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UBSS EXPEDITION TO NORTHERN THAILAND

by

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ABSTRACT

The UBSS expedition to northern Thailand during December and early January 2000/2001 investigated a previously unexplored area of karst near the northern border with Myanmar. A total of 2.5 km of cave passage was mapped in four adjacent areas and a large number of karst sites were investigated. The two largest caves were 718 m and 758 m in length. However, high levels of carbon dioxide in many of the caves proved a major hindrance to exploration. A description of the finds, coupled with a brief interpretation of the geology and geomorphology of the area is given below.

INTRODUCTION

The UBSS expedition spent 3-4 weeks in December and early January 2000/2001 investigating a previously unexplored area of karst in the northern hills of Thailand. The area comprises an extensive, heavily dissected limestone region lying some 100 km north of the city of Chiang Mai, close to the Myanmar border. This region extends west from the main Chiang Mai to Fang highway across into Myanmar, 20-30 km away, encompassing an area of several hundred square kilometres. The northern margin of the area is delimited by the sandstone uplands of the Mae Fang National Park which reaches a maximum elevation of 1918 m at Doi Ang Khang, while to the east it is bordered by the Fang basin, a low lying flat intermontane lake basin at c. 500 m asl. Southwards, the limestone region becomes fragmented into isolated outliers forming a Fenglin style of karst. Within this region, four sub-areas were examined in more detail (see Figure 1). Given the lack of local names, these areas have been termed the Northern Escarpment, the Central Plateau, the Ban Nong Khaem Plain, and the Southern Massif.

The Northern Escarpment is a thin belt of limestone extending northwards from the main limestone expanse, flanking the eastern margin of the Mae Fang National Park uplands and overlooking the Fang Basin

To the south is the Central Plateau, the most extensive of the four sub-areas. The dominating landscape style of this region is one of well-developed Fenglin karst. This is typified by towers emerging from a common bedrock base, interspersed with closed depressions among them. This type of karst landscape is also known as cone karst or kegelkarst. Much of the upland area is covered by bamboo forest, although many of the dolines and inter-cone areas have been cleared for agriculture. The average elevation is around 900 m, with isolated towers and cones rising to 1100 m. No surface drainage occurs except for along the northern margin where streams draining the sandstone outcrop sink. The eastern margin of the plateau is marked by the escarpment overlooking the Fang Basin where several major springs emanate. To the south, it is bounded by a poorly defined escarpment at around 900 m running north-west – south-east just north of the village of Ban Nong Khaem.

The Ban Nong Khaem plain is defined by isolated towers and cones interspersed with lower lying areas of alluvium, shale, lateritic sediments and weathering products. Much of the terrain is around 700 m elevation, with large isolated hills (outliers of the main plateau) rising to over 1000 m, creating a landscape more analogous to a Fengcong karst (also known as tower karst, where each tower is separated by an alluvial plain). Surface drainage occurs during the rainy season, with dams holding back water for use in the dry season. Some of these streams sink into the limestone towers or where they meet the limestone ridge to the south. For the most part the area is cultivated except for the towers. To the west the relief gradually subsides. Here, a major spring rises at the base of the escarpment draining the plateau behind, and low lying rice paddies dominate the landscape.

The Southern Massif is a large outlier of the Central Plateau, much of which is comprised of steep or vertical bamboo covered limestone cones. However, the southern part of the massif gradually fragments into a series of isolated cones and merges into the surrounding lowlands. Drainage from the surrounding sandstone uplands flow into several spectacular stream sinks that resurge at the foot of the mountain close to the main highway.

LOGISTICS

Modern facilities can be found in most of the larger villages close to the main highway, particularly in Ban Ai [47Q 0515800 2175400], 30 km south of Fang. Away from the highway, only a few un-surfaced roads and tracks occur which lead to remote 'Hill Tribe' villages. There are few permanent settlements high on the plateau, but there is a network of lower quality tracks and footpaths that serve the needs of farmers and hunters, most of which are not depicted on any maps. Local knowledge, guides and a GPS are therefore essential for route finding and locating caves.

At the time of writing, the political situation in the region is fraught. Bandits and drug traffickers operate in the border areas and rebel forces from Myanmar regularly cross the border into Thailand. Hence, it is recommended not to stray too many kilometres away from main roads and settlements, and not to be away from settlements after dark. Areas to the north and west, closer to the Myanmar border, are particularly sensitive.

The climate in this part of Thailand is monsoonal with an annual rainfall of 3300 mm in Chiang Mai. There are three distinct seasons: the cool season, which runs from November to February, when there is no little or no rainfall and air temperatures are pleasant at 28-30°C; the hot season from March to May, when temperatures are in the mid-thirties, and the rainy season from May to October. Consequently the best time for caving is during the cool season as the caves are generally dry and temperatures not too oppressive. However, the problem with carbon dioxide levels may be greater (see below).

Away from cultivated areas the vegetation is dominated by bamboo forest. However, it is advisable to wear clothes that cover both forearms and legs, because mid-height vegetation can be particularly thorny. Underground, most caves are warm and dry, with a temperature around 20-25°C. Cotton boiler suits are ideal, and protect against insect bites and minor abrasions. Precautions for assessing air quality such as lighters or candles, or preferably more sophisticated gas detection equipment, should be taken.

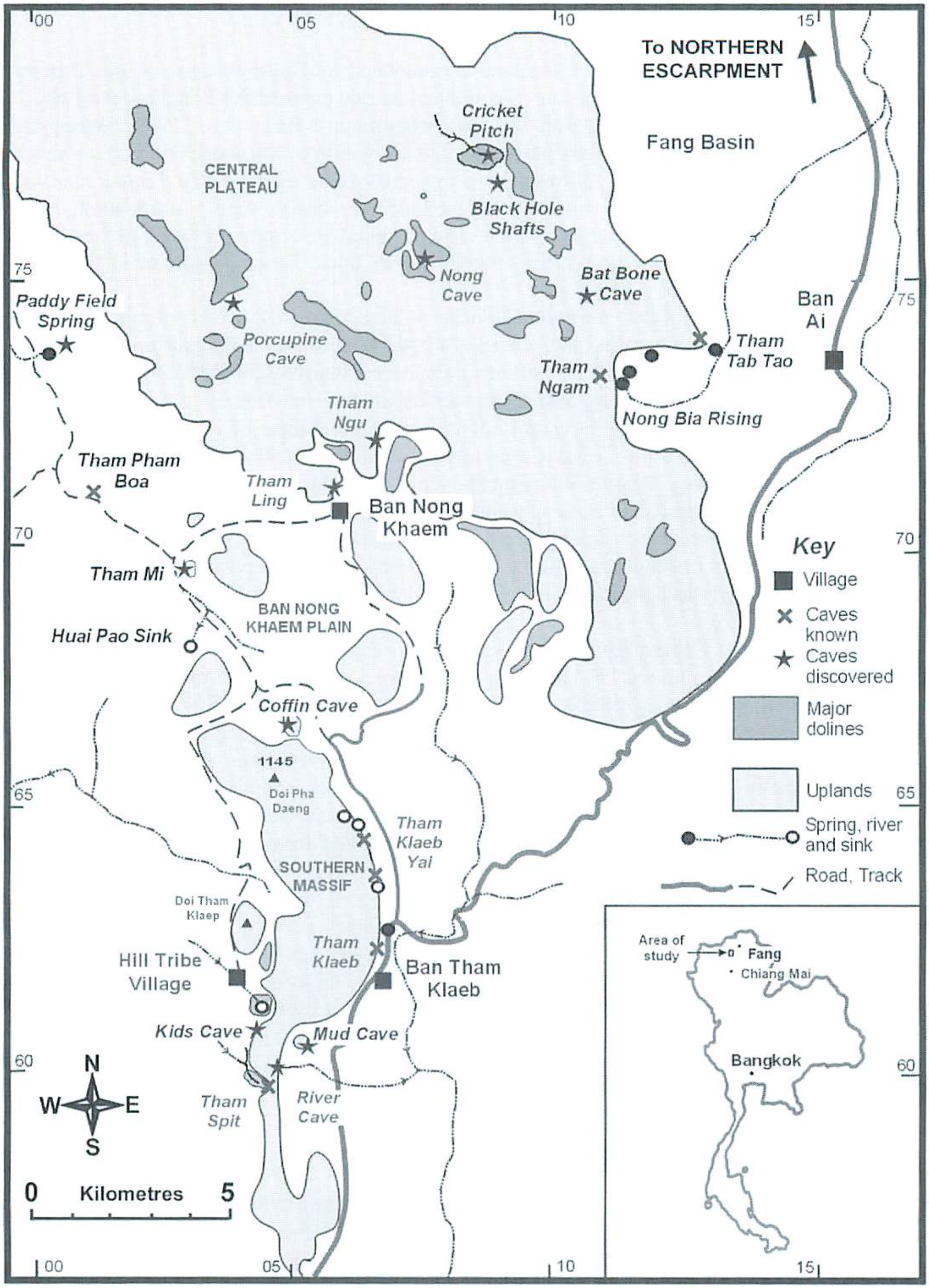

Figure 1. *Topographical map of the expedition area in Thailand.*

GEOLOGY AND GEOMORPHOLOGY

The geology of this part of Thailand is dominated by Upper Palaeozoic and Tertiary rocks (Figure 2). The region was the site of continued marine deposition throughout the Palaeozoic, until a major orogenic event during the late Carboniferous (Baum *et al.*, 1970). During the Permian a renewed transgression took place with the deposition of limestones throughout much of northern Thailand. This was followed by a major orogenic event in the Triassic causing uplift and erosion. Later, major intermontane sedimentary basins with a north-south trend developed during the Tertiary, many of which were occupied by freshwater lakes. In the area of study, Devonian-Permian strata outcrops, together with thick Tertiary deposits in the Fang basin.

Devonian rocks occur as faulted blocks or preserved in the core of tightly folded anticlines, and comprise greenish-black cherts, carbonaceous shales and sandstones. The total thickness is probably less than 500 m, but they have been extensively folded. Exposures on the highway between Fang and Chiang Mai in the vicinity of Ban Hua Tha, a few kilometres north of Ban Tham Klaep display highly contorted strata with graptolites of Lower Devonian age. These facies occur up into the Lower Carboniferous, where a thick sandstone unit marks the base of the Carboniferous. Above is a complex series of highly contorted shales, sandstones, and conglomerates, estimated to be several hundred metres thick. Carbonate deposition began when Upper Carboniferous oolitic and massive reef limestones were deposited trangressively on top of the Lower Carboniferous sandstones and shales. The deposition of this 'Ratburi Limestone' continued throughout the Lower-Middle Permian and is the main karstic limestone in the region.

Tertiary and Quaternary deposits occupy the Fang Basin, a major inter-montane lake basin, 10-20 km wide and over 50 km long. The boundary between the limestone plateau and the basin is marked by a major break of slope, and is probably fault controlled. The throw on this fault is estimated to be about 2 km. The Tertiary deposits infilling the basin vary from coarse fluviatile material to lignites and oil shales of Miocene-Pliocene age. Over 1000 m of Tertiary sediments have been proved in the Fang basin, which contains several hydrocarbon plays. Extensive sheets of tufaceous limestone emanate from the foot of the escarpment around Tham Tab Tao and Ban Ai. These were probably deposited from springs emanating into a shallow freshwater lake.

The structure of the area is very complex and poorly understood. The regional structures are oriented north-south, but local faulting and folding is complicated, especially in the incompetent Devonian shales. In general, the limestone appears to be quite steeply dipping and outcrops in the core of north south aligned synclines. Dips up to 60° are not uncommon. The topography is discordant with the structure, and is controlled by both the block faulting on a regional scale, and by lithology on a more local scale, with the limestone areas generally forming the higher relief than the adjacent Devonian rocks, especially to the south.

PREVIOUS WORK IN THE AREA

Although little spelæological study has been conducted by the Thai population, there is much national interest in caves; many have religious significance, being Buddhist shrines or places of meditation, and others have been used as places of burial. Tham Chiang Dao [47Q 0492800 2144300], 40 km to the south of the expedition area, is a major Buddhist shrine that

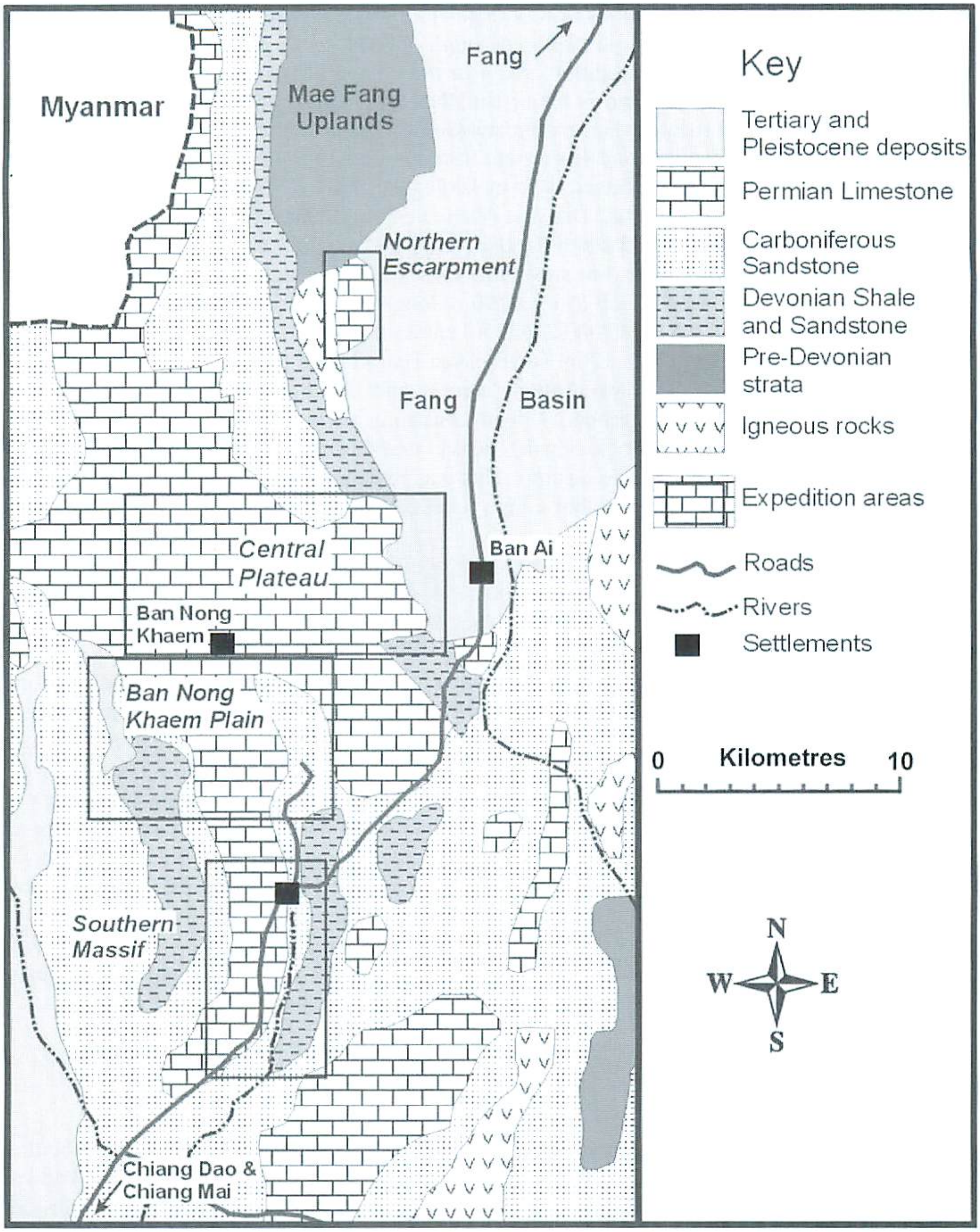

Figure 2. *Simplified geological map of the expedition area.*

has been known for centuries and is now a major tourist attraction. This cave is one of the longest systems in Thailand with an explored length of 5190 m. A second show-cave, Tham Tab Tao, is located within the expedition area near the village of Ban Ai. This is a 1 km long cave (Dunkley, 1995), which again is major Buddhist shrine. This cave has been known for centuries and is well documented (Deharveng and Gouze, 1983a, White, 1988).

From an extensive literature search and from a source in Bangkok, it was clear that the hills north of Chiang Dao have received little spelæological study. There were two French visits to the expedition area in the 1980s. The first (Deharveng and Gouze, 1983b) explored Tham Tab Tao [47Q 0512700 2173650] but little else. A second expedition (Deharveng and Rigal, 1986), explored part of the region, but apparently only sites close to the main highways. Their principal discovery was Tham Klaeb Yai, a 2190 m long stream cave with sink [47Q 0506800 2164600] and resurgence [47Q 0507000 2163750] entrances. Other caves recorded were: Tham Klaeb [47Q 0507000 2162150], a 176m fossil cave; Tham Ngam [47Q 0511150 2172900], a single large chamber approximately 100 m across, and Tham Pham Boa [47Q 0501000 2171500 +/- 1 km], a cave of around 150 m consisting of two large chambers, not fully explored. Further south, a major seasonally active stream sink, Tham Spit [47Q 0504750 2159850], was explored for 60 m to a sump. This was revisited during our expedition and the sump was found to be a mud choke, but a high level connection was made with a resurgence cave, River Cave (described below).

Deharveng and Rigal (1986) also reported two springs, Nam Rue Luang [47Q 011400 2173000] and Nam Rue Takhaen [47Q 0511700 2173300], located in a large embayment, a few hundred metres south-west of Tham Tab Tao. The former, Nam Rue Luang, which feeds Nong Bia, was investigated during our visit.

In 1983, an American expedition examined an area adjacent to the Myanmar border, 5 km north of our study area. Only survey notes are available, which were acquired through personal correspondence, a copy of which is available in the UBSS library (Rigg, Benedict and Blakely, 1984). Six sites were explored in all. A surface survey is available to relate the caves to each other, but the exact position of these caves is unknown. Five of these caves, all within 1 km of each other, were found in grid square [47Q 0504500 2200400]. The longest is Big Horse Cave with a surveyed length of 585 m. The other caves are: Cricket Cave (347 m), Dead Rotten Cave (570 m), Dig Cave (207 m), and Poppy Sink Cave (107 m). The sixth cave, Horse House Water Cave (417 m), was found in the bottom of a large doline at [47Q 05004100 2190500]. This turned out to be a deep cave that appeared to be getting bigger, but exploration was stopped by lack of rope at c. 150 m depth. Despite being of an impressive depth, it was not investigated during our visit owing to the considerable political instability in the area.

THE EXPEDITION

The initial focus of the expedition was the Central Plateau. This was deemed to be the most promising area owing to the 500 m depth potential between the plateau and the known resurgences, and the numerous dolines marked on the 1:50 000 map. Many of these dolines on the plateau were explored but unfortunately only a few showed signs of enterable cave development. Those that did, though sometimes of considerable proportions, were either choked a short distance from the entrance or had high concentrations of carbon dioxide. A number of surface shafts were found which had depths of between 30 and 60 metres, but exploration was again prevented by high carbon dioxide levels.

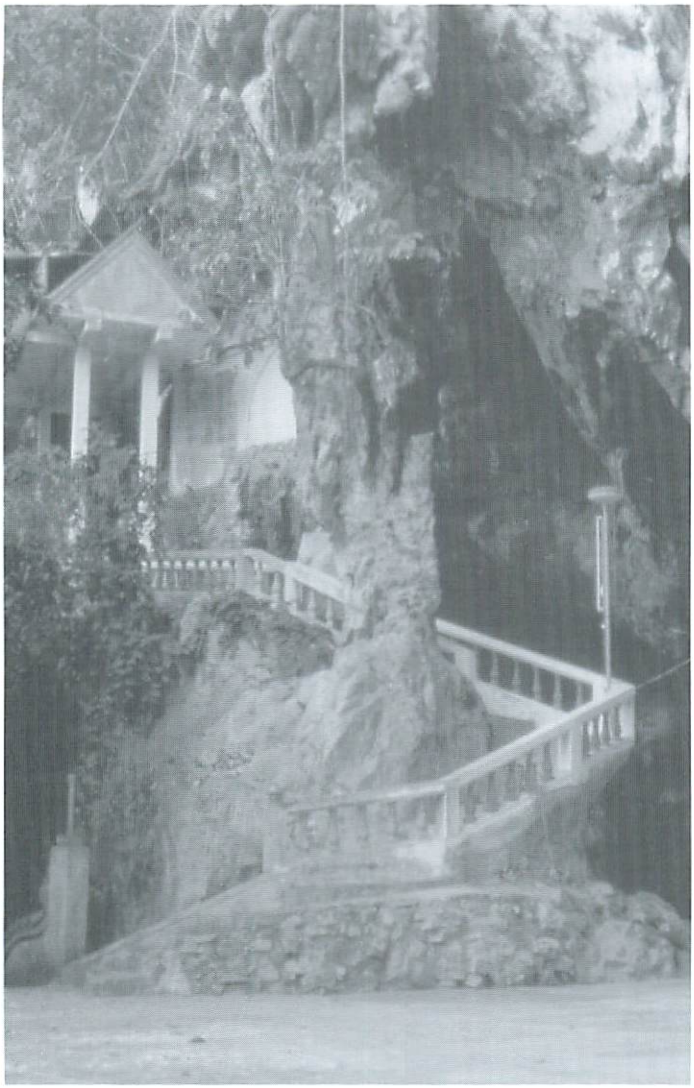

Figure 3. *The entrance of Wat Tham Pha Phung.*

As the expedition progressed, attention also focused on the other areas. Several caves were discovered around the village of Ban Nong Khaem, in both the southern margins of the Central Plateau and some of the towers of the Ban Nong Khaem Plain. A number of stream sinks were noted in the south of this area, whilst further west a major resurgence probably drains much of the Central Plateau. Most of the prospecting on the Southern Massif took place around the massif margins owing to the steep and inaccessible nature of the terrain. The caves that were found were usually stream sinks or resurgences.

The caves and sites of spelæological interest in each region are described in turn, along with sites that were explored but revealed no enterable cave passage. Nearly all the caves 'discovered' were known to the local people and had been explored by them, but none had been surveyed or documented.

Where possible, the local Thai name is given for the caves we explored. Often however, the local names were not known. In these instances, the cave names given are in English.

All measurements taken within the caves explored were accurate to the standards required to produce BCRA grade 5 surveys. However, owing to the apparent inaccuracy of local maps, our instruments could not be reliably calibrated. For this reason, the surveys in this report are to BCRA grade 4. The north-point in each drawing is Magnetic North.

All co-ordinates given for the cave locations were determined using Global Positional Systems.

1. Northern Escarpment.

Wat Tham Pha Phung (Bee Cave Temple) Length: c 20 m
UTM: 47Q 0509519 2182233

This cave, located in the temple grounds, consists of a single large entrance chamber approximately 20 m across, and extending back into the cliff face (see Figure 3). There is a large Buddhist shrine at its far end. A tube to the right climbs into the roof of the main chamber. It appears to be nothing more than a large solutional alcove at the base of a steep cliff. In the adjacent temple were several doors set back into the cliff and it is probable that the monks have explored any caves in this area.

Tham Phra Chao (God Cave)
Length: 285 m
UTM: 47Q 0509435 2182122
Survey: Figure 4

Known to local monks and located approximately 50 m above the valley floor, the entrance to this cave is a 2 m high arch at the head of a small embayment in the steep hillside. The arch opens out into a well-decorated chamber up to 15 m wide and over 20 m high (see plate 5). Avens can be seen in the roof here. The way on is through a boulder collapse at the far end of the chamber, around 70 m from the entrance. Climbing up in the boulders leads to a choke with no way on. Down to the right drops into a short section of phreatic passage, which leads to a choice of two routes over boulders:

To the left a passage leads to the Meeting Room. There are two exits, the most obvious of which is a 5 m climb down into another well-decorated chamber. One passage descends to the left about two metres but is blind. The second is a climb down to a small room, leading to a rift which becomes too tight. The third, leading off to the right at the top of the 5 m climb, is the main continuation of the cave. Here, a short crawl leads to a 2 m climb

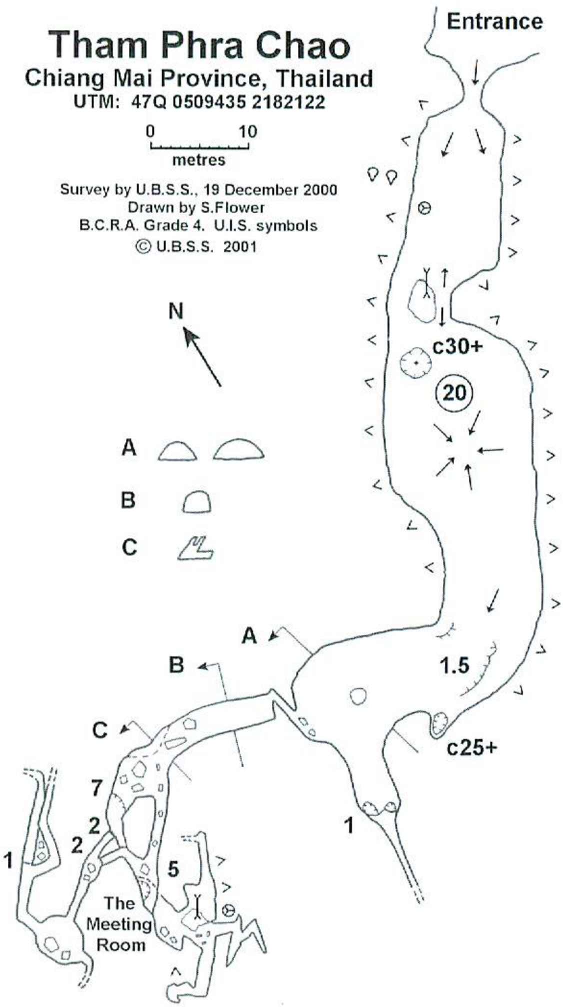

Figure 4. *Survey of Tham Phra Chao.*

down into a well decorated chamber about 3 metres wide. Three passages lead off here, but all quickly close down.

Back at the phreatic passage, straight on leads to a rift, which descends to a small hole in the floor, but the way on here is choked with boulders and mud. Higher and to the right, a cross rift leads via upper and lower levels to a small chamber (a passage to the left just before this connects back into the Meeting Room). In the chamber there are ways on to the left and right; to the left quickly closes down, while the passage to the right leads, via a brief stoop, to a short section of rift passage, divided into upper and lower levels by boulders. At the far end of this passage the rift begins to descend, but quickly becomes too tight to pass.

It appears from the graffiti that the entire cave has been explored by the local monks, who also claim that it is possible to climb down to a streamway. However, it is not known where this streamway is, as no water was seen in the cave. If it does exist, the route to it is not obvious, although determined pushing in some of the rifts and chokes may reveal a way on. The cave is entirely fossil and appears to be a truncated part of a long abandoned phreatic system. Well preserved large scallops, up to 50 cm diameter near the entrance indicate slow phreatic flow towards the entrance. The source of the water is unclear, but it is probably fed by the complex series of narrow phreatic rifts at the rear of the cave. A green Cave Racer Snake (*Elaphe taeniuria ridleyi*) was noted in the main chamber. No remains of pottery or archaeological artefacts were found and the entrance area was much disturbed.

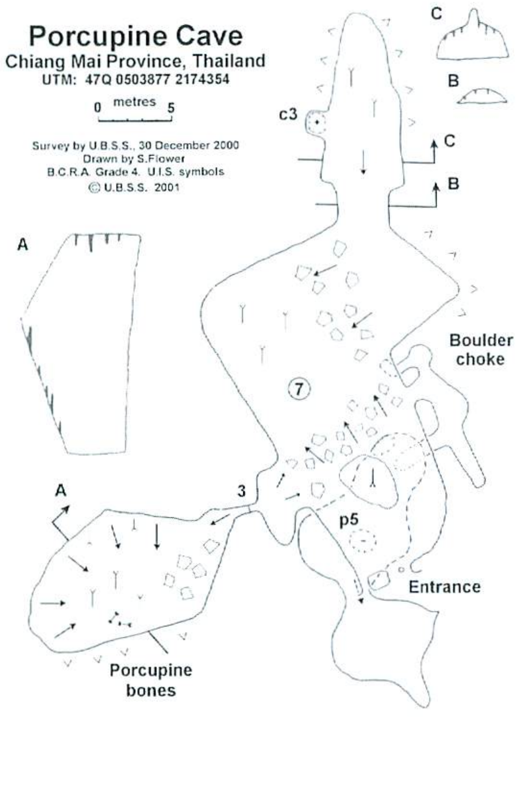

Figure 5. *Survey of Porcupine Cave.*

Spring UBSS 2000-SP1
UTM: 47Q 0509730 2183119

This spring, about 1 km north of Tham Phra Chao, discharged from a low wet passage which was pushed for about six metres before getting too low and wet. The discharge of this and the next spring was each estimated at around 10-20 l per second.

Spring UBSS 2000-SP2
UTM: 47Q 0509415 2183328

This spring, about 350 m south-east of the previous spring proved impenetrable. The water emerges from tufaceous boulders.

2. The Central Plateau Area

Porcupine Cave
Length: 133 m
UTM: 47Q 0503877 2174354
Survey: Figure 5

A 4 m wide entrance leads into the very well decorated main chamber, dominated by a single large stalagmite at the top of a 7 m boulder descent to the chamber floor. To the right of this stalagmite is a drop through boulders into two chambers, the furthest of which can also be accessed via a 5 m drop just inside the entrance. Further along to the right is a short climb up into a boulder choke, but no way on was found. Over to the left, on the other side of the chamber, a passage leads to another well-decorated chamber, in which porcupine bones were found. Descending to the floor of the main chamber, a low crawl gains a small chamber but with no ways on.

Tham Ngu (Snake Cave) Length: 119 m
UTM: 47Q 0506576 2171684 Survey: Figure 6

This cave is best accessed from Ban Nong Khaem. The 6 m wide entrance to this cave is located at the foot of a steep cliff and leads via a short section of passage to a 10 m diameter chamber. From here, two passages lead off. To the southeast, it terminates in a small chamber after 25 m. The passage to the southwest leads to a narrow descending rift, after a stoop and short climb. Progress in this rift is prevented by high concentrations of carbon dioxide. It is possible that the rift continues down, but no draught can be felt. The name of the cave is derived from the narrow meandering channel (the 'snake') etched in the roof of the entrance chamber. This is a fine paragenetic half tube. Much of the cave contains evidence for a complete sediment fill, with good stalagmite false floors, paragenetic pendants and anastomosis. Scalloping on the passage walls indicates the cave once functioned as a resurgence.

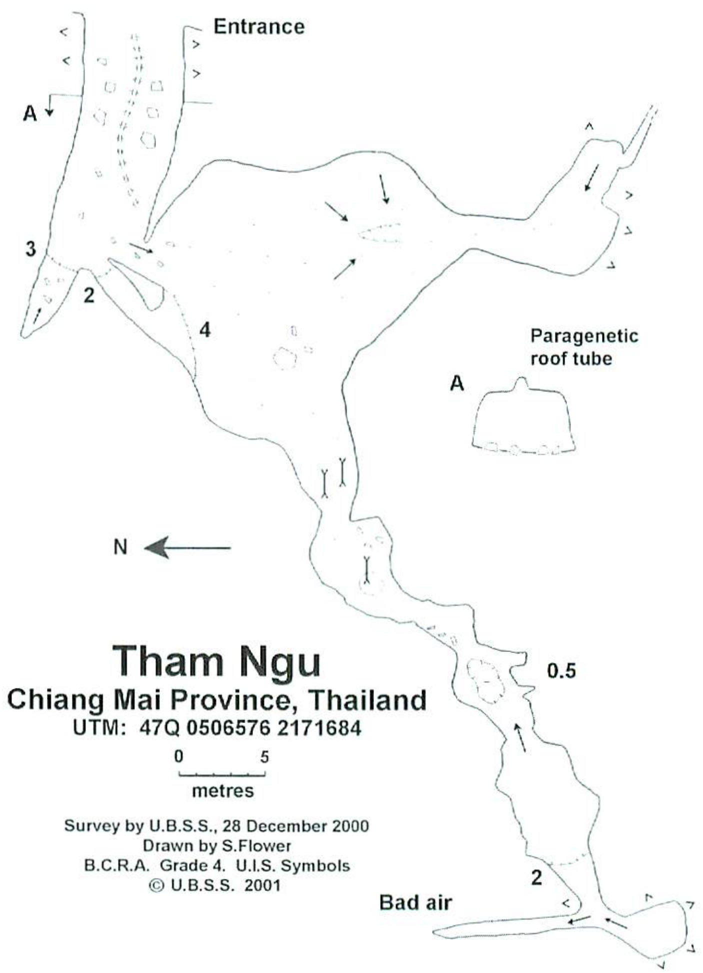

Figure 6. *Survey of Tham Ngu (Snake Cave).*

Tham Ling (Monkey Cave) Length: 76 m, Depth: 40 m
UTM: 47Q 0505868 2170906 Survey: Figure 7

The entrance is located in an outcrop high on the slopes of a karst tower, above the village of Ban Nong Khaem. An exposed climb is required to access it. Just inside the entrance chamber a passage to the left leads to the head of a fine 12 m pitch. Traversing on a narrow ledge around the top of this pitch leads to a large boulder-strewn chamber with no way on . The way on at the foot of the pitch is through a narrow slot located behind a boulder. A number of routes appear to lead off from the small chamber beyond this, but only one is passable: a descent, via a 6 m pitch, into the terminal chamber. A number of side passages can be explored in here but only one, beyond a squeeze at the foot of the pitch, has any potential. A draught can be felt, and a sizable passage can be seen, but the squeeze would require enlarging to enable it to be entered.

Bat Bone Cave Length: c 80 m Depth: c. 25 m
UTM: 47Q 0510680 2174600

Located on the interfluve between two dolines, the entrance to this cave is at the foot of a steep slope, and opens into a large cavern 40 m across. At the base of the slope, bearing right leads to a 2 m climb down through a narrower passage ending at a pitch head, estimated at 15 m depth. This leads to another large chamber with a possible way off it, but it was not descended due to foul air. Leading off to the left from the base of the entrance chamber is a 3 m climb down over a large boulder collapse, but there is no passage beyond.

Cricket Pitch
Length: 22 m, Depth: 35 m
UTM: 47Q 0508550 2177317
Survey: Figure 8

Located in the base of a doline, close to the limestone-shale boundary, this is a large seasonal stream sink. A spectacular open

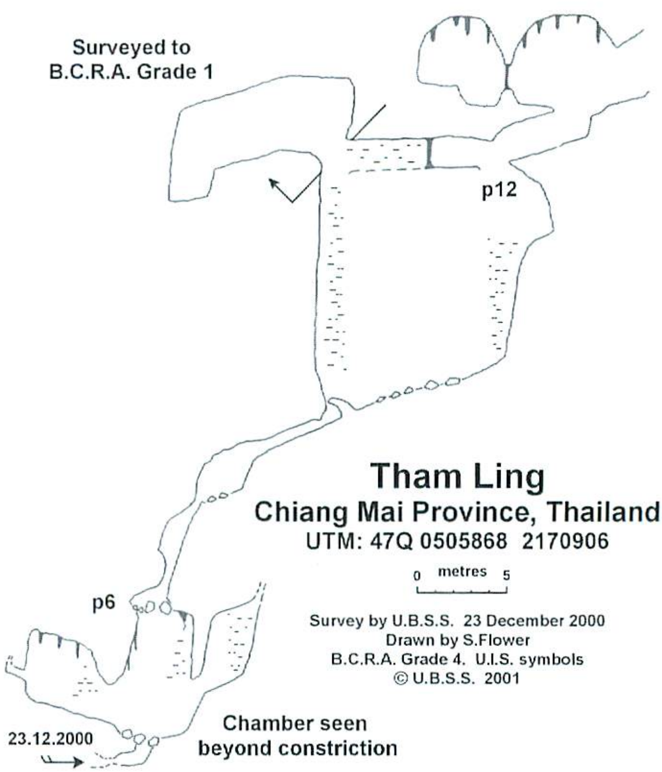

Figure 7. *Survey of Monkey Cave.*

shaft over 20 m deep opens in the floor of a steep doline. Following the stream to the shaft head leads to an 8 m pitch down to a ledge. This pitch can be avoided by a climb through boulders. An 8 m pitch to a mud floor and a final pitch of 6 m follow this. Shortly beyond this, the cave becomes choked with flood debris. Almost the entire cave is open to daylight and has no problems with bad air. It appears to take a considerable amount of water during the wet season.

Nong Cave Length: 35 m, Depth: 21m

UTM: 47Q 0508027 2175063

Survey: Figure 9

This 12 m diameter, 10 m deep surface shaft is located in the floor of a large, shallow doline. The mud floor descends steeply to enter a lofty passage that gradually decreases in size to end in a calcite choke after only 20 m.

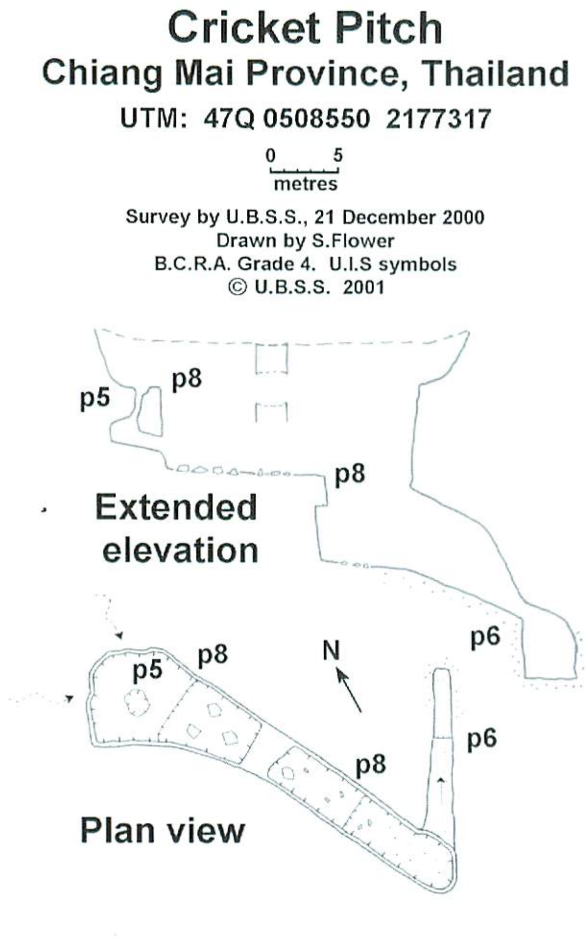

Figure 8. *Survey of Cricket Pitch.*

Black Hole Shafts

The next five sites are all located very close to each other on the interfluve between two dolines, and are marked on Figure 1 as the Black Hole Shafts.

Black Hole

Depth: 50 m

UTM: 47Q 0508992 2176814

Survey: Figure 10

This is a vertical pothole approximately 50 m in depth. A shaft at the end of a shallow valley, 3-5 m in diameter is descended for about 30 m, where it bells out to 15 m in diameter. At this level a 7 m wide balcony extending back 3 m can be seen, but there are no ways on. Continuing down, the cave opens out into a chamber approximately 20 m in diameter and a passage approximately 3 m across can be seen leading off. However, a few metres from the floor the air quality becomes dangerously foul.

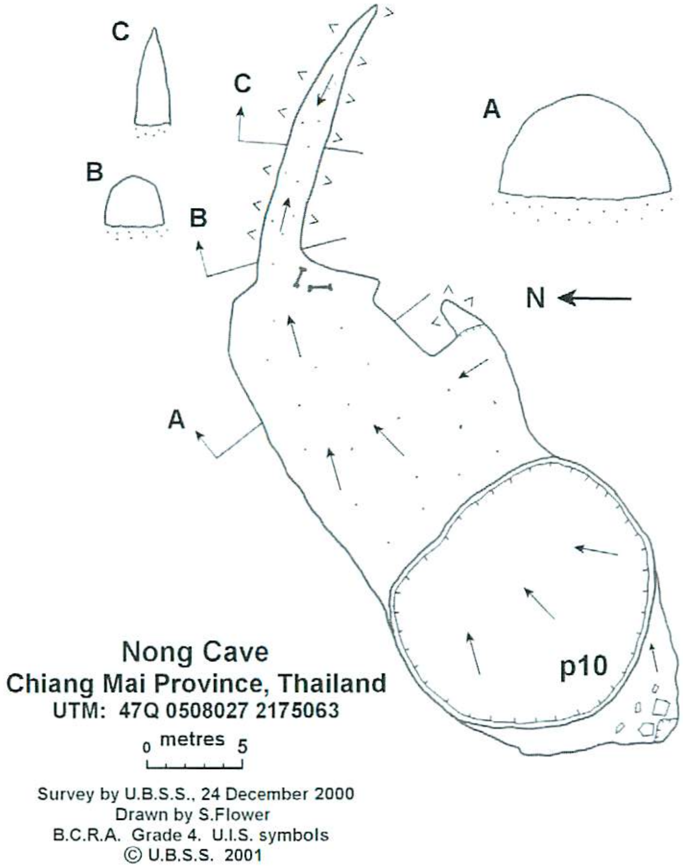

Figure 9. *Survey of Nong Cave*

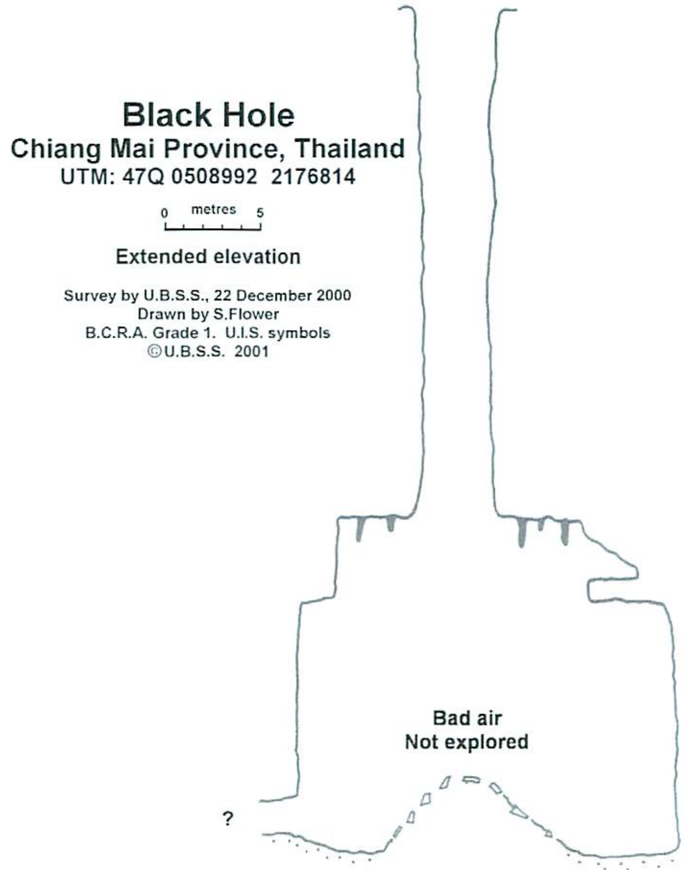

Figure 10. *Survey of Black Hole.*

Pan Pipe Pot Depth: 33 m
UTM: 47Q 0509104 2176861 Survey: Figure 11

This is a wide surface shaft, 30 m deep and 7 m in diameter. A small chamber can be accessed through an arch at the foot of the pitch, but further vertical progress is blocked by soil and debris. Air quality is good, presumably due to the open nature of the shaft.

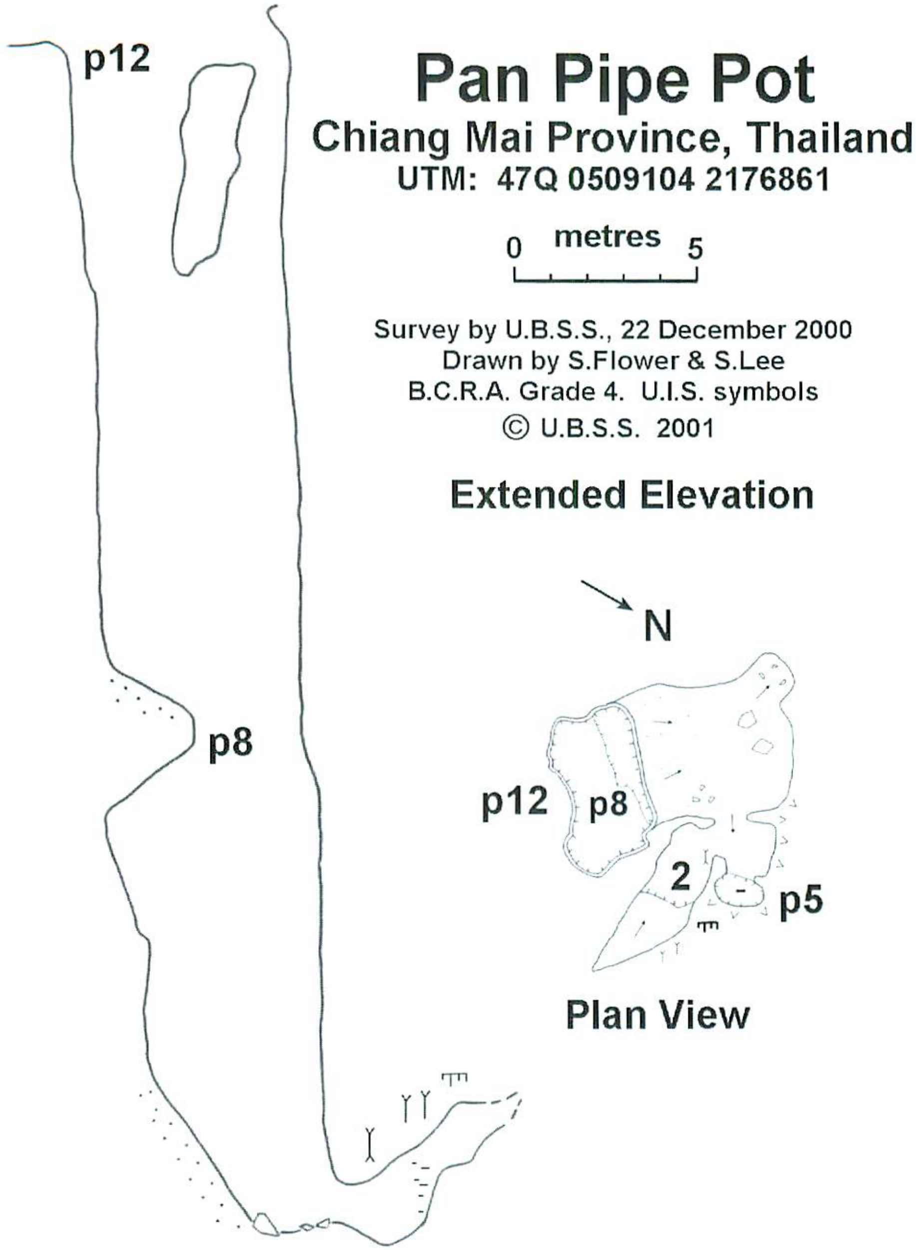

Figure 11. *Survey of Pan Pipe Pot.*

Rift Hole Length: 22 m + Depth: 35 m
UTM: 47Q 0508836 2176976 Survey: Figure 12

To the west of the track a shaft at the base of a doline drops down a 5 m pitch to a boulder floor. This descends to a 4 m climb down through boulders to the head of a 6 m pitch. At the foot of this, the cave continues to a short 2 m climb, then another 6 m pitch. At the bottom of this bad air is encountered so no further progress was made, but a 1.5 m diameter passage could be seen leading off at ground level and continuing out of sight.

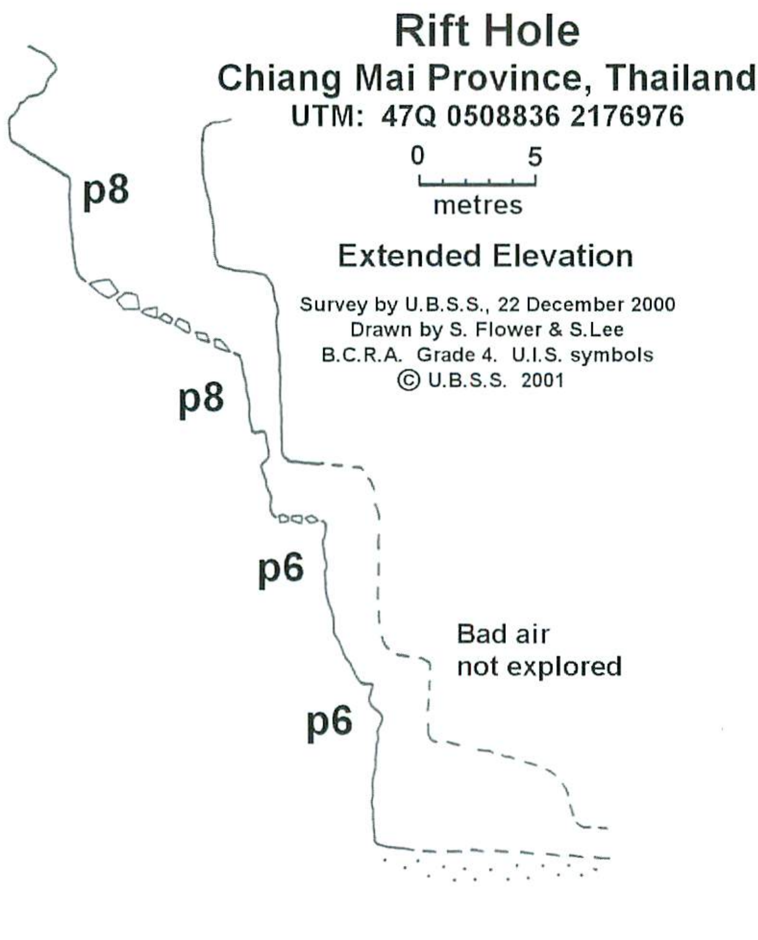

Figure 12. *Survey of Rift Hole.*

Crystal Pot
Depth: 25 m +
UTM: 47Q 0508957 2176872

This was descended only part way due to time restrictions. The small entrance to this pothole is located in a shallow depression and was seen to descend for about 30 m. However, no continuation could be seen and no draught was felt, although the air quality was good at -20 m. This shaft was very well decorated with crystalline stalagmite below -5 m.

Cave Ten
UTM: 47Q 0509135 2176833

This has an entrance 2 m by 1 m which leads immediately to a pitch with a 3 second drop. No draught was felt and the floor is mud, suggesting that it is probably choked and thus has high carbon dioxide concentrations like the neighbouring shafts. It was not descended due to time restrictions.

Nam Rue Luang Rising (Nong Bia Rising)
47Q 0511300 2173100 (+/- 100 m)

This large spring, located in a broad embayment a few hundred metres southwest of Tham Tab Tao, consists of a deep pool at the base of a steep slope. The pool was dived to a depth of about 7 m before it became choked with fallen trees and boulders. The water from here joins the stream which resurges at Tham Tab Tao. The discharge was estimated at approximately 50 litres

UBSS2000-1
UTM: 47Q 0509336 2174688

A short 9.5 m deep pit, with high carbon dioxide concentrations at the bottom. There is no passable way on.

UBSS2000-2
UTM: 47Q 0508817 2177010

A simple 5 m deep shaft with no passable way on.

UBSS2000-3
UTM: 47Q 0508509 2177286

A circular entrance, 1 m in diameter, located in floor of doline. This was seen to descend for 3-4 m, but appeared to be choked with mud. High carbon dioxide concentrations occur just inside the entrance.

UBSS2000-4
UTM: 47Q 0508930 2177228

A depression 4 m across and 2 m deep. The small cave entrance is choked with foliage and mud. There are high carbon dioxide concentrations in the depression.

UBSS2000-5
UTM: 47Q 0511540 2174124

This is located at the bottom of a shallow doline and is a simple 7 m deep pit. A small passage runs off to the northeast but soon closes down.

UBSS2000-6
UTM: 47Q 0509163 2174359

A 12 m deep pit, 2.5 m by 1.5 m is located in the floor of large doline. The floor is choked with mud and foliage and there is no passable way on.

3. Ban Nong Khaem Plain.

Tham Mi (Bear Cave) Length: 718 m
UTM: 47Q 0503160 2169223 Survey: Figure 13

The entrance (Entrance 1) is located in an outcrop in the side of a modest-sized karst tower 3 km south west of Ban Nong Khaem, adjacent to the seasonal Huai Pao river. A short section of stooping passage opens out into a large well-decorated phreatic passage up to 10 m wide, ending at a stalagmite and boulder choke and a small second entrance after 35 m.

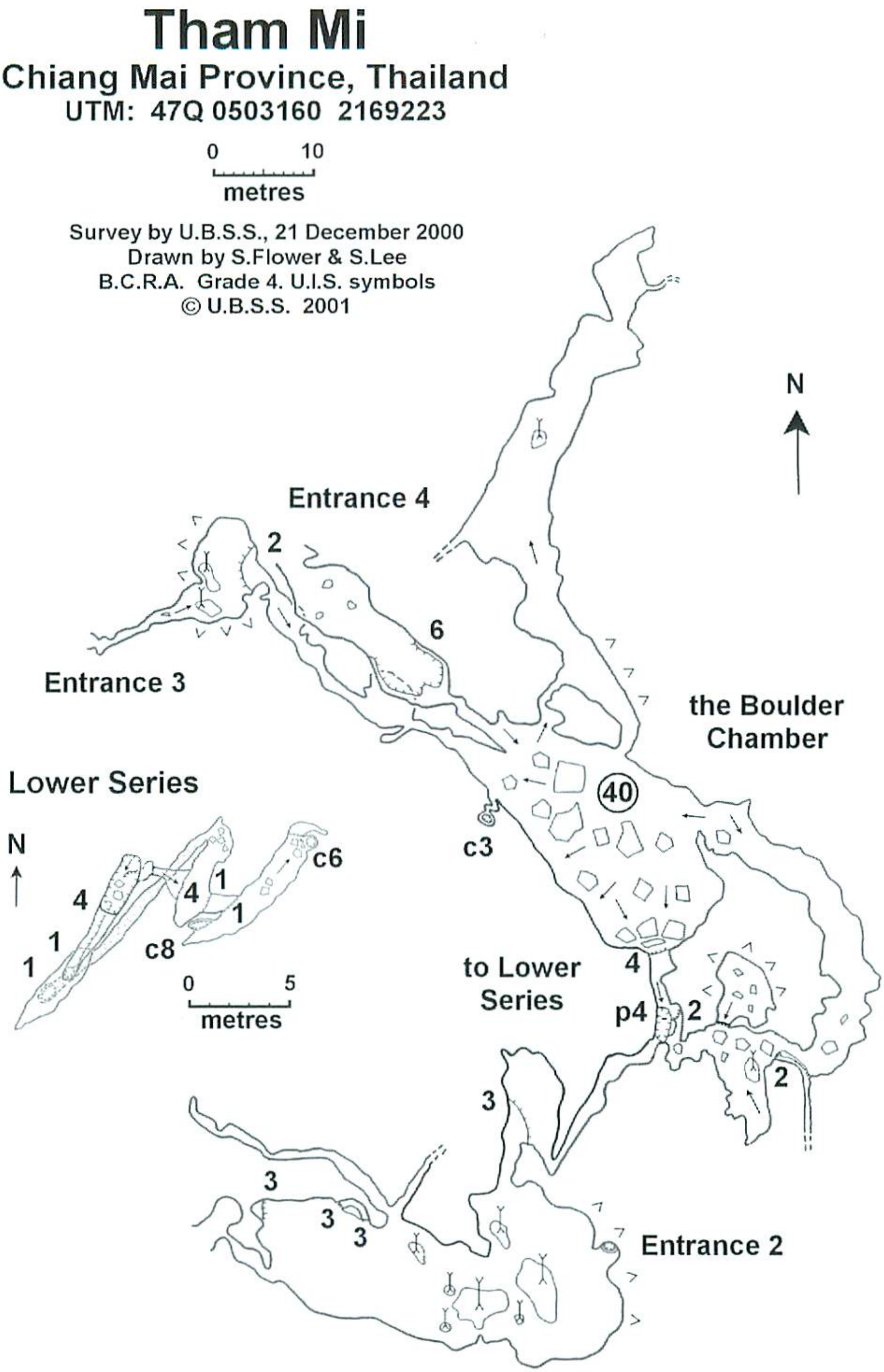

Figure 13. *Survey of Tham Mi.*

However, several side passages exist, most of which close down after a few metres. The main way on is a small side passage near the end of the main passage which leads, via a small chamber, to the head of a 5 m deep rift. This can be bypassed on the right to a ledge on the far side. From here there are three ways on: the Lower Series, the Boulder Chamber, and a passage to the right that eventually leads into the Boulder Chamber after 50 m.

The Lower Series. The rift can be easily entered by climbing down from the ledge. A series of interconnecting parallel rifts can be accessed in two separate places via holes in the floor. The nearest of these enters the roof of the second rift. The furthest, located at the foot of a 4 m ladder pitch, enters the first rift. A gap at the far end of the first rift leads to the second and the third can be accessed via a squeeze part of the way along this. The third rift was climbed for 5 m before becoming too difficult. It can be seen to ascend for at least 6 m.

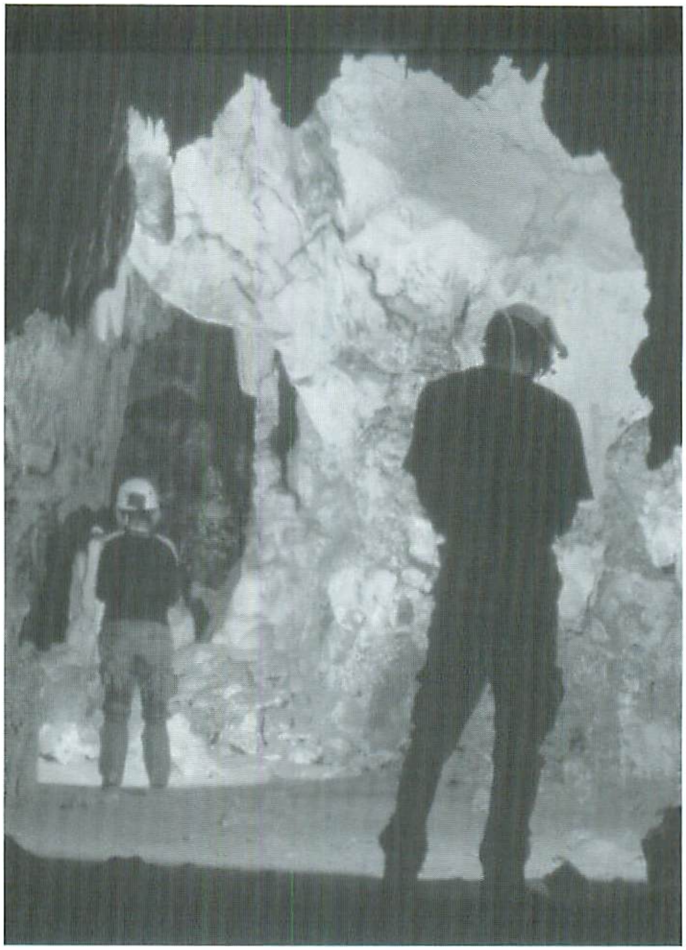

Figure 14. *Tham Mi*

The Boulder Chamber. This is entered by a short scramble to the right from the ledge which leads up a scree slope to a vast chamber, 14 m by 25 m by 25-40 m high. There are five routes out of here, which will be described in order of approach along the left-hand wall: The first is found at the lowest point of the chamber. It consists of a 40 m long passage, mainly crawling, to a 2 m climb down into a chamber and a third entrance [UTM: 47Q 0503149 2169228]. The entrance is in a rift and is difficult to see from the road. The second route is located in an alcove. It leads to a 6 m climb down into a chamber. Here, there is a 5 m diameter exit to the surface, about 10m m away from the third. It is also difficult to see from the road.

The third route is immediately adjacent to the second, in the same alcove. A passage leads into a large scalloped passage broken up by localised chambers with supporting columns. It is 60 m in length, with a number of side passages which close down. Tree roots at the far end suggest close proximity to the surface. The fourth route, 15 m further round, also leads into this passage. The fifth passage, adjacent to the fourth, loops back to the bypass (see Figure 14). A 4-5 m wide passage runs for 60 m to reach a well-decorated chamber strewn with boulders. A 4 m climb to the right leads to another well-decorated chamber with no way on, whilst straight on leads back into the passage that bypasses the drop into the Lower Series.

The large passage near Entrance 1 appears to be part of a major strike oriented phreatic passage passing straight through the hill. The limestone here is dipping at 45° at a bearing of 035°. The rest of the system appears to be a floodwater maze developed on several levels. The cave is probably similar to other maze caves developed at the base of towers elsewhere in the tropics and is probably formed by the stream which drains the alluvial plain outside occasionally flowing through the hill.

Coffin Cave — Length: 55 m
UTM: 47Q 0505057 2166561 — Survey: Figure 15

This cave is entered via two obvious entrances located part of the way up a cliff on a tower immediately north of the Southern Massif. It is a short fossil cave fragment, which contains the remains of several wooden coffins. The first entrance is a 2.5 m free-climb. The second entrance, located to the left, is accessed either by a difficult 3.5 m climb, or by an aging bamboo ladder. The former entrance enters the cave at its most northerly point and the main passage extends to the south of this, running parallel to the cliff-face. The second entrance enters the passage after 22 m. Initially this passage is 5 m wide and strewn with large boulders, but after 50 m the passage closes down to a 1 m diameter crawl. This enters a chamber that was not surveyed as bad air was encountered. Shortly before this, there is a raised platform on which there are several damaged coffins.

Back in the main passage, between the two entrances, it is possible to gain a balcony 3 m above the ground, either directly via difficult climb, or via a 5 m chimney closer to the first entrance. From the balcony it is possible to reach a third entrance higher in the cliff, surveyed to BCRA grade 1.

Paddy Field Spring Cave — Length: 15 m
UTM: 47Q 0499112 2172731

This cave is located directly above Paddy Field Spring (see below). A partially boulder-choked rift entrance leads down into a sizeable chamber 20 m across. The rear wall of the chamber is composed entirely of stalagmite, in which a small eyehole opens out into a second chamber. However, this was too tight to pass, but a large deep pool could be seen beyond, and the cave was seen to curve away out of sight. A slight draught was detectable blowing out.

This cave is a high level fossil outlet to the major conduit which resurges at the large spring below. If the eyehole was enlarged, more passage might be gained, together with a very promising dive site.

Paddy Field Spring
UTM: 47Q 0499112 2172731

This major spring northwest of Ban Nong Khaem rises from a deep pool at the foot of the steep hill. Even in the dry season the water can be seen to well up with considerable force. The water appeared to be very clear and probably drains much of the Central Plateau. The site

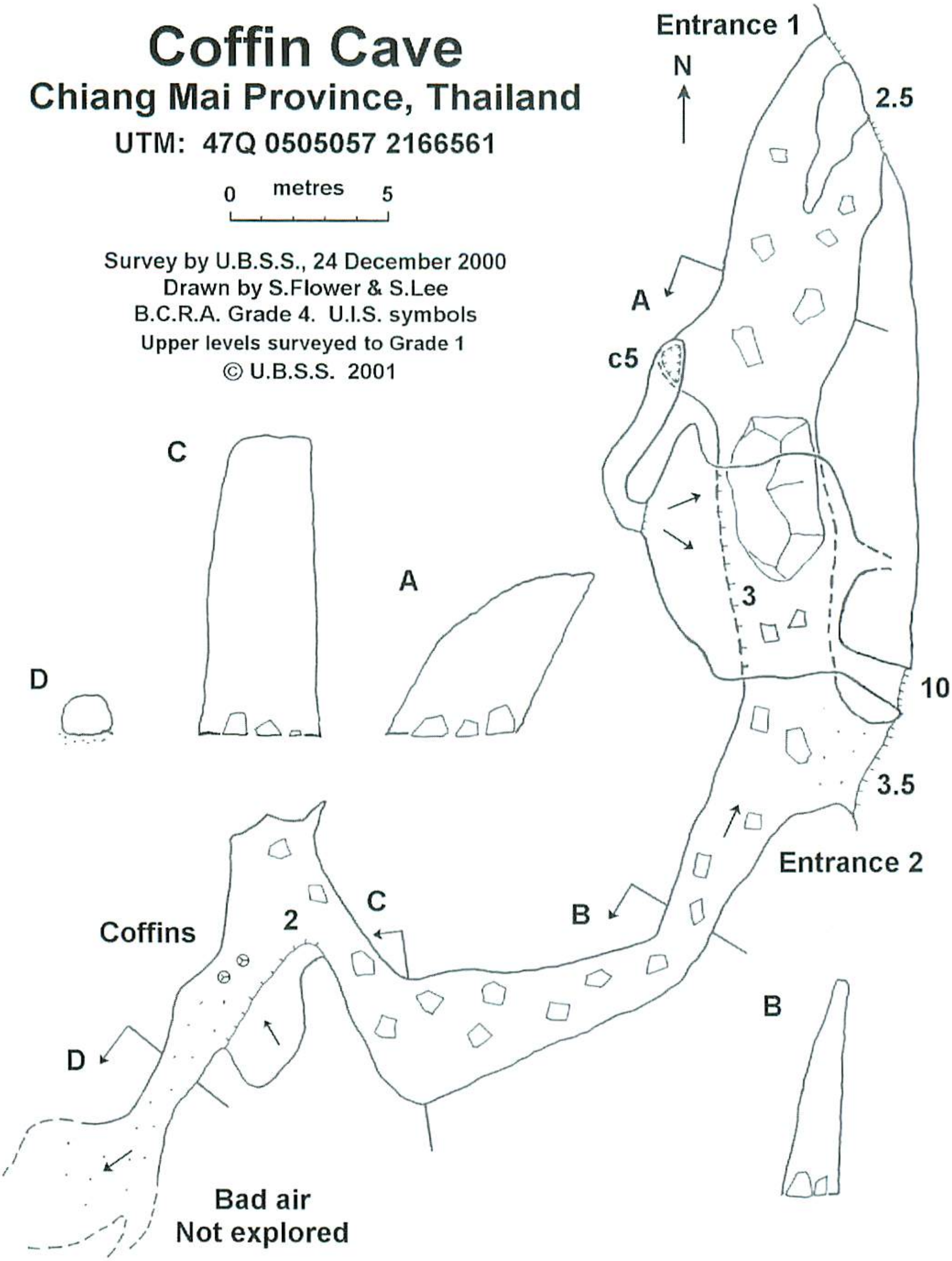

Figure 15. *Survey of Coffin Cave.*

was dived to a depth of a few metres but the route was obscured by tree roots and fast current. It is clearly linked to the cave just above.

UBSS 2000-7
UTM: 47Q 0505919 2170927
A small stream sinks into a muddy impenetrable choke in the floor of the doline, just below Tham Ling, immediately north of Ban Nong Khaem.

UBSS 2000-8
UTM: 47Q 0503387 2168228
There is a major seasonal stream sink where the Huai Pao (river) sinks at the base of a small cliff. The limestone here dips steeply to the south. Two large, 5 m by 5 m, sinks, heavily choked with brushwood and mud occur within 10 m of each other. Both are impenetrable. The water possibly resurges in a spring rumoured to exist on the other side of the ridge to the south, but this was not visited.

UBSS 2000-9
UTM: 47Q 0504328 2166527
This is a small cave at foot of a cliff in the same large depression as Coffin Cave. There is a chamber 3 m by 1 m with no way on.

4. The Southern Massif.

River Cave / Tham Spit Length: 758 m
UTM: 47Q 0505128 2160039 Survey: Figure 16
This is a large seasonally active resurgence cave, near the village of Ban Tham Klaeb, on the main highway. The entrance is located at the foot of a limestone outcrop, and is partially concealed by large boulders. A 3 m pitch leads to start of a 550 m long passage which averages 10-20 m wide and 6-8 m high and is well decorated with flowstone, speleothems and gour pools (Figures 17, 19 and 20). The passage terminates in a muddy duck and a sediment choke. Above, two high avens can be climbed for 13 and 15 m to establish separate connections (French Connection I & II, respectively) to Tham Spit, a stream sink explored previously by the French expedition in 1985 (Deharveng and Rigal, 1986). Shortly before the terminal choke, a higher level fossil tributary passage can be followed for about 70 m. Two chambers can be

The resurgence is fed by the stream sinking into Tham 'Spit', a large stream sink less than 400 m away on the other side of the limestone ridge, which drains approximately 3 km^2 of sandstone hills to the west. From the large number of sizeable logs and bamboo canes, coupled with the large clasts of sandstone on the passage floor, it appears that the streamway takes a large amount of water in flood. It is essentially a single stream passage, with the only fossil development related to headward vadose incision and capture close to the stream sink.

The cave follows the jointing for part of the distance and near the resurgence the passage is aligned along a small inclined fault. In flood the water backs up at least 4 m behind the entrance boulder choke. Several good sediment sections up to 4 m thick, exhibiting coarse grained cross-bedded sand and gravel can be seen in the middle portion of the cave. At one

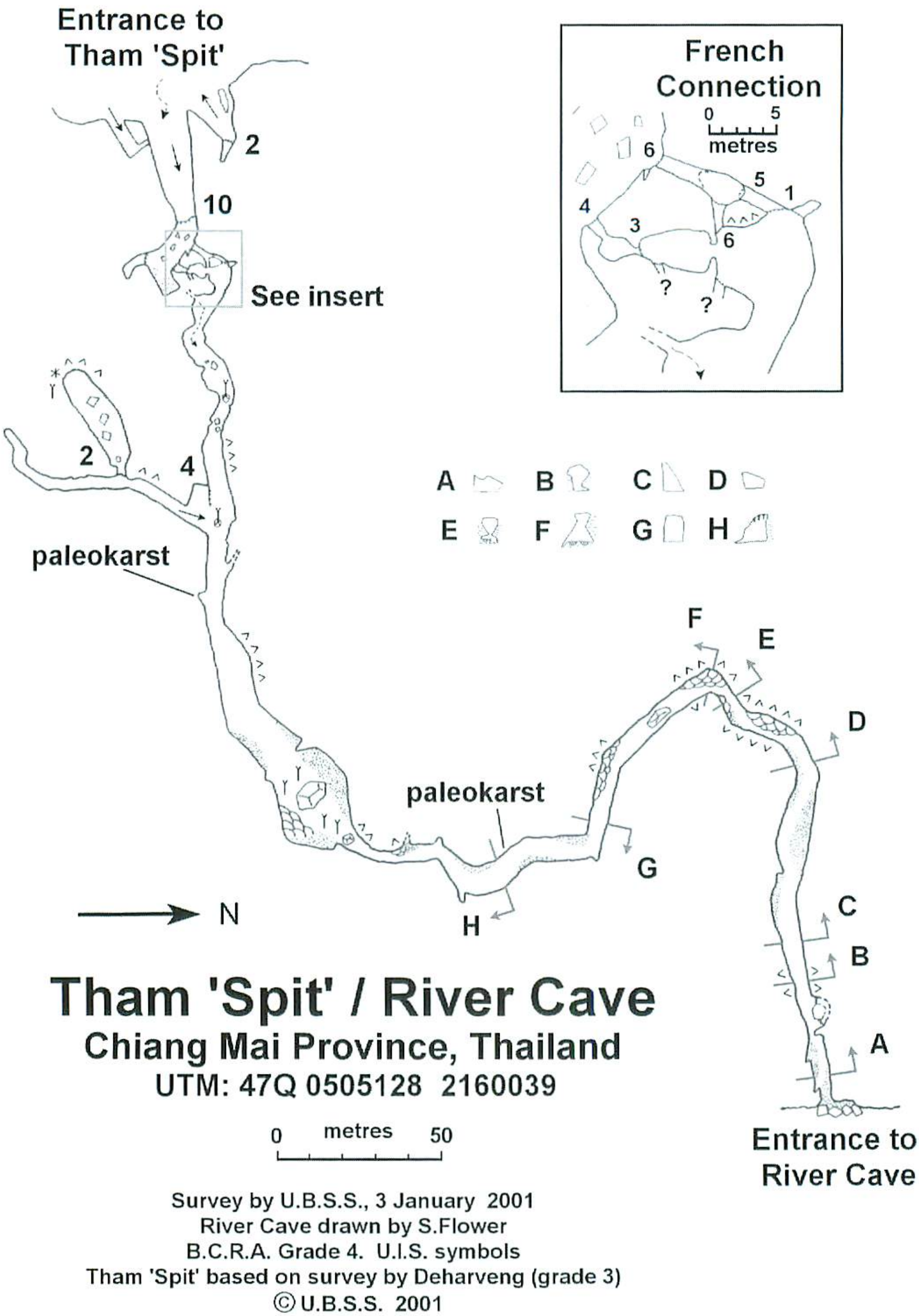

Figure 16. *Survey of Tham 'Spit' / River Cave.*

point in the cave, good exposures of a limestone conglomerate can be seen, which may be evidence of Permian or Triassic palaeokarst.

Figure 17. *River Cave*

Kids' Cave Length: 151 m
UTM: 47Q 0504869 2161050 Survey: Figure 18

This cave is located on the western cliffs of the Southern Massif, a few hundred metres south of a hill tribe village not marked on 1978 issue 1:50 000 maps. A 10 m wide entrance arch leads via a large, steeply sloping boulder strewn passage to the final boulder choked pit after 30 m. The floor of the pit can be reached by a climb down boulders. At the foot of this climb, a drop through boulders leads to a 45° rift which terminates in a mud choke after 50 m. Continuing to the far end of the pit, there are 2 ways on: a 2 m drop to short passage and a small chamber in boulders, and a 5 m climb up a stalagmite bank to a short but very well decorated passage. Just inside the entrance arch, a dusty chamber may be entered through a 1 m high arch where a 4 m pitch leads to another low chamber. The way on at the foot of this is a 0.5 m wide rift that draughts a little, but becomes impassable after 3 m. Daylight penetrates almost the entire cave.

This appears to be an abandoned stream sink. The passage descends steeply down dip and is in an advanced stage of breakdown. Many of the smaller passages are simply alcoves in boulders. The cave is well decorated throughout.

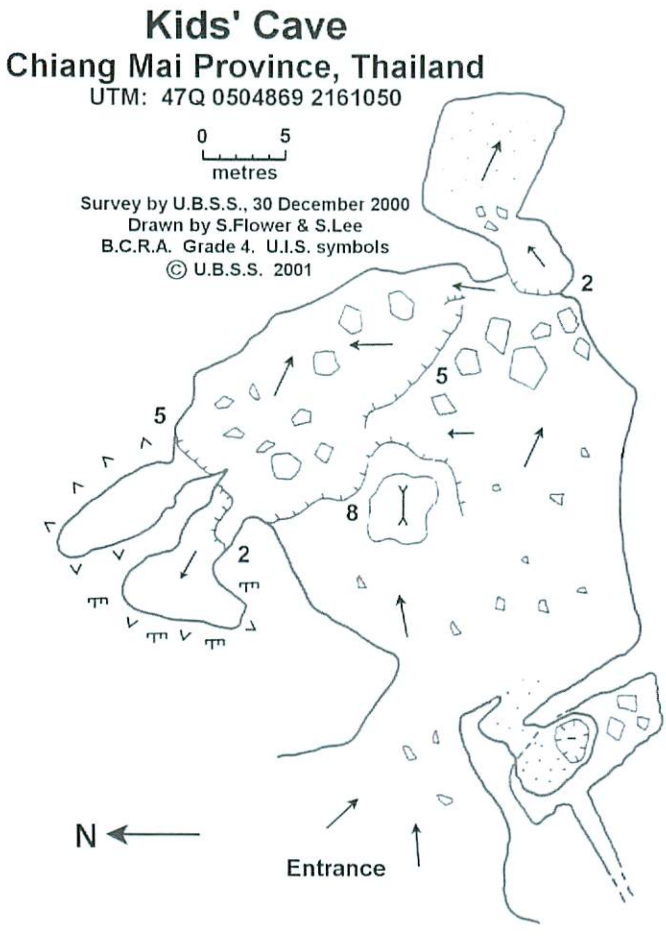

Figure 18. *Survey of Kids' Cave.*

Mud Cave Length: 30 m +
UTM: 47Q 0505504 2160552

Located at the foot of a small tower adjacent to the alluvial plain, this small, 1 m by 2 m wide, resurgence entrance lies at the head of a small seasonal streamway. The cave can be followed as a small constricted phreatic passage over glutinous mud and sand. It clearly fills to the roof in wet weather. No draught was felt and the passage was not fully explored. There is a possibility that this is the resurgence for one of the sinks to the north of Kids' Cave as no other seasonal resurgences were identified on the eastern flank of the mountain.

Figure 19. *Large gour pools in River Cave.*

UBSS 2000-10
UTM: 47Q 0506705 2165608

Several small seasonal streams sink at the base of the steep cliff below Doi Pha Deng, close to the road. Two drain into the scree at the base of a cliff. The other, 100 m further on, is located in a pit a couple of metres deep in alluvium and is choked with mud and logs. None have any passable way on.

UBSS 2000-11
UTM: 47Q 0504815 2161486

A large seasonal stream flows off higher sandstone hills and sinks at base of limestone cliff, in a well-developed depression 20 m deep and 800 m across, 1.5 km south of Doi Tham Klaep. There are two sinks, one of which can be penetrated for a few metres in what appears to be a massive boulder pile at the foot of the cliff. The second is a mud choked hollow.

UBSS 2000-12
UTM: 47Q 0504901 2159281

There is an exposed 10 m climb up to a 6 m by 3 m entrance in a tower south of River Cave. It leads to a scalloped chamber 7 m long with a 2.5 m climb to 4 m of passage.

CARBON DIOXIDE IN CAVES

High concentrations of carbon dioxide were encountered in many of the caves investigated, most of which were found on the Central Plateau. The depth at which the foul air was encountered varied from just above the surface (in dolines), to depths greater than 40 m in the Black Hole Shafts. Tests in Coffin Cave demonstrated that the foul air interface is very well stratified and abrupt. A lit butane cigarette lighter was lowered up to 20 cm below the fresh/foul air interface, but the flame remained in the same position at the boundary, burning the lighter fluid vapours as they rose into the oxygenated air. The consequence of this is that exploration, particularly abseiling, is potentially hazardous in this area. There was at least one instance on this expedition where foul air almost proved fatal. Therefore, the source of foul air, its physiological effects and strategies for detecting it are discussed below.

Physiological effects of foul air

Foul air can be the result of either high levels of carbon dioxide, low levels of oxygen or a combination of the two (James, 1977, James *et al.*, 1975, Smith, 1993). Normal concentrations of oxygen and carbon dioxide in the atmosphere are 20.95% and 0.03% respectively. The physiological effects of changes in these concentrations vary according to each individual and their fitness levels.

Carbon dioxide levels control the rate and depth of respiration. At levels of 1%, there is a slight increase in the rate and depth of respiration, which is doubled at concentrations around 3%. Increasing concentrations to 4% causes throbbing headaches, nausea, sweating and a trebling of ventilation. 6% levels can be tolerated for a few hours, but narcotic effects begin to occur. Anything above 10% is intolerable for more than a few minutes and over 12% leads to unconsciousness within minutes. All these values are for normal subjects at sea-level; any strenuous activity will increase carbon dioxide levels in the blood which cannot be expired efficiently in carbon dioxide rich atmospheres. Thus any increase in carbon dioxide levels in the inspired air will cause a decrease in the capacity to do physical work, a finding that should be heeded before going underground.

Foul air is also caused by reduced oxygen levels although the amount of oxygen can be reduced to less than 13% before any ill effects occur. If concentrations fall below this, hyperventilation begins to occur, although not as severe as with elevated carbon dioxide levels. Visual appearances of the onset of hypoxia include cyanosis where the lips, nail beds, earlobes and mucus membranes turn blue. Judgment and muscular coordination are impaired and brain damage and death can rapidly result.[1]

Where foul air is a combination of both low oxygen and elevated carbon dioxide, the increased ventilation due to carbon dioxide levels will offset the low oxygen depending on the gas mixture experienced. However, it should be noted that a reduction in the amount of oxygen will change the physiological response for a given level of carbon dioxide (James *et al.*, 1975).

[1] Such levels have been reached in Thai caves. The 2001 Shepton Mallet Caving Club expedition to Tak Province recorded a level of 13.0% oxygen in a hole in the floor of the cave of Tham Mutalu (Ellis *et al*, 2001). (Editor's note).

A further complication is that some individuals do not hyperventilate on exposure to foul air and will not experience the warning symptoms of elevated carbon dioxide. These individuals will thus be at greater risk of cyanosis, unconsciousness and death in foul air than most people.

Causes of foul air in caves

Carbon dioxide in caves may come from several sources (James, 1977):

1.
2. Evolution of carbon dioxide from cave waters.
3. Production of carbon dioxide from microorganisms.
4. Respiration of plant and animals.
5. Burning of hydrocarbons.
6. Venting of volcanic gases.
7. Deep seated geochemical processes.

The contribution of each source is difficult to assess, and carbon dioxide sinks can reduce levels in certain circumstances. In this region of Thailand, sources 3 and, possibly, 7 probably account for the majority of carbon dioxide levels in the caves, but the relative merits of each hypothesis should be discussed.

The diffusion of soil carbon dioxide downwards into caves has been cited as a cause of elevated carbon dioxide levels in some caves. Elevated levels of carbon dioxide occur in the soil as a result of vegetative and bacterial activities, which then diffuse downwards under the influence of gravity. On this expedition, no gas analyses were carried out, but it is thought that this process is not a major contributor to the foul air in the caves. It would however, be an interesting topic for further study.

Increased levels may be produced by degassing of carbon dioxide from drip waters and cave streams. However, the lack of speleothem growth, produced by the deposition of calcite following carbon dioxide degassing, suggests this mechanism is not a major contributor in this area. In fact, speleothem dissolution seems to be taking place in some caves.

A more likely source is the production of carbon dioxide in situ by micro-organisms. Decomposition of organic debris washed into the cave will produce large amounts of carbon dioxide. The conditions in the cave are conducive to bacterial decomposition of organic matter. Moisture levels, especially in the deep caves, remains at 95-100%, even during the dry season. Temperature is also fairly constant at around 20-25°C, a favourable temperature for bacterial growth. The supply of organic matter is probably very seasonal, being at a maximum during the wet season. Much can get washed in through stream sinks and can be observed to accumulate at the bottom of shafts, in stream passages (often strewn with bamboo debris) and in passages subjected to seasonal flooding. Oxygen levels are not necessarily required for biogenic carbon dioxide production as anaerobic decomposition also produces carbon dioxide. Where anaerobic bacterial action occurs, the oxygen may be used up and 'black-damp' (atmospheres with high carbon dioxide and unexpectedly low oxygen levels) or 'stink-damp' (if hydrogen sulphide is also present) may occur.

Figure 20. *Crystal pools in River Cave.*

In caves with large bat or swiftlet populations, plant and animal respiration may be significant enough to contribute to carbon dioxide production. However, no significant bat or swiftlet roosts were seen in any caves.

Burning of hydrocarbons (candles, carbide lamps) does produce carbon dioxide, but neither could be considered to be the cause of foul air in these caves as the amount produced is

Volcanogenic sources of carbon dioxide may be significant in some areas, but the lack of any volcanic activity in this area effectively precludes this as a source.

A geologic source, however, cannot be ruled out. The Fang basin is a deep hydrocarbon rich sedimentary basin with a high geothermal gradient and well-known thermal springs. Diagenetic and thermal alteration of sediments at depth, or reaction of carbonate rocks with acidic groundwaters are capable of producing significant amounts of carbon dioxide, which commonly degas via thermal springs. Oxidation of hydrogen sulphide supplied by hydrocarbon basins can generate sulphuric acid, which then reacts with limestone at depth to produce extensive caves such as Carlsbad Caverns, Lechuguilla Cave, in New Mexico (Hill, 2000). It is not inconceivable that such processes occur at depth in this area. However, none of the characteristic mineralisation of such sulphuric acid hypogene karst systems were seen, possibly because no caves were penetrated to the water table. For this reason, it is considered an unlikely source.

The most likely carbon dioxide source/oxygen sink is in situ decomposition of organic matter. However, to get a foul air situation, the carbon dioxide must either stay in situ once produced, or the rate of production exceeds the rate of ventilation All simultaneous measurements of carbon dioxide and oxygen so far taken in Thailand suggest that the former increases while the latter decreases roughly % for % (Dean Smart *pers com.* 2001). This is evidence of a biological source although the number of actual measurements is small. Bad air usually collects because the carbon dioxide is produced in a place where little or no exchange with other environments exists, either within the same cave or outside. So, blind, non-draughting caves and passages with a biological energy source generally have the most severe foul air problems. The problem varies on a daily, seasonal and prevailing long-term climatic basis. Prolonged heavy rain seems to reduce bad air, most likely due to increasing ventilation by water-flow and piston effects. The pressure drop associated with the onset of evening accentuates it by drawing bad air out from deeper into the cave. Some years are better than others, for reasons as yet unknown.

Many of the shafts on the plateau were found to be blind, and had a high concentration of organic matter on the floor, conditions ideal for the production and retention of carbon dioxide. Furthermore, the deep phreatic nature of the conduit systems in much of the Central Plateau curtails free air circulation from sink to resurgence, unlike in River Cave in the Southern Massif. Many of the springs around Tham Tab Tao appear to be partially dammed by extensive spreads of tufaceous limestone. Another contributory cause of poor air circulation is the

Effects of foul air on combustion, and strategies for detection

Combustion depends upon adequate atmospheric oxygen concentration. Carbon dioxide, the principle determinant of foul air, has very little effect and even high concentrations will not extinguish a flame if the oxygen is in adequate supply. The exact concentration of oxygen required to keep a flame alight, at any given temperature and pressure, depends upon the fuel type. In a study by Smith (1997), the oxygen requirements of a number of fuels were investigated. He found that a candle flame was extinguished at concentrations below 15%, and a lighter will be extinguished below 14.25%, but will continue to flash down to 12.5%. The requirements of a carbide lamp vary widely due to the many variables affecting the flow rate of acetylene, namely the drip-rate of water; the quality and size of carbide particles, and the resistance to flow in the generator. The implications of this are that flame tests, particularly using

In caves of the expedition area, a cigarette lighter flame was extinguished in foul air before any physiological effect produced by carbon dioxide was appreciated. This strengthens the argument for a respiratory source of foul air, because combustion requires the oxygen consumed by organisms. Although cigarette lighters were adequate for detecting foul air on this expedition, ideally gas detectors or oxygen re-breathing apparatus, such as those used for mine rescue, would be taken on trips where foul air may be a problem. If these are not available, appropriate precautions for getting out of a cave with foul air should be taken. In particular, descending pitches poses high risks; it is easy to abseil into bad air, but far more difficult to prussik back out. Furthermore, the time required to effect a change over on SRT rigs from descent to ascent may be critical. The use of z-rigs on all pitches and personnel to haul an unconscious person up a pitch in case of problems is therefore recommended.

CONCLUSIONS AND CONSIDERATIONS

Further Potential

There is considerable potential for further discovery in all three areas investigated. However, sinks, doline caves and surface shafts are likely to be choked with mud, organic debris or calcite. This means that many caves will have high concentrations of carbon dioxide and low oxygen levels. Resurgence caves are likely to yield the most cave passage, particularly those with vadose streamways like River Cave or with multiple entrances. Better prospects may occur to the north and north-west, where stream sinks are more common. However, the political situation here is more fraught. The limestone mountains to the east of the Chiang Mai to Fang highway have received little, if any, spelæological study.

GLOSSARY OF THAI TERMS.

Tham	Cave	*Doi*	Mountain
Huai	River or stream	*Nong*	Lake or marsh
Ban	Village		

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