical caving equipment and techniques 1994.

Speleological Research Council Limited
A.C.N. OOO 456 42

Helictite

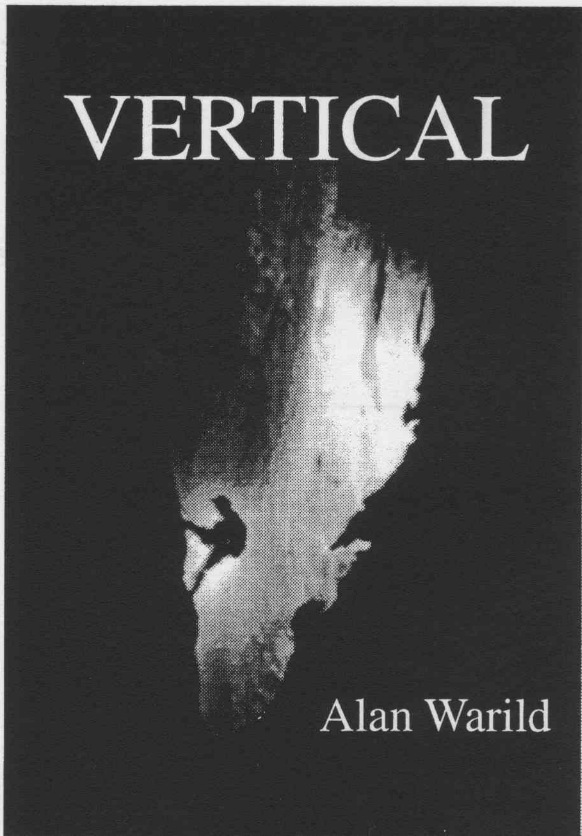
Journal of Australasian Speleological Research

Volume 33 (1/2) 1995

Contents

Cover: Gunung Tempurung

Helictite, Volume 33, 1995 consists of two issues. Price per volume Aust. $20.00 post paid. "Helictite" is printed and published by the Speleological Research Council Ltd. All correspondence to: PO Box 183 Broadway, NSW 2007



VERTICAL
- third edition

➪ Completely reviewed and updated.

➪ European **and** American vertical caving techniques.

➪ Techniques tested in the world's most demanding caves.

➪ Ten chapters cover **everything** today's caver needs to know in an easy to understand form.

➪ Expands the repertoire of the expert caver.

➪ An informed introduction for the first time vertical caver.

➪ 134 pages, 345 line diagrams, 42 B&W photos, 21 tables.

➪ Price **A$29.50** each (includes packing and sea mail postage worldwide).

➪ Available from -
Alan Warild
41 Northwood St, Newtown 2042
Australia

➪ Speleological Research Council Ltd.
P.O. Box 183 Broadway, NSW 2007
Australia

.......................or any good caving supplier.

Investigations of the Wyanbene Caves Area

Jill Rowling

Abstract

Wyanbene Caves are located about 50 km south of Braidwood, NSW, Australia, about half way between Canberra and the coast. This paper discusses some preliminary findings by the author concerning the geological structure of these and other caves in the area. Other caves include Clarke's Cave, Ridge Mine Pot, Goat Cave and several unnamed caves and springs. Wyanbene Cave is a streamway cave, formed primarily along a south striking joint in Late Silurian limestone. Drainage of the surface above Wyanbene Cave is affected by the south west striking joints of a Late Devonian conglomerate cap. Secondary deposits in the cave are affected by hydrothermal ore deposits.

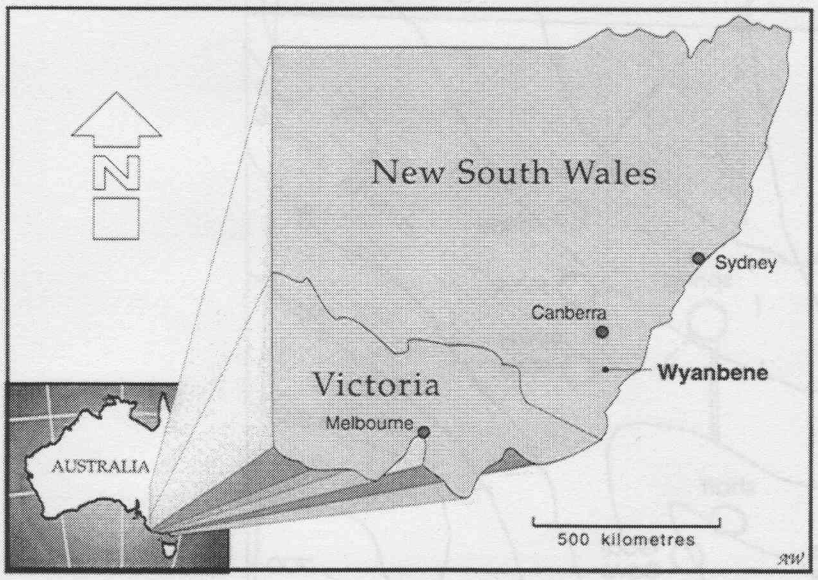


Figure 1. Location of Wyanbene Caves.

Introduction

Wyanbene Cave has 1830 m of mapped passage. It is presently used for recreation under a permit system which is managed by the Narooma District office of the National Parks and Wildlife Service of NSW, Australia as part of the Deua National Park. The cave contains extensive speleothem deposits and a perennial stream. It has a locked gate about a quarter of the way in. Figure 1 shows the location of Wyanbene Caves in NSW. Figure 2 shows a general plan of the area. To the east of Wyanbene Cave lies the Minuma Range, which divides the Shoalhaven drainage from the Deua drainage. To the south of Wyanbene Cave lies Wyanbene Caves Mountain. The Sydney University Speleological Society library has a copy of the excellent maps of Wyanbene Cave (Brush et al, 1972-3). The maps revealed several interesting structural features of the cave, but the area hydrology was unknown. This raised some interesting questions:

Where is the cave with respect to the topographic map? Does the cave get its water from the Shoalhaven side of the Minuma Range, or the Deua side? If the water comes from the Shoalhaven side, is it from the north or south side of Wyanbene caves mountain? What are the soft, sub-vertical dyke-like structures found throughout the cave? Why do many of the cave cross-sections display a tilt toward the west? Is there a relationship between the avens of the cave and geological structures on the hillside? In 1994, a survey was completed from the carpark near the cave entrance to the trig station on top of Wyanbene Caves Mountain. Both forward and backward bearings were required at each survey station to help reduce errors due to the known magnetic ore deposits in the vicinity. Figure 2 shows how this survey positioned the cave on the topographic map, together with approximate positions of the other caves, abandoned mine adits and other features in the area. Note how the cave runs fairly straight in a north to south direction. Figure 3 is an elevation of the cave, looking to the west. This drawing has a vertical exaggeration of 2 times in order to show vertical features.

Wyanbene Cave description

Wyanbene Cave is essentially a horizontal streamway cave. The first 150 m of passage are fairly large and well decorated with calcite speleothems, including flowstone, gours, stalactites, cave coral, shields, shawls and helictites. After Helictite Chamber (HC in Figures 2 and 3), the nature of the cave changes to a series of interconnected tall muddy rifts, occasionally decorated with helictites and anthodites. Sub-vertical dyke-like structures are most noticeable in this area. After a further 100 m or so, the rift is blocked by a rockpile. However progress may be made through the streamway via a low, phreatic tunnel (the Wet Stretch) for about 30 m. A larger, upper tunnel may then be entered. Above this tunnel and separated by a rockpile is the Avens Area (AA in Figures 2 and 3). Three avens here are interconnected by a south striking narrow rift. Continuing southwards along the tunnels, one passes through a rockpile and enters the lower part of Rockfall Chamber. To the west of this boulder-filled room, and separated by a rockpile, is the large aven known as the Gunbarrel (GB in Figures 2 and 3). Errors in the positioning of the cave features and/or the topographic map have resulted in the top of the Gunbarrel being drawn about 5 metres above the surface of the mountain. Lower Rockfall Chamber and Upper Rockfall Chamber are separated at the northern end by an unstable rockpile, and combine at the southern end at a 5 m drop. In Upper Rockfall Chamber, the northern end is terminated by a pile of alluvium. There is a dyke-like structure forming the western wall. Associated with this structure are banks of white coralloid deposits, possibly gypsum. The roof is flat and decorated with calcite pseudomorphs after aragonite. High in the walls are abandoned phreatic tubes. The floor is rockpile with deep holes.

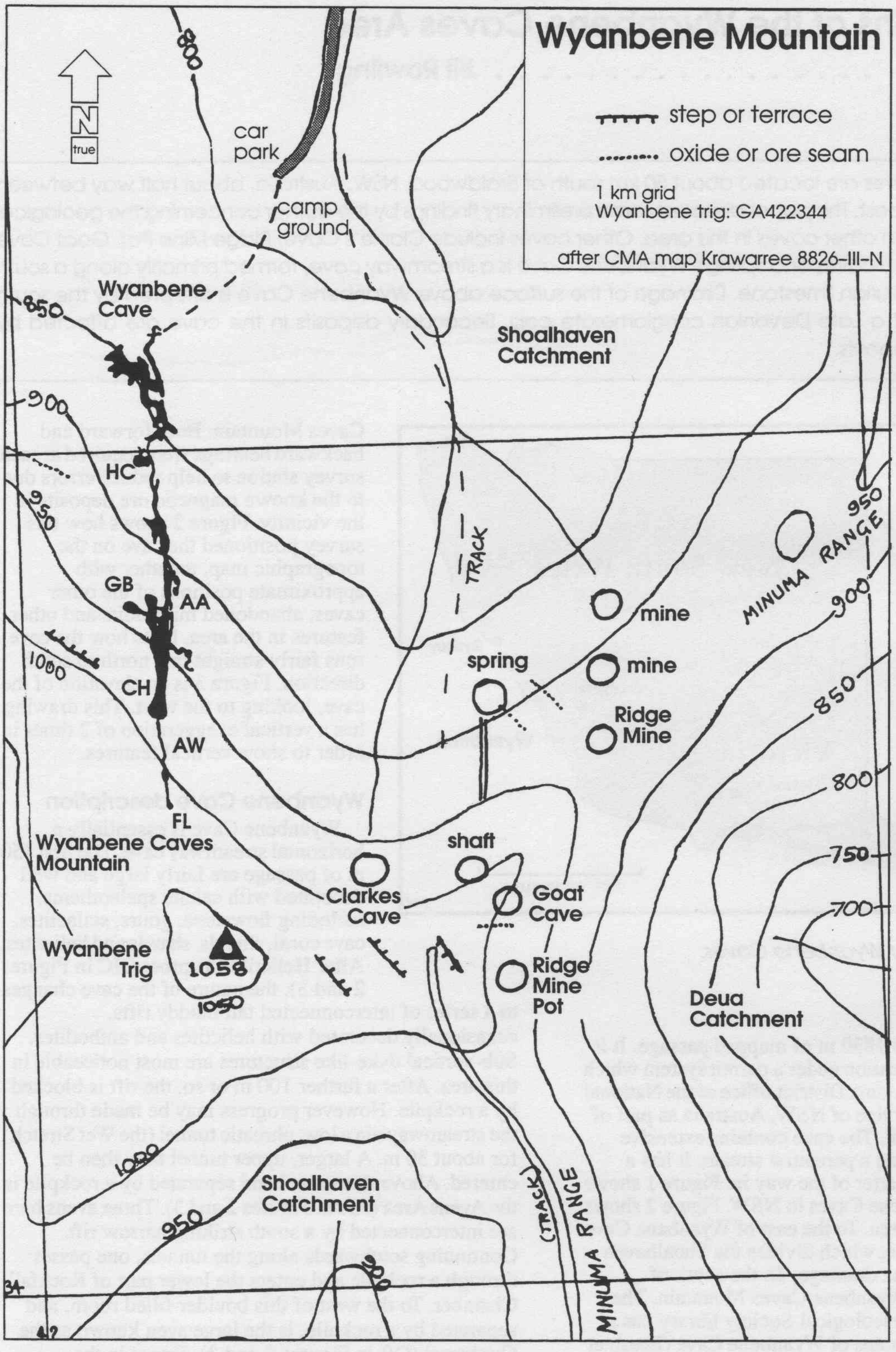


Figure 2. Wyanbene in relation to surface features.

To the east, the rock is significantly shattered and unstable, leading to Lower Rockfall Chamber. Near the south eastern end of Rockfall Chamber are gours where a small stream enters (the Meanders). This may be followed along a serpentine passage to a chamber containing a dyke-like structure.

A rockpile in the southern end of Rockfall Chamber gives access to another large room; Caesar's Hall (CH on Figures 2 and 3). The northern end of this room has a steep floor of alluvial gravels below an aven and has extensive white frostwork and coralloid speleothems on its walls. At the southern end is another aven. The muddy floor slopes steeply to the streamway. The nature of the cave changes markedly at the southern end of Caesar's Hall. A 10 m drop gives access to a high, narrow, muddy rift containing obstacles such as Anderson's Wall (AW in Figures 2 and 3). The cave ends in a narrow sump called Frustration Lake (FL in Figures 2 and 3) out of which the stream flows.

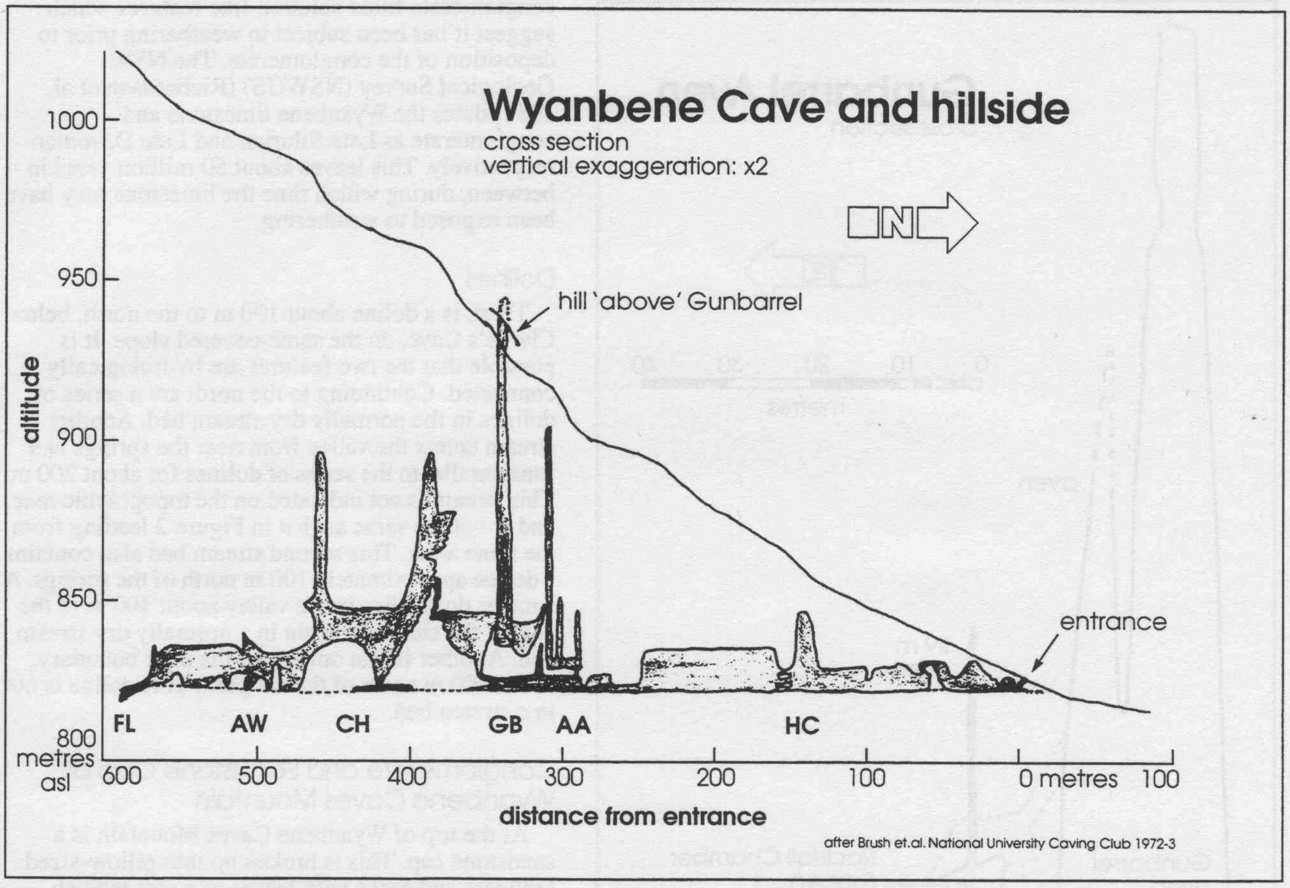


Figure 3. Cross section through Wyanbene Cave.

Avens In Wyanbene Cave

There are several avens of interest. The Gunbarrel is by far the most spectacular and well known, rising some 110 m to what is either a boulder choke or part of the conglomerate and sandstone cap of the mountain. The evidence for this includes a large boulder of red, fine grained silicic volcanoclastic material in the base of the Gunbarrel, together with many smaller pieces of sharp quartz sandstone and conglomerate. Figure 4 is a cross section through the Gunbarrel looking north. The Gunbarrel is a double-barreled aven. The height of the larger aven of the Gunbarrel was measured using helium filled balloons (Brush et al, 1972-3). It has been climbed to approximately 80 m by Alan Warild (pers. comm.), who reported that above this point it narrows, then widens, and the limestone becomes poor and crumbly. The smaller aven is coated with a reddish mud. The lower access to the Gunbarrel is virtually at stream level. Also, during wet weather it rains in the Gunbarrel. This would help to explain why there is usually a puddle in this chamber. Figure 4 also shows an aven in upper Rockfall Chamber. The roof of this aven has two domes. Rockfall Chamber is, strictly speaking, part of Caesar's Hall (CH on Figures 2 and 3) which itself contains two avens, one at each end. Aitcheson's Avens are marked AA in Figures 2 and 3. The most northerly of these is readily accessed from the southern end of the Wet Stretch. An unstable rockpile leads to a room with a calcite-cemented blocky floor. The roughly domed roof rises approximately 12 m above the floor and approximately 25 m above the streamway. The main feature of this room is a south striking joint coated with reddish mud. The joint is approximately 0.5 m wide and leads to the more southerly avens. To the north, this joint is blocked by fallen rocks and reddish infill. Minor avens exist above Anderson's Wall and Frustration Lake. It would appear from Figure 3 that the steeper parts of the hillside are directly above the avens in the cave.

Evidence for north - south jointing

The cross sections of Figure 5 are all looking north. They were drawn from the National University Caving Club (NUCC) map (Brush et al, 1972-3). The passage shapes appear to be controlled by a joint which dips steeply to the east. Cross section P (near Helictite Chamber) appears to be controlled by both bedding and jointing. There are a number of north striking planes of oxide material in Wyanbene Cave between Helictite Chamber and the Wet Stretch. In Goat Cave, high on the Deua saddle, the bedding has a dip of 20° in the direction 268° (i.e. approximately west). This was measured along a contiguous band of fossil shells on the roof and both sides of the passage. The bedding near the entrance of Wyanbene Cave was measured and found to be similar. A huge north striking joint structure on the surface can be followed over the cave and up the hillside until it disappears under loose conglomerate rubble. Additionally there are some major north striking grikes (3°) on the hillside, south of the springs as shown in Figure 2.

Other caves

Springs

Referring to Figure 2, near the lower (north) end of the pronounced surface grikes is a small cave. Just above this cave are a series of small springs which flow during wet weather to form tufa terraces.

Vertical Shaft

Near the top (south) end of the surface grikes is a tight vertical shaft approximately 23 m deep. Its walls are covered with cave coral.

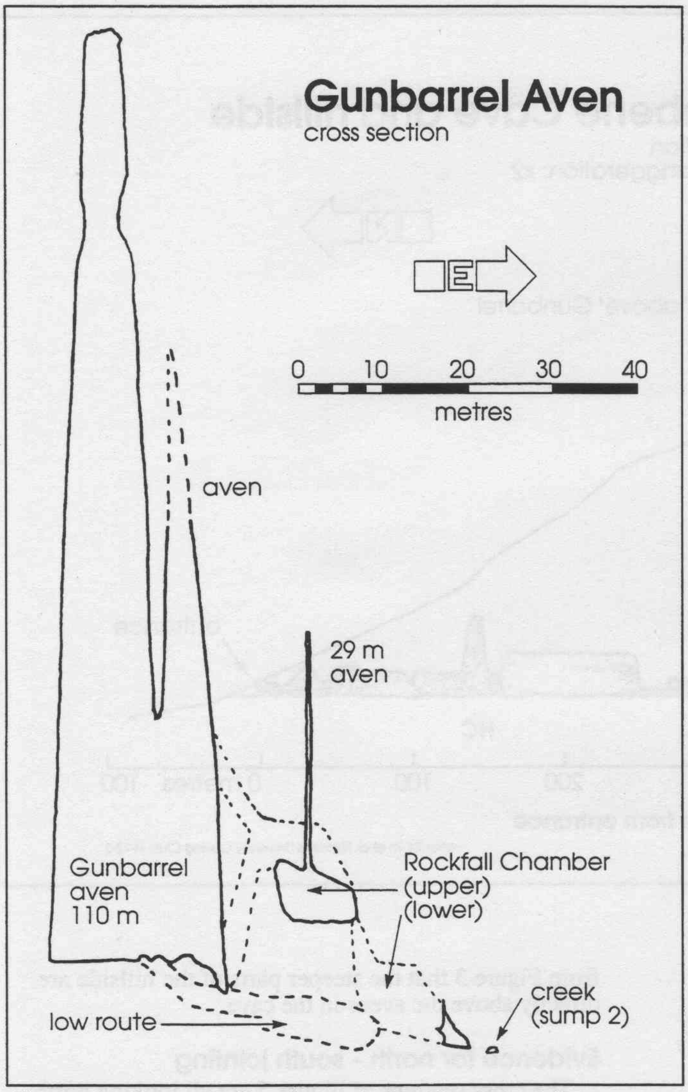


Figure 4. Cross section through the Gunbarrel Aven.

Goat Cave

To the south east and on the Deua side of the Minuma Range is Goat Cave. This is a small two-chambered cave with an earth floor. It is an important roost for Horseshoe bats.

Ridge Mine Pot

Ridge Mine Pot (see Figure 2) is a 60 m deep vertical cave, choked with calcite, and generally similar to the above—mentioned vertical shaft. Jennings (1963) wondered about the relative altitudes of the streamway in Wyanbene Cave and the bottom of Ridge Mine Pot. From his article and from field observations by Norton (pers. comm.), the bottom level of Ridge Mine Pot has been estimated to be approximately 100 m above the level of the Wyanbene Cave streamway, and possibly 60 m above the springs. It is possible, that at some earlier time, Ridge Mine Pot was part of a cave system which took water from what is now the Deua side to the Shoalhaven side of the Minuma Range.

Clarke's Cave

Clarke's Cave, also known as Bushranger Cave after the infamous Clarke brothers, is a rock shelter which lies on the unconformity between the limestone and the conglomerate. It appears to contain a large joint or dyke filled with reddish material. The limestone at the conglomerate interface is not flat; rather, it has conglomerate-filled solution-like features which suggest it has been subject to weathering prior to deposition of the conglomerate. The NSW Geological Survey (NSWGS) (Richardson et al, 1981) dates the Wyanbene limestone and conglomerate as Late Silurian and Late Devonian respectively. This leaves about 50 million years in between, during which time the limestone may have been exposed to weathering.

Dolines

There is a doline about 100 m to the north, below Clarke's Cave, on the scree-covered slope. It is possible that the two features are hydrologically connected. Continuing to the north are a series of dolines in the normally dry stream bed. Another stream enters the valley from near the springs and runs parallel to the series of dolines for about 200 m. This stream is not indicated on the topographic map, and is not the same as that in Figure 2 leading from the mine adits. This second stream bed also contains a doline approximately 100 m north of the springs. A smaller doline lies in the valley about 100 m to the east of the car park, again in a normally dry stream bed. Another is just outside of the park boundary, about 600 m north of the car park. This doline is not in a stream bed.

Conglomerate and Sandstone Cap of Wyanbene Caves Mountain

At the top of Wyanbene Caves Mountain is a sandstone cap. This is broken up into pillow-sized boulders and rocks with lenses of a soft reddish material resembling lapilli. These rocks have rounded, almost solution-like features. Below this lies a maroon conglomerate layer, which overlies the limestone, and shares the same dip of 20° to the west. The lowest conglomerate is made of angular volcanoclastics which are cemented together with purplish fine-grained material. This grades upwards to more rounded pebbles set in the same matrix with the finer sandstone material on top. This entire sequence appears to repeat a number of times to the top of the trig. This conglomerate overlies the limestone. With the exception of Clarke's Cave, the boundary between the conglomerate and the limestone is usually hard to find because of scree. To the northwest and downslope of the trig, the conglomerate is terraced. There are also steep to slightly overhanging structures about 2m high and resembling faults (see Figure 2). They also occur directly above Clarke's Cave and near the saddle to the east of the trig, where the structures strike in the direction 338°. The conglomerate also occurs in Wyanbene Cave, all along the streamway, as loose rounded pebbles. The extent of the conglomerate cap corresponds approximately to the end of Far Caesar's Hall (CH on Figure 2), where the nature of the cave changes from an open hall to a narrow, vertical rift system. The conglomerate may be impervious to water, except at the "fault" structures. If so, surface water may be able to reach the limestone under the conglomerate via these structures as well as via the main north striking joint.

East-West Banding and Dyke-like Structures

The surface limestone has almost vertical bands of reddish material resembling iron oxide and running approximately east-west. This material does not follow a straight line, but tends to wander both in dip and strike. Some of these surface bands are edged with quartz. The limestone nearby appears brownish, possibly

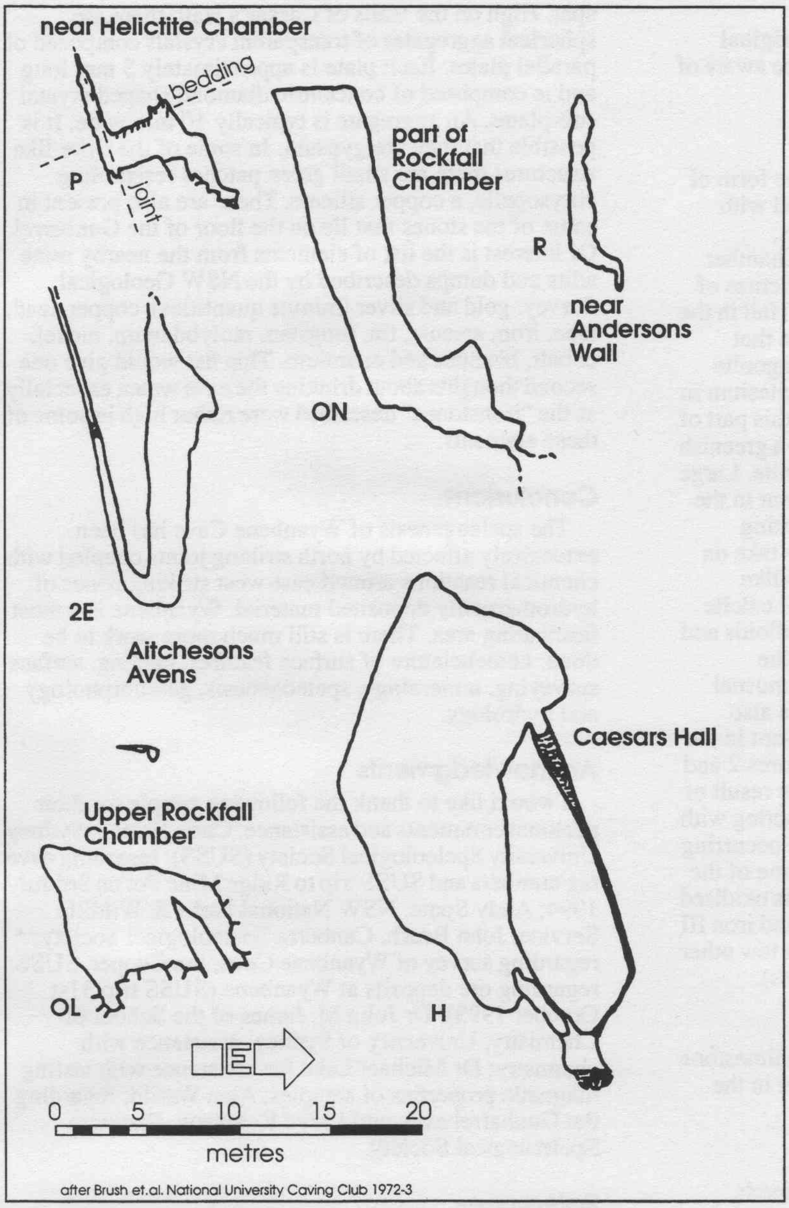


Figure 5. Cross sections through major chambers in Wyanbene Cave.

dolomitised. One of these bands winds its way across the lower terraces of the hillside above the springs (see Figure 2). This band contains sparkly material described as Maghemite by Cooper (pers. comm.) and is still being investigated. Another band in a gully to the south of Goat Cave appears to be made of the same material and may be a similar structure. The NSWGS describes similar structures found near the mine adits as hydrothermally deposited base metal ore deposits (Richardson et al, 1981). It is proposed that the West Passage of Ridge Mine Pot (ref Jennings 1963) is developed along one of these structures, whereas the North Passage may be developed along a joint. On the hillside there are a number of occurrences of east-west bands broken by north-south joints, indicating that the north-south jointing postdates the east-west banding. On the surface this material shows up as hard black, brown or reddish bands in the limestone, but inside the cave it is soft and chemically altered. In Wyanbene Cave, these structures show up as walls through which the streamway has penetrated. One of the most pronounced is near the Wyanbene Cave entrance, about 25 m in along the streamway. This has a dip of approximately 50° in the direction 160° and striking approximately 70° to true north. It is about 300 mm thick and is highly weathered.

Other dyke-like structures in Wyanbene Cave include:

- A large, laminated dyke-like structure in the Gunbarrel aven can be seen running vertically up the western wall. There was insufficient information to determine further orientation data on this structure. It is composed of black to red material that resembles iron oxide and is apparently 0.5 m thick.
- A smaller dyke-like structure which protrudes from the south western wall of the Gunbarrel aven has a dip of approximately 60° in the direction 60° to true north and a strike of approximately 150°. This is composed of the same type of material as above and is about 30 mm thick.
- A large dyke-like structure in Rockfall Chamber forming part of its western wall (see Figure 5, cross section ON) is composed of sandy, reddish material that resembles infill. It is about 0.5 m thick. The structure has a dip of approximately 70° in the direction 70° to true north and strikes approximately 160°. This seems to be an important controlling structure, as the route of the narrow passage from Far Caesar's Hall to Frustration Lake approximately follows this strike. Dyke-like structures in The Meanders (to the east of Rockfall Chamber) are also controlled by this strike angle. This particular structure is interesting because it appears to be internally folded and convoluted. It is composed of a black, shaley material and is approximately 0.5 m thick.
- The western wall of northern Caesar's Hall appears to be composed of a similar dyke-like structure to the one in Rockfall Chamber. However, it is relatively inaccessible, so no measurements have been made.

Breccias On the surface

At the saddle between Clarke's Cave and the steep eastern side of the Minuma Range, the rocks are a breccia of limestone fragments surrounded by dark reddish material. In Wyanbene Cave, a similar material forms the floor of the area known as the Chamber Pot, near Anderson's Wall (AW in Figures 2 and 3). Some of this material can be magnetised (see below).

Magnetics

There was concern that the original survey may have been affected by remnant magnetism of the oxide material, as some key stations of the original survey were located on oxide bands, so some of the surface material was tested. The brecciated material affected a compass slightly; approximately 1° when the compass rested on the material. After it was placed in a strong magnetic field, the material became permanently magnetic (ferromagnetic) and was able to deflect a compass by approximately 5°. This effect could be attributed to the brecciated material being a hydrothermal deposit, which may include magnetic iron compounds such as magnetite or siderite. These would have initially had small, randomly oriented magnetic domains. The domains grew and aligned with an applied magnetic field: a ferromagnetic material. This means that the original survey is probably accurate to 1°. One should be aware of this effect when using a compass in this area.

Mineralogy

Aragonite is found in Wyanbene Cave in the form of *flos ferri* (literally "flowers of iron") associated with bands of oxide material in north striking joints, particularly in the section between Helictite Chamber and the Wet Stretch. *Flos ferri* are tangled helictites of aragonite. Aragonite is also found in Caesar's Hall in the form of coralloids and frostwork. It is possible that calcium carbonate has precipitated into the aragonite crystal form as a result of the presence of magnesium in dolomitised limestone near the joints. Also in this part of the cave, there are a number of anthodites with a greenish tinge, possibly from small quantities of malachite. Large calcite pseudomorphs after aragonite are present in the roof near Frustration Lake in the form of radiating masses. In the roof of Rockfall Chamber, they take on several forms of irregular needle-like or sheaf-like transparent stalactites. In The Meanders, small calcite pseudomorphs after aragonite form sharp coralloids and aggregates on the walls. In the lower route to the Gunbarrel aven, the walls are coated with an unusual encrustation of coralloids and frostwork that is also assumed to be pseudomorphs. Gypsum is present in the floor of Helictite chamber (marked HC in Figures 2 and 3) in the form of fine needles. It is possibly the result of oxidation of iron pyrites in the ore deposits reacting with the limestone. Pyrite and goethite are listed as occurring in the mines area (Richardson et al, 1981). Some of the chemical reactions are as follows: Iron pyrites is oxidised in the presence of water and air forming hydrated iron III oxide (goethite) and sulphuric acid (there are a few other possible reactions forming different iron oxides).

$$4\ FeS_2\ (s) + 14\ H_2O\ (l) + 15\ O_2\ (aq) \rightarrow$$
$$4\ Fe(OH)_3\ (s) + 16\ H^+\ (aq) + 8\ SO4^{2-}\ (aq)$$

Sulphuric acid in water reacts with calcite in limestone to form gypsum and carbon dioxide (and holes in the limestone).

$$2H^+(aq) + SO4^{2-}(aq) + CaCO_3\ (s) + H_2O \rightarrow$$
$$CaSO_4{\bullet}2H_2O + CO_2\ (g)$$

Between Helictite Chamber and the Wet Stretch, gypsum crystals have been observed in the form of "transistors" (Hill & Forti 1986). These were present on the flat faces of boulders aligned with the north striking joint. Gypsum formation could also be responsible for the instability of the rockpile between upper and lower Rockfall Chamber. Calcite in the form of extensive flowstone is found in the cave before the water crawl. Some of the flowstone is cracked. It is possible that it has been affected by gypsum crystals wedging from underneath the flowstone. Gypsum has a higher solubility in water than has calcite. The presence of gypsum in solution will cause calcite to precipitate from solution (the common ion effect). This could be the reason for the extensive flowstone in this section. There are also other unusual minerals in the cave, especially in Caesar's Hall and Rockfall Chamber. They have not yet been identified, however they could be an uncommon form of calcite speleothem. They take the form of white, pink and light brown coralloids with crystals faces in the calcite system ranging from smooth surfaces to coarse 4 mm dogtooth spar. High on the walls of Caesar's Hall, there are spherical aggregates of transparent crystals composed of parallel plates. Each plate is approximately 3 mm long and is composed of concentric diamond shaped crystal sub-plates. An aggregate is typically 10 mm wide. It is possible that they are gypsum. In some of the dyke-like structures there are small green patches resembling chrysocolla, a copper silicate. These are also present in some of the stones that lie on the floor of the Gunbarrel. Of interest is the list of elements from the nearby mine adits and dumps described by the NSW Geological Survey: gold and silver (minute quantities), copper, lead, zinc, iron, arsenic, tin, tungsten, molybdenum, nickel, cobalt, bismuth and cadmium. This list would give one second thoughts about drinking the cave water, especially as the "ironstones" described were rather high in some of these elements.

Conclusions

The speleogenesis of Wyanbene Cave has been extensively affected by north striking joints coupled with chemical reactions around east-west striking zones of hydrothermally deposited material. Wyanbene is a most fascinating area. There is still much more work to be done: nomenclature of surface features, tagging, surface surveying, mineralogy, speleogenesis, geomorphology and hydrology.

Acknowledgments

I would like to thank the following people for their personal comments and assistance: Chris Norton, Sydney University Speleological Society (SUSS): regarding cave tag numbers and SUSS trip to Ridge Mine Pot on 3rd July 1994; Andy Spate, NSW National Parks & Wildlife Service; John Brush, Canberra Speleological Society: regarding survey of Wyanbene Cave; Ian Cooper, SUSS: regarding ore deposits at Wyanbene (SUSS trip 31st October 1993); Dr Julia M. James of the School of Chemistry, University of Sydney: assistance with chemistry; Dr Michael Lake for assistance with testing magnetic properties of samples; Alan Warild: regarding the Gunbarrel aven and Lloyd Robinson, Illawarra Speleological Society.

References

BRUSH, J., FURLONGER, J., PALMER, K., HUGHES, D., ELLIS, M., COLLINS, E., COGGAN, M., KEPPIE, C., HARDING, A., ALLEN, W. and COLLINS, C., 1972 - 1973 Map of Wyanbene Cave. National University Caving Club, Canberra.

JENNINGS, J.N., 1963 Ridge Mine Pot, Wyanbene, New South Wales. Helictite, January 1963.

RICHARDSON, S.J., BYRNES, J. and DEGELING, P., 1981 A Rock Chip Geochemical Survey of the Wyanbene Base Metal Prospect, near Braidwood. Metallic Minerals Section, Geological Survey of New South Wales Department of Mineral Resources (GS1981/430, M79/2979).

HILL, C.A. and FORTI, F., 1986 Cave Minerals of the World. National Speleological Society, USA.

Address for correspondence: 2 Derribong Place
Thornleigh NSW 2120 Australia

Karst Geomorphology and Hydrology of Gunung Tempurung, Perak, Malaysia

. . . David Gillieson, Ernst Holland & Gareth Davies

Abstract

Gunung Tempurung is a 600-metre high limestone tower in the Kinta Valley located to the south of the city of Ipoh, Perak State, Malaysia. The tower contains at least one extensive cave system, Gua Tempurung, which has a length of approximately 4800 metres and a vertical range of about 200 metres. The tower is an erosional remnant of a thick sequence of Silurian - Permian Kinta Limestones initially formed as a shelf deposit near an ancient coastline. The carbonate rocks lie adjacent to, and are laterally bounded by, Late Mesozoic granite plutonic rocks emplaced by activity related to Late Triassic uplift from plate boundary stresses along the western edge of the Malay Peninsular. The limestones have been folded and compressed between the granites and have been altered by contact metamorphism to marbles and skarn. Hydrothermal mineralisation of the limestone host rock has yielded deposits of tin, with some tungsten minerals and other minor ores. In the central part of the karst tower a river-cave system, Gua Tempurung, developed from local damming of the north and south outlets of a small catchment derived from the granite upland area to the east. In several locations inside the dry upper chambers of the cave, vein deposits of tin (cassiterite) are evident in walls and ceilings. Additionally alluvial tin deposits derived from the Old Alluvium are present in the cave.

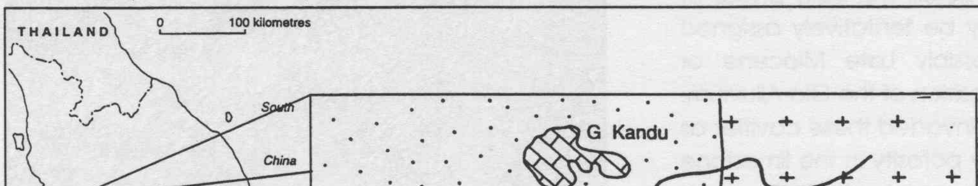


Figure 1 Regional geology of Gunung Tempurung

The limestones are folded and faulted along a north-south axis with the limestone being compressed between two granite plutons. Associated with the east and west compressive forces are two conjugate joint sets that control much of the plan-morphology of the tower. One joint set is aligned NNE-SSW with another NNW-SSE. Large eroded fissures occur on the sides of the tower aligned with the joint sets. The eastern side of the tower with juxtaposed granite has resulted in a massive limestone-marble lithology weathering to rugged tower-karst relief. In contrast, the western and southwestern flanks of the tower are characterised by less altered limestone resulting in cone-karst terrain of gentler relief. This cone karst has numerous enclosed depressions or dolines which drain via short caves to the alluvial marginal plain to the west.

The granite upland areas east and west of the tower result in the limestone forming a laterally-confined carbonate aquifer. The east side of the tower is characterised by the limestone-granite contact; the west side is characterised by a broader corrosion plain. Both surface water and ground water supplies recharge for the limestone aquifer from the east side. Flow is not diverted to the north or south by the tower, rather corrosion of

Paper presented to 3rd Australian Karst Research Symposium, Naracoorte, S.A., 12-16 February 1996

an embayment has allowed the large allogenic (granite upland) catchment to be developed, with the entire basin contents flowing through a large conduit system (Gua Tempurung) down the most efficient hydraulic gradient to emerge as a cave spring on the west side of the tower.

Gua Tempurung is a classic example of a watertable levelled cave which breaches a strike ridge of limestone. As such, its passages may be divided into two types, those initiated by dissolution of autogenic water percolating down from the upper tower surface and those related to allogenic water draining from the marginal granite into the streamsink. However there is good evidence to suggest that the original cavities were formed by hydrothermal action, that is, through the dissolution of limestone by rising hot mineralised water. The emplacement of tin ores as veins in the limestone may have been accompanied by corrosive action due to sulfuric and other acids. This early phase of cavern development may be tentatively assigned to the late Tertiary, possibly Late Miocene or Pliocene, prior to the deposition of the Old Alluvium. Subsequently, karst water invaded these cavities as zones of higher secondary porosity in the limestone mass. This may have occurred when the land surface was much higher than today and with less relief. Fragments of these early cave conduits are visible as phreatic tubes or phreatic roof sections at high levels (100m above present stream level). In several chambers there are extensive deposits of well rounded tin-bearing alluvium which is clearly related to the Old Alluvium of the Kinta Valley. This would suggest that the main stream passage was in existence prior to the deposition of the Old Alluvium, over 750,000 years ago.

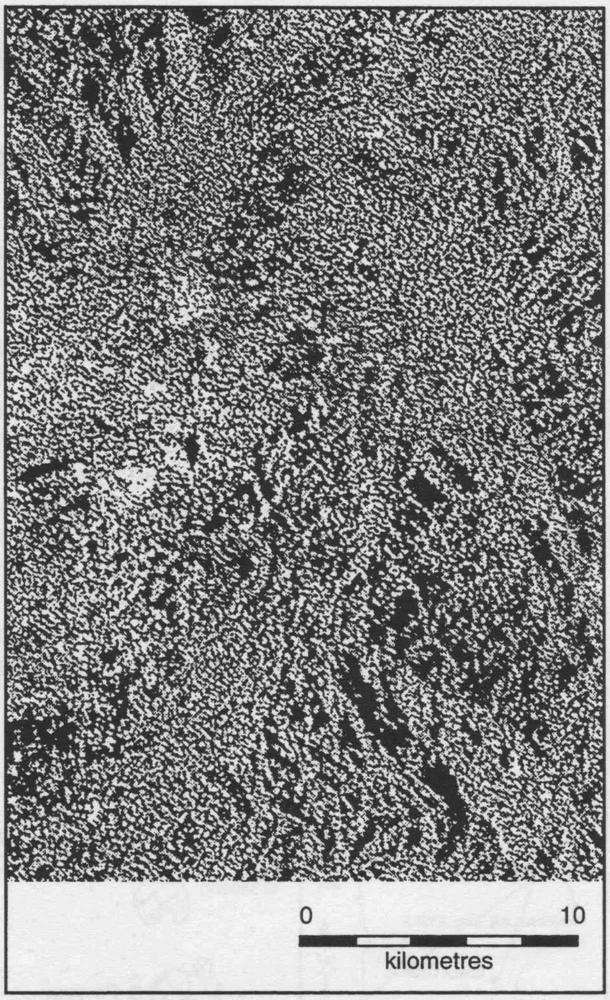


Figure 2 L-band radar image of the Kinta valley showing Ipoh, limestone towers and Gunung Tempurung. This also shows the adjoining granitic terrain, dominant joint sets and scars of mining activity visible in the surrounding alluvium. Resolution of the image is 100m. SIR-C image supplied by the Jet Propulsion Laboratory, NASA, USA.

Figure 2

Introduction

Gunung Tempurung is a 600-metre high limestone tower in the Kinta Valley located to the south of the city of Ipoh (Figure 1). It is typical of a large number of tropical karst landforms formed by the dissolution of limestone by percolating rain water. The tower contains at least one extensive cave system, Gua Tempurung, which has a length of approximately 4800 metres and a vertical range of about 200 metres. The purpose of this report is to provide a preliminary overview of the geomorphology and hydrology of the tower and its hinterland. A more detailed analysis of the chronology of cave development and related geological controls of surface and subsurface geomorphology will require more data to be collected and interpreted. This would involve radiometric and palaeomagnetic analysis of cave deposits as well as detailed geological field investigations, and is planned for 1997. Tracing investigations will also have to be conducted to establish the flow pattern of many components of ground water that characterise the hydrology of the Gunung Tempurung tower and its surroundings.

Geology and Geomorphology

The Gunung Tempurung Tower is an erosional remnant of a thick sequence of Silurian - Permian Kinta Limestones initially formed as a shelf deposit near an ancient coastline. The carbonate rocks lie adjacent to, and are laterally bounded by, Late Mesozoic granite plutonic rocks (Figure 2) emplaced by activity related to Late Triassic uplift from plate boundary stresses along the western edge of the Malay Peninsular. The limestones have been folded and compressed between the granites, and have been altered by contact metamorphism to marbles and skarn. Hydrothermal mineralisation of the limestone host rock has yielded deposits of tin, with some tungsten minerals and other minor ores. The limestones were subaerially exposed, and have been extensively karstified. In the central part of the karst tower a river-cave system, Gua Tempurung, developed from local damming of the north and south outlets of a small catchment derived from the granite upland area to the east. In several locations inside the dry upper chambers of the cave, vein deposits of tin (cassiterite) are evident in walls and ceilings. Additionally, alluvial deposits are

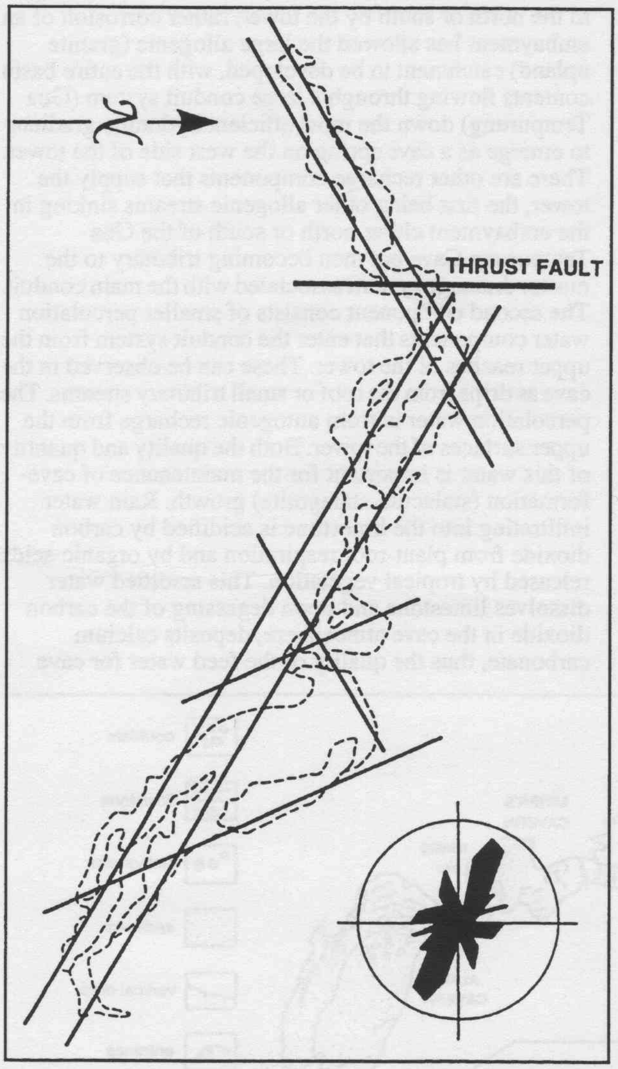


Figure 3 Dominant joint sets controlling plan form of Gua Tempurung (after Gebauer & Price, 1995).

present in the cave. The limestones are folded and faulted along a north-south axis with the limestone being compressed between two granite plutons. Associated with the east and west compressive forces are two conjugate joint sets that control much of the plan-morphology of the tower. One joint set is aligned NNE-SSW with another NNW-SSE. Large eroded fissures occur on the sides of the tower aligned with the joint sets. Extensive joints formed from unloading stresses occur on the sides and flanks of the tower and promote spalling. Where the joint spacing is small, pinnacle-karst features develop, mostly on the flanks of the tower. There are also many shutteridges which enclose small ponded basins analogous to the poljes of classical karst. Deep ravines score the sides of Gunung Tempurung, and both these and the shutteridges are aligned with dominant joint sets. There is no evidence of major faulting, but joint sets are well developed in the Kinta Limestone. Shear faults due to compression run parallel to the strike or on bedding planes. Minor tensional faults run obliquely across the valley. These two major joint sets control much of the orientation of Gua Tempurong (Figure 3) and also have influenced the location of vein tin deposits. The major change in orientation of Gua Tempurung may be related to the presence of a minor thrust fault visible as a gangue in the cave walls.

The eastern side of the tower with juxtaposed granite has resulted in a massive limestone-marble lithology weathering to rugged tower-karst relief (Plate 1). The crests of the towers are rounded with numerous small gullies and some large depressions. One depression near the summit of G. Tempurung has two clearly visible cave entrances which may connect to underlying Gua Tempurung. The cliffs which characterise this karst terrain are maintained by regular spalling and the undercutting promoted by ponding of water in old tin workings and in karst depressions. In contrast, the western and southwestern flanks of the tower are characterised by less altered limestone resulting in cone-karst terrain of gentler relief. This cone karst has

Plate 1 The eastern face of Gunung Tempurong showing tower karst terrain and rainforest vegetation.

numerous enclosed depressions or dolines which drain to the alluvial marginal plain to the west.

The Old Alluvium which infills the Kinta valley is estimated to be 3-10m thick on the northern side of Gunung Tempurung and from 10-20m thick on the southern flank. The likely age of the Old Alluvium, investigated elsewhere in Malaysia, is Tertiary and probably Late Pliocene to Pleistocene (Smart et al., 1984; Yeap, 1995). It overlies the Gopeng Beds, which are comprised of sandy clay and clay with pebbles and boulders. Bedding is indistinct in this formation, in which the boulders are matrix supported. It is likely to be a mudflow deposit derived from the steep granitic terrain to the east and west of Gunung Tempurung. The Gopeng Beds may have had a crucial role in the ponding of water which promoted the enlargement of Gua Tempurung.

Karst Hydrology

The granite upland areas east and west of the tower result in the limestone forming a laterally-confined carbonate aquifer. The east side of the tower is characterised by the limestone-granite contact; the west side is characterised by a broader corrosion plain. Both surface water and ground water supplies recharge for the limestone aquifer from the east side. Flow is not diverted to the north or south by the tower, rather corrosion of an embayment has allowed the large allogenic (granite upland) catchment to be developed, with the entire basin contents flowing through a large conduit system (Gua Tempurung) down the most efficient hydraulic gradient to emerge as a cave spring on the west side of the tower. There are other recharge components that supply the tower, the first being other allogenic streams sinking in the embayment either north or south of the Gua Tempurung Cave but then becoming tributary to the master drainage system associated with the main conduit. The second component consists of smaller percolation water components that enter the conduit system from the upper reaches of the tower. These can be observed in the cave as drips from the roof or small tributary streams. The percolation water is from autogenic recharge from the upper surfaces of the tower. Both the quality and quantity of this water is important for the maintenance of cave-formation (stalactite-stalagmite) growth. Rain water infiltrating into the limestone is acidified by carbon dioxide from plant-root respiration and by organic acids released by tropical vegetation. This acidified water dissolves limestone and upon degassing of the carbon dioxide in the cave atmosphere, deposits calcium carbonate, thus the quality of the feed water for cave

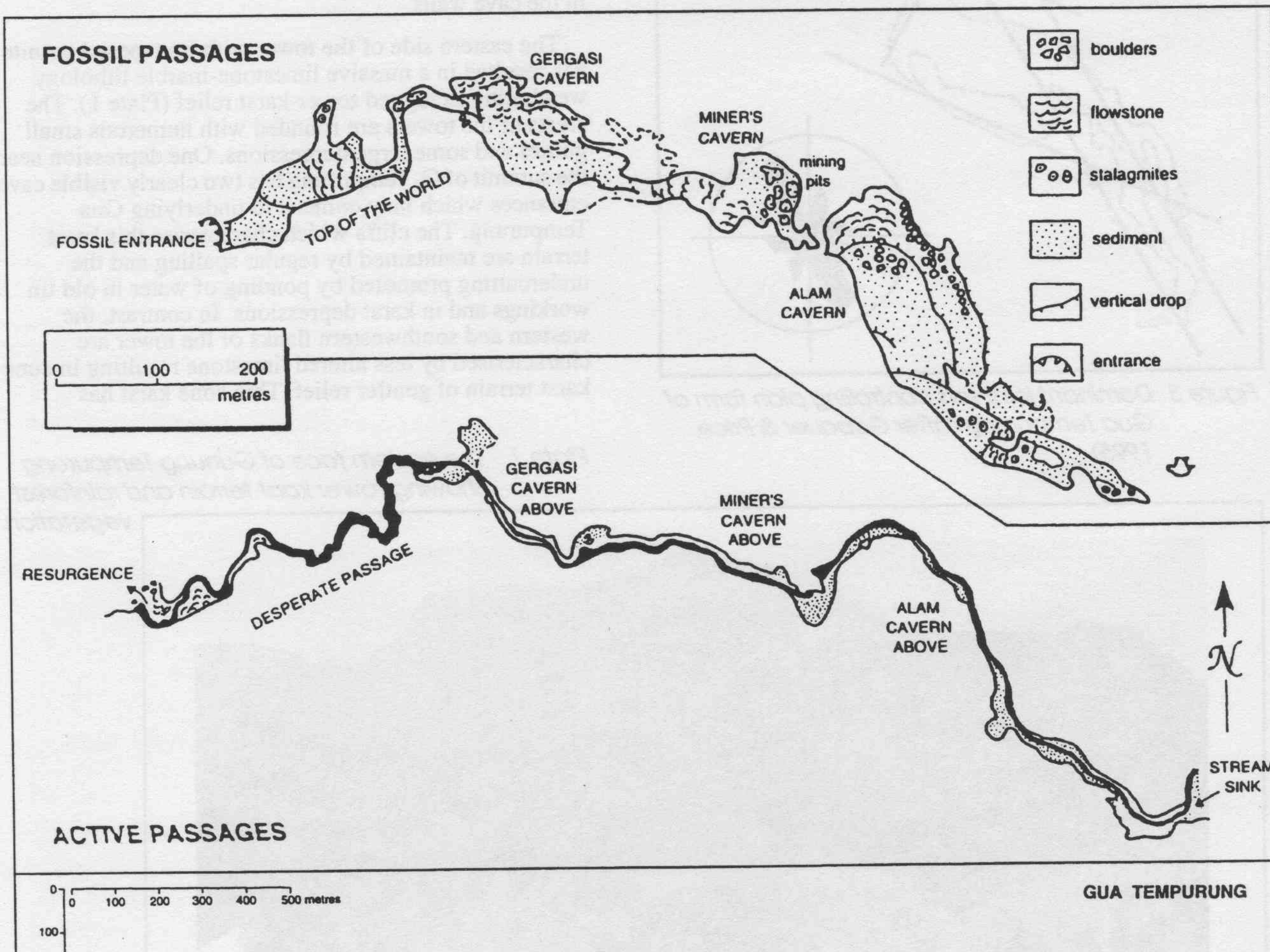


Figure 4 Plan and projected section of Gua Tempurung showing passages mapped by 1995 Australian exploration and passages mapped by Gebauer & Price (1995).

formation growth is totally dependent on the maintenance of healthy forest vegetation on the limestone towers.

The allogenic recharge components are chemically different, with a rapid-flowing allogenic source from surface water from the granite upland, and another component of deeper circulation from the granite bedrock and a narrow strip of the limestone, low down near the east flank of the tower. The basin that feeds the Gua Tempurung sink has been filled with sediments from two sources, detritus and alluvium from weathering of the granite, and sediments from mining operations and construction of the highway, which runs to the east of the tower, almost parallel to the granite-limestone contact. Discharge from the limestone aquifer occurs either through the cave streams or through a deep fissure system into ponds or springs. Steep bedding, as reported by other workers, suggests deep circulation with steeply rising conduits feeding springs. There are reports of thermal springs on the west side of the tower, suggesting deep circulation.

Local informants, some having worked in the mining business, report that occasionally the basin feeding Gua Tempurung sink becomes flooded, with water input exceeding the output capacity down the cave stream. This flooding occurs at a frequency of about four times a year. Preliminary dye tracing experiments and dye-dilution gauging under low flow conditions have shown that flood pulses move rapidly though the cave with a velocity of at least 1.1 ms^{-1}. This means that a pulse moves from the entrance to the low, constricted section of the cave in about 15 minutes. The alluvium and detrital deposits in the basin have allowed a few relief springs to rise through the sediments near the Gua Tempurung sink, and then flow down the cave conduit.

The unvegetated tailing deposits from the tin mining operations, being relatively impermeable, permit relatively large run off components to also contribute to the Gua Tempurung sink. The road batters of the highway are rapidly eroding and also contribute large amounts of coarse granite colluvium to the stream feeding Gua Tempurung. This excessive sediment supply reduces the channel capacity of the cave conduit. Effective erosion control may involve terracing, bund construction, and revegetation of the steep highway batters. The allogenic catchment of Gua Tempurung may be defined as all of the road pavement extending from a knoll overlooking the cattle ranch in the north to a broad fallow paddy to the south near the roadside rest area, and includes the granitic catchment which drains under the highway as well. The northern end this catchment is bounded by a low alluvial ridge. To the north of this, water flows in a surface channel around the northern perimeter of the tower and is not part of the karst hydrological system.

Cave Evolution

Gua Tempurung is a classic example of a through-cave which breaches a strike ridge of limestone (Figure 4). As such, its passages may be divided into two types, those initiated by dissolution of autogenic water percolating down from the upper tower surface and those related to allogenic water draining from the marginal granite into the streamsink. Early interpretation of cave development in this part of Malaya (Paton, 1962; Walker, 1960) suggested that higher sea levels (up to 100m above mean sea level) may have produced the higher level passages and horizontal niches visible in the landscape. Higher global sea levels have been reported throughout much of the Tertiary (Nunn, 1994): there is evidence for a sea level at least 90m above present in the Middle Miocene, and also in the Pliocene. During the last interglacial period (c.125,000BP) sea level attained an altitude of 1.5-9.0m. There is widespread evidence for sea levels 2-3m above present mean sea level in Malaya, but although much higher sea levels have been postulated, no unequivocal evidence has yet been obtained for these in the Malay Peninsula. In the absence of such evidence, the high level passages and niches may be related to local ponding behind mudflow deposits, and valley aggradation in the Sungai Kampar (Figure 1). In Sarawak, Smart et al. (1985) have invoked a similar mechanism for the formation of some passages in Clearwater Cave, Mulu.

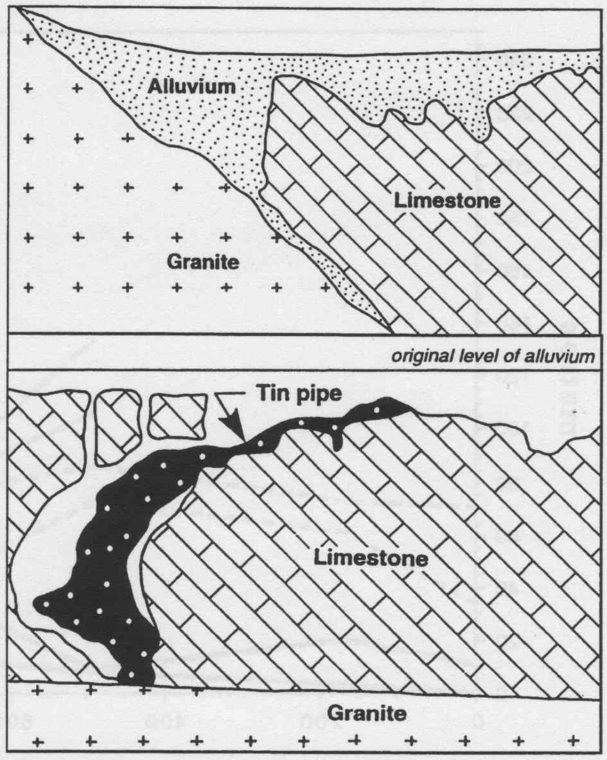


Figure 5: Schematic sections showing context of (a) alluvial tin deposit near Menglembu and (b) vein tin deposits at the Beatrice Mine near Selibin in the Kinta Valley. After Ingham & Bradford (1960).

However, there is good evidence to suggest that the original cavities were formed by hydrothermal action, that is, through the dissolution of limestone by rising hot mineralised water. The tin ore occurs in sulfidic stanniferous "pipes" which, in many cases are infilled karst cavities, some clearly caves (Figure 5). All the deposits of tin are fissure fillings or metasomatic replacement of the limestone by warm fluids containing sulfur, arsenic, tin, copper and iron. Thus the principal minerals in the tin veins are cassiterite, arsenopyrite, chalcopyrite, bornite and pyrite, often found in a calcite matrix. The oxidation of the pyritic minerals due to watertable fluctuations (both short- and long-term), has probably produced sulfuric acid, which has a key role in cave development. Modern deep circulation of acidified water to 100-130m is evidenced by pumping tests. On the southern side of Gunung Tempurung, the Jehosophat Mine was developed along a vein which followed a near-vertical fault plane in the limestone. This ore body had a length of 440m, a width of 1m and an excavated depth of 40m. The deposit was comprised of cemented stanniferous alluvium of sand size; associated minerals being cassiterite, quartz, tourmaline, topaz and ferric oxides in a calcitic cement.

The emplacement of tin ores as veins in the limestone may therefore have been accompanied by corrosive action due to sulfuric and other acids. This early phase of

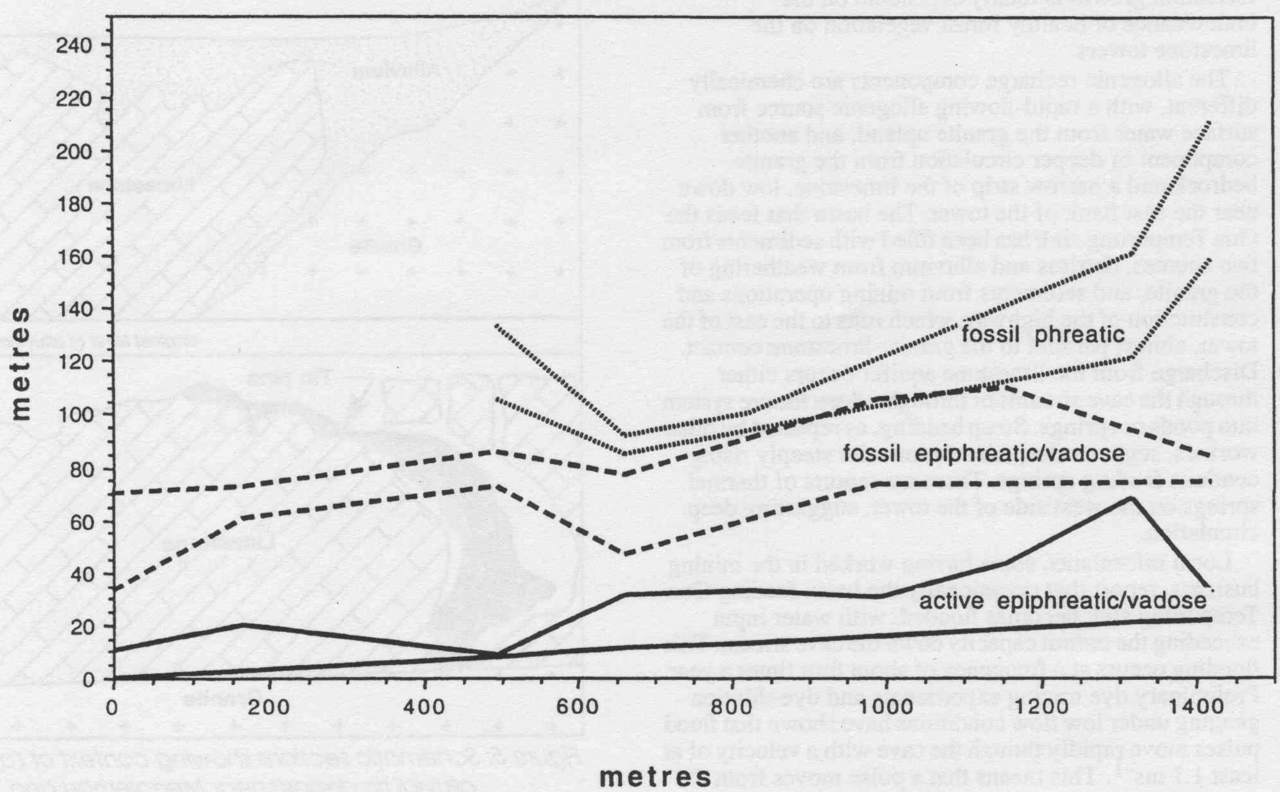


Figure 6 Schematic projected section of Gua Tempurung showing active and fossil passages.

cavern development may be tentatively assigned to the late Tertiary, possibly Late Miocene or Pliocene, prior to the deposition of the Old Alluvium. Subsequently, karst water invaded these cavities as zones of higher secondary porosity in the limestone mass. This may have occurred when the land surface was much higher than today and with less relief. Stratigraphically, many of the caves are older than the Old Alluvium. In many places, excavation of the alluvial tin deposits has revealed buried stalagmitic columns which link epiphreatic roof sections with lower bedrock. In several chambers there are extensive deposits of well-rounded tin-bearing alluvium which are clearly derived from the Old Alluvium of the Kinta Valley. This would suggest that the main stream passage was in existence prior to the deposition of the Old Alluvium, over 750,000 years ago.

Fragments of these early cave conduits are visible as phreatic tubes or phreatic roof sections (Figure 6) at high levels, 100-140m above present stream level. One example is preserved as a tube, 20m in diameter, with scalloped walls indicating substantial water flow, and a hydraulic jump where it leaves the main stream canyon above Gergasi Cavern. A flat, scalloped roof section is visible at the highest levels of the cave, and has been formed under conditions of passage-full discharge. In most locations this has been entrenched to a depth of 80m to form a vadose canyon. Large incuts on the walls of this canyon suggest that downcutting has been episodic, with phases of sediment infilling and lateral channel migration of the sediment fill. This has been followed by downcutting, leaving wall niches with either partial alluvial sediment fills or bare rock surfaces. These downcutting phases may be related to increased catchment runoff and a lowering of regional base level. Conversely, phases of sediment infilling may be related to increased sediment supply consequent on tectonic uplift, seismic events or destabilisation of vegetation due to climatic change. It is very likely that these episodes of sediment infilling and incision are related to glacial—interglacial cycles over the last two million years. Finely laminated sediments in these deposits would be amenable to palaeomagnetic dating, and suggest that there have been long periods of relative stability in the catchment. Today the cave stream is incising older sediments and is carrying a bedload of poorly sorted angular colluvium derived from erosion of the road batters and remobilisation of fine clays from tailings. Present suspended sediment yields from rivers in Perak State range from 88-144 $m^3 km^{-2} y^{-1}$ (Douglas & Spencer 1985). These are high by world standards.

Significance of Gunung Tempurung

In contrast to the flat-lying or gently folded pure limestones of southern China, the limestones of the Kinta valley have been steeply folded and partially metamorphosed. This has resulted in a diversity of tropical karst landforms, found in a smaller area than comparable karst styles in the classic karst of Guanxi Province, near Guilin. Karsts in southern China are widely scattered, are formed on pure, thick and old limestones, have been subjected to strong Cenozoic uplift, and have formed under a long warm humid monsoonal climate, unaffected by glaciations. Three principal karst styles are recognised there:

- *Fenglin* or tower karst, characterised by a forest of limestone towers standing above a comparatively flat surface, often alluviated.
- *Fengcong* or peak-cluster depression, where a limestone massif has a large number of closed polygonal depressions united in a common rock base, often elevated above the surrounding terrain. The depressions are separated by conical hills (hence the alternative name "cone karst"), whose shape may depend on local details of structure and lithology.
- *Gufeng*, isolated towers in alluvial plains, are the result of extensive dissection of fenglin by meandering rivers which isolate blocks of limestone

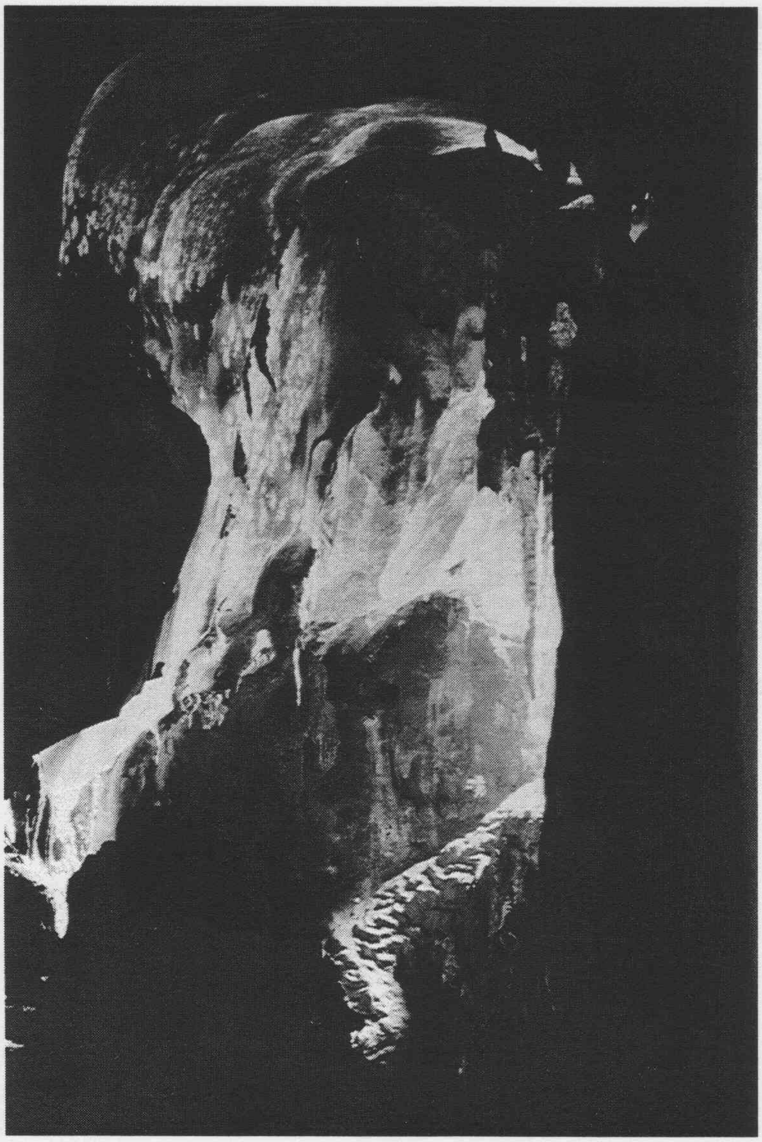


Plate 2 Downstream passage in Gua Tempurong showing breached phreatic tube and vadose canyon. Vein tin deposits in the roof of this cavern have served as inception zones and directed its development. Figure in white helmet, lower centre of photo, for scale.

and then reduce them by undercutting, foot cave development and cliff spalling.

The Gunung Tempurung-Gajah massif shares similarities with the *fenglin* and *fengcong* styles of tropical karst, with the eastern side resembling *fenglin* and the western side *fengcong*. This juxtaposition is unique and is due to the greater degree of metamorphism on the eastern side, adjacent to the granite upland. The steep cliffs of the eastern side, the sinking streams and the dramatic cave entrances resemble the classic tower karst, long celebrated by artists, poets and students of karst since the writings of Xu Xiake in the seventeenth century. In contrast, the western side has relatively gentler relief, with a complex network of karst depressions separated by conical hills, some cliffed. It is nearer to the *fengcong* style, and has formed on softer rocks. There is a wide range of small-scale solution features on the karst—solution rills, deep runnels, and pinnacles—and the largely intact rainforest vegetation ensures the continuity of limestone solution processes. This is an outstanding massif in which visitors can see a wide range of tropical karst landforms in a small area, accessible by road and by foot.

Gua Tempurong cave is a regionally outstanding example of a tropical river cave and its significance may be assessed from several perspectives:

- there are several cave temples in the tower, regularly used by local residents of both Taoist and Hindu faiths. Such temples are widespread in the Ipoh district and natural features of the cave serve as objects of contemplation and veneration.
- Gunung Tempurung is a virtually intact tower, unlike many in the Kinta Valley which have been quarried. As such it has greater conservation value than many of the other towers.
- the large, well decorated chambers attract large numbers of visitors, including organised school groups and field naturalists from all over Malaya. There is thus considerable scope for the development of ecotourism in Gua Tempurong and nearby caves.
- there is also scope for controlled nature-based tourism ranging from developed tourist cave experiences to adventure caving. The cave is close to the main freeway which runs the length of the Malay Peninsula linking Singapore, Kuala Lumpur, Ipoh and the southern cities of Thailand.
- the cave and its tower could be the site for a karst education and research centre which would attract a range of scientists and students from geology, geography and biology.

Acknowledgements

We are very grateful to Mr. Gerald Lui of the Adorna Group of Companies, Kuala Lumpur who hosted our visit to Ipoh and Gunung Tempurung and made our stay both enjoyable and productive. Mr. Steven Reilly and Mr Andrew Lawrence, Jenolan Caves Reserve Trust, were part of the team which carried out much of the cave exploration and surveying on which the figures are based.

References

GEBAUER, H.D. & PRICE, L., 1995 Gua Tempurung. A tunnel cave in the marble hills of Kinta valley, Perak, West Malaysia, *Journal of the Malaysian Nature Society* 68:29-52.

NUNN, P. D., 1994 *Oceanic Islands*, Oxford, Blackwell Publishers.

PATON, J.R., 1962 *The origin of the limestone hills of Malaya*. Professional Paper E-58-1T, Kuala Lumpur, Geological Survey of Malaya.

SMART, P.L., ANDRES, J.N. & BATCHELOR, B., 1984 Implications of uranium series dates from speleothems for the age of landforms in northwest Perlis, Malaysia: a preliminary study. *Malaysian Journal of Tropical Geography* 9, 59-68.

SMART, P.L., BULL, P.A., ROSE, J., LAVERTY, M. & NOEL, M., 1985 Surface and underground fluvial activity in the Gunung Mulu National Park, Sarawak: A palaeoclimatic interpretation. In I. Douglas & T. Spencer (eds) *Tropical Geomorphology and Environmental Change* London: George, Allen & Unwin, 123-48.

WALKER, D., 1955 The alluvium, and changes in the relative levels of land and sea, In Ingham, F.T. & Bradford, E.F. 1960. *The geology and mineral resources of the Kinta valley, Perak.* District Memoir 9, Geological Survey of Malaya.

YEAP EE BENG, 1995 Origin of the subsurface limestone karst and development of placer tin deposits of peninsular Malaysia, Paper presented to International Association for Geomorphology - SE Asia Regional Conference, Singapore 18-30 June 1995, in Program with Abstracts p83.

Addresses for correspondence:

David Gillieson
School of Geography & Oceanography,
University College, University of New South Wales,
Canberra, ACT 2601, Australia.

Ernst Holland
Jenolan Caves Reserve Trust,
PO Box 1495,
Bathurst, NSW 2787.

Gareth Davies
Cambrian Ground Water Co.
109 Dixie Lane,
Oak Ridge, TN 37830 USA

Information for Contributors

Scope

Contributors from all fields of study related to speleology will be considered for publication. Suitable field include Earth Sciences, Speleochemistry, Hydrology, Meteorology, Conservation, Biospeleology, History, Major Exploration (Expedition) Reports, Equipment and Techniques, Surveying and Cartography, Photography and Documentation. Comprehensive descriptive accounts of the exploration and morphology of individual caves will be welcomed, but simple trip reports and brief cave descriptions are not adequate. Papers overall should not exceed 20 printed pages in length. Contributors intending to write at greater length or requiring any advice on details of preparation are invited to correspond with the Editors. All manuscripts will be read by referees. Short "Letters to the Editor", expressing a personal view or giving a preliminary report of interesting findings, are welcomed, and will be given preference for speedy publication.

Manuscripts

Submitted manuscripts should be in final form ready for publication. As proofs are not normally sent to authors particular care should be taken to check for typing errors. Manuscripts should be typed, double spaced, on one side of the paper. The title should be upper case bold and the author's names should follow. A brief and explicit summary of the notable aspects of the paper, headed abstract, should precede the main text.

Throughout the main text headings should be in upper case, centred and bold, while subheadings should use lower case bold aligned with the left margin. Acknowledgements should be placed at the end of the text before the references, and the author's addresses for correspondence should follow the references.

Authors are requested to submit a copy of their manuscript on floppy disk as well as hard copy in the first instance. Disks may be 3 1/2" or 5 1/4" in either MSDOS or Macintosh format. If sending text as a word processing document (Microsoft Word etc.), please send a copy as text on the same disk.

References

References should be listed alphabetically at the end of the manuscript and cited in the text by the author's name and the year of publication (e.g. "(Grey, 1988)"). Where there is more than one reference to the same author in one year the letters a, b, c, etc. should be added. If there are more than two authors, they should all be named at the first citation and in the reference list, but the first name followed by *et al.* should be used in subsequent citations. References should be checked particularly carefully for accuracy. Journal titles should be abbreviated following the "World List of Scientific Periodicals", which is available in most large libraries.

The following examples illustrate the style:

GREY, M.R., 1973 Cavernicolous spiders from the Nullarbor Plain and south-west Australia. *J. Aust. ent. Soc.* 12: 207-221.

VANDEL, A., 1965 Biospeleology. *The Biology of the Cavernicolous Animals.* Pergamon, London. Pp. xxiv, 524.

WIGLEY, T.M.L. and WOOD, I.D., 1967 Meteorology of the Nullarbor Plain Caves. In: J.R. DUNKLEY and T.M.L. WIGLEY (eds), *Caves of the Nullarbor. A Review of Speleological Investigations in the Nullarbor Plain. Southern Austalia*: 32-34. Speleological Research Council, Sydney.

Illustrations

Figures and photographs should not duplicate information in tables or other material. Photographs should be clear black and white prints with sharp focus. The number of pages with photographs will be kept to a minimum. Where several photographs are to form one plate they should be mounted together on white card. Any lettering required on photographs should be applied with "Letraset". Figures should be drawn in Indian ink on white card, heavy paper or tracing material and lettered using stencils or "Letraset" or supplied as Laser prints. Most computer drawn documents can also be handled if they are in Macintosh format. Please avoid using unusual fonts unless they are included with the diagram.

All illustrations should be drawn to fit a full page print area of 170 x 215 mm or 80 x 215 mm to fit single columns. They may be larger provided that these proportions are maintained, but allowance for reduction must be made when choosing letter sizes and line thickness. Diagrams for inclusion in the text must be drawn to a width of 80 mm.

Figures and plates should each be numbered consecutively and specifically referred to in the text. The numbers should be marked lightly in pencil on the margin or back of each illustration. Captions should be typed on a separate sheet.

Units

The S.I. system (Australian Standard AS 1000) should be used unless citing historical data, in which case the original units should be quoted and appropriately rounded metric equivalents added; "100 feet (30 m)".

Offprints

Offprints of papers will be supplied after publication, at the author's expense. The number required should be stated when submitting the manuscript.

Speleological Research Council Limited
A.C.N. 000 456 42

Helictite

Journal of Australasian Speleological Research

Volume 33 (1/2) 1995

Contents

Speleological Research Council Limited
A.C.N. OOO 456 42