Chapter 88

Mulu caves, Malaysia

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One of the world's great tropical karst regions lies below Gunung Mulu (Mount Mulu) in the Malaysian state of Sarawak on the island of Borneo, off Southeast Asia. Here, the Miocene Melinau Limestone is exposed in a range of precipitous massifs, low mountains and hills, in a northeast-oriented outcrop 10 km wide and 35 km long, broken by the floodplains of the Medalam, Melinau, and Melinau Paku rivers. Within the limestone lie cave passages of which more than 500 km have been surveyed to date (Fig. 1). These include the largest cave room in the world (Sarawak Chamber), the largest cave passage in the world (Deer Cave), and perhaps the largest cave in the world (when measured by total volume—Clearwater Cave, with 226 km of passages, most of which are very large).

The terrain around Gunung Mulu is spectacular and dramatic, due to the precipitous rise of the mountains above the coastal plain, the white limestone cliffs more than 100 m high round their lower margins, the prolific dense vegetation, and an almost persistent cloud cover. The three main limestone mountains, Gunungs Api, Benerat, and Buda, lie 75 km from the South China Sea at the edge of the Sarawak's interior highlands. They lie 4° north of the equator, and receive an annual average of more than 5000 mm of year-round rainfall.

The Melinau Limestone is a lenticular unit, and the rock is very massive and white or gray with generally less than 1% insoluble material. It is lagoonal in origin, and was deposited within a reef complex. Fossils are locally common and include corals, bryozoans, bivalves, gastropods, and algal balls. The massive beds of the Melinau Limestone dip to the northwest, perpendicular to the trend of the range and are folded with minor faulting. The limestone is overlain conformably by the Setap Shale, which is 4000–5000 m thick, and is underlain by the Mulu Formation, with 4000–5000 m of shale, sandstone, and orthoquartzite.

Local forest nomads were the first explorers of some of the caves. The Berawan, Tabuan, and Penan peoples still make use of the caves, some of which are burial sites. The caves also house several species of swiftlets, whose nests are used to make bird's nest soup, a highly priced Asian delicacy. Harvesting of nests at Mulu, and elsewhere in Southeast Asia has not been on a sustainable scale, leading to a steep decline in the numbers of these birds, beside significant damage to some of the caves.

The first significant cave explorations in the rugged and remote forests of Mulu were made by G. E. Wilford of the Malaysian Geological Survey in 1961. He mapped Deer Cave (but both he and readers of his report underestimated its size), the first part of Cave of the Winds (later connected to Clearwater Cave), and three inlet passages of the Terikan River Caves (but without venturing into the main underground river). His was pioneering work, but it was only in 1978 that the Mulu caves were again visited, by British cavers on the Royal Geographic Society expedition sponsored by the Malaysian government. This project sought to survey the flora and fauna of the region and to study the area's geology and hydrology in the newly designated Gunung Mulu National Park.

In 1978, the caves were almost perceived as an expedition sideline, but they proved to be truly spectacular. Consequently, the British cavers followed up with major expeditions in 1980 and 1984, and then with visits that have almost become annual events since the National Park became more accessible; the Mulu Caves Project continues to make new discoveries. Parallel explorations by American cavers revealed caves in and around Gunung Buda during four expeditions between 1994 and 2003.

Caves in the southern hills

Separated from Gunung Api by the Melinau Paku valley, the southern hills contain Deer Cave (Gua Payau in Malay). This could be dismissed as a fragment of ancient trunk cave that has been left in a limestone hill now isolated from the Api massif. But it is the largest cave passage in the world, reaching 168 m wide and 125 m high along its southern half (Fig. 2). The passage size makes its geomorphology difficult to appreciate; phreatic origins have been lost in progressive roof collapse, and it appears that much of the passage was cut as a giant vadose canyon by the Melinau Paku River, which took this underground route for a very long time. The giant passage is almost entirely within reach of daylight for its kilometer course through to a northern entrance in the Garden

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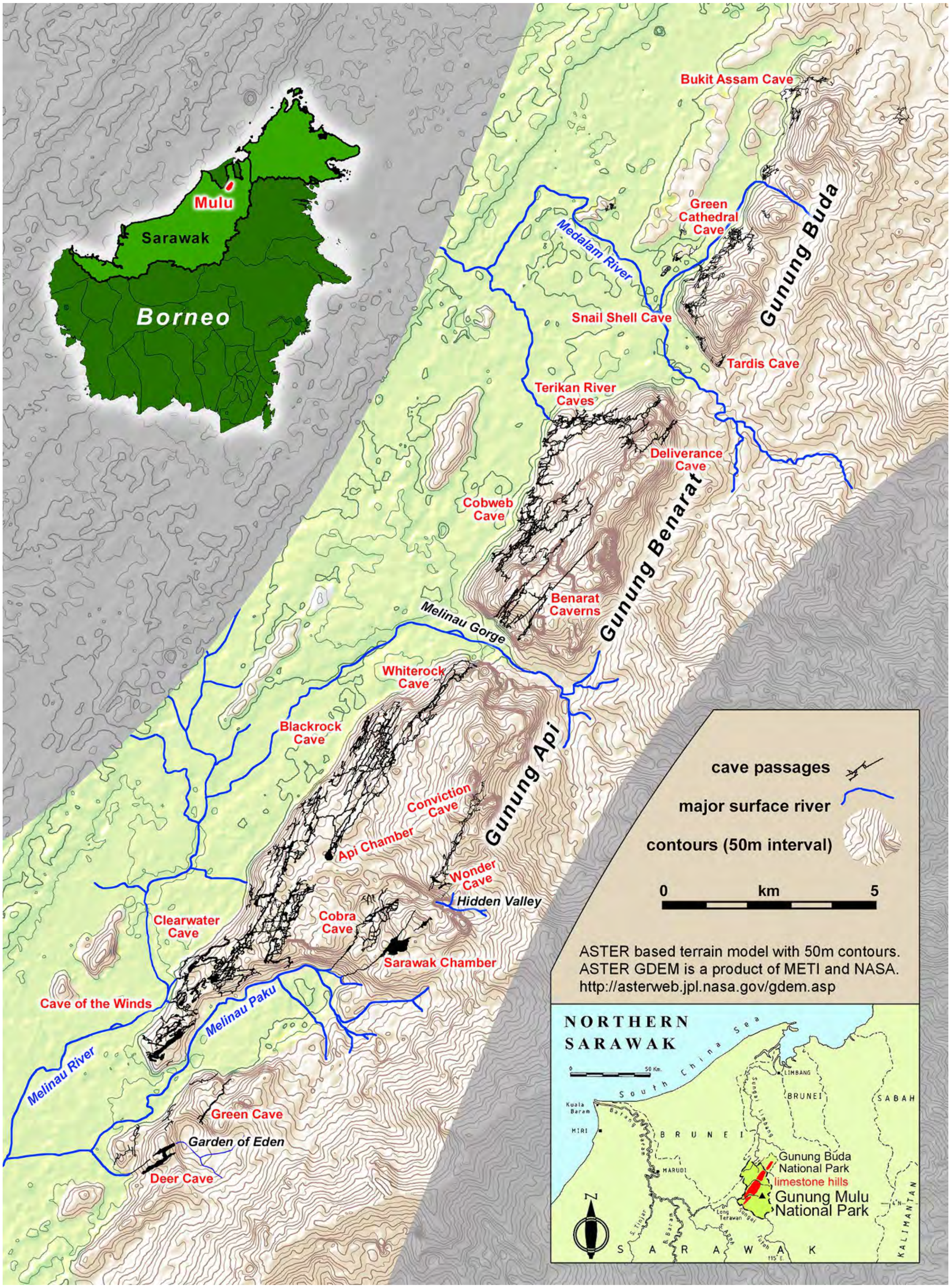

FIG. 1 Outline map of the known caves within the limestone mountains adjacent to Gunung Mulu.

FIG. 2 The very large passage in Deer Cave looking out toward the main entrance at its southern end, which is nearly 600m from the camera. *(Photo by the author.)*

of Eden, beyond which Green Cave is its continuation on only a slightly smaller scale. A network of smaller cave passages lies within the hills parallel to Deer Cave.

The Garden of Eden is an almost enclosed chunk of rain forest within a massive doline on the edge of the limestone outcrop. It may be described as a very large but well-degraded tiankeng, with vertical cliffs still forming its margins on three sides. The concept of development by collapse of a very large cave chamber is reasonable when it is compared with the nearby Sarawak Chamber, which is not much smaller, although any large chamber may always have been open through an inlet from the shale outcrop on its southeast side.

Caves in Gunung Api

Mount Api is riddled with caves, and more than 226km of the passages are now linked to form the Clearwater Cave System (or Gua Air Jernih in its Malay translation), named after the clear karst water that pours from its resurgence into the muddy Melinau River. The main Clearwater River Cave, upstream from its resurgence, is a magnificent canyon passage 30m high and wide, whose clean walls, cut and undercut in pale limestone, are the epitome of underground sculpture (Fig. 3). This one cave river drains most of Gunung Api, and, beyond short sumps, Clearwater Cave contains two more sections of magnificent large river passage. The river is seen at only a few places within the central Blackrock Cave section of the system, but upstream in Whiterock Cave the main cave river can be followed uninterrupted through 5km of streamway to the its source from choked inlets nearly 70m beneath the floor of the Melinau Gorge. All sections of the river are connected by high levels into the sprawling Clearwater system.

The river passages are only the latest phase of the cave development, as a maze of huge abandoned cave tunnels forms the high levels of Clearwater. Underfit streams drain down through some of these, but the main passages are otherwise inactive, and many are truncated at exits hidden in the impenetrable forest. At the southern end, Revival is the main old trunk route above the Clearwater River; it is mostly 30m high and wide and lies about 100m above the modern streamway. Further north, Bigness South, Borderline and 1954 form a contiguous trunk route nearly 8km long and 200m above the river level. There are numerous other high levels throughout most of the system. Api Chamber (300m long and 200m wide) formed where parallel trunk passages coalesced by collapse; and an even higher level at the resurgence end includes an opening into the forested floor of the Secret Garden tiankeng. Above this level, the Creedence passages are the highest and oldest yet to be found in the Clearwater System, and reach to an altitude more than 500m above the resurgence. All the main cave passages are aligned on the strike of the dipping limestone, as they are stacked obliquely up just a few bedding planes.

The middle cave levels continue beyond the resurgence to link to cave of the winds, a streamway carrying water through from the Melinau Paku. Lagang's Cave has another segment of large old trunk passage at an intermediate level, but there is as yet no connection to Clearwater.

Parallel to and southeast of Clearwater, two separate cave systems drain from the huge blind gorge of Hidden Valley through to the Melinau Paku lowland. The Cobra-Bridge-Cloud Cave provides a convoluted through-route within more than 20km of passages. Gua Nasib Bagus can only be entered at its resurgence, and its high-level route from Prediction Cave is choked with sediment. Midway through the mountain, Sarawak Chamber is the world's largest underground void. It is 700m long and reaches to

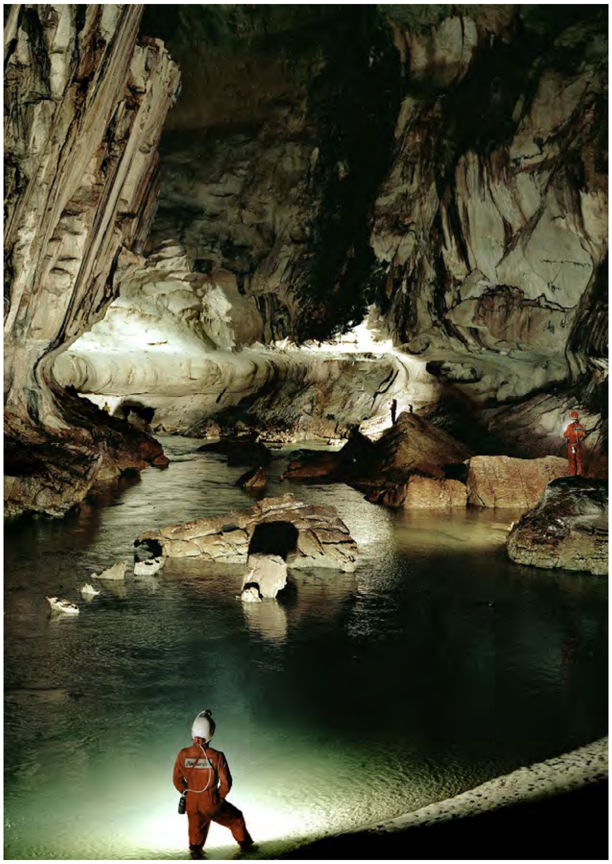

FIG. 3 Clearwater River Passage, with a conspicuous wall notch at 2–4m above the present water level. *(Photo by Jerry Wooldridge.)*

nearly 400m wide; its low-profile roof arch rises to 100m above the ramp of fallen blocks that forms its sloping floor. The chamber was formed where the river from Hidden Valley slipped sideways, down the steep bedding, and created the giant undercut; this has subsequently been modified as the roof has collapsed upwards to form a stable arch. The river has since found a new entrance passage further down-dip, and now just drains through the boulders at the foot of the chamber, leaving the main part of the chamber and Prediction Cave dry.

Sarawak Chamber almost defies comprehension. The three cavers who explored the cave in 1980 did not know that they were in a chamber; they could only see one wall, which they followed to make their survey. Only when they had gone most of the way round a huge loop did they realize that they might be in a vast cavern, instead of in a very large, curving passage; they calculated a compass bearing and then climbed over the boulders across the middle of the chamber to regain their entry point. Midway, they could see no walls, no roof, nothing—the sense of agoraphobia was acute.

In the northern side of Hidden Valley, Wonder Cave has 17km of passages, now best reached through its Conviction Cave entrance. Their trunk passages are typical, large, abandoned phreatic tunnels along the bedding, but there are also some large canyons entrenched in them, and parts are prone to flooding by invading streams.

All the main trunk passages inside Gunung Api have formed where large flows of water have poured off the sandstone slopes of Gunung Mulu and sunk into the limestone. The Melinau Gorge cuts clean through the limestone ridge, and has long been at the upper apex of a huge gravel fan spread out onto the lowlands. This fan has continually evolved and reformed at lower levels as both Gunung Mulu and the plains were lowered by surface denudation, while the limestone escarpment proved more resistant to surface lowering.

The highest and oldest passages yet discovered in Gunung Api are those within Wonder Cave, which originally drained northwards to the Melinau Gorge, as clearly indicated by scallops within the abandoned phreatic tubes. At some later stage, the huge complex of passages in Clearwater Cave develops to drain Gunung Api toward the south. Today, some of the water flowing through the Melinau Gorge leaks downwards to feed the upper end of the Clearwater cave river, but the high-level passages in Clearwater Cave appear to have been carrying water from the Melinau Gorge for many millions of years.

Evolution of the surface profile, with its successive falls of the Melinau gravel fan, lowering of the plains beyond, and a stepped decline of the water table within Gunung Api, can be recognized in the falling sequence of trunk cave passages within Clearwater Cave, most of which lie almost along the strike of the dipping limestone. Clear indicators of the past water levels are the deep wall notches that were undercut by the cave rivers whenever they flowed over stable gravel fills. Abandoned notches are among the most distinctive features of Mulu's caves; generally 2–3 m high and cut 4–5 m into the vertical walls, they provide cavers with terraced walkways round deep lakes or large boulder piles in both the old high levels and in the modern river passage.

The graded trunk passages, wall notches and gravel profiles within Clearwater have been correlated with the gravel terraces of the Melinau Plain. The clastic sediments of both the cave and the plain are essentially the lower ends of enormous gravel fans supplied from the slopes of Gunung Mulu and poured through the breaches in the limestone escarpment. Each terrace was formed by aggradation during wetter interglacial periods, followed by incision during drier glacial periods. More than 25 km of passages with traceable wall notches have been mapped within Clearwater Cave, and these fall into a sequence of 20 levels, spread over more than 300 m of altitude. Uranium-series dating of calcite on sediments within the lower, more recent, indicates a mean rate of base-level decline of 0.19 m per 1000 years. The sequence correlates well with all the interglacial peaks on the oxygen isotope record, and implies that the gravel aggradation was controlled by climatic variations and not by episodic uplift. Preliminary data from Al/Be dating of clastic sediments in some upper levels indicate ages of well over two million years, which fit with extrapolation of the erosion rates inferred from the younger stalagmite ages, and with palaeomagnetic data from clastic sediments. The constant background rate of base-level lowering is interpreted as the rate of isostatic uplift in response to regional denudation. The limestone blocks have risen almost uneroded on this uplift, while the adjacent plains, and the noncarbonate slopes, have been denuded at rates close to that of the uplift. The limestone mountains of Mulu have taken around 10 million years to evolve to their present topographic relief.

Caves in Gunung Benarat

Massive cave systems within Gunung Benarat largely follow the style of those in Gunung Api. From high-level entrances in the cliffs of the Melinau Gorge (Fig. 4), the Benarat Caverns System has just over 50 km of mapped caves with large abandoned trunk passages heading northeast along the strike of the steeply dipping beds; four main levels lie at altitudes roughly 100 m apart. They also link, across the beds, to the complex of passages in Cobweb Cave. Many of the Cobweb passages are less mature as they still had switchback profiles, up and down the dipping beds, when they were abandoned, although Swift Highway is one high-level trunk with a well-graded profile. One outlet of these old trunk routes is through Deliverance Cave where 4 km of passage open into the high slopes of the Medalam Valley, but there is a long section choked by sediments and as yet unexplored through the center of Benarat. Within Cobweb, only short sections of low-level streamway have been reached, and these head north toward the Terikan resurgence.

Across the north end of Gunung Benarat, the Terikan River Caves contain another 32 km of passages, with an active cave river largely fed from various sinks along the floodplain margin, and draining out to a resurgence at the head of the Terikan River, a major tributary of the Medalam. Above the river passage, multiple high levels almost parallel the modern river, but also include a complex of caves that reach very close to the northern ends of the Cobweb passages in Benarat Caverns.

It appears that the large phreatic trunk passages through Benarat have at various times in the past carried water in both directions, toward the Melinau and toward the Medalam, but the geomorphology of the Benarat caves is still not understood as well as that in Api. Many of these caves did not mature to graded profiles, and consequently wall notches are not as widespread as they are

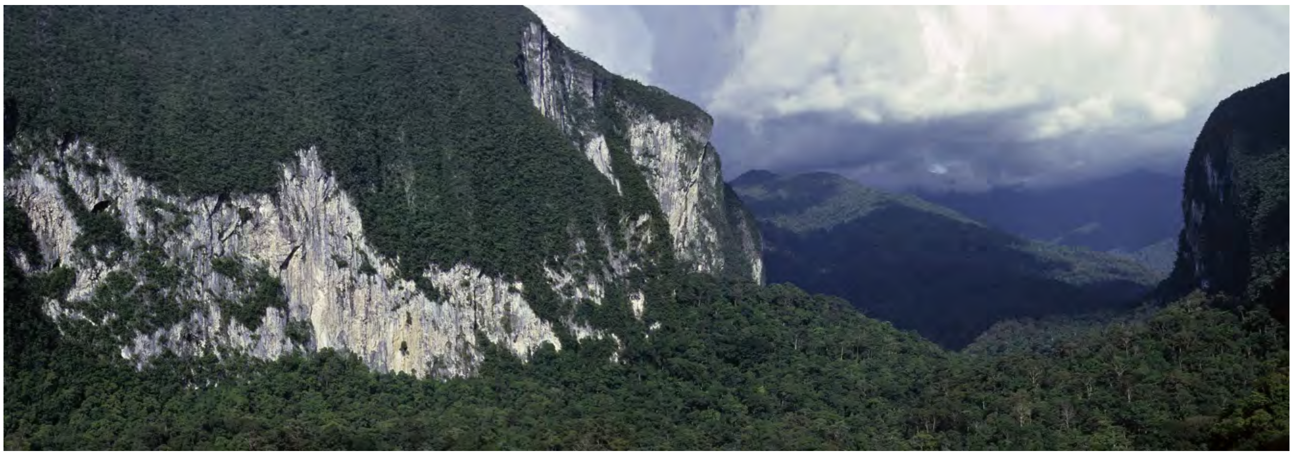

FIG. 4 The Melinau Gorge, looking upstream toward the cloud-covered slopes of Gunung Mulu; the cliffs along the left side are broken by the dark cave entrances 400 m above the river that are the truncated ends of old trunk passages in Benarat Caverns. *(Photo by the author.)*

in Api. As yet, there have been no programs of detailed leveling and sediment dating to confirm exactly how the Benarat caves correlate with those in Api. The Terikan caves are altogether different, as they were formed at lower levels by water from a separate alluvial fan built by the River Medalam.

Caves in Gunung Buda

Gunung Buda contains nearly 70 km of known cave passages, although that it lacks the ancient and very large trunk passages that lie within Benarat and Api. Green Cathedral Cave has 27 km of mapped passages formed as a complex series of old phreatic drains on multiple levels. Caves in the northern part of Buda have been formed also by rivers from the sandstone in the southeast sinking into the limestone and then draining broadly along the strike toward outlets associated with the Medalam River. Some passages switchback up and down to follow the steeply dipping bedding planes and available joints, whereas others have achieved more level profiles graded to the contemporary Medalam. In contrast, passages along the southern edge of Buda (Fig. 5) were probably formed by distributaries of the Medalam; a stream passage in Snail Shell Cave still carries water from the Medalam away to the north. These caves have even more local relief where they are aligned directly across the limestone strike; the large phreatic ramp in Snail Shell Cave has been followed over a vertical range of 470 m. Buda's high-level caves are currently being truncated by surface erosion, creating the many entrances in the forest.

The lower levels of the Buda caves contain active streamways. Most of these are flood prone because they drain through from large sinks from sandstone catchments along the southeastern edge of the limestone and also gather flood pulses of rainwater straight down the fissures from the forest above. In contrast, Turtle Cave contains long lakes that vary little in level or flow within an old phreatic tube. Northwest of Gunung Buda, various outlying limestone blocks contain another 11 km of mapped caves; these are mostly active stream passages at low level, and include 5 km of passage in Spirit River Cave.

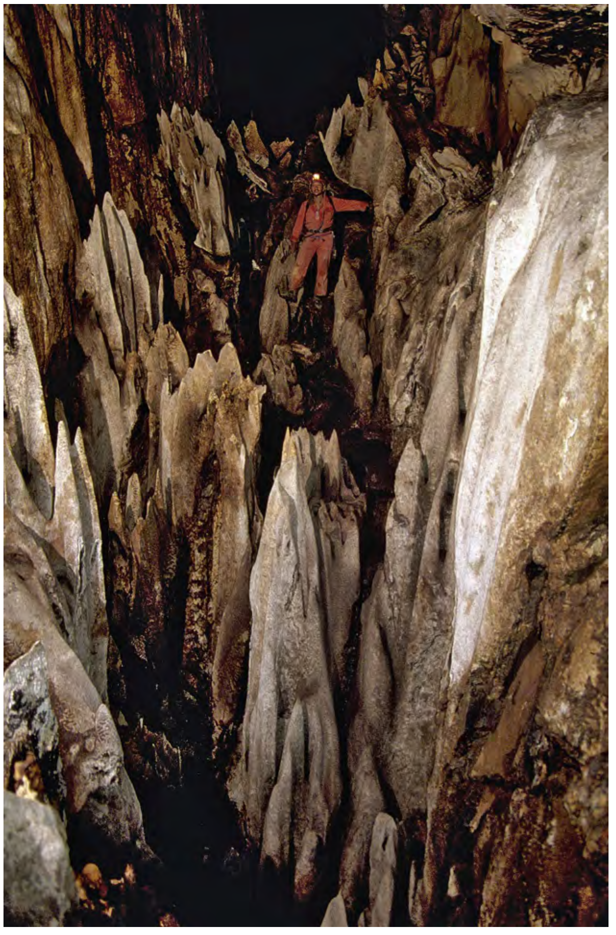

FIG. 5 Giant pinnacles etched into the passage floor by eons of percolation water in Tardis Cave, in the southern tip of Gunung Buda. *(Photo by David Bunnell.)*

Gunung Mulu National Park

The caves are not the only outstanding feature of Mulu. Gunung Api is one of the world's most spectacular chunks of limestone karst. Except for the vertical cliffs of its margins, its entire surface is fretted into dramatic pinnacle karst. Widely spaced vertical joints have been etched out by dissolution, and are now almost choked by vegetation and organic soils. The remnant blocks of limestone have been carved by direct rainfall into razor-sharp ridges. Most of these pinnacles are just a few meters high, and the terrain is seriously difficult to cross because it consists entirely of steep pinnacles and tapering fissures choked with unstable plant debris. High on Api, pinnacles that are more than 30-m tall rise above the forest canopy to create an amazing landscape, and most of the ground has never been trodden by man.

The British Royal Geographic Society and other researchers before and since have documented an amazing diversity of plants and animals in the area. The large range in elevations, various soil and rock substrates, and tropical climate have produced what may be the world's most diverse assemblage of tree species, an amazing variety of herbaceous plants, 109 species of palms, and a total of 3500 vascular plants in 17 vegetation zones. More than 270 bird species including all Bornean hornbills, broadbills, and barbets are known from Mulu, and primates found in the area include monkeys, prosimians, and the Bornean gibbon. Other important wildlife includes dozens of snakes, civets, many bats, and more than 200 species of cave-adapted invertebrates.

Cave biology work was undertaken by both British and American expeditions. Four dominant terrestrial habitats (and bio-communities) are recognized within the Mulu caves: bat guano, bird guano, the entrance transition zone, and the deep cave community. Each has unique species of crickets, spiders, beetles, cockroaches and, in some communities, isopods and millipedes. Some species are found to occur throughout the caves, whereas others are restricted to specific habitats. Swiftlets fly far into many of the larger caves. More than two million bats roost on the roof of Deer Cave, far above any predators. They feed outside the cave, but droppings from their roost accumulate to form great banks of guano on the cave floor. These are both home and food supply for millions of beetles, earwigs, cockroaches, millipedes, and crickets, together with large, predatory spiders and centipedes and an active population of racer snakes. Members of the Mulu cave community include snakes found deep within the caves that predate primarily on birds but also on bats, several species of crabs including some that lack pigment, and at least two species of large centipedes.

The Gunung Mulu National Park was established primarily to conserve forever a substantial section of the Borneo rain forest—which was ever diminishing and under continued threat from Sarawak's powerful logging industry. To save the forest, the park needed economic viability through tourism, and the caves were seen as potential visitor attractions. The fabulous cave discoveries made the initial plan work out very well, and the Mulu Park now offers the dual attraction of the forest environment and the great caves.

The Gunung Mulu National Park was formally established by the Sarawak state government in 1974, with 52,864 ha of forest protected, along with its spectacular caves and its wonderful array of plants and animals. It was inscribed as a World Heritage Site by the United Nations in 2000. The Park includes the sandstone mountain of Gunung Mulu rising to 2377 m, the rugged limestone mountains along its western flank, and the adjacent terraced floodplains that reach to as low as 28 m above sea level. It was opened in 1985, and now boasts a visitor center, forest boardwalks, tourist cave facilities, a large resort hotel and a small adjacent airport, while the high mountains are preserved as almost inaccessible wilderness. Gunung Buda was established as a separate but adjacent National Park in 2001. It protects another 6235 ha of limestone uplands, swampy floodplains, forested hills, and rivers, but is kept as a wilderness with neither facilities nor easy access.

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