CAVES of MULU '80

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THE LIMESTONE CAVES
OF THE GUNONG MULU NATIONAL PARK
SARAWAK

Continuing Caves of Mulu (1978)

Compiled by A. J. Eavis

Andy Eavis

Cathay Pacific Airways

MULU '80 EXPEDITION

British-Malaysian Speleological Expedition to Sarawak

Patron: Her Royal Highness The Duchess of Kent

Hosts: The Sarawak State Secretary and the Director Sarawak Forestry Department

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The start of the ramps to the Mulu '80 discoveries in Benarat Caverns (A. Eavis)

CAVES OF MULU '80

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Surveys drawn by Colin Boothroyd and others
Photographs by Jerry Wooldridge and others

The full report and scientific results of the Mulu '80 Expedition forms number 1 of volume 9 of the Transactions of the British Cave Research Association, to be issued in January 1982.

Cover photographs: Front: The Plunge Pool in Lubang Nasib Bagus (C. Boothroyd)
Back: River crossing in the Melinau Gorge (A. White)

The southern entrance to Deer Cave from the air (J. Wooldridge)

THE GUNONG MULU NATIONAL PARK

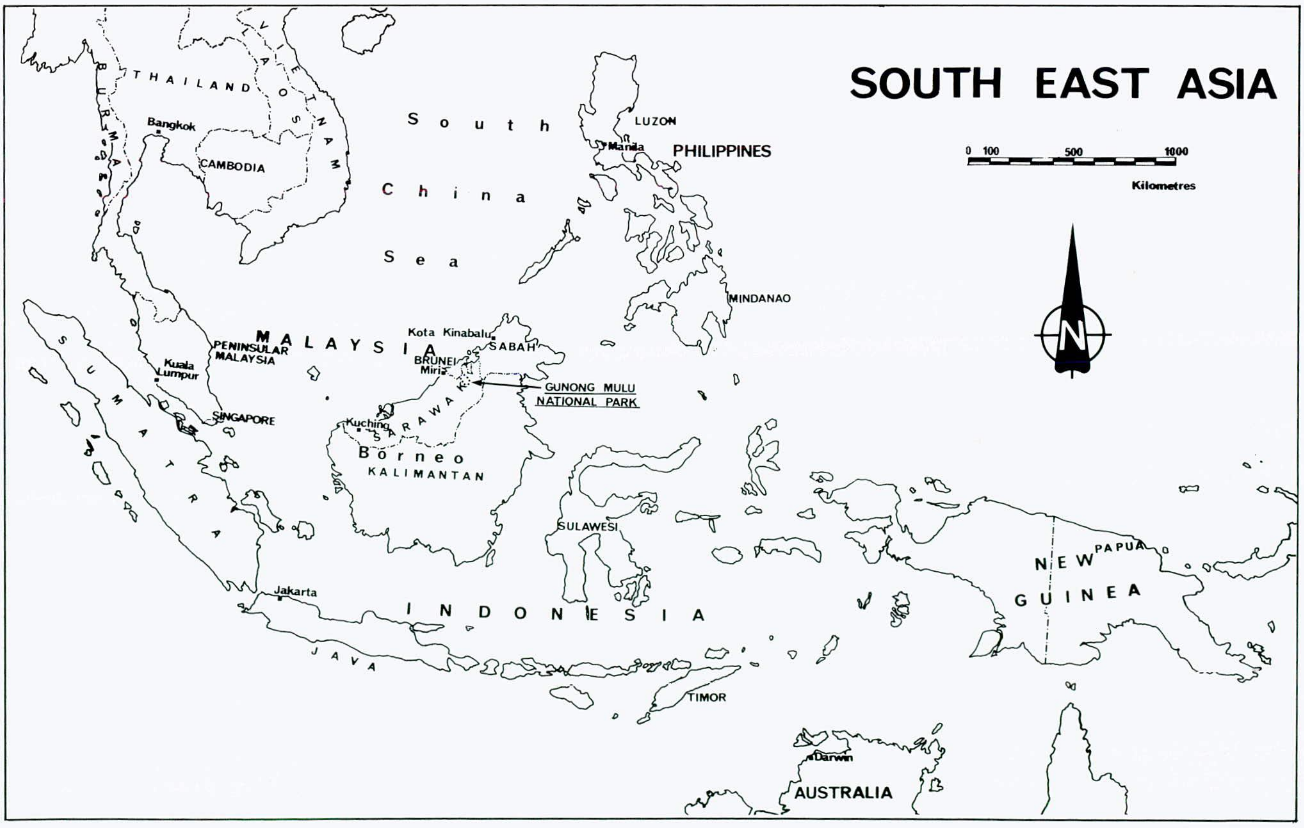
Ben Lyon

The Gunong Mulu Park includes the outcrop of the Melinau Limestone between the Tutoh and Limbang rivers, in Sarawak's Fourth and Fifth Divisions. A spectacular line of peaks is formed by the limestone, aligned along a bearing of 30° from the Tutoh, with alluvial plain to the West, and the shale and sandstone slopes of Gunong Mulu to the East. Most of the limestone is in the National Park, but it continues northward into the Medalam Protected Forest. Three major rivers cross the limestone — the Melinau Paku, Melinau and the Medalam — and a number of other rivers and streams disappear into its outcrop. It is this drainage which has been responsible for the development of the magnificent caves of the area and which form the subject of this publication.

Before descending into the depths of the hills it is worth looking at their surface landscape. Tree smothered slopes rise steeply from the alluvial plain, giving way at around 600 metres to more undulating ground, containing numerous dolines and shakeholes, and, on southern Api, breaking into cockpit karst. Higher still, on Api and Benarat, the slope steepens again to reach summit ridges at around 1600 metres, before dropping abruptly down to the junction with the eroded ridges and valleys of the Mulu sandstones. Here and there patches of white limestone struggle free of the clinging vegetation. Towering cliffs surround the blind Hidden Valley , with one overhanging rock prow rising unbroken for over 600 metres, and again on the northern side of the Melinau Gorge, where massive cliffs rear up like a strange tropical parody of a glacial valley-side. Around 10,000 millimetres of rain a year falls on the hills, percolating immediately into the rock, but leaving terrain among the most difficult to traverse in the world, and culminating in the pinnacle karst best seen on the northern shoulder of Api. Very little of the limestone surface has been trodden due to the extreme combination of jungle, steepness and corroded rock.

EXPLORATION OF THE MULU CAVES

The Melinau River area has been known to contain caves since time immemorial. Burial sites ascribed to the Tring people have been found, mainly in stream-notch caves in isolated hills. The first explorer with the caves as his objective was Dr. G. E. Wilford of the then Geological Survey of the Borneo Region, Malaysia, in 1961. His remarkable surveys of Deer Cave and parts of Wind Cave and the Terikan Caves left him in little doubt as to the



potential of the area. In his book on the geology of the caves of Sabah and Sarawak he wrote: 'Large spectacular caves are most likely to be discovered in the uninhabited and relatively unexplored Melinau area ...... where the Api and Benarat Mountains could contain cave systems several miles long.'

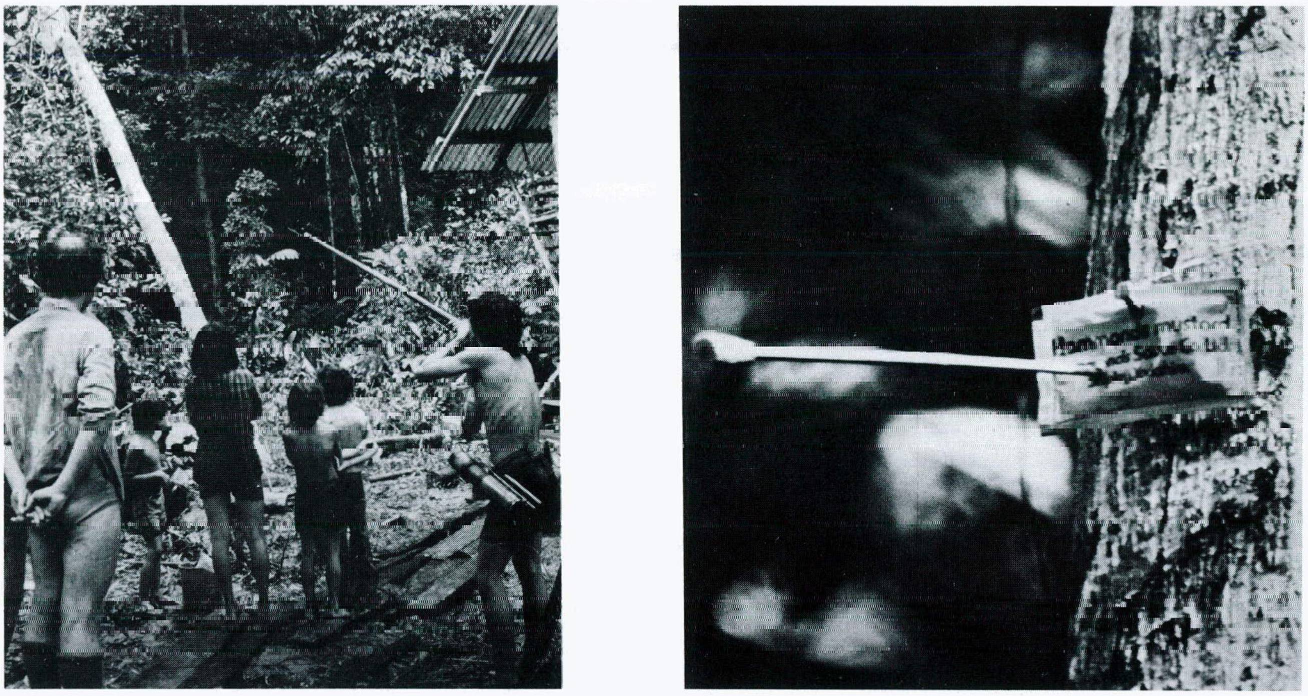
Caves were not uppermost in the minds of the organisers of the Royal Geographical Society's 1977/8 expedition to the Gunong Mulu National Park, with a team of just six speleologists among 130 scientists. However that expedition found that not only had Wilford been correct in his prediction, but that the caves were real world-record beaters. Much was found on that visit and is documented in 'Caves of Mulu'. It was however clear that much more remained to be discovered. In 1978, three members of the RGS expedition, Andy Eavis, Ben Lyon and Paul Chai discussed plans for another expedition to continue the work in the caves. As a result the 1980 expedition was launched. Its organisation was probably unique, cave specialists from Britain joining the staff of Sarawak's Forest Department and local forest people in a joint venture. While Eavis and Lyon organised from Britain, Dr. J. Yong, Director of Forests co-ordinated in Sarawak.

THE MULU '80 EXPEDITION

Unlike modern mountaineers, cave explorers are never certain of their goal. Objectives cannot be studied in advance from photos, and the trail of unsuccessful expeditions which were going to find world-beating caves, threads the annals of speleology. After plotting the dimensions of Deer Cave, and finding mile after mile of Clearwater Cave in 1978, it could have been that Mulu '80 would be an anti-climax. But not so! The eye of faith was rewarded. The Medalam area was shown to hold numerous active cave systems: the Terikan river system was more than doubled in length: the Melinau Gorge revealed massive ancient caves: Clearwater Cave continued to grow, and is now the longest in South East Asia: even Cave of the Winds turned out to be a major system in its own right!

But the high spot of the expedition must be Sarawak Chamber in Lubang Nasib Bagus. Here the enigma of the Mulu caves reaches its climax. Outside Nasib Bagus is the all-embracing, claustrophobic forest; inside is the Sarawak Chamber, total black space, so huge its boundaries cannot be seen, producing feelings of agoraphobia in the strongest spirit! This chamber is over 12 million cubic metres in volume, almost three times the size of any previously discovered cavity. Its dimensions can be gained from the survey, but not the spirit of the place. When the first team to enter it returned to camp they were almost incredulous of their own find. Seventeen hours had been spent in surveying, climbing over and around house-sized boulders sloping away at alarming angles, trying — sometimes unsuccessfully — to keep within sight of a wall! Thus they had entered a strange world no writer of fiction would invent.

Base Camp at Long Pala, when the expedition long house was still being built (J. Wooldridge)



A mustard packet is used by a local tribesman as a target to demonstrate his skill with the blowpipe (A. Eavis, R. Willis)

Before reaching the caves much work had to be done, and effort expended. A total of ten sub-camps were established, in addition to the magnificent base-camp at Long Pala built jointly by us and the Sarawak Forest Department. Camping in this environment bears little resemblance to the same activity in Britain. We were in the expert hands of our Berawan assistants, who were able to make a framework of saplings for living and eating, beneath a polythene sheet or in a cave portal. Underground bivouacs were used regularly without the problems associated with living in colder and smaller caves. Protective sleeping gear was unnecessary, and a normal rucsac could be used for carrying gear through the caves. Very often the caves were much dryer and quieter than outside — in many ways more pleasant than the forest. With up to six camps occupied at the same time, and no one group large enough to effect its own rescue, communications were most important. An excellent radio link was established from base-camp to the coast, with portable radios linking sub-camps to base.

Travel provided its own problems. The present Park base is at Long Pala, on the Melinau River, and for the rich and the fortunate is accessible by helicopter. The expedition fell into the second category, and with assistance from the Royal Malaysian Air Force, all five tons of the expedition's stores were flown in, half to Long Pala, and half to a clearing at the entrance of the Melinau Gorge, thus eliminating weeks of back-packing. For regular transport from Marudi, the nearest town down-river, the Sarawak Forest Department generously provided longboats. These could make the up-river journey of 100 kilometres in a long day, each with around half a ton of people and baggage combined. Once at Long Pala, the caves are still a journey of up to three days away, mostly on foot. Deer Cave is closest, an hour's march. Nasib Bagus is four hours, and a couple of river-crossings. To get to caves further north a smaller long boat can usually be taken up the Melinau. The Clearwater area is nearly always reached by boat, a most civilized state of affairs. Long Berar, the up-river end of boat journeys, is in the middle of nowhere. A hard two-hour march through the alluvial forest is then needed to reach the Melinau Gorge camp. To get to the Medalam and beyond is a further day's march. Some of the best used tracks become easy to recognise, but the forest is constantly altering, and in the two years that had passed since the RGS expedition even river courses had altered.

There were periods of a week and more without rain, but these were the exception. During the latter half of January '81 the opposite was encountered and we had record floods, with 600 millimetres of rain falling in one three day period. Rivers flowing off the mountain slopes cut off parties at the Medalam camp, and the whole alluvial area including base-camp, was under a metre or more of water. However with camps adjacent to the limestone, cave exploration continued even then. The first part of Nasib Bagus was entered, though the canal was three metres deeper than it can be; the dry Tiger Foot series was extended to Benarat Highway; and Blue Moonlight Bay Cave was being explored from the Medalam camp. After a long surveying trip in this cave the party returned to the active river section to find their route sumped off. Twelve hours later it was still sumped, though dropping, and Tony White dived out to secure a line for the rest of the party.

The camp by Nasib Bagus was typical of the many expedition sub-camps (C. Boothroyd)

Hazards can be over-emphasised, but experience on Mulu '80 showed that they do exist. There were two cave rescues, both effected by the people around at the time. In the first, Jerry Wooldridge, the expedition photographer, slipped a few feet, slicing his upper leg on sharp limestone as cleanly as any knife could do. Almost miraculously, given the extent of the cut, nothing vital was severed, and he was helped out of the cave. Outside, this was one of the occasions when the radio-link failed, so Roni King, one of the outstanding men employed by the expedition ran back to Base Camp through trackless forest in the dark to contact our doctor — Jon Buchan. The following night Jon himself was nearly caught when, sitting on one end of his camp-bed he was narrowly missed by a tree branch that smashed through the camp sheet and mattress! Bat guano is known as a carrier of histoplasmosis, but it was an allergy to it that floored Pete Bull. He collapsed in the Cave of the Winds unable to breathe, but was rescued so quickly, with the assistance of our friends from Shell Sarawak, that in less than two hours from his collapse he was in hospital in Miri.

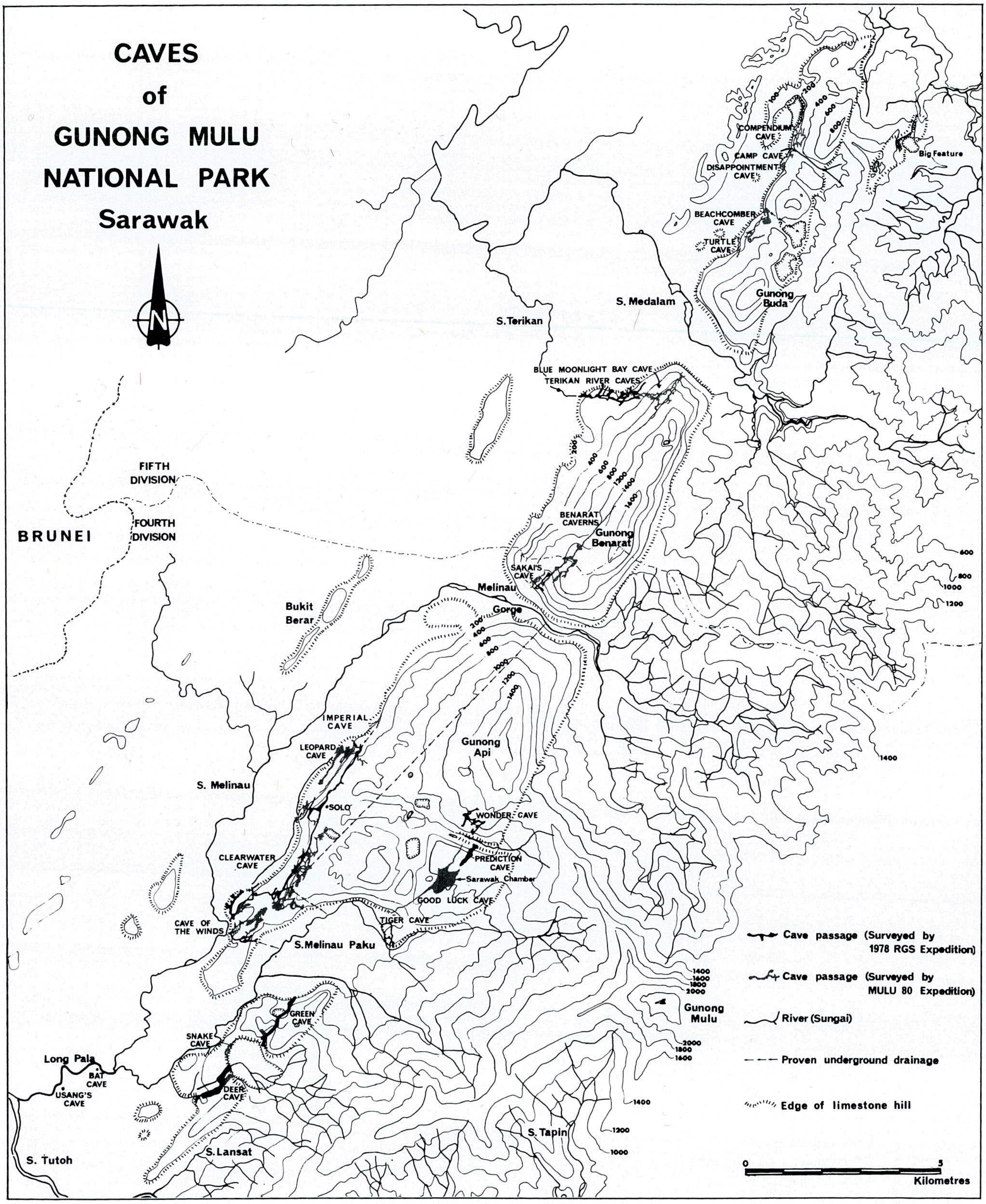
A high priority was placed on recording the discoveries made, so the party included Sid Perou and his film team of Lindsay Dodd and Geoff Yeadon. In addition to the normal problems of underground filming there was the difficulty of lighting bigger passages than had ever been filmed before. The high reflectivity of the light coloured cave walls helped, and by using 1000 watt lights powered by car batteries strapped to pack frames success was achieved. While the cavers were pushing new frontiers, teams of scientists from Bristol (Pete Smart, Hans Friederich and Phil Chapman) and Oxford Universities (Pete Bull, Marjorie Sweeting and Martin Laverty) were making their detailed studies in the caves that had been surveyed in 1978. However the temptation to look into unknown places was too strong to resist, and they too found much new passage — that is all except Jim Rose, our sole surface scientist, whose dedicated work on the alluvial sediments will help unravel the history of drainage in the area — itself the key to the development of the caves. Less tangible were the results of the programme of training Forest Department officers and local men as cavers. The process that normally takes years had to be compressed into weeks, but with the incredible physical skills of our porters they were very quickly taking the lead on many occasions, and developing a real understanding of cave formation. As a result future visitors to the caves will find a pool of trained cavers, able to act as guides and, should the need arise, to effect underground rescue.

The Mulu caves are all within the National Park or Protected Forest, so that permission to visit them must be obtained in advance from the Sarawak Forest Department. Clearly this unique natural heritage will be carefully conserved by the Sarawak authorities, but those fortunate enough to be able to make a visit will see one of the wonders of the world.

LENGTHS AND DEPTHS OF THE MULU CAVES

English name	Malay name	Surveyed length RGS 1978	Surveyed length Mulu '80	Length	Depth
Southern Hills					
Deer Cave	Gua Payau	1760m	400m	2160m	+220m
Deer Water Cave	Lubang Sungai Payau	885m		885m	+3m
Mayday Cave	Lubang Darurat	900m		900m	61m
Snake Cave	Lubang Ular		780m	780m	31m
Green Cave	Lubang Hijau	2895m	550m	3445m	320m
Gunong Api					
Cave of the Winds	Lubang Angin	2300m	4250m	6550m	+140m
Clearwater Cave	Gua Air Jernih	26330m	11255m	37585m	+330m
Leopard Cave	Gua Harimau Bintang		3375m	3375m	+78m
Imperial Cave	Gua Imperial		705m	705m	−1m
Solo	Sendirian	–			−259m
Tiger Cave	Gua Harimau	1000m			10m
Good Luck Cave	Lubang Nasib Bagus		2900m	2900m	+423m
Prediction Cave	Lubang Ramalan	610m		610m	−46m
Wonder Cave	Gua Ajaib	4770m		4770m	104m
Gunong Benarat					
Benarat Caverns	Lubang Benarat	1355m	4870m	6225m	299m
Sakai's Cave	Lubang Sakai		1120m	1120m	−140m
Terikan Rising Cave	Gua Sungai Terikan	775m		775m	+12m
Terikan River Cave West	Gua Sungai Terikan Barat	2270m		2270m	+30m
Terikan River Cave East	Gua Sungai Terikan Timor	3840m		3840m	+61m
Blue Moonlight Bay Cave	Gua Teluk Cahaya Bulan Yang		9400m	9400m	119m
Gunong Buda					
Beachcomber Cave	Lubang Penghuni Pantai		1965m	1965m	+30m
Turtle Cave	Lubang Penyu		1155m	1155m	+38m
Compendium Cave	Lubang Ular Dan Pangga		1910m	1910m	+34m
Other minor caves		375m	5525m	5900m	
TOTAL EXPLORED CAVES		**50065m**	**50160m**	**100225m**	

Support by the Royal Malaysian Air Force was a major contribution to the expedition (A. Eavis)


CAVES
of
GUNONG MULU
NATIONAL PARK
Sarawak
N
BRUNEI
FIFTH
DIVISION
FOURTH
DIVISION
S. Terikan
S. Medalam
COMPENDIUM CAVE
CAMP CAVE
DISAPPOINTMENT CAVE
BEACHCOMBER CAVE
TURTLE CAVE
Big Feature
Gunong Buda
BLUE MOONLIGHT BAY CAVE
TERIKAN RIVER CAVES
BENARAT CAVERNS
Gunong Benarat
SAKAI'S CAVE
Melinau Gorge
Bukit Berar
IMPERIAL CAVE
LEOPARD CAVE
Gunong Api
S. Melinau
SOLO
WONDER CAVE
CLEARWATER CAVE
PREDICTION CAVE
Sarawak Chamber
GOOD LUCK CAVE
TIGER CAVE
CAVE OF THE WINDS
S. Melinau Paku
GREEN CAVE
SNAKE CAVE
Long Pala
BAT CAVE
USANG'S CAVE
DEER CAVE
S. Lansat
S. Tutoh
S. Tapin
Gunong Mulu
Cave passage (Surveyed by 1978 RGS Expedition)
Cave passage (Surveyed by MULU 80 Expedition)
River (Sungai)
Proven underground drainage
Edge of limestone hill
0
5
Kilometres

CAVES OF THE SOUTHERN HILLS

Dick Willis and Mike Meredith

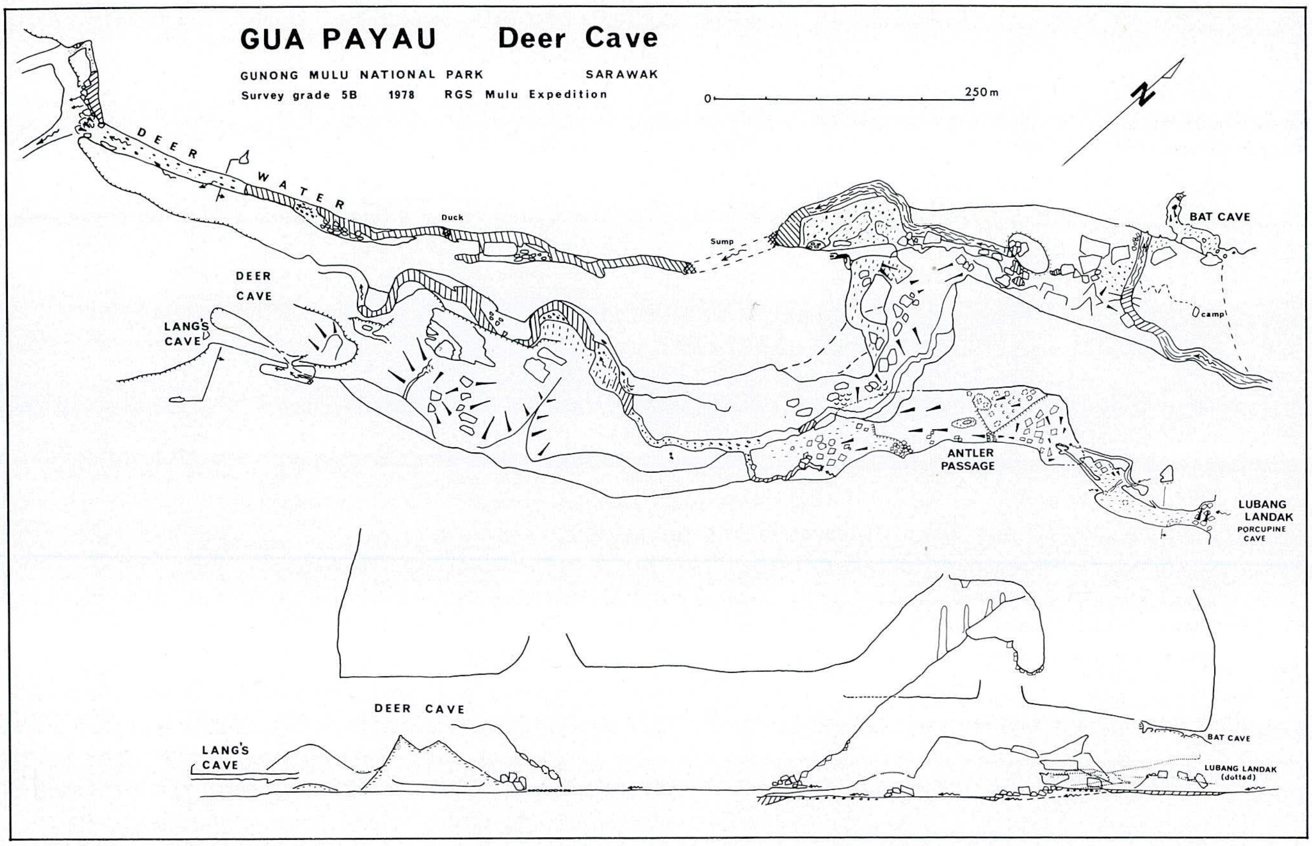
Due east of the base camp at Long Pala lies a limestone ridge which forms the southern edge of the Melinau Paku Valley. The spectacular Deer Cave passes right through this ridge and at its northern end opens out into a blind valley, the Garden of Eden. Under the arch at the far end of the cave is a camp site from which another huge entrance may be seen in the cliffs on the far side of the valley. This is Green Cave which again passes completely through the ridge, eventually opening out in the Melinau Paku Valley.

GUA PAYAU — Deer Cave

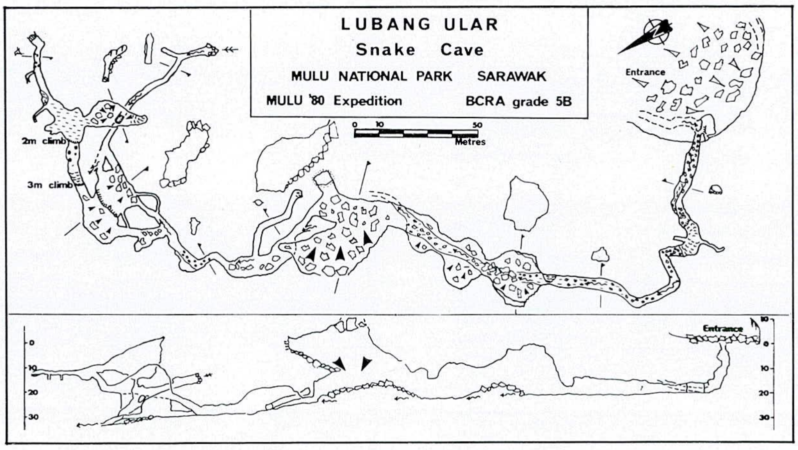
The cave is enormous and has been known for many years. In 1957 Tom Harrisson, the Curator of the Sarawak Museum, wrote during a visit "While others cooked, the solitary European lay on a soft bed of guano and peacefully absorbed the pleasures of this superb cave". Superb it is, and Deer Cave contains many soft beds of guano — most of them heaving with animal life. The cave almost defies description but the underground scenery is truly magnificent. Most of the cave was surveyed in 1978.

A tributary runs into the main stream from a passage in the east wall which is hidden by the base of an obvious boulder ramp. This can be easily climbed to a short, awkward section of greasy flowstone in which steps were cut by Dick Willis and Mike Meredith. Above this is a climb up inadequately cemented boulders which give access to an enormous ramp of dry guano at its angle of rest. Remains of rotted ropes and scaling poles indicate that local people have explored this part of the cave in the past, presumably in search of edible birds' nests. The slope can be climbed to a sharp lip beyond which a boulder slope leads down, between patches of wet guano, into Antler Passage and an impassable collapse. An ascent left from the lip leads to a platform with massive stalagmite columns from which the floor of the main passage, lit by daylight, can be seen 190 metres below.

An expedition member is dwarfed by the northern entrance to Deer Cave (J. Wooldridge)



Porcupine Cave has an arched entrance 20 metres above the valley floor in the Garden of Eden and 150 metres south of Deer Cave. An obvious track made by porcupines leads into the cave and can be followed in a pleasant passage to a boulder choke which lies beneath the collapse in Deer Cave's Antler Passage.

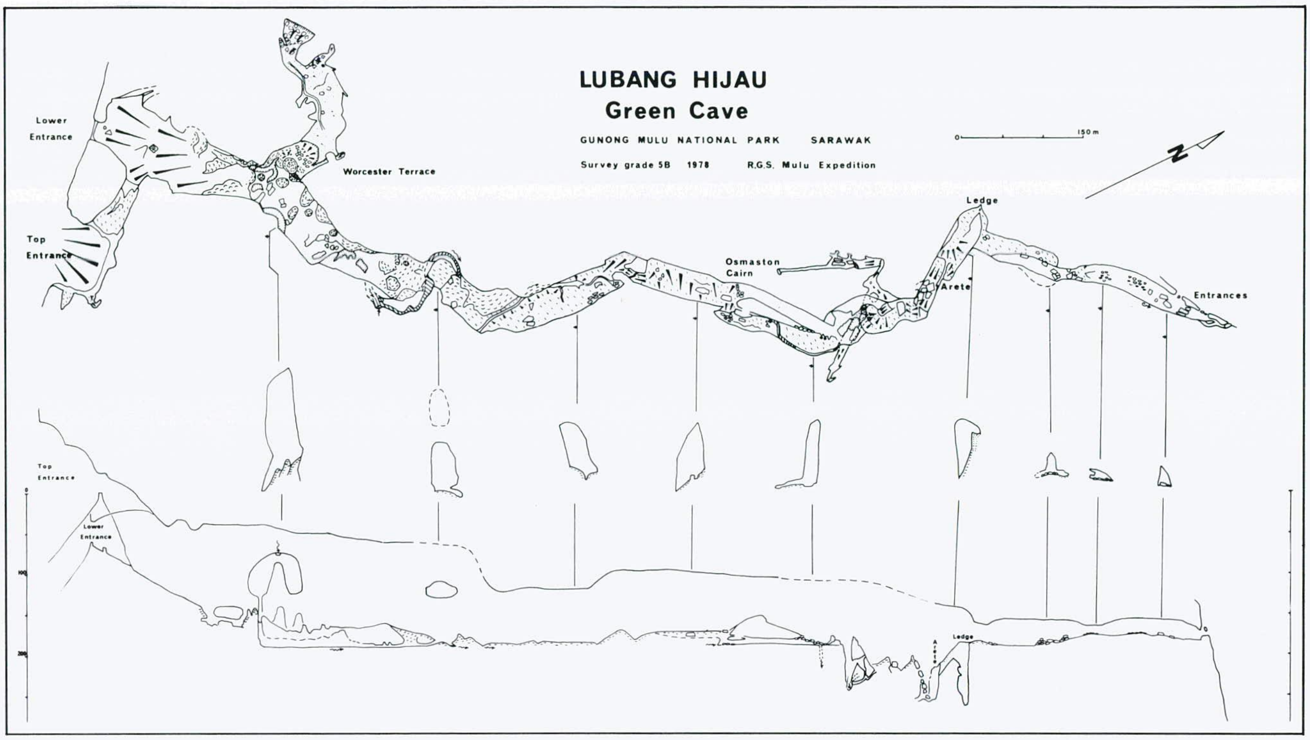


Snake Cave is entered 200 metres north of Deer Cave in the Garden of Eden. It was explored in 1978 but only mapped in 1980, when a dye test also proved the drainage connection to a waterfall resurgence above the Melinau Paku on the opposite side of the ridge. All known passages end in chokes, and the streamway cannot be followed through to its resurgence.

LUBANG HIJAU — Green Cave

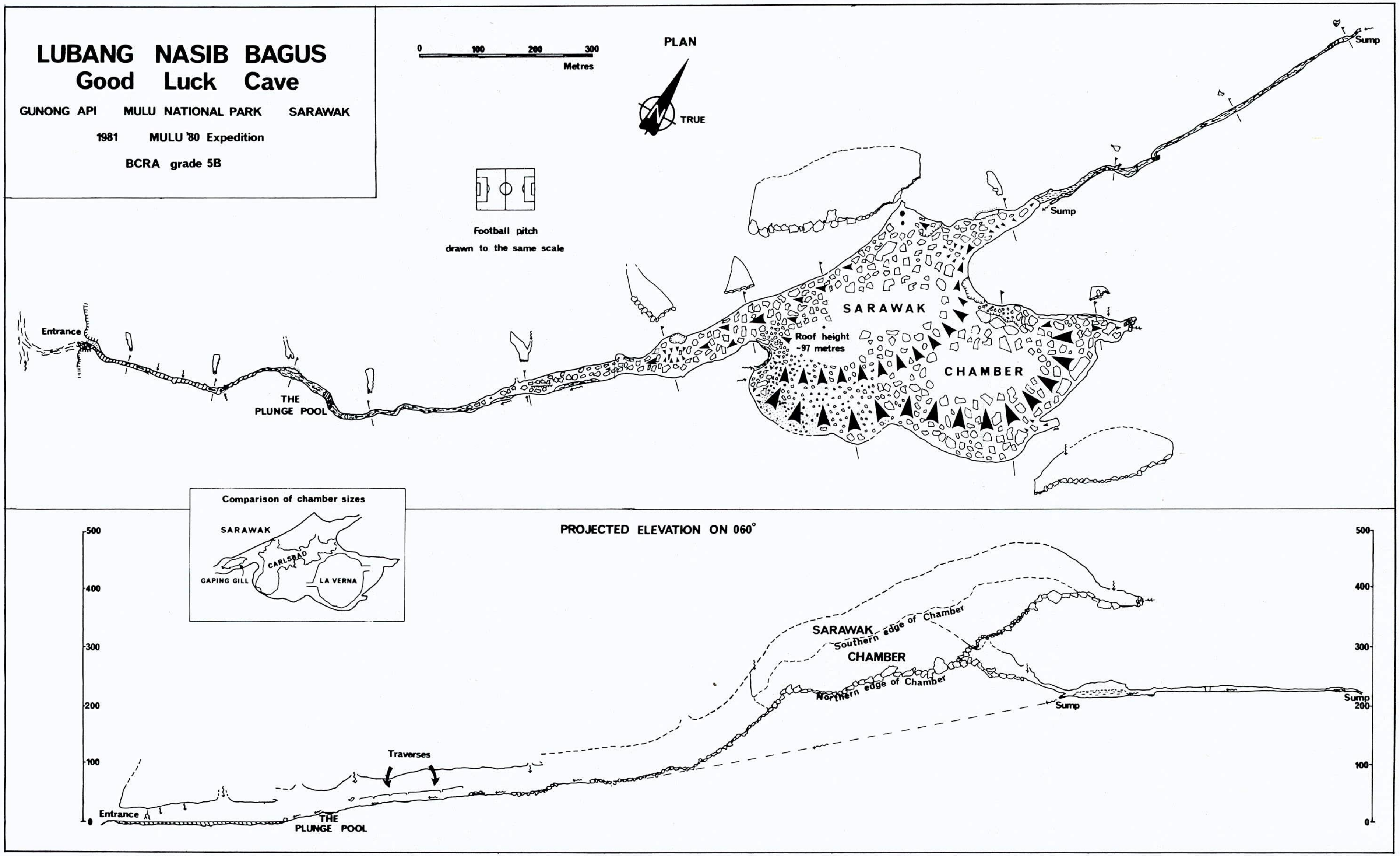
The main route through the cave was explored in 1978, but side passages were added by Mulu '80. At the base of the entrance ramp is a level area on the east side of the passage from which a climb down over sharp cave coral leads to the foot of two immense stalagmite columns with a small stream running down the wall between them. Back towards the entrance is an obvious climb up steep stalagmite, from the top of which an ascending traverse around the column leads to easy ground. Beyond this is an amphitheatre formed by the collapse of the alluvium which almost completely fills the large side passage. Climbing the slope at the back of the amphitheatre gives access to a terrace with superb views of the main cave. Behind this, a low wide passage may be followed past formations to a loose boulder choke.

Past the Osmaston Cairn a small stream is followed until it sinks in the floor. Immediately beyond this a window in a flake gives an impressive view across a wide shaft. Beyond is a loose slope descended with a



handline, and part way down this an obvious 20 metre deep pitch on the right leads to more climbs and the foot of the window shaft, but then only to a sump. An alternative route to these lower levels is down the slope below the Arete and then to the left. Down the same slope and ahead, a slippery climb up leads to a 30 metre shaft down to a maze of small phreatic tunnels and a sumped streamway. At the top of the Arete, the obvious open shaft descends for 60 metres and then closes down.

The figure in the middle distance shows the enormous scale of the main Green Cave entrance (J. Wooldridge)


LUBANG NASIB BAGUS
Good Luck Cave
GUNONG API MULU NATIONAL PARK SARAWAK
1981 MULU '80 Expedition
BCRA grade 5B
0 100 200 300
Metres
PLAN
TRUE
Football pitch
drawn to the same scale
Entrance
THE
PLUNGE POOL
SARAWAK
CHAMBER
Roof height
~97 metres
Sump
Sump
Comparison of chamber sizes
SARAWAK
CARLSBAD
GAPING GILL
LA VERNA
PROJECTED ELEVATION ON 060°
500
400
300
200
100
0
SARAWAK
CHAMBER
Southern edge of Chamber
Northern edge of Chamber
Sump
Sump
Traverses
Entrance
THE
PLUNGE POOL

CAVES OF THE MELINAU PAKU VALLEY

Hans Friederich and Andy Eavis

Gunong Api is bordered to the south by the wide valley of the Melinau Paku River. Between the Melinau in the north and the Melinau Paku in the south another river flows westwards down the slopes of Gunong Mulu. It penetrates Gunong Api in Hidden Valley, a narrow, blind gorge bounded by steep limestone cliffs. The only means of access is an arduous two-day walk from Long Pala. However, tracing with fluorescent dyes has now proved that the Hidden Valley water drains to Lubang Nasib Bagus, and not to the Clearwater Cave as previously suspected. Although the actual sink cannot be entered, several other fine cave systems were discovered in Hidden Valley in 1978, notably Wonder Cave and Prediction Cave.

The southern flank of Api is marked by a prominent buttress, Batu Nigel. This is a block of limestone, with steep cliffs on three sides which due to a major fault is partly detached from the main mountain. A proportion of the Melinau Paku sinks into Batu Nigel, and flows through Tiger Cave, reappearing several hundred metres to the west. A further hundred metres to the west a second resurgence was discovered by Hans Friederich which led to the exploration of Lubang Nasib Bagus.

Where the Melinau Paku curves to the south and meets the southern hills, a proportion of the river sinks under a low arch. Further south a collapse in the side of the mountain gives access to an underground stream cave passage which runs parallel to the edge of the valley. Eventually the downstream section of the passage ends in a sump, which presumably connects to an outside pool where the water flows back into the Melinau Paku. Only a short distance downstream several waterfalls cascade into the river. The source of these was proved to be the stream sinking in Snake Cave, but the water resurges through a narrow fissure and there is no connection from an adjacent small foot cave. Above the waterfalls a pig track leads over into the Garden of Eden. From the crest of the ridge a number of deep dolines are visible along with one large cave entrance, as yet unvisited.

LUBANG NASIB BAGUS — Good Luck Cave

After the 1978 expedition to Mulu the only known major sink and rising in Gunong Api were the Hidden Valley sink and the Clearwater River resurgence. Other sinks and risings were recognised but they were either very minor or they led to explored cave passages. It was therefore not surprising that most people expected the Hidden Valley river to reappear in Clearwater Cave, though a dye test carried out by the caving team was not conclusive.

Geological structure suggested that the flow from Hidden Valley could go south to the Melinau Paku. Therefore a new detailed investigation of the footslope of Gunong Api was suggested by Andy Eavis for 1980, and was carried out by Hans Friederich. This led to the discovery of three risings; the most easterly one is the resurgence of the Tiger Cave stream; the middle rising is related to a large cave passage which had a strong wind blowing out, and was named, by Hans and his guide Danny, Lubang Nasib Bagus (Good Luck Cave); the third westerly rising flows from an impenetrable boulder pile, but water tracing tests prove a connection to Nasib.

The discovery of Nasib Bagus Cave was made on the 28th December 1980 when Hans was on the way to Hidden Valley to carry out the first dye test. On the 30th December at dawn 13 kilograms of the green dye Fluorescein was put into the water in Hidden Valley. On the way back to base-camp no dye was visible in any of the surface streams, but Nasib Bagus was not visited. Next morning the Melinau Paku was bright green while the Clearwater resurgence was only weakly coloured. This seemed to confirm that water from Hidden Valley does drain to the south, and therefore a new dye test was planned while water in the Nasib Bagus rising was to be sampled. And surely, four hours after the input of red dye in Hidden Valley, much to the delight of Hans, Andy and Pete Smart, the Nasib Bagus river changed colour.

Although the hydrology research project was now running into problems the Nasib Bagus cave exploration had all of a sudden taken on a new dimension. Minds were running wild on whether to expect a huge underground waterfall or merely a very sporting river passage. It was decided to mount a small exploration party joined by the filming team of Sid Perou and Lindsay Dodd. This meant that the actual exploration of a new cave system was filmed directly.

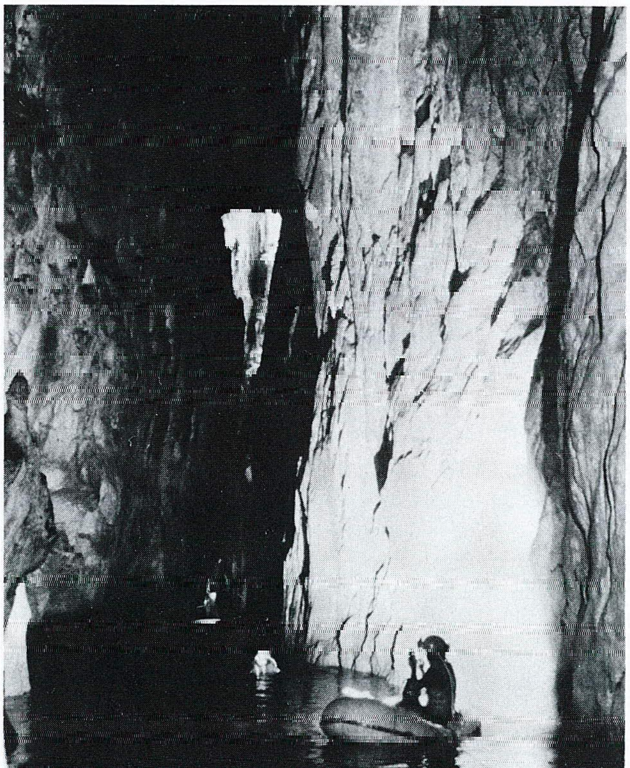
The entrance of Nasib Bagus is a canal 5 metres wide in a high rift passage with spectacular limestone pinnacles both on the wall and in the water. During the first trip the canal was traversed using an inflatable dinghy, but after long periods of dry weather the water flows through the boulder pile at the entrance and the canal drains down. After 500 metres the river changes into a turbulent torrent and the boat is left behind. The roof soars up to a high level passage above the fine sporting stream. A beautiful whirlpool 15 metres across, the Plunge Pool, is passed by some clever swimming and the start of the traverses reached. In low water a route just above stream level can be used, but even in moderate water conditions high level traversing for the next 500 metres proves interesting, with fixed ropes used in a number of places. Suddenly the narrow trench widens and the roof takes another huge step upwards into the start of the "biggest thing in Borneo".

At this point on the original exploration by Andy, Tony and Dave, Tony was greatly disappointed because the passage was not quite the 70m by 70m he had been told to expect by Hans and Andy who had reached that point before; his disappointment was however short-lived! Beyond, the passage grows bigger and bigger, and begins to rise steeply until at the angle of rest of the boulders; no roof or walls can be seen. Surveying without being able to see any walls was something of a waste of time, so after a turn due south for 70 metres, a wall of underlying Mulu Formation rocks was reached — the chamber being on the base of the limestone. This wall was followed for 77 survey legs each of 30 metres, until sore feet and tiredness forced a retreat. A short, blocked, but draughting, passage that looked very similar to the end of Prediction Cave was surveyed. It was then Tony who began to suggest the team was in a gigantic chamber; until then it had been assumed to be a gently curving gigantic passage. Once the main exit passage was reached, a cairn marked the end of the survey and the hundredth 30 metre leg. Discussions over the chamber possibility were continuing, so a direct route back to the entrance passage was decided upon, assuming a chamber existed. After walking on a compass bearing over the most monumental boulders for over half a kilometre, during which time acute agoraphobia affected at least one member of the party, the entrance slope was reached. It really was a gigantic chamber!

A subsequent survey completed the circumference of the chamber and added over 500 metres up the exit passage along a small streamway to a sump. The survey, when drawn up, amazed even the explorers; maximum dimensions of over 700m by 400m make Sarawak Chamber by far the largest underground cavity in the world. The experience of clambering across it, seeing the predator-free swifts nesting on the floor, hearing the incredible echo and feeling the immensity in every direction can only be described as awe-inspiring.

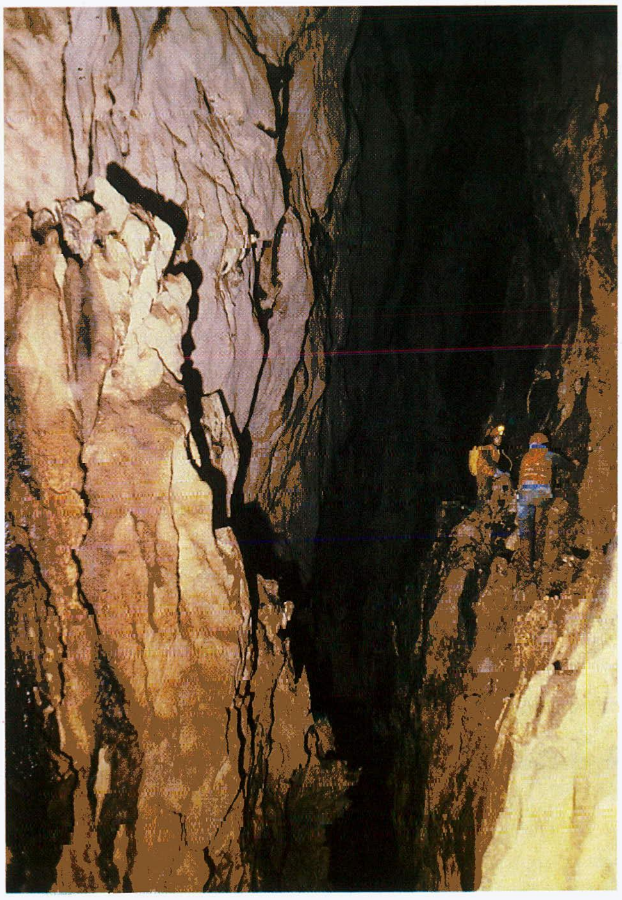
There is no doubt that there is a lot more huge passage to be found in the Nasib Bagus area, and there is a strong chance of a connection to Hidden Valley, maybe through Prediction Cave.

Stalactites in Clearwater
(J. Wooldridge)

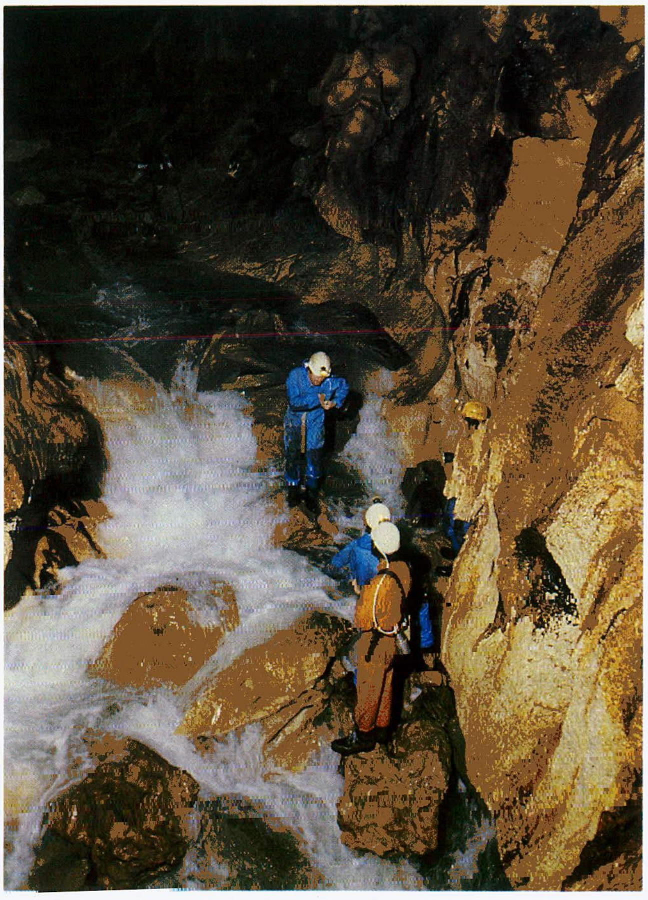


Looking out towards Nasib Bagus entrance
(C. Boothroyd)

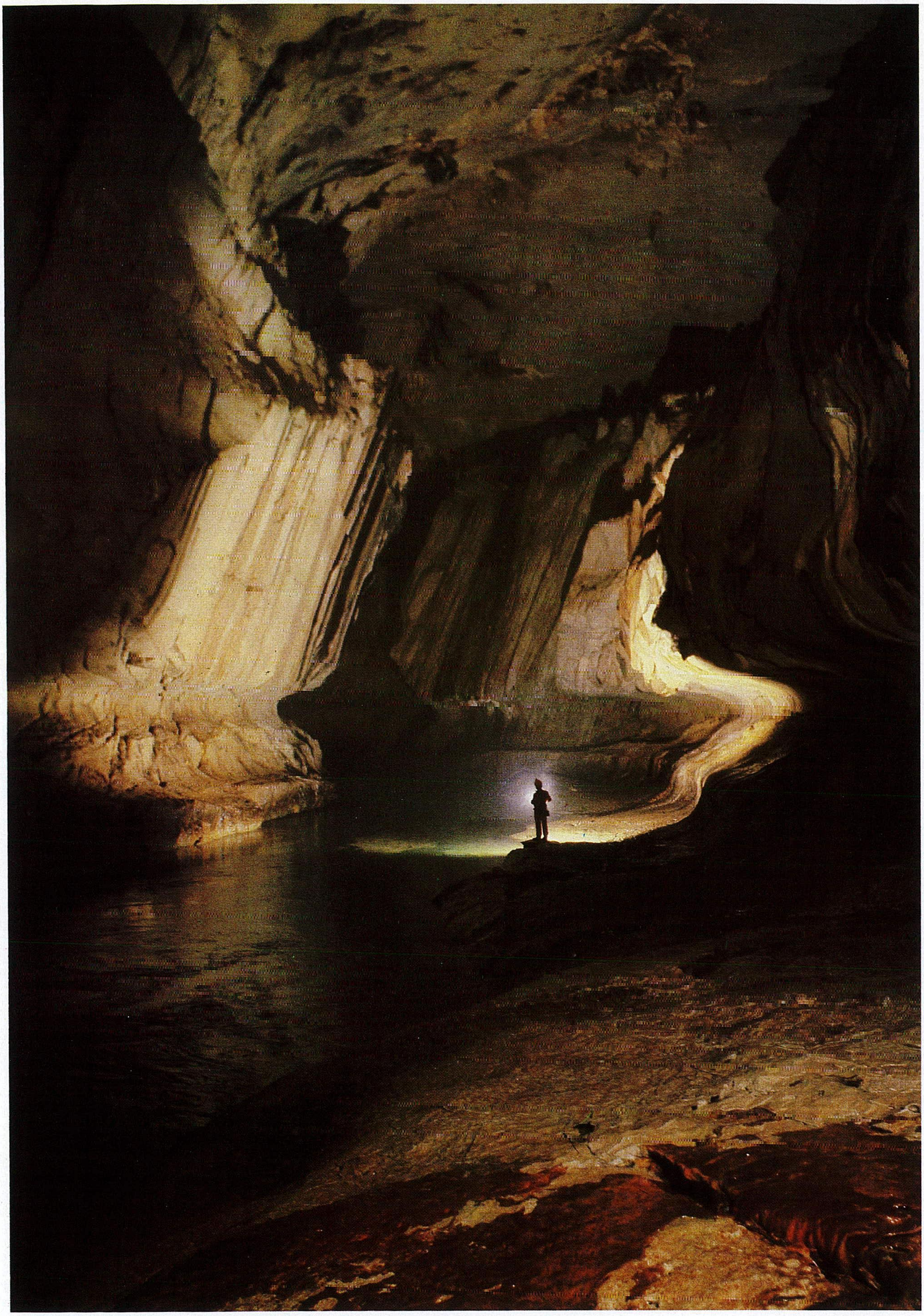
The tiny figures, barely discernible against the bright flashes, give an idea of the size of Sarawak Chamber (C. Boothroyd)



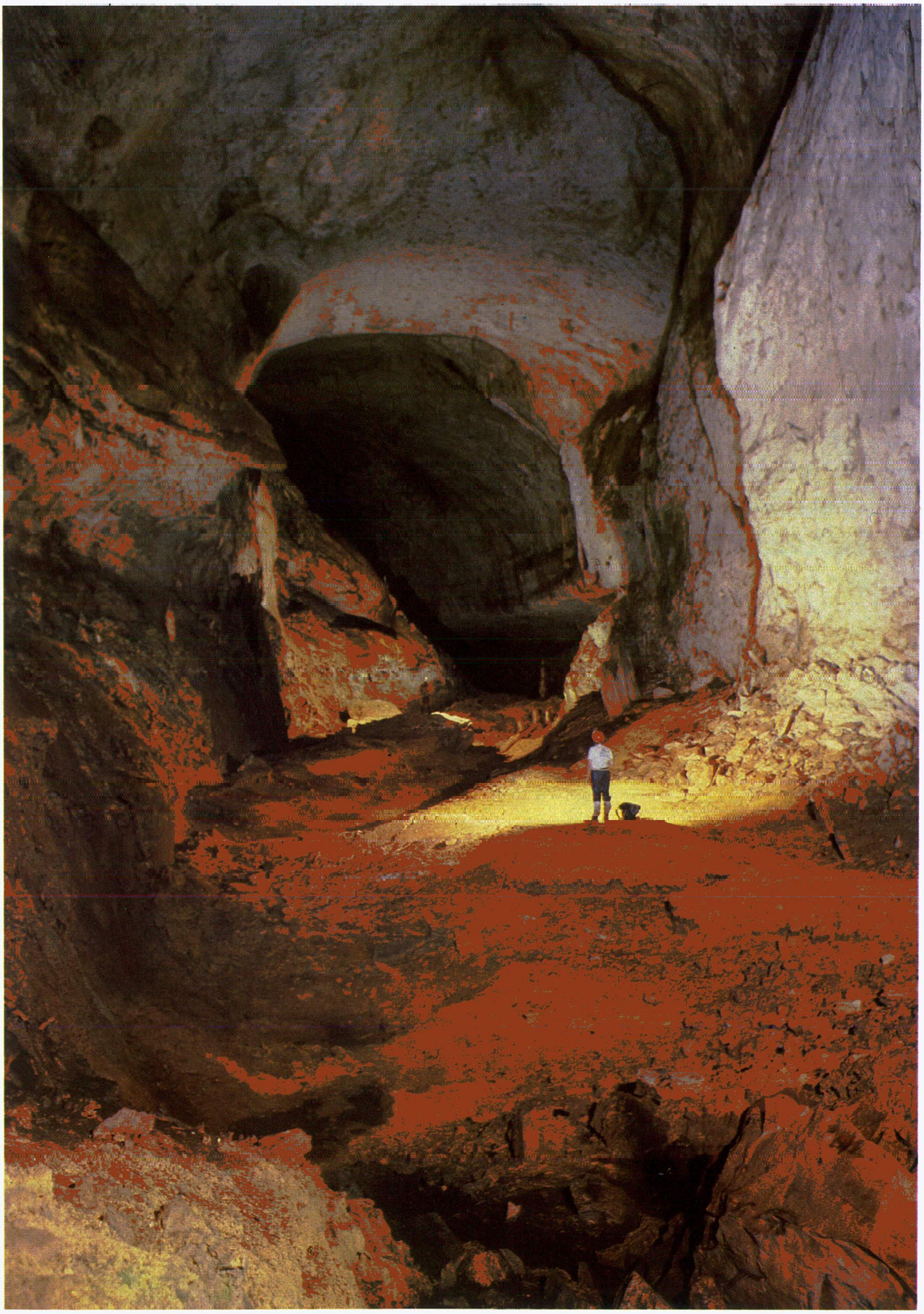
Traversing in Nasib Bagus (A. Eavis)



Filming the original exploration of Nasib Bagus (A. Eavis)

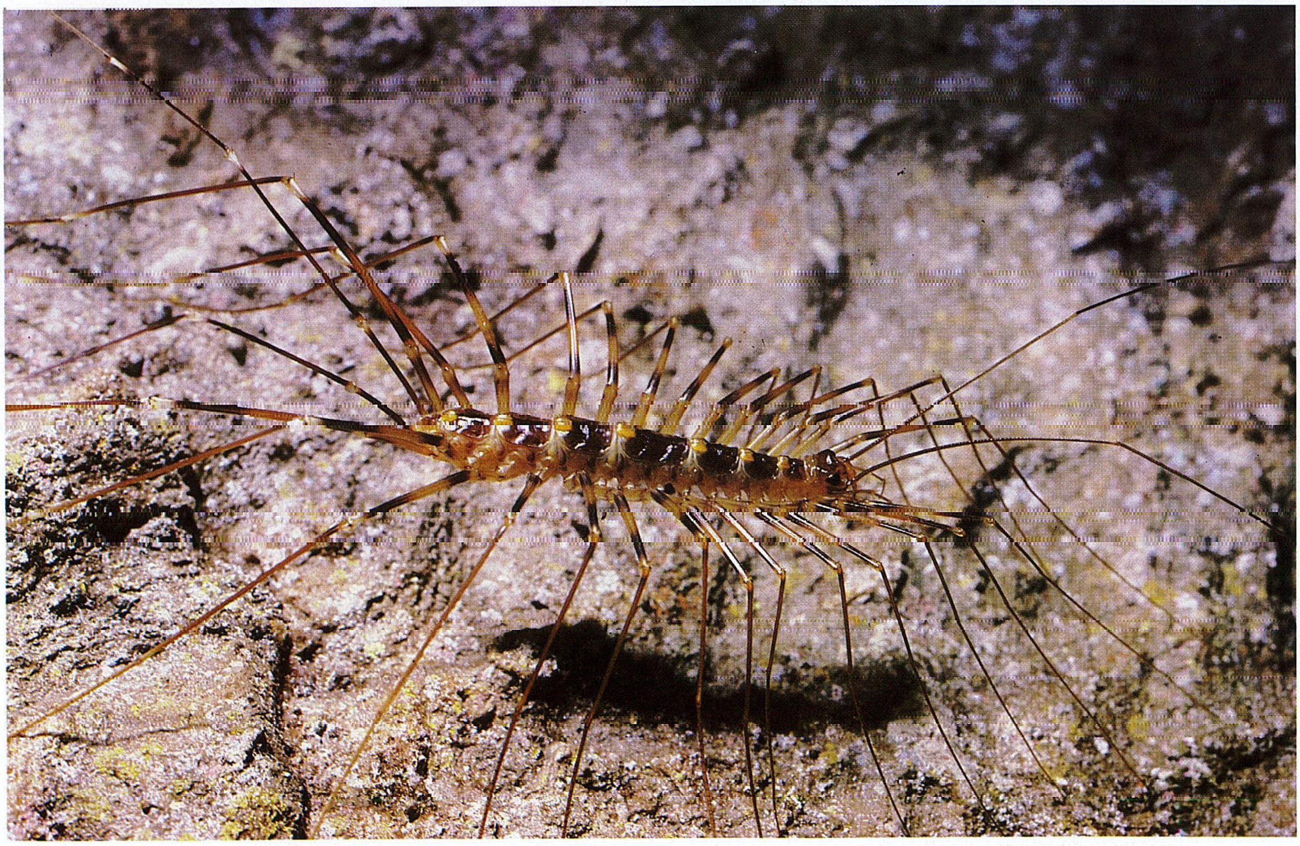


The magnificent Clearwater River Passage (A. Eavis)



Revival, Clearwater Cave (A. Eavis)

Partial collapse of the passage roof has produced the Secret Garden, Clearwater (C. Boothroyd)



The shy centipede, found widely in the Mulu caves, has a vicious sting (P. Chapman)

CAVES OF SOUTHWEST GUNONG API

Phil Chapman and Colin Boothroyd

The west flank of Api is rich in caves. It has been explored at alluvial plain level for only about half its length northwards fron the Clearwater resurgence, a distance of about 5 kilometres. In this stretch, a number of entrances are known, most of which connect to shallow caves, developed by migrations of the surface Goldwater stream into the limestone. Goldwater is squeezed into a narrow channel between the flank of Api and steep ridges of alluvium to the west. As it flows south, a progressively greater proportion of its course is spent underground in immature flood-prone tubes which link with the older and larger Clearwater Cave. The Goldwater stream and the Clearwater river eventually merge at the exit sump which dives deeply to well up a few metres beyond at the main resurgence. This feeds into the Melinau river, and half a kilometre further south passes the arched, outflow entrance to the Cave of the Winds. The upstream end of Goldwater is the choked Leopard Cave rising, and 300 metres further north lies the inconspicuous entrance to Leopard Cave. To the north, the alluvial terraces throw ridges obliquely north east into the flank of Api, chopping the alluvial catchment into small units draining mainly to the west, but occasionally east to sink in Api.

The widely-spaced western exits from Clearwater which are not related to the Goldwater passages, all break out into featureless, forested hillsides. They range in level above the plane from the Snake Track exit at +30m, and the Revival and Troll Cavern exits at +70m, to suspected high-level entrances such as Solo (+450m), while the Hole in Time overlooking the Paku Valley is at +300m. In exploration terms, this means that unless entrances are, like Solo, large enough to be seen from a helicopter they can only be found by systematic exploration on the ground. Fortuitous erosion has allowed Leopard Cave, the only significant cave on the west side of Api not yet connected to Clearwater, to be entered and explored. There must be many more extensive caves at higher levels awaiting exploration, but the chances of finding these by surface exploration are slim, unless they receive tributaries off the alluvial plain. One offbeat discovery method is by "guano-sniffing", the method by which Tharg's series was discovered; this consists of following a strong smell of guano uphill until the cave of origin is reached.

The potential for future cave discovery in Api is immense. Most of the 38 kilometres of mapped passages in Clearwater are developed in a single bed of limestone, or in the Goldwater streamways. A connection between the Clearwater, Leopard and Cave of the Winds systems is surely only a matter of time. This would give a 50 kilometre cave system with enormous potential for future exploration. The discoveries beyond the foot of Ronnie's Delight pitch in Clearwater suggest the possibility of a multilevel system parallel to Revival, but in a lower bed. The high levels of Revival still have much potential for upward and northward extensions while only a small fraction of the main streamway has been followed (2,500 metres to sump 2, beyond which the straight line distance to its Melinau gorge sinks is 9 kilometres). A high level connection to the Nasib Bagus caves is another possibility, and the limestone south of Cave of the Winds has considerable cave potential. To add a salutary note — at the end of the 1978 expedition Clearwater and Cave of the Winds were thought to have around ten interesting unfollowed leads which required checking. Six of these were looked at by the Mulu '80 expedition and there are now about fifteen leads remaining for the next expedition to check!

LUBANG ANGIN — Cave of the Winds

The large open entrance in the bank of the River Melinau, half a kilometre south of Clearwater, gives inviting access to Cave of the Winds. The upstream river passages were surveyed in 1978, but lack of time on that survey meant that large open passages, north of the skylight near the entrance, were not found.

The passage on the left at the skylight breaks out after a series of climbs into a large tunnel that extends to the left to an entrance which is the home of family of wild boar and overlooks the Melinau River. The larger passage at the skylight, on the right, is Not Before Time, which carries the main wind which gives the cave its name. It is floored with steep sediment banks and large collapse blocks, and extends to a junction. Left ascends to an entrance into a doline floor, while right along Over Time continues to a calcited choke surmounted by a rope climb up into Babel.

Babel, a passage 50 metres in diameter, is floored with boulders and large stalagmites, and ascends to the south-west where it pops out on the surface. To the north, its continuation, the well-decorated Illusion Passage ends at a calcited boulder choke. Disillusion Passage lies opposite the doorway into Babel, hidden behind an impressive ridge of stalagmites. There are two passages, with the lower branch ending at a boulder scree choke.

The upper of the two heads south, splitting 100 metres in, to offer bouldery or mud-floored alternatives. Disillusion Passage was so named by the surveyors who thought they were following a draught to the surface, but were stopped at two inviting pitches into large chambers, only to discover, when the survey was drawn up, that they had been looking into Clay Hall discovered in 1978.

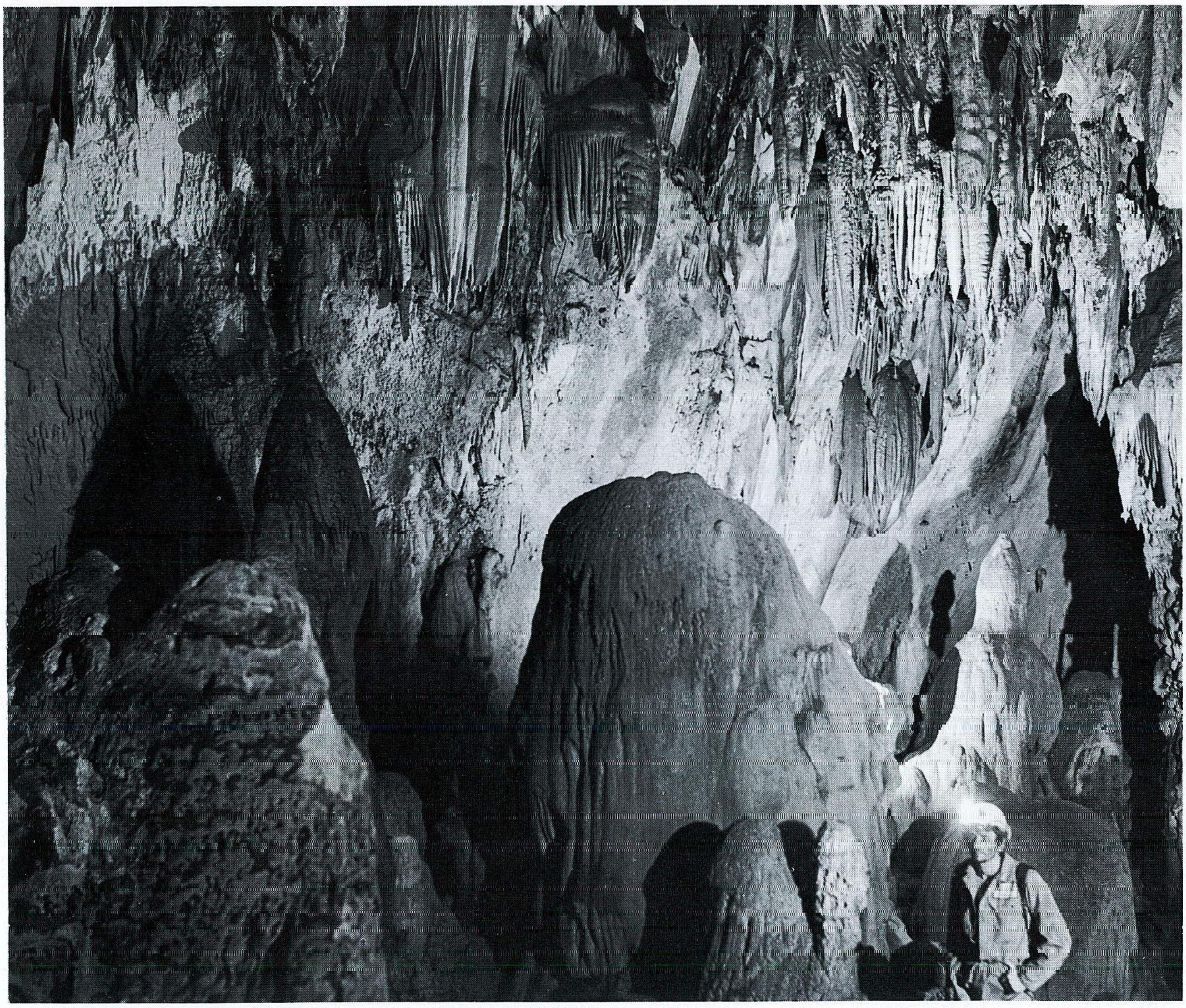
The passages found in 1980 appear to be much older than the River Passage, and their association seems to be incidental. Although many hours have been spent in Cave of the Winds looking for a connection through to the neighbouring Clearwater Cave, the link has remained elusive. It is even possible that a surface valley above the Clearwater has cut through all the passages which once continued between the two caves.

GUA AIR JERNIH — Clearwater Cave

The Clearwater River Cave and the main fossil passage through to Troll Cavern were explored in 1978, but Mulu '80 added major passages in several parts of the system (the survey is in the centre fold-out).

The Southern High Levels.

From Junction Cavern, Revival Passage runs north-east while south-east at the same level, a scramble over boulders leads into the 800 metres of Infinite Improbability Drive. After 500 metres of easy going, a scramble up boulders leads to two high levels. The easterly follows a joint to a dripping choke, with a branch to another choke beneath the Secret Garden. The south-westerly high level links to Hyperspace Bypass, a gigantic split-level chamber with two connections at its northern end back into Infinite Improbability, close to where the latter swings north to link with Broadside Chamber. At the south-western corner of Hyperspace, a ramp leads down



Just inside the Snake Track entrance of Clearwater Cave (A. Eavis)

The Snake Track passage in Clearwater Cave (A. Eavis)

into the complex of King Seth's Maze. By following the draught a low-level northerly passage is reached which quickly widens at a T-junction. Both ways on end in chokes beneath Infinite Improbability, but a dip-tube drops into a lower maze. The draught leads northwards between fallen block, to emerge in the Battleship.

From the top level of Hyperspace, a low passage with a good draught and heavy swiftlet traffic leads into a series of ascending, bedding-controlled passages. These develop into a maze and become ever more heavily calcited until a climb emerges at a balcony overlooking the Secret Garden. This remarkable chamber, with a floor area of around one hectare, is flooded by light from a huge skylight 50 metres above and supports a luxuriant vegetation including small trees. A large gallery drops from its eastern end, then ascends steeply to end abruptly at a spectacular entrance, the Hole in Time, overlooking the Melinau Paku Valley 300 metres below.

The Northern High Levels

From Junction Cavern, a scramble up boulders into the roof of Revival continues to a small waterfall which is climbed to a junction. To the right, a loop of passage and a short climb through large blocks enters a large chamber followed by an awkward climb into the stalagmite-strewn expanse of Dr. Fu Yen's Mystical Earthly Paradise. From the waterfall junction a passage loops to a balcony overlooking Fu Yen's, while the main route extends to the base of a huge, guano-floored ramp leading to a choke. Past the base of the ramp the passage widens but the 30 metre diameter main passage beyond is unexplored, and an eastern ramp climbs to a large undescended shaft. A northerly passage continued past a maze of unexplored ramps to the head of a gigantic boulder slope leading back into Revival.

Northwards across the top of this slope, a joint-controlled canyon takes off eastwards. The canyon passage forms a T-junction with Scumring Series, blind to the right, but continuing leftwards over short climbs and scum-ringed mud basins for 150 metres to a draughty constriction. Through this, a series of short climbs leads to a junction. Straight on is an undescended pitch, while to the right a parallel passage goes north, via a swamp and a greasy climb into Ronnie's Delight. Splendid scenery, including an alcove with fine helictites, ends at a dramatic 100 metre deep shaft. At its foot a steep boulder slope is traversed to a wide, sandy passage which climbs in short, vertical tiers, some unascended. A draughting passage in the right wall eventually closes down to an impassable but very wide bedding plane.

The Northern Low Levels

Wells Series is a muddy passage branching off Snake Track and features a number of greasy climbs on stalagmite. A guano-covered 19 metre pitch drops into even muddier passages and an obscure route through boulders into a hole in the floor of Revival. Also off Snake Track, but on its west side, a shattered alcove conceals an insignificant hole to a 20 metre shaft into the streamway of Tharg's Series. This is essentially a flood-prone underground oxbow of the surface Goldwater stream. Downstream chokes below an exit to the alluvial plain, while upstream can be followed further along some pleasant stream passage. This eventually splits and leads to a large gloomy chamber, boulder chokes and yet another entrance.

From the southern end of Troll Cavern there extends Python Passage as a huge boulder-floored tunnel. At a hairpin bend, a flowstone canopy shelters a 4 metre long python skeleton, and not far beyond safe progress is halted by successively steeper tiers of greasy flowstone. In the same part of the cave, West Passage provides an alternative but inconvenient route between Gnome Oxbow and Great Wall Chamber — just one more link in the complicated series of ancient tunnels which run the length of Clearwater Cave.

GUA HARIMAU BINTANG — Leopard Cave

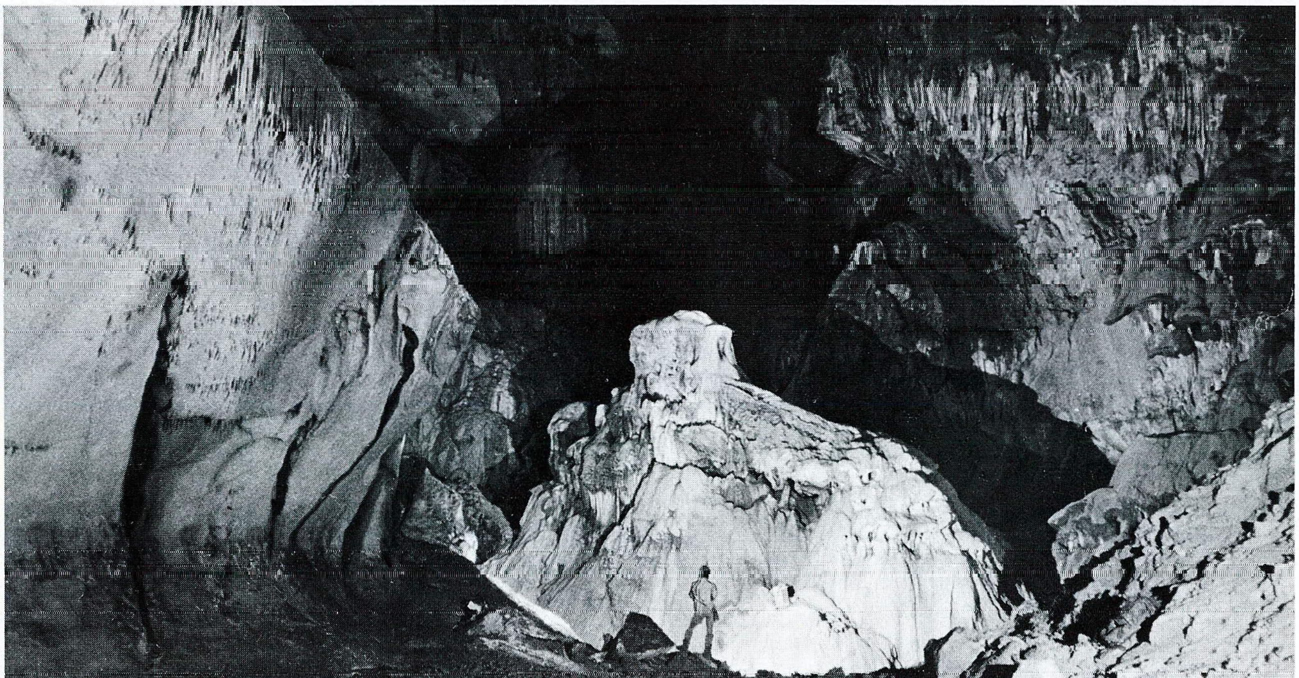
Southward along the limestone cliff from the Troll Cavern exit of Clearwater Cave, a small stream sinks into the entrance to Leopard Cave. Just inside, a junction leads left and ahead to canals and chokes, but right to a shallow canal passage through to Jerry's Junction. A boulder climb to the right ascends to Pussyfoot Chamber, home of a leopard cat, and lit by daylight from more entrances. On the south side of the chamber, a ridiculous thrutch up a vertical rift emerges in the fine tunnel of Goldwater Foot which extends southwestwards for 600 metres to an unclimbed flowstone bank.

Left at Jerry's Junction the draught heralds the continuation of a splendid streamway. Deep canals, towering rifts and razor-sharp submerged limestone flakes mark progress to a sump 700 metres upstream. The draught emerges from the roof joint which can be climbed at one point using artificial aids, into the high level galleries of Sceptics' Scenic Series. The large main tunnel of the series contains extensive sand banks and boulder piles, and eventually chokes in both directions along its route mainly directly below the large northern caverns of Clearwater. A major branch is Instep Passage, a bedding controlled tube which extends for 750 metres to a sump just short of its obvious continuation in Clearwater's Porcupine Passage. To the east, a smaller tube extends to undescended shafts which drop to water. Althuogh Leopard Cave is so close to Clearwater and so clearly related,there is as yet no possible connection between the two caves.

The Leopard Cave water eventually resurges to form the Goldwater stream and just above the rising lies Water Polo Cave — a single chamber extending to a lake rich in fish. The water which sinks into the Leopard entrance may be followed upstream to isolated hills on the alluvial plain which contain pretty and complicated caves with over a kilometre of unsurveyed passages.

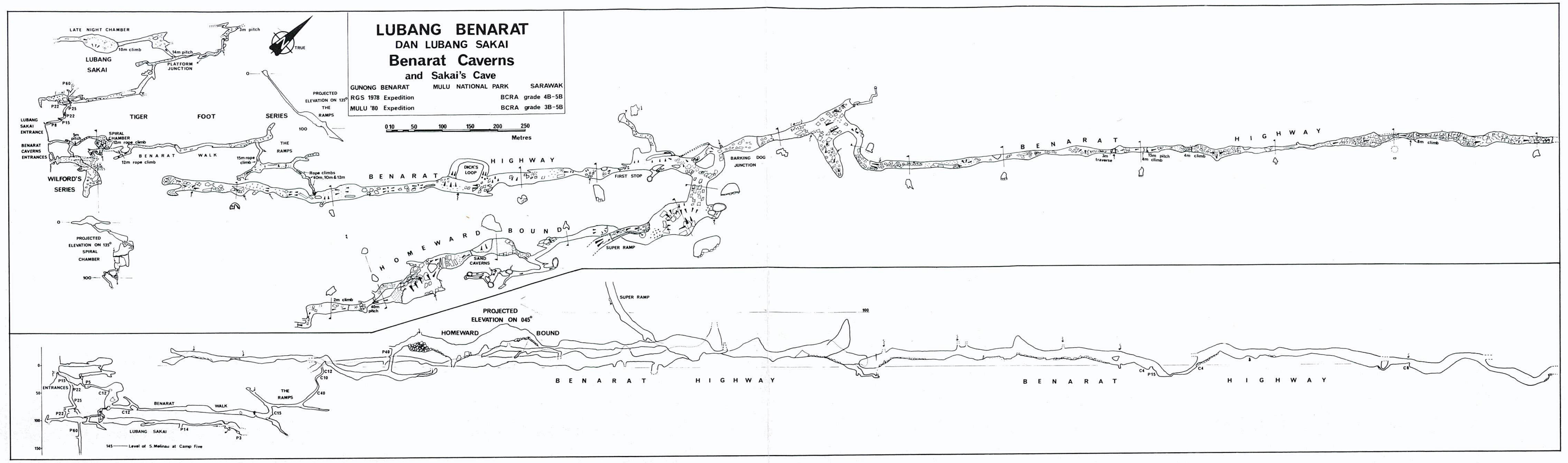
Imperial Cave

Half a kilometre north of Leopard Cave, the edge of the Api limestone reveals entrances to Imperial Cave. Two streams sink and flow through pleasant streamways to converge and continue downstream to a sump, which drains into the Leopard Cave streamway. A notable feature of this cave is that the journey between the two entrances is much easier underground than through the forest.



Looking along Revival towards Edge of the World, in Clearwater (C. Boothroyd)


LUBANG ANGIN
Cave of the Winds
GUA AIR JERNIH
Clearwater Cave
GUA HARIMAU BINTANG
Leopard Cave
GUNONG API
MULU NATIONAL PARK
SARAWAK
RGS 1978 Expedition
BCRA grade 5B
MULU '80 Expedition
BCRA grade 5B
Metres
TRUE
CAVE OF THE WINDS ENTRANCE
CLEARWATER CAVE ENTRANCE
GOLDWATER
CLEARWATER RIVER
BALCONY SERIES
NOT BEFORE TIME
OVER TIME
ILLUSION PASSAGE
BABEL
RIVER PASSAGE
ONE WAY STREET
CLAY HALL
DISILLUSION PASSAGE
DEAD END
INNER RIVER PASSAGE
SOUTH BRANCH
NORTH BRANCH
KING SETH'S MAZE
THE BATTLESHIP
RIVER JUNCTION
ANOTHER STOREY
HYPERSPACE BYPASS
BROADSIDE CHAMBER
INFLATION PASSAGE
INFINITE IMPROBABILITY DRIVE
JUNCTION CAVERN
CLEARWATER II
DR. FU YEN'S MYSTICAL EARTHLY PARADISE
THE SECRET GARDEN
HOLE IN TIME
DETENTE CAVERN
VOLCANO SERIES
REVIVAL
RONNIE'S DELIGHT
SCUMRING SERIES
WELLS SERIES
SNAKE TRACK
PORCUPINE PASSAGE
THARG'S SERIES
FISHFORK
EDGE OF THE WORLD
BOULDER CHAMBER
BECKONING FINGER PASSAGE
SHEER DELIGHT
DUNE SERIES
GOLDWATER STREAM
GOLDWATER FOOT
INSTEP PASSAGE
GREAT WALL CHAMBER
WEST PASSAGE
EAST PASSAGE
GNOME OXBOW
TROLL CAVERN
PYTHON PASSAGE
KING'S LOOP
JERRY'S JUNCTION
PUSSYFOOT CHAMBER
WATER POLO CAVE
LEOPARD CAVE ENTRANCE
IMPERIAL CAVE
Entrance
Sump
Offset
SCEPTICS' SCENIC SERIES
PROJECTED ELEVATION ON 090°
PROJECTED ELEVATION ON 030°
CROSS SECTIONS



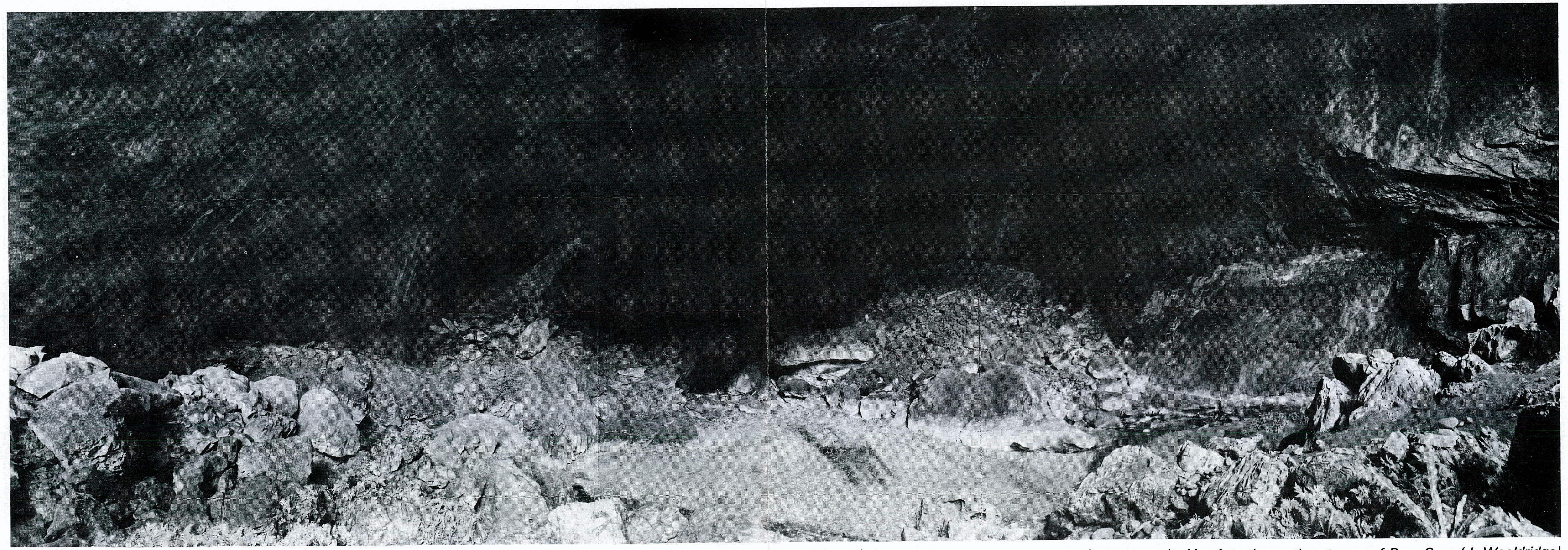
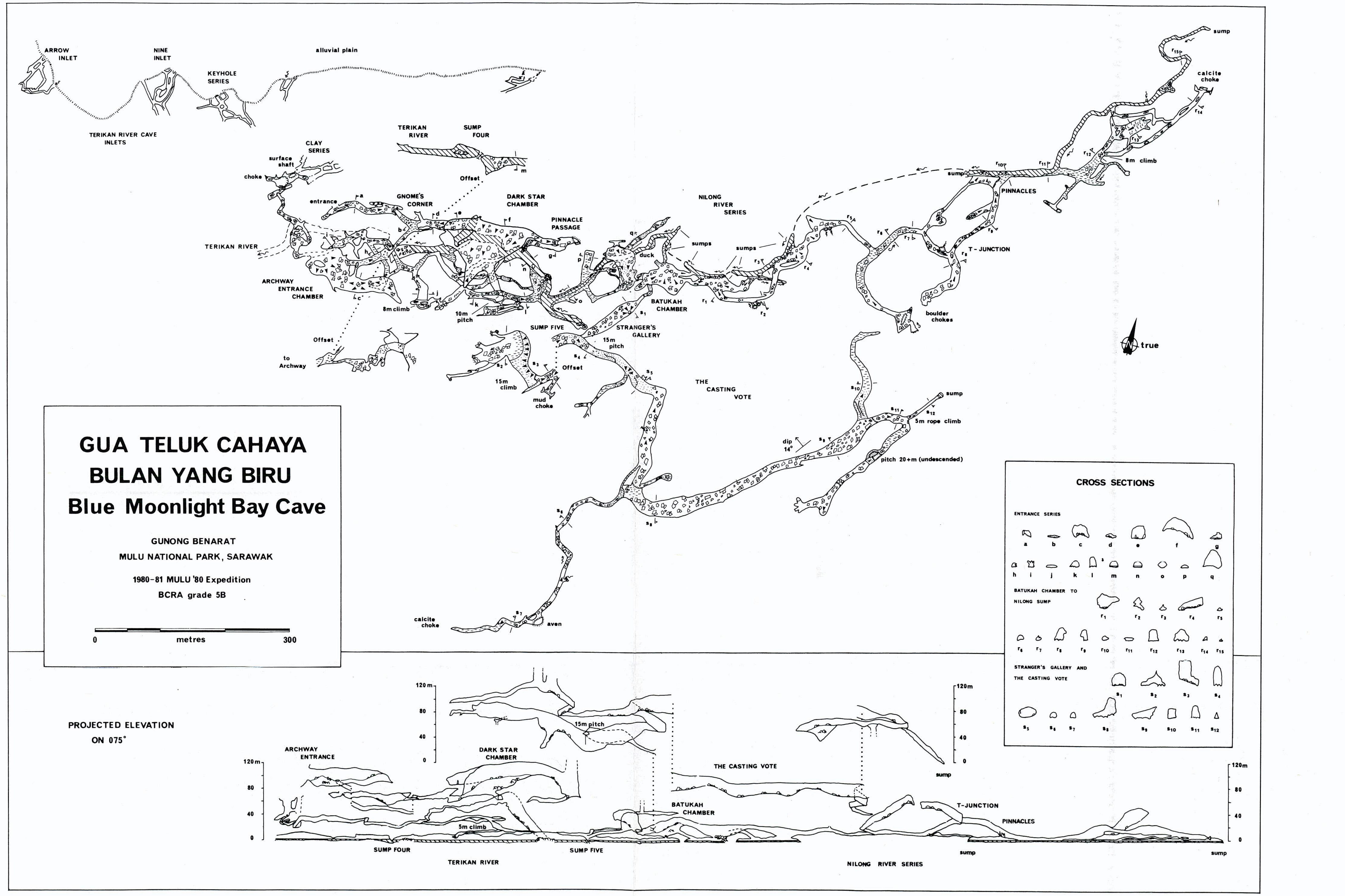


Figure ▲ ▲ Figure *A panorama looking into the north entrance of Deer Cave (J. Wooldridge)*



CAVES OF THE MELINAU GORGE

Ben Lyon

The southern end of the Gunong Benarat is precipitous even by the standards of Mulu, with overhanging cliffs guarding almost the entire length of the mountainside as it borders the Melinau Gorge. The massive beds of limestone, dipping steeply to the west, are separated by occasional clinging bands of vegetation and inaccessible cave entrances. Largest of these, high in the cliff, is locally known as Tiger Cave. Further east an even higher face overhangs the gorge, and though a large cave entrance and a massive collapse feature have been seen from the air they remain unvisited.

The route north to Lubang China and beyond passes the south-western end of Benarat, where a stream sinks into the base of the mountain but remains untraced. Further north a track was cut directly up the side of Benarat to a shaft previously located by helicopter, at an altitude of about 750 metres. This is a smaller version of Solo, perhaps 90 metres deep, and it is still undescended.

The permanent camp at the foot of the Gorge is on the left bank of the Melinau, with the helipad across the river. This presents no problems when the river is low, but a ropeway is needed to cross the river in flood. From the camp to the entrance of Benarat Caverns is a walk of a kilometre, over alluvium and terraces and then up a limestone scree slope to the foot of the cliff, 145 metres above river level.

LUBANG BENARAT — Benarat Caverns

In 1978 the Tiger Foot Series was surveyed along a comfortable dry fossil passage, but the explorers were stopped by lack of equipment on the steep ascending ramp which they then called Way-On Aven. The name was prophetic for it led the team of Mulu '80 straight into a large level tunnel, and marked the real breakthrough into the major system of Benarat Caverns. This tunnel, named Benarat Highway penetrates nearly 3 kilometres into the mountain, virtually in a straight line strictly controlled by the limestone bedding.

South of the entry into the Highway, the 350 metres of passage as far as its terminal choke are marked by boulder-floors, formations associated with water inlets that intersect the passage, and an almost total absence of living bats or swifts. Northward is similar but with occasional holes in the floor. The passage, which is normally between 10 and 25 metres wide, narrows at First Stop to about 3 metres, with a traverse around a wet shaft. Up to this point Benarat Highway is floored by limestone boulders, calcite or mud, with a remarkable array of bones including some from members of the cat family.

Beyond First Stop the passage widens and the floor is littered with rotted sandstone cobbles. A bivouac was used several times during the Mulu '80 explorations. A solitary up-dip passage ends in a calcite floored chamber, with the sound of water from a window high in the wall. Shortly beyond, the most important junction in the Caverns is reached — Barking Dog Junction (named after the noise made by the water-drip!) Two passages loop to the continuation of Benarat Highway. The route to the known end continues for 1500 metres with a number of climbs, traverses and one awkward 15 metre pitch, shortly after which a choke appears to block the passage. However a climb through the choke on the right brings one back into continuing large passage. Finally the rift-passage is filled to a height of 8 metres by an unstable wall of sediment, and to pass this may require bolting up the wall, to get into the passage which can be seen to continue.

There are a number of shafts in the Barking Dog area, none of which have been descended. The largest is at the end of two short side passages — and like the others, it takes a considerable flow of water in times of rain, the water falling from a hole in the roof, and continuing on down a hole in the floor, only cutting through the fossil passages by pure chance. The other main direction from Barking Dog turns east, and then back south, so moving down through the limestone succession. Beyond, huge boulders mark the base of the climb up to the Super Ramp. A climb to the right of a pit leads to a tube some 20 metres across. For the first 70 metres this is floored by boulder scree, the angle increasing from 30 to 40 degrees. The floor then becomes clean rock, at a still increasing angle. After another 50 metres it rears to the vertical — and remains unexplored.

Continuing past the base of Super Ramp, collapse narrows the passage to the left hand wall, before a zig-zag escapes the loose material and leads to a number of shafts, none of which have been descended. In the collapse, a climb through boulders leads into a large, sand-floored cavern. The passage becomes less sandy, and a large hole in the centre takes some water falling from the the roof. A steep climb up sand and boulders beyond leads to a fill-terrace along the right hand side of the passage with shafts on the left, and a scramble leads down to the top of an awkward 40 metre drop. Below, the passage extends the Homeward Bound line through boulders, and continues on unexplored down a large slope. Since there is a draught, and it is heading straight back towards the cliff face, the chances of a further entrance appear good.

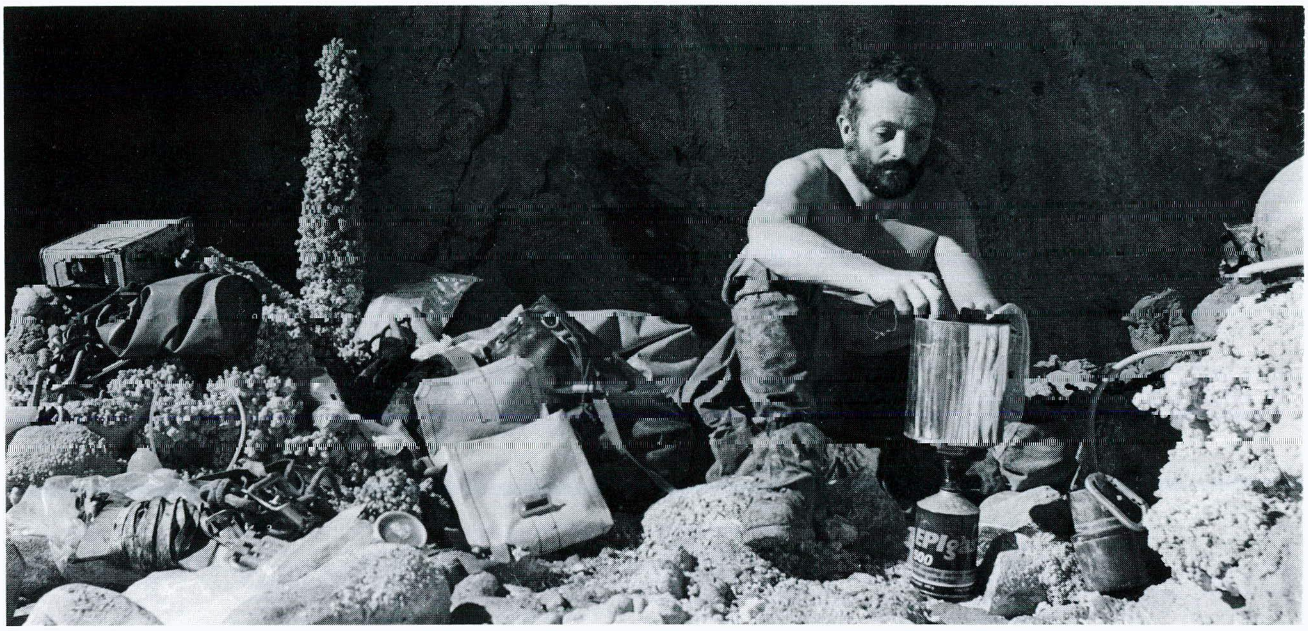
LUBANG SAKAI — Sakai's Cave

Just 30 metres from the lower entrance to Benarat Caverns, and at the same level, Sakai, one of the Mulu '80 team, spotted leaves being blown by a wind from the cliff. The wind emerged from a round tube one metre across. This led the explorers down a series of shafts into the tunnels of Sakai's Cave.

Four shafts in rapid succession lead to a junction with an undescended shaft ahead, but left continues to a fifth shaft, 22 metres deep, which lands in an extensive series of cobble-floored horizontal passage, once more strike aligned, but, unlike Benarat Caverns, with wall features showing that they were formed long ago by water moving northwards towards the Medalam. It may be significant that bats use the known entrance for access to the cave, and that they are common in the calcite-choked southern end of the main passage, which finishes in line with the cliff face exposed 100 metres above. However swifts, which were heard and seen in the lower parts of the cave, were not encountered in the entrance shafts.

Mike Meredith at the 1978 breakthrough in Benarat Caverns (A. Eavis)

Parallel passages continue northeastwards from the base of the last pitch. The cobble fill flooring them is punctured by many holes and general collapse areas, indicating the influence of a lower level. One of the most obvious holes was descended at 60° for 60 metres, to where the rope ran out, at a point ten metres below the Melinau river level. There was no sign of water. Further on, the passage cuts up-bed to a new strike alignment, and then a large passage opens on the left to a 14 metre drop at Platform Junction. Down the drop, a slope leads upwards into a breakdown chamber, and on into Late Night Chamber at high level. Beyond, the passage continues, its conclusion unexplored. Northwards from Platform Junction a small passage leads to a vadose trench, and into a complex rift area which is yet unexplored in both directions.



Barking Dog bivouac in Benarat Caverns (A. Eavis)

CAVES OF THE TERIKAN RIVER

Nick Airey

The country between the Terikan and Medalam rivers is dominated by the towering slopes and cliffs of the northern ridge of Gunong Benarat. Mulu '80 established a camp beside one of the streams that flow off the alluvial terraces and sink against the limestone, eventually joining the underground course of the River Terikan. As usual, the thick undergrowth and broken limestone of the uplands made for heavy going by comparison to the open forest of the terraces, but the 1978 exploration of 7 kilometres of passages in the Terikan River Caves had shown that work here could be rewarding.

The plan was to search for a depression that had looked promising on the helicopter recce, but the second excursion on to the limestone revealed a draughting entrance which eventually led down to the Terikan River above the upstream sump in the known caves. The underground river is wide, with deep, blue flowing water. It was promptly christened Blue Moonlight Bay Cave, and gradually it revealed its secrets as it was surveyed back into the mountain towards the Medalam. Progress was good, especially with the excellent help from the local porters, Ricki, Mani and Nilong, who played an important part in the surveying and exploration. The general freedom from ailments was celebrated by adopting the radio callsign 'Medalam Health Farm', but this quickly became an unpleasant irony as Colin went down with a totally incapacitating fever, to be followed rapidly by Dave. Assistance arrived in the shape of Jon, Mike and Dick but they were followed by heavy flooding, including one remarkable 25 hour downpour.

When time ended the Mulu '80 explorations, many interesting problems remained. Chief amongst these is the source of the Terikan water. Along the limestone boundary, to the east, there are no obvious new entrances and only one small, boulder-blocked resurgence. On the limestone bench above the alluvial plain there are numerous entrances which remain unexplored. It seems likely that there is extensive fossil development well above the alluvial plain, and the possibility of a link with the caves of the Melinau Gorge cannot be ignored.

GUA TELUK CAHAYA BULAN YANG BIRU — Blue Moonlight Bay Cave

The passages of Blue Moonlight Bay Cave form the upstream continuation of the Terikan River Caves, but there is no known open connection. Unlike the lower caves, Blue Moonlight cannot be entered by inlets off the alluvial plain, but its entrances lie up in the dry valley east of Arrow Inlet in Terikan West (the Blue Moonlight Survey is on the centre fold-out). The lower, and smaller, entrance draughts strongly, and leads direct to boulder-strewn passages past a junction from a second entrance and on into Dark Star Chamber. Of the five massive exit passages from the chamber, one leads to a cross rift. The original route explored by Dave and Colin is along the rift to the right, and then round a circuitous route involving climbs and a crawlway to a sandy beach overlooking the impressive river passage of the Terikan. Downstream lies sump 4 of the River Caves, while swimming and wading upstream leads to the River Junction. A side passage in the dry series leads to the foot of a daylight shaft very close to the Clay Series in Terikan East. A short pitch in the initial cross rift drops into a massive descending passage straight to the River Junction — the easiest way into the cave.

At River Junction the main Terikan water comes in on the right, but sumps only a short distance upstream. Left is the Nilong River Series which can be followed through a low duck and up into the boulder strewn Batukah Chamber. Beyond the chamber a complex of ancient tunnels are partly occupied by the Nilong River but eventually sump very close to the edge of the Medalam alluvial plain. An early exploration trip was forcibly extended when torrential rain flooded the Nilong River and closed the duck when the water rose a metre in less than 30 minutes. The team retreated to a dry chamber and shared a Christmas pudding. After 8 hours the water level had fallen a little but then stabilised, and Tony White therefore decided to free-dive the sump with the aid of a rope. The sump was 6 metres long, but, with the rope through, the rest of the team followed and then had to swim down the rest of the river passages where the Terikan had backed up in the flood. On the next trip into the cave a by-pass was discovered, avoiding the threat of the temporary sump.

A third passage out of Bakutah Chamber leads south-west to a balcony overlooking a large void. A pitch of 15 metres drops into the 20 metre diameter tunnel known as The Casting Vote. Eastwards the passage contains vast sand deposits and continues firstly as a fine tube and then along collapse-modified bedding plane galleries; all the branches end in either boulder chokes or sumps. To the west, The Casting Vote leads to a junction with a huge old phreatic tube, but all ways on finally choke.

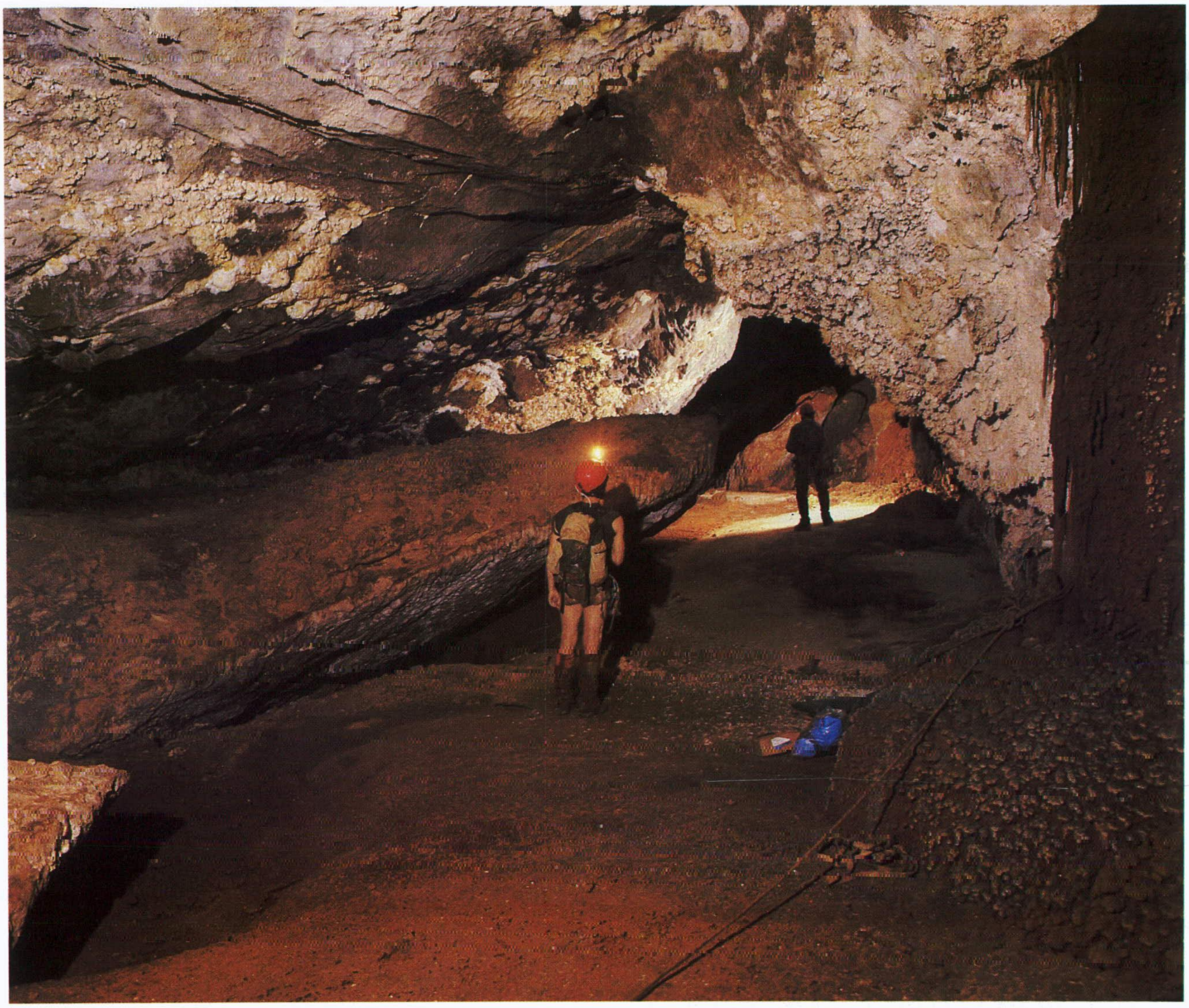
Continuation of the large phreatic tunnels in the inner reaches of Blue Moonlight Bay will probably best be sought from the surface as the various chokes appear to lie beneath dolines. The source of the Terikan water is still an interesting problem. None of the previous sumps is very long and so it may be possible to rejoin the river further upstream by access from the surface. As the river is followed eastwards it becomes more reasonable to suggest water leaking from the Medalam as a major component, especially considering the large flow of the Terikan and the relatively limited catchment of northern Benarat.

CAVES OF GUNONG BUDA

Dave Checkley

Gunong Buda is the most remote of the three main limestone blocks lying at the northern end of the National Park. The remoteness of the area presented many logistic supply problems and imposed restrictions on the exploration approach. Colin Boothroyd, Dave Checkley, Nick Airey and Tony White walked past dozens of huge cave entrances while making their way to the northern Buda Gorge. They planned to camp by the gorge since this offered access to both the west and the east sides of the northern block, even though crossing the limestone and its pinnacle karst is nowhere easy. Also the gorge was the most likely route to a large depression, which became known as the "Big Feature".

The Buda Gorge camp was close to an apparently good water supply, the stream running out of the Gorge. Unfortunately, when the rain stopped the stream stopped and the specialities of the camp were mosquitoes and a complete absence of sunlight. Large distances can be covered relatively quickly on the alluvial plain and since much of the edge of the limestone is cliff, plain-level cave hunting was relatively easy. The team checked out the cliffs for cave entrances on treks around the western flank of the limestone and only left out a few areas of difficult scree. However the odd patch of scree seems an inconsequential omission compared to the 99% of the upper limestone surface which was left completely untouched.



Benarat Highway at the top of the breakthrough climb in Benarat Caverns (A. Eavis)

The main river passage in Blue Moonlight Bay Cave (D. Checkley)

Looking towards the south entrance of Deer Cave (J. Wooldridge)

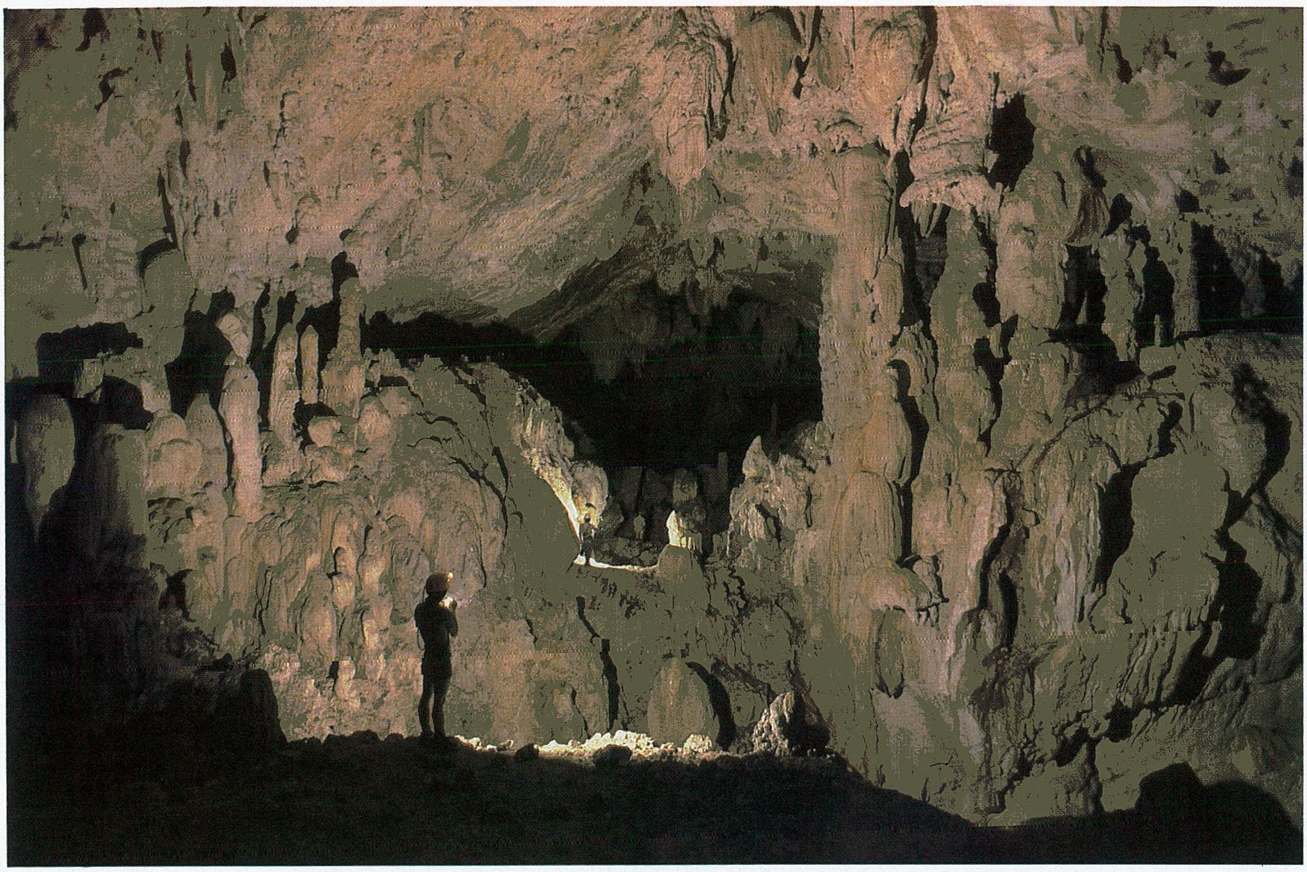
North of the Buda Gorge on the alluvial plain side of the limestone, only one important system, Compendium Cave, was found. At its furthest point an impressive rift was reached and is one of the largest passages yet found in Buda, perhaps a taste of explorations still to follow. Collapse and infill terminate many of the Buda cave passages, and the cause for the great extent of both is still unclear. In most cases the best guide to cave discoveries is the underground wind, but draughting chokes caused considerable frustration.

Fortunately rivers have kept open the two major systems that were explored south of the Buda Gorge. Both Beachcomber and Turtle caves have fair sized streams flowing out of them in normal weather and torrents in flood. Surprisingly, these rivers sink into the limestone underlying the alluvial plain, within a short distance of the resurgences, but can't be missed if the cliff line is followed closely. Both caves provided exciting exploration, but though close together they are two very different types of cave. The Beachcomber stream floods much of the entrance series after rain and in parts of the system water pours in through every crack in the roof even after a shower. The far series in Beachcomber was fascinating because it was completely incomprehensible until the survey was drawn up. All the passages linked round to each other, but never in the way expected and the problem was really that the river flows round in a circle.

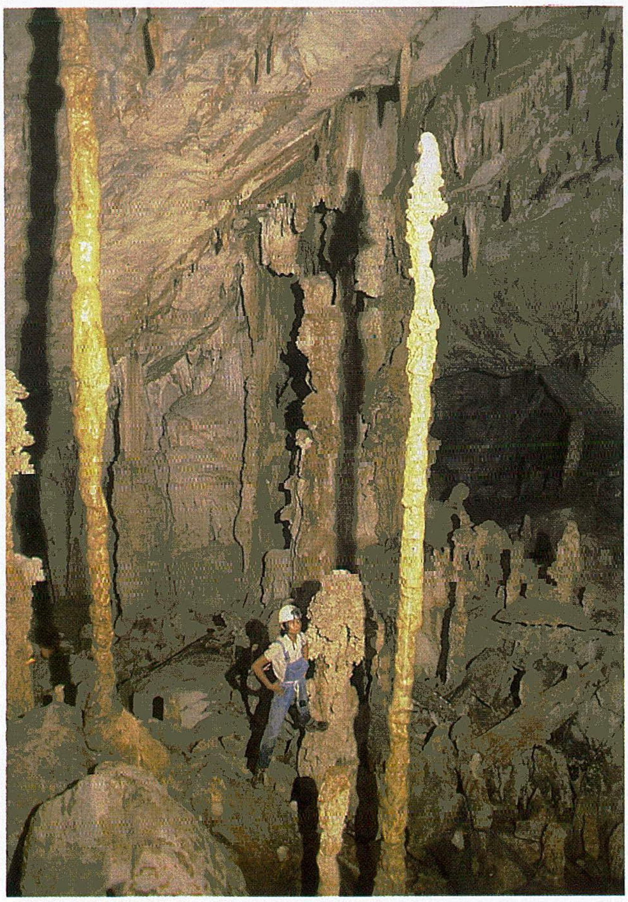
The main entrance to Green Cave photographed from the terrace climbed by Dick Willis and Mike Meredith (R. Willis)

Turtle Cave is not prone to the rapid flooding of Beachcomber. It is a sedate system with its water level rising and falling quite slowly in its long deep canals. Fish and turtles are the regular inhabitants of these passages, but they were little disturbed by the Mulu '80 explorers on improvised rafts of sticks and plastic water carriers. Even raft riding was strenuous against the current, and balancing precariously in the deep canal Tony and Nick did well to lasso a flake in the roof and climb out of the water, into a passage above the sump.

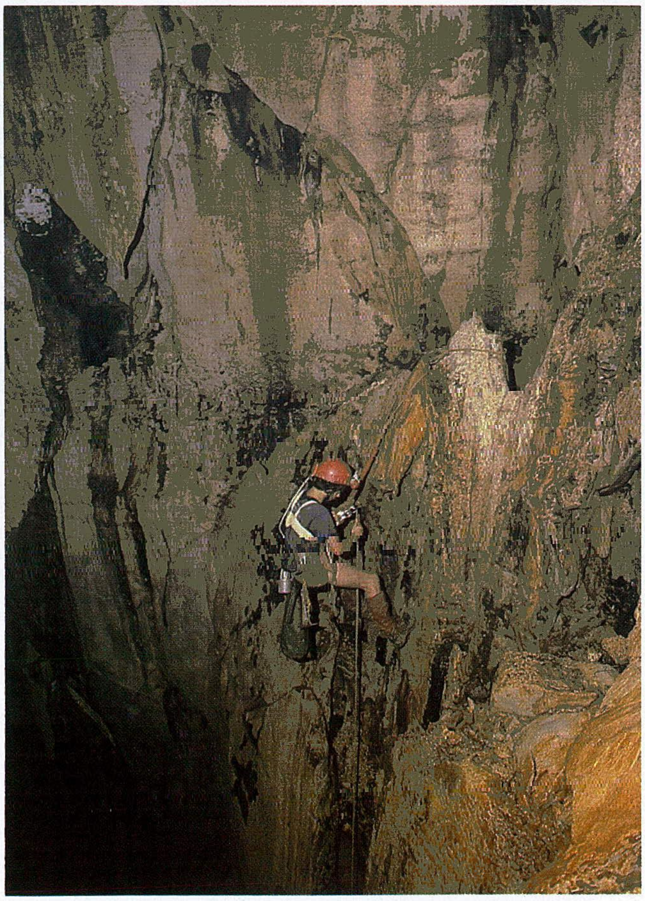
It was quite late on during Mulu '80 that tracks were made through the Hanging Valley to the large depression east of the limestone. The last few metres were a struggle, cutting steeply down through the vegetation into the depression, but it was worth it. The river sink is incredibly inviting and holds the prospect of a really exciting through cave to the Beachcomber system. Turtle Cave is by comparison a mystery, and leading off under the main limestone block of Buda it may be the key to the area's master drainage, the equivalent of Terikan and Clearwater. Buda still hides its major systems.



Not Before Time, a part of the Mulu '80 discoveries in Cave of the Winds (C. Boothroyd)



Babel, in the Cave of the Winds (C. Boothroyd)

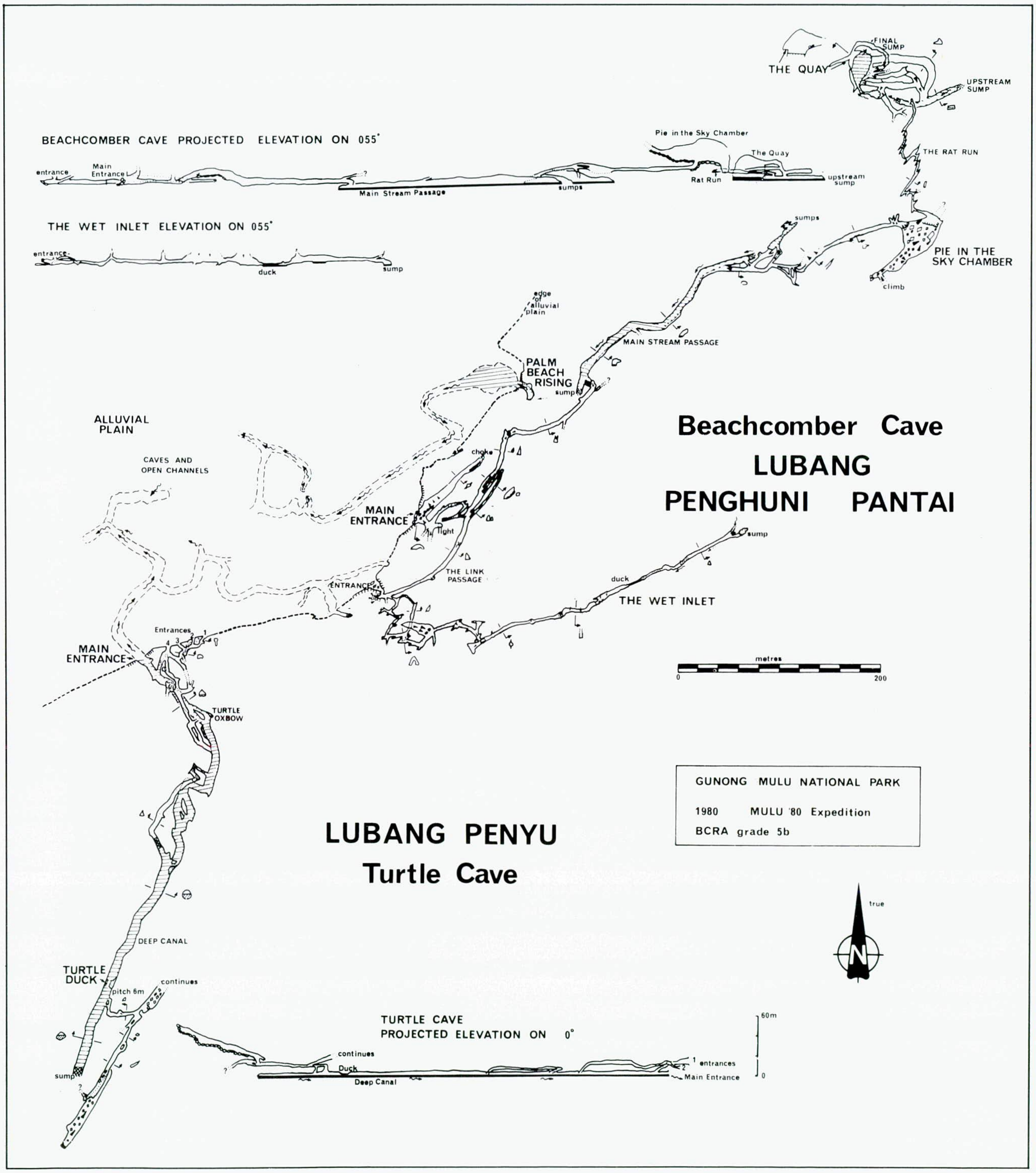


One of the pitches in Blue Moonlight Bay (A. White)

LUBANG PENGHUI PANTAI — Beachcomber Cave

The entrance to Beachcomber lies between the two resurgence streams of Palm Beach Rising and Turtle Cave. Inside, the way to the right is small and has a flat-out muddy crawl leading to the Link Passage. This roomy sand-floored passage extends right, to the second smaller entrance and a complex of small passages into the Wet Inlet. A traverse left along the phreatic rift is quite sporting, and leads on to the inevitable sump.

Left at the start of Link Passage is a flood passage to a duck through to the main streamway. Fast flowing, deep water leads to the upstream sump and obvious by-pass, then into a complex of steep crawls and low



passages, before regaining the larger continuation. A climb through boulders at the end is the route into Pie in the Sky Chamber, named after the large but inaccessible roof passage. Left down through boulders is the Rat Run with its endless muddy, wet crawls, back to the streamway at an incredibly confusing area of tunnels around the Quay. The stream appears to flow round in a circle in these passages, and clearly floods to the roof with even moderate rainfall — demanding considerable care in its exploration.

LUBANG PENYU — Turtle Cave

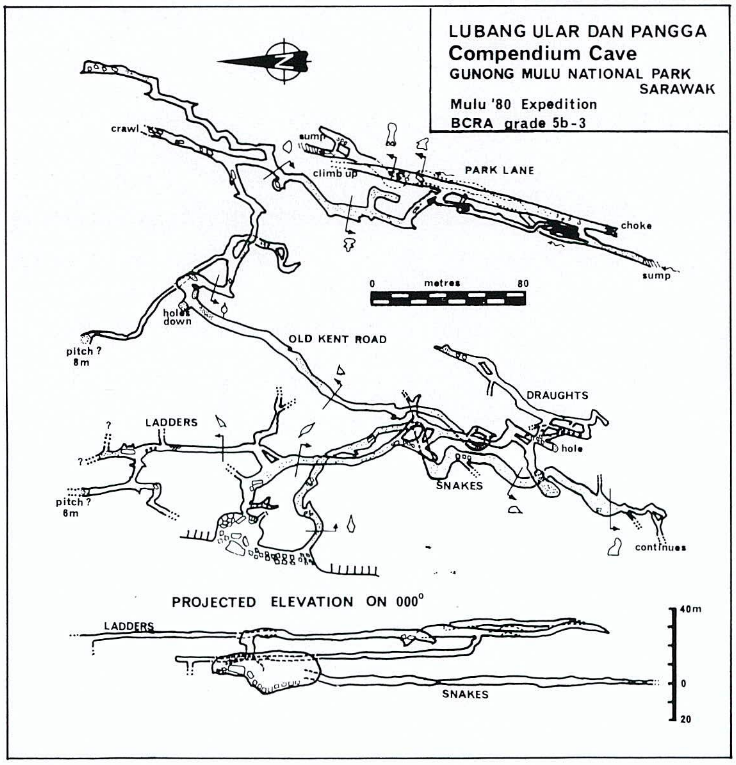
Turtle Cave is the most southerly of the resurgences which flow from the western edge of the Buda massif. The entrance is 5 metres high and wide and leads straight into deep water. This continues with almost unbroken swimming or rafting for half a kilometre to the upstream sump. The passage is a partly drained phreatic tube with few oxbows and branches. It carries a noticeable wind, which just before the sump comes down from a hole in the roof. Only by lassoing an eyehole can this be reached on a rope, and above is 100 metres of unpleasant and complex passage which is not fully explored.

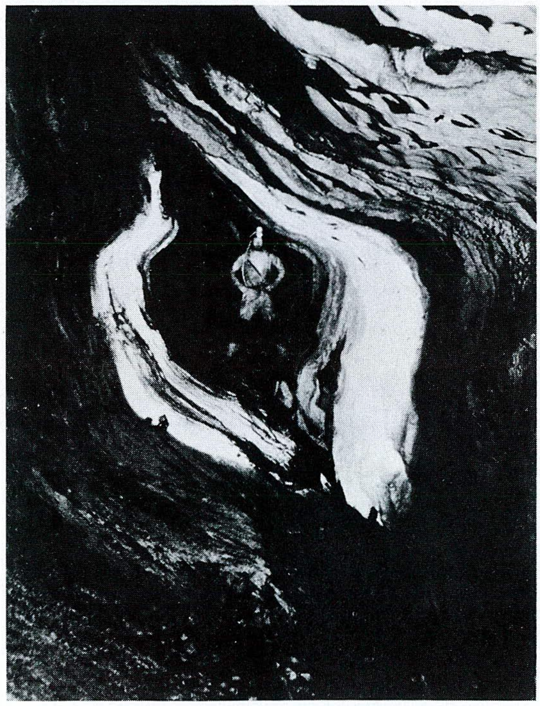
If the high level can eventually be persuaded to yield a by-pass to the sump, the wind and drainage of Turtle Cave indicate that it could be the key to a major cave system in Buda.

LUBANG ULAR DAN PANGGA — Compendium Cave

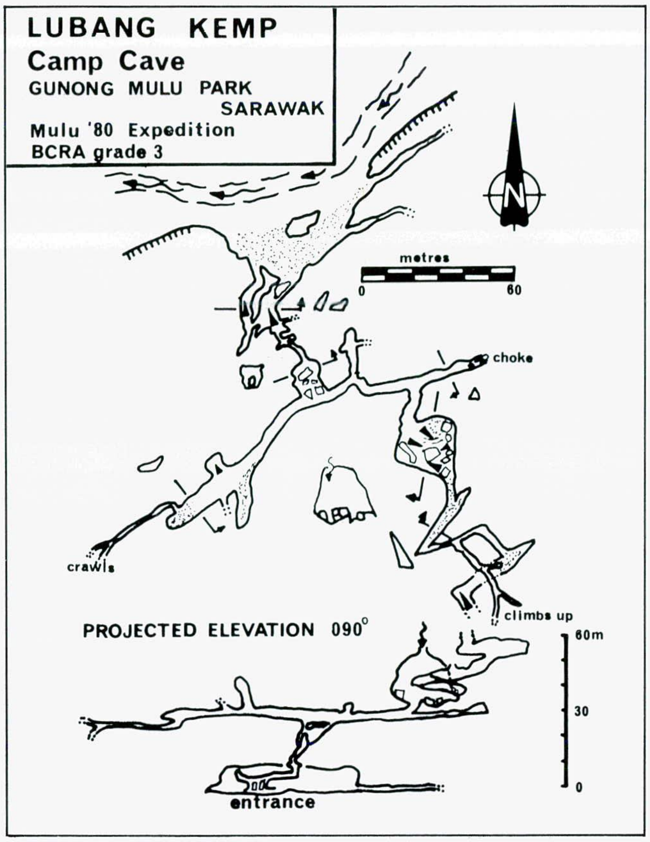
The two entrances to Compendium Cave lie at the back of a deep undercut in the cliff face, about half a kilometre north of the northern Buda gorge. The right hand entrance leads to Snakes, named after a large green resident met on the exploration, and this continues as a meandering canyon downstream to a narrow section which was not followed to a conclusion.

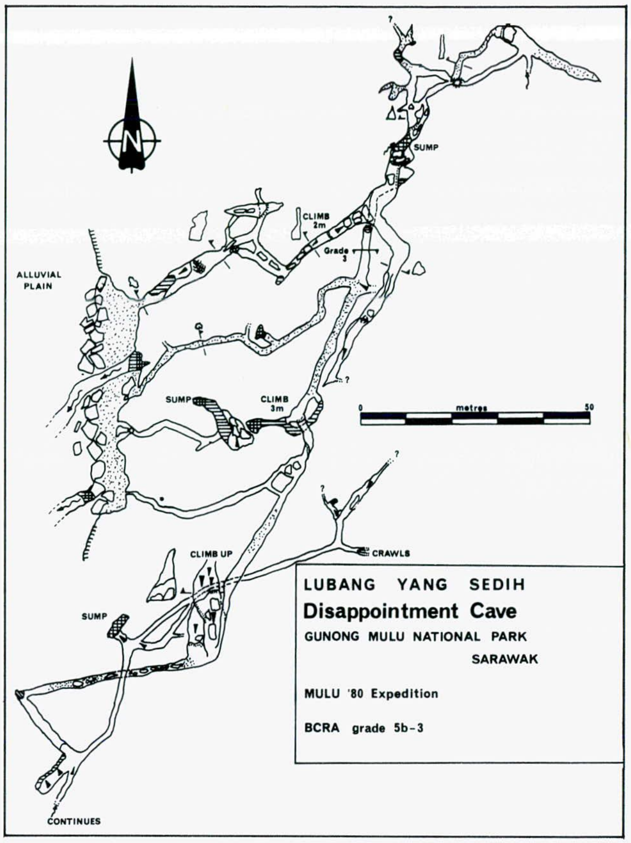
A climb over mud and calcite into the left hand entrance reveals Ladders, a maze of high level fossil passages. Northern branches end at undescended shafts, and at the southern end the passages subdivide into the narrow rifts of Draughts. An improbable hole in the floor drops into Old Kent Road, a gallery which enlarges, passes a number of junctions and eventually leads to Park Lane. This is an impressive rift 5 metres wide and 20 metres high, but one end chokes and the other rises steeply, beyond which it is unexplored. A lower streamway sumps in both directions. Compendium poses many questions, as the destination of both its drainage and its ancient trunk passage of Park Lane are unknown.





An inclined rift passage in Beachcomber Cave (C. Boothroyd)





Other Caves around Buda

Consolation Cave lies 500 metres southeast of Palm Beach Rising in the floor of a dry valley. An easy entrance climb drops into 200 metres of large dry passages, with an unexplored 40 metre deep shaft in the floor.

Camp Cave opens at the foot of the cliff 100 metres south of the northern Buda gorge. 500 metres of dry passages end in chokes and ascending rifts.

Disappointment Cave lies another half kilometre south of Camp Cave, again at the foot of the cliff. Four entrances lead to a maze of passages surveyed for over 700 metres. Most are immature phreatic tubes which only intersect short sections of two underground streams. 400 metres further south two stream sinks are choked and sumped, while a large dry entrance leads only to a rubble-filled and choked old phreatic network.

Hillside Hole lies in the northern wall of the first hanging valley south of the northern Buda gorge. A climb through boulders and down a sparkling calcite ramp leads to 350 metres of large branching passage, all of which end in chokes, except one only explored to the head of an 8 metre shaft.

The more northerly of the two large depressions east of the hanging valley, immediately northeast of Buda, contains an impressive open sinkhole. A large stream cascades 30 metres down the smooth black rock of the rift, and is more than likely the water which resurges through Beachcomber Cave.

The "Big Feature" on the northeast corner of the Buda massif is a rocky doline 300 metres across and flanked on the western side with 150 metre high cliffs. A massive cave entrance shrinks to a descending passage 10 by 15 metres at the head of an 8 metre deep waterfall shaft which was the limit of exploration.

On the northwest edge of the Buda massif a closed valley contains a number of caves. Sinks and resurgences have been explored mostly to sumps without yielding any significant length of passage. Another kilometre further north, a sink to resurgence through-cave of 250 metres was explored, but no more caves were found along the edge of the alluvial plain.

GEOLOGY

Barry Webb

The Melinau Limestone is a lenticular reef complex of Lower Tertiary age which crops out along the flank of the Mulu uplift. Its broad form is of a massive escarpment facing southeast with weaker rocks occuring on both sides of it — the younger Setap Shales cropping to the northwest and the sandstones and shales of the older Mulu Formation lying below and to the southeast.

The geological programme of Mulu '80 was primarily concerned with the structural features within the limestone and surrounding rocks which may have acted as controls on cave development. The discovery of fairly intense folding of the limestone explains certain anomalies in the existing outcrop pattern, and indicates a much lower generalised dip to the limestone than was previously supposed. It now appears that the upper limestone previously thought to crop out only in the alluvial plain and on Berar must be present on Benarat and Api, and the upper slopes of these hills must be very close to the top of the limestone.

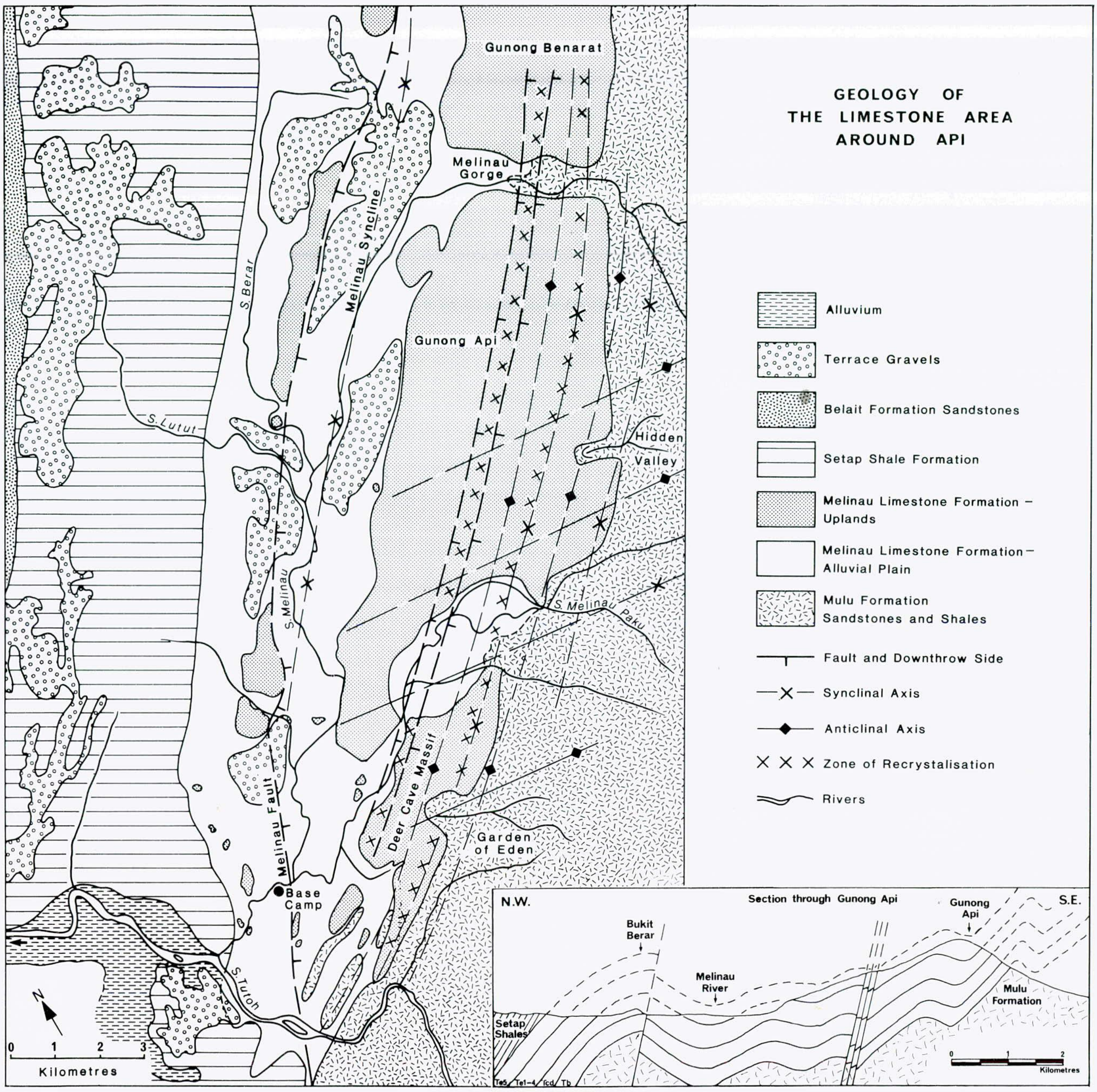
Deformation of the limestone commenced soon after its deposition and reached a peak in Pliocene times. The limestone was faulted, and locally metamorphosed to marble and the resultant structures are the primary controls on both the early drainage development and the later caves. The folds are periclinal structures forming a series of elongate basins and domes. The present drainage pattern still largely follows the lines of the synclines in which it must have originated on the surface of the once-overlying Setap Shales. Within the limestone the folding-induced slip on some of the bedding plains, particularly on the flanks of folds, opened them up for later access of water and hence cave formation. In addition, joints opened up in the fold zones: those of the dominant set are nearly vertical trending about 30° east of north; a secondary set, also vertical, is aligned close to east-west and is developed mostly on the fold crests; and a third set lies at right angles to the bedding oriented along the strike.

The fractures form the major routes for water into and through the limestone, and therefore constitute the major influence on cave development. Control by the bedding and the major joint set is almost ubiquitous and is reflected in passage shape and direction in the majority of caves. Passages appear to be initiated along the bedding-joint intersection and then develop preferentially along one or the other depending on local geological and hydrological controls. The east-west joints are restricted to zones and relate to cross-cutting anticlinal structures. One zone locates the east-west passage in Wonder Cave and also the Edge of the World line in Clearwater, while another zone further south guided the Prediction to Nasib Bagus drainage. Less important is the third fracture set, locally notable around Clearwater's Snake Track entrance.

In addition to these features promoting cave formation, the zones of metamorphism within the limestone act as barriers, inhibiting water movement. Intense recrystallisation and consequent sealing of the limestone is associated with a major fault zone lying near the axis of the hills. It appears to affect the limestones up to quite a high level and has severely restricted water movement across the hill line. It was this barrier and the proximity of the Tutoh valley further south that caused the Melinau Paku to flow southwards through Green and Deer Caves during its earlier history. A second zone of recrystallisation follows the western limb of a syncline near the eastern edge of the hills. Its effects appear limited to the lower levels of the limestone, but it forms a significant barrier to water movement at that level. In association with the adjacent anticline to the west it promotes resurgence into the Melinau and Melinau Paku valleys of all water draining into the eastern part of Api. These two hydrological barriers effectively isolate the central, anticlinal, belt of Api, in which no major caves have been discovered.

Within the limestone the Melinau Paku is unlikely to have ever flowed north while the steeper hydrological gradient existed southward to the Tutoh. In addition, the domed nature of the folds in Api causes the underlying sandstones and shales of the Mulu Formation to slope up immediately north of Hidden Valley and further inhibit throughflow. The form of Hidden Valley suggests that at higher erosional levels, water once flowed across the eastern barrier into the anticlinal zone, but again in response to the upfold immediately north, it turned south to join the Melinau Paku drainage system. The high level course is now preserved as a major surface depression, and the water which formed it was eventually captured into the caves of Prediction and Nasib Bagus.

The main zone of recrystallisation is now breached by both the Melinau and Melinau Paku rivers. Though the former may once have flowed north through Benarat, once the barrier was crossed an unimpeded hydrological gradient existed between the western end of the Melinau Gorge and the lower reaches of the alluvial plain, and Clearwater Cave developed along this line. Whether the breakthrough of the Melinau Paku was achieved by that



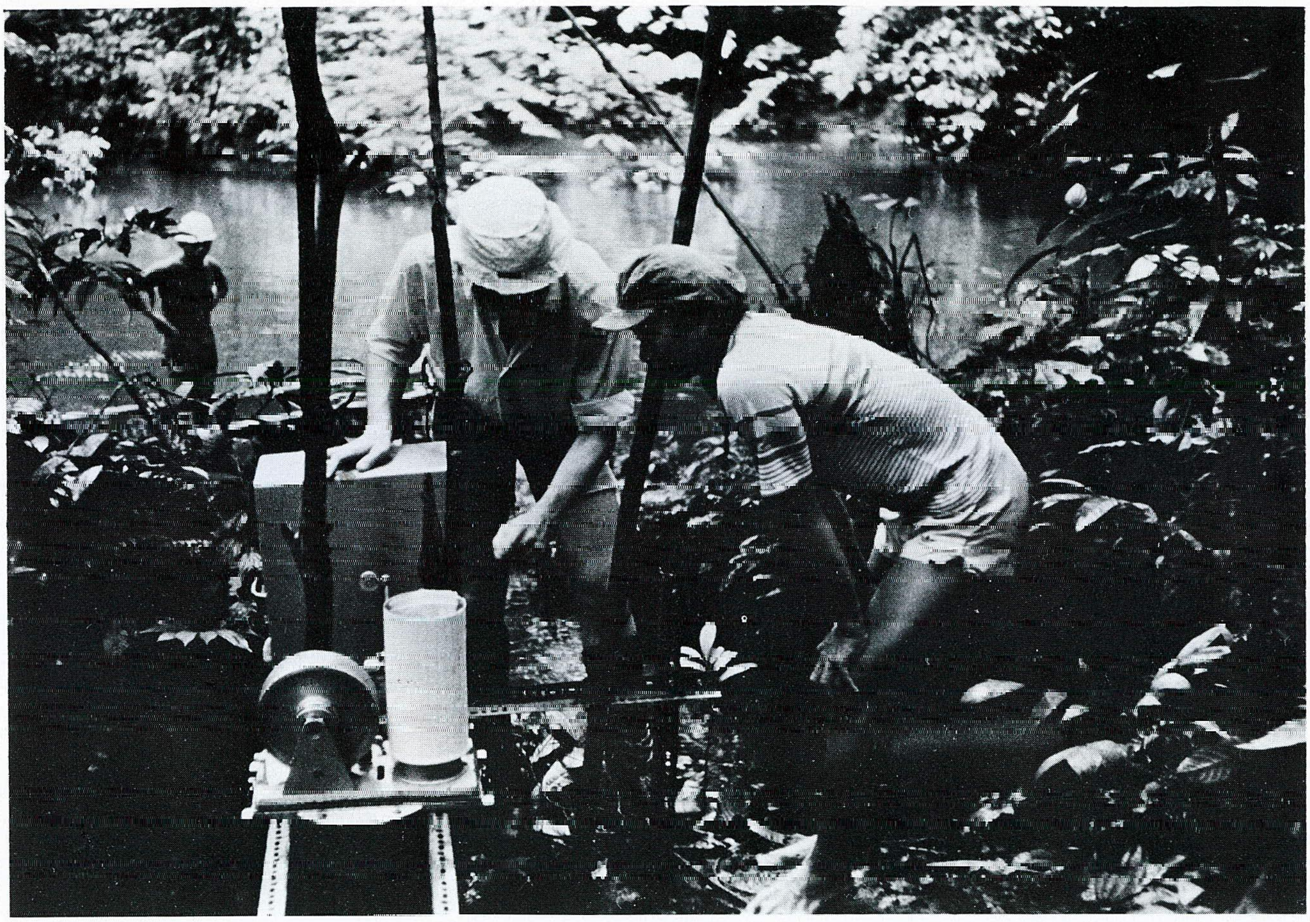
river itself or by a tributary of the Melinau is not known, but once the connection was made the steep hydrological gradient would ensure rapid erosion and capture of the drainage into the Green and Deer Cave System. The relationship of the Garden of Eden to Green and Deer Caves strongly suggests it is an unroofed cavern of the Sarawak Chamber type. Perhaps more of the major valleys originated in this way.

In conclusion, it is clear that the caves have their patterns guided by well defined structural weaknesses in the limestone, but their actual locations are more closely controlled by the hydrological barriers.

HYDROLOGY

Hans Friederich and Pete Smart

The drainage pattern of the limestone uplands of Mulu exhibits a classicly simple pattern. Each limestone block drains mainly along the strike to discharge at the lowest point, where the limestone is crossed by the major regional drainage lines. For Benarat this is to the north into the Terikan River, while for Api it is to the south and the Clearwater River. This pattern is supported by the dye trace made from a minor sink in the south side of the Melinau Gorge through to the Clearwater rising — a distance of 10.5 kilometres travelled in 24 hours.



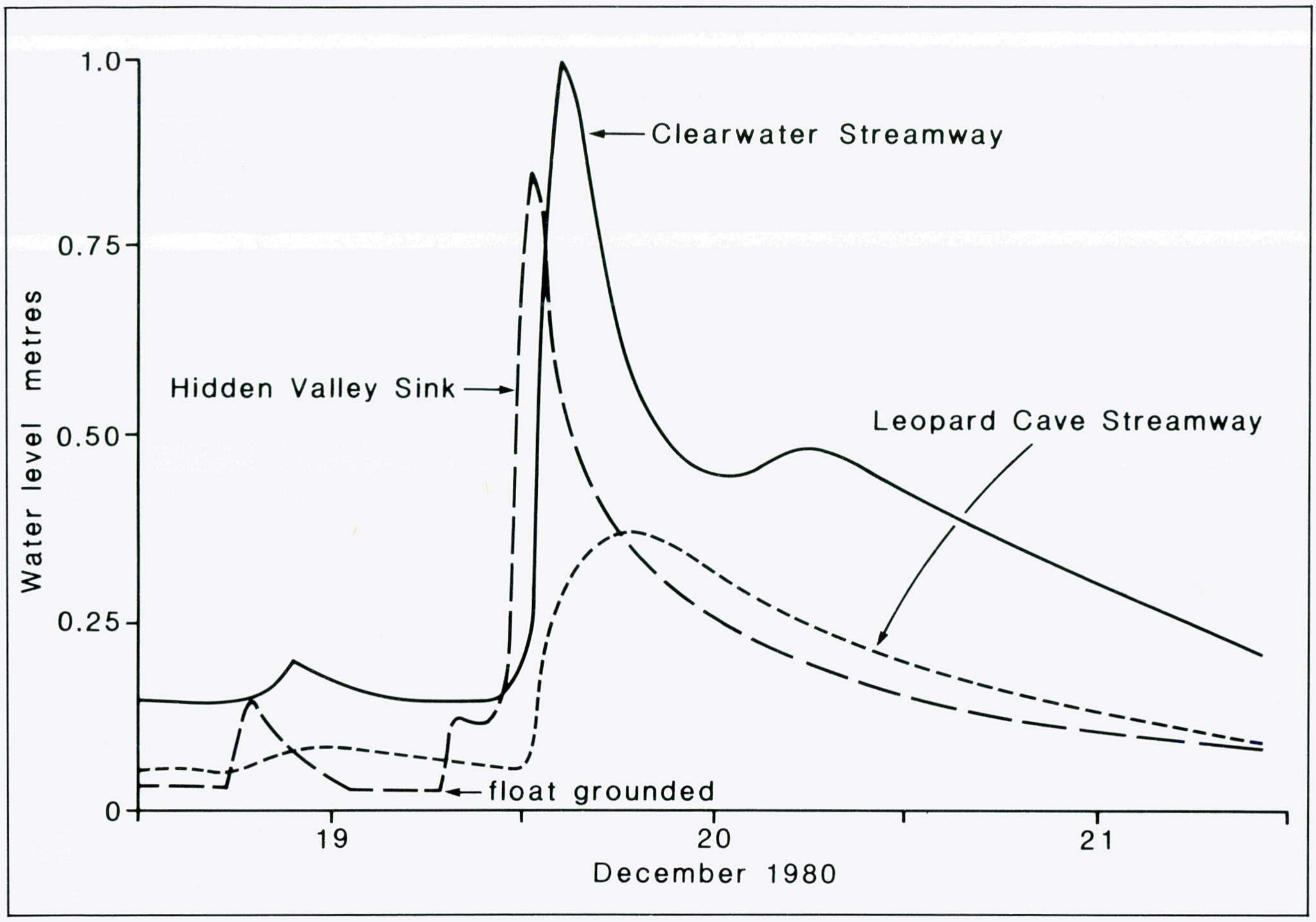
Hans Friederich explains the operation of a constant recording water level meter to Park Warden Siduck (P. Smart)

However, tracing also proved that the previously expected downdip flow from the Hidden Valley sink to Clearwater did not exist, but that the sinking river drains along the strike to the Nasib Bagus resurgence. This flow may well represent the preferred steepest hydraulic gradient, but localised control by the basement geology may also be important.

In contrast to this remarkably ordered drainage, that in the Southern Hills (and also in Buda) is more chaotic. Water from the Garden of Eden may drain along the strike through Deer Cave, along a similar line in the opposite direction beneath the main floor of Green Cave, or downdip via Snake Cave direct to risings in the Melinau Paku Valley. No route has a clear hydraulic advantage in this more mature and dissected relief, and the relative importances are controlled by such random features as rockfalls.

The drainage of Api is however more complex in detail particularly along its western edge against the alluvial plain. There a series of streams, in the area of Leopard Cave and Goldwater, switch between mainly underground routes in low flow and surface routes in flood. A considerable volume of water from the alluvial plain is discharged into the limestone via these systems, because water levels in the limestone are lower than those on the plain which is built up by the alluvial terraces of the Melinau River. Water also enters by leakage from the Melinau Paku, and dye traces have shown this to emerge at both Cave of the Winds and the Clearwater resurgence.

This water derived from non-limetone areas is partiularly important in generating flood flows within the limestone — as shown by the contrasting hydrographs in response to a rainstorm of 19 millimetres on the night of December 19th 1980. The steep impermeable catchment of the Hidden Valley stream responds very rapidly to rainfall, peaking within 3 hours. In contrast the Leopard Cave streamway, draining the more permeable alluvial terraces and also a considerable unit of limestone, shows a more subdued response peaking after 12 hours and recessing much more slowly. The Clearwater River combines both these types of response to give a remarkable double discharge peak. While some inputs from the alluvial plain may contribute to the first peak, those from the Melinau Paku are probably dominant. The second broader peak is derived from both the other alluvial inlets and also the limestone catchment fed by direct percolation.



Stream hydrographs for the December 19th storm

Cave inlets at shallow depths within the limestone respond very rapidly to rainfall. For a site in Clearwater Cave, at a depth of 50 metres, discharge increased less than 30 minutes after the start of rainfall. However the average depth of the unsaturated zone in the Clearwater catchment is close to 1,000 metres, and it is therefore not surprising that, despite this rapid vertical transmission, there is a substantial time lag in the arrival of limestone waters to the cave streamways. The inlets also dry up remarkably rapidly, and after a week without significant rainfall in January 1981, some of the fossil passages in Clearwater Cave were completely without water. Although flow at the Clearwater rising was reduced to only 2.28 m^3/sec. — compared to a flood flow in excess of 35 m^3/sec. — the rate of recession was quite slow. This does confirm the existence of significant storage within the limestone and the contributions of non-limestone water which continue even at low flow.

SURFACE GEOMORPHOLOGY

Pete Smart

The geomorphology of the caves of Mulu can only be explained if they are considered within the wider context of the evolution of the whole landscape. Surface erosion first directly affected this area after uplift in late Pliocene times over two million years ago. Initially the limestone was buried beneath a cover of Setap Shales and the original topography was primarily controlled by the greater elevation of the eastern areas which border the Mulu uplift. The regional drainage therefore developed towards the northwest with the Tutoh and Limbang forming major lines, and the Belait a more minor system localised by the subsiding Belait syncline. Due to the larger size of the Tutoh and the Limbang, combined with the strong northeast/southwest structural grain, the Belait headwaters were captured by both the Tutoh (forming the Melinau) and the Limbang (forming the Medalam).

The Melinau Limestone was first exposed on the eastern flanks of Gunong Mulu. As the eastern extent of the limestone (now removed by erosion) is not known, it is probable that many karst landscapes have been formed and subsequently lost and that the eastern limit of the present Gunong Api was previously the western limit of an earlier landscape. Whilst this view must remain largely conjectural, there is supporting evidence that the eastern and southern parts of the limestone areas are the oldest. The surface landforms of the Deer Cave hills and the area south of the Hidden Valley comprise mature cockpit karst, with deep depressions separated by precipitous ridges and towers. The extreme dissection of these areas contrasts remarkably with the north-western slopes of Gunong Api where depressions are poorly defined, shallow and of a great variety of sizes — indicating a relatively brief erosive history since the stripping of the Setap Shale cover. It is not therefore surprising that the earliest known caves in the Park are concentrated in the east, where limestone was at its highest elevation, and in the south, where the River Tutoh (and the regional base level) was at its lowest. This dominant hydraulic control was moderated by the availability of suitably open fissures in the limestone. Thus Wonder Cave is arguably a fragment of the oldest strike system explored in the Park, its huge phreatic chambers being localised by the folding north of Hidden Valley. Flow was probably to the south, the connections to the surface only developing when Hidden Valley truncated the cave passages and flow was reversed in the system. Similarly Deer and Green Caves conducted water to the south from the Melinau Paku through the most southerly limestone massif.

It is important to recognise that the western flank of Gunong Api was covered until recently with Setap Shale, although this cover was breached at an earlier date as the anticline associated with the Melinau Fault. The persistence of this insoluble cover may well explain the substantial amounts of Cricket Mud sediments found throughout Clearwater Cave, the origin of which from the insoluble residue of the limestone would be difficult to accept. It is also significant because it formed a barrier restraining down-dip water movement in the limestone. Flow from the east would be forced to gain some stratigraphic height along joints and faults crossing the bedding, and then discharge along the strike to the south. The breaching of the limestone ridge by the Melinau Paku is particularly important in controlling this southerly discharge point.

The drainage situation changed when the Setap Shale cover of the Melinau syncline was removed in the southwestern part of the Park. Down-dip cave development, guided by strong faulting, was rapidly followed by collapse and gorge development by the erosive streams draining from the Gunong Mulu side. These debris laden streams were then directed along the margins of the limestone massif by the continuing development of alluvial fans with a strong westerly surface slope. Undercutting occured, with lateral retreat of the limestone margin to form the spectacular vertical walls which loom over the planed surface of the Melinau Paku Valley to this day. A substantial portion of the Clearwater area caves has been removed by this retreat, notably near the Secret Garden, and other passages, for example around Babel have been intersected and lost due to surface lowering.

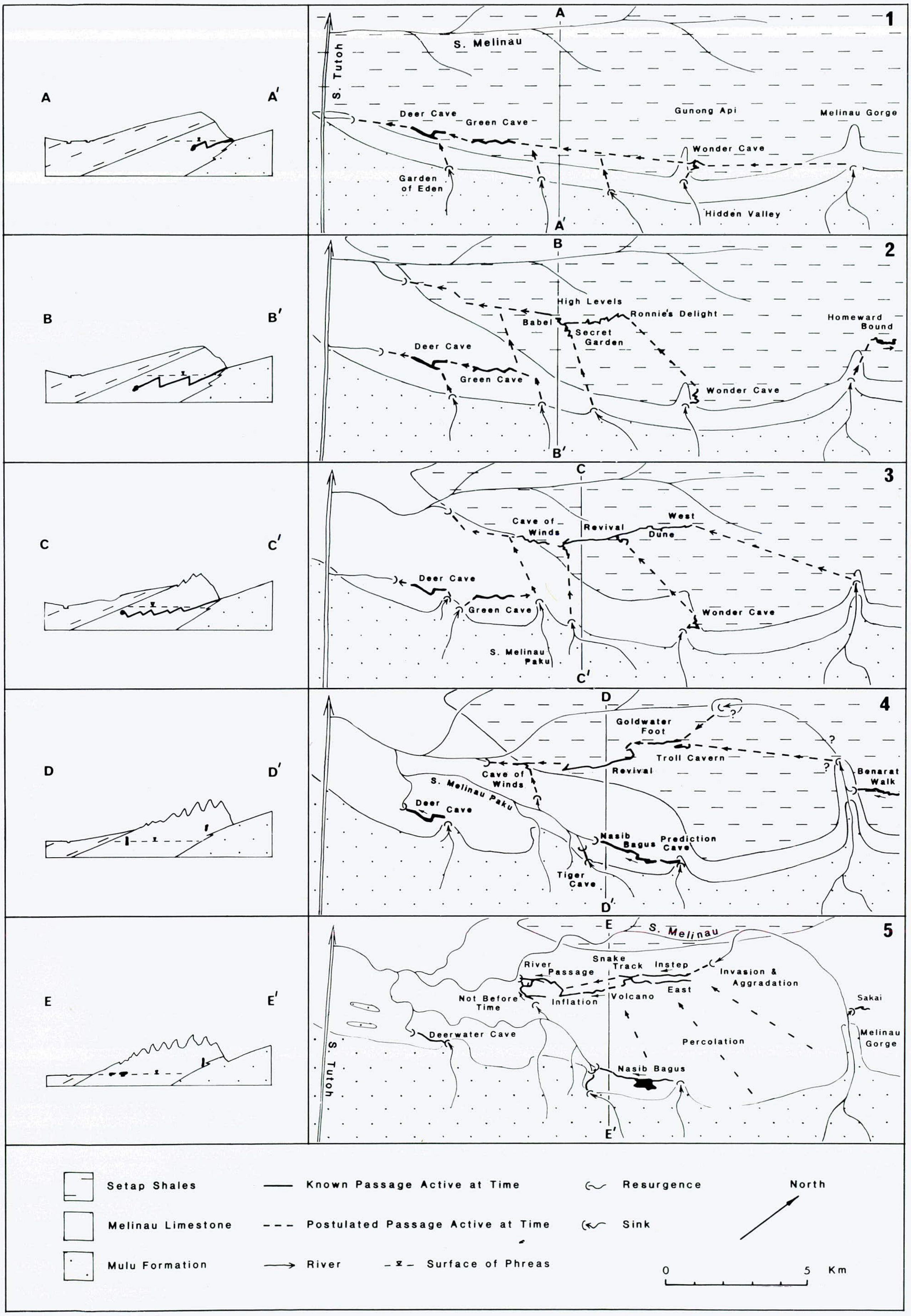
UNDERGROUND GEOMORPHOLOGY

Pete Smart

In many ways Gunong Api and Benarat represent mirror images symmetrically disposed about the Melinau Gorge between the major regional drainage routes of the Tutoh and Limbang Rivers. Their sequences of cave development are therefore very similar, and will be discussed here primarily by reference to the caves of Api.

The earliest passages of Clearwater Cave form undulating strike conduits developed towards the south along major bedding partings, at a level between 180 and 280 metres above the resurgence. These cannot be traced further north than Ronnie's Delight, which functions as a major phreatic lift bringing water up 100 metres from the dip passage at its base. There is little doubt that the source of this water was down dip flow from the Hidden Valley area. The great vertical range of these passages indicates a deep phreatic circulation and attests to the intact nature of the Setap Shale barrier overlying the limestone to the west. The second major inlet to this system, the Secret Garden complex, derives from an earlier high level course of the Melinau Paku, a level perhaps also indicated by gravel remnants on the surface of the Green Cave massif.

As circulation of the aggresive water continued, further secondary partings in the limestone became opened, and a more hydraulically efficient route evolved, cutting off the loops and ramps of the high level passages to form the prodigious horizontal tube of Revival. The down dip inputs were now supplemented by a major inlet from the north forming the phreatic tubes of Dune Series. The latter involved an enormous phreatic lift of over 80 metres, attesting to the less well developed secondary permeability of this zone where little prior ground-water circulation had occured. This route derived its water from the Melinau Gorge, the Melinau valley to the west still being sealed by the shales. Prior to this southerly capture, drainage from the gorge moved northward probably via the Highway conduit of Benarat Caverns. Such switches in drainage direction are common in Mulu due to both differential erosion and uplift which caused alterations in the hydraulic gradients in the limestone.



Sequence of cave development

There was then a very important change. The Hidden Valley and the Melinau Paku waters were diverted to a surface route by the breaching of the Api ridge. Hidden Valley was captured through Prediction Cave into the Nasib Bagus System, following rapid incision of the Melinau Paku. This head advantage, combined with control of cave development by structures in the impermeable basement, ensured that this has remained the preferred drainage line. The breaching of Gunong Api may well have had important effects at base level in the Clearwater system due to incision of the Melinau River following the increase in discharge caused by capture of the Melinau Paku. Thus, for the first time, the Clearwater River, on its route through Revival, developed a vadose canyon as its cut downward, keeping pace with the falling base level.

This horizontal conduit did not however prevent deeper circulation in the limestone, and there was simultaneous enlargement of low level routes, a process which appears to continue today. However, a more profound change was caused by the penetration of the shale cover by erosion in the Melinau valley. Due to the efficiency of the karst drainage, water levels in the limestone are similar to those of the resurgence, and therefore much lower than river levels in the surface valley.

Thus, once the impermeable shales were removed, capture of the surface stream could readily occur. The earliest known of these captives is that occuring via the large Edge of the World branch of Revival. This must have been contemporaneous with the demise of the Dune route, because it rapidly developed as a huge air filled streamway below the Dune level. This again may be associated with discharge changes as the Melinau finally cut its gorge through to the axis of the Melinau syncline.

As base-level continued to fall, Revival was gradually abandoned into a lower series comprising Goldwater Foot, East Passage and Sheer Delight, Instep and Porcupine Passages, Snake Track, Volcano and Inflation, fed via Battleship into the roof tube of the present Clearwater River Passage. This development was very slow, sections of isolated vadose passage persisting in Revival, as at the Volcano itself. Flood flows were accomodated by periodic reactivation of the higher level passages, whilst at low flow only the lower routes functioned. This process has continued to the present as base level has fallen, generating a vertical sequence of passages, for instance the active Tharg's Cave below Snake Track. However, near the resurgence, the gently rising tube of the main river passage has simply been trenched to form a huge vadose passage.

The final removal of the shale cap of Gunong Api itself has permitted the development of direct rainfall inputs to supplement the previous sources of drainage from non-limestone rocks. The distribution of these inputs, or the development of several cave-forming bedding planes due to progressive solutional enlargement, may explain the apparent disintegration of the major Revival flow route into two or more contemporaneous passages — for example, Instep and Porcupine Passages in parallel with East Passage and Sheer Delight. Even near the resurgence, modification of the Clearwater River Passage occured giving rise to the distributory at the entrance and at least some of the tubes at a similar level in Cave of the Winds. In fact the separation of these caves is relatively recent and Clearwater may well have once resurged much further to the south, before lateral planation by the surface river caused truncation of the River Cave at the present resurgence.

One final process must be discussed to explain the prominent notch features found at a number of levels in the Clearwater system: these are related to aggradation due to the accumulation of coarse fluvial sediments. There are two possible causes of this aggradation: firstly the catastrophic invasion of existing cave passages by surface rivers captured along the margins of the limestone, and secondly widespread increases in fluvial sediment supply causing terrace building on the alluvial plain. The former may well be indicated by the matrix-supported gravels, which are deposited as steeply bedded banks, in some places completely filling passages to the roof as at Detente Cavern. The latter are best recognised by their lateral persistence, near-horizontal bedding and clean washed nature, such as in Snake Track and Sheer Delight. As aggradation proceeds, the vadose portions of cave passages are infilled, the cross sectional area is restricted, flow becomes confined and velocity increases. This curtails the aggradation and a coarse lag gravel develops on the top of the fill. The erosive debris-laden flow cannot therefor erode downward, but is not restricted laterally. A wide notch, or bevel, therefore develops above the fill level, with small vadose scallops superimposed on larger original forms. This feature is displayed in the spectacular Over Time section of Cave of the Winds.

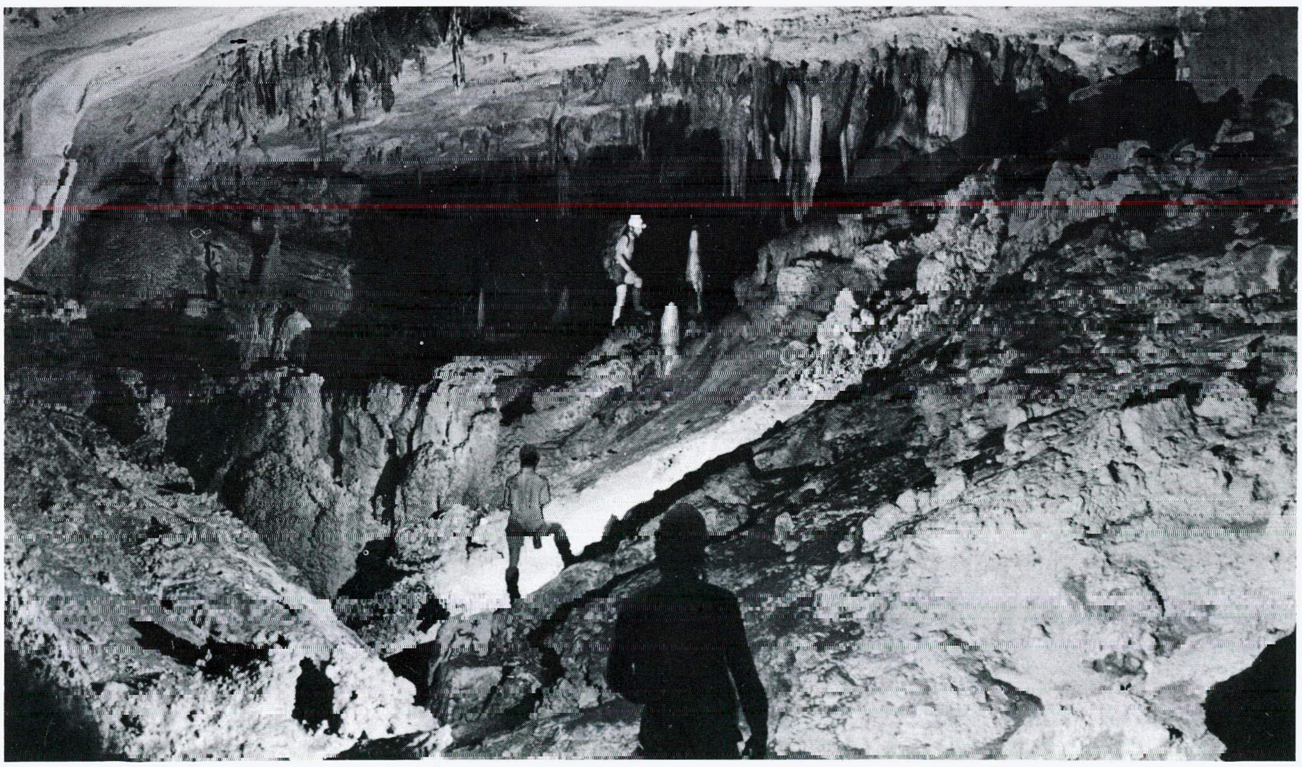
Thus, the dominance of strike development, the switching of different inputs into the limestone (controlled largely by breaching of the limestone massifs by surface rivers), and the progressive decline of base level through time, characterise the evolution of the Mulu caves. Work is now in progress to establish an absolute chronology on which to fix this relative sequence of events.

CAVE SEDIMENTS

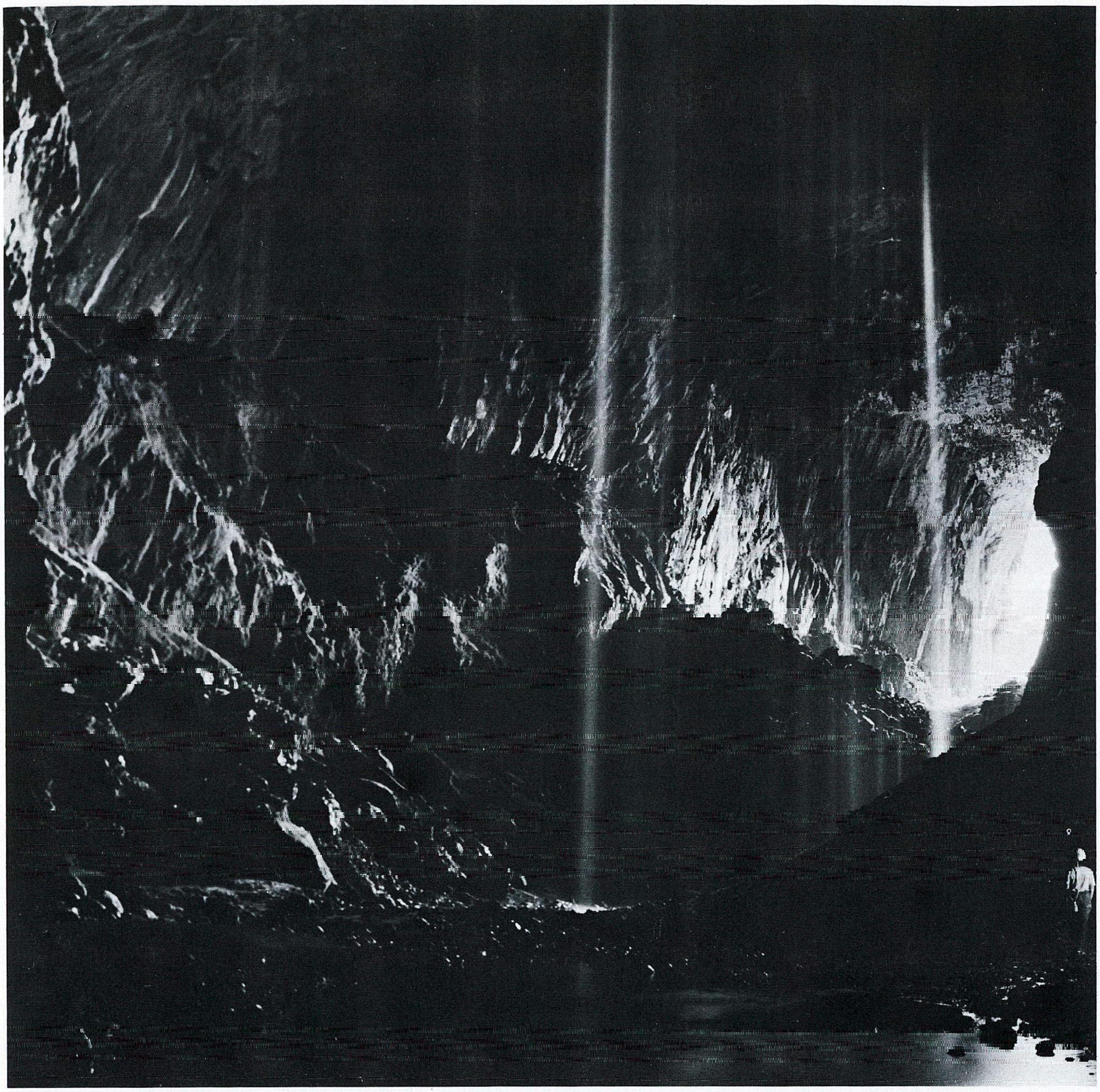
Pete Bull and Martin Laverty

The sequence of sedimentary fill in the caves beneath Api is surprisingly straightforward. The earliest phase of inwash of surface material that remains in Clearwater Cave and Cave of the Winds is a coarse gravel sequence that originated far to the east on the Mulu mountains. The gravels, predominantly of sandstones, shales and siltstones with occasional quartz pebbles, were washed into the developing caves and transported by largely phreatic waters through the main Revival level routes in the caves. A major river inlet at Detente caused the passage junction with Revival to fill to the roof with coarse gravels. Elsewhere, Sheer Delight and Clay Hall being exceptions, gravels were deposited less extensively. Many passages in the caves have reworked gravels, particularly Inflation and the active streamways. There is also evidence of in situ weathering, locally very severe. A curious feature of many of these ancient gravels is that they are matrix supported, that is to say that the fine-grained sediments are mixed in with pebbles in such a manner that the pebbles 'float' within the finer deposits. This implies that the streams that deposited the material did so very quickly and did not have time to sort out the material in the way that most streams do. The overall implication is that these lower gravels were deposited very quickly at a time when there was plenty of available surface material, when the river was extremely fast, and in one major event; such deposition is uncommon in temperate caves.

Following the discrete deposition of the gravels, the power of the river fell (often gradually, a fact supported by the frequent development of upward-fining gravels in the deposit) and the water speed slackened. It would appear that many of the upper passages (Revival and above) were filled with water and that periodic drainage of seepage from the surface brought fine-grained silts and clays into the cave, through the many cracks and joints within the limestone. This sediment settled out on top of the gravels in lake conditions in the caverns. Repeated incursions of sediment-laden water caused laminated sediments to accumulate to form what is termed the Lower Cricket Mud. This deposit is ubiquitous in the middle levels but is absent in the lowest levels except where it has been washed down from above. In some areas this cricket mud was deposited in shallow water that periodically drained. This caused the drying of the sediment and, on the onset of flood conditions, caused the formation of small air pockets in the sediment. Whether these sediments had air pockets or not can be shown to be important for the location and burrowing of cave crickets. In normal levels of population of crickets in a passage, the animals utilise the aerated sediment to dig their own burrows more easily. It is only in exceptional circumstances that the crickets burrow into cricket mud that does not contain the air pockets. Whilst the fluctuating lake levels continued in the caves a discrete influx of different material from the surface oçcured. This remains as a white, waxy, laminated sediment. It is a weathered breakdown deposit of volcanic ash which



Calcite deposits and sediments in the northern low levels of Clearwater Cave (C. Boothroyd)



Waterfalls 120 metres high cascade into Deer Cave after heavy rain (J. Wooldridge)

must have derived from a considerable blanket of ash which once fell over this part of Northern Borneo. The material is allophane, and can be found in thicknesses of up to 2 metres, an accumulation never before recorded in caves. This material is less ubiquitous in the cave passages within Api than the Lower Cricket Muds, but nevertheless is common in many passages, particularly in proximity to large input areas.

The allophane is capped by the Upper Cricket Muds, much the same deposit as the lower muds, and derived from the same surface soil source by the same mechanism of deposition. These Upper Cricket Muds normally contained most of the air pockets, and hence the larger proportion of cricket burrows.

Covering the Upper Cricket Muds is normally a layer of flowstone, stalagmite or a dark brown encrustation of guano-related minerals. Sundry breakdown and guano normally cap the whole sequence which is often eroded by the downcutting action of the streams. This erosion also causes slumping of the sections into a series of faulted outcrops which give the impression of even greater depths of sediment than actually exist.

Whilst this sediment sequence described is a fair approximation of the events of deposition in the cave, it is obviously simplistic. Local anomalies cause variation even to the larger scale deposition events, and synchronous cave passage development further complicates the picture.

The present-day sedimentation is restricted to small inlet passages through which contemporary soils are washed in the same manner as they were thousands of years before, and to river sorting, winnowing and transportation in the lowest level active streamways. It would appear that the system was, and still is, fed by predominantly percolation water, a fact indicated by the large quantities of cricket mud and allophane found in Clearwater Cave and Cave of the Winds and by the presence of surface-derived insoluble minerals in some stalactite deposits unquestionably formed by such water.

In addition to the clastic sediments within the caves, there are extensive and varied chemical deposits. Calcium-rich waters have deposited calcite, gypsum and apatite as discrete crystals within clastic sediments, as encrustations on sediment surfaces, and on cave walls. Uniquely, huntite, a magnesium calcium carbonate with more magnesium than dolomite has been deposited in extremely pure form as an efflorescence in close association with gypsum at isolated localities.

Guano from bats and swifts is common in some parts of the caves. It is often associated with inorganic minerals, of which gypsum and apatite are most important in Mulu. The gypsum can be distinguished as guano-derived by its X-Ray diffraction properties, which appear to be strongly influenced by the organic environment. Cave entrances often posess large quantities of moonmilk — micro-crystalline calcite clay — which may be associated with photosynthetic bacteria or with fungi. Elsewhere, cave walls, boulders or speleothems may have a 'skin' up to a centimetre thick of the same sort of material, in some places due to deposition and elsewhere due to weathering.

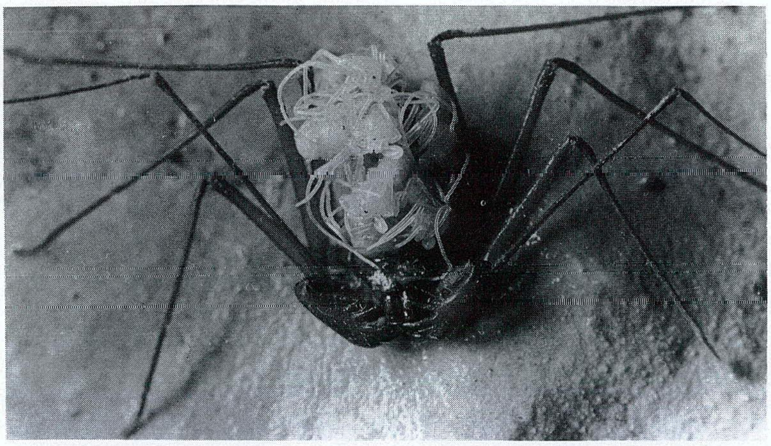
BIOLOGY

Phil Chapman

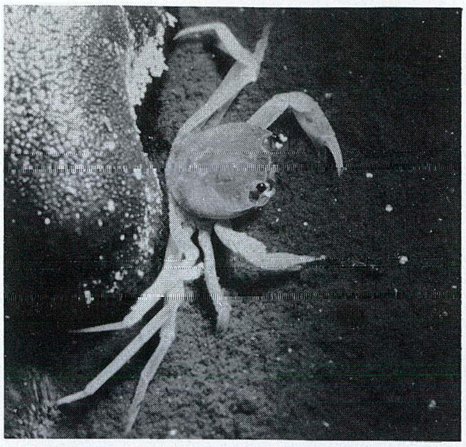
The Mulu caves contain every variety of passage imaginable. Rushing streamways enter quiet, muddy canals; narrow rifts and huge shafts open into dry, draughty tunnels or damp, silent caverns; passages may be floored with guano or sand dunes, or may sparkle with glistening stalactites. Quite different animals inhabit these very different habitats.

While some cave-dwelling creatures are found almost everywhere, others seem to be restricted to a handful of passages. The critical factors involve aspects of the cave environment — temperature, humidity, air movement and evaporation rate at ground level and in the tiny pockets and cracks in which the creatures live, in other words their micro-climate. Equally significant is the terrain over which they move, the sediments, sheltering cracks and crannies — and finally the food supply and its abundance. Detailed recording of all these factors at

Cave scorpion collected in Leopard Cave (P. Chapman)



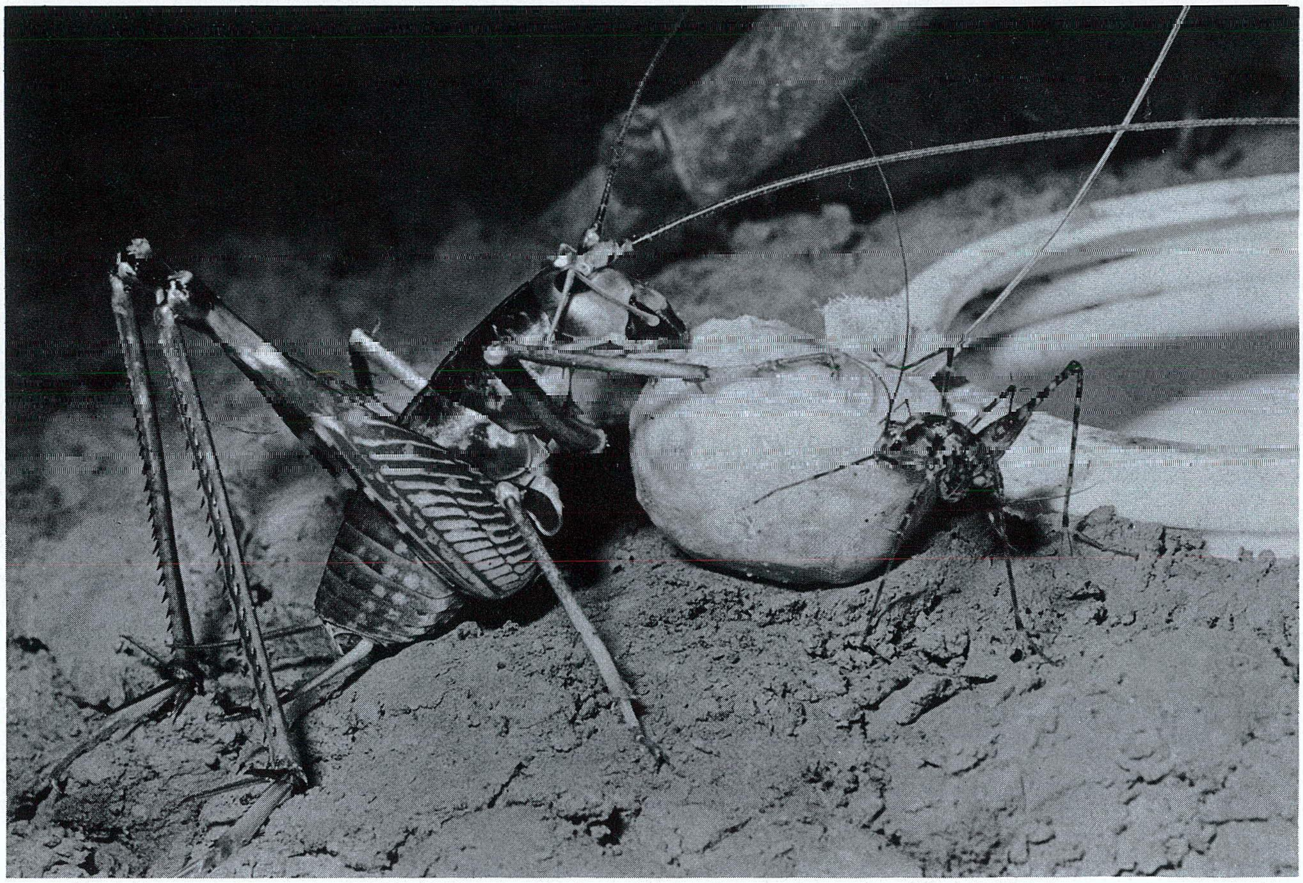
Tailless whip-scorpion carrying its young (P. Chapman)



White cave-adapted crab (P. Chapman)

each site, and counting numbers of each species where they occur make it possible to put together the whole picture, to understand the way in which the cave community functions, which species depend on what aspects of their environment and what limits their distribution. It can then be predicted what is likely to happen to the cave community if the cave is altered, for example to make it easier for tourists to get around. This has led to an understanding of how the environment must be managed if the cave life is to be conserved.

There are four main sub-divisions within the terrestrial community of the Mulu caves — a bat-guano, a swiftlet-guano, a transition zone and a deep-cave group. The bat-guano group is confined to near cave entrances as bats do not venture far beyond the twilight zone. It is dominated by two species of cockroaches, three species of moths (related to the familiar clothes moths) and a number of quite large beetles. The swiftlet-guano group is found where swiftlets roost, whether in damp or dry passages, near entrances or deep into the caves. It contains one or other of two small crickets (but never both together), a huge egg-eating cricket, a moth, small beetles, flies and their predators including a powerful huntsman spider. The transition group is found where there is little or no fresh guano, but where there is a drying wind (often near entrances). It contains



Cave crickets stealing the bait from a pitfall trap (P. Chapman) a rag-bag of species equally at home in cave and sheltered surface habitats, including ants, harvestmen and long-legged centipedes, plus the swiftlet-guano crickets and huntsman spider. The deep-cave group is confined to passages or habitat patches with a zero-evaporation rate and little or no fresh guano. It consists of cave-limited, highly evolved species including millipedes, woodlice, a beetle, two spiders and a cockroach. They depend for food on nutrient rich soils washed down joints in the limestone or on old moist guano.

The distribution of these four groups within the Mulu caves is controlled by the presence of draughts, bats and swiftlets. Bats roost near entrances but swiftlets penetrate large distances into caves (they occur throughout the Clearwater Cave). Swiftlets prefer to nest in fairly dry passages, thus tend to commute along airflow routes, from roosts to entrances. The draught in Clearwater is downwards from high to low entrances. It reverses nightly in main trunk routes such as Revival and Main Entrance to Goldwater Series, but otherwise lower entrances draught inwards only as a result of steep falls in temperature caused by violent thunderstorms. Given the huge size of the Mulu cave passages, theory predicts that significant evaporation effects should be felt throughout the major known cave systems investigated. This is confirmed by observation. Very few known passages escape this effect, so that the deep-cave fauna of species (which have physiologically adapted to cope with a hydrating atmosphere) have a very limited distribution within the çaves, being largely confined to a few small, blind-ending passages where the air is still and moist. Because the Mulu limestone is massive and poorly-jointed, water inputs into many high level passages are few and far between. Here, the drying winds produce desert-like conditions as in Benarat Caverns and also the Dune Series of Clearwater. Such passages are almost devoid of life except where guano occurs.

One extra result of understanding the controls on community structure is that in some cases it is possible to predict the type of passage present beyond an obstruction, such as a choke, by the fauna present in the choke. And once the climatology of the cave is better understood it may even be possible to pinpoint which unexplored high level passages in the cave hold the best potential for further discoveries.

A cave snake has caught a swiftlet in flight (P. Chapman)

Jerry took the photo

THE MULU '80 TEAM

The British Team: Andy Eavis and Ben Lyon (Joint Leaders), Pete Smart and Pete Bull (Scientific Co-ordinators), Phil Chapman (Biologist), Barry Webb and Steve Crabtree (Geologists), Hans Friederich and Martin Laverty (Geomorphologists), Dave Checkley, Mike Meredith, Colin Boothroyd, Nick Airey, Dick Willis and Tony White (Speleologists), Jon Buchan (Doctor), Jerry Wooldridge (Photographer), Marjorie Sweeting and Jim Rose (Geomorphologists), and Sid Perou, Lindsay Dodd and Geoff Yeadon (Film Crew).

The Malaysian Team: Kron Aken (Sarawak National Wildlife Officer), David Labang (Assistant Sarawak National Wildlife Officer), Abdul Manaf (National Park and Wildlife, Miri), Lewin Roman (Assistant Forest Officer), Danny Lawi and Ronnie King (Field Foremen) and Tama Bulan and Siduck (Park Wardens).

Base Camp Administrator: Uschi Trosch.

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