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Helictite

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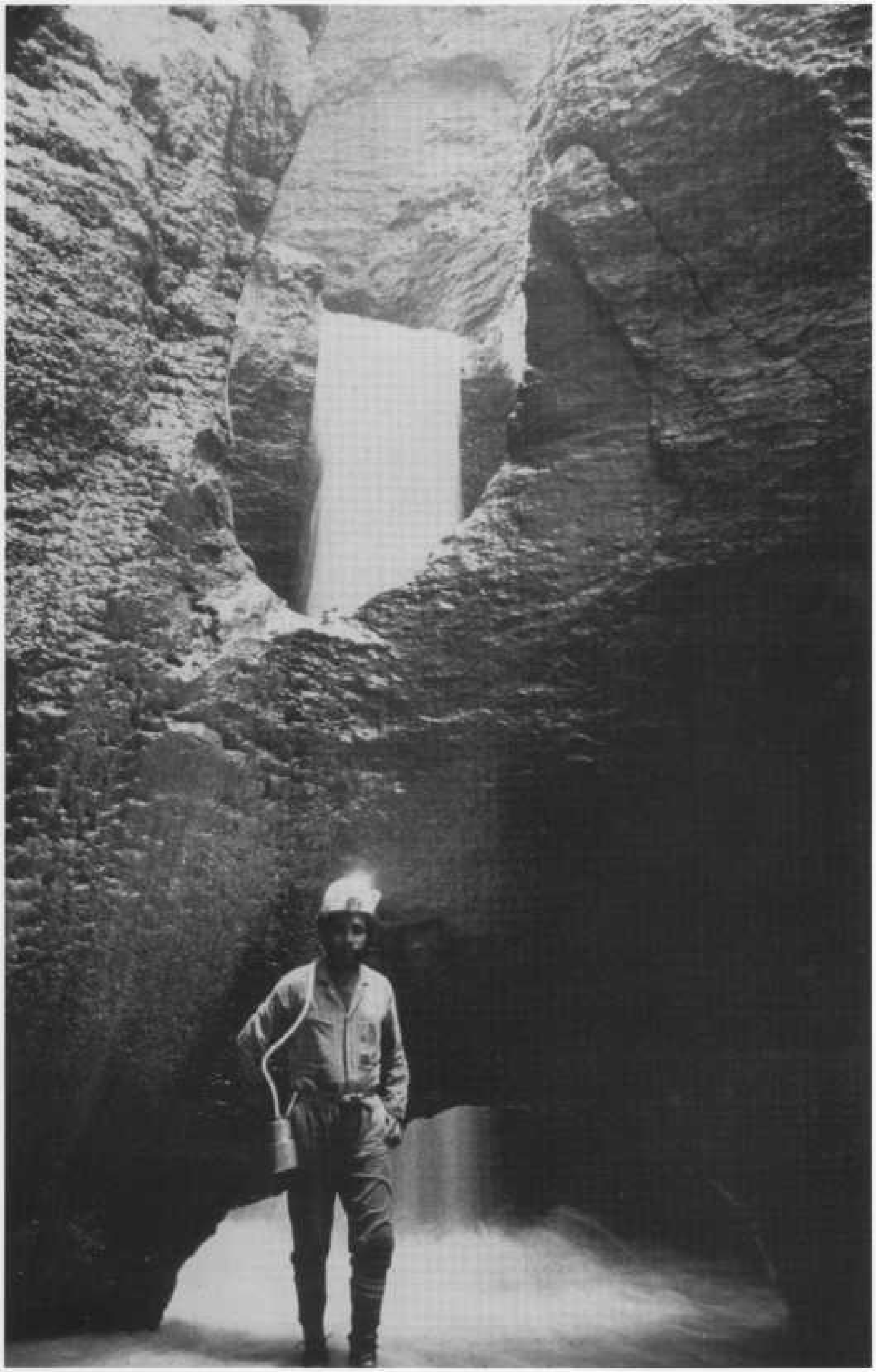

M. Bonwick

Waterfall entrance LV16 to Ok Bedda Cave

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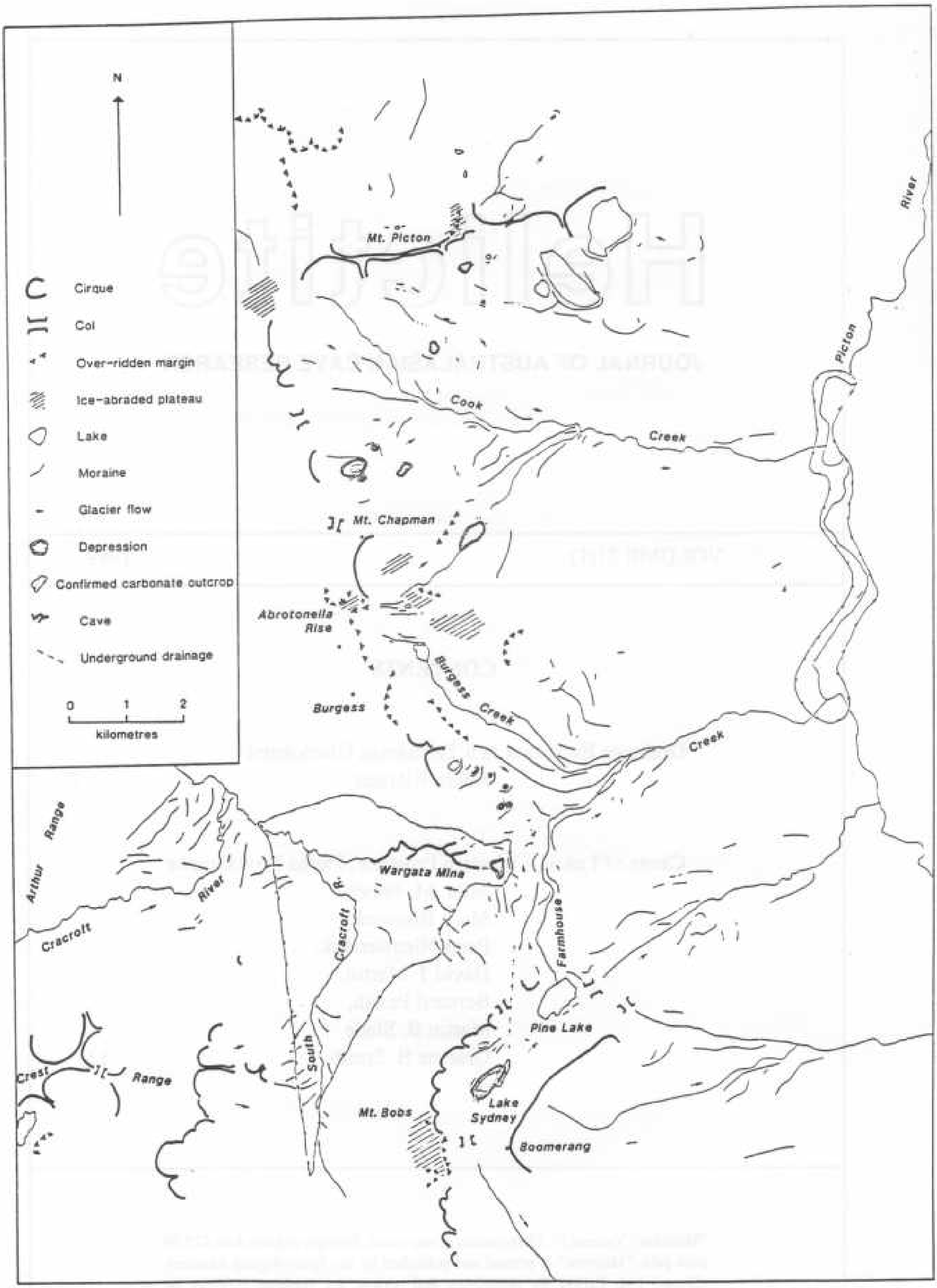

Figure 1. Reconnaissance map of karst and glacial features in the Picton Range - Mt. Bobs area, southwestern Tasmania.

DRAINAGE EVOLUTION IN A TASMANIAN GLACIOKARST.

Kevin Kiernan

Abstract

The intensively glaciated mountains of the Picton Range - Mt. Bobs area in southwestern Tasmania contain prominent karst features that have been developed in carbonate formations of Devonian, Ordovician and possibly Precambrian age. This paper reviews the extent of the karst and glacial features and records the tracing of the underground drainage from the alpine Lake Sydney. Glacial erosion has exposed areas of limestone to karstification and glacial diversion of drainage has played a critical role in the evolution of the present underground drainage patterns. Prior to the late Last Glacial Stage the deflection of marginal meltwaters from the former Farmhouse Creek Glacier against the Burgess - Bobs Saddle led to the development of an underground breach of a major surface drainage divide. Subglacial or submarginal meltwaters associated with a much smaller glacier that developed in the same valley during the late Last Glacial Stage probably played a significant role in the breaching of a minor divide within the Farmhouse Creek catchment. This led to the development of an underground anabranch of Farmhouse Creek that by-passes the glacial Pine Lake. However, it is possible that the latter diversion is entirely Holocene in age and is related to postglacial dilation of the limestone rather than meltwater flows.

INTRODUCTION.

Karst caves may be among the longest lived landforms in many alpine landscapes and, as a result, they commonly provide evidence of palaeoenvironmental conditions of considerable antiquity (Ford *et al.*, 1981). In Tasmanian alpine environments that were subject to glaciation during the late Cainozoic ice ages this legacy may include evidence of speleogenesis related to the considerable volumes of meltwater generated beneath and adjacent to glaciers or to postglacial dilation of bedrock; cave sediments laid down by meltwater or sometimes by ice; or an isotopic record of palaeoclimate contained in speleothem carbonates (Jennings and Sweeting, 1959; Kiernan, 1982, 1983, 1984).

The Picton Range and Mt. Bobs Range lie in the Southern Forests area of southwestern Tasmania. The mountains are capped by Jurassic dolerite and Permo-Triassic sedimentary rocks that overlie carbonate formations of Devonian, Ordovician and possibly Precambrian age. The ranges stretch north-south and are drained by streams that flow eastwards to the Picton River and westwards to the South Cracroft and Cracroft rivers (figure 1). The highest points along the range are Mt Picton (1327 m) in the north, Mt. Chapman (1088 m), Abrotanella Rise (1023 m), Anderson Bluff (1092 m) Burgess Bluff (1082 m) and Mt. Bobs (1111 m). An outlying ridge known as the Boomerang (1081 m) is present 1 km east of Mt. Bobs.

The present mean annual rainfall in the area probably varies from over 1700 mm on the summits to a little over 1000 mm on the valley bottoms. Annual mean maximum and mean minimum temperatures at the Hastings Chalet station, 24 km southeast of

Mt. Bobs, are 15.9 C and 5.8 C respectively. Estimated mean annual discharge from the Picton River is 516 X 106m³ (SWTRS, 1978). There is considerable variety in the biokarstic environment. The diverse vegetation of the area has led to the area being recognised as worthy of World Heritage status (Helsham *et al.*, 1988). Eucalypt forests are widespread in the valleys. Mt Bobs is the only area in Australia where a transition from mature rainforest to true alpine communities survives on all apects of a mountain rather than simply on fire sheltered slopes. A highly significant alpine community is present on this mountain and there are also very diverse alpine and subalpine forests due to climatic, topographic, geologic and geomorphic variability and highly infrequent fire (Kirkpatrick, 1987a,b). Thick scrub and sedgeland are present in the South Cracroft Valley and elsewhere. Hence, there is also only limited geomorphological visibility in some areas.

Detailed geological maps are not yet available. However, Ordovician limestone crops out extensively on the slopes of the range east of the South Cracroft River forming an outcrop at least 6 km long (Dixon and Sharples, 1986). This limestone extends across the saddle between Burgess Bluff and Mt. Bobs into the catchment of Farmhouse Creek, a tributary of the Picton River (Goede, 1977). Ordovician limestone also crops out on the floor of the Picton Valley downstream of Farmhouse Creek (Eastoe, 1976). An eastward dipping sequence of crinoidal and bryozoal limestone ~119 m thick occurs on the northeastern shoreline of Lake Sydney. This was initially regarded as Odovician limestone metamorphosed close to the dolerite sill that caps Mt. Bobs, but it has since been reinterpreted as being Devonian in age (Correy, 1983). Further north along the eastern flank of the range there are at least nine flat-floored amphitheatres or enclosed depressions. Some of these hint at the possibility of further carbonate outcrops (Kiernan, 1987a). The largest depression lies just east of Abrotanella Rise in the apparent catchment of Cook Creek and is formed in carbonate bedrock that may be Precambrian dolomite (A. McNeil, pers. comm.). While some of these depressions are probably the result of glacial erosion or deposition, others are undoubtedly karstic and some may have resulted from both glacial and karstic processes.

KARST GEOMORPHOLOGY

The most conspicuous confirmed karst landform is an 18 ha enclosed depression that contains Lake Sydney at ~676 m at the head of Farmhouse Creek. Another sinkhole only slightly smaller in size lies at ~85 m below the Burgess - Bobs Saddle in the Farmhouse Creek Valley. Its floor lies at ~450 m altitude (Collin, 1973) (figure 1). The depression east of Abrotanella Rise is ~21 ha in extent and 60 m deep.

The best known streamsink lies at the eastern end of Lake Sydney and is developed in styolitised biomicrite (Correy, 1983). This engulfs the water from Lake Sydney, and also some smaller streams from the adjacent hills, one of which passes through a small natural arch. The main inflow cannot be entered by humans because it is largely blocked by sediment, but it is possible to get undergound for a very short distance through a nearby hole that gives access to a short length of stream passage with limited air space. Although a considerable volume of water flows into this streamsink the capacity of the underground channel is insufficient to evacuate the winter rains. Hence, the streamsink becomes sub-lacustrine for part of the year. The resulting dramatic fluctuations of water level in the enclosed depression and to a lesser extent in Lake Sydney itself have given rise to a rare and important vegetation community that may also be of evolutionary interest due to the interaction between marsupial grazers and native plants in an unusual hydrological context (Kirkpatrick and Harwood, 1986; Kirkpatrick and Tyler, 1987; Kirkpatrick, 1987). Sinkhole formation is very active in the glacigenic sediments that overlie the limestone at the lake outlet.

A smaller streamsink occurs several hundred metres to the northeast of Lake Sydney in the same belt of limestone. This engulfs a tributary stream from the slopes of The Boomerang. Other streamsinks are present in the sinkholes below the Burgess - Bobs Saddle and east of Abrotanella Rise. Examination of aerial photography of the area southeast of Burgess Bluff in the Farmhouse Creek catchment suggests further streamsinks may be present there, but these have yet to be confirmed on the ground. Initial impressions suggest that some of the apparently enclosed depressions in this area are likely to be hollows behind small terminal moraines.

Only one significant outflow has been recorded to date. This discharges from Wargata Mina (previously known as Judds Cavern), a multilevel stream cave the exit from which lies at ~290 m asl on the eastern margin of the South Cracroft Plain. About 3 km of passages have been explored in Wargata Mina (S. Eberhard, pers.comm.), the upper levels of which contain thick deposits of fossil clastic sediment that includes coarse gravel. The cave lies just inside the limestone margin of a valley that descends from the Burgess - Bobs Saddle towards the South Cracroft River. A number of smaller caves have been explored in the vicinity of Wargata Mina. Uranium series assay of speleothem carbonate that overlies gravel in Matchlight Cavern, 20-40 m above the present level of the Wargata Mina stream indicates that the clastic sediment there predates 189 ka BP and possibly 231ka BP (Goede and Harmon, 1983). Hence, some of the gravels were not deposited more recently than isotope stage 6, globally defined (Colman and Pierce, 1981), and may reflect torrential streamflows during isotope stage 8 or even earlier.

KARST HYDROLOGY

Water tracing reported by Goede (1977) has shown that the streamsink east of the Burgess - Bobs Saddle forms a tributary of the Wargata Mina stream. The drainage breaches the divide underground and emerges on the surface 2.5 km distant and 130 m lower. The test was performed using 3 kg of fluorescein and the transit time was was between 11 hours and 13 hours. Yet this streamsink alone is insufficient to account for the volume of water that discharges from Wargata Mina. An additional source that has been suggested in caving circles in the past has been the Lake Sydney streamsink which lies 390 m above Wargata Mina and 4.5 km to the south (Household and Davey, 1987). However, at least four other possible destinations for the Lake Sydney water appeared to exist. These include the possibility of resurgence into Pine Lake, which lies 1.5 km downstream from Lake Sydney, somewhere further down Farmhouse Creek or in the valleys that extend eastwards and northeastwards from Pine Lake.

An initial attempt was made to inject fluorescein into the Lake Sydney streamsink on 21 September 1987 during the course of helicopter-supported archaeological fieldwork in the South Cracroft Valley. An activated charcoal detector was successfully installed on lower Farmhouse Creek but heavy rain, very severe turbulence and poor visibility prevented access by air to Lake Sydney. This meant that the planned visual watch for fluorescein at Wargata Mina during the course of the other fieldwork had to be replaced by the installation there of another charcoal bag in anticipation of later injection of the fluorescein at the lake. This bag was placed close to the confluence of the Wargata Mina stream with the South Cracroft River where it could be readily recovered by a brief helicopter stop at a later date. In anticipation of the streamsink now being totally flooded beneath the lake, and therefore being inaccessible for ground-based fluorescein injection, a fluorecein bomb was prepared for dropping from the helicopter while hovering over the lake above the approximate position of the streamsink. This comprised 1 kg of pre-dissolved fluorescein in a small thin plastic bag that also contained a rock both to ensure rupture of the bag and to maximise the likelihood of the bag being carried to depth in the lake such that at least some concentrated fluorescein would be released as close as possible to the lake-bed. The fluorescein bomb was dropped from a height of ~15 m at 10:15 am, 24 September 1987. Disturbance of the water surface by the downdraft from the helicopter rotor rapidly dispersed the colour over an area ~10 m in diameter.

An aerial inspection on the morning of 26 September 1987 revealed no visual evidence of fluorescein in Lake Sydney, Pine Lake or adjacent streams. A charcoal bag recovered from the Wargata Mina stream proved negative. A second bag installed on the Wargata Mina stream and the bag from lower Farmhouse Creek were recovered by helicopter one week later. Initial examination of the decant revealed no evidence of fluorescein in either sample, either under plain light or ultra-violet light. However, while the water that flows from Wargata Mina is clear, Farmhouse Creek is strongly discoloured by tannin derived from the vegetation. This raised the possibility that, particularly given the very severe dilution likely to have ocurred in the waters of Lake Sydney, any fluorescein potentially present in the detector may have been masked by biogenic leachates retained in the activated charcoal. Spectrophotmetric analysis susequently demonstrated that fluorescein was indeed present in the Farmouse Creek sample and confirmed that it was absent from the Wargata Mina bag. These results indicate that the Lake Sydney water does not flow to Wargata Mina but resurges somewhere along the course of Farmhouse Creek. The underground drainage almost certainly by-passes Pine Lake given that the small amount of the fluorescein used would probably not have been detectable if diluted in the waters of a second lake. The second streamsink below The Boomerang is probably integrated with the drainage system from Lake Sydney.

To check the possibility that the base flow from Lake Sydney might discharge directly into Pine Lake with only a peak flow component by-passing the latter lake fluorescein was again injected into the Lake Sydney streamsink on 16th January 1988 with the stream at low stage. No evidence of fluorescein was detected at Pine Lake. There are two further pieces of circumstantial evidence. Firstly, the slightly higher pH of the Lake Sydney water (6.92) than that of Pine Lake (6.47) may reflect that the water in Pine Lake has less contact with limestone than does the water in Lake Sydney. Secondly, in contrast to Pine Lake, Lake Sydney appears to be devoid of large fish, and contains high numbers of aquatic fauna likely to form a food source if a significant fish population was present (G. Shiel, pers. comm.). This contrast may reflect, at least in part, that there is no direct drainage connection between the two lakes.

GLACIAL GEOMORPHOLOGY

The Picton Range forms a major snowfence that stretches across the path of the prevailing westerly winds. This has given rise to intensive glaciation during the glacial periods of the late Cainozoic (Derbyshire *et al.*, 1965). Figure 1 provides an interpretation of some of this glacial legacy, based on aerial photography, helicopter inspection of some of the features and limited ground survey.

The most prominent erosional landforms are cirque basins formed along the leeward eastern flank of the range, and small U-shaped glacial troughs that include the upper Farmhouse Creek Valley between Mt. Bobs and the Boomerang and the valley of Burgess Creek, a major southeastward flowing tributary of Farmhouse Creek. Small areas of glaciated plateau occur atop Mt. Bobs, near the summit of Mt Picton and elsewhere (Colhoun and Goede, 1979). Small rock-basin lakes are present in some areas.

The largest alpine lakes are at least partly impounded behind cirque moraines. Lake Sydney is dammed by a moraine at its downstream end, the stream cascading into the streamsink over the 10 m high ice-distal face of this moraine. The streamsink has been formed in an intra-morainal swale that has been partly filled by rhythmically-bedded glaciolacustrine clays. These clays are up to 4 m thick and if they are true varves they would imply that the ice margin lay close to this position for over 1000 years. Rhythmites are also present at the lake outlet. The glacial deposits at Lake Sydney overlie a bedrock limestone topography with a relief of at least 10m.

Some of the possibly enclosed depressions on the eastern flank of the South Picton Range may be poorly developed cirques or may have resulted from the deposition of end moraines across the valleys. Large lateral moraines and till deposits extend down the eastern flank of the range to below 280 m asl and possibly down Cook Creek almost to its confluence with the Picton. Till deposits that lack a morainal expression are present below 300 m in the Cook Creek Valley. Dolerite boulders that are probably glacigenic occur down the length of the Farmhouse Creek Valley where definite till is also present (Colhoun and Goede, 1979). Weathered till deposits are overlain by slope deposits at ~200 m asl on the ridge between Farmhouse Creek and Cook Creek. Glacial features are less readily discernible on the eastern side of the range but low ridges on the floor of the South Cracroft Valley below the Burgess - Bobs Saddle may be degraded moraines (Goede, 1977; Gillieson and Taylor 1980). Sharp-crested lateral moraines extend to ~240 m asl close to the confluence of the Cracroft and South Cracroft rivers from the Federation Peak area to the west (Kiernan, 1987a). Other possible moraines reach close to the floor of the South Cracroft from elsewhere in the Eastern Arthur Range and the Crest Range.

THE PATTERN AND HISTORY OF GLACIATION

The distribution of glacial landforms and glacigenic sediment indicates that cirque and valley glaciers developed on the leeward slopes of the Picton-Bobs Range and the Eastern Arthur and Crest ranges further to the west. One of the largest of the mountain glaciers extended down the Farmhouse Creek Valley with another major valley glacier in the Cook Creek Valley to the north. A major valley glacier that flowed down the Picton Valley was probably responsible for deposition of the till at ~200 m asl between Farmhouse Creek and Cook Creek (Colhoun and Goede, 1979) although this sediment could have been deposited by the Farmhouse Glacier during an early phase if the ice cover was very extensive. The extent of glaciation in the South Cracroft Valley is uncertain. The degree to which ice flowed down the western slope of the Picton Range is also unclear. Glacial landforms are not conspicuous on the steep western flank of the range despite their prominence on the gentler eastern slopes. On the other hand, till deposits and meltwater channels occur transverse to the Burgess - Bobs Saddle where the Farmhouse Glacier emerged from the glacial trough between Mt. Bobs and the Bomerang and turned eastwards down the valley. These indicate that the Farmhouse Glacier reached very close to the divide and raise the possibility of ice having once spilled through the saddle from the ice margin.

There is clear evidence for more than a single phase of glaciation having occurred. Post-depositional modification of glacial landforms and sediments permits broad differentiation and correlation of features related to different episodes of glaciation. Although detailed analysis of the glacial legacy in the Picton Range - Mt Bobs area is not yet available, previous research into other areas in Tasmania has produced strong evidence for at least three and possibly as many as six glaciations having taken place between the late Pliocene or early Pleistocene and the late Last Glacial Stage (Kiernan, 1983, 1988; Colhoun, 1985; S.J. Fitzsimmons, pers. comm.). The oldest deposits are generally heavily weathered and the glacial landforms very degraded. Features of more recent age generally retain a readily discernible topographic expression while those of late Last Glacial age tend to be topographically fresh and the deposits largely unweathered.

The presence of fresh moraine forms and unweathered till indicate that during the late Last Glacial Stage the Farmhouse Glacier reached as far downstream as Pine Lake (Colhoun and Goede, 1979). Meltwater would have been discharged down Farmhouse Creek and into the valleys that extend eastwards and northeastwards from Pine Lake. Fresh moraines further north along the range probably also indicate the maximum ice limit of the late Last Glacial Stage and suggest that the Equilibrium Line Altitude (ELA) lay at ~700 m. They generally lie well inside glacial troughs carved by earlier glaciers and in some cases are restricted to the cirques from which much larger glaciers once emanated.

The weathered tills that are widespread in the area indicate that the ice cover was much more extensive during earlier episodes of glaciation prior to the late Last Glacial Stage. This is consistent with evidence from elsewhere in Tasmania which suggests that the extent of the ice cover during the late Last Glacial maximum was generally less than 20% of that attained earlier during the late Cainozoic glaciations (Colhoun and Goede, 1979; Kiernan, 1983, 1985; Colhoun, 1985). The probability of a diffluent lobe of the Farmhouse Glacier having spilled through the Burgess - Bobs saddle when the ice was more extensive during the earlier glaciations is compounded by the likelihood that ice flow down the upper reaches of the Farmhouse Creek Valley would have been slowed both by the right-angle bend in its course adjacent to the Saddle and also by the discharge from the tributary Burgess Glacier.

DISCUSSION - GLACIOKARSTIC DRAINAGE EVOLUTION.

Glaciation has played a prominent role in facilitating and encouraging karstification in these mountains, and on the evolution of some elements of the underground drainage. Glacial erosion has exposed areas of carbonate rock to weathering and erosion at Lake Sydney, near Abrotanella Rise and possibly elsewhere. It has also probably accentuated stripping of the non-carbonate rocks that overlie the limestone in the middle reaches of the Farmhouse Creek Valley. In addition, glaciers have also generated large volumes of meltwater that have facilitated solution of the limestone. This meltwater contained many lithic tools that facilitated mechanical erosion.

There is now additional evidence to support earlier speculation that glacial diversion of drainage may have occurred (Goede, 1977, Gillieson and Taylor, 1980; Kiernan, 1982). The till and meltwater channels on the eastern side of the Burgess - Bobs Saddle indicate that marginal meltwater would have been decanted against the divide thereby encouraging solutional attack on the Ordovician limestone. This situation is rather similar to the decanting of meltwater from the margin of glaciofluvial fans envisaged by Jennings and Sweeting (1959) as having been important in speleogenesis at Mole Creek in northern Tasmania. The much steeper hydraulic gradient into the South Cracroft Valley than down the Farmhouse Creek Valley would have further encouraged westward flow of the groundwater through the surface divide between the two drainage systems. On the other hand, although this divide is breached underground by at least some of the drainage that discharges from Wargata Mina it has now been confirmed that the water which sinks at Lake Sydney remains part of the Farmhouse Creek drainage system. The most likely course that would permit this while by-passing Pine Lake is northwards along the strike of the Devonian limestone. A sequence of non carbonate rocks ~53 m thick underlies the Devonian limestone at Lake Sydney (Correy, 1983). This probably forms an aquiclude that prevents the penetration of the Lake Sydney water into the karst systems developed in the Ordovician limestone.

The extent of cave development at Wargata Mina, the demonstrated age of the cave sediments and the limited ice cover in these mountains during the most recent episode of glaciation all point to the diversion of drainage through the Picton - South Cracroft divide having been initiated not later than the middle Pleistocene. If an ice lobe spilled westwards through the Burgess - Bobs Saddle then meltwater is likely also to have been decanted against the northern flank of the valley that descends from the Saddle towards the South Cracroft River . The location of the Wargata Mina passages just inside this flank of the valley is consistent with the possibility that marginal meltwaters may also have played a role in defining the broad geometry of the cave system. Resolution of this question must await further work on the relationship between glacigenic sediments, meltwater channels and the cave passages on the western side of the divide.

The limited capacity of the underground conduit from Lake Sydney hints at a comparatively recent age. However, although it is subject to flooding under wet conditions a significant amount of water is accomodated by this outlet. If the Lake Sydney drainage follows the strike of the Devonian rocks northwards it is likely to regain the surface not far beyond Pine Lake and within the area that was covered by ice at the time the Wargata Mina drainage was diverted. The development of a resurgence beneath the sole of a glacier seems unlikely given the probability of confining ice pressures and basal meltwater pressures generally being high, although it is not impossible. However, the resurgence seems more likely to date from a time when ice was absent from that part of the valley. This suggests it formed either under interglacial conditions or when the glacier terminus lay further upstream. Initiation of the streamsink may have been encouraged by the presence of ice blocking the narrow valley outlet beyond Pine Lake during the late Last Glacial Stage and by a steep hydraulic gradient from the glacier surface. It is conceivable that the Lake Sydney streamsink is a pre-late Last Glacial karst feature filled by glacigenic sediment and now being re-excavated, with the accessible passage segments in bedrock being essentially paragenetic. This would be consistent with the substantial base flow that it is able to accomodate, the preglacial relief of the limestone surface and the considerable collapse activity in the general area. However, development of the Lake Sydney conduit may be a wholly Holocene phenomenon.

Whatever the age of the conduit, glaciation has played a prominent role in the evolution of the underground drainage from Lake Sydney. Firstly, it was stripping of the covering rocks by glacial erosion that exposed the Devonian limestone to weathering and erosion. Secondly, glacial depositon was responsible for impounding water at the site where the streamsink developed. Thirdly, bedrock dilation following the removal of previously superincumbent rock or ice would have facilitated solutional opening of the limestone.

An understanding of the drainage of this area has important land management implications. In addition to its geomorphological importance, Wargata Mina is significant for its fauna which, although as yet little studied, is already known to include at least one troglobitic species (S. Eberhard, pers. comm.). It is also a very significant archaeological site that contains the southernmost ice age art on earth and is the first site in the world where blood has been shown to be a component of the ochre used to produce rock art (Jones *et al.*, 1988). The area appears to be the only glaciokarst yet recorded from southern temperate latitudes where a major legacy remains of ice-contact karst evolution during glaciations earlier than that during the latest Pleistocene (Kiernan, 1987). Although the Lake Sydney water does not flow to Wargata Mina it is evident from earlier work that at least one breach of the major surface drainage divide does exist and recent exploration in the far upstream limits of Wargata Mina has revealed the existence of two further tributary streams. These may also breach the divide, possibly from the upper Burgess Creek area. This is an important consideration in view of the likely impacts of any land-use changes in the Farmhouse Creek catchment. These include the possibility of alterations to the hydrological regime and sedimentation conditions further downstream that may adversely affect Wargata Mina.

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CAVES OF LUKWI - WESTERN PROVINCE, PAPUA NEW GUINEA.

Julia. M. James, Mark Bonwick, Peter Nieuwendyk, David J. Martin,
Bernard Pawih, Martin B. Slade and Graeme B. Smith.

Abstract

In this paper the caves of the Lukwi valley in the Western Province of Papua New Guinea are introduced. The caves were explored in January, May and June 1985 at the request of Ok Tedi Mining Limited. Seventy seven karst features are described and are located on a surface map of the Lukwi valley. Surveys of the major caves are presented. Descriptions of the caves include geological, geomorphological, hydrological and biological observations. The quality of the Lukwi Caves is assessed relative to other known caves in Papua New Guinea.

INTRODUCTION

Lukwi Caves are in the Western Province of Papua New Guinea. Figure 1 shows their location with respect to Tabubil and the Ok Tedi (Ok is the word for river in the Min language) gold and copper mine at Mount Fubilan. Exploration of the Lukwi Caves was initiated by Ok Tedi Mining Ltd (OTML). Lukwi is the area along the banks of the Ok Ma between its junction with the Ok Mi in the north and its junction with the Ok Dui in the south. The Lukwi karst was investigated in January, May and June 1985 by the authors of this paper. There had been a previous expedition to the Ok Tedi area (White,1977) but it did not extend to the Lukwi karst.

At the commencement of exploration several cave entrances were known at Lukwi but there had been no recorded entry into these. The exploration and documentation of the Lukwi karst was completed by June with two reports being prepared for OTML (James *et al.*, 1985 a,b). The exploration of the karst was greatly assisted by having available the resources of a large mining organisation. The support for caving was excellent and there was complete elimination of the hardships encountered on previous Australian expeditions to PNG (James. 1974, James *et al.*, 1977, James and Dyson. 1980 and James *et al.* 1983). Tropical rainforest prospecting for caves, caving and associated scientific studies were pleasurable and rewarding. The Lukwi Karst was investigated in January, May and June 1985.

Some 500 karst features on, and in, a 5 km^2 area produced 25 caves containing some 7.0 km of passage, of which 4.5 km has been surveyed (Appendix 1). The clearing of the rain forest for surveying, drilling, and seismic investigations made searching for cave entrances difficult in some locations. On the other hand, the results of these investigations were invaluable both for predicting where there were likely to be caves, and in subsequent correlations and interpretations of observations made in the caves. It is unusual to have such high quality information available for cave exploration, and this was the major factor in achieving so much explored and surveyed cave passage in a comparatively short time. In addition, the exploration of the caves at Lukwi was greatly assisted by the exceptionally dry conditions in both January and May. The low water levels enabled parts of the caves that would normally be flooded to be safely explored.

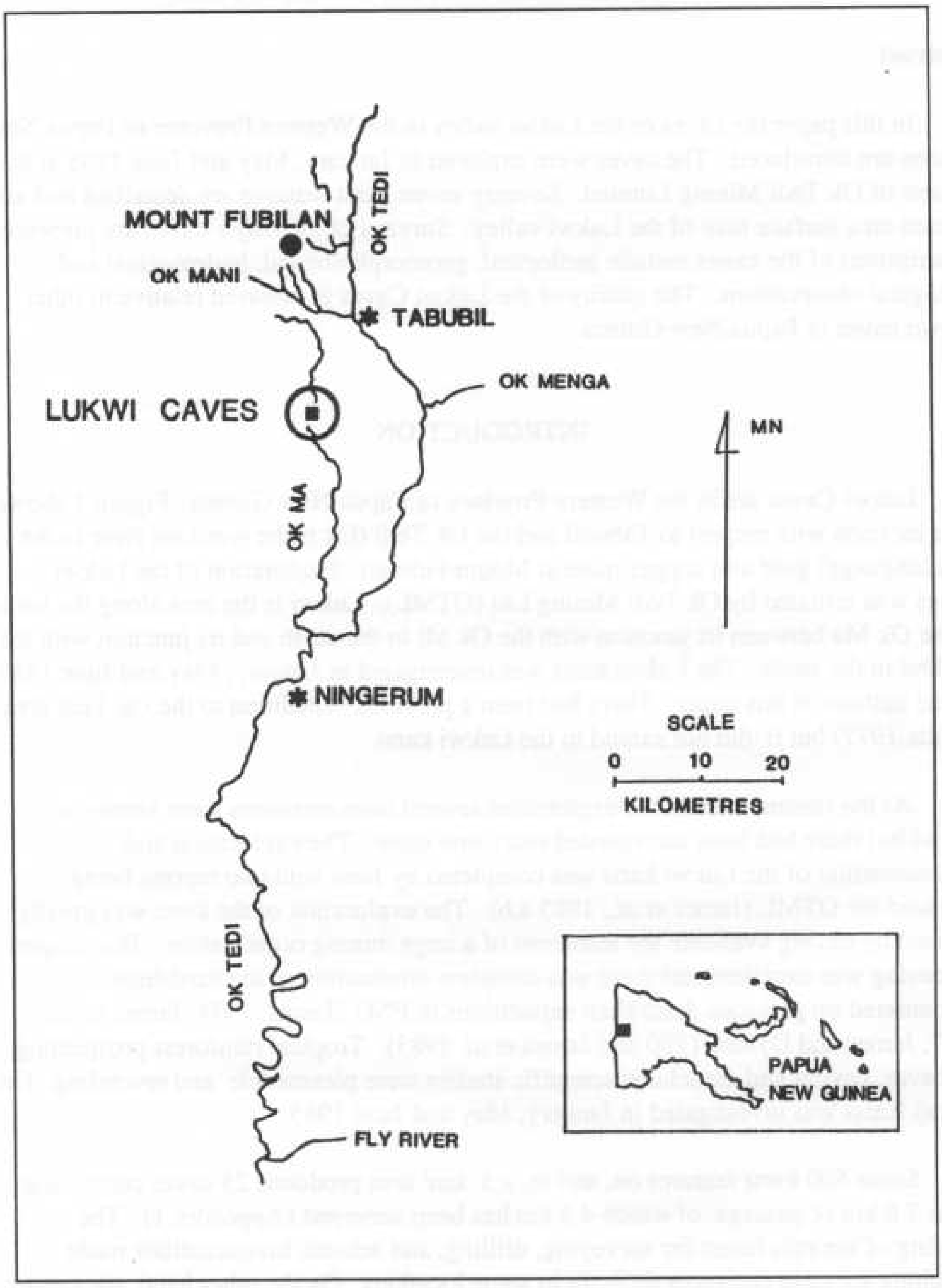

Figure 1. The location of Lukwi Caves

REGIONAL EVIRONMENT

Relief

The Lukwi karst lies in a valley of the Ok Ma whose non karst topped ridges rise to over 600 m asl. The highest caves in the area have entrances at 410 m asl "LUKWI CAVES". The sides of the valley above the karst are steep but the karst forms gently sloping plateaux bordered on the river side by cliffs. The Ok Ma flows along the 320 m contour giving Lukwi caves a depth potential of less than 100 m.

Climate

The Lukwi climate falls into the classification Lowland perhumid (with an annual precipitation of 3500 mm) (McAlpine et al.,1983). The precipitation for 1984 was measured as 8400 mm per year (R. Wallwork pers. comm.). Evaporation for such a perhumid climate is expected to be in the order of 1400-1800 mm per annum. These numbers indicate that there will be a mean annual water surplus of some 6000 mm, making Lukwi one of the wettest caving areas ever studied. The resultant hydrology and water chemistry from such a high runoff will be the subject of a later paper (James and Martin, in prep.). The expected range of temperature in the Lukwi area is between 20 - 30 C and the cave temperature was 24 C. The rainfall regime seems to show some seasonality - but without climatic figures it is difficult to establish which is the dry 'wet' and which is the wet 'wet'. It is currently impossible to predict what would be a 'safe' season for further exploration of Lukwi caves.

Vegetation

The Lukwi vegetation is typical lowland tropical rainforest; its composition and density appears to be similar on both the limestone and the non karst rocks. It contains some magnificent trees with trunks up to 1 m in diameter, 30 - 40 m high and with a luxuriant canopy. Throughout the Lukwi area where there is original forest, the light undergrowth is easy to negotiate. The ridge crests have heavier forest than the side slopes but still can be negotiated without cutting track. The cleared areas have a dense regrowth that is extremely dificult to negotiate and prospect for caves. On the sandy and rocky banks and beds of the rivers and streams, that are subjected to a brief sudden flooding by fast running water grows a flood resistant shrub. This shrub has horizontal branches spreading in the direction of the stream flow and narrow willow-like leaves and are firmly anchored by a wide spreading root system. The limestone bed of the Ok Dui which floods more regularly has less permanent vegetation and mosses, ferns and Impatiens feature.

GEOLOGY

A more complete geology of Lukwi will appear in this journal.

Stratigraphy

The Lukwi area is developed on three distinct Neogene stratigraphic units, the Era beds, the Orubadai Beds and the Pnyang Formation (figure 2). These Neogene sequences of carbonates and clastics are gently folded and faulted. There are three limestone units which have developed surface karst features and are cavernous at Lukwi. Two of these are in the Orubadai beds and the other is the Warre Limestone member of the Pnyang.

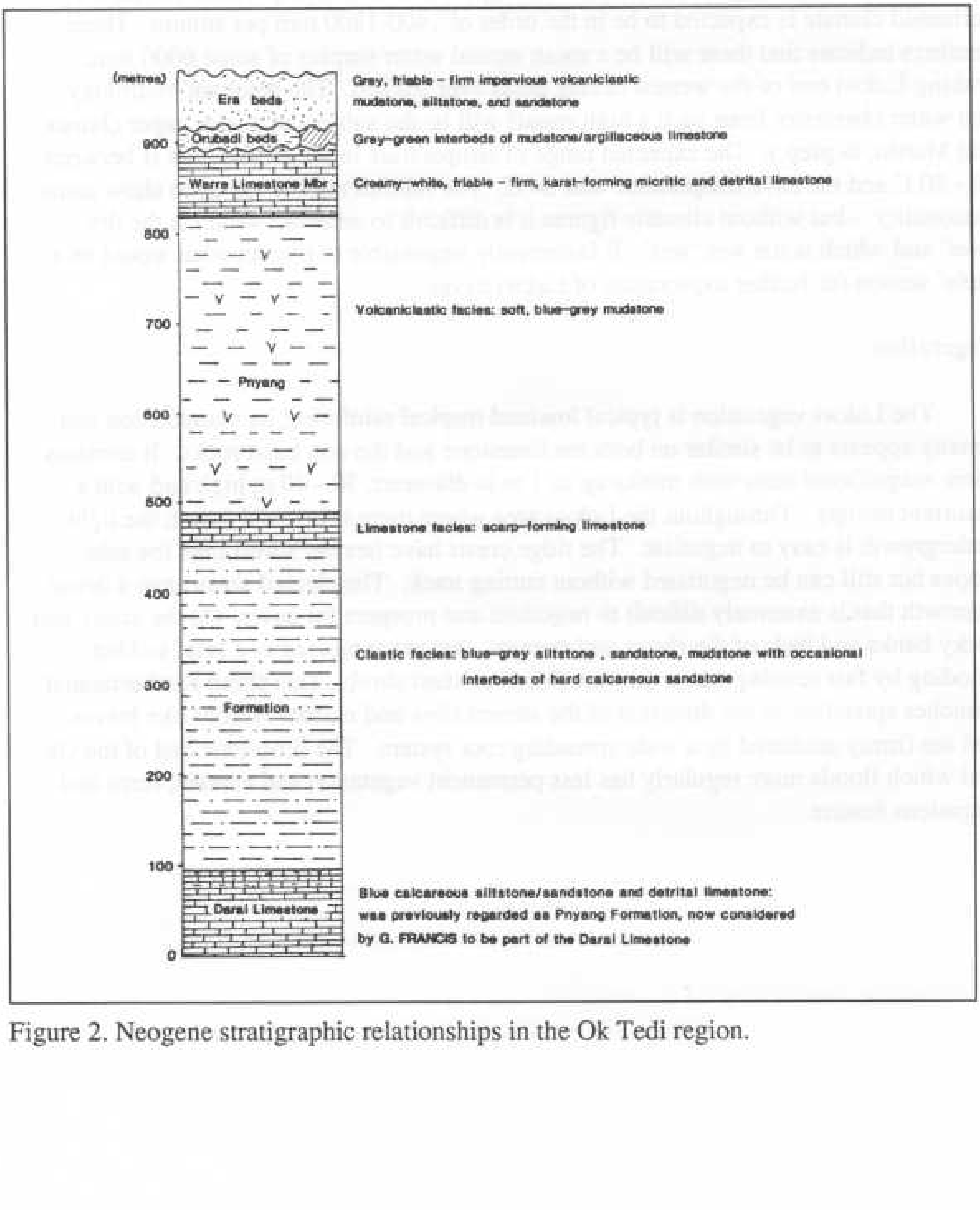

Figure 2. Neogene stratigraphic relationships in the Ok Tedi region.

Warre Limestone Member

This limestone is 65 - 85 m thick throughout the Lukwi area. It is creamy white to yellowish grey, massive, medium to fine grained, calcareous, fossiliferous (containing coral, bryozoa, algae, molluscs and some tuffaceous materials) moderately hard to moderately soft where leached, micritic and detrital limestone. It dips gently upstream in a northeasterly direction, with dips rarely exceeding 10^0. The subordinate sandy/silty and conglomeratic interbeds occur at about 20 - 30 m above the base. The Warre Limestone contains all of the large caves at Lukwi.

Structure

There are two prominent joint sets trending at 40^0 and 120^0 these control the morphology of the surface karst features and the caves. There is an easterly dipping synclinal trough in the Ok Mi valley and there is an anticline the crest of which is either in or slightly to the north of the Ok Dui Valley. Both of these major fold structures have influenced the development of the caves

KARST SURFACE GEOMORPHOLOGY

Lukwi karst is the first on the Warre Limestone and Orubadai beds to be studied in detail.

Karst type

The Lukwi karst can be classified as both a fluviokarst and a shallow karst. The major features of the Lukwi karst have developed as a result of surface stream flow despite the perviousness and solubility of the limestone. The dominant karst feature at Lukwi is the canyon of the Ok Ma, this valley perfectly illustrates the principle of fluviokarst. The Ok Ma arrives at the edge of the Warre Limestone with a considerable volume of water (average flow approximately 19 m^3s^{-1}, (Klohn Leonoff, 1984) and does not appear to lose any of this into its bed. The Warre Limestone has gently sloping beds only 60 - 85 m thick and its less pervious beds are exposed by erosion near its base. The springs are close to local base level and there are simple hydrogeological relationships at Lukwi all characteristics of a shallow karst.

Major karst forms

The karst surface underlain directly by the Warre Limestone has a variety of surfaces. It has areas of dolines and corridors, areas of dolines on colluvium, areas of cliff breakdown on colluvium and crevice karst. The dominant karst form at Lukwi is the crevice karst. Crevice karst occurs both on the surface of the Orubadai limestones and on the Warre limestone. On the Orubadai limestones it is limited to small areas with the crevices cutting right through the limestone beds on the Warre Limestone there are large areas of crevices extending back from the cliff tops. In this paper all features associated with open joints will be called crevices. Crevice karst is a surface which consists largely of a network of crevices. The depth of the crevices is highly variable with the deepest visibly open crevices being close to cliffs or where there is a streamsink. Other major karst features on the Warre and Orubadai limestones are gorges, canyons, dry valleys and blind valleys, the common feature on the Orubadai beds being semi-blind valleys.

Minor karst forms

The Lukwi karst is largely covered by rainforest and typically small scale solution features are limited. Limited numbers of solution ripples, solution runnels and solution wall runnels were found.

THE PEOPLE OF LUKWI AND THEIR USE OF CAVES.

There are no villages on the Lukwi karst, and there does not appear to have been any in the past. There are two village several kilometres from Lukwi inhabited by Ningerum people, the traditional owners of the landrights of Lukwi (Jackson, 1984). There was not time to approach the inhabitants to see if they had names for the larger caves or if they would translate the names for the newly discovered caves. There are a number of tracks in regular use in the area, major ones that follow the courses of the Ok Mi, the Ok Ma and the Ok Dui. These avoid the karst if possible.

Parts of the Lukwi area have been cultivated in the past and wild taro is found throughout the area. Near the exploration camps on some of the recently cleared areas a variety of vegetables have been planted and appear to thrive. There are a number of sago palm stands on swampy ground. In some of the stands are found the remains of the bark troughs used for kneading and washing the sago pith. The sago plants take about 8 - 15 years to mature (Powell, 1976) and harvest visits to the various Lukwi sago groves will be very intermittent. The Ningerum people bury the bones of their dead in rock crevices (Jackson, 1984) and we were warned to anticipate such anthropological remains in the caves. The caves are largely unsuitable for either habitation or burials and any contents would have long been flushed out of most of them. Evidence of human use was found in the caves of the Ok Mi system. (Appendix 1, LV1, LV2, LV3). In these caves at all levels there are climbing poles and wedged perches in narrow sections. They have been placed there by the fruit bat (flying fox) hunters who balance on the perches armed with whips. The whip is made from a straight cane to which is atttached numerous tails of a particularly nasty clinging creeper . The whip is lunged at the passing bats who become trapped in its tails.

Ok Bedda cave is a tourist attraction at present for the more adventurous Tabulbil residents. The Ok Mi cave system if it were in a more accessible part of the world and less prone to reqular flooding could be developed into a first class tourist cave. Its riverways, decorated passages and huge chambers are superb. All the other caves at Lukwi are only of interest to the sporting caver, and then they are relatively insignificant in both size and depth.The longest cave at Lukwi other than the Ok Mi cave is 610 m and the deepest is 61 m. The caves around Tabubil in the Darai limestone are deeper, longer and larger than those found in the Warre limestone at Lukwi (White, 1977).

CONCLUSION

Most of the cave at Lukwi has been found, but there are still holes that have not been entered and cave entrances that will not yet have been so there are prospects for further discoveries.If Lukwi is typical, the potential for cavern development in the Warre Limestone is great and other areas of it are worthwhile prospecting for caves. Caves developed in this Limestone member of the Pnyang Formation should make a significant contribution to the total cave length in Papua New Guinea.

ACKNOWLEDGEMENTS

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APPENDIX 1

KARST FEATURE DESCRIPTIONS

Karst Feature Locations: Using established Australian practice, the karst features at Lukwi have been given a code number consisting of LV for Lukwi valley and an arabic numeral. This enables the significant karst features to be located and referred to in the text without having to name them. The locations of the karst features are given in Table 1. The locations of the karst features in the central area of the Lukwi are shown on Figure 3. Those associated with the Ok Dui and Ok Mi are shown on Figure 4. Silhouettes of the cave passages are shown on both Figures 3 and 4. Cave maps are attached where the caves have been surveyed.

Underground Surveying Techniques: The instruments used in underground surveying wereSuunto compasses read to the nearest degree, Suunto PB5 clinometers read to the nearest degree and fibreglass tapes read to the nearest 0.1 m. Survey stations were located to the nearest 0.1 m. For some distances between 15 and 50 m an optical range finder (Ranging Inc. Optometer 620) was used. These instruments were calibrated using Arman Larmer survey stations.

Radio Direction Finding Techniques: The radio direction finding apparatus used was built by M. Bonwick and P. Nieuwendyk. It was a modernised version of a system designed by P.Wellings of the Sydney Speleological Society in 1965. This apparatus works on magnetic induction principles and for positioning directly above the transmitting coil has a horizontal accuracy of +/- 1 m for the 0-60 m depth range encountered at Lukwi.

Random errors are inherent in a cave survey due to instrument reading and station positioning tolerances. These tend to cancel out as the survey progresses and their magnitude may be determined for a given traverse. Irwin and Stenner (1975) have produced a set of curves which relate traverse length and mean leg length to random error for various grades of survey precision. The expected random error may be termed a standard deviation. In order to allow for the effects of systematic errors and undetected minor gross errors Irwin and Stenner suggest, from an analysis of actual survey misclosures, that plan errors should not exceed three standard deviations and vertical errors two standard deviations. Applying the methods used by Irwin and Stenner to the surveying tolerances used at Lukwi a standard deviation of 1.45 m is obtained for the 501 m traverse to the sump in Swiftlet Cave. Radio direction finding techniques were used to confirm the surface point above the sump in Swiftlet Cave.

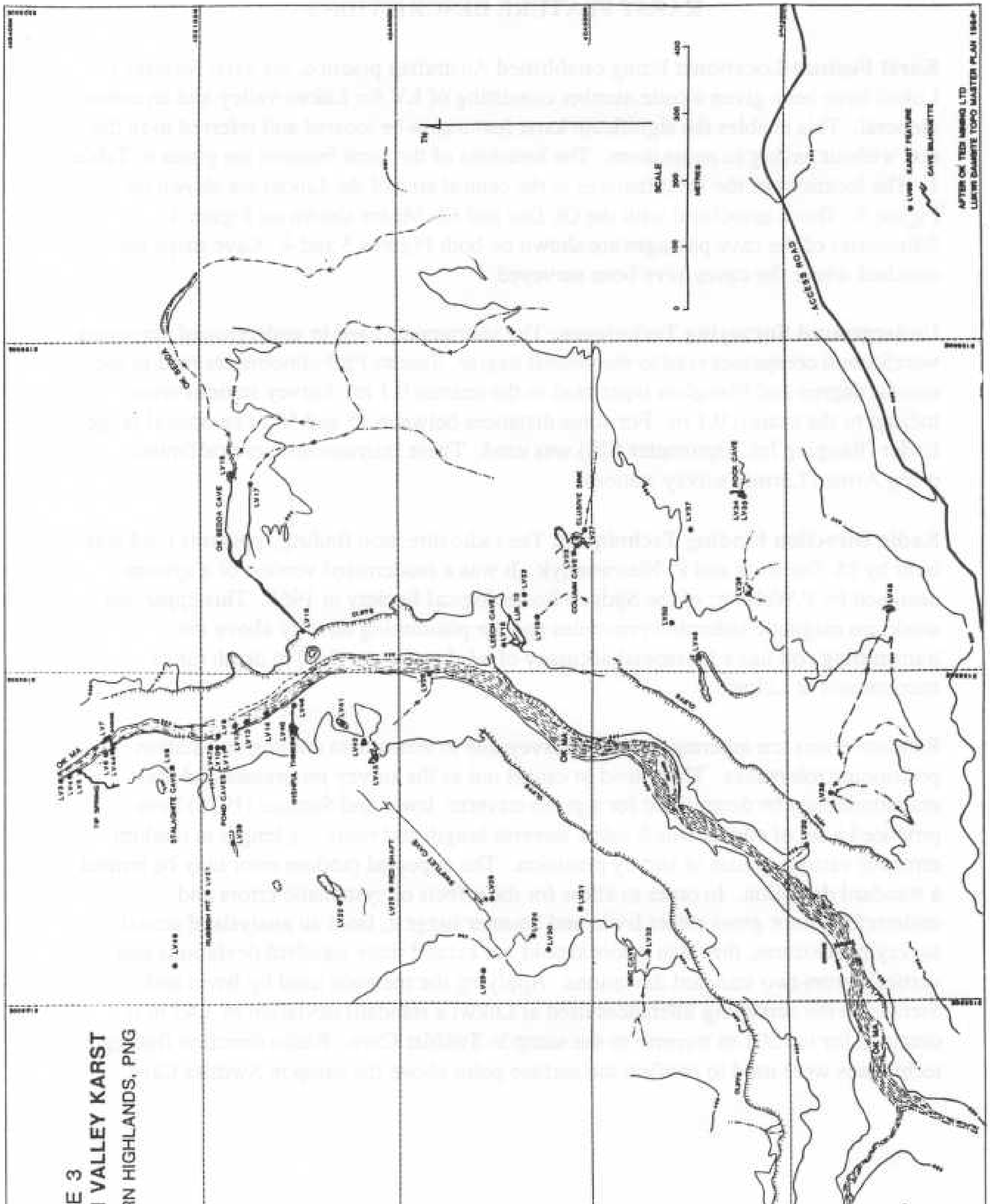


FIGURE 3
LUKWI VALLEY KARST
WESTERN HIGHLANDS, PNG
ACCESS ROAD
SCALE
METRES

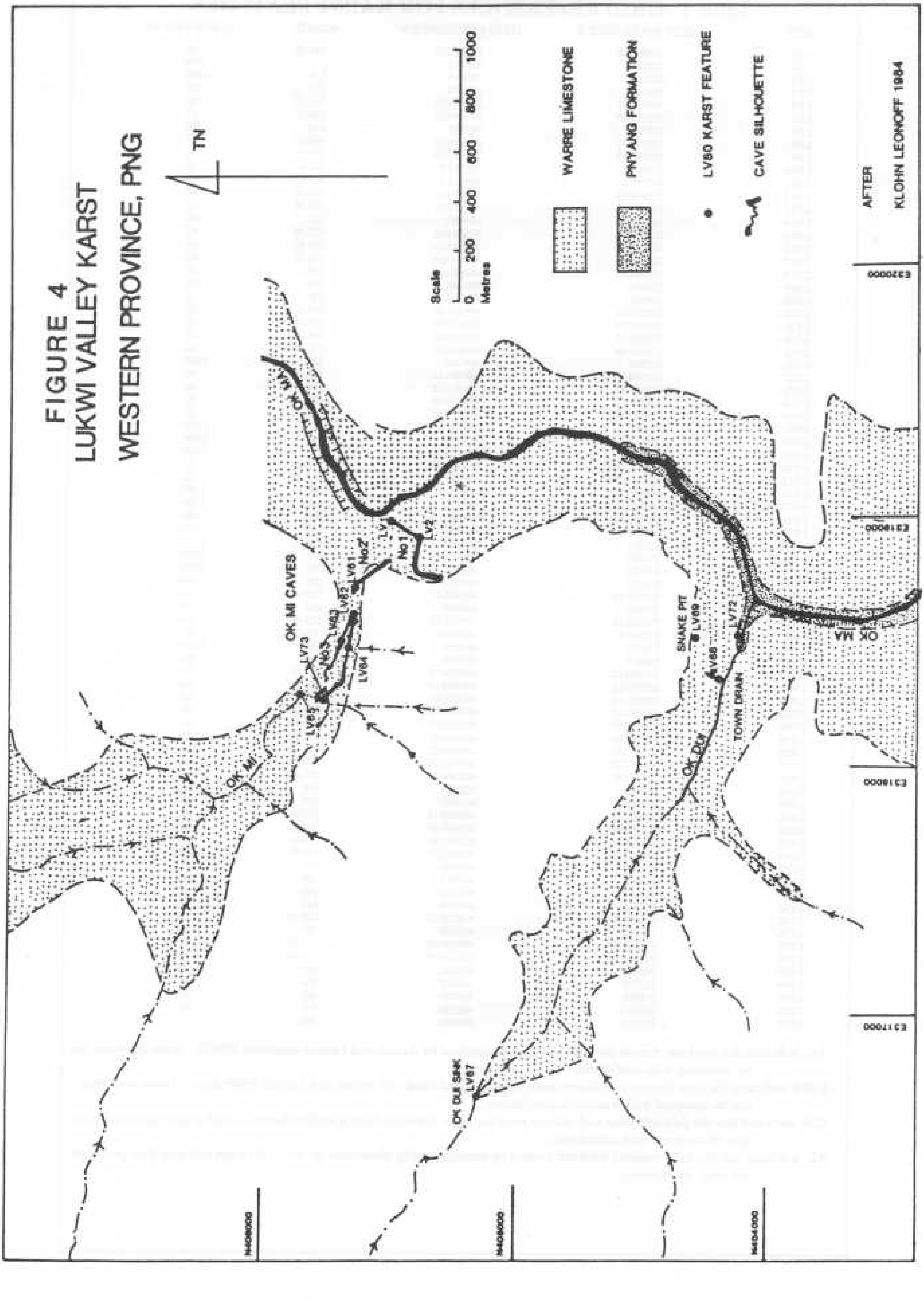


FIGURE 4
LUKWI VALLEY KARST
WESTERN PROVINCE, PNG
TN
Scale
0 200 400 600 800 1000
Metres
WARRE LIMESTONE
PNYANG FORMATION
LV80 KARST FEATURE
CAVE SILHOUETTE
AFTER
KLOHN LEONOFF 1984
OK MA
OK MI CAVES
LV1
LV2
No 1
No 2
LV61
LV62
LV63
LV73
LV64
LV65
OK MI
SNAKE PIT
LV69
LV72
LV68
TOWN DRAIN
OK DUI
OK DUI SINK
LV67

Table 1 GRID REFERENCES FOR KARST FEATURES

SITE	GRID REFERENCE E	GRID REFERENCE N	RL/ASL	SURVEYED BY
LV1	318964.74	405510.07	323.06	AL
LV2	318915	405416	-	CM
LV3	319158	405294	319	1:500
LV4	319164	405279	319	1:500
LV5	319170.16	405264.32	321.53	AL
LV6	319184.48	405246.27	319.24	AL
LV7	319202	405239	319	1:500
LV8	319147.61	405136.17	345.86	AL
LV9	319196.35	405077.43	319.48	AL
LV10	319169.3	405047.8	324.9	AL
LV11	319170.6	405042.3	325.6	AL
LV12	319238.33	404994.83	318.06	AL
LV13	319245.18	404978.61	318.56	AL
LV14	319257	404960	318	NL
LV15	319354.74	404943.06	322.74	AL
LV16	319598.16	405049.26	341.64	AL
LV17	319557.96	405002.45	345.15	AL
LV18	319342.6	404631.9	328.2	AL
LV19	319380	404580	356	1:500
LV20	319040	404175	320	AL
LV22	318956.44	404891.34	375.21	AL
LV23	318976.78	404807.69	378.55	AL
LV24	318899.49	404590.23	386.66	AL
LV25	318963.44	404655.91	377.41	AL
LV26	319300	404750	320	1:500
LV27	319502.15	404492.42	369.16	AL
LV28	319469.94	404511.18	361.34	AL
LV29	318850.58	404669.06	407.25	AL
LV30	318893.54	404568.42	388.16	AL
LV31	318945	404520	392	1:500
LV32	319415	404600	368	1:500
LV33	318875	404415	390	1:500
LV34	319551.34	404263.99	412.23	AL
LV35	319547.28	404266.23	411.52	AL
LV36	319420	404260	398	1:500
LV37	319520	404350	398	1:500
LV38	319110	404140	355	1:500
LV39	319040	405050	360	1:500
LV40	319233	404940	340	1:500
LV41	319220	404875	344	1:500
LV42	319195	404850	350	1:500
LV43	319170	404835	350	1:500
LV44	319187.99	405242.9	318.98	AL
LV45	319390	404045	405	1:500
LV46	319258.90	404935.63	323.68	AL
LV47	319169.6	405089.3	327.3	AL
LV48	319320	404336	375	1:500
LV49	318810	405235	370	NL
LV50	319364.12	404374.73	383.45	AL
LV51	319195.22	405204.14	325.41	AL
LV52	319544.14	404504.07	372.33	AL
LV53	319561.19	404557.68	374.70	AL
LV54	319190.02	405239.32	318.78	AL
LV55	319387.24	404461.61	375.29	AL
LV56	319382.62	404419.47	380.14	AL
LV57	319379.78	404423.48	379.59	AL
LV58	319307.91	404381.84	371.66	AL
LV59	319203	405093	318	NL
LV60	319202	405087	318	NL
LV61	318697.58	405646.14	336.74	AL
LV62	318599.32	405657.66	340.24	AL
LV63	318479.56	405697.96	352.85	AL
LV64	318451.79	405672.85	355.42	AL
LV65	318290	405860	335	NL
LV66	319513	404811	356	1:500
LV67	316625	405170	440	NL
LV68	318345	404196	342	1:500
LV69	318498.75	404326.62	422.19	AL
LV70	319740	404860	350	NL
LV71	319062.37	404353.30	315.33	AL
LV72	318499.58	404109.74	316.48	AL
LV73	318236	405732	345	CM
LV74	319333	404606	350	AL
LV75	318960	404720	385	AL
LV76	319175	404790	355	AL
LV77	318530	405630	360	

AL indicates that the karst feature position has been determined by Arman and Larmer surveyors (PNG). These positions can be accepted with confidence.

1:500 indicates the karst feature coordinates have been obtained from the Arman and Larmer 1:500 maps. These positions can be accepted with reasonable confidence.

CM indicates that the grid reference and relative level has been obtained from a surface datum using the cave survey. These can be accepted with confidence.

NL indicates that the karst features were not located by surveying or by placement on the 1:500 maps and thus their positions are very aproximate.

LV1 OK MI CAVE NUMBER 1 (Flying Fox Cave), Figure 5, (Length 350 m)
LV2 DAYLIGHT HOLE IN OK MI CAVE NUMBER 1 (LV1)

The entrance to Ok Mi Cave is a 8 m high arch above a deep stream pool which flows to the Ok Ma. Beyond the entrance is a vadose river passage 2-5 m wide with a 5-8 m water depth which follows a major joint. After 110 m there is a daylight hole, LV2, and the direction of the riverway changes in order to follow another joint. At this point a small stream enters from a narrow joint. The riverway continues to follow the new joint for about 130 m; remnants of a phreatic tube can be seen in the roof. At the end of this section the riverway has no apparent current. The direction of the passage changes again and the roof is low; there is evidence that the river frequently completely fills this passage.
After 30 m there is a muddy oxbow in the east wall which gives access to a further series of deep pools. In this section a small stream enters. The passage possibly continues beyond the limit of exploration, but there is only O.5 m of airspace. The Ok Mi Cave passage in this area is epiphreatic.

The exploration of Ok Mi Cave took place during the relatively dry conditions of January 1985. when the flow from the entrance was measured as O.8 m^3. The clean-washed scalloped cave walls indicate that enormous flows must pass through this cave. Caution is required when visiting Ok Mi Cave Number 1 as it is expected to respond rapidly to rainfall and flashflood. An added danger is that when the Ok Ma is high it backfloods the cave (P. O'Brien, pers comm).

Throughout Ok Mi Cave flying foxes roost, and small bats were found in the muddy oxbow. Visible in the river waters are fishes, crabs and shrimps.

LV3 AND LV4 SPRINGS

These springs are in the bed of the Ok Ma. They rise in Warre Limestone beds.Water tracing has shown that one of the water sources for these springs is the stream in Rubbish Pit, LV21.

LV5 TIP SPRING, Figure 6 (Length 90 m)

This is a resurgence cave with water issuing from its entrance only in periods of normal and high flow. In periods of normal and low flow the cave can safely be entered. At the entrance there is a 1.5 m climb which gives access to a vadose streamway. The walls of the streamway are clean and scalloped indicating that there are frequent large water flows through this passage. Water tracing has shown that the stream in Rubbish Pit, LV21, is one of the sources of water in this cave.

After 8 m the stream passage divides for a few metres; during periods of low flow the water in the cave sinks through a hole in the floor of the smaller branch. Beyond this the cave passage contains a series of wading pools. At one point where the roof is low, the explorer is required to swim for a few metres (plate 1). Directly above the swimming section is an abandoned passage which provides a dry alternative for competent climbers. After the swim there is a small chamber with an alcove containing breakdown on its east side. The streamway continues for another 10 m until a sump prevents further exploration. The floor of the sump descends at about 30° in a southerly direction for at least 2.5 m. The sump walls are lined with a fine coating of mud, the only sediment to be found in the cave. A small passage close to the sump trending east is only negotiable for a few metres. Also from the sump region a passage back to the small chamber has developed parallel to the streamway.

LV6 SPRING

A large spring in the bed of the Ok Ma whose waters issue from beds of Warre Limestone. Water tracing has shown that one of its sources is the stream in Rubbish Pit, LV21.

LV7 SPRING

A small spring in the bed of the Ok Ma. Its waters emerge just below normal river level from beds of Warre Limestone. The source of water is unknown. In May 1985 there was no visible flow from this spring.

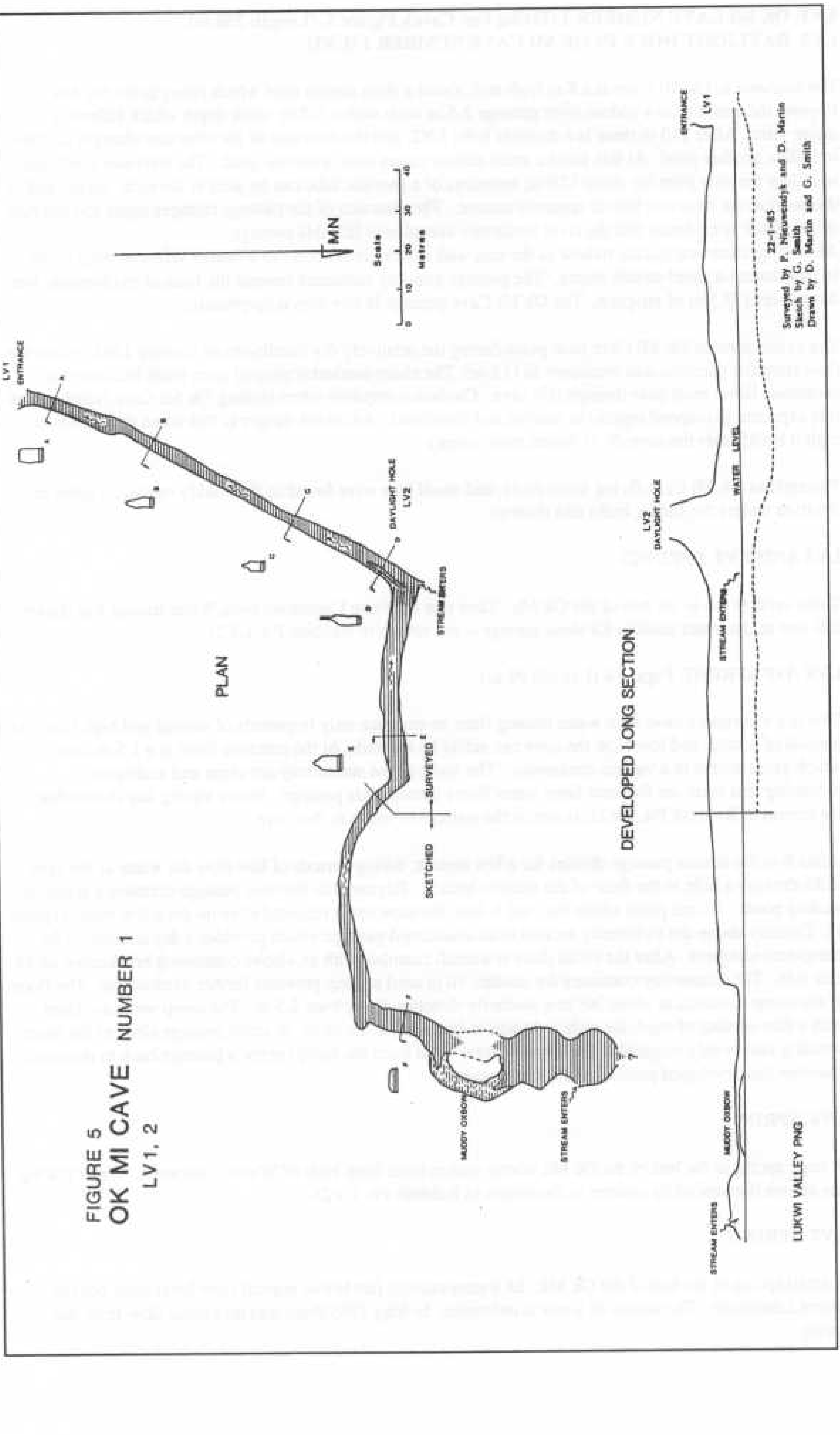
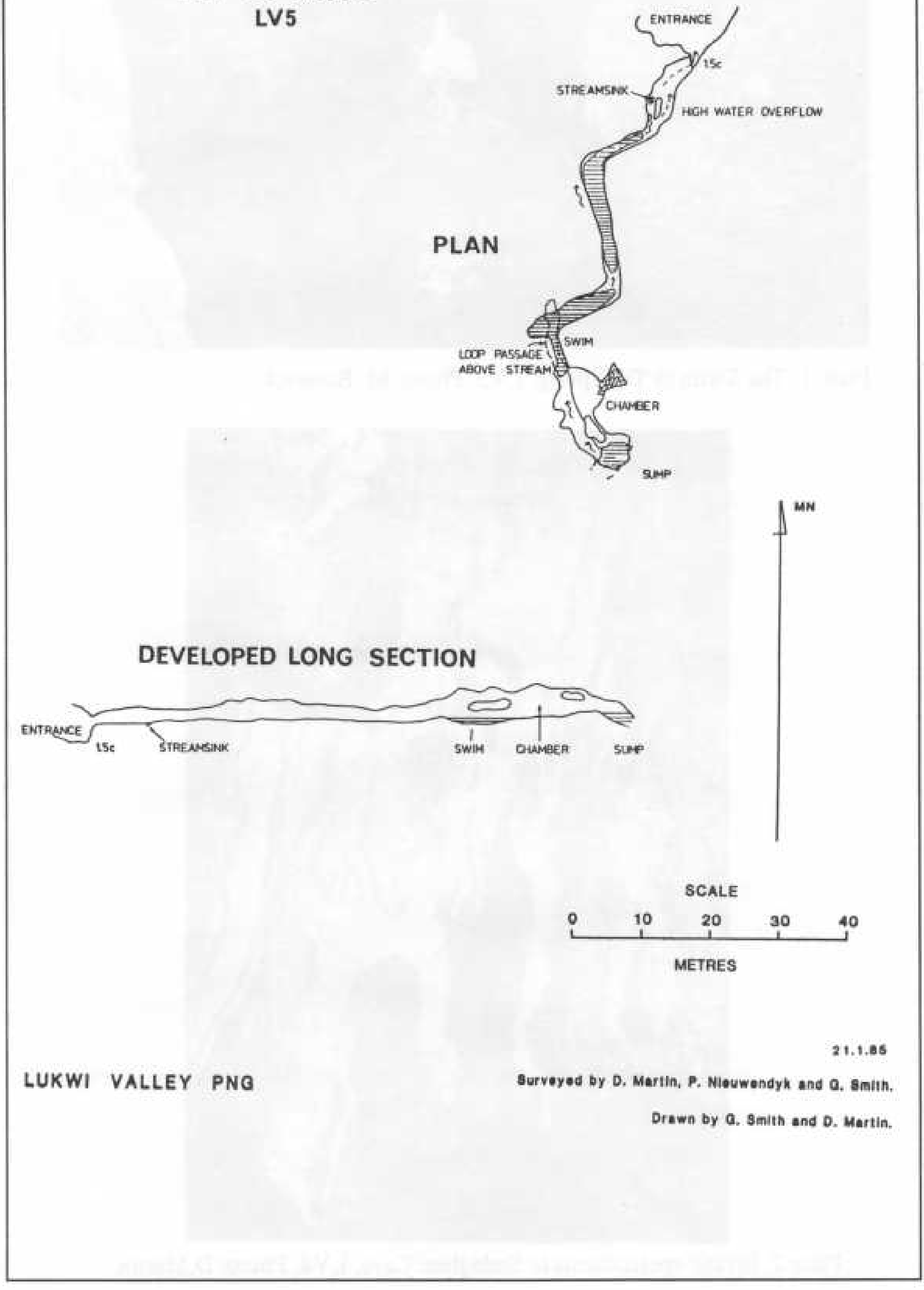


FIGURE 5
OK MI CAVE NUMBER 1
LV1, 2
PLAN
LV1 ENTRANCE
DAYLIGHT HOLE LV2
STREAM ENTERS
MUDDY OXBOW
SKETCHED
SURVEYED
MN
Scale
0 10 20 30 40
Metres
DEVELOPED LONG SECTION
WATER LEVEL
LUKWI VALLEY PNG
22-1-85
Surveyed by P. Nieuwendyk and D. Martin
Sketch by G. Smith
Drawn by D. Martin and G. Smith

FIGURE 6
TIP SPRING
LV5



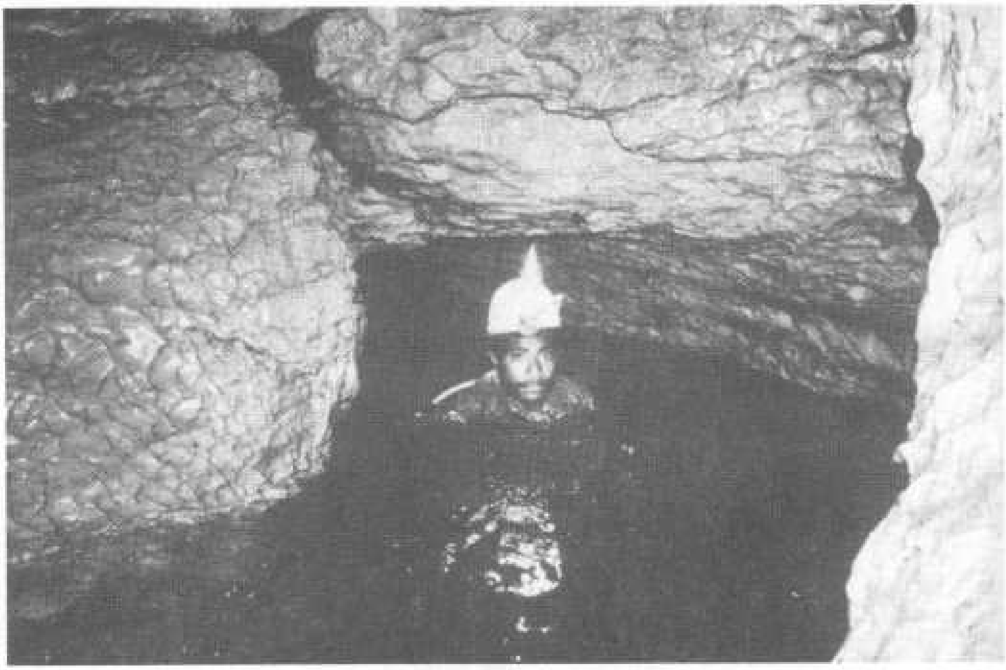


Plate 1. The Swim in Tip Spring, LV5. Photo: M. Bonwick

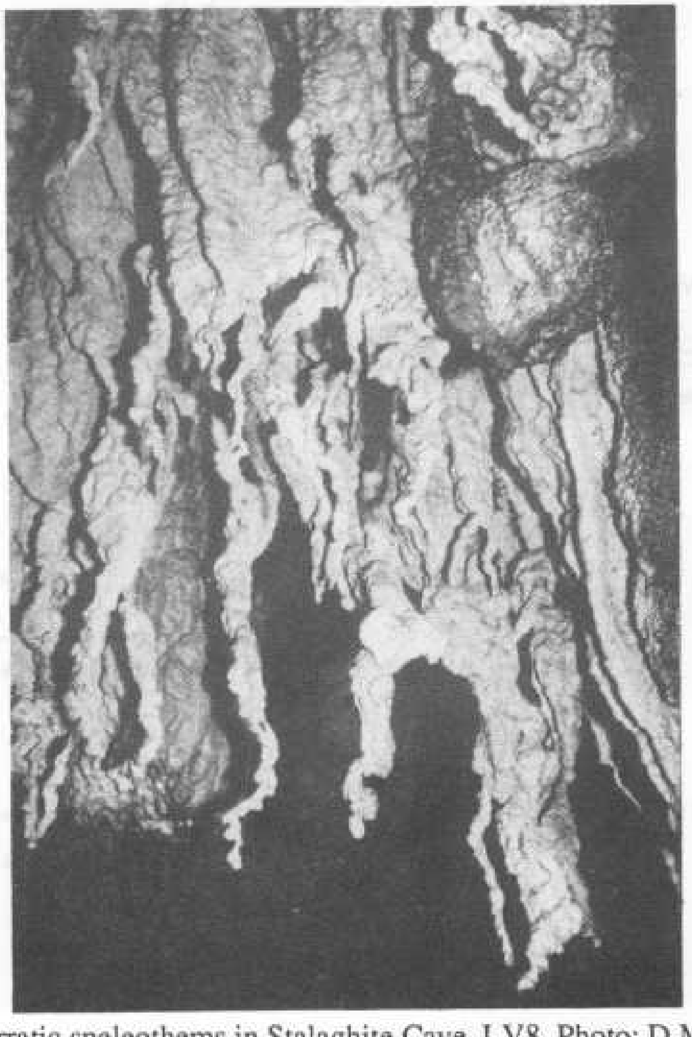


Plate 2. Erratic speleothems in Stalaghite Cave, LV8. Photo: D.Martin.

LV8 STALAGHITE CAVE (Warren's Cave) (Length 30 m, Depth 10 m)

Stalaghite cave is named after the unusual speleothems it contains which are a cross between stalactites and helictites (plate 2). The 9 m shaft entrance requires a 15 m rope to reach a horizontal passage which extends 11 m to a squeeze in the north-west corner of the cave passage, this squeeze led to a 4 m continuation of the entrance rift. A stream can be heard clearly at roof level over a flowstone blockage in the north-west corner. Directly below the blockage a small vertical tube in the floor can be descended for 3 m until it becomes impassable. During heavy rain the cave collects water from a small catchment, which drains out of it through boulders at the base of the entrance shaft. The cave is in Warre Limestone.

LV9 CAMP WATER SPRING

This spring consists of a number of smaller springs emerging from below several metres of colluvium. The waters in the spring come from two caves at the foot of the cliff, Pond Caves 1 and 2, LV10 and LV11. Water tracing has shown that one source of water is Rubbish Pit, LV21 and a second source is Camp Water Sink, LV22.

LV10 AND LV11 POND CAVES 1 & 2

Pond Caves 1 and 2 are both part of what was once a large resurgence cave. A cliff fall from above this cave has blocked the entrance separating the one cave into two. Both are short 4-5 m sections of cave passage which end in sumps. The normal water flow from the caves finds a route out through the rockfall at the LV10 entrance. High flow floods out of the cave entrances and over the rockfall. At high water levels the Ok Ma floods into the caves. Water tracing experiments indicate that there is a considerable volume of water held back by the cliff fall.

LV12, LV13 AND LV14 SPRINGS

These are subaqueous springs; they all emerge below the low water level of the Ok Ma. They were located by fluorescein plumes in the Ok Ma during the water trace from LV10.

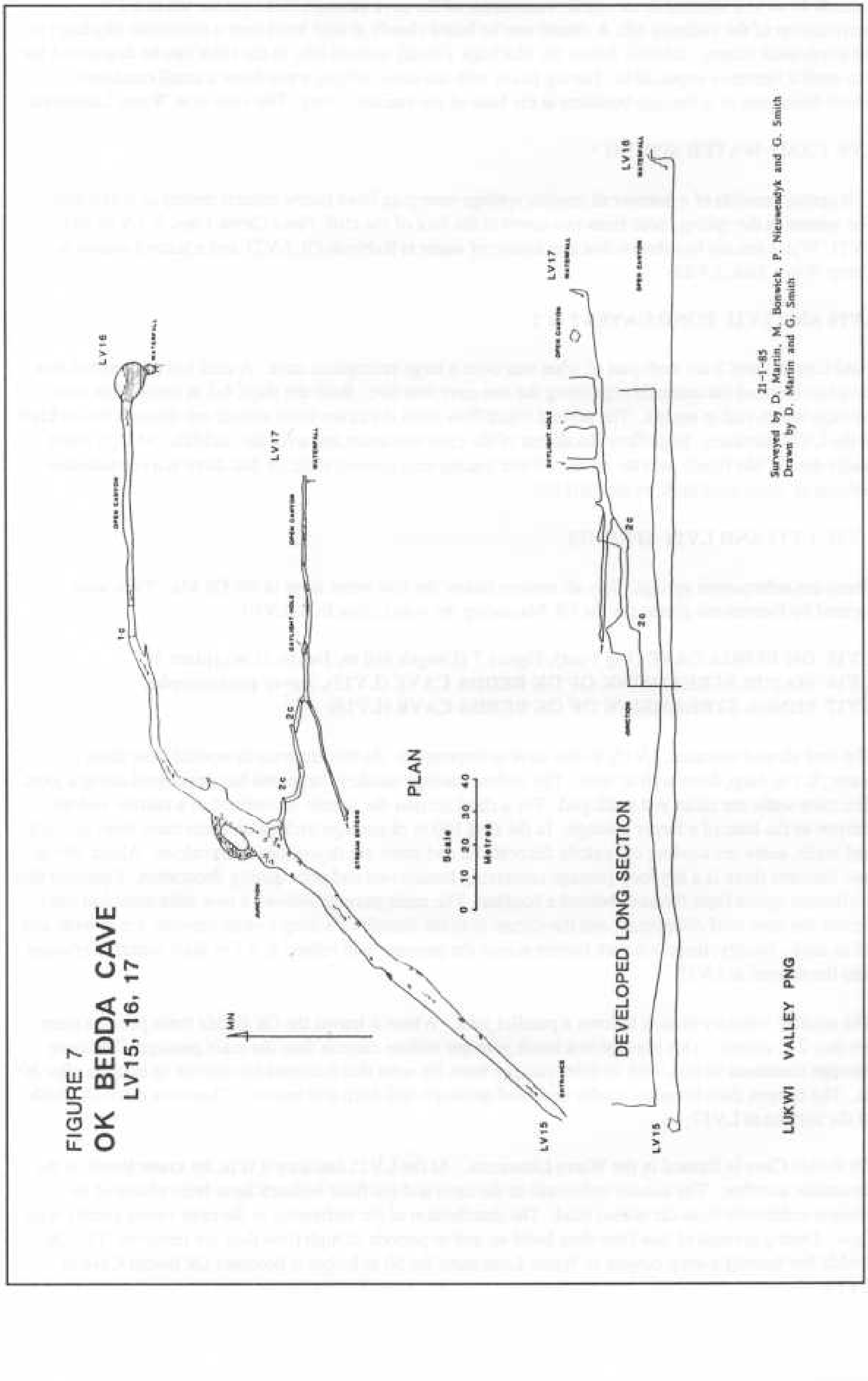
LV15 OK BEDDA CAVE (Big Foot), Figure 7 (Length 460 m, Depth 22 m),(plate 3).
LV16 MAJOR STREAMSINK OF OK BEDDA CAVE (LV15), (cover photograph).
LV17 MINOR STREAMSINK OF OK BEDDA CAVE (LV15)

The lens shaped entrance, LV15, to this cave is impressive. At this entrance in normal flow there is water, 0.3 m deep, from wall to wall. The vadose passage inside is large and has developed along a joint. The cave walls are clean and scalloped. For a short section the stream is confined to a narrow vadose canyon in the base of a larger passage. In the first 100 m of passage trickles of water enter from the roof and walls, some are eroding old calcite decorations and some are depositing fresh calcite. About 100 m into the cave there is a dry loop passage containing breakdown and poor quality decoration. Opposite this a tributary enters from the east, behind a boulder. The main passage follows a new joint direction until finally the cave roof disappears, and the stream is in the bottom of a deep vadose canyon, 1.5 m wide and 15 m high. Finally, there is a rock barrier across the passage, and behind it, a 5 m high waterfall plunges into the canyon at LV16.

The smaller tributary branch follows a parallel joint. Where it leaves the Ok Bedda main passage there are two 2 m climbs. This passage is a much younger vadose canyon than the main passage. The cave passage continues to rise, with an inlet passage from the west that becomes too narrow to explore after 30 m. The canyon then becomes totally unroofed although still deep and narrow. There is a difficult climb to the surface at LV17.

Ok Bedda Cave is formed in the Warre Limestone. At the LV15 entrance it is in the lower levels of the limestone member. The natural sediments in the cave and the floor bedrock have been obscured by erosion sediments from the access road. The distribution of the sediments in the cave varies greatly with flow. During periods of low flow they build up and in periods of high flow they are removed. The Ok Bedda has formed a deep canyon in Warre Limestone for 50 m before it becomes Ok Bedda Cave at LV16.

A number of small surface streams collect together in a sediment filled depression, and then cut a narrow, meandering canyon and flow over a waterfall at LV17 into the Warre Limestone; finally the canyon gets a roof and becomes a cave. The cave is used by bats for roosting.



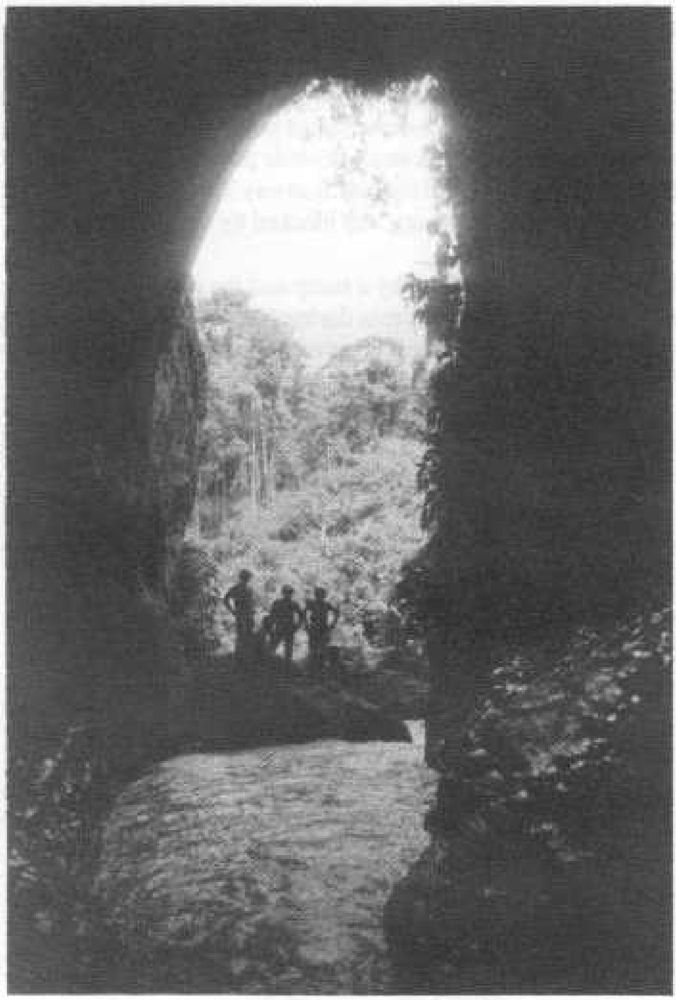


Plate 3. LV15 entrance to Ok Bedda Cave. Photo: J. James.

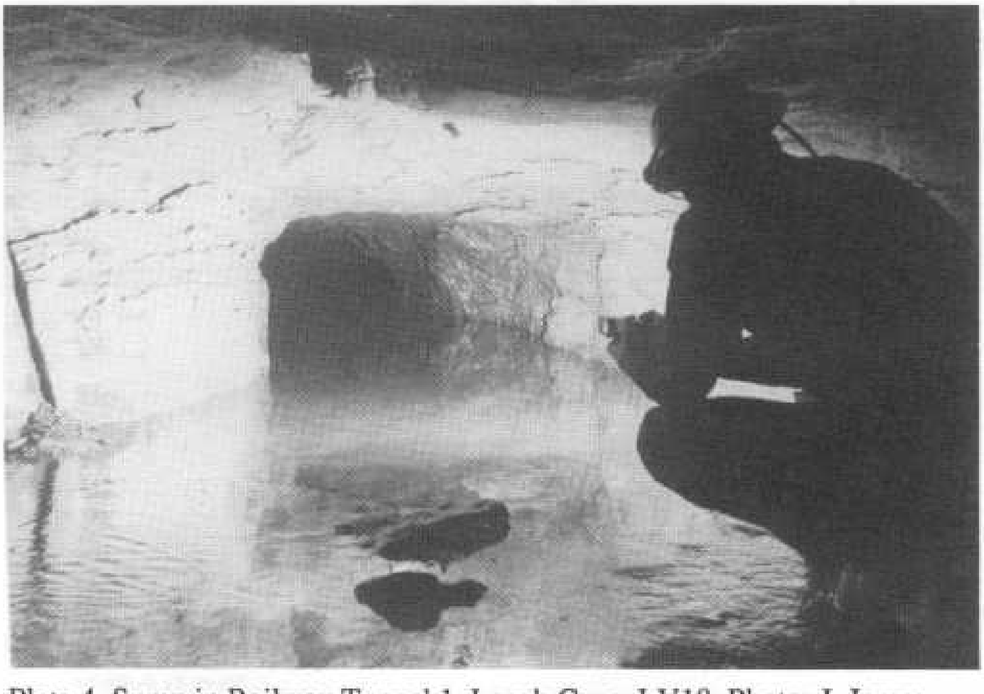


Plate 4. Sump in Railway Tunnel 1, Leech Cave, LV18. Photo: J. James.

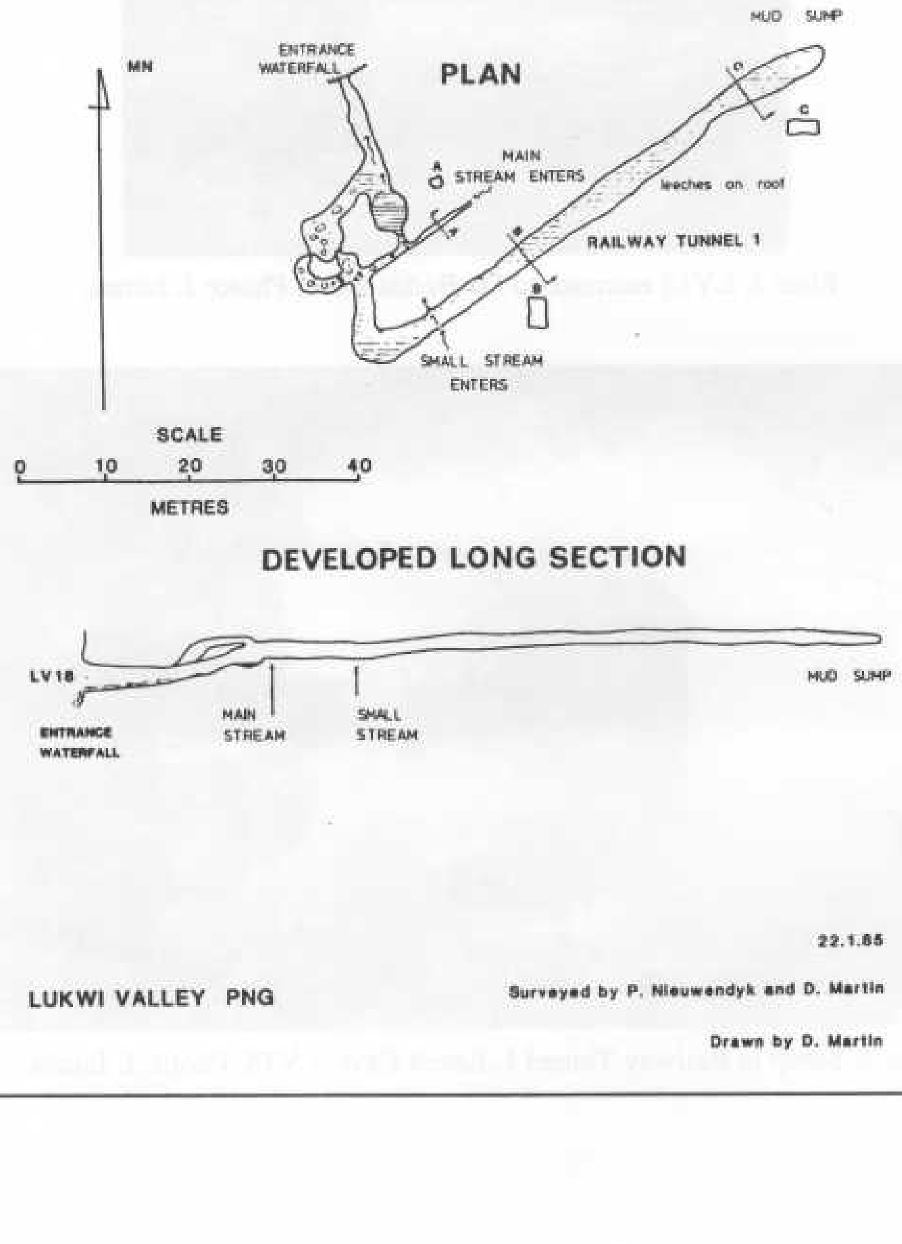
LV18 LEECH CAVE, Figure 8, (Length 140 m, Depth 7 m)

Leech Cave is a resurgence cave. The entrance to the cave is small and to reach it requires a scaling pole. The waterfall issuing from the cave falls into a deep plunge pool. Inside the cave the passage follows joints, and the main water flow enters it from a small keyhole passage approximately 0.4 m in diameter. After several metres, the passage becomes flat roofed "Railway Tunnel 1" (plate 4), 2.5 m high and 2 m wide, this trends north-east and its end in January was blocked by sediments.

Railway Tunnel 1 in May 1985 was terminated by a sump and the main stream of Leech Cave was flowing along it. The cave was visited several times during May and the hydraulic regime varied each time, the changes appeared to result from redistribution of sediments. The cave is formed in a fossiliferous (coraline) bed of the Warre Limestone and is joint controlled throughout.

This is a roosting cave for bats. It is named after the rows of leeches hanging from the roof of Railway Tunnel 1 waiting for the bats to return with their blood meal

FIGURE 8
LEECH CAVE
LV18



LV19 DOLINE/STREAMSINK

This streamsink is in a solution doline. There is no cave developed. The position of LV19 is such that waters sinking there in times of high rainfall would most likely drain to Leech Cave, LV18.

LV20 SPRING

This spring was the only substantial flow of water located on the east bank of the Ok Ma between Leech Cave, LV18, and its junction with the Ok Dui. Both the base of the cliff, and the normally submerged banks of the Ok Ma, were examined with only insignificant trickles located. In low flow the LV20 spring waters emerge from colluvium. However, there are well developed surface channels around the spring, which when followed upstream, show that normal and high flows emerge from boulders closer to the cliff base. The water source for this spring has been shown by water tracing to be the stream flowing over a waterfall at LV45.

LV21 RUBBISH PIT

This "sinkhole" is really a wider spot in a 10 m deep system of crevices At the bottom a very small stream can be seen. The crevices all proved to be too narrow for exploration. It is the rubbish pit for the OTML camp at Lukwi.

LV22 CAMP WATER SINK, Figure 9 (Length 140 m, Depth 50 m)

A stream drops into a crevice which forms a 20 m shaft. At the base of the shaft, a wet scramble through boulders is followed by two short climbs. There is a second wet 10 m shaft (plate 5). The descent of this shaft is hazardous as there are no convenient safe anchor points, and the rock is too weathered for the safe insertion of a bolt.

At the base of the 10 m shaft three small inlets join the main stream. The stream then flows north-east, south-east then north-east through a narrow passage which is clearly joint controlled. This passage then intersects a wider passage with a small stream inlet to the north-west and a sump to the north-east (plate 6). The walls around the sump are covered with fine silt.

The cave is in Warre Limestone throughout. It is impossible to comment whether the wall rock of the shaft is competent as it is heavily weathered. The streamway which descends along a limestone bed is in good rock and free from sediments.

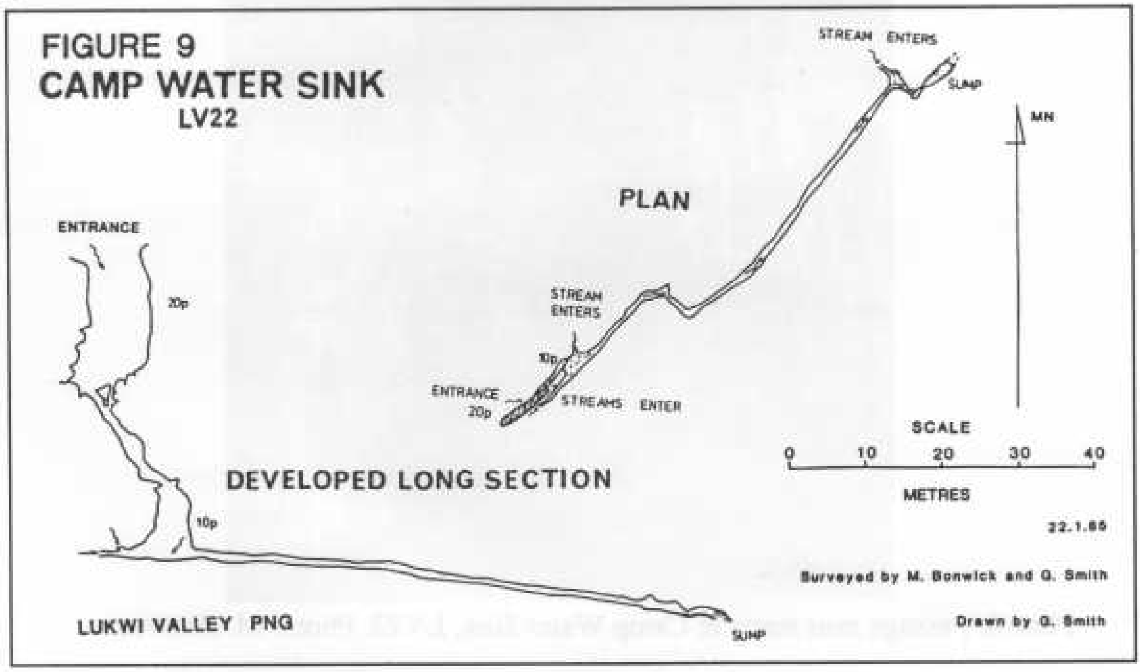


Plate 5. 10 metre shaft in Camp Water Sink, LV22. Photo: M. Bonwick.

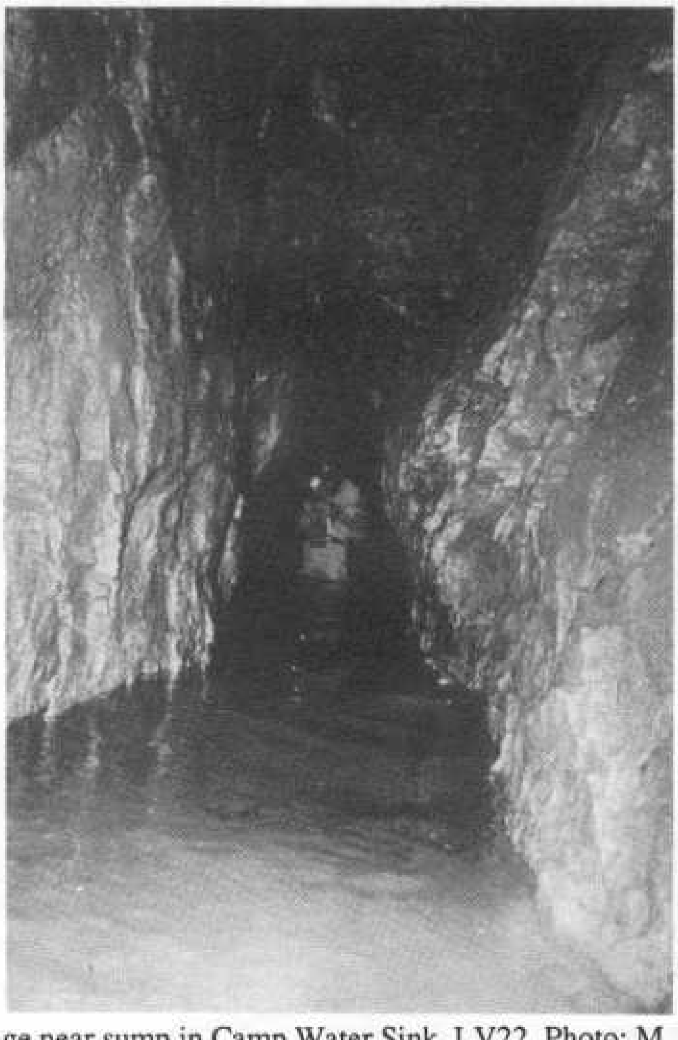


Plate 6. Passage near sump in Camp Water Sink, LV22. Photo: M. Bonwick.

LV23 RED SHAFT (Length 40 m, Depth 30 m)

A small stream flows into a spectacular 3O m shaft. At the bottom, the shaft is blocked by collapsed material which has been consolidated by sediments.

Two attempts were made to trace the water which disappears at the bottom of this shaft. The first used Rhodamine and gave the shaft its name after the dye stained the walls and organic debris in the shaft. The second attempt used 3 kg fluorescein and also failed to give a positive result.

LV24 SWIFTLET CAVE, Figure 10 (Length 610 m, Depth 59 m), (plate 7)
LV25 DAYLIGHT HOLE TO SWIFTLET CAVE (LV24),

The overflow course of a sinking stream can be followed to a deep crevice. A small stream splashes into this crevice even when the overflow streambed is dry. At this point the crevice is wide enough to descend.
The 21 m entrance shaft is narrow and drops into a very small streamway. A climb over boulders leads to a second shaft of 6 m. A further climb down over boulders leads to an intersection with a north-east trending canyon that has a stream inlet from the south-west. Another stream enters from the south-east about 10 m along. The passage continues as a narrow canyon for over a 150 m at first trending north-west and then north east with occasional stream inlets. The passage widens; there is a junction, and a dry passage continues straight ahead up over flowstone into a high chamber floored with collapsed blocks. Two small streams enter this chamber and sink on the south-east side.

The main stream continues beyond the first junction around a couple of bends to another junction. At the second junction another stream enters from the south-west. Upstream this smaller passage divides. To the north-west, after 5 m a small inlet joins, and there is a higher level passage back to the main stream. To the south, a muddy climb leads to a high chamber with flowstone decorations, and a high shaft at the end of a passage on the south-east side of the chamber contains a small stream. Reflected daylight is visible from the base of this shaft (LV25).

The main streamway continues down a very straight section of passage named the Gun Barrel. There are two 3 m climbs that could require a rope in high water conditions. This is an remarkable section of passage: even though it is mostly 0.6 m wide and dead straight for 200 m.

At the end of the Gun Barrel the passage trends north-west, the roof height is 1.5 m, and there is a band of fractured limestone in the roof. This small length of passage is square in cross-section in marked contrast to the rest of the cave (plate 8). After this section a narrow joint-controlled north-east trending canyon ends in a sump.

There are sediments in the chambers, and close to the sump. The limestone in the shaft is heavily weathered, and throughout the streamway it is clean and compact. Swiftlets use the Gun Barrel for nesting. During exploration two small snakes of the same species were found in the cave; one at the bottom of the entrance shaft and the other only 50 m from the sump.

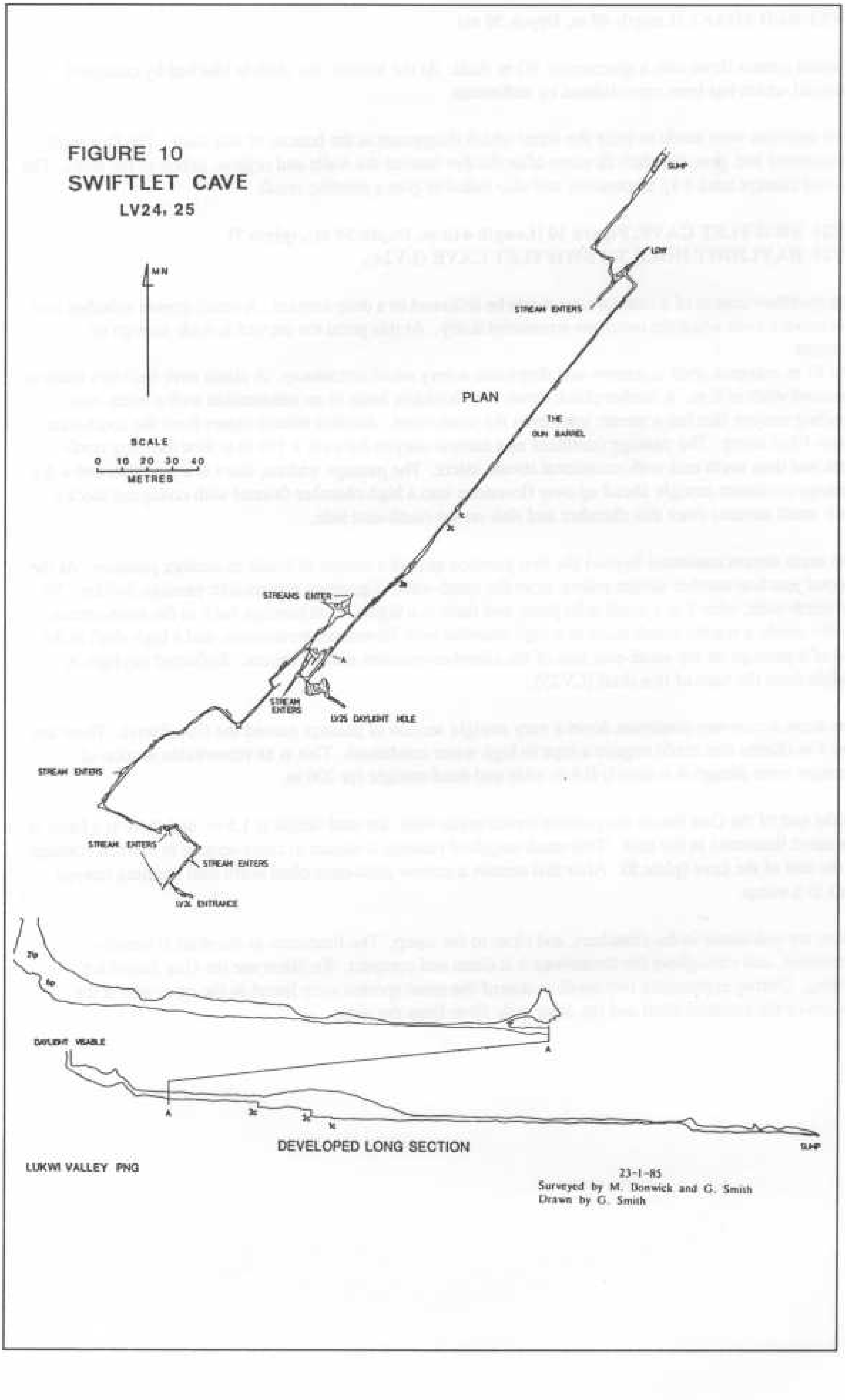


FIGURE 10
SWIFTLET CAVE
LV24, 25
MN
SCALE
0 10 20 30 40
METRES
PLAN
SUMP
LOW
STREAM ENTERS
THE GUN BARREL
STREAMS ENTER
A
STREAM ENTERS
LV25 DAYLIGHT HOLE
STREAM ENTERS
STREAM ENTERS
STREAM ENTERS
LV24 ENTRANCE
DAYLIGHT VISIBLE
A
A
DEVELOPED LONG SECTION
SUMP
LUKWI VALLEY PNG
23-1-85
Surveyed by M. Bonwick and G. Smith
Drawn by G. Smith

Plate 7. Entrance to Swiftlet Cave, LV24. Photo: M.Bonwick

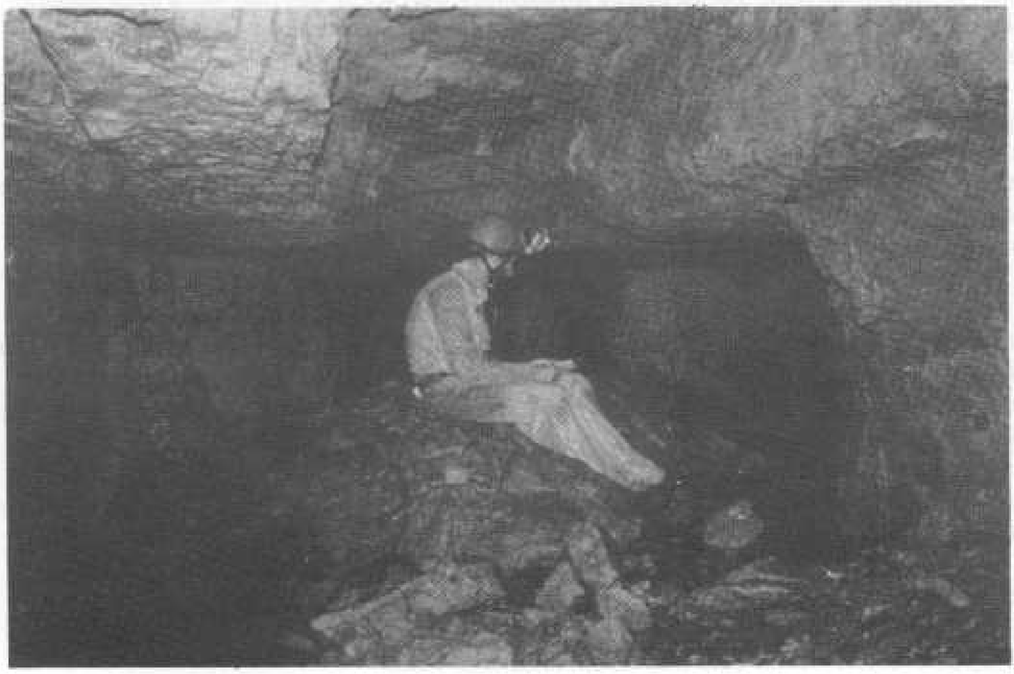


Plate 8. Rockfall in Swiftlet Cave, LV24. Photo: M. Bonwick.

LV26 SPRING

A small spring on the west bank of the Ok Ma, the waters of which have cut a shallow gully in the colluvium. Its source is not known.

LV27 ELUSIVE SINK, Figure 11 (Length 90 m, Depth 33 m)

A number of surface streams collect together and then cut a shallow canyon into the Warre Limestone. The combined stream flows over a number of waterfalls to sink in a doline. The entrance to the cave is a 9 m shaft down which water flows. There is a second, parallel, dry shaft. At the bottom of the 9 m shaft there is a vadose streamway, 1-2.5 m wide, which is less than 2 m high. This passage floods to the roof in periods of intense rainfall. After 50 m this vadose streamway flows over a 7 m waterfall into Column Cave, LV28.

The stream in Elusive Sink has been traced through Column Cave, LV28 to Leech Cave, LV18. The name Elusive Sink arises from the failure to locate its resurgence with the the first dye tracing experiment. This failure was attributed to insufficient observation time. The waters do no take a direct route to Leech Cave, LV18.

LV28 COLUMN CAVE, Figure 11 (Length 340 m, Depth 26 m)

The cave entrance is in the side of a doline. There is no evidence that water has entered it in the recent past. Just inside the entrance there is a chamber which narrows to a low meandering passage. After 20 m there is a 1.5 m climb down to a narrow vadose canyon. A small stream enters from the left and opposite the climb there is a high level passage which extends for some metres to a flowstone blockage (plate 9). The vadose canyon leads to an 8 m pitch which is decorated with flowstone. Five metres down on a ledge the small Column Cave stream emerges from behind a rimstone pool. The upstream passage containing this stream is too small to enter. The stream flows through a decorated canyon to meet the Elusive Sink, LV27 stream.

The Elusive Sink, LV27 stream enters Column Cave as a 7 m waterfall into a chamber with a large flowstone slab on the opposite wall. At its junction with the Column Cave stream a high level phreatic oxbow can be seen in the roof. The combined streams flow over a 2 m waterfall into a large chamber approximately 10 m across. In the chamber there is another high level passage 3 m up the wall. This passage leads to Column Cave extension which is described under LV52.

The large chamber is the start of Railway Tunnel 2, a 4 m wide by 3 m high passage of phreatic origin modified by breakdown. The stream sinks into the floor after 30 m and the passage continues with its impressive size and shape. A stream appears from the east wall after 30 m, and disappears 30 m further on, behind a large flowstone knob (plate 10). The size of this stream makes it unlikely that it is the combined Column Cave and Elusive Sink streams. A stream reappears a further 20 m along Railway Tunnel 2; this is most likely the combined stream. This sinks in sediments at the end of the passage.

The extent and characteristics of any natural sediments in Column Cave have been masked by sediments from the access road. These sediments may have caused the blockages that are preventing complete exploration of the cave. The directions of the passages in Column Cave, like Leech Cave, LV18, are joint controlled.

Between January and May 1985 the large chamber filled with 3 m of sediments; Railway Tunnel 2 was 80 m in length and most of this had only 0.5 m of airspace.

LV29 SHAFT (Depth 10 m)

A small dry shaft blocked at the base with rubble in Orubadi beds.

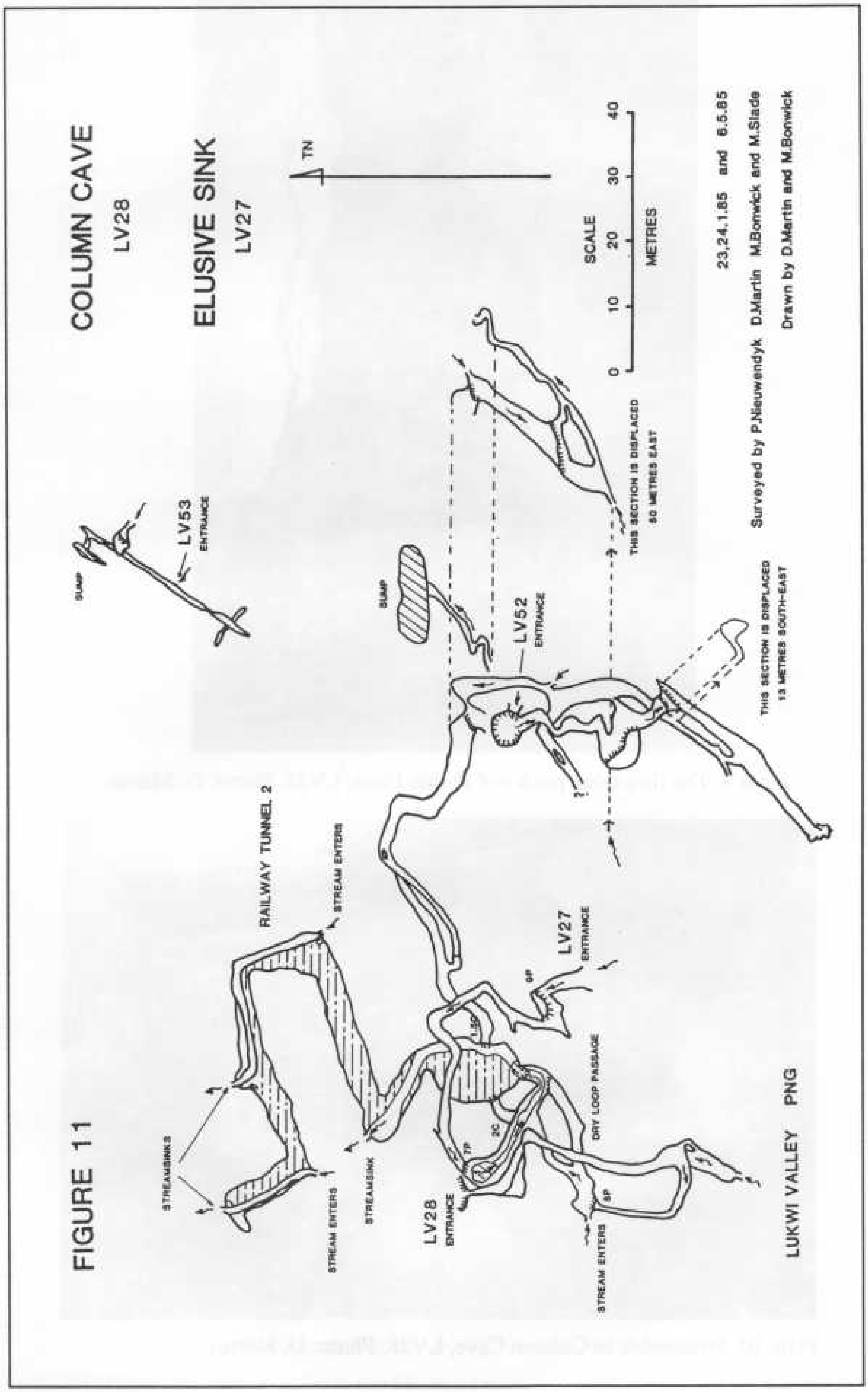


FIGURE 11
COLUMN CAVE
LV28
ELUSIVE SINK
LV27
TN
SCALE
0 10 20 30 40
METRES
23,24.1.85 and 6.5.85
Surveyed by P.Nieuwendyk D.Martin M.Bonwick and M.Slade
Drawn by D.Martin and M.Bonwick
LUKWI VALLEY PNG
RAILWAY TUNNEL 2
STREAM ENTERS
STREAMSINKS
STREAMSINK
STREAM ENTERS
LV28 ENTRANCE
DRY LOOP PASSAGE
STREAM ENTERS
LV27 ENTRANCE
LV52 ENTRANCE
SUMP
SUMP
LV53 ENTRANCE
THIS SECTION IS DISPLACED 50 METRES EAST
THIS SECTION IS DISPLACED 13 METRES SOUTH-EAST

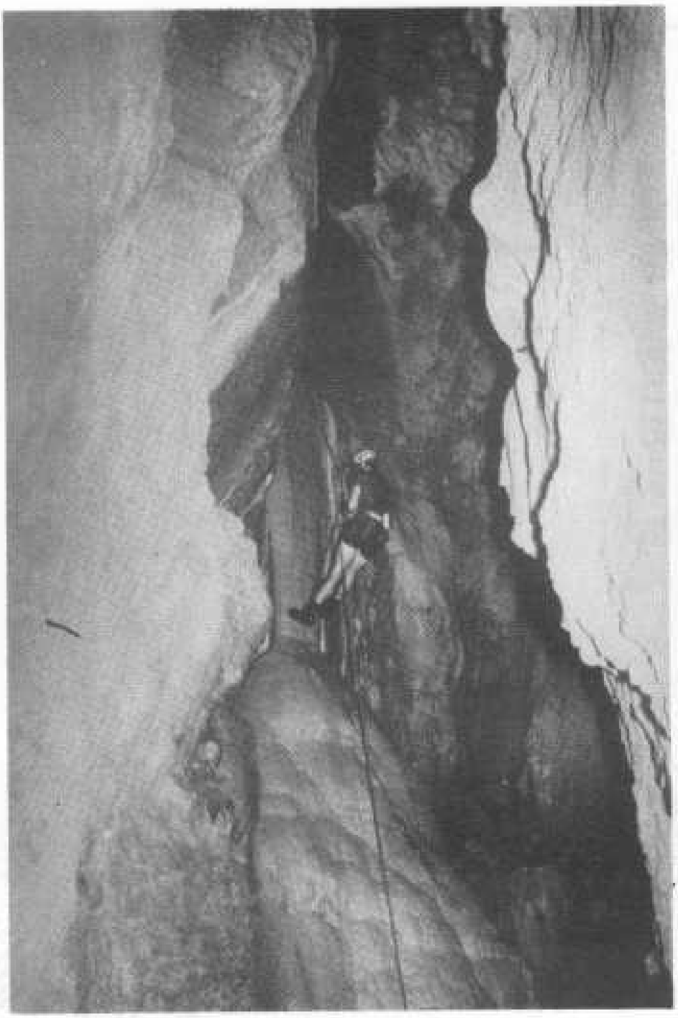


Plate 9. The flowstone pitch in Column Cave, LV28. Photo: D. Martin.

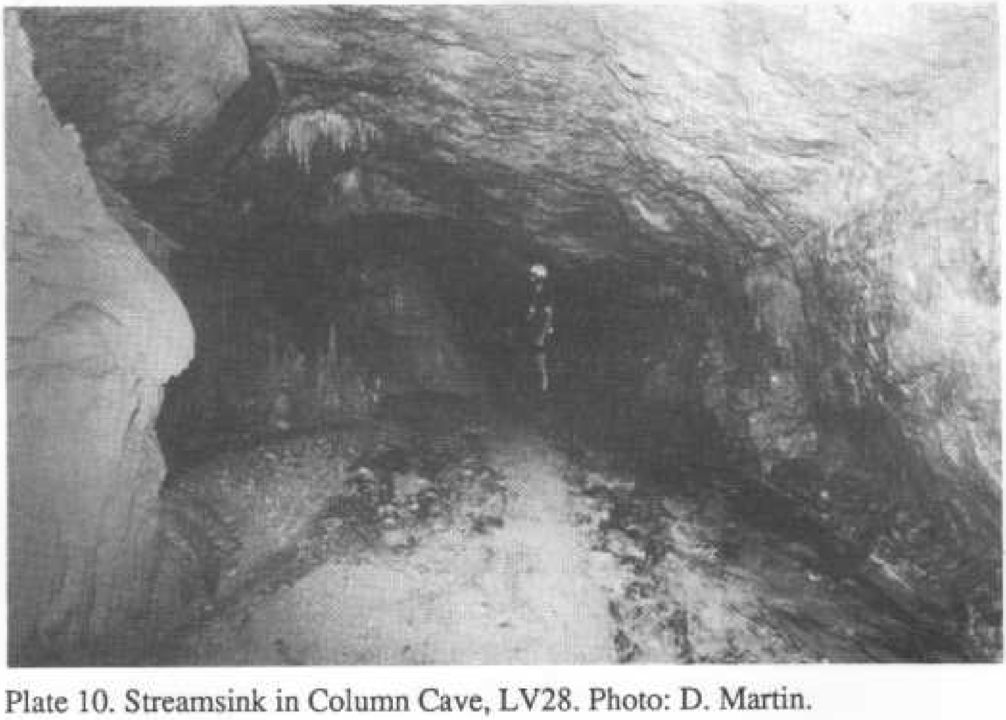


Plate 10. Streamsink in Column Cave, LV28. Photo: D. Martin.

LV30 STREAMSINK

The impassable main streamsink for Swiftlet Cave, LV24.

LV31 SHAFT

A dry shaft blocked at the base with logs.

LV32 SHAFT

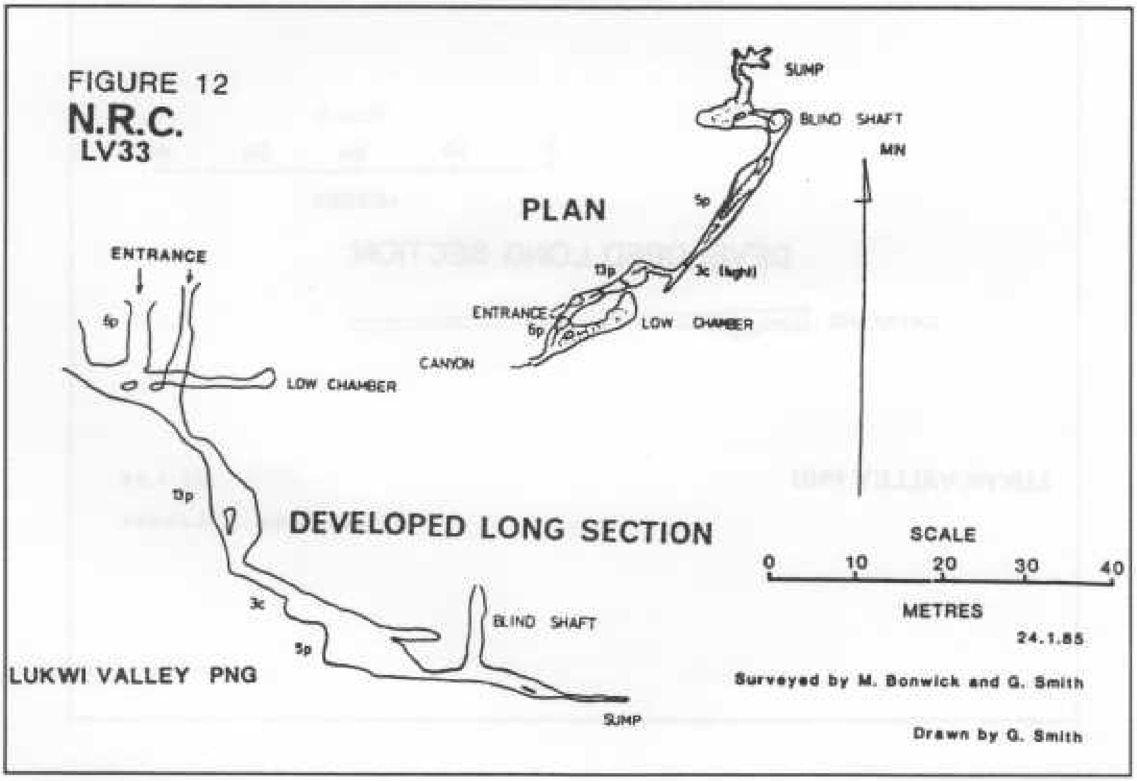
An unexplored shaft next to a drillhole (LUK10). The sediment blockages at the ends of Leech Cave, LV18, and Column Cave, LV28, are separated horizontally by 100 m and vertically by approximately 1 m. A straight line between these two points passes directly below LUK10 at an elevation consistent with the level of the void in the LUK10 core. This shaft may be an additional sink for the Leech Cave, LV18, system.

LV33 N.R.C., Figure 12 (Length 90 m, Depth 46 m)

Three streams collect together and then flow through a series of crevices into a cave. The easiest approach to the cave is from the ridge on the northside, then down into a doline and descending a 6 m shaft to a stream. A dry abandoned passage on the east side of the shaft can be followed to a low chamber.

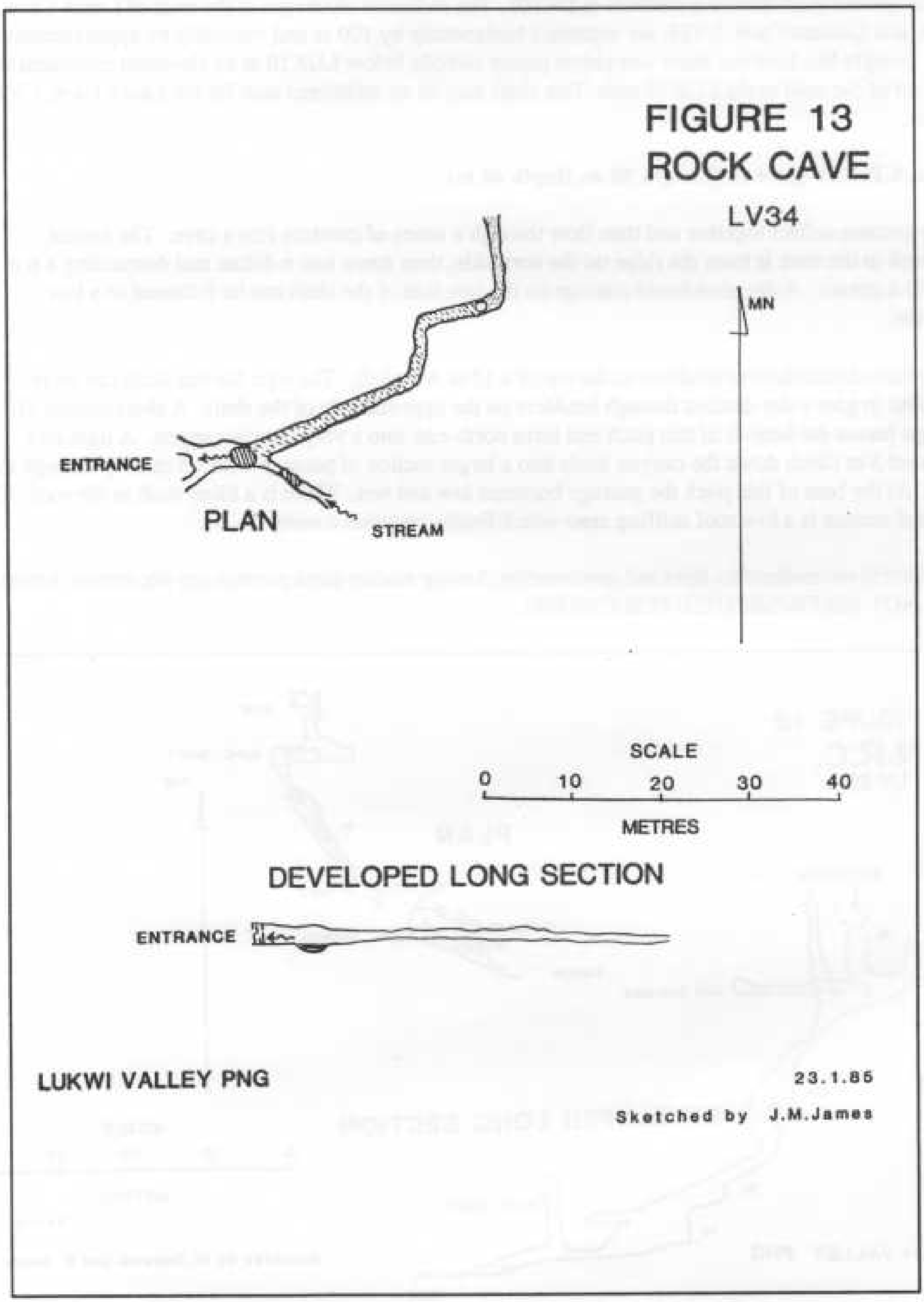
The stream descends over boulders to the top of a 13 m wet shaft. The rope for this shaft can be re-anchored to give a dry descent through boulders on the opposite side of the shaft. A short section of passage leaves the bottom of this pitch and turns north-east into a very narrow canyon. A tight and awkward 3 m climb down the canyon leads into a larger section of passage with a 5 m drop through the floor. At the base of this pitch the passage becomes low and wet. There is a blind shaft in the roof. The terminal section is a low roof sniffing zone which finally becomes a sump.

This cave is uncomfortably tight and unrewarding, having neither good passage nor decoration, hence the name NOT RECOMMENDED FOR CAVING.



LV34 ROCK CAVE, Figure 13 (Length 60 m, Depth 5 m)

Rock Cave and its neighbour LV35 are the only caves at Lukwi found in the limestones of the Orubadi beds (see Caves and Karst of Lukwi Part 2, Geology). The water that resurges from Rock Cave sinks some 80 m to the east of the entrance. The entrance to the cave is divided into two by a rock pillar and water showers down from the roof at this point. There is a short section of stream passage and then the stream emerges from a tight joint-controlled side passage which is only negotiable for 10 m. The main passage is a poorly developed vadose passage, now abandoned by the waters that formed it. It gets smaller and smaller further away from the entrance.



LV35 SEISCOM CAMP WATER RESURGENCE

A tight joint controlled rift with water flowing down a series of cascades at the bottom.

LV36 DOLINE/STREAMSINK

A 15 m deep doline in Orubadi beds. There are three dry stream courses to its lowest point. In high flow the water sinks through rubble. There is no enterable cave.

LV37 STREAMSINK

The streamsink for the combined streams of LV34, LV35, and a waterfall next to these caves.

LV38 DOLINE/STREAMSINK

This streamsink was originally a deep doline. The doline has since been filled with sediment from the access road so that sometimes it is a lake, and at others a large sand pit. Water flows across the sand pit and sinks in a variety of places, most of which are at the foot of the west rock wall. Any cave that was present in the doline has been blocked by the sediments. The water that sinks in this doline has been traced to LV20

LV39 GRIKE/CORRIDOR

This is a classical example of a tropical grike/corridor. It is a 9 m deep, narrow, vertical slot formed from the surface by solution along a joint.

LV40 WISHFUL THINKING, Figure 14 (Length 40 m, Depth 14 m)

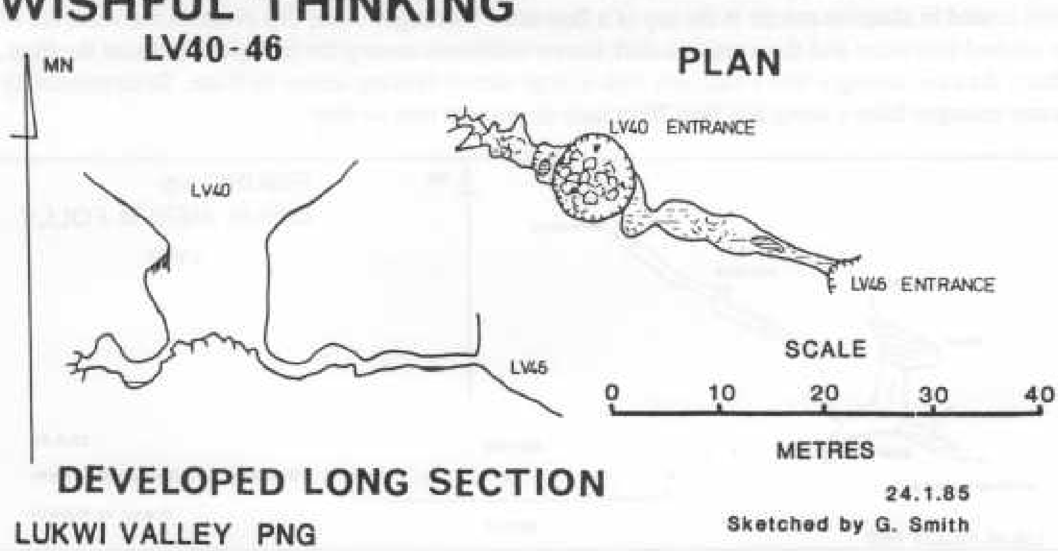
A cave at the bottom of a solution doline modified by collapse. A 15 m rope was used to descend the doline. The upstream section of the cave is entered through a small slot under the western wall of the doline. A flowstone slope leads to a rockfall blockage. The flowstone is still forming and the seepage waters flowing over it sink into boulders.

The eastern section of the cave is entered through a low arch on the south-east side of the doline. The passage is generally low with muddy pools. Some flowstone and gours are present. The LV46 entrance is below a small cliff about 6 m from, and 3 m above, the Ok Ma.

FIGURE 14

WISHFUL THINKING

LV40-46



DEVELOPED LONG SECTION

LUKWI VALLEY PNG

24.1.85

Sketched by G. Smith

LV41, LV42, LV43 DOLINES

Solution dolines modified by wall retreat.

LV44 SPRING

This spring is located in the bed of the Ok Ma next to LV6.

LV45 WATERFALL PLUNGE POOL

LV46 LOWER ENTRANCE TO LV40

LV47 HIGH WATER OVERFLOW (Depth 6 m)

The entrance to this cave was originally blocked by boulders and logs. Two squeezes between the wall rock and a mud coated boulder pile lead to a clean sump pool with the water in it flowing from south to north.

LV48 THE RIFT

A gorge like feature with a line of solution dolines along its floor.

LV49 SHAFT/STREAMSINK (Depth 20 m)

This shaft is the end of a grike containing a small stream. It was descended 20 m to a boulder pile. There is a miserable grovel down through the boulders to a short pitch which was not descended. The shaft could give access to passages upstream of the Tip Spring, LV5 sump.

LV50 SHAFT/STREAMSINK

A stream sinks into a 4 m shaft being used as a rubbish pit. At the base of the shaft the stream flows into a narrow rift that is too narrow to explore.

LV51 LIKLIK MERI'S FOLLY, Figure 15 (Length 82 m, Depth 4 m)

An overflow streamway is followed from the bank of the Ok Ma to the base of a small cliff where there is a cave entrance. Two very tight squeezes down through jammed boulders lead to a small horizontal passage. This streamway is still intermittantly active as is evidenced by organic debris plastered on its roof. However, in the past it has been dry long enough for the walls and roof to become coated with poor quality calcite and the floor to be covered with rimstone pools. The decorated passage leads to a a squeeze coated in abrasive calcite at the top of a flowstone blockage. After this obstacle the walls are of clean washed limestone and there are fine dark brown sediments among the collapse blocks on the floor. Suddenly the cave enlarges into a chamber with a large stream flowing across its floor. Disappointingly, the water emerges from a sump and then 20 m later disappears into another.

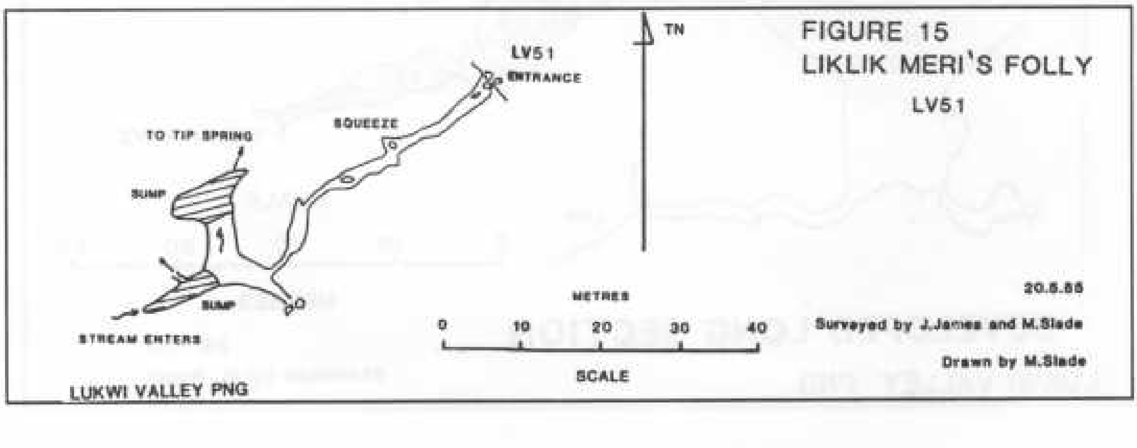


FIGURE 15
LIKLIK MERI'S FOLLY
LV51

LV52 ENTRANCE TO COLUMN CAVE, Figure 11 (Length 325 m, Depth 38 m)

LV52 is a streamsink. The survey datum point is a nail in the streambed at the top of the entrance waterfall. The cave is a complicated spiral of joint controlled passages with three levels vertically superimposed. The cave is part of the Elusive Sink, LV27 and Column Cave, LV28 system and is connected to them by an abandoned phreatic passage.

At the entrance there is a 4 m climb down a waterfall. A small stream flows into a zig-zag crawl, with the passage dropping in height on the south-west legs of the zig-zag, while the south-east legs are horizontal. After 26 m the crawl enters the side of a 3 m high, 4 m wide rift heading east-south-east, which after 6 m turns through a right angle and decreases to a 1 m diameter tube. Around another sharp corner the passage enters a large rift near the roof. A large boulder in the floor of the previous rift is the best anchor point for the 10 m descent into the rift. There is a re-anchor available; a small stalagmite knob on the lip of the drop.

The 4 m wide rift at the foot of the pitch extends 32 m south-west before ending in several small open joints. Near the middle of the rift a 1 m diameter tube in the north wall turns and runs parallel to the rift floor. This tube has a silt floor and probably sumps after heavy rain. After 10 m the tube divides with the right hand fork doubling back under the floor of the rift and is blocked with Era bed pebbles. The stream in this passage appears to be the same stream as is found at the foot of the 10 m pitch in the large rift passage. The left fork of the tube turns a sharp left hand corner and rapidly increases in size to 3 m wide by 2 m high. After 20 m the passage narrows again to 0.5 m and the floor drops away to become a 10 m deep slot which connects to the shaft above the waterfall in the lower stream passage. The passage can be seen to continue on the other side of the slot in the floor but has not been entered.

The lower streamway can easily be reached through a crawl 18 m back from the slot. A stream entering through boulders at the start of the crawl is considerably larger than the stream in the cave entrance. After 25 m the stream drops through a tight rift and emerges into a larger passage. Immediately after the tight rift an 8 m climb on the right leads to a phreatic passage that after 60 m connects with Column Cave, LV28.

Continuing down the stream in LV52, 13 m of 3 m high passage leads south-west to a 3 m climb down a waterfall. The passage then turns north-east for 38 m to a sump. This last section of passage is 1 m wide and 1.5 m high. The level of the sump, at 334 m, was 1 m lower than the level of the sediment in Column Cave, LV28 at the time of surveying in May 1985. When visited one week later the level of the sump had risen approximately 0.5 m, as had the sediments in Column Cave.

LV53 SERIES OF SHAFTS

LV53 is a streamsink 90 m north-east of Column Cave, LV28. There are three shafts on a 030° joint with the stream normally sinking into only the two most northerly of these. The survey datum is a nail in the stream bed on the edge of the central shaft. The shafts found in LV53 are tight and jagged with very little horizontal development. The lowest point in the cave can only be reached via the central shaft which splits into two at a depth of 6 m. The tight southernmost shaft is 11.7 m deep and drains to the north through an impenetrable crack. The northerly branch of the central shaft gives access to a tight crawl at a depth of 21 m.

LV54 SPRING

LV54 is a spring in the bed of the Ok Ma just below the normal water level. Its waters issue from beds of Warre Limestone.

LV55 SHAFT/STREAMSINK

A small stream trickles over the calcite covered walls of this 16 m deep shaft and sinks in fine sandy sediment at its bottom.

LV56 SHAFT/STREAMSINK

This sink is an 8 m deep shaft that is blocked with rubbish.

LV57 SHAFT

This 4 m deep shaft is blocked with rubbish.

LV58 SHAFT

This shaft is an enclosed *wandkarren*, the half tube is in solid rock and the remaining side is breakdown. It is 12 m deep and the trickles of water that flow down the half tube sink into debris at its bottom.

LV59 SPRING

A small spring on the banks of the Ok Ma.

LV60 SPRING

A small spring on the banks of the Ok Ma.

LV61 OK MI CAVE NUMBER 2, Figure 16 (Length 163 m, Depth 14 m)

The cave is entered from a collapsed doline at the end of a surface flood overflow of the Ok Mi which commences at LV62. There is a 10 m climb down through the collapse blocks to the riverway. Upstream the Ok Mi emerges from a sump at the base of the eastern wall. Downstream it flows through a large passage 10 m wide by 10 m high containing 6 m high boulders. In this section the river flows through several small rapids along the north wall. It is heading south-west towards Ok Mi Cave Number 1. The roof suddenly drops to within O.5 m of the surface of the river, and at least a further 15 m of passage could be seen. The water levels encountered during exploration were high and to proceed further would have been extremely hazardous as it would have been impossible to swim against the fast flowing Ok Mi.

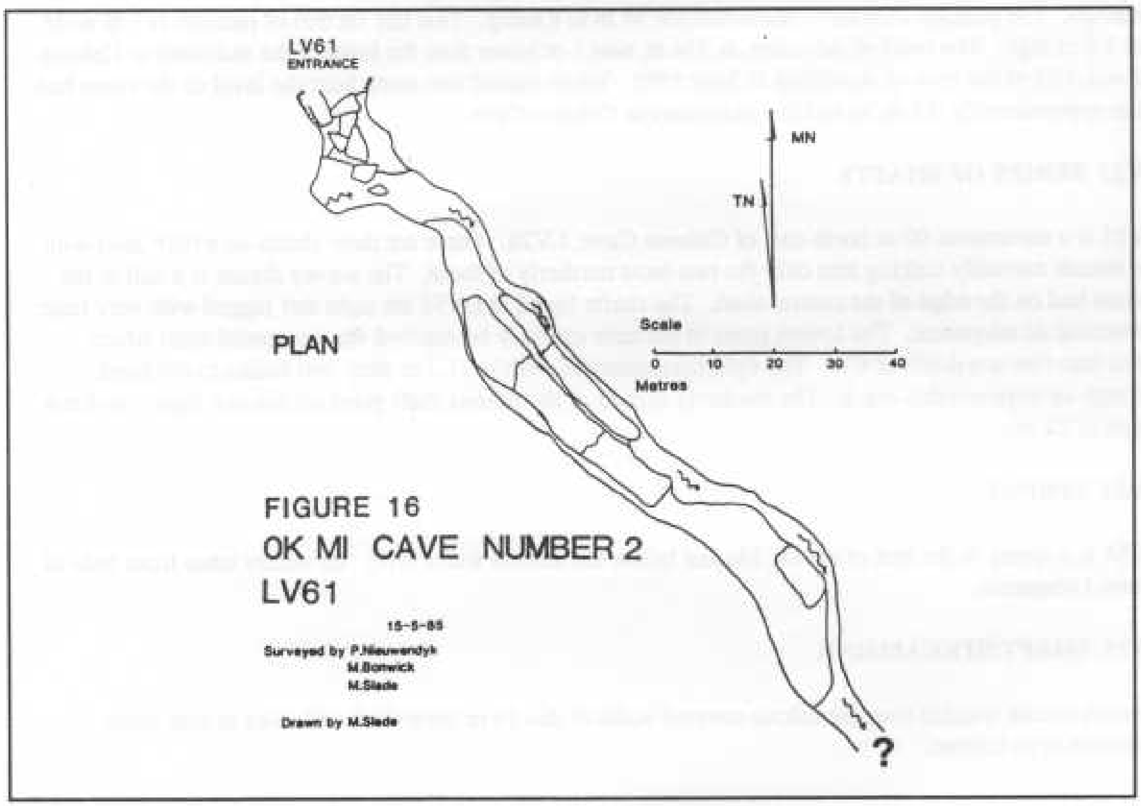


FIGURE 16
OK MI CAVE NUMBER 2
LV61

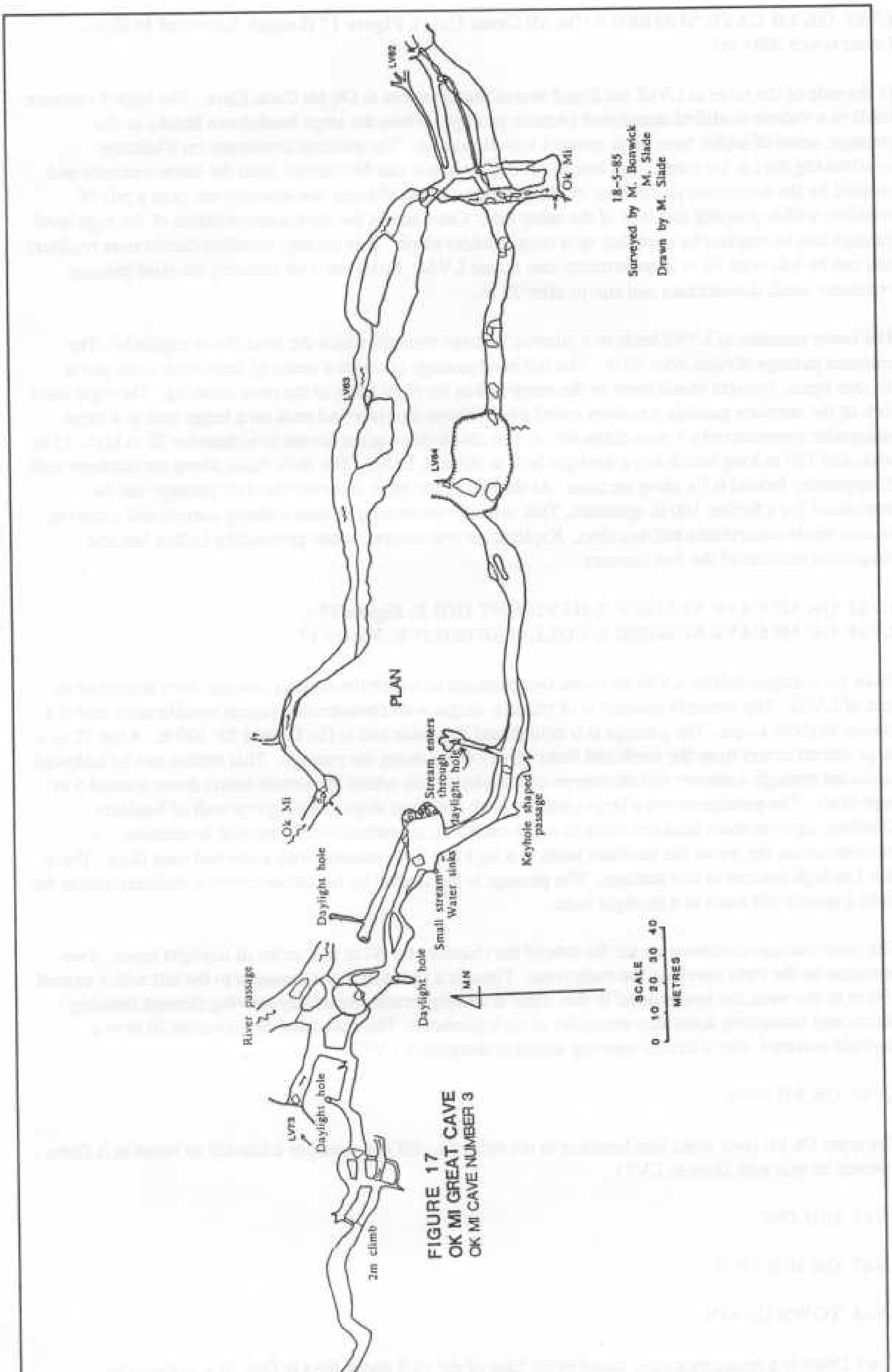


FIGURE 17
OK MI GREAT CAVE
OK MI CAVE NUMBER 3

LV62 OK MI CAVE NUMBER 3 (Ok Mi Great Cave), Figure 17 (Length Surveyed 1010 m, Unsurveyed 300+ m)

In the side of the ridge at LV62 are found two of the entrances to Ok Mi Great Cave. The higher entrance leads to a vadose modified abandoned phreatic passage. There are large breakdown blocks in this passage, some of which have been covered with flowstone. The passage terminates on a balcony overlooking the Ok Mi some 15 m below. The river below can be reached from the lower entrance and crossed by the hazardous proceedure of allowing the current to carry one downstream onto a pile of boulders within jumping distance of the other side. Once across the river a continuation of the high level passage can be reached by climbing up a steep boulder slope. This passage contains climbs over boulders and can be followed 70 m to an entrance into doline LV64. From the river crossing the river passage continues south downstream and sumps after 25 m.

The lower entrance at LV62 leads to a phreatic passage through which the river flows regularly. The entrance passage divides after 50 m. The left hand passage contains a series of large rock mills and it divides again. Straight ahead leads to the sump and to the right leads to the river crossing. The right hand fork of the entrance passage traverses round a hole above the river and ends on a ledge next to a large stalagmite aprroximately 4 m in diameter. A 3 m climb down gives access to a chamber 30 m high, 15 m wide and 120 m long which has a daylight hole in its roof, LV63. The river flows along the northern wall disappearing behind it for short sections. At the end of the large chamber the river passage can be negotiated for a further 100 m upstream. This involves swimming against a strong current and climbing around small watershutes and boulders. Exploration was stopped when proceeding further became dangerous because of the fast currents.

LV63 OK MI CAVE NUMBER 3, DAYLIGHT HOLE, Figure 17
LV64 OK MI CAVE NUMBER 3, COLLAPSE DOLINE, Figure 17

From the collapse doline, LV64 there are two passages of which the easterly one has been described as part of LV62. The westerly passage is of phreatic origin with considerable vadose modification and is a classic keyhole shape. The passage is 6 m high and 3 m wide and is flat floored for 100 m. After 70 m a large stream enters from the north and sinks 15 m further along the passage. This stream can be followed upstream through a narrow vadose canyon to a daylight hole where the stream enters down a small 5 m high shaft. The passage enters a large chamber with sediment slopes leading to a wall of boulders. Climbing up over these boulders leads to some excellent, characteristically tropical decorations. A traverse across the top of the boulders leads to a high dry level passage with a cracked mud floor. There is a 3 m high column in this passage. The passage is terminated by flowstone covered boulders and to the right a narrow rift leads to a daylight hole.

The main passage continues on the far side of the chamber for 60 m to a series of daylight holes. Two passages on the right overlook the main river. There is a series of maze passages to the left which extend 100 m to the west, the lowest level in this maze is an epiphreatic streamway flowing through bedding planes and containing some fine examples of rock pendants. The cave continues another 20 m to a daylight entrance with a stream entering which is designated LV73.

LV65 OK MI SINK

The main Ok Mi river sinks into boulders at the foot of a cliff and resurges a number of times as it flows towards its real sink close to LV73.

LV66 DOLINE

LV67 OK DUI SINK

LV68 TOWN DRAIN

Town Drain is a resurgence cave found at the base of the cliff above the Ok Dui. It was found by following a small stream flowing over the colluvium upstream until it emerged from boulders. The entrance to the cave is a squeeze between a tufa slope and loose boulders leading to a stream passage in solid rock. About 3 m from the entrance the main stream sinks into a narrow joint. The rest of the cave is surprisingly uniform in shape and its uniformity is enhanced by the fact that it is water filled from wall to wall. The passage is following a 040° joint the roof varies in level as do the sediments which form the floor. The sediments are a fine sandy material and contain no large boulders or logs. After 60 m the roof drops to within 10 cm of the water; at this point a strong breeze could be felt. Fresh organic debris plastered on the roof throughout the cave indicated that it had flooded recently.

LV69 SNAKE PIT

This cave has not been explored.

LV70 SHAFT/STREAMSINK

A small stream sinks into a shaft 2 m by 4 m. It is 8 m deep and ends in a muddy crawl.

LV71 SPRING

A spring in the bed of the Ok Ma.

LV72 SHAFT/CAVE

A stream in the side of the Ok Dui.

LV73 DAYLIGHT HOLE TO OK MI CAVE NUMBER 3

LV74 WOMBAT HOLE

The small entrance to Wombat Hole is in a gully south of Leech Cave, LV18. The top section of the cave is a 0.3 m high by 0.6 m wide horizontal phreatic passage whose walls and roof are of weathered limestone. The 10 m long passage is termninated by a sediment blockage. The floor is covered with a thin layer of consolidated earth and sediments with a hole in it 5 m from the entrance. The hole leads to a clean washed shaft in limestone whose walls are covered with sharp rock spikes. At the top of the shaft a trickle of water enters from an open joint. The shaft becomes too tight for exploration after 3 m. Rocks thrown into the shaft indicate that it has developed to a considerable depth. The water flowing down the shaft will probably drain to Leech Cave, LV18.

LV75 "THE 300 m DEEP CHASM"

A small stream flows off Orubadi beds and then for a few metres over Warre Limestone to sink in a shaft. The shaft is a joint widened where the stream flows down it. The shaft can be descended for 15 m until it gets too tight for further safe exploration. The joint has opened as a narrow rift on both sides of the wide section and can be seen to extend for some metres in both directions. The shafts depth was plumbed at 30 m using a weighted cotton thread.

LV76 STEVE'S CAVE

The major entrance, LV76, to Steve's Cave is in a depression surrounded by crevices. At the bottom of a tallus slope in the depression there is a large cave entrance decorated with erratic speleothems. Inside there is entrance chamber which develops into a rift some 5-6 m high with a metre tall stalagmite poised high on one wall. In the rift there is a blockage which can be climb over to give access to an upper level series of passages which leading to another entrance. This is a low entrance with restricted access due to speleothems. Below the obstruction is a tight, nasty metre long belly crawl. On the other side of the obstruction the passage again connects with the higher level. Then the passage widens into a chamber that has been intersected by a crevice and daylight can be seen through a jumble of loose boulders in the roof. The passage continues as an ascending crawlway with a sharp bend to the right. It terminates in the side of a covered crevice about one metre above the floor. The crevice passage is some 2-3 m wide and

4-5 m high and downslope to the right is blocked by breakdown. To the left there is a boulder collapse which with careful negotiation leads to the surface in another region of deep interconnecting crevices. Back in the crawlway just before it terminates in the crevice, there is an ascending phreatic tube on the left. On the surface side of the boulder collapse in the final crevice there is a crawlway on the right that does not appear to connect with the ascending tube.

The crawlway passages are all of phreatic origin and have some shallow sediment deposits in them. These appear to be largely allochronous sediments as they contain organic and surface materials. All the rock in the phreatic cave is coated with a weathering rind which is protecting it from further erosion. All the phreatic passages appear to be inactive and the insecting crevices are vadose and active. Any waters from catchments above the cave now appear to be captured by crevices and drain through the crevice bottoms. The cave except near its entrances appears to be free from seepage as there are only a few dead decorations in it. The phreatic cave would have formed much earlier than the crevices that now dissect it.

LV77 THE MI-DUI SHAFT

A small stream flows over Orubadi beds then cuts a shallow canyon into the Warre Limestone before it sinks into a well developed shaft. The shaft was not explored, however, a rock test indicated it has a floor or ledge at about 10 m. The stream in this shaft is probably the source of the stream that can be seen emerging into Ok Mi Cave along the Mi-Dui Lineation Figure 17.

INFORMATION FOR CONTRIBUTORS

SCOPE

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

MANUSCRIPTS

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

Throughout the main text major headings should be in upper case, centred and not underlined, while subheadings should use lower case, underlined and aligned with the left hand margin. Acknowledgements should be placed at the end of the text before the references, and the authors' addresses for correspondence should follow the references.

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References should be listed alphabetically at the end of the manuscript and cited in the text by the author's name and the year of publication (e.g. "(Grey, 1973)"). Where there is more than one reference to the same author in one year the letters a,b, c, etc. should be added. If there are more than two authors, they should all be named at the first citation and in the reference list, but the first name followed by 'et al.' should be used in subsequent citations. References should be checked particularly carefully for accuracy. Journal titles should be abbreviated following the "World List of Scientific Periodicals", which is available in most large libraries. The following examples illustrate the style:

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

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

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

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