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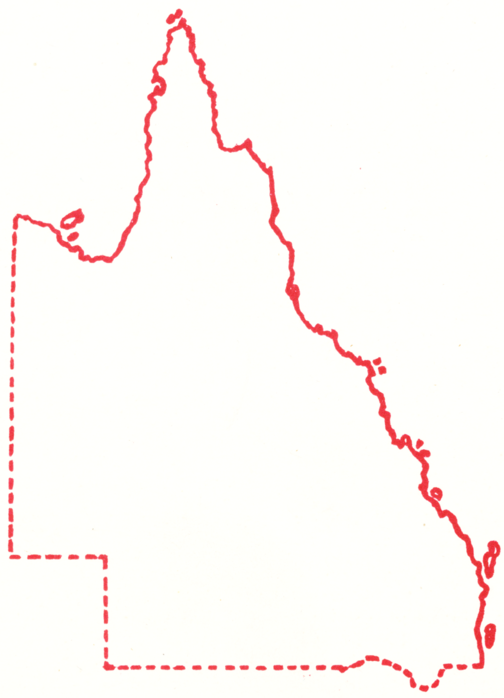
AUSTRALIAN SPELEOLOGICAL FEDERATION

PROCEEDINGS OF THE TENTH BIENNIAL CONFERENCE 27 - 29 DECEMBER 1974



Edited by A. W. Graham.

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AUSTRALIAN SPELEOLOGICAL FEDERATION

PROCEEDINGS OF THE TENTH BIENNIAL CONFERENCE

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Editorial

EDITORIAL

Publication of this volume marks the end of activity for the Tenth Biennial Conference Committee of the University of Queensland Speleological Society. Before the Conference, the committee decided that the proceedings would consist of papers specially written, rather than a transcript of the event. Further, in the interests of saving time, space and money, discussions were not included in the volume.

As editor, I must express special thanks to the majority of contributors for the presentation of their material. For production of the final copy, thanks go to June Canavan and D.S. Gillieson for their skill, understanding and patience. Without the guidance of Ian Usher of the "Printing Centre", the easy and economical production would not have been possible.

The committee would confirm all problems noted in the editorial of the proceedings of the Eighth Conference (Tasmania). For the benefit of future A.S.F. conference organizers, a file has been established, noting problems, grievances and ideas.

Views expressed in the volume are those of the respective authors. Editorial responsibility for errors of fact, or expression is disclaimed, and it is hoped that very few production typographical errors remain.

At the time of going to press, the financial situation of the Proceedings Fund is in doubt due to inflationary trends, the size of the publication, the relatively small run, and postal increases.

Andrew W. Graham
Editor

June, 1975

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AUSTRALIAN SPELEOLOGICAL FEDERATION
PROCEEDINGS 10TH BIENNIAL CONFERENCE

SECTION 1
GEOLOGY AND GEOMORPHOLOGY - LIMESTONE KARST

PRELIMINARY REPORT ON THE GEOLOGY AND GEOMORPHOLOGY OF THE MARBLE ARCH CAVE AREA, NEW SOUTH WALES

R.S. Nicoll[+], A.P. Spate* and J.B. Brush'
(Canberra Speleological Society)

INTRODUCTION

The Marble Arch Cave Area is located 35 kilometers south of Braidwood in southeastern New South Wales. The cave area is one of a number of small limestone bodies situated along or near the divide between the Shoalhaven and Deua Rivers. Marble Arch is located just east of the divide and drainage is into the Deua River. This is a preliminary report of detailed studies of the cave area now being undertaken by the Canberra Speleological Society, a final report will be published at a later date. This has, in part, been necessitated by the discovery of a new, and geomorphically important, cave in mid-December of 1974.

GEOLOGY

Despite its small size, about 120 metres wide and 1 km long, the area is geologically complex (fig. 1). The caves are developed in a carbonate unit that trends roughly North-South along the valley of Reedy Creek. Exposure of the carbonate is generally good but contacts with adjacent rock units are usually obscured by scree or soil cover. The carbonate unit in which the caves are developed is named the Marble Arch Limestone (Best et al., 1964). This unit is believed to be of Silurian age, based on data obtained from the Wyanbene Limestone to the south and the Cheitmore Limestone to the north which are believed to be lateral equivalents along the regional strike. There is no paleontologic evidence from Marble Arch on which to establish an age.

The Marble Arch Limestone consists of coarsely recrystallised and brecciated carbonate along with irregular dolomitic lenses. The term marble more appropriately describes the lithology, than does the term limestone, and will hereafter be used. The marble consists of angular fragments of grey to white, coarsely crystalline carbonate set in a ferruginous, silty to calcareous matrix. There is no preservation of original bedding or sedimentary structures but there are well developed cleavage planes that appear to have had some control on cave development. Dolomite occurs as irregular patches near the northern and southern extremities of the main carbonate body but appears to be absent in the central portion. South of Moodong Creek the marble near the top of the ridge is very dolomitic. The dolomite is secondary in origin.

Where exposed, both the eastern and western margins of the marble appear to be in contact with a waterlain tuff. Thickness of this unit appears to be variable, from approximately one to 20 metres. To both the east and west of the tuff is a

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thin dark, fine grained quartzite. This unit, about one to three metres thick, is resistant to erosion and is thus a good marker bed. It forms the ridge crest immediately east of the marble and talus from this unit obscures much of the eastern slopes of Reedy Creek. The quartzite is generally not exposed west of the marble but a good exposure was observed near the southern end of the main carbonate body on the ridge that separates Moodong and Reedy Creeks.

Granite surrounds the sedimentary rocks on the north, east and southwest sides. The granite varies in colour from white to pink and may be either fresh or deeply weathered. Relationships to the south are unclear but the sedimentary rocks appear to be cut off from the granite by a fault. The western margin is not well exposed but metasediments, of both cherty carbonate and silty clastics are found as float along the western valley margin of Reedy Creek and the adjacent hill slope. These rock types have not been observed in place.

Structurally, there is very little control in the area. As a result of poorly preserved bedding the only dip reading taken in the area was on the quartzite and gave a value of strike N10°E, dip 85°E. Two faults effect the area. One fault, with right lateral movement, separates the southern extension of the carbonate from the main portion of the unit. This fault is topographically expressed by the course of Moodong Creek. The southern extension appears to be terminated by a second fault that brings the marble up against granite. Faulting probably took place at a late stage following emplacement of the granite.

GEOMORPHOLOGY

The Marble Arch Cave Area includes at least five major caves, Thermocline, Nargun, Marble Arch, Moodong and Bettowynd Caves (fig. 2). There are also an additional thirteen known minor caves and a total of 21 entrances have been tagged as of December, 1974. Surface exploration of the area has been reasonably thorough and it is not expected that further major discoveries will be made.

An elevation datum point for this study was taken as the junction of Reedy and Moodong Creek. On the Kain 1:25,000 topographic map this junction is at 1990 feet elevation and this was converted to an assumed value of 580 metres. The highest elevation of the marble is approximately 710 metres, near the south-eastern portion of the main marble body. The elevation of Reedy Creek where it leaves the lower end of the marble is 595 metres. This gives a figure of 115 metres (or approx. 380 feet) for the relief on the marble.

Within the marble three major levels of cave development have been recognized (fig. 3). These are level A, characterized by Bettowynd Cave and possibly by Nargun Cave; level B, by the upper passages of Marble Arch and Moodong Caves; and level C, by the active stream levels in the latter two caves. Because Bettowynd Cave was only recently discovered and has not been mapped, our discussion of level development will deal only with levels B and C.

This detailed study of the B and C erosion levels in Marble Arch and Moodong Caves can only be regarded as preliminary. We have not, as yet, attempted to relate, with confidence, these caves with Thermocline or Nargun Caves located further up Reedy Creek.

The elevation of the uppermost passage, the Ba level of the Marble Arch-Moodong Cave System is 642 metres at the upstream end. The Ba level passage has a flattened ovate cross-section and represents a period of base level stability during which enlargement of the cave cross-section is horizontal rather than vertical. The Ba level passage is partly filled with fine sediments and gravels but the time at which this sediment was deposited is unknown. The Ba level, at 642 metres, is 3.5 metres above the lowest elevation in the saddle above the Arch which indicates that surface stream erosion probably continued until some time during erosion of the Bb level.

After the Bb level all surface drainage in Reedy Creek was channelled through a cave passage.

A probable lowering of base level then lead to a period of rapid downcutting forming Dunn's Crack (level Bb). This passage is up to 7 metres high and is usually less than a metre wide. The Bb level connects the Ba and Bc levels, usually as an open, vertical passage intersecting the flat roof of the Bc level.

The Bc level is the lowest recognized part of the B level. The level represents a return to base level stability with development of large, anastomosing stream channels. Two extensive flat roof levels can be differentiated in part of the Bc level. The Bc level is up to 4 metres high, 12 metres wide and must represent a relatively long period of slow downcutting.

Bc level downcutting is apparently terminated by a period of deposition in the level of both coarse and fine clastic sediments. The change from degrading to agrading conditions could have been the result of a blockage of the valley at some point further downstream by slumping of large blocks into the stream. The Bc level was entirely filled with sediment and the active stream meandering on top of the deposited sediments began to cut upward into the ceiling. The phreatic conditions and hydraulic pressures developed an upward cutting channel with an irregular roof level. The meandering passage is cut into the ceiling from 10 cm to as much as 1.5m, using the flat ceiling of the Bc level as a datum. This mode of development would produce features analogous to those produced in subglacial ice caves. The lack of anastomosing ceiling channels probably indicates that this period of ceiling solution was of short duration. The stream then cut down through the accumulated sediments and into the underlying bedrock floor preserving with remarkable fidelity the meander form found in the ceiling.

There is no known stream passage connection between the lowermost B level and the uppermost C level. It may be that the transition from B to C levels took place by phreatic sapping upstream from the present extent of the cave. The separation of the lowermost B level from the highest C level is about 3 metres.

The uppermost C level (Ca) represents another period of base level stability. The Ca level passage is up to 12 metres wide but less than a metre high. This passage has subsequently become fully or partially sediment filled but the timing of this event is not known. The base level stability of the Ca level was replaced by a period of downcutting forming a passage, the Cb level, two to three metres wide and 11 metres high before another period of base level stability, level Cc, developed in which the cave passage again developed laterally.

At present level Cd, the active stream level, development downward appears to be taking place in three ways. First there appears to be continual downcutting by the stream at high flow periods in the major cave floor. Second there is sapping with resurgence of the stream in a minor cave (MA18) on the right wall of the gorge about 18 metres below the downstream entrance of the Arch. Thirdly a portion of the stream is diverted at two points through the Lake Chamber passage and exits through the lower entrance of Moodong Cave (MA4). Some water enters this flow path from within the Arch and the rest is believed to enter the system from the bed of Reedy Creek just upstream from the present cave entrance. The northern-most part of the Lake Chamber passage is about 7 metres horizontally from the surface stream and the top of the waterfall is 2.5 metres below the stream.

STREAM GRADIENTS

Using flat ceiling levels or meander niches it is apparent that during periods of base level stability that stream gradients in the abandoned B and C levels of the Marble Arch-Moodong Cave System were very close to measured stream gradients of the present day Reedy Creek when it flows on limestone. There is a marked change in the stream gradient of Reedy Creek at the lower end of Marble Arch Cave where a major tributary enters from the left. As far as we are now able to determine this change in gradient is not reflected in the abandoned cave levels.

References

BEST, J.G., *et al.*, 1964 Canberra, A.C.T. and N.S.W. - 1:250,000 Geologic Series. *Bur.Miner.Resour.Aust.* Sheet SI/55-16, (second edition).

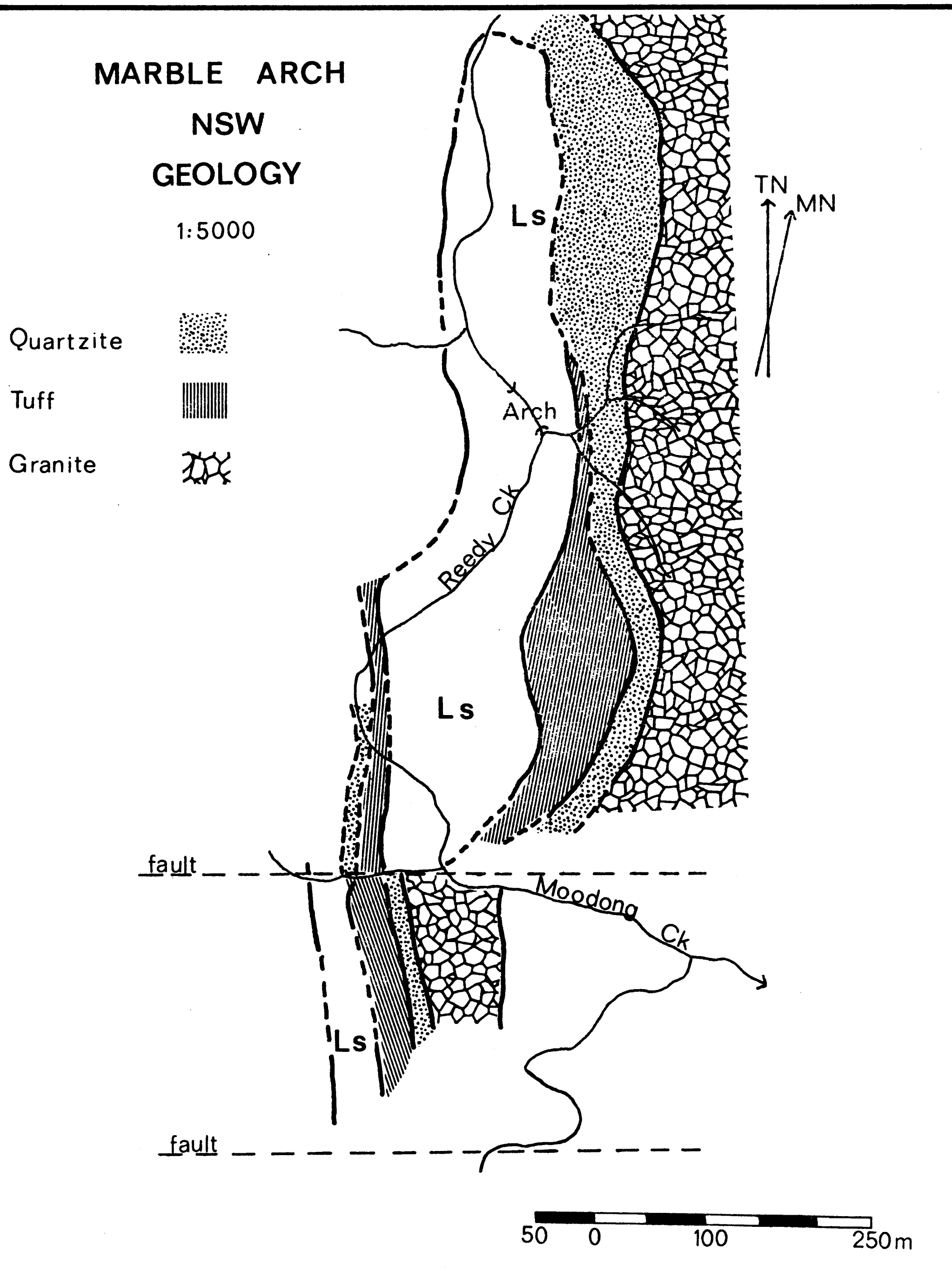

Figure 1. The geology of the Marble Arch cave area, N.S.W.

tropical climates (e.g. Wall & Wilford, 1966; Dragovich, 1968); in Tasmania a cave produced by solution of secondary minerals in an alteration zone of a dolerite, described by Hale & Spry (1964); volcano-karst, a form produced when labile minerals in newly erupted volcanic ashes are rapidly dissolved to produce weird sculpturing forms (Fairbridge, 1968 b, and Bourke in this volume); and laterite-karst, where silicate minerals are removed in solution from within a deep weathering profile (Grimes, 1974). (Laterite-karst is distinct from the laterite caves in West Australia described by Lefroy & Lake (1972) which appear to be a piping phenomena).

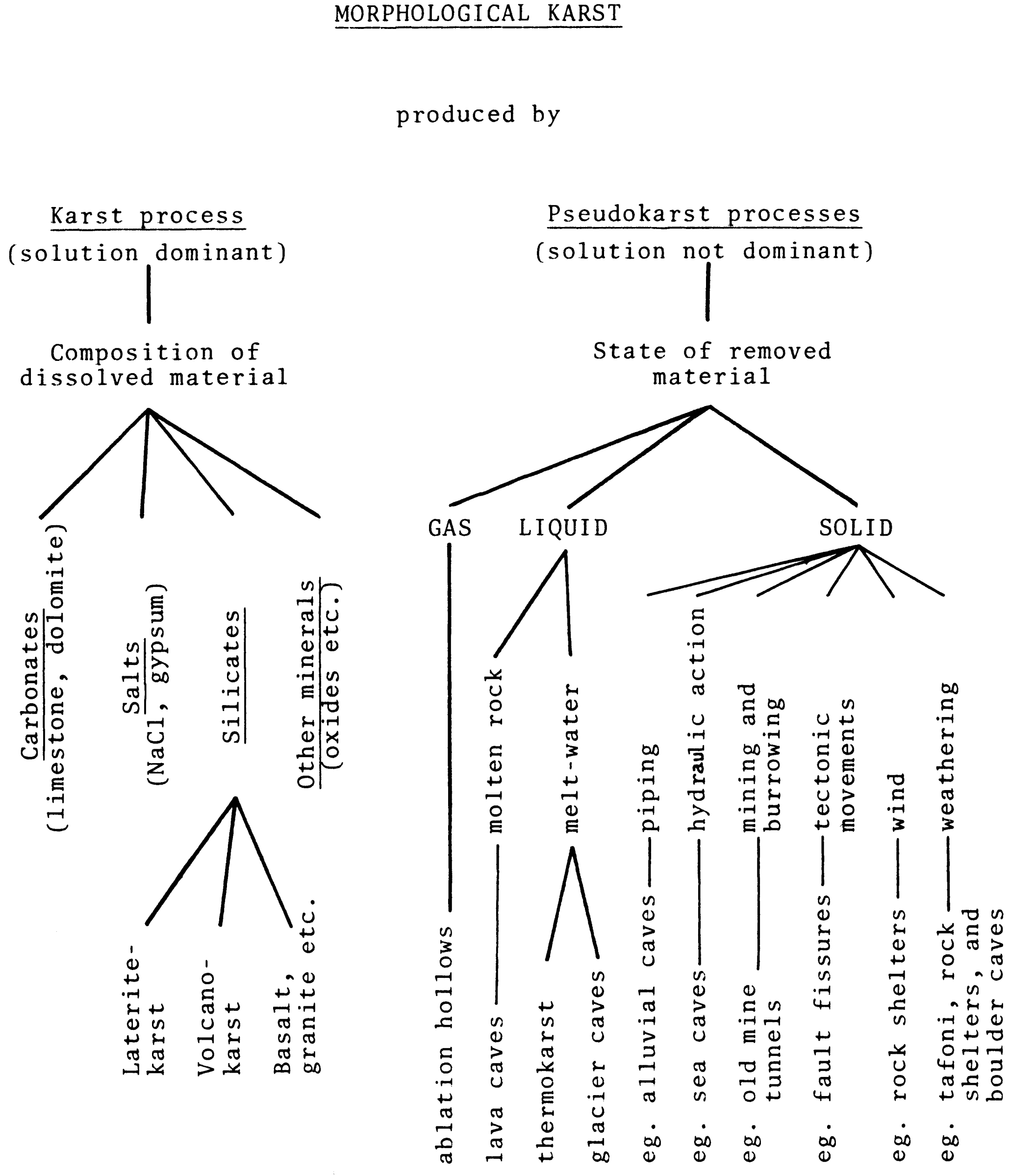

Table 1. Classification of Karst and Pseudokarst

(B) True pseudokarst

The different types of pseudokarst are grouped here according to the phase in which the material is removed (see Table 1):

(i) Solid phase removal. The greatest variety of pseudokarsts result from the removal of solid material. Piping is a form of soil erosion which can also occur in poorly consolidated deposits. The process is one in which clay particles are removed in suspension by groundwater percolating through cracks or pore spaces in the sediment. In conjunction with this headward sapping occurs at springs. Once underground tunnels are produced by these processes they can be enlarged by the normal corrasive action of streams flowing through them. Fletcher et al (1954) postulated five conditions for the development of piping: (1) a source of water, (2) a surface infiltration rate which exceeds the permeability rate of some subsoil layer, (3) the existence of an erodable layer just above the retarding layer, (4) the water above the retarding layer must have a hydraulic gradient along which it can flow laterally, and (5) there must be an outlet for the lateral flow. The process is facilitated by the presence of swelling clay minerals and by a high exchangeable sodium potential. Piping can result in intricate forms of morphological karst, including caves, underground streams, dolines, etc. (Parker et al, 1964; Parker, 1968; Mears, 1968; Feininger, 1969). The process is characterised by its rapidity when compared with solution karst; Parker et al (op cit) quote rates of 2,700 cu.ft. per year for enlargement of Officer's Cave, U.S.A.. Some authors (eg. Khobzi, 1972, and the Cave Summary sheets produced by the A.S.F.) use "suffosion" as a synonym for piping. This is not valid as suffosion is a periglacial phenomenon (see Fairbridge, 1968 c).

Some Australasian examples of piping caves will be described by Bourke and by Shannon elsewhere in this volume. A good local example is the Flagstone Creek Caves (Gillieson, 1971).

Sea Caves result from the combined hydraulic action of waves and the pressure of compressed air, aided by salt spray weathering. Dolines can form above the caves. A large number of sea caves in N.S.W. have been described in recent years and Toomer & Welch will be summarising these studies elsewhere in this symposium.

The mechanical removal of material from animal burrows or by human mining activities could be considered as a form of pseudokarst. Mine tunnels are analagous in form to natural caves and disused mines are often occupied by bats and other cave dwelling species. They can develop speleothem deposits if conditions are suitable and these may include some of uncommon mineralogy in the case of metalliferous mines. Some beautiful stalactites of malachite and azurite have formed in disused parts of the Mt. Isa mines. Subsidence areas and dolines can form above old mine workings.

Some other forms are fault fissures resulting from tectonic movements, and the formation of rock shelters and small caves by weathering or wind erosion. Weathering can combine with piping of the resultant clay material to enlarge joints in granite and produce an underground drainage, e.g. the Labertouche Cave in Victoria (Ollier, 1965) and the Underground River at Wyberba, Qld., (Pound, 1971).

(ii) Liquid phase removal. The most common form in this group is the formation of lava tunnels by the draining of molten lava from within a solidifying flow. Ollier & Brown (1965) have described in some detail the process which formed the Victorian lava caves. In these the lava solidified in laminae separated by still molten material which then became segregated into discrete cylindrical tubes. These were at first filled with molten rock and capable of remelting their walls and moving uphill for short distances under hydrostatic pressure. If the tube were then drained a lava cave would result and sagging or collapse of the roof could form surface depressions. Hatheway (1971) presents a similar

theory but considers that the mobile cylinders of liquid lava originate at the toe of the flow and develop backwards up the flow to its source. Greeley (1971, 1972) has observed the formation of tunnels by the crusting over of lava channels on the surface of an active flow in Hawaii. In Queensland the best known lava tunnels are in the Mt. Suprise area (Watt, 1972; White, 1965, pp. 91-101). The lava cave at Bunya Mountains may be a weathering feature rather than a true lava tunnel (Graham, 1971).

Melting of ice and snow produces several types of pseudokarst. Meltwater caves in snow banks or in glaciers are of most interest to speleologists. Glacier caves can reach 2.5 km length (Halliday & Anderson, 1970). Local examples have been described from the Snowy Mountains by Halbert & Halbert (1972) and from New Zealand (Shannon, 1972). An interesting form is the summit firn cave of Mt. Rainier, U.S.A., in which the melting is mainly due to heat from volcanic activity (Kiver & Mumma, 1971).

In arctic areas seasonal thawing of frozen ground results in a terrain known as thermokarst (Dylik, 1968; Anderson & Hussy, 1963) which includes pits, dry gullies, small hummocks and closed depressions. The processes involved include subsurface mudflows which erupt at the surface as mud volcanoes and this is the preferred use of the term "suffosion" (Fairbridge, 1968 c).

(iii) Gaseous removal. This is a theoretical possibility, as in the ablation of snow and ice, but I don't know of any examples where this is the dominant process. Ablation could have formed the steam cups and fluting of the ice walls of the caves on Mt. Rainier (Kiver & Mumma, op cit).

References

The following list will provide an introduction to the various types of pseudokarst and non-limestone karst. Perusal of Australian Speleological Abstracts will disclose a large number of Australian pseudokarst examples.

ANDERSON, G.S., & HUSSEY, K.M., 1963 Preliminary investigation of thermokarst development on the North Slope, Alaska. *Proc. Iowa Acad.Sci.*, 70, 306-20.

DRAGOVICH, D., 1968 Granite lapies at Remarkable Rocks, South Australia. *Rev. Geomorphol.Dyn.*, 18(1), 8-16.

DYLIK, J., 1968 Thermokarst. In *The Encyclopedia of Geomorphology*. Ed. R.W. Fairbridge, New York, Reinhold. Pp.1149-51.

FAIRBRIDGE, R.W., 1968 a Salt Karst. In *The Encyclopedia of Geomorphology*. Ed. R.W. Fairbridge, New York, Reinhold. Pp.967-8.

FAIRBRIDGE, R.W., 1968 b Volcano-karst. In *The Encyclopedia of Geomorphology*. Ed. R.W. Fairbridge, New York, Reinhold. Pp.1205-8.

FAIRBRIDGE, R.W., 1968 c Suffosion and Tundra Craters. In *The Encyclopedia of Geomorphology*. Ed. R.W. Fairbridge, New York, Reinhold. Pp.1099-1100.

FEININGER, T., 1969 Pseudokarst on quartz diorite, Colombia. *Z.Geomorph.*, 13(3), 287-96.

FLETCHER, J.E., HARRIS, K., PETERSON, M.B., & CHANDLER, V.N., 1954 Piping. *Trans.Am.Geophys.Union*, 35(2), 258-62.

GILLIESON, D.S., 1971 Flagstone Creek Caves. *Down Under*, 10(4), 93-4.

GRAHAM, A., 1971 A preliminary note on a cave in basalt, Bunya Mountains National Park, Queensland. *Helictite*, 9(4), 73-6.

GREELEY, R., 1971 Observations of actively forming lava tubes and associated structures, Hawaii. *Modern Geol.*, 2, 207-33.

GREELEY, R., 1972 Additional observations of actively forming lava tubes and associated structures, Hawaii. *Modern Geol.*, 3, 157-60.

GRIMES, K.G., 1974 The Mesozoic and Cainozoic geology of the Lawn Hill, Westmoreland, Mornington, and Cape Van Dieman sheet areas. *Bur. Miner. Resour. Aust. Rec.*, 1974/106 (unpubl.)

HATHEWAY, A.W., 1971 Lava tubes and Collapse Depressions. (Ph.D. Thesis, Univ. Arizona). *Diss.Abstr.Int.*, 32(4), 2234B. (Abstr.)

PSEUDOKARST - K.G. Grimes

HALBERT, E., & HALBERT, S., 1972 Meltwater caves in the Snowy Mountains. *J.Syd.Speleo.Soc.*, 16(8), 223-4.
HALE, G.E., & SPRY, A., 1964 A cave in dolerite at Wayatinah, Tasmania. *J.Geol.Soc.Aust.*, 11(2) 213-6.
HALLIDAY, W.R. & ANDERSON, C.H., 1970 Glacier Caves - a new field of Speleology. *Stud.Speleol.*, 2(2), (extract printed in *Oolite*, 2(3), 12-13)
KHOBZI, J., 1972 Erosion chimique et mechanique dans la genese de depressions "pseudo-karstiques" souvent endoreiques. *Revue Geomorph.Dyn.*, 21(2), 57-70.
KIVER, E.P., & MUMMA, M.D., 1971 Summit Firn Caves, Mount Rainier, Washington. *Science*, 173, 320-2.
LEFROY, T., & LAKE, P., 1972 A laterite cave system in the Chittering Region, West Australia. *Western Caver*, 12(3), 68-77.
MEARS, B., 1968 Piping. In *The Encyclopedia of Geomorphology*. Ed. R.W. Fairbridge, New York, Reinhold. Pp.849-50.
MONROE, W.H., 1970 A glossary of Karst Terminology. *U.S. Geol.Surv. Water Supply Pap.*, 1899K.
OLLIER, C.D., 1965 Some features of granite weathering in Australia. *Z.Geomorphol.*, 9, 285-304.
OLLIER, C.D., & BROWN, M.C., 1965 Lava caves of Victoria. *Bull.Vulcanol.*, 28, 215-29.
PARKER, G.G., 1968 Officer's Cave, Eastern Oregon, Revisited. *Geol.Soc.Am.Spec.Pap 101*, p415 (Abstr.).
PARKER, G.G., SHOWN, L.M., & RATZLOFF, K.W., 1964 Officer's Cave, a pseudo-karst feature in altered tuff and volcanic ash of the John Day Formation in Eastern Oregon. *Geol.Soc.Am.Bull.*, 75, 393-402.
POUND, M., 1971 Wyberba (trip report). *Down Under*, 10(3), 67-8.
SHANNON, C.H.C., 1972 Meltwater caves in the glaciers of the Southern Alps. *Down Under*, 11(2), 36-8.
SWEETING, M.M., 1972 Karst Landforms. London, Macmillan.
WALL, J.R.D., & WILFORD, G.E., 1966 A comparison of small-scale solution features on microgranodiorite and limestone in West Sarawak, Malaysia. *Z.Geomorph.*, 10, 462-8.
WATT, A., 1972 Lava Caves in North Queensland, Einasleigh-Mt.Suprise area. *Proc. 8th Biennial Conf.Aust.Speleo.Fedn.*, 18-24.
WHITE, D.A., 1965 Geology of the Georgetown/Clark River area, Queensland. *Bur.Miner.Resour.Aust.Bull.*, 71, 91-101.

Additional references not mentioned in text:

GIBSON, I.L., 1974 Blister Caves associated with an Ethiopian Volcanic Ash-Flow Tuff. *Stud.Speleol.*, 2(6), 225-232.
HALLIDAY, W.R., & ANDERSON, C.H., 1970 Glacier Caves, a new field of Speleology. *Stud.Speleol.*, 2(2), 53-59.
PETERSON, D.W., & SWANSON, D.A., 1974 Observed Formation of Lava Tubes during 1970-71 at Kilauea Volcano, Hawaii. *Stud.Speleol.*, 2(6), 209-222.

AUSTRALIAN SPELEOLOGICAL FEDERATION
PROCEEDINGS 10TH BIENNIAL CONFERENCE

A REVIEW OF NON-LIMESTONE CAVES IN NEW SOUTH WALES

A.J. Pavey*

ABSTRACT

A brief description and suggested mode of formation is given for a number of non-limestone caves within N.S.W. These caves are perhaps best classified in terms of their mode of formation.

INTRODUCTION

Unlike caves formed in limestone, caves formed in non-limestone rocks usually occur singly and are often unique in their mode of formation. In this paper I wish to briefly review the different types of known non-limestone caves found in New South Wales. It is hoped to demonstrate the variety of features which can be produced in non-limestone rocks and how closely they can resemble caves produced by karst processes. The order of discussion is solely geographically from South to North in N.S.W. and does not indicate importance or priority of any kind. The numbering used is arbitrary since some caves have yet to be assigned cave numbers compatible with the A.S.F. Documentation system.

1. (WY7) Bushrangers (Clarks) Cave, Wyanbene Caves Area

This cave is more accurately described as a rockshelter situated on the side of a steep hill. It comprises a cavity approximately 8m long and up to 4m deep with a roof height increasing to approximately 3m. The cave is formed along the uncomformity separating the Devonian conglomerate from the Upper Silurian limestones below.

The initiating mechanism for the cave is not clear but enlargement seems to be occurring by weathering of the poorly sorted conglomerates forming the roof of the cave with a consequent floor composed of rounded pebbles and gravels from the conglomerate. Some enlargement may be occurring by a process of solution of the limestone by percolating groundwater.

Of historical interest is the rumour that it was a hideout used by the bush-ranging Clark brothers, who terrorised the surrounding countryside during the local goldrush at Araluen.

2. The Big Hole, near Braidwood

The Big Hole is a big angular and precipitous pit located near the top of a ridge of quartzitic Devonian sandstone and conglomerates and is much deeper than it is wide. Jennings (1966, 1967) has reported it as varying in diameter from 30-53m and of greatest depth 113m. The floor comprises an asymmetrical cone of sandstone blocks covered with a number of man-ferns. Several recent, small collapses of the walls have occurred. A fault crosses the Big Hole but does not seem to have initiated its formation. The cave is thought to represent a type example of a subjacent collapse doline (Jennings). Although no limestone is found in the cave it is expected that Silurian limestone unconformably underlies the Devonian sequence and that the cave is a result of a sudden collapse into a large cavity created phreatically in the limestone below. Although large chambers have been found in Wyanbene Cave nearby, indicating that

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the limestone could support a sufficient sized cavity, the bottom of the Hole is approximately 21m above the nearby Shoalhaven River and well below the base of the hill in which it is found, so that there is some question as to the postulated mode of formation.

3. Nangwarry Sandstone Caves, Nowra

These caves are formed in sandstone along the banks of the Shoalhaven River west of Nowra. They were first reported by Renwick (1972) and recent investigations by N.S.W.I.T.S.S. have resulted in considerable extension and consolidation into a network of rifts and chambers of total length approximately 400m (Mannell, 1973).

The caves have been formed initially by strong beds of sandstone being undermined by the river, and as the blocks break off and rotate or slip downwards, they leave cracks which form the cave. Enlargement is due to some small extent by wind scour, spallation and collapse.

At least two similar areas of caves are reported from nearby localities, Riverside to the east of Nowra and in the Kangaroo Valley to the north (P. Dykes, pers. comm.).

4. Hilltop Natural Tunnel, Hilltop

This cave comprises a tunnel in sandstone approx. 82m long, 2-4m high and 2-10m wide, of fairly regular cross-section with an almost planar roof of slightly dipping sandstone. The stream meanders across small angular rocks and sand and bedrock in its path through the cave. At the lower entrance the stream falls over a 3m waterfall under a large overhang, (Pavey, 1972a). It is not clear what initiated the cave but it seems certain that it is structural control. It has been suggested that the cave formed down a shale band between two sandstone members and that the waterfall has accentuated the down cutting which is proceeding now by the normal erosive action of the stream. The probable future history for the cave is that as the waterfall continues upstream, the cave will widen and collapse and progressively grow shorter until it ceases to exist.

Some speleothems (mainly flow stones) are observed on the northern wall, presumably indicating some carbonate content in the shale below the sandstone member comprising the roof.

A similar cave approximately 60m long occurs on Cowan Creek in Ku-ring-gai Chase (Shannon, 1963).

5. Limestone Cave, Royal National Park

This cave is in fact only a sandstone overhang similar to many thousands of others around Sydney and the Blue Mountains, but unlike them, it possesses genuine speleothem deposits. This overhang on Palona Brook is some 47m long, 14m deep and 9m high (Pavey 1972b, Nedwich, 1974) with a floor of sand and some fallen rock.

The main feature of the cave is the group of stalactites and a large stalagmite boss in the centre of the cave. They appear to have been formed from water draining through a carbonate rich layer of shale evident at the back of the overhang near the roof. The speleothems have the usual dull non-lustre associated with calcite deposits near cave entrances.

A nearby tunnel below the Palona Brook also contains speleothems. In the same area there is another cave formed from an overhang but this has collapsed and resulted in a complete dark zone within. This cave contains a number of bats (Minopterus sp) (I. Wood, pers. comm.). Some other overhangs in the Blue Mountains have been reported as developing limonite straws (Pickering, 1972).

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A more complex cave is Tarrawonga Cave, Sun Valley in the Blue Mountains which may be the result of wind scour and collapse. It comprises one chamber with a rubble strewn floor (Matthew, 1974).

6. St Michael's Cave, Avalon

There are a number of large sea caves along the coast of N.S.W. and recently many of these have been documented (Middleton, 1971; Moore & Taylor, 1973; Toomer, 1973; Ellis, 1974; Stibbs, 1974a, b; Anon., 1973; Toomer & Welch, 1975).

In many caves the size and shape of the sea cave is directly controlled by a structural feature of the rock which has been enlarged by both wave (and spray) action, and mechanical action (rocks pounded against cliff by waves).

As a type example, St Michael's Cave has been selected here for brief discussion as Toomer & Welch (1975) have covered this topic more fully.

The cave is now located 21m above sea level and has an impressive entrance 4.5-9m high, 15m wide. It runs back into the cliff in almost a straight line for over 100m, gradually tapering in width and height. The floor is littered with angular sandstone blocks and consolidated sand (thousands of trampling feet!). The lowest point in the cave is still some 10m above sea level and as depth into the cliff increases, the cross-section changes from wide rectangular through triangular to small, narrow rectangular (Pavey 1972c).

Pratt (1971) considers the history of the cave to be quite complex. Basically a dolerite dyke was eroded and replaced with a poorly consolidated ferruginous sandstone, which was then eroded by the sea during a mid-recent high sea level going back approximately 50,000 years. Since that time the cave has been widened and filled by roof-collapse (giving rise to its characteristic cross-sections).

Certainly not all of the sea caves found along the coast feature such a complex history, many currently at sea level may only be in the initial stages of the process.

Sea caves are not only formed along dykes, the sea caves of the Fraser Park area (Pavey 1972d; Ellis, 1974) formed in a poorly sorted conglomerate seem to have been formed by wave action along a line of weakness such as a joint, giving rise to long narrow tunnels which have then been enlarged isotropically giving rise to almost hemispherical caverns. A more complex and less easy to explain cave is Durras Cave near Batemans Bay (Ibbotson, 1973). The cave was formerly a breeding site for *Rhinolophus megaphyllus* (Hall & Young 1975).

7. Sanchos Hole, near Campbell River

This is a deep narrow slot 25m long up to 8m wide, and between 30 and 50m deep, and partially water filled (Culberg, 1972). The rock type is Silurian phyllite (Shannon, 1963), and how the cave came to be there is somewhat of a mystery. It is well up near the top of a hill and would not be below the level of the Campbell River some 2km to the east. There is no known limestone in the immediate vicinity, so it is not likely to have been formed by subjacent collapse.

8. Endless Cave, Kincumber

The cave is formed in sandstone approx. 150m a.s.l. and 3.2km from the coast. At the entrance there is an overhang 7m wide and 4m deep, 2m high. From the back of the overhang the cave extends back to a depth of 35m. Initially the passage is smooth bedrock 1 x 1m but after 4m the floor rises until the cave is 0.5m high, with a wet earth floor. A flattener leads to a chamber 1.5m high and 3m in circumference, containing about 50 bats (*Miniopterus schreibersi* and *Rhinolophus megaphyllus*). Two small tubes lead off but are too small to explore (Culberg 1973, Mumby 1972a, b). It is unlikely that this is a sea cave and it may possibly be formed in a similar manner to the Hilltop Natural Tunnel. Further work is needed, however, before anything definite is stated.

9. Lava Caves

Some "lava" caves have been found in the Warrumbungle National Park (James, 1967). These are "blister" caves up to 15m in diameter, low and hemispherical in shape (James, pers. comm.). They are located in the sides of the cones and lava flows. They appear to have been formed by gas bubbles in the molten lava and as the lava cools, it solidifies around these spaces leaving parts of the lava flow and volcanic cones full of holes. When erosion takes place these are exposed and can be classified as caves. Twenty to thirty entrances are recorded from the southern side of Belougery Split Rock. They do not extend far but some entrances are quite large. The other main site is on the eastern side of Mt Exmouth. The lava caves are inhabited by wallabies, goats, possums, etc.

CONCLUSION

As can be seen from these caves found in N.S.W., many different processes operating in a number of rock types can produce cavities. The task of documenting non-limestone caves has only just begun and it is clear that there is wide scope for future research in this field.

References

ANON., 1973 Summary of Sea Caves on Part of the South Coast. *PSG Bull.*, 3(1), 8.
CULBERG, T., 1972 Sanchos Hole. *Spar*, 14, 12-13.
CULBERG, T., 1973 More Non-limestone Caves North of Sydney. *Spar*, 23, 15.
ELLIS, R., 1974 The Sea Caves Near Fraser Park. *J.Syd.Spel.Soc.*, 18(2), 23-26.
HALL, L.S., & YOUNG, R.A., 1975 Roost Selection of the Eastern Horseshoe Bat *Rhinolophus megaphyllus*. *Proc. 10th Biennial Conf. A.S.F.*
IBBOTSON, J., 1973 Sandstone Caves. *Spar*, 25, 6-7.
JAMES, J., 1967 Caves in the Warrumbungle National Park. *Stop Press*, 11(9), 131-132.
JENNINGS, J.N., 1966 Australian Landform Examples No. 7 - Solution Doline and Subjacent Karst Doline. *The Aust. Geographer*, X(2), 132-133.
JENNINGS, J.N., 1966, The Big Hole Near Braidwood, New South Wales. *J.Proc.Roy.Soc. N.S.W.*, 98, 215-219.
JENNINGS, J.N., 1967, Further Remarks on the Big Hole Near Braidwood, New South Wales. *Helictite*, 6(1), 3-9.
MANNELL, R., 1973 Nangwarry Sandstone Caves - Nowra, N.S.W. *Labyrinth*, 3, 10-12.
MATTHEW, G., 1974 Sandstone Caves in Sun Valley. *Spar*, 35, 12-13.
MIDDLETON, G., 1971 The Sea Caves of Nadgee. *J.Syd.Spel.Soc.*, 15(12), 251-255.
MOORE, D., & TAYLOR, J., 1973 Bermagui Sea Caves. *Bermagui Caver*, 1(1), 7-8.
MUMBY, U., 1972a Kincumber. *Oolite*, 4(2), 53-55.
MUMBY, U., 1972b Sandstone Cave at Kincumber - Afterthought. *Oolite*, 4(2), 55-56.
NEDWICH, R., 1974 More Surveying in Royal National Park. *Spar*, 35, 16-17.
PICKERING, K., 1972 Speleothems in the Caves of the Blue Mountains National Park. *Oolite*, 3(3), 1-4.
PAVEY, A.J., 1972a Hilltop Natural Tunnel. *Spar*, 17, 18, and *Spar*, 18, 17.
PAVEY, A.J., 1972b Limestone Cave Royal National Park. *Spar*, 19, 14-15.
PAVEY, A.J., 1972c Sandstone Caves of the Barranjoey Peninsula. *Spar*, 16, 14-16.
PAVEY, A.J., 1972d Fraser Park Sea Caves. *Spar*, 21, 29.
PRATT, B, 1971 St Michael's Cave, Avalon. *Spar*, 8, 2.
RENWICK, J., 1972 Cave Discovery at Nowra. *Spar*, 13, 4-5.
SHANNON, H., 1963 A Conspectus of the Cave Systems within 500 miles of Sydney. *Syd.Uni.Spel.Soc.J.*, 6(4), 8-9.

PSEUDOKARST - A.J. Pavey

STIBBS, G., 1974a More Sea Caves in Royal National Park. *Spar*, 32, 19-20.
STIBBS, G., 1974b Sea Caving and Surveying in Royal National Park. *Spar*, 34, 10-12.
TOOMER, P., 1973 The Basin Cave. *PSG Bull.*, 2(8), 68, and 2(9), 76.
TOOMER, P., & WELCH, B., 1975 Investigation of Sea Caves. *Proc. 10th Biennial Conf. A.S.F.*

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PSEUDOKARST CAVES OF THE GAZELLE PENINSULA, NEW BRITAIN, PAPUA NEW GUINEA

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ABSTRACT

Volcanic pumice ash deposits blanket much of the north east lowlands of the Gazelle Peninsula of New Britain. Ten pseudokarst caves are known in this area, nine occurring in the volcanic ash and one within an active volcano. Clay or rock layers have been noted at about floor level in some of the caves. It is postulated that cave formation occurs because ground water moves more easily through the coarse sand ash layers then it can through the denser lower beds. Lateral movement of water occurs and tunnels commence forming where the water effluxes. A carbon sample from one cave was dated by radiocarbon age determination as 1475± 80 years B.P., thus indicating maximum cave age. Other areas in Papua New Guinea where similar cave development is possible are noted.

INTRODUCTION

New Britain is barely known in the speleological literature. Some of the features of the island are extensive karst landforms occurring on upland plateaux, several very large dolines, a number of explored limestone caves, and cave depth potential of 750 m and possibly up to 1000 m. The caves discussed here are developed in recent volcanic deposits, and whilst small, they are nevertheless interesting. They were first reported by the author in an earlier paper (Bourke 1972). The pseudokarst caves should not be confused with the numerous and sometimes extensive man-made tunnels dug for the Japanese occupation forces in World War II.

The only other reported pseudokarst caves in Papua New Guinea are in the Cape Hoskins area of New Britain and on Lihir Island. Johnson and Blake (1972) include a photograph of a cave containing boiling mud pools on the flank of Witori volcano. In the same general area, they report volcano-karst erosion features in moderately welded pyroclastic flow deposits south of Waisisi. Fluted gullies and small sink holes connecting with underground channels are developed where the moderately welded deposits are exposed in valley floors. Karst-like erosion features also occur in some older tephra deposits. On Lihir Island off New Ireland there is at least one pseudokarst cave developed in basalt (H. Gallasch, pers. comm.).

Rainfall varies in the different areas where caves occur on the Gazelle Peninsula, but is of the order of 2500 mm per year.

GEOLOGICAL BACKGROUND

The Gazelle Peninsula consists of a low isthmus in the south-west that separates it from the rest of New Britain, the rugged Baining Mountains, and the north-east lowlands. The Keravat and Warangoi River valleys separate the north-east lowlands from the mountains (see Figure 1).

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There are four eruptive centres on the Gazelle. The Rabaul eruptive centre is now a partly submerged caldera, breached on one side, and forming Rabaul harbour. It was formed during a climactic eruption 1000 to 1500 years ago. Two other centres, Mt. Varzin and another peak, are about 20 km south of Rabaul and the fourth is Watom Island 15 km north-west of the town (Macnab 1970).

Quaternary pyroclastic deposits from the Rabaul eruptive centre blanket much of the north-east lowlands (Macnab 1970), and a layer of pumice ash underlies the present day soil cover. Buried clay horizons a few metres below the present landsurface can be seen in road cuttings, these being old soils derived from earlier volcanic deposits.

THE CAVES

Ten caves are known to the author. These will not be described fully here, but descriptions and maps will be published in *Niugini Caver* in the future. Caving activity has not been concentrated on these caves because of their small size. Many others probably exist. In general the caves consist of a single stream passage with few or no branch passages.

The five Malabunga Caves are near the High School. Malabunga No. 1 is 52 m long. The cave is several metres tall and wide for most of its length. A small stream flows through the cave, and small springs emerge in places from the walls. The cave has five entrances, three occur in two dolines, the fourth is an efflux entrance, and the fifth is a daylight hole. There are two side passages. The floor of the cave is at or just below the contact between an overlying coarse sand layer containing pumice and a layer of heavy clay. At the contact there is a hard layer some 1 cm thich. The contact can be seen for most of the length of the cave.

Malabunga No. 2 is about 27 m long. Again, it is several metres wide and tall for most of its length. The cave is formed along the contact between the sand and clay. The contact is steeply dipping in places, and passage shape reflects this. Caves 3, 4 and 5 are about 24 m, 10 m and 30 m long respectively. They are smaller in section than the former two, and exploration involves crawling. The contact has not been observed in these caves.

All caves contain streams except No. 3. The entrance of this cave was located in a natural archway but was blocked by the collapse of the arch during a major earthquake in July, 1971. All caves have efflux entrances which are located at the base of cliffs. Tubes generally of 10 cm diameter and up to 30 cm in diameter occur in the walls of the caves, as do pieces of carbon. The latter are presumably the remains of trees buried with the ash falls.

Ngoat cave in the Gaulim area is 73 m long and also is a stream cave. There is an influx and efflux entrance. Similarly a small stream cave 10 m long at Keravat has both influx and efflux entrances. The influxes are not located in dolines. The streams are in fact underground sections of surface streams. Komunga cave near Taulil village is about 18 m long. The cave is dry and is on the side of a steep ridge some 15 m above the nearest creek. These three caves consist of single passages.

Matanakamalan cave near Rabagi village is 51 m long and contains a small stream. This cave is formed along the contact of the volcanic sand and the underlying volcanic rock. There are two passages. In a section where bats are very numerous it appears possible that they have enlarged the cave upwards as coconut roots are exposed in the roof.

The final cave is not in pumiceous ash as are the others, but is located within one of the craters of the active Tavurvur (Matupit) volcano. Cave origin is not known but the cave appears to be formed by collapse. It is well decorated with a variety of coloured sulphur containing minerals. The minerals appear to be precipitates from the sulphur containing volcanic gases.

DISCUSSION

It is postulated that the caves were formed as follows. The presence of a buried soil profile of heavy texture, or a rock layer that underlies the coarse volcanic sand deposit is a prerequisite for cave development, as is a place where the contact between the two layers reaches the surface. Water infiltration and percolation through the coarse permeable layers is rapid, but it is impeded by the denser lower layers. Lateral movement of water occurs and tunnelling commences where the water effluxes. The tunnelling process moves back from the efflux at the same time enlarging the cave. Collapse may open dolines. Collapses at the efflux are likely, thus forming the cliffs observed at the efflux entrances of the caves. Stream erosion may occur within the cave thus lowering the floor below the contact level. Alternatively subsequent collapse of material within the cave may raise the floor level above the contact. This is likely where streams are no longer active. Graham and Baseden (1956) have proposed that similar processes give rise to tunnel erosion in these soils.

Freshly erupted volcanic minerals, especially pyroclastics such as certain tuffs and agglomerates that contain unstable minerals, are highly susceptible to corrosion by rainwater and a variety of karst-type microrelief forms develop, just as in a limestone karst. This is termed volcano-karst (Fairbridge, 1968). Weathering of volcanic sands to fine clay particles which can be readily washed out of the coarse sand framework is likely. However the significance of solution processes, as distince from erosional ones, in cave development here is unknown. It is suggested that the erosional processes are dominant.

A sample of carbon was collected from the wall of Malabunga No. 1 cave for radiocarbon age determination which was performed by the Sydney University Radiocarbon Laboratory, The age of the sample (SUA-245) was 1475 ± 80 years B.P. (475 A.D.). This date sets the upper age of the cave, and indicates that cave development has been rapid when compared with limestone caves. The age lies within the eruption period of the Rabaul caldera proposed by Macnab (1000 to 1500 years ago). However, all the caves described here, except the one within Tavurvur volcano, are located closer to Mt. Varzin than the Rabaul caldera, so the origin of the parent material is uncertain.

Ash deposits also occur along the north coast and at the western end of New Britain, on much of Bougainville, on the islands off the north coast of the New Guinea mainland, such as Umboi, Karkar and Manam Islands, around Mount Lamington in the Northern District, in volcanic areas in the Gulf, Western, Southern Highlands, and Western Highlands Districts, and on some of the small islands off New Ireland. Similar caves are likely to occur in these areas, where ash deposits overlie buried soil profiles.

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References

BOURKE, R.M., 1972 Caves of New Britain - a Preliminary Report. *ASF Newsletter*, 57, 3-6. Also *Niugini Caver*, 1(1), 13-18, (1973).

FAIRBRIDGE, Rhodes W., 1968 Volcano-karst. In *The Encyclopedia of Geomorphology*. Ed. R.W. Fairbridge, New York, Reinhold.

GRAHAM, G.K., & BASEDEN, S.C., 1956 Investigation of Soils of the Warangoi Valley. *Papua and New Guin. Agric. J.*, 10(3), 73-91.

JOHNSON, R.W., & BLAKE, D.H., 1972 The Cape Hoskins Area, Southern Willaumez Peninsula, The Witu Islands, and Associated Volcanic Centres, New Britain:

Volcanic Geology and Petrology. *Bur.Min.Res.Geol.Geophysics Record*, 1972/133 (unpubl.).

MACNAB, R.P., 1970 Geology of the Gazelle Peninsula T.P.N.G. *Bur.Min.Res.Geol.Geophysics Record*, 1970/63 (unpubl.).

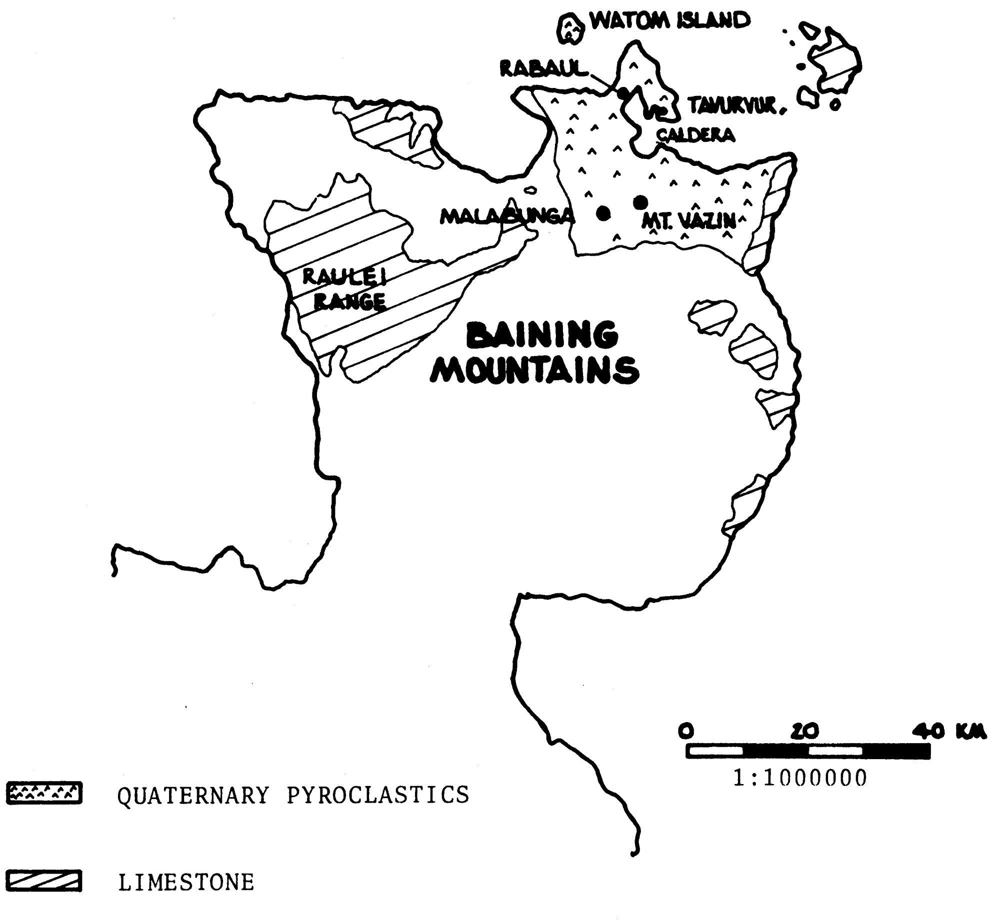

Figure 1. 1:1,000,000 Geological sketch map of the Gazelle Peninsula, New Britain.

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PSEUDOKARST CAVES IN DURICRUST/GRANITE TERRAIN, BANANA RANGE, CENTRAL QUEENSLAND

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ABSTRACT

Three enterable through caves, ranging up to 67 m in total passage length are described from the Barfield area. The caves occur in and under a sandstone duricrust resting on weathered granite. The sandstone is an indurated colluvial deposit derived from the surrounding granite and accumulating as sheets in low gradient sections of gullies. Induration to mottled sandstone occurred later in a lateritic weathering regime. The rock is very resistant and forms cliffs and waterfalls.

Cave development is initiated along disconformity surfaces; most commonly along the granite/sandstone contact but sometimes in an internal disconformity in the sandstone. The clay component of the rock can be dispersed into colloidal suspension. The process mimics true solution and provides a close analogy to true karst.

Three caves were located and mapped in the area which was traversed extensively during a mineral exploration program. As an area for the study of pseudokarst the area has the advantage of having more than one cave so it is possible to assess variation.

The terrain is granitic and is mapped as Glandore Granodiorite on the regional map. My own work in the area showed that there are several bodies within the granitic area which should be named separately, however the caves occur in the area of common granodiorite. This rock type has few fresh outcrops and these are found in creek sections and occasional tors. The usual surface expression of the granite is coarse arkosic sand, with angular grains of feldspar prominent and some brick sized pieces of aplite.

Overlying the granodiorite along the drainage lines of the area is a peculiar duricrust material which has been derived in the following manner: arkosic sand has been shed from the hillslopes to accumulate in the lower gradient zone along the gullies. The material is unsorted but crudely stratified, and thus was deposited as slopewash (colluvium) presumably by sand lodging against grass or rushes. The deposit was later subjected to a profound form of weathering in which it was converted to a duricrust. The feldspar and clay matrix material of the original sediment are now a dense (siliceous?) clay and the rock is much harder than the weathered granite below it.

The duricrust is exposed in cliffs mostly where a tributary gully comes in to a creek. At present rejuvenation has passed up the main creeks and the knick point is held at the waterfalls on the gullies. Elsewhere the duricrust surface expression is a fine quartz sand.

Caves were found only in hanging valley situations where a gentle gradient tributary gully drops over a cliff. There was always an inlet sinkhole where the level duricrust area abutted against the granite hillside, but sometimes there were others penetrating the duricrust pavement itself which seem to have developed later.

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The stream in the cave is a lineal descendant of the stream which cut the valley and deposited the arkose, thus giving the paradox of a cave stream being older than the cave (cf. West Australian dune limestone caves).

All the caves can be seen to follow disconformities; most often the contact of the duricrust sandstone and the granodiorite but one cave (Pool Cave) follows two disconformities within the duricrust sandstone.

In the case of the largest cave (Wedding Present) the basic passage section is a rounded off flat rectangle 2-3 m wide and 1-1.8 m high in the main passage, which is mostly excavated in the granite. The granite/sandstone contact is visible throughout near the ceiling. At the inlet end a flattener connects to the original entrance doline, and near the other end another flattener at ceiling level loops round to emerge in the downstream entrance rock shelter. The modern stream bed is a small affair fed by local catchment of the entrance dolines. The main gully now runs over the surface to the downstream end rock shelter where it comes in as a waterfall during rainy weather.

This larger gully is sufficient to fit the size of the passages in the cave, and the probable history of the cave is as follows: once the modern cliff face was established the gully ran over the site of the inlet dolines; water leaked along the granite/sandstone contact entraining deflocculated clay particles in a colloidal suspension. The piping process continued with actual erosion of sand from the downstream end until the pipe got through the capture the gully entirely. Initially the course followed was through the flatteners, but later a direct route was cut to bypass the loop flattener and also the main entrance doline developed capturing the gully from the initial entrance. This arrangement persisted while the cave cut down into the granite. Late in the history of the cave the main gully was diverted well upstream. The modern relic stream has not done much to modify the cave.

The Scrubber Cave is similar to the Wedding Present Cave in that it follows the granite/sandstone contact and is currently occupied by a relic stream with small catchment. More water enters the cave through a hole in the roof near the downstream entrance.

The basic cross section of the cave is quite different; it is much wider with most of the extra width occurring as a flattener along the sandstone/granite contact typically 0.3 m high in contrast to the winding channel cut into the granite where the cave is 1.0 m high.

The flattener appears to be essentially a rock shelter, developed in a zone where much clay matrix had been removed before stream capture took place. The basic cause of the variant shown here is delay in capture with prolonged preparation of the contact zone.

The Pool Cave differs fron the others in having a greater fall through the cave and in particular lying within the sandstone for most of its length; the pool which is the name feature of the cave is a plunge pool in solid sandstone and a continuous bar of sandstone crosses the cave floor below it.

So there is no doubt about the cave being inside the sandstone at this point. Two disconformity surfaces can be traced in parts of the cave in wall niches which separate sandstones with differing styles of duricrust mottling. The nature of the crossover between the two surfaces was not established but it seems likely that there is some vertical jointing in the duricrust which was sufficient control.

This cave also has a number of domes, so it lacks a regular cross section; its affinities are with the Wedding Present Cave in that it lacks development beyond the width needed by its original feeder gully.

The caves are quite closely analogous to true karst caves, since the colloidal suspension of clay mineral flakes in water is very close to true solution of calcium carbonate. The disconformity surfaces have taken the place usually filled by vertical joints, etc. in true karst in providing initial openings for enlargement. The further development of the caves has been by corrosion acting on the stream bed and the fretting action which operates to produce rock shelters; actions which are normally subordinate in karst caves.

Though there were a large number of gullies with duricrust sandstone bodies most did not have caves. It seems that it is very difficult for long through caves to form. One factor that may be important is that drainage diversion seems to have occurred only at the very edge of the sandstone outcrop.

References

SHANNON, Henry, 1973 Explorations in the Barfield Area. *Down Under*, Vol. 12, No. 3, pp 83-89, August 1973.

SHANNON, Henry, 1974 More on the Barfield Area. *Down Under*, Vol. 13, No. 2, pp 60-61, May 1974.

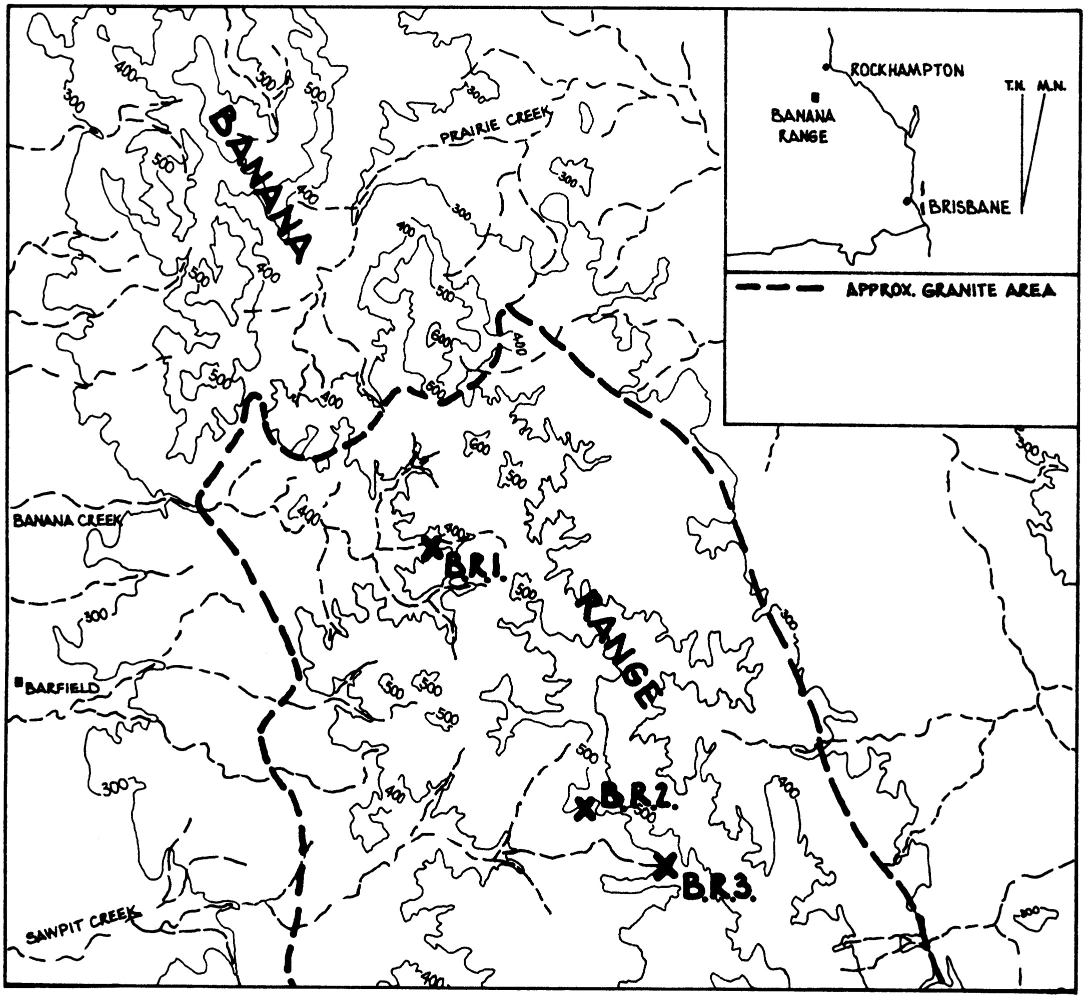

Figure 1. Location sketch for Banana Range pseudokarst area.

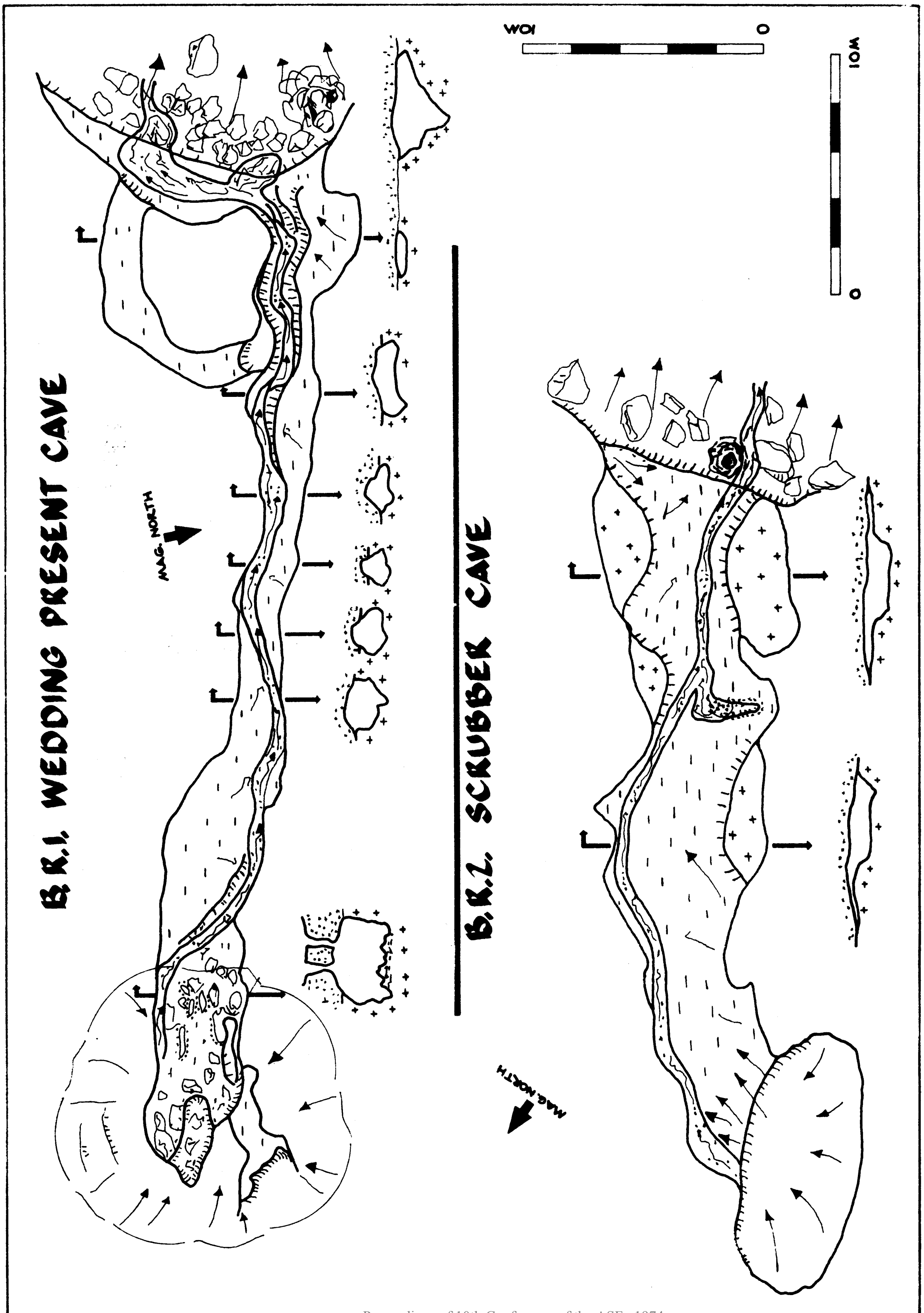

Figure 2. Plans and cross-sections of B.R.1 Wedding Present Cave and B.R.2 Scrubber Cave.

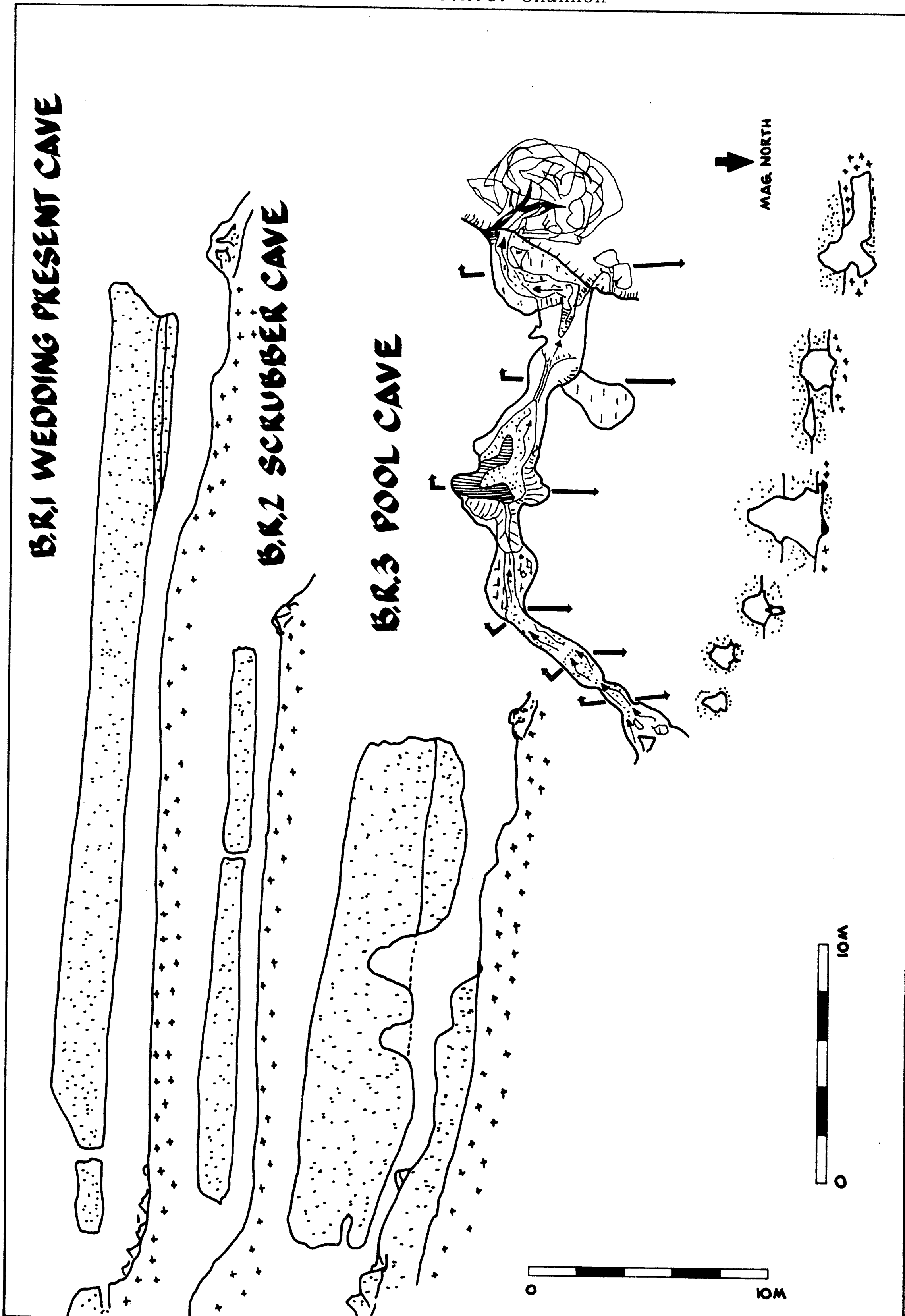

Figure 3. Extended long sections of B.R.1, B.R.2 and also plan and cross-sections of B.R.3 Pool Cave.

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INVESTIGATIONS OF SEA CAVES

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B.R. Welch*

INTRODUCTION

Over the past few years members of the Peninsula Speleological Group have been systematically documenting seacaves in the area of coast between Newcastle and Seven Mile Beach (South of Wollongong). Most of the work has been of a purely documentative nature, the principle aims being a cursory examination of the cave, the recording of a description and location of each cave and the assigning of a number. As a result, this work has also involved the development of a numbering system, techniques for locating and marking the caves and application of the A.S.F. cave record sheet to the storage of the data collected. Although the examination of each cave has not been particularly involved, it has been possible, in a general way, to relate structural control and lithologies to the form which the cave finally takes. Features covered in the paper include:

1. Joint control of caves in sandstone, conglomerate, and igneous rocks.
2. Dyke controlled development in sandstone and conglomerate.
3. The relation of cave debris to rock type, and the effect of debris on cave development.
4. Problems encountered in the locating, tagging and numbering of sea caves; technique used to overcome these problems.

STRUCTURAL CONTROLS

The majority of seacaves so far encountered in our investigations have some form of structural control. This control may be broadly divided into two categories. The first we have termed joint control. This encompasses firstly, simple joints caused presumably by the application or removal of stress where there has been no relative vertical movement, and secondly, faults, which result from similar stress situations but where there has been relative vertical movement. The distinction is made since there are often differences in the material adjacent to the joint planes, the faults often having breccia associated with them. The second form of structural control, which in many cases is consequential to the first, is dyke control. Dykes may have either intruded along pre-existing joint planes, or may have caused sufficient stress to cause the formation of joints and fractures. In many cases there is also evidence of post-intrusional stresses which cause joints thus providing joint rather than dyke control.

JOINT CONTROL

The most notable feature of a joint controlled cave is usually the linear style of development. As with limestone caves, the result is usually either long straight passage or frequent sharp bends. A further feature, which may in some circumstances be apparent is that of vertical walls. This seems to occur in regions where the vertical jointing is very pronounced, but in general the cross sectional shape of a cave which has formed along a joint due to mechanical erosion of sandstones is triangular e.g. The Ovens, Whale Beach, Sydney.

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PSEUDOKARST - P.B. Toomer and B.R. Welch

Bedding is also a significant factor, since with suitable jointing, collapse is facilitated by parting along bedding planes. Bedding also enables the distinction between joint control in different sedimentary rocks to be made. Inter-bedded sandstones and shales found in the Sydney area contrast markedly with the conglomerates of the Newcastle area.

The typical example of a cave formed in conglomerate, with joint control is Fraser Park sea cave (2I6E40). The curved cross section of this cave is attributable to the nature of the rock, conglomerate which under continual mechanical erosion, readily breaks down to its constituents. The sea cave south of Flat Is., N.S.W. (2I6E19), shows a similar style of development on the ocean side. However, on the less exposed side, an earlier stage of development is apparent, the typical triangular cross section being noted.

The forms of jointing already mentioned may also occur in igneous rocks. Sea caves such as the Blow Hole at Kiama, N.S.W. may result. A joint type which is usually restricted to igneous rocks is columnar jointing. This form of jointing is a cooling phenomenon and results in the development of polygonal columns, within the rock, normal to the cooling surface. Joints are usually present parallel to the base of these columns, thus eroding waves may readily dislodge relatively large pieces of rock from sea cliff exposures to form caves. Admittedly the occurrence of such sea caves is very limited, the Little Blow Hole at south Kiama is the only example of which we know. In this example the blow hole itself has formed due to the collapse of a single column from the rock platform roof to leave a polygonal hole.

DYKE CONTROL

Igneous material, which had intruded normal to the bedding usually along planes of weakness, are termed dykes. In many places along the stretch of coast which we have investigated, the dykes seem to be the controlling factor in the formation or at least the initial development of the caves. The usual explanation given for this is, that although igneous rocks are frequently more resistant to mechanical erosion than are sedimentary rocks, the chemical stability of igneous rocks is in general far less than that of sedimentary rocks of non-chemical origin.

The chemical instability of igneous material, particularly the basic intrusives found along the N.S.W. coast, results from formation at high temperature and pressure. In ambient conditions the minerals are intrinsically unstable (particularly in an electrolyte atmosphere such as that provided by the sea). The breakdown of only a few of the minerals will facilitate increased mechanical erosion. Examples of caves whose development may be attributed to the presence of a dyke include Bilgola Sea Cave (2XSC3.UNS1), St. Michaels Cave (2XSCI.UNS3), Stanwell Park Sea Cave (2I6I.PSG1).

Large slots are also common along the stretch of coast which we have examined. These are presumed to be formed by near total removal of dyke material.

The shape of caves which have formed due to dyke erosion often have fairly angular cross sections reflecting the shape of the original intrusion. On some occasions the style of erosion changes as the cave matures, for example Warriewood Sea Cave (2I6E.PSG2) which is eroded along a dyke, shows a change in cross section indicative of a combination of mechanical and chemical weathering at cross-section A (see map) where the elongate narrow cleft is due largely to chemical weathering and the wider chamber at the base is largely attributable to mechanical erosion. Further into the cave the effect of mechanical erosion is less than that of chemical weathering, which has (see cross-section B) removed a similar volume of dyke material to that removed at the entrance, cross-section A. By approximately forty metres from the entrance (see cross-section D), a different form of development is expressed, at that point bedding is such that planes of weakness exist and this in combination with the jointing associated with the dyke, results in fairly substantial collapse, the debris being buried in the sand floor. Towards the end of the cave there is a total absence of evidence of mechanical erosion, the cross section is uniform and the walls are parallel to each other (cross-sections E, F and G), rather than being convergent as at the entrance.

Another factor becomes apparent at the end of the passage. Ground water percolates through the rock surrounding the cave and this seems to be a suitable agent to aid the chemical decomposition, the floor of the cave beyond cross-section E is composed of clay, there are also limonite (or similar) formations present, which tends to substantiate the role attributed to percolating ground water in chemical weathering in this part of the cave.

CAVE DEVELOPMENT AND DEBRIS

The principal source of energy for the removal of rock and the formation of a cave is obviously the sea. The waves having once located a plane of weakness, are focused along it. The shape of the developing cave affects the approach of the waves and thus the shape of the cave may be a significant factor in the continuing development of the cave. It is possible that the presence of the sea within a sea cave may actually inhibit further development. In effect, standing waves may develop and act as a barrier to the more destructive waves coming straight in from the sea.

However, the observation that development is inhibited by the presence of the sea within a cave may be invalidated by a further observation that these standing or captive waves in general have a traction load, which although the wave action within the cave may be less than that at the cliff base, may make the captive waves more aggressively erosive. In some cases the material comprising the traction load is derived locally from the beach, thus giving the cave a sandy floor e.g. 2I6E23. In other cases the material in the cave is of pebble or cobble size and may have been derived from the decomposition of the rock surrounding the cave e.g. 2I6E40 (Fraser Park sea cave), or may have been transported. From current observations it appears that the caves undergoing most active development have pebble rather than sand floors. Continuous wave action tends to cause the pebble floor to move and thus mechanical erosion is intense.

It is apparent that since caves at sea level, which have pebble beaches are more prone to continued development than are other caves at sea level, the caves formed in conglomerate should be more active in their development. This in fact does appear to be the case as formation of the cave actually produces further abrasive material.

On the south coast of N.S.W. where the seas are frequently very rough, the majority of sea caves at sea level, have pebble beaches but the material is not locally derived since the caves in that region are formed in sandstones or fine conglomerates. Thus development is not self perpetuating as it appears to be in the Newcastle area.

The debris found in the sea caves of the Sydney area is markedly different to that of either the Wollongong or Newcastle areas. This is attributable principally to the geology of the various areas being different. Also, differences in wave activity exist. The conglomerates of the Newcastle area give rise to sea caves, which have little massive debris since the rocks are readily degraded back into pebbles. In contrast the sea caves of the Sydney region, which are in general formed in sandstones and shales of the Newport Formation, contain large pieces of debris resulting from the combined effect of the vertical joint planes and the near horizontal bedding planes. The presence of these large blocks of debris tend to reduce the rate of development due to the formation of a rock barrier to wave action e.g. Platform Cave, Avalon, Bilgola Sea Cave, St. Michaels Cave.

In the Wollongong Area, few caves appear to have much locally derived debris and most of the major caves are extensively wave washed. The smaller caves, as mentioned previously, have pebble beaches. This is attributed to the intensity of wave action rather than to the lithology.

PROBLEMS OF TAGGING

Rock Type

The standard method of fixing tags for cave numbers has for some time been to drill a hole, plug the hole with wood or lead and affix an aluminium tag by hammering a copper nail through a hole in the tag into the prepared hole. In many of the rocks encountered along the N.S.W. coast this practive is not practical. The soft rocks are easy to drill but the presence of a hole increases the rate of weathering to such an extent that the tag may drop out. To remedy this, an absurdly deep hole is needed. In the harder rocks the drilling of a hole takes an excessively long time and in conglomerates the pebbles are especially hard.

After much consideration of possible alternatives to the standard method a Ramset gun was used. Durability of the nails will be discussed later. The Ramset method solves the penetration problem and tagging is very swift. However a relatively flat surface is requred for efficient functioning of the Ramset gun, and trouble is also encountered in driving nails into quartz. 1½" nails have been found to be satisfactory and the charge is selected according to the estimated hardness of the rock. Green or yellow is usually sufficient for sandstone and hard shales, red being necessary for harder sandstone and conglomerates, purple charges are required for basalts and the more solid conglomerates.

Tag Durability

Due to the extremely corrosive nature of the sea water, tag materials need to be carefully selected. Aluminium is very easily corroded and steel rusts very readily. The only materials sufficiently durable so far found are Polycarbonate plastic and Phosphor Bronze. In order to stop the Ramset nail passing right through the tag the plastic needs to be about 5mm thick. Phosphor Bronze is expensive. So even these materials present problems. We are at present conducting tests but current observations show that the Ramset nail is corrosion resistant to a sufficiently high degree to be used for tagging sea caves. (It is high tensile steel.)

Tag Site

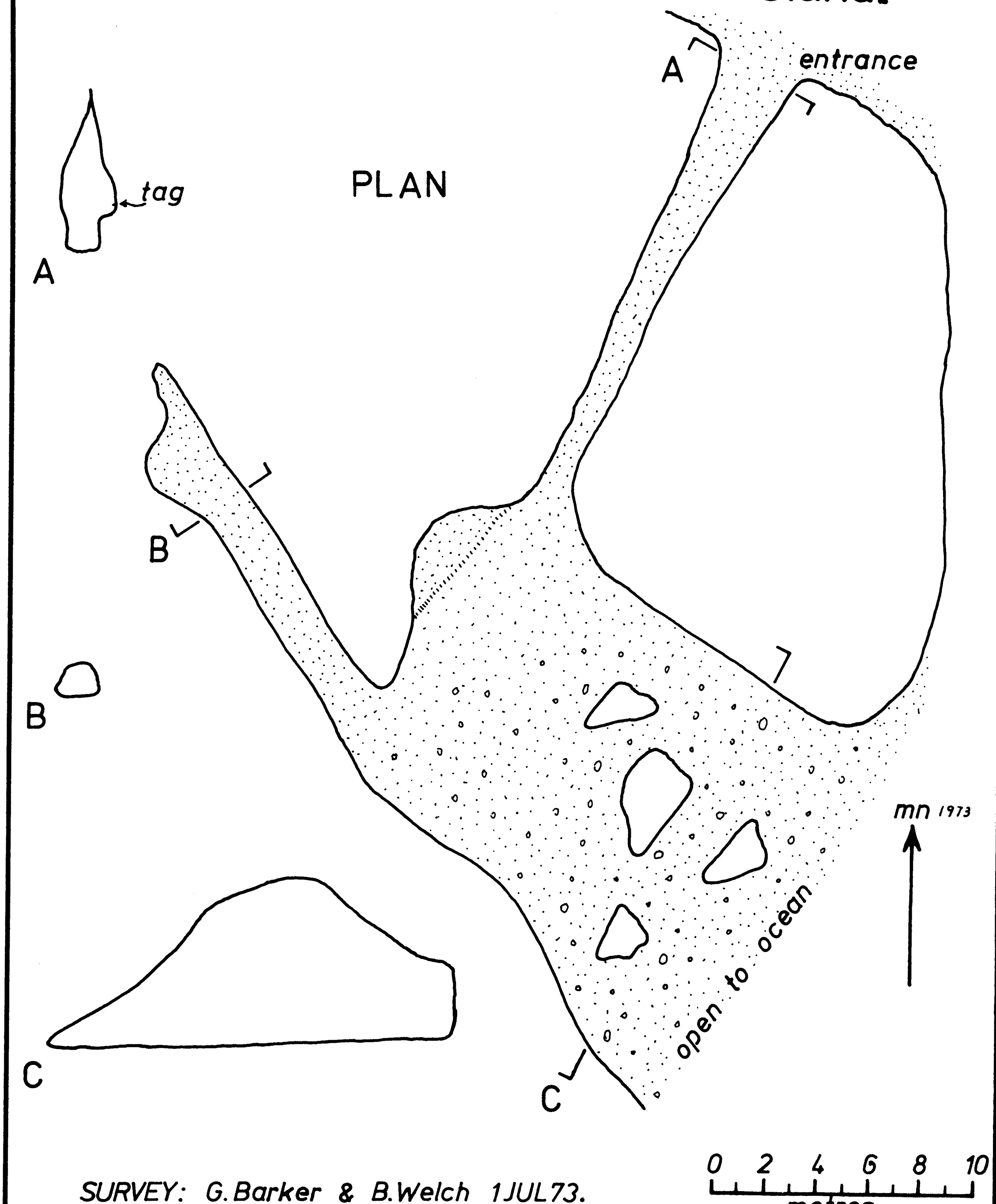
Several problems are encountered when attempting to tag a cave. On occasions it is impossible to reach the entrance so placing a tag there may not be possible, and the tag may have to be placed above the cave entrance.

Consideration must also be given to re-location of the tag. In some situations heavy seas have removed several metres of sand, or deposited similar quantities thus placing the tag metres above eye level or under a beach. Here the method of sequential numbering aids in determining the number of the cave (See Toomer & Welch elsewhere this volume).

It is felt that a cave should be numbered as soon as publication is contemplated and that whenever possible a cave should be tagged as soon as documentation commences, to prevent confusion and duplication.

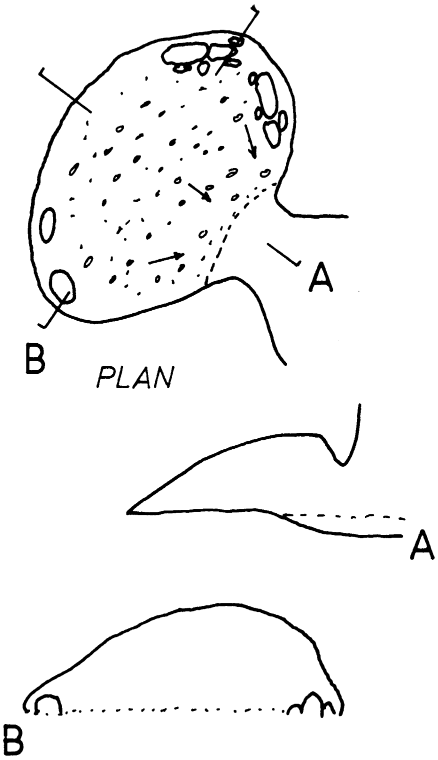
The authors hope that the foregoing has given some insight into the current investigation of sea caves, the deductions made or sought from the data collected, and the problems encountered in the documentation.

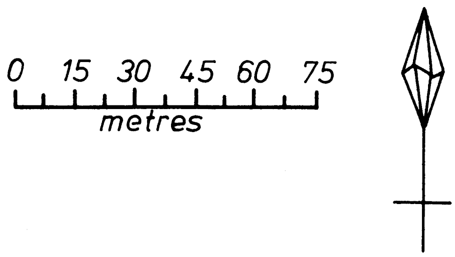
SEA CAVE, south of Flat Island.



SURVEY: G. Barker & B. Welch 1JUL73.
DRAWN: B. Welch 12APR74.
INSTRUMENTS: SUUNTO KB14, tape, clinometer. 1:200 2I6E19.PSG 1

FRASER PARK SEA CAVE





redrawn from ;
SPAR 21 (29)
by P. Toomer

SURVEY : R. Allum, R Connor & C. Fisher 22 OCT 72
DRAWN : R. Connor 25 OCT 72
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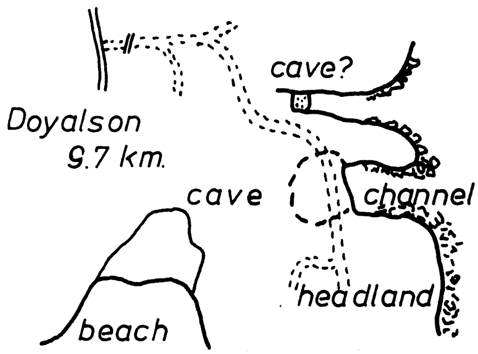
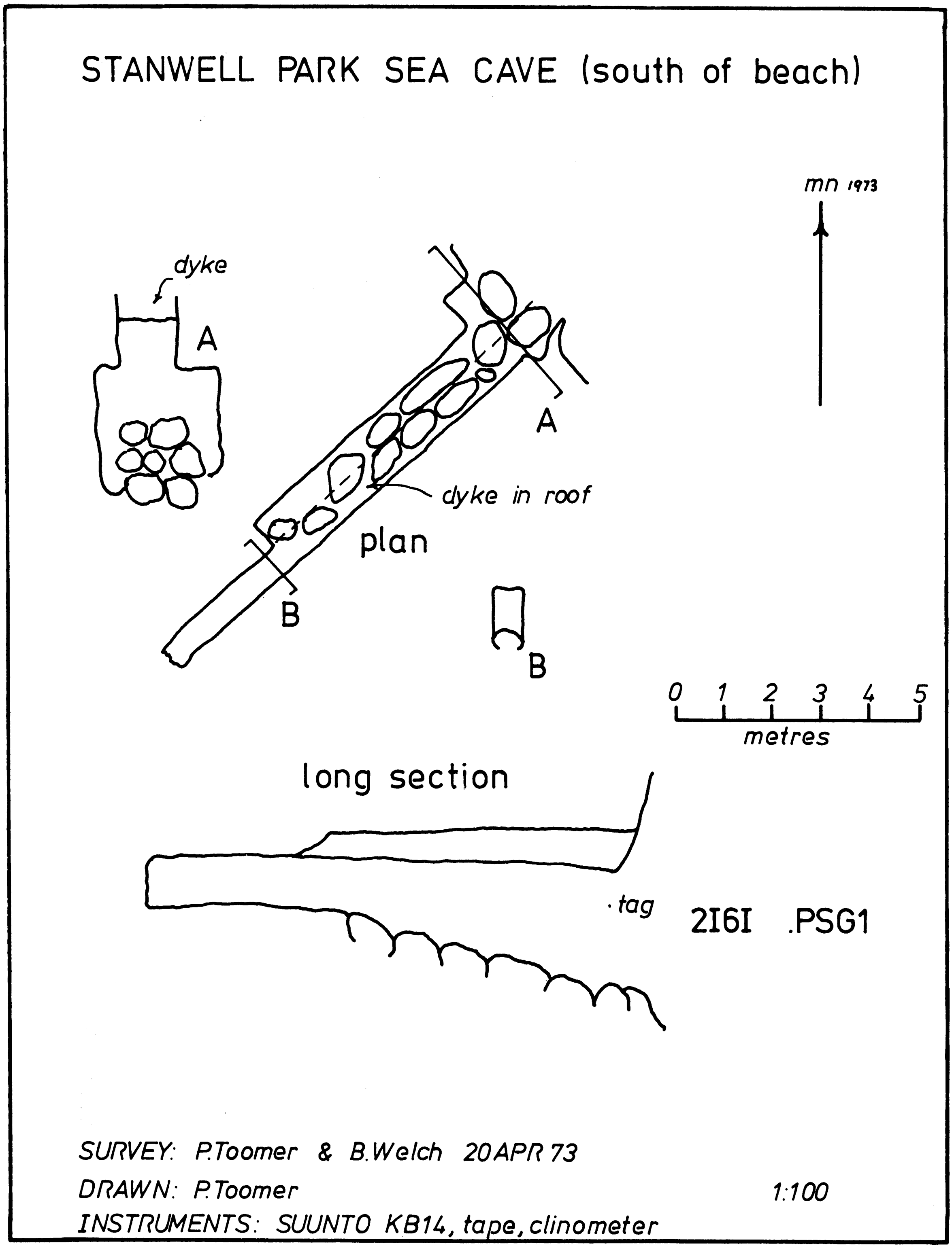
2I6E40.




STANWELL PARK SEA CAVE (south of beach)
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A
dyke in roof
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B
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metres
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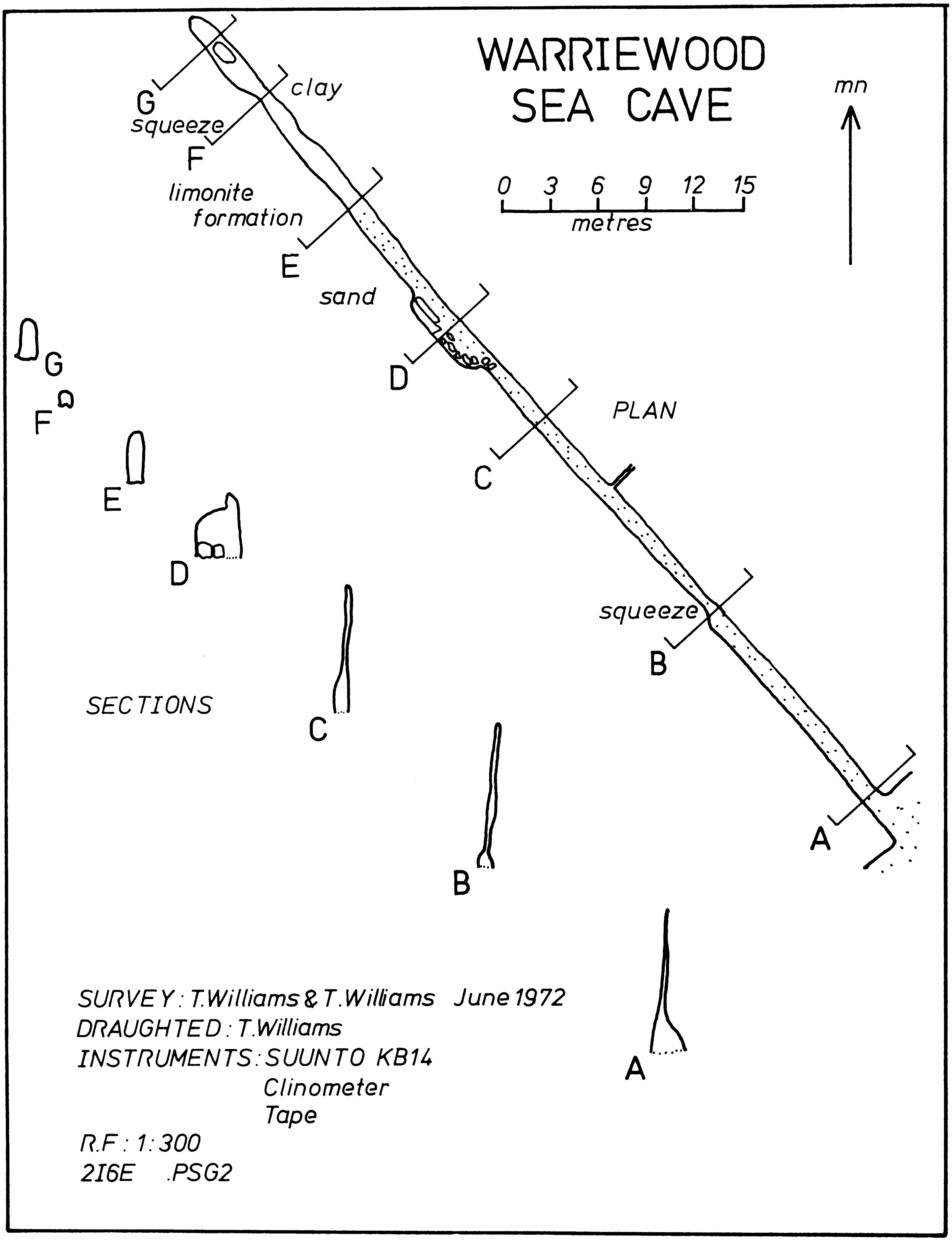
·tag
2I6I .PSG1
SURVEY: P.Toomer & B.Welch 20APR 73
DRAWN: P.Toomer
1:100
INSTRUMENTS: SUUNTO KB14, tape, clinometer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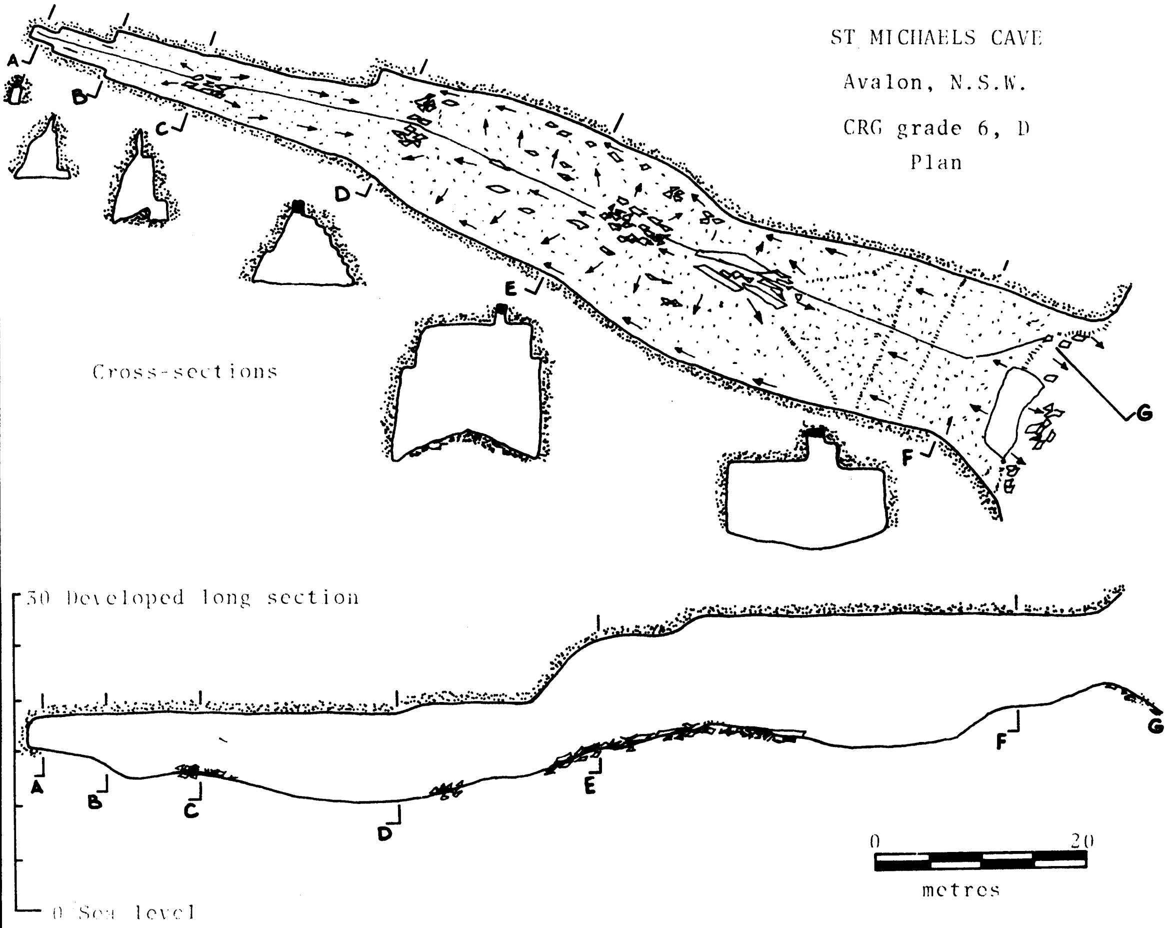
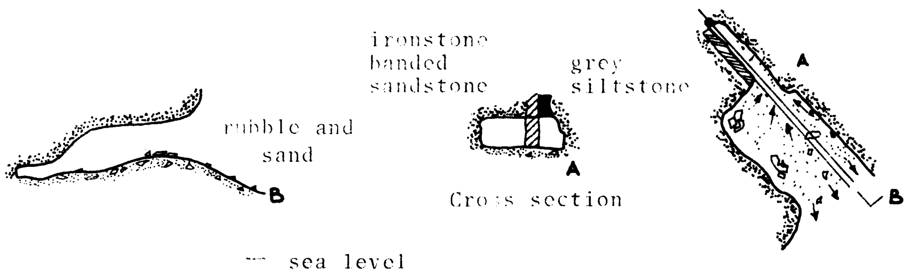
SURVEY: T.Williams & T.Williams June 1972
DRAUGHTED: T.Williams
INSTRUMENTS: SUUNTO KB14
Clinometer
Tape
R.F: 1:300
2I6E .PSG2





BILGOLA BEACH SEA CAVE

North End of Bilgola Beach, Sydney.

CRG grade 6, D

(both maps from SPAR, 16, pp 16-17, June 1972).

SECTION 3

PALAEONTOLOGY, BIOLOGY, ANTHROPOLOGY

AUSTRALIAN SPELEOLOGICAL FEDERATION
PROCEEDINGS 10TH BIENNIAL CONFERENCE

SECTION 3
PALAEONTOLOGY, BIOLOGY, ANTHROPOLOGY

A RECENT BONE DEPOSIT AT MARBLE ARCH, N.S.W.

L.S. Hall*

ABSTRACT

Preliminary investigations of a recent bone deposit at Marble Arch, N.S.W. revealed the presence of twenty three species of small mammals, several of which are now extinct and others which are not found in the area. The deposit is the result of an accumulation of a large number of regurgitated pellets, believed to be from Masked Owls, *Tyto novaehollandiae*. Changes in food selection or availability for the owls are shown and some comments on the possible age of the deposit are made. A key for identification of the dentaries of small mammals in south-eastern Australia is presented.

I. INTRODUCTION

Marble Arch is a naturally occurring cave located 40 km south of Braidwood on Reedy Creek, a tributary of Moodong Creek which flows into the Deua River (Figure 1). The cave is approximately 60 m long and is extremely complicated in nature, there being at least seven separate entrances (see article by Nicoll, Spate and Brush, Section 1).

The bone deposit is located on top of a large block of limestone which is approximately 3.5 m high and is located near the down-stream entrances to the cave. The block is triangular in plan view and moderately flat on top. The bone deposit covers approximately 8 sq. m and is of varying but shallow depth. There are several other bone deposits located on inaccessible ledges in other areas of Marble Arch Cave.

Several partly decomposed, but still intact, regurgitated owl pellets were found on the deposit. It is assumed that the bone deposit is a result of a large accumulation of these owl pellets and that the limestone block has served as a roosting site for owls over a long period of time.

The pellets represent indigestible food items which have been prevented from passing down the birds alimentary canal by the gizzard. Generally speaking the pellet is composed of hard materials such as bones, claws, chitin, fur and cellulose, rolled into an elongated form and regurgitated by mouth (Welty, 1968). Frequently the pellets contain dentaries (jaw bones), skulls and long bones which are sufficient to determine the food species of the owl. Most owls produce two pellets a day, one of which is usually regurgitated while the bird is at its diurnal roost (Glue, 1970). Quite often some of the small mammal species preyed upon by owls are particularly difficult to trap or find and the analysis of owl pellets has been used in this way in several fauna surveys (Papp, 1970; Glue, 1970).

This report outlines the collection of a sample from the Marble Arch deposit and the identification and development of a key for the small mammals present in the material. An analysis of the deposit is made with regards to the fauna of the bone material and the knowledge of the present small mammal fauna of the area.

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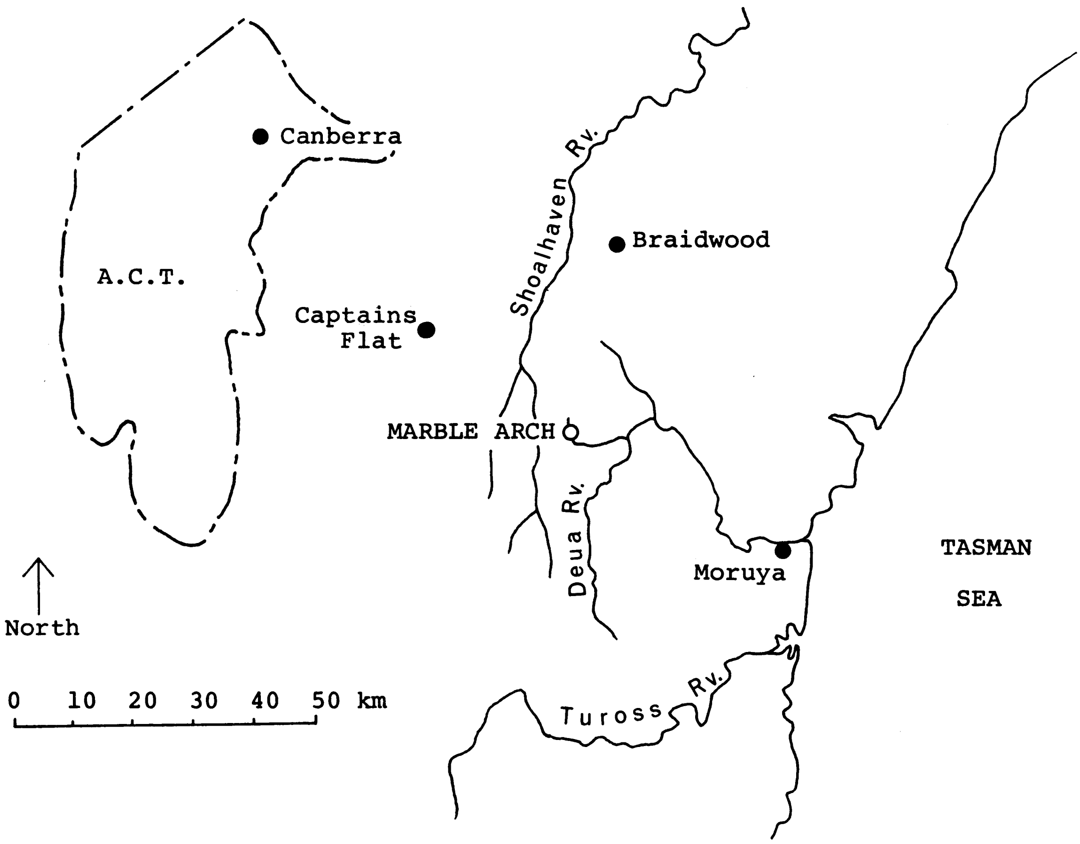
Figure 1. Location of Marble Arch.



II. METHODS

A. Collecting the sample:

After the deposit was mapped and photographed (Plates la and b), the deepest part of the deposit was located by probing amongst the bone material with a piece of wire. On the deepest area a 0.5 x 1.0 m rectangle was marked with cloth tape. A 25 cm steel cementing trowel and a stiff 5 cm paint brush were then used to remove a 1 cm layer of the deposit at a time. The deposit was 11 cm deep (Plate 2), and the eleven layers were each placed in a plastic bag and labelled. Long bones, particularly tibias, provided some difficulties when located in a vertical position between several layers. These bones were removed and placed in the sample from the highest layer in which the bone was located.

B. Processing the sample:

The samples were weighed and double sieved; first through a 0.63 cm wire mesh and then through a 0.35 cm wire mesh. Bones separated by the meshes were stored separately and the remaining material was returned to the plastic bag.

Bone samples from each layer were sorted into dentaries, skull fragments, long bones and other bones by using a large illuminated magnifying glass ("Maggi lamp"). The dentaries were labelled with an individual number and sorted into approximate groups according to size and obvious features.

C. Development of the key:

To develop the identification key it was necessary to use dentaries of known specimens from the CSIRO Division of Wildlife Research's Museum. Where possible specimens that had been collected in south-eastern N.S.W. were selected. Comparative material was not available for all species, and when this occurred, key features were taken from the work of Wakefield (1960a, 1960b and 1969).

The key was developed by identifying features of the dentary particular to a species (Figures 2a, b, c and d). This involved observations on the number, position, relative size and shape of teeth, the shape of the dentary and its associated features, and the location of these features. The presence or absence of these features was also used, and it was found useful to compare the dentaries of similar species or species with close taxonomic relationships. In the murids, the length of the molar tooth row, molar and incisor width were also used.

The key was then applied to the top two layers (1 and 2) and the bottom two layers (10 and 11) of the sample. Considerable time was needed to become familiar with the key and the material and hence processing of the other layers has not yet been done.

III. RESULTS

A. Identification of the owl species:

During the collecting of the sample, two primary wing feathers of the Boobook Owl *Ninox novaeseelandae* were found in the material. Calaby (1969) states that the food of the Boobook Owl consists almost entirely of insects and only occasionally is a house mouse or small bird added to the diet. He also mentions that they will rest in caves during the day. As there did not appear to be any invertebrate remains it is deduced that Boobook Owls visit Marble Arch Cave to roost but played little or no part in the building up of the bone deposit.

Several partly decomposed pellets which were found on the deposit showed signs of having a "dried skin" type of coating (Plate 3), indicating that they were produced by an owl of the genus *Tyto* (Wakefield, 1960b; Fleay, 1968). This, coupled with the large size of the pellets (average length 8.0 cm), suggests that they should have been produced by a Masked Owl, *Tyto novaehollandiae*.

When considering the body size of some of the mammal species contained in the bone deposit, it is obvious that the predator must have been a large owl (Table 1).

Table 1. Size of those mammals whose dentaries were found in the Marble Arch deposit.

Species	Head and Body length
Potoroo *Potorous tridactylus*	42 cm
Bandicoot *Perameles nasuta*	40 cm
Ringtail Possum *Pseudocheirus peregrinus*	40 cm

Apart from the Masked Owl the only other owl capable of killing the species in Table 1 is the Powerful Owl, *Ninox strenua* (Fleay, 1968). However, the Powerful Owl must be discounted because its pellets have a felty external appearance (Wakefield, 1960b), and as Fleay (1944) points out, the Powerful Owl does not normally roost in caves, nor does it hunt terrestrial mammals for food.

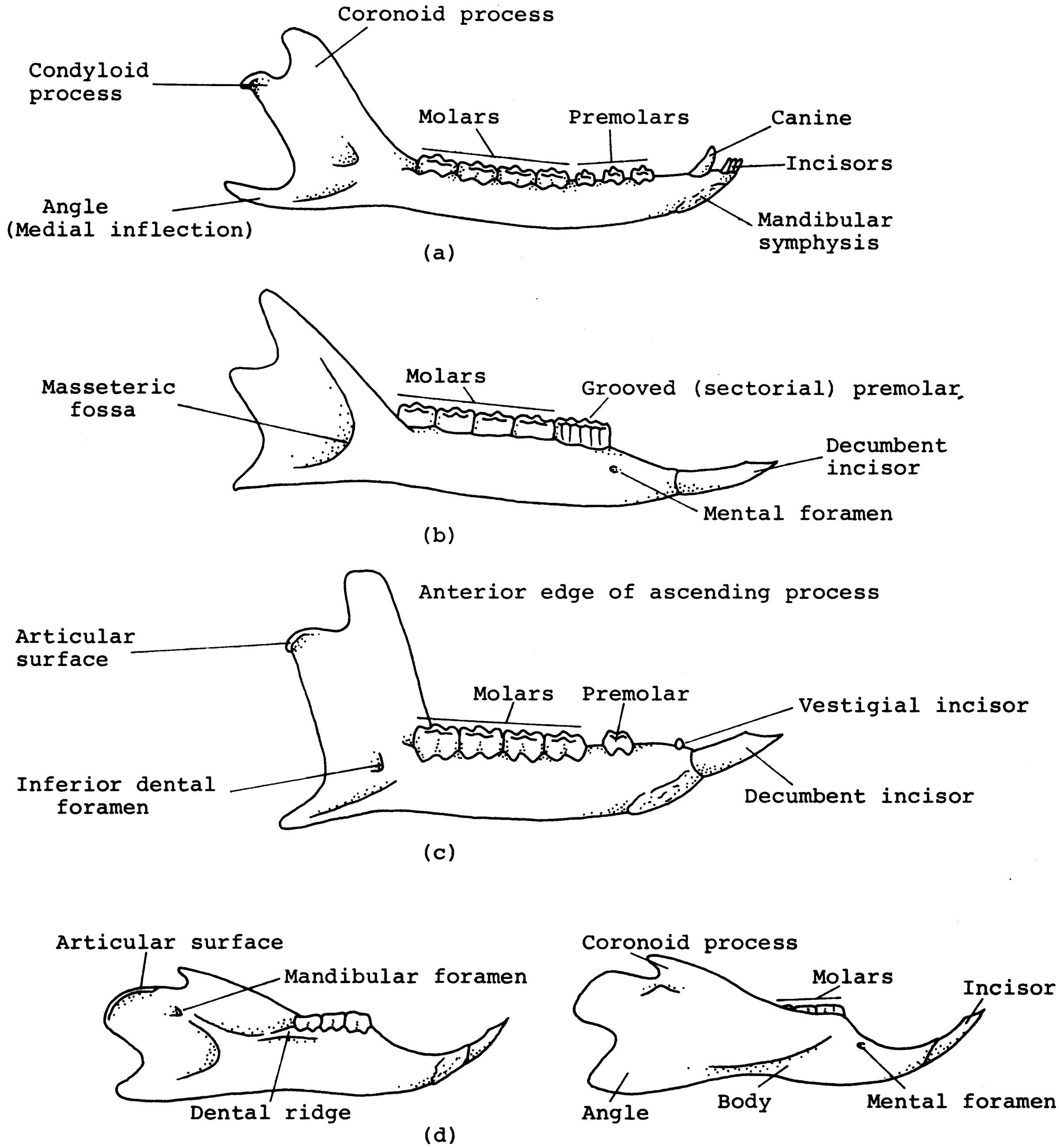


Figure 2. Features of Marsupial and Murid dentaries (not to scale).

(a) Marsupial, Polyprotodont (Peramelidae) - Medial aspect
(b) " , Diprotodont (Potoroinae) - Lateral aspect
(c) " , " (Phalangeridae) - Medial aspect
(d) Murid dentary - Medial and lateral aspects

Available evidence leaves little doubt that the predator was of the genus *Tyto*, and it suggests strongly that the species was the Masked Owl, *T.novaehollandiae*.

B. Analysis of the sample:

The key developed for the identification of dentaries of the mammal species present in the sample appears as Appendix A.

The key initially requires a person to sort the dentaries into approximate groups, according to size, shape and then obvious features. Then by using the photographs (Plates 4, 5 and 6) and the diagrams (Figures 2a, b, c and d) in conjunction with the key, it is possible to identify all the dentaries of the species so far found in levels 1, 2, 10 and 11 of the Marble Arch deposit.

(i) Identification and number of species in the two surface levels:

A total of 75 dentaries were found in level 1, and 70 in level 2. This represented 18 species of mammals. The maximum number of left or right dentaries of a species was taken as the number of individuals present in a level. This totalled 44 individuals for level 1 and 46 individuals for level 2. The samples are not regarded as having enough material to make a valid comparison, so they have been combined. Table 2 shows the identification information from levels 1 and 2.

Table 2. Species and Number of Mammals Identified in Levels 1 and 2

Species	Level 1	Level 2	Combined
Isoodon obesulus	0	2	2
Perameles nasuta	2	2	4
Potorous tridactylus	0	2	2
Antechinus stuartii	7	9	16
Antechinus swainsonii	1	0	1
Antechinus flavipes	0	1	1
Sminthopsis murina	1	0	1
Sminthopsis leucopus	0	1	1
Pseudocheirus peregrinus	2	0	2
Schoinobates volans	6	3	9
Petaurus breviceps	5	6	11
Rattus fuscipes	8	7	15
Rattus lutreolus	1	1	2
Mastacomys fuscus	2	1	3
Pseudomys oralis	6	8	14
Pseudomys fumeus	1	0	1
Oryctolagus cuniculus	1	1	2
Rattus rattus	1	2	3
Species total	44	46	90
Total of dentaries in deposit	75	70	145

Antechinus stuartii, *Rattus fuscipes* and *Pseudomys oralis* make up the majority of dentaries, followed by *Petaurus breviceps* and *Schoinobates volans*. The other 13 species are represented by 25 dentaries.

(ii) Identification and number of species in the two bottom levels:

In levels 10 and 11 there were 95 dentaries representing 16 species. There were 49 individuals in level 10 and 45 in level 11. These levels have also been combined and the results are shown in Table 3.

Table 3. Species and Number of Mammals Identified in Levels 10 and 11

Species	Level 10	Level 11	Combined
Perameles nasuta	3	1	4
Antechinus stuartii	6	9	15
Antechinus swainsonii	1	1	2
Antechinus flavipes	0	1	1
Sminthopsis leucopus	1	0	1
Pseudocheirus peregrinus	3	0	3
Schoinobates volans	2	0	2
Gymnobelideus leadbeateri	1	3	4
Petaurus breviceps	7	6	13
Petaurus norfolcensis	1	0	1
Rattus fuscipes	6	9	15
Rattus lutreolus	4	5	9
Mastacomys fuscus	1	1	2
Conilurus albipes	0	1	1
Pseudomys oralis	13	7	20
Pseudomys novaehollandiae	0	1	1
Species total	49	45	95
Total of dentaries in deposit	93	78	171

Pseudomys oralis has the greatest number of dentaries followed by *Antechinus stuartii*, *Rattus fuscipes*, *Petaurus breviceps* and *Rattus lutreolus*. The remaining 11 species are represented by 22 dentaries.

(iii) Comparison of levels 1 and 2 with levels 10 and 11:

Table 4 compares the two surface layers with the two bottom layers. The combined species numbers are given and the percentage composition shown by each family or group is shown.

Some of the major features are:

(a) *Isoodon obesulus*, *Potorous tridactylus*, *Sminthopsis murina*, *Pseudomys fumeus*, *Oryctolagus cuniculus* and *Rattus rattus* are all present in the surface levels but absent from the bottom levels of the deposit.

(b) *Gymnobelideus leadbeateri*, *Petaurus norfolcensis*, *Conilurus albipes* and *Pseudomys novaehollandiae* are present in the lower levels but absent from the surface levels.

(c) The presence of the following species has remained relatively constant - *Perameles nasuta*, *Antechinus stuartii*, *Petaurus breviceps*, *Rattus fuscipes*. The following may also be included in this group, though figures for them are too small to be really significant - *Antechinus flavipes*, *Sminthopsis leucopsis*, *Pseudocheirus peregrinus* and *Mastacomys fuscus*.

(d) There is more *Schoinobates volans* material in the surface levels than in the lowest levels, and the reverse case applies to *Rattus lutreolus* and *Pseudomys oralis*.

(e) Over half of the lower levels' species are Murids (52%), with the Petauridae (24%) and Dasyuridae (20%) making up most of the rest. In the surface layers the percentages for the Petauridae and Dasyuridae remain much the same as in the lower level, but the Murids drop to 39%. The rest is made up by Peramelidae (7%), introduced mammals (6%), and Macropodidae (2%).

(f) The dentaries from the lowest levels were usually a dark brown colour which contrasted with the light "bone" colour of the surface level material. Dentaries from the lower levels were often extremely fragile.

Table 4. Comparison of Species and Numbers Between Levels 1 and 2 and Levels 10 and 11

Species	Levels 1 and 2 Number	Levels 1 and 2 Percentage	Levels 10 and 11 Number	Levels 10 and 11 Percentage
Peramelidae				
Isoodon obesulus	2	7	0	4
Perameles nasuta	4		4	
Macropodidae				
Potorous tridactylus	2	2	0	0
Dasyuridae				
Antechinus stuartii	16		15	
Antechinus swainsonii	1		2	
Antechinus flavipes	1	22	1	20
Sminthopsis murina	1		0	
Sminthopsis leucopus	1		1	
Petauridae				
Pseudocheirus peregrinus	2		3	
Schoinobates volans	9		2	
Gymnobelideus leadbeateri	0	24	4	24
Petaurus breviceps	11		13	
Petaurus norfolcensis	0		1	
Murids				
Rattus fuscipes	15		15	
Rattus lutreolus	2		9	
Mastacomys fuscus	3		2	
Conilurus albipes	0	39	1	52
Pseudomys oralis	14		20	
Pseudomys fumeus	1		0	
Pseudomys novaehollandiae	0		1	
Introduced mammals				
Oryctolagus cuniculus	2	6	0	0
Rattus rattus	3		0	

IV. DISCUSSION

Published information on the identification of skeletal parts of Australian mammals is mainly restricted to the works of Wakefield (1960a and b, 1969), Tidemann (1968) and Smith (1971, 1972). Specialised work, such as that on the taxonomy of *Antechinus*, (Wakefield and Warneke, 1963 and 1967) and *Rattus*, (Taylor and Horner, 1973) supply sufficient information to identify the dentaries of those species.

The development of a key for the Marble Arch area required information on which species were extant in the area and on comparative museum material.

The key, while only partly a dichotomous type, is functional and similar to several developed overseas for owl pellet analysis (Corbet, 1964). Because a certain number of the key features are derived from Wakefield's work, especially those features for rare or extinct species, the key resembles the one he developed for the deposit in Pyramid Cave at Buchan, Victoria (Wakefield, 1969).

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Throughout this study, identifications of species from the Marble Arch deposit were made according to observed similarities and absence of major dissimilarities between the sample material and museum specimens of known identity, together with a consideration of known geographic distributions. It is also recognised that such identifications, made with no knowledge of plastic characters of the mammalian dentary, are more or less hypothetical, but must be accepted if there is to be any identification of species in the sample.

The technique described for sampling the deposit appears to be reasonable. The number of dentaries removed from each layer (75, 70, 93 and 78) shows that the technique is relatively consistent provided the layers represent equal periods of time and pellet deposition.

It is possible however, that the smallest sieve size (0.35 cm) may be too large to retain the very small dentaries of *Cercatetus*, *Acrobates* and members of the family *Chiroptera*. None of these were found in the Marble Arch deposit, but were frequently found in the Pyramid Cave deposit at Buchan, Victoria (Wakefield, 1969).

As regards the Marsupials, the fauna in the surface levels at Marble Arch is essentially that of the modern marsupial fauna of the area. *Antechinus stuartii*, *Pseudocheirus peregrinus*, *Schoinobates volans* and *Petaurus breviceps* were all seen in the area during the study. A surprising omission from the surface material is *Petaurus australis* which is present in the area. It is interesting to note the presence of *Perameles nasuta*, *Isoodon obesulus* and *Potorous tridactylus*, three marsupials which are regarded as being restricted to coastal areas in south-eastern N.S.W. (Marlow, 1958, Ride, 1970).

It is known that *Antechinus swainsonii* and *A.flavipes* occur in the general area along with *Sminthopsis murina* and *S.leucopsis* (Wakefield and Warneke, 1963 and 1967; Marlow, 1958; Ride, 1970, and Tidemann, pers. comm.).

Distributionwise, there does not appear to be any reason why *Petaurus norfolcensis* is not present in the bone material (Marlow, 1958).

Of the Murids in the surface levels at Marble Arch, *Rattus fuscipes* is common in the area and *R.lutreolus* is known from the general area (Taylor and Horner, 1973).

Pseudomys fumeus, once regarded as being confined to western Victoria (Ride, 1970), and *P. oralis*, thought to be in coastal northern N.S.W. (Ride, 1970), have been recently caught in east Gippsland and south eastern Queensland, respectively. It is possible that the former could also be found in the Marble Arch area. The distribution of *Mastacomys fuscus* was detailed by Calaby and Wimbush (1964). In New South Wales it is restricted to areas with an elevation greater than 1,500 m. This would exclude the Marble Arch area, but it is felt that trapping in suitable areas will reveal the presence of *M.fuscus*.

The presence of *Oryctolagus cuniculus* and *Rattus rattus* in the surface levels shows that introduced mammals are now included in the owl's diet.

The marsupial fauna of the bottom levels of the Marble Arch deposit is interesting in that it contained the dentaries of *Gymnobelideus leadbeateri*, a small possum now only known from southern Gippsland in Victoria (Ride, 1970). The rest of the marsupials, *Perameles nasuta*, *Antechinus stuartii*, *A.swainsonii*, *A.flavipes*, *Sminthopsis leucopsis*, *Pseudocheirus peregrinus*, *Schoinobates volans*, *Petaurus breviceps* and *P.norfolcensis* could be reasonably expected to occur in the area (Marlow, 1958; Ride, 1970). The absence of *Isoodon obesulus* is interesting as Wakefield (1969) also records the absence of this species from the bottom level of the deposit in Pyramid Cave, Buchan, Victoria.

The Murids found in the bottom levels of the deposit are essentially the same as those found in the surface levels with the exception of the presence of *Conilurus albipes* and *Pseudomys novaehollandiae*. *C.albipes* has not been seen alive this century (Ride, 1970), and *P.novaehollandiae* has only been recently "re-discovered" in central coastal N.S.W. (Keith and Calaby, 1968).

Mastacomys fuscus has been found in several cave deposits in south-eastern Australia (Calaby and Wimbush, 1964), indicating that it once had a wider distribution than its present one.

The absence of *Oryctolagus cuniculus* and *Rattus rattus* from the lowest levels, suggests that the lower part of the deposit pre-dates the introduction of these two mammals. For *O.cuniculus* this would be in the late 1800's, but there is no reliable information on *R.rattus*.

These differences in faunal composition, the obvious visual differences in colour of dentaries from the surface and bottom levels, and the associated super-positioning of the levels in the Marble Arch deposit suggest that the bottom levels are considerably older than the surface levels.

It is likely that the roost has been occupied by only one or two owls at a time, or a family group at the most (Smith et al, 1974). With the production of only one pellet per bird per day (Glue, 1970), the deposit represents a long period of use by the owls.

The decline in the number of Murids, and in particular the absence of *Conilurus albipes* shown in the deposit, appears to be part of the recent general decline in numbers and species of Murids in south-eastern Australia reported by Ride (1968) and Wakefield (1969). It could, however, indicate that in the Marble Arch area, owls have changed their feeding habits and now rely more on introduced mammals.

Wakefield (1969) used the differences between levels in Pyramid Cave to speculate on past climatic conditions and the effect European man and introduced mammals have had on the native fauna. The fauna of Pyramid Cave was not unlike that of Marble Arch Cave, but the vegetational changes around the Pyramid Cave have been much greater than around Marble Arch. The land surrounding Marble Arch does not appear to have been altered by man to any extent and offers considerable variation in habitat types. Hence speculation on past climatic conditions, as indicated by faunal assemblages in different levels of the bone deposit, were not attempted.

V. CONCLUSION

This report has outlined a method of removing and identifying a sample of bones from a deposit in Marble Arch Cave. The technique involved the removal of material in 1 cm layers and separation of bones from other material by double sieving. Dentaries were removed from the bone material and identified by using a key developed for the Marble Arch area (Appendix A).

Using the method sufficient material was obtained and identified to permit a preliminary analysis of the deposit. The fauna from different levels of the deposit were compared and discussed in relation to the present knowledge of the existing fauna of the Marble Arch area.

VI. ACKNOWLEDGEMENTS

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The photographs of the dentaries were taken by Mr. Edric Slater of CSIRO Division of Wildlife Research whose help is appreciated.

References

CALABY, J.H., 1969 In *Birds of the High Country*. Ed. H.J. Frith. Reed. Sydney.

CALABY, J.H. and WIMBUSH, D.J., 1964 Observations on the Broad-toothed Rat, *Mastacomys fuscus*. Thomas. *CSIRO Wildl. Res.* 9, 123-133.

CORBET, G.B., 1964 "The Identification of British Mammals". British Museum, London.

FLEAY, D.H., 1944 Watching the Powerful Owl. *Emu* 44, 97-112.

FLEAY, D.H., 1968 "Nightwatchmen of Bush and Plain". Jacaranda Press, Brisbane.

GLUE, D.E., 1970 Avian predator pellet analysis and the mammalogist. *Mammal Review* 1(3), 53-62.

MARLOW, B.J., 1958 A survey of the marsupials of N.S.W. *CSIRO Wildl. Res.* 3, 71-114.

PAPP, J.L., 1970 The small mammal fauna of Aranyosgadany, based on collecting and the examination of regurgitated owl pellets. *Vertebr. Hungarica* 12, 69-78.

RIDE, W.D.L., 1970 "A Guide to the Native Mammals of Australia". Oxford. Melbourne.

SMITH, D.G., WILSON, C.R. and FROST, H.H., 1974 History and ecology of a colony of Barn Owls in Utah. *Condor* 76(2), 131-136.

SMITH, M.J., 1971 Small fossil vertebrates from Victoria Cave, Naracoorte, South Australia. I. Potoroinae (Macropodidae), Petauridae and Burramyidae (Marsupialia). *Trans. R. Soc. S. Aust.* 95(4), 185-198.

SMITH, M.J., 1972 Small fossil vertebrates from Victoria Cave, Naracoorte, South Australia. II. Peramelidae, Thylacinidae and Dasyuridae (Marsupialia). *Trans. R. Soc. S. Aust.* 96(3), 125-137.

TAYLOR, J.M. and HORNER, B.E., 1973 Results of the Archbold Expedition No. 98. Systematics of Native Australian Rattus (Rodentia, Muridae). *Bull. Amer. Mus. Nat. Hist.* 150, Article 1, 130pp.

TIDEMANN, C.R., 1968 Some Mammal Remains from Cave Deposits in the South-East of South Australia. *S. Aust. Nat.* 42(2), 21-27.

WAKEFIELD, N.A., 1960a Recent Mammal Bones in the Buchan District -1. *Vic. Nat.* 77(6), 164-178.

WAKEFIELD, N.A., 1960b Recent Mammal Bones in the Buchan District -2. *Vic. Nat.* 77(8), 227-240.

WAKEFIELD, N.A., 1969 An Investigation of Late Pleistocene and Recent Cave Deposits in South-eastern Australia. M.Sc. Thesis. Melb. Uni.

WAKEFIELD, N.A. and WARNEKE, R.M., 1963 Some revision in *Antechinus* (Marsupialia) -1. *Vic. Nat.* 80, 194-219.

WAKEFIELD, N.A. and WARNEKE, R.M., 1967 Some revision in *Antechinus* (Marsupialia) -2. *Vic. Nat.* 84, 69-99.

WELTY, J.C., 1968 "The Life of Birds". Saunders. Philadelphia.

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APPENDIX A

Key recognition features of dentaries of species of small mammals found in the Marble Arch deposit.

1.	Dentary angle medially inflected	2 (Marsupials)
	Dentary angle not inflected	5 (Eutherian)
2.	Dentary narrow with many teeth. 3 incisors, canine, 3 premolars and 4 molars	3 (Polyprotodonts)
	Dentary with one large decumbent incisor, also occasional vestigial incisor, canine absent, 1-3 premolars, 3-4 molars	4 (Diprotodonts)

The key now relates to various dentary features and is not necessarily dichotomous. Figure 2a, b, c and d, Plates 4, 5 and 6, should be used in conjunction with the key.

3. POLYPROTODONT MARSUPIALS

PERAMELIDAE: $M_{1-3} > 10$ mm

Perameles nasuta - Immediately posterior to M_4 the upper edge of the dentary is angled at approximately 130° to the line of the alveoli, after which the anterior edge of the coronoid process rises at approximately 100° to the line of the alveoli.

Isoodon obesulus - Immediately posterior to M_4 the upper edge of the dentary is angled at approximately 110° to the line of the alveoli, and the anterior edge of the coronoid process continues at the same angle to the alveoli.

DASYURIDAE: $M_{1-3} < 9.5$ mm

Sminthopsis and *Antechinus* $M_{1-3} < 7$ mm.
Sminthopsis: P_4 larger than P_3 (this can be also deduced from the size of the alveoli). Mental foramen anterior to centre of M_1.
Sminthopsis murina - $M_{1-3} < 4.8$ mm, coronoid process only slightly curved.
Sminthopsis leucopus - $M_{1-3} > 5.0$ mm, coronoid process strongly curved.
Antechinus: P_4 smaller than P_3. Mental foramen posterior to centre of M_1.
Antechinus swainsonii - Premolars spaced slightly apart; $P_{1-4} > 3.5$ mm.
Antechinus stuartii - Premolars tightly crowded together; $P_{1-4} < 3.2$ mm, $M_{1-3} < 5.2$ mm.
Antechinus flavipes - Premolars tightly crowded together; $M_{1-3} > 5.3$ mm.

4. DIPROTODONT MARSUPIALS

MACROPODIDAE: Large masseteric canal present; two deciduous premolars are replaced by permanent P_4; no tooth present between large incisor and permanent P_4.

Potorous tridactylus - $M_{1-3} < 15$ mm; cusps of molars blunt. The deciduous P_3 with 2-3 grooves and the permanent P_4 with 3-4 grooves.

PETAURIDAE: Large masseteric canal not present, one or more teeth present between large incisor and P_4.

Pseudocheirus and *Schoinobates*: Anterior edge of ascending process angled at approximately 90° - 100° to line of alveoli. Cusps of molars are sharp, crescentric. Molars 4.
Schoinobates: Angle strongly inflected, the inner margin of the angle flattened; the inferior dental foramen recessed behind the anterior margin of the angle.

Schoinobates volans - $M_{1-3} < 11.0$ mm
Pseudocheirus: Angle not greatly inflexed, the inner margin of the angle curved; the inferior dental foramen not recessed behind the anterior margin of the angle.
Pseudocheirus peregrinus - $M_{1-3} > 11.2$ mm
Petaurus and *Gymnobelideus*: Molars 4, M_{1-3} between 4.5 and 6.0 mm
Petaurus: Decumbent incisor curved, angle only slightly inflexed, molar row inflexed posteriorly.
Petaurus breviceps - $M_{1-3} > 5.0$ mm
Petaurus norfolcensis - M_{1-3} between 6.7 and 7.3 mm
Gymnobelideus: Decumbent incisor straight, angle strongly inflected, molar tooth row almost straight.
Gymnobelideus leadbeateri - $M_{1-3} < 4.0$ mm

5. EUTHERIAN

MURIDAE: Molars 3. Premolars and canine absent. Incisor of continuous growth.

Rattus: M_1 with four roots. Coronoid process long, falcate.
Rattus lutreolus - Incisor > 3 mm wide, M_1 W > 2.15 mm
Rattus fuscipes - Incisor < 1.25 mm, M_1 W < 2.14 mm
**Rattus rattus* - Incisor < 1.15 mm, M_1 W < 2.0 mm
Pseudomyinae: M_1 with 2 or 3 roots, normally with 2 large roots only but occasionally with also a small medial root.
Conilurus albipes - Teeth large, $M_{1-3} > 8$ mm, M_1 W > 2.2 mm. Coronoid process absent. Dentary shallow beneath M_1.
Mastacomys fuscus - Teeth large, $M_{1-3} > 7$ mm, M_1 W > 2.4 mm. Coronoid process present. Dentary comparatively deep beneath M_1.
Pseudomys: Dentary comparatively shallow beneath M_1. No medial root present on M_1, except rarely in *P.oralis*.
Pseudomys novaehollandiae - $M_{1-3} < 4.2$ mm
Pseudomys fumeus - M_{1-3}, 4.4-5.5 mm; M_1 W, 1.2-1.4 mm
Pseudomys oralis - M_{1-3}, 6.2-7.0 mm; M_1 W, 1.6-2.0 mm. Coronoid process poorly developed.
**Mus musculus* - M_{1-3}, 2.7-3.2 mm, total length of dentary approximately 13 mm.

LEPORIDAE: Molars 3, 1 grooved premolar, incisor of continuous growth.

**Oryctolagus cuniculus* - PM with 2 deep grooves, $M_{1-3} > 10$ mm. Ramus deep.

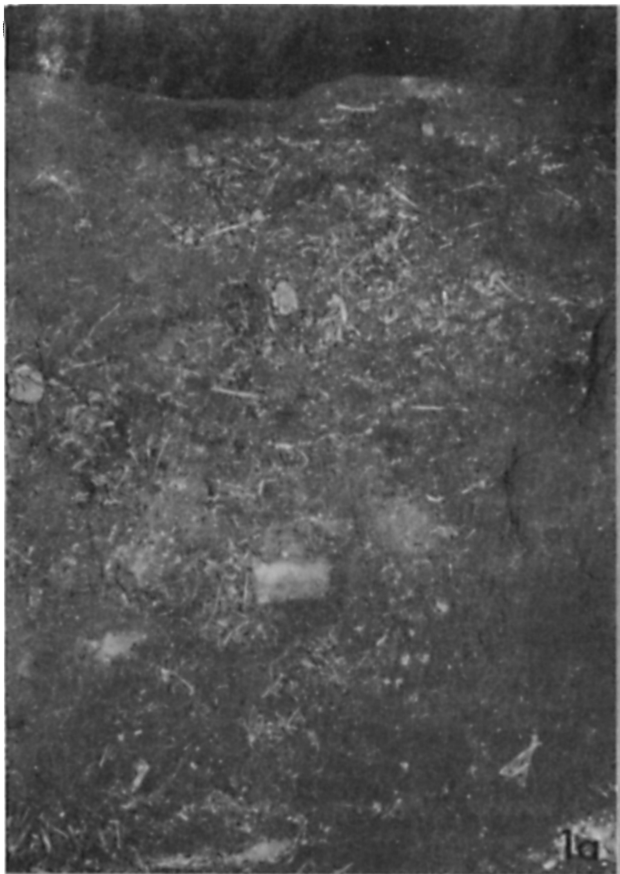
* Introduced mammal.

PLATE 1. a) General view of the Marble Arch bone deposit.

b) Close up of the bone deposit showing individual bones.

PLATE 2. Profile of bone deposit at sampling site

PLATE 3. Partly decomposed pellet showing "skin" type coating.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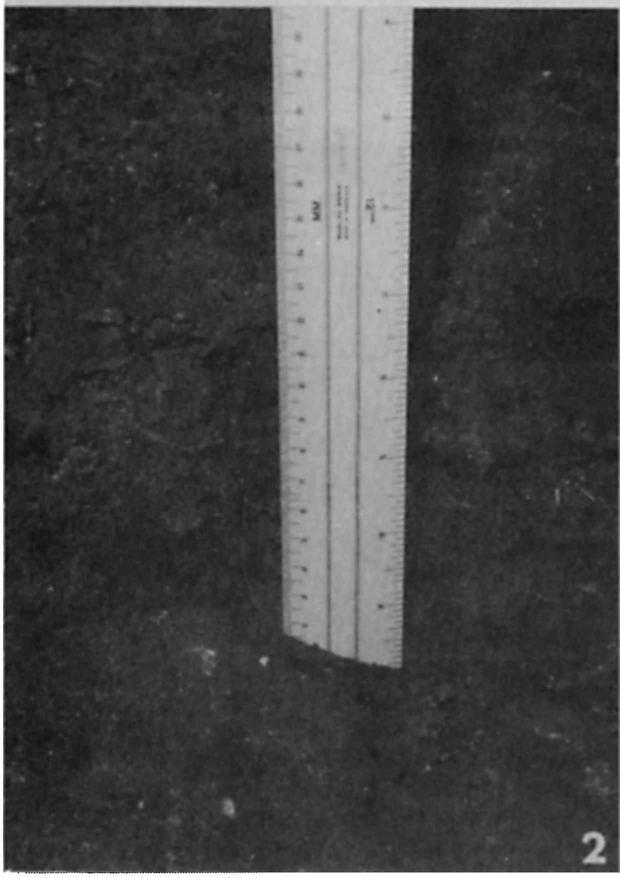
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PLATE 4. I - *Perameles nasuta* (X2)

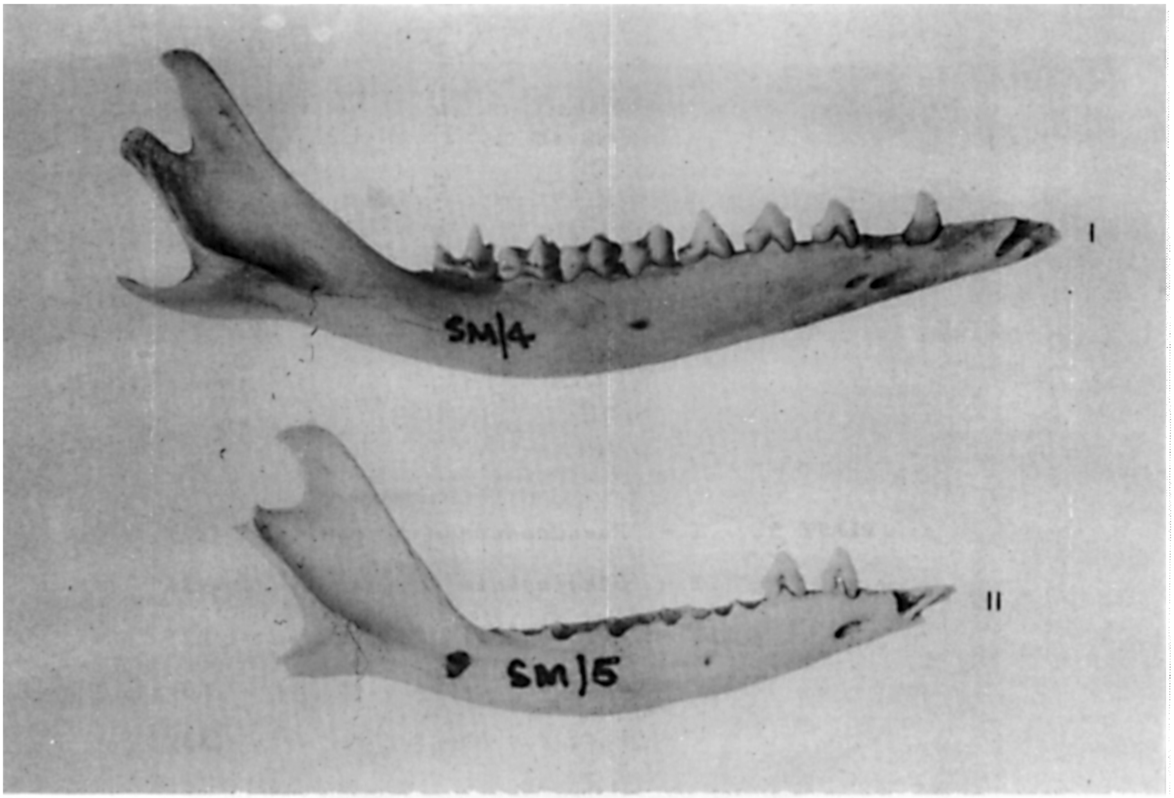
II - *Isoodon obesulus* (X2)

III - *Antechinus swainsonii* (X3)

IV - *Antechinus stuartii* (X3)

V - *Sminthopsis murina* (X3)

(N.B. Owing to the similarity of the dentaries of *Antechinus stuartii* and *Antechinus flavipes*, only the former is shown.)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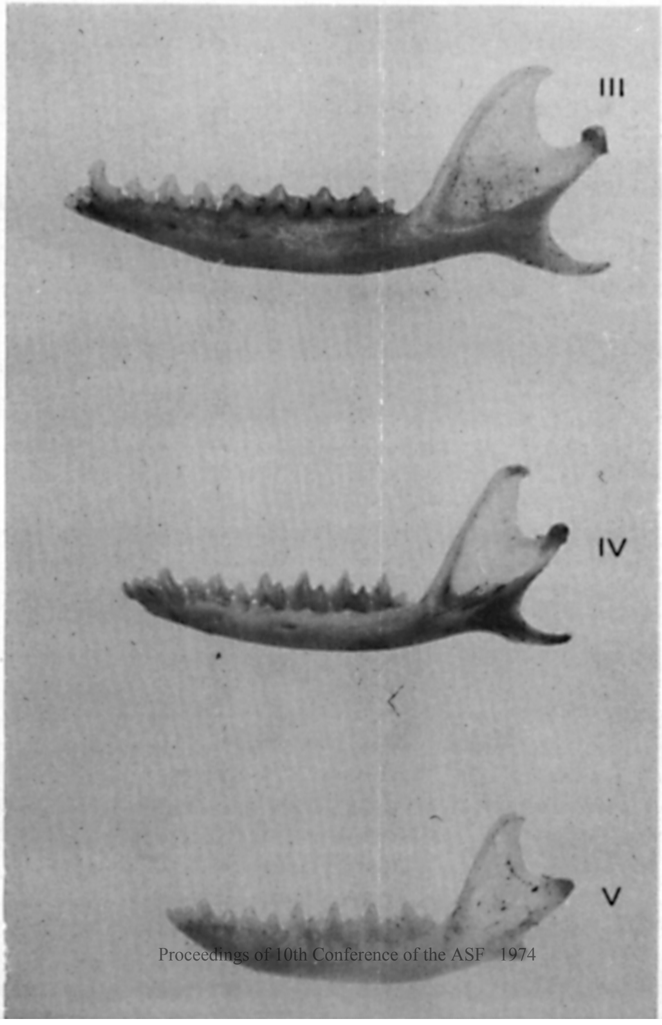
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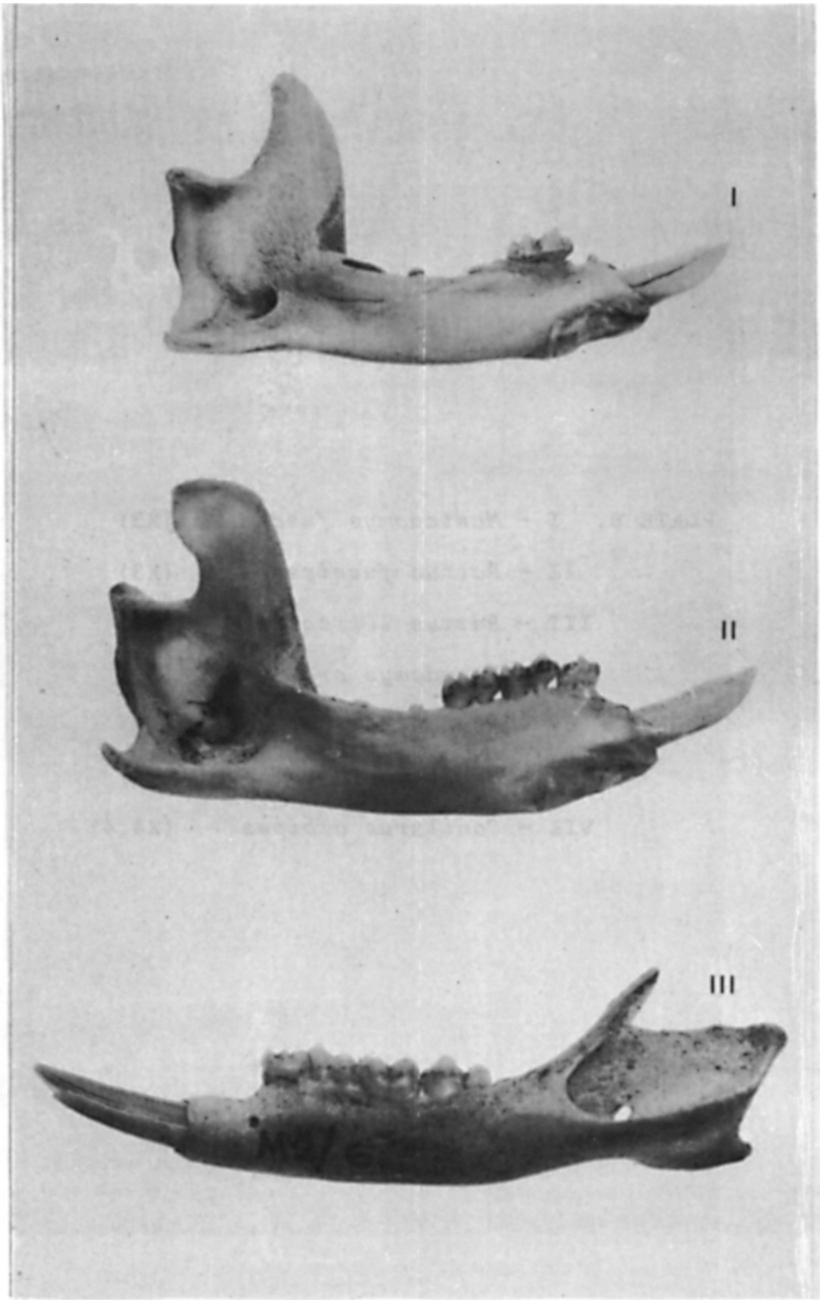
PLATE 5.	I -	*Pseudocheirus peregrinus*	(X2)
	II -	*Schoinobates volans*	(X2)
	III -	*Potorous tridactylus*	(X2)
	IV -	*Gymnobelideus leadbeateri*	(X3)
	V -	*Petaurus breviceps*	(X3)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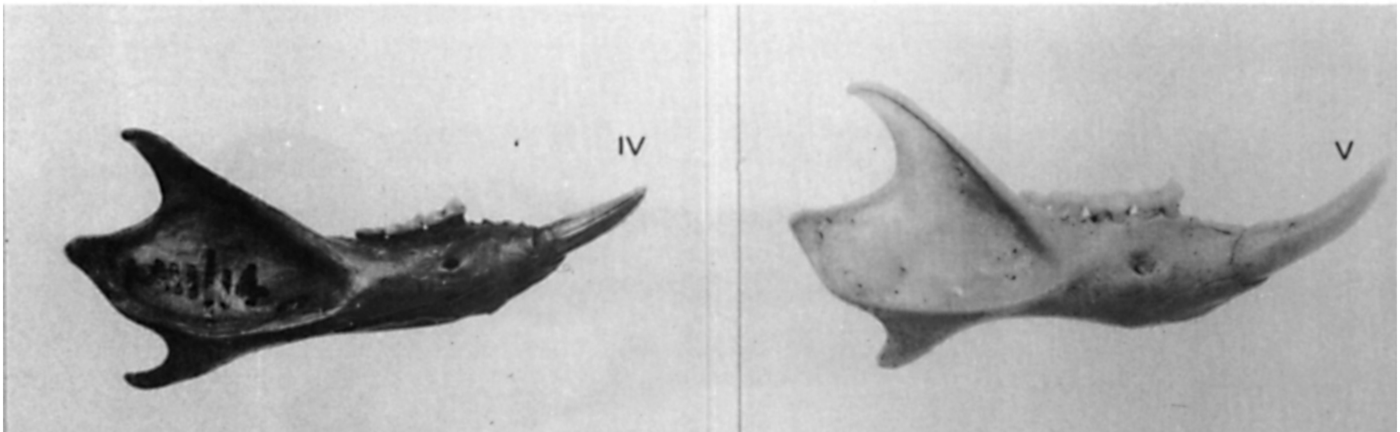
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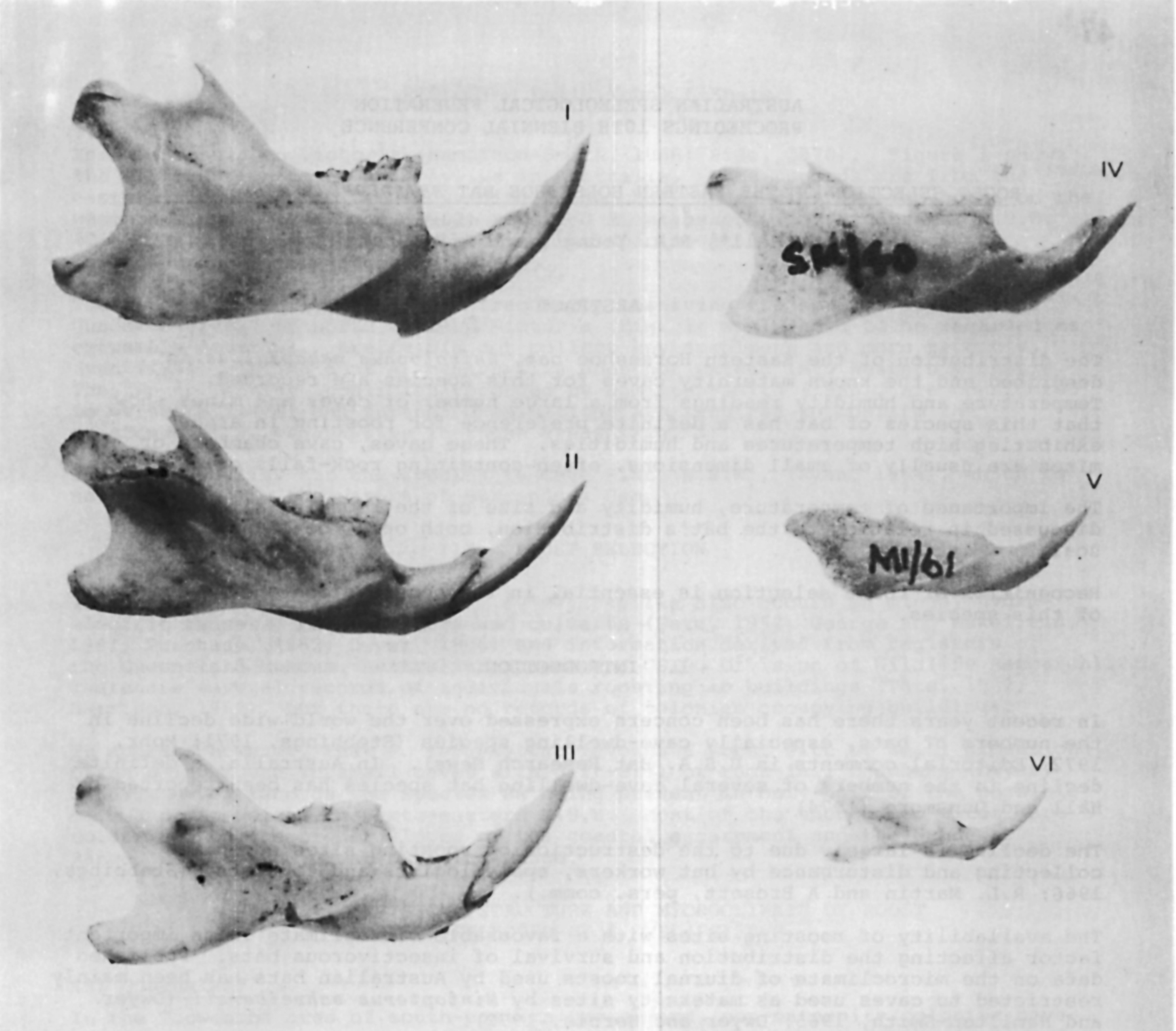
PLATE 6.	I -	*Mastacomys fuscus*	(X3)
	II -	*Rattus fuscipes*	(X3)
	III -	*Rattus lutreolus*	(X3)
	IV -	*Pseudomys oralis*	(X3)
	V -	*Pseudomys fumeus*	(X3)
	VI -	*Mus musculus*	(X3)
	VII -	*Conilurus albipes*	(X4.4)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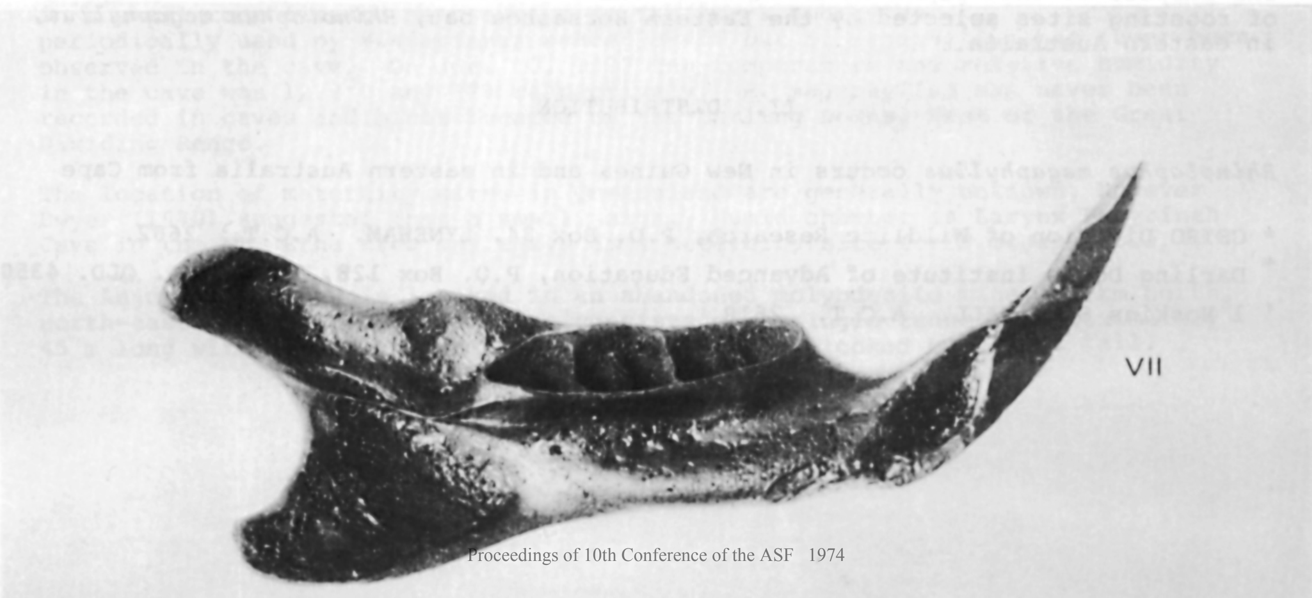
VII

AUSTRALIAN SPELEOLOGICAL FEDERATION
PROCEEDINGS 10TH BIENNIAL CONFERENCE

ROOST SELECTION OF THE EASTERN HORSESHOE BAT *RHINOLOPHUS MEGAPHYLLUS*

L.S. Hall*, R.A. Young+, and A.P. Spate'

ABSTRACT

The distribution of the Eastern Horseshoe bat, *Rhinolophus megaphyllus* is described and the known maternity caves for this species are recorded. Temperature and humidity readings from a large number of caves and mines show that this species of bat has a definite preference for roosting in areas exhibiting high temperatures and humidities. These caves, cave chambers or mines are usually of small dimensions, often containing rock-falls or dirt-fill.

The importance of temperature, humidity and size of the roosting site is discussed in relation to the bat's distribution, both on a local and extended scale.

Recognition of roost selection is essential in the conservation and management of this species.

I. INTRODUCTION

In recent years there has been concern expressed over the world wide decline in the numbers of bats, especially cave-dwelling species (Stebbings, 1971; Mohr, 1972; Editorial comments in U.S.A. Bat Research News). In Australia, a definite decline in the numbers of several cave-dwelling bat species has been reported by Hall and Dunsmore (1974).

The decline is largely due to the destruction of roosting sites, specimen collecting and disturbance by bat workers, speleologists and tourists, (Stebbings, 1966; R.L. Martin and A Brosett, pers. comm.).

The availability of roosting sites with a favourable microclimate is an important factor affecting the distribution and survival of insectivorous bats. Published data on the microclimate of diurnal roosts used by Australian bats has been mainly restricted to caves used as maternity sites by *Miniopterus schreibersii* (Dwyer and Hamilton-Smith, 1965; Dwyer and Harris, 1972).

The purpose of this paper is to describe the physical structure and microclimate of roosting sites selected by the Eastern Horseshoe bat, *Rhinolophus megaphyllus*, in eastern Australia.

II. DISTRIBUTION

Rhinolophus megaphyllus occurs in New Guinea and in eastern Australia from Cape

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York Peninsula to Victoria (Hamilton-Smith, 1966; Ride, 1970). Figure 1 shows the distribution of *R. megaphyllus* in Australia. Most records are from the eastern slopes of the Great Dividing Range, but the species is also found on the western slopes. Purchase (1962) recorded *R. megaphyllus* at Mandurama, N.S.W. (Cleifden), and Dwyer (1966) observed the species at 15 localities on the inland North-western Slopes of N.S.W.

The record of Krefft (1866) of "frequently observing the species flying over Gunbower Creek" in north western Victoria (Fig. 1) would have to be regarded as extremely doubtful. Krefft did not collect any specimens and more recently, Ryan (1964) claimed that *R. megaphyllus* does not extend into Western Victoria. The two collecting localities recorded by Hamilton-Smith (1966), are considered to be extralimital and further observations are required to confirm the existence of *R. megaphyllus* in these areas (Fig. 1).

The type locality for the species is Cave Flat, N.S.W., (Ryan, 1964), which is now submerged by the waters of Burrinjuck Dam.

III. ROOST SELECTION

In addition to roosting in caves, *R. megaphyllus* also occurs in mines, hydro-electric tunnels, bomb shelters and culverts (Tate, 1952; George and Wakefield, 1961; Purchase, 1962; Dwyer, 1966; and information derived from registers of the Queensland Museum, Australian Museum and CSIRO Division of Wildlife Research). There are several records of individuals roosting in buildings (Tate, 1952; Harrison, 1962), but there are no records of colonies occupying buildings.

It appears however, that *R. megaphyllus* favours a roost site of small dimensions, often being found in small caves with dirt-fill or rock-fall chambers (Dwyer, 1966). Dwyer records the species as being present in only half of the possible cave and mine sites in north-eastern N.S.W. Most of the unoccupied sites were colder and on the higher slopes of the coastal escarpment and the Nandewar Range, west of the Great Dividing Range.

IV. PHYSICAL STRUCTURE AND MICROCLIMATE OF ROOST SITES SELECTED BY *R. MEGAPHYLLUS*

(A) Queensland

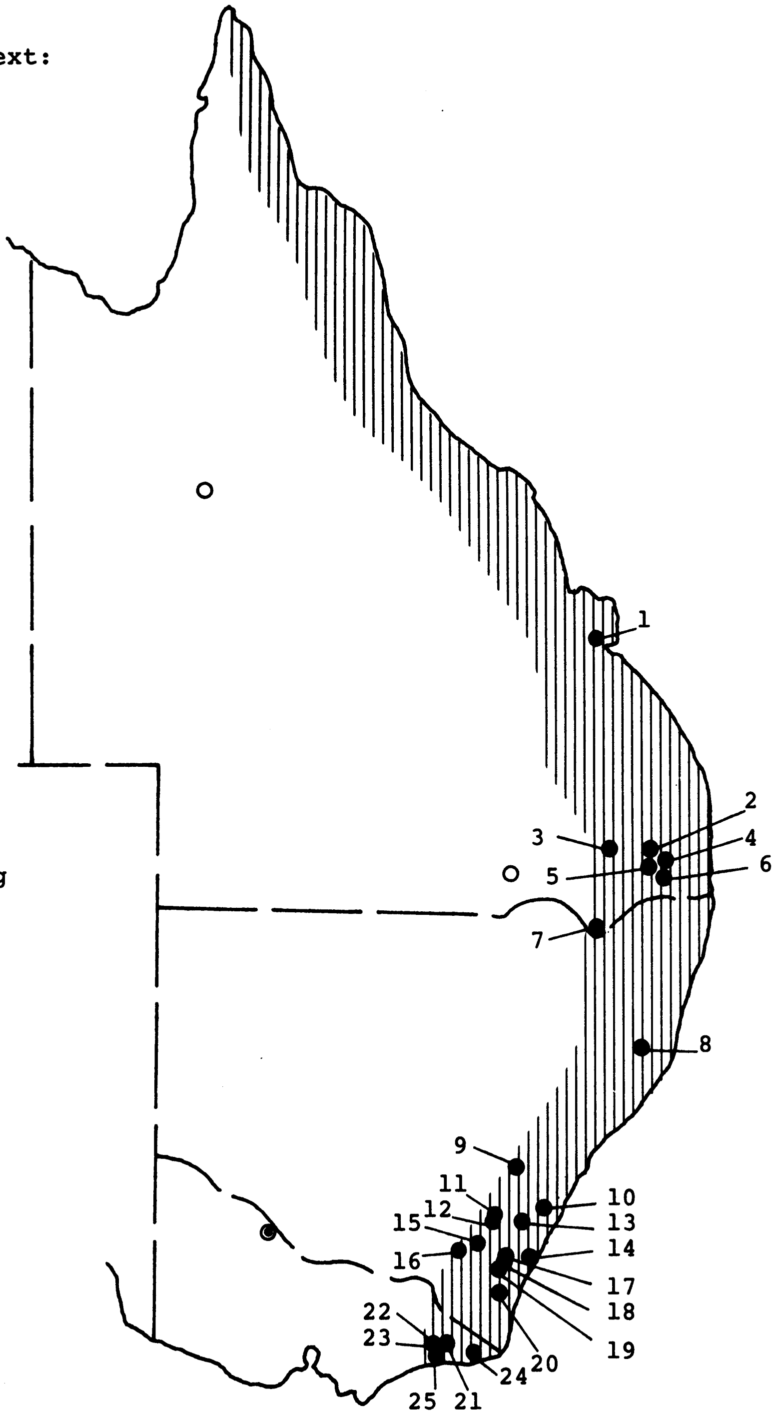
In the Toowoomba area of south-eastern Queensland, non-maternity colonies have been located in two abandoned mines (Anjuramba and Black Duck Creek mines) and in a cave located in Ravensbourne National Park. A single individual was found in a small rock fissure near a cave in the Bunya Mountains, periodically used by *Miniopterus schreibersii* but *R. megaphyllus* has never been observed in the cave. On June 10, 1972 the temperature and relative humidity in the cave was 12.2^{o}C and 88% respectively. *R. megaphyllus* has never been recorded in caves and mines located on the Darling Downs, West of the Great Dividing Range.

The location of maternity sites in Queensland are generally unknown, however Dwyer (1970) suggested that a small, highly humid chamber in Larynx Labyrinth Cave in the Mt. Etna area may serve as a maternity site for *R.megaphyllus*.

The Anjuramba colony is located in an abandoned molybdenite mine, 59 km north, north-east of Toowoomba. The mine consists of a single tunnel, approximately 45 m long with access to the last 8.8 m partially blocked by a dirt fall.

Localities mentioned in text:

1. Mt. Etna
2. Bunya Mts.
3. Big Hill Mine
4. Anjuramba Mine
5. Ravensbourne Nat. Park
6. Black Duck Creek Mine
7. Riverton
8. Willi Willi
9. Cleifden
10. Talwong Mine
11. Cave Flat
12. Wee Jasper
13. Mount Fairy
14. North Durras
15. Cooleman Plains
16. Yarrangobilly
17. Cleatmore
18. Marble Arch
19. Wyanbene
20. Bendethera
21. Mooresford Cave
22. Anticline Cave
23. Dickson's Cave
24. Club Terrace Mine
25. Nargun's Cave



○ Extralimital collecting locality.

◉ Gunbower Creek.

Figure 1. Distribution of the bat *R. megaphyllus* in Australia.

The temperature and relative humidity of the mine were taken on 14 occasions between 1970-72. Fluctuations in temperature and humidity towards the mine entrance were noticed, but the deep internal microclimate remained very constant. (Table 1). The greatest maximum-minimum temperature difference recorded at the end of the tunnel over a 28 month period was 2.2°C. The maximum temperature recorded was 22.2°C with a minimum of 20.0°C. Relative humidity varies from 85.5% to 95.5% in the deeper recesses of the mine.

The Ravensbourne colony occurs in a relatively small cave, located 30 km north-east of Toowoomba. There are several entrances to the cave, the largest of which is approximately 45 cm in diameter. Most of the other openings are too small to allow human entry. In most areas of the cave the ceiling height is between 15 cm and 100 cm. There is one small chamber with a domed ceiling, located about 15 m from the largest entrance.

Environmental conditions within the Ravensbourne Cave were only measured on one occasion (March, 1972). The temperature and relative humidity in the chamber was 22.0°C and 95.5% respectively. (Table 2).

The Black Duck Creek Mine is situated in a diatomaceous earth deposit, 40 km south-east of Toowoomba. The mine consists of a relatively short passage with two lateral excavations (chambers) and a terminal chamber. The terminal chamber is partially blocked by a rock-fall.

Miniopterus schreibersii and *M. australis* also use the mine as a roosting site, but only under conditions of extreme disturbance was *R. megaphyllus* observed roosting near *Miniopterus*. Dwyer (1966) also noted the segregation of adult *R. megaphyllus* from *Miniopterus* in northern N.S.W.

Temperatures recorded in the Black Duck Creek Mine chamber occupied by *R. megaphyllus* are given in Table 2. During a dry winter period in 1974, the relative humidity in the chamber occupied by *R. megaphyllus* was 95.5%, compared with 32% near the mine entrance.

There is very little information on the microclimate of roosting sites selected by *R. megaphyllus* in northern Queensland. In the Mt. Etna area this species occupies caves varying greatly in structure and microclimate, but most larger colonies occur in relatively enclosed chambers with a high relative humidity (Dwyer, 1970; R. Ladynski, pers. comm.).

(B) New South Wales

R. megaphyllus has been recorded from a large number of caves, mines and tunnels in N.S.W. Although the temperature and relative humidity throughout these roosts is generally quite high, the sites where *R. megaphyllus* has been found roosting is always the warmest and most humid part of the cave or mine. (Table 2). A comparison of the microclimate in roosts regularly used by *R. megaphyllus* with the microclimate of caves and mines never or infrequently used is also given in Table 2. In most instances the temperature in caves and mines not used as roosting sites is considerably lower than the temperature in regularly used roosting sites.

Data on the range of temperature and relative humidity measured over a two year period in several maternity and non-maternity roosts of *R. megaphyllus* is given in Table 1. The temperature and relative humidity in maternity chambers is substantially higher than in the unoccupied areas of the same roost. Temperatures recorded in non-maternity roosts are lower than those recorded in maternity chambers, however the relative humidity in the occupied areas of non-maternity roosts is very high.

Almost all of the caves and mines where *R. megaphyllus* is found are of small dimensions, an exception being Bendethera Main Cave. Generally the areas in caves occupied by roosting *R. megaphyllus* are small chambers with rock or dirt-fill. These small chambers are frequently close to the cave entrance or near the ground surface. In these chambers the humidity is extremely high and areas surrounding roost sites are often covered with a film of water. In Bendethera Main Cave *R. megaphyllus* roosts in small avens at the far end of the cave.

The sea cave at North Durras has the maternity site located in a small rock-fall chamber close to the surface of the ground. (Fig. 2a). In 1972, the entrance to this chamber was enlarged and some slumping of the rock-fall occurred. This resulted in an air flow which decreased the temperature in the chamber and since then no *R. megaphyllus* have been observed in the cave.

The maternity site in Humidicrib Cave, Wee Jasper occurs in a small, high level chamber which is close to the ground surface (Fig. 2b). Geothermal activity in the immediate vicinity of the cave might account for the high temperatures recorded in the maternity chamber.

At Bendethera, Cleatmore and Marble Arch large numbers of *M. schreibersii* are found in the same caves as *R. megaphyllus* in the winter months. In Wyabene, Humidicrib and Durras Caves and in Talwong mine, *M. schreibersii* occurs in small numbers at infrequent intervals.

(C) Victoria

In Victoria a number of caves in the Buchan area and a mine near Club Terrace are known as roosting sites for *R. megaphyllus*. These sites are also occupied by *Miniopterus schreibersii* and small numbers of *Myotis adversus* also occur in several of the caves.

Maternity colonies of *R. megaphyllus* occur at Anticline, Mooresford and Nargun's Caves.

Anticline Cave is a relatively large cave consisting of two main chambers, separated by a narrow passage. Lactating females and juveniles roost in high-level avens just inside the main entrance. However, on several occasions clusters of juveniles have been observed in the deeper, more inaccessible areas of the cave. Temperatures and relative humidities recorded during December, 1974 in several areas of Anticline Cave are given in Table 2.

Mooresford Cave is located on the Snowy River, east of Buchan. The maternity colony of *R. megaphyllus* occurs in a small, collapsed chamber approximately 8 m from the cave entrance. This chamber is a cul-de-sac located close to the ground surface under a cliff which has a north-westerly aspect. Temperatures 5 m below the roosting site of *R. megaphyllus* are 2-4°C higher than in other parts of the cave. *M. schreibersii* has been observed roosting in these other areas.

The third maternity site for the East Gippsland population of *R. megaphyllus* occurs in Nargun's Cave. The cave consists of a long (300 m) passageway with a single main chamber (Fig.2c). An intermittent stream flows along the passage-way and sinks under the floor of the main chamber. Two maternity colonies of *R. megaphyllus* occur in small, high-level avens, whereas the year round roosting sites are closer to the chamber floor. One maternity site is in one of several high-level avens in the main chamber. The second maternity site occurs in high level avens located in a small side passage, approximately 14 m from the upstream entrance to the cave. Temperatures and relative humidities recorded in Nargun's Cave are given in Table 2.

Nargun's Cave also serves as a maternity site for up to 60,000 *Miniopterus schreibersii* (Dwyer and Hamilton-Smith, 1965). This species selects four separate maternity areas; one in the main chamber and the other three in the upstream areas (Dwyer and Hamilton-Smith, 1965; Spate, unpublished).

V. DISCUSSION

The selection of a diurnal roosting site with a favourable microclimate is an important factor in the total ecology of small insectivorous bats. A suitable microclimate assists in maintaining a favourable metabolic and water balance during periods of inactivity and also promotes the growth of juveniles. Verschuren (1957) considered that the microclimatic conditions are of greater importance in a roosting site than the total nature of the environment where the roost is situated. Ransome (1968), on the other hand, considered that the population size of *Rhinolophus ferrum-equinum* in various caves, is not simply a function of microclimate, but can be determined by such factors as food supply and feeding conditions near roosts.

Although individual *Rhinolophus megaphyllus* may select relatively exposed roosting sites, such as shallow caves or overhangs (Dwyer, 1966), most larger aggregations are found in relatively closed subterranean roosts. Within these roosts *R. megaphyllus* appears to select high-level avens or high level chambers partially blocked by dirt and/or rock-falls as roosting sites (e.g. Humidicrib, Nargun's and Mooresford Caves). These sites frequently exhibit higher temperatures and humidities when compared with other parts of the caves or caves in the same general area.

Several intrinsic and extrinsic thermal processes can account for the high temperatures recorded in roosts occupied by *R. megaphyllus*. They are: 1. metabolic heat produced by large numbers of bats. 2. the oxidation of guano and naturally occurring sulphides. 3. geothermal activity in the immediate vicinity of roosting sites. 4. solar insolation. Heat produced by these processes would be readily trapped by high-level avens and enclosed chambers in mines and caves with little or no air circulation.

The role of metabolic heat in increasing cave temperatures within maternity roosts of *Miniopterus schreibersii* has been well documented by Dwyer and Hamilton-Smith (1965) and by Dwyer and Harris (1972). A number of these roosts (Nargun's, Mooresford, Willi Willi and Riverton caves), also serve as maternity sites for *R. megaphyllus*. The metabolic heat produced by large numbers of *Miniopterus* would be readily retained by the high-level roosting sites occupied by *R. megaphyllus*.

There appears to be very little information available on the importance of guano decomposition and sulphide oxidation in heating cave and mine atmospheres. The oxidation of iron pyrites (iron sulphide) yields 4.3 cal/ccO_2 absorbed compared with 2.1 cal/ccO_2 for that of coal (Peele, 1966). The oxidation of sulphides might account for the relatively high temperatures recorded in Talwong Mine.

Geothermal activity in the immediate vicinity of Humidicrib Cave, Wee Jasper coupled with guano decomposition could possibly account for the high temperatures recorded in the maternity chamber of *R. megaphyllus*.

The possibility of solar insolation as a heat source can only be considered when cave chambers are <u>very</u> close to a ground surface that is relatively free of soil and vegetation or in the case where the aspect and structure of cave entrances (e.g. Nargun's Cave) facilitates the heating of air moving into the cave. Chambers in limestone caves would have to be very close to the surface in order to be heated externally due to the relatively low thermal conductance of limestone and soil. Limestone and dry soil have thermal conductances of approximately 6×10^{-3} and less than 0.5×10^{-3} cal/cm sec °C respectively (Clark, 1966).

The sea cave at North Durras could possibly be heated from an external source because the maternity chamber is very close to the surface which is exposed to the west and consists of loose aggregations of sandstone-conglomerate rocks.

R. megaphyllus is very prone to desiccation in conditions of high temperature and low relative humidity. It has been noted that the wing membranes of this species often become dried-out when the animal is removed from the humid conditions of its roost.

The high humidity requirement of *R. megaphyllus* probably prevents this species from regularly using buildings as a roosting site. A nursery colony of *Chalinolobus morio* occupying the attic of a building in the Bunya Mountains (Qld.) regularly experiences temperatures of 40°C and humidities as low as 30% during the summer months (Young, unpublished).

Present data suggests that *R. megaphyllus* does not make extensive journeys between roosts and that males are more sedentary than females (Dwyer, 1966; Young and Spate, unpublished). From the data available on roost site selection, movement patterns, and reproductive biology it appears that the numbers and the geographical distribution of *R. megaphyllus* is controlled to some degree by the availability of warm and humid maternity sites in close proximity to other roosting sites with a constant, high relative humidity. This predeliction for warm caves with high humidities possibly explains why this species of bat has never been recorded from caves at Cooleman or Yarrangobilly, N.S.W. Hamilton-Smith (1966) suggested that the greater distance between caves west of the Great Dividing Range might be a factor limiting the distribution of *R. megaphyllus*.

Due to the special roost site requirements of *R. megaphyllus* every effort should be made to minimize disturbances (by humans) within roosts, particularly during winter months and during maternity season (Nov. to Feb.). The preservation of roosting sites and their environs is also essential for the continued survival of this species.

References

CLARK, S.P. Jr., 1966 Handbook of Physical Constants. Geological Soc. of America. N.Y.
DWYER, P.D., 1966 Observations on the Eastern Horse-shoe Bat in North-Eastern New South Wales. *Helictite* 4(4), 73-82.
DWYER, P.D., 1970 "Mammals", in Mount Etna Caves. Ed. J. Sprent. *Univ. Qld. Speleol. Soc. Pub.* 44-64.
DWYER, P.D. and E. HAMILTON-SMITH, 1965 Breeding caves and maternity colonies of the Bent-Winged Bat in South-Eastern Australia. *Helictite* 4(1), 3-21.
DWYER, P.D. and J.A. HARRIS, 1973 Behavioural acclimatization to temperature by pregnant *Miniopterus* (Chiroptera). *Physiol. Zool.* 45(1), 14-21
GEORGE, G. and N.A. WAKEFIELD, 1961 Victorian cave bats. *Vict. Nat.* 77, 229-302.
HALL, L.S. and J.D. DUNSMORE, 1974 A survey of Cave Dwelling bats. *Aust. Speleol. Fed. Newsletter* 64, 9-10.

HAMILTON-SMITH, E., 1966 The geographical distribution of Australian cave-dwelling Chiroptera. *Inter. J. Speleol.* II. 91-104 + plates.
HARRISON, J.L., 1962 Mammals of Innisfail. I. Species and distribution. *Aust. J. Zool.* 10, 45-83.
KREFFT, G., 1866 On the vertebrated animals of the Lower Murray and Darling, their habits, economy and geographical distribution. *Trans. Phil. Soc. N.S.W.* (1862-5) : 1-33.
MOHR, C.E., 1972 The status of threatened species of Cave-dwelling bats. *Bull. Nat. Speleol. Soc.* 34 : 33-37.
PEELE, R., 1966 Mining Engineers Handbook. 3rd Ed. Vol. 1. Wiley Handbook Series.
PURCHASE, D., 1962 A second report on bat-banding in Australia. CSIRO Aust. Wildl. Res. Tech. Pap. 2, 16 pp.
RANSOME, R.D., 1968 The distribution of the Greater Horse-Shoe Bat, *Rhinolophus ferrum-equinum* during hibernation, in relation to environmental factors. *J. Zool. Lond.* 54, 77-112.
RIDE, W.D.L., 1970 A guide to the native mammals of Australia. Oxford University Press, Melbourne.
RYAN, R.M., 1964 The type locality of the Australian horseshoe bat, *Rhinolophus megaphyllus. Aust. J. Sci.* 27, 259-60.
STEBBINGS, R.E., 1966 Bats under stress. *Studies in Speleology* 2, 103-108.
TATE, G.H.H., 1952 Results of the Archbold Expeditions. No. 66. Mammals of the Cape York Peninsula, with notes on the occurrence of rain forest in Queensland. *Bull. Am. Mus. Nat. Hist.* 98(7), 567-616.
VERSCHUREN, J., 1957 Exploration du Parc National de la Garamba. 7 Cheiropterès, Brussels.

TABLE 1.

Temperature and humidity ranges recorded in two maternity caves and three non-maternity sites of *R. megaphyllus*. Figures represent the range of measurements during the time period indicated for each locality.

Maternity Caves				
	Maternity Site		Unoccupied Areas	
Locality	Temp. °C	Humidity (%)	Temp. °C	Humidity (%)
Humidicrib, Wee Jasper (N.S.W.) 1970-72	23-33	100	14-24	62-100
Sea cave, Durras (N.S.W.) 1970-72	17-31	64-100	13-20	45-78
Non-maternity Roosts				
	Occupied Areas		Unoccupied Areas	
Anjuramba Mine (Qld.) 1970-72	20-22.2	85-95.5	17-20	76-95*
Thermocline Cave, Marble Arch (N.S.W.) 1971-73	12.2-15.0	88.5-100	8.9-13.5	72-76

* *R. megaphyllus* occasionally present.

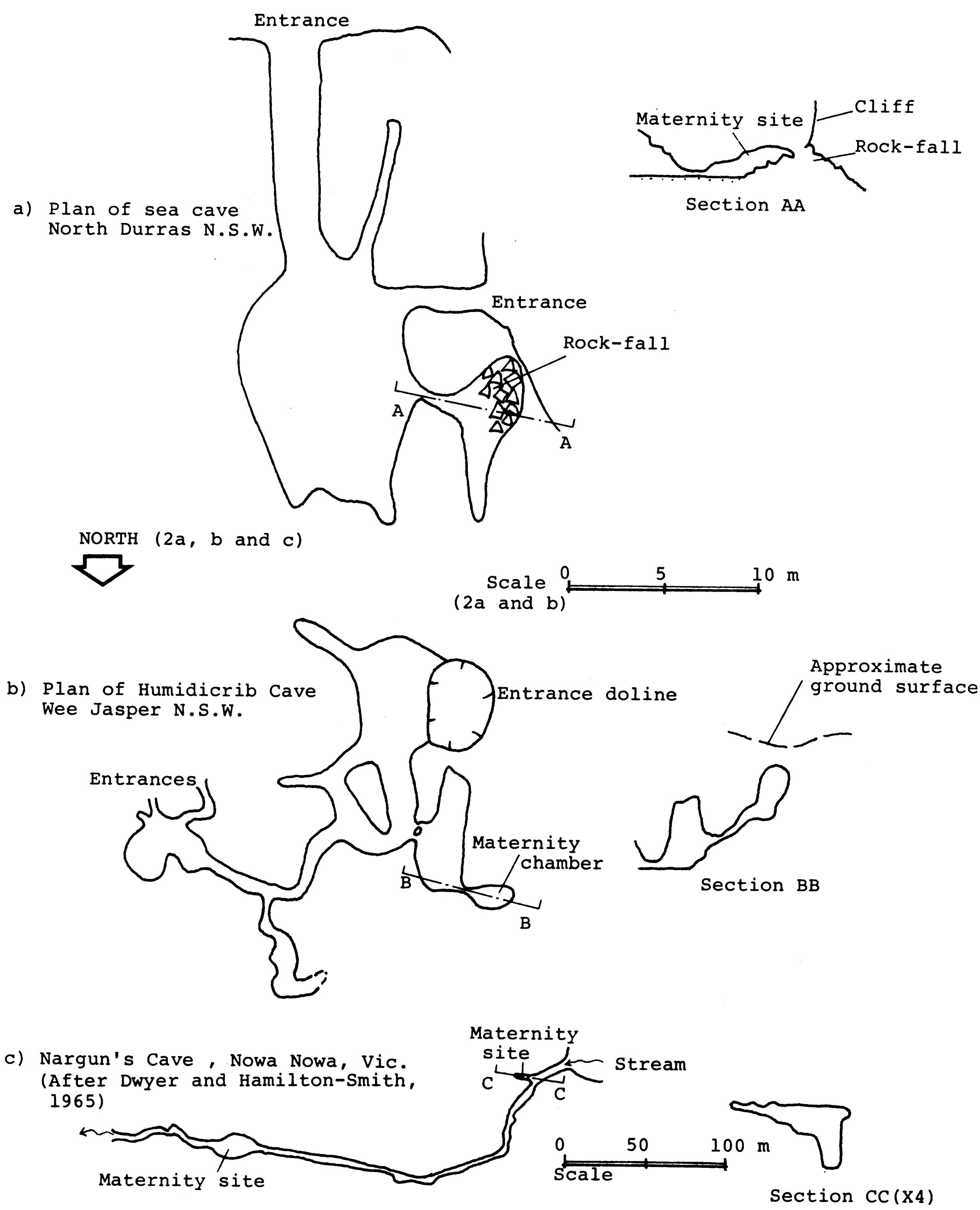
TABLE 2.

Spot temperature and relative humidity records from a number of caves and mines in eastern Australia.

Sites regularly used by *R. megaphyllus*		Unoccupied Areas		Roosting areas	
Locality	Date	Temp. °C	Humidity (%)	Temp. °C	Humidity (%)
Black Duck Cr. Mine (Qld.)	18.7.74	-	-	18.3	95.5
	20.9.70	-	-	18.0	-
	12.11.70	-	-	19.0	-
Ravensbourne Cave (Qld.)	18.3.72	-	-	22.0	95.5
Bendethera Cave (N.S.W)	27.11.74	15.0	86	20.2	100
Marble Arch (N.S.W.)	23.6.72	10.5	64	15.5	95 plus
	18.10.74	13.5	82	17.5	100
Cleatmore (N.S.W.)	12.5.73	11.0	80	15.2	95 plus
	15.12.73+	13.0	90	19.5	100
Wyanbene (N.S.W.)	18.10.65	15.0	-	21.0	-
Talwong Mine (N.S.W.)	12.3.72	-	-	23.0	-
Nargun's Cave, Nowa Nowa (Vic.)	7.12.74	14.0-15.5	91	15.5-17.0	84-93
Anticline Cave, Buchan (Vic.)	8.12.74*	15.5-16.0	85-94	17.0-17.5	95
Mooresford Cave (Vic.)	8.12.74*	13.4	94	16.1	89.5
Sites never or infrequently used by *R. megaphyllus*					
Bunya Mts. Cave (Qld.)	10.6.72	12.2	88		
Big Hill Mine, Pratten (Qld.)	30.7.74	17.8	78		
Mt. Fairy Cave (N.S.W.)	30.7.73	10.0	86.5		
	15.12.70	12.2	94.5		
Punchbowl Cave, Wee Jasper (N.S.W.)	28.6.65	12.8	83-87		
	13.9.65	11.6	94-96		
Dickson's Cave, Buchan (Vic.)	8.12.74	12.8	94.5		

+ *Miniopterus schreibersii* also present
* Roost unoccupied.

Figure 2. Details of three caves contining maternity sites of the bat *R. megaphyllus*.



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NOTES ON THE ROCK ART OF AIBURA CAVE, KAINANTU, EASTERN HIGHLANDS DISTRICT OF PAPUA NEW GUINEA

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ABSTRACT

A detailed description of the rock art of Aibura Cave, near Barapuna Village in the Kainantu Sub-district of the Eastern Highlands of Papua New Guinea is given. Techniques used are described, and the form compared with Kundiawa sites. Previous investigation has revealed two periods of occupation, 4000-2000 and 1000-600 BP. Two distinct art styles and techniques are present but correlation with occupation periods is difficult. The paper does not attempt to detail fully the purpose and symbolism of the art. Brief notes on the pre-history of the area, a local legend associated with the cave, and an account of its more recent uses are provided.

AIBURA CAVE

Location

Aibura Cave is situated 19 km south-south-west of Kainantu, as the crow flies, and 35 km by way of the Obura road, and a short walk from Karata, an extension of Barapuna Village, in the Tairora Census Division of the Kainantu Sub-district in the Eastern Highlands of Papua New Guinea. It is at an altitude of approximately 1600 m and is located in a small swampy valley which drains into the Kondanauta Creek, a small tributary of the Lamari River.

Topography and Geology

The area surrounding the isolated limestone block in which the cave is contained is undulating in contrast to the usual rugged Papua New Guinea terrain. Trees are almost completely absent from the area. "Pit pit" grass is the only pronounced vegetation. The area is swampy with the exception of a small section of drained and cultivated land east of the limestone outcrop where shrub regrowth and induced grassland are prevalent.

Sub-recent and recent alluvial and colluvial clayey soils with some peat are developed on greywacke, siltstones and granodiorite (CSIRO, 1970).

Recent history

Aibura was probably first visited by Europeans in 1945. Later, in 1961, it was noted as a possible archaeological site (White, 1972). White visited Aibura and carried out archaeological research during 1964-65. The cave is apparently regularly visited by Europeans and the location is consequently quite well known.

Pre-history

Human habitation and use are immediately obvious on entering the cave by the abundance of charcoal drawings and white clay paintings that appear throughout the cave. It has been ascertained by artifactual evidence (White, 1972) that Aibura was first used some 4000 years ago. Then followed a period of 2000 years abandonment or infrequent use. A second phase of extensive use commenced about 1000 years

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ago. A wide variety of artifacts discovered by White supports his proposal. Post holes indicate that some form of structure, a shelter or dwelling, was erected inside the cave during this second phase (White, 1972).

While no confirmation can be offered in this paper, it is reasonable to assume that the occupants of the cave, during this second period were, at least in part, responsible for the diverse and unique drawings and paintings.

Description of Cave

The cave is quite small and measures 60 x 25 x 15 m (see survey). It has four negotiable entrances converging on the main chamber (10 x 15 m) which is dimly lit by a number of holes in the roof, With the excaption of the north-west passage, the walls and roof are heavily smoke stained and blackened above 0.9 m (presumably due to fire lighting during occupation). The roof varies in height from two to four metres. Apart from some deposition in the main and western chambers, the cave appears to be "dead". Normally, the cave is damp but not wet. White (1972) records floor wash occurring during the wet season. Some algae are apparent in places on the walls which are normally quite dry. Drawings and paintings are protected and located behind the "dripline". On the western side of the outcrop a small alcove-like cave is located.

Local mythology

One Taka-Kaino, an elder of Karata, related the following legend (translated from local dialect to "pidgin" and further translated to English).

"About three generations ago, seven children of Barapuna Village came to Aibura Cave to play, Whilst they were playing an elder from the village came down and told them to stop playing in the cave because it was dangerous. The cave was then heard to say the following (dialect), "Bitori mau ori pempu urau bainbain". (Roughly translated, this means 'I am going to close'.) With that, all entrances of the cave sealed themselves, and the walls began to close in, trapping the children inside. The parents of the children came to the cave when they heard what had happened, and brought freshly killed pigs and cooked vegetables in an offering, and begged the cave to release their children. The cave remained closed and occasionally the children could be heard crying and shouting for help, until finally only one child remained. Later he too died, and the crying stopped. Some weeks later the cave opened up again. The parents went inside and recovered the bodies of their children. They were carried back to the village where there was great sadness and mourning."

Taka also related that the cave was used, in the time of "tumbuna" (ancestors) and during his lifetime, by the women of the village during the act of childbirth. This was corroborated by other informants who also said that the alcove on the western side was used for this purpose, It is interesting to note a figure that is obviously female at the rear of the alcove (Fig.II). It was also said that the cave was used as a place of refuge during tribal warfare against the once traditional enemies, the Tsaiora. Local people account for the blackening of the roof and walls with the story that the Tsaiora once set fire to the grasses that grow over the outcrop. Taka said that the cave was occupied at the time, and that all the possessions of the occupants were destroyed in the ensuing fire.

THE ART

The techniques used, the motifs and patterns, and their occurrence and repetition in the cave are briefly described. Detailed location descriptions are provided in Appendix I.

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Techniques

Four techniques appear at Aibura: (1) drawing with charcoal, (2) finger painting with white clay, (3) finger dotting with white clay, and (4) finger painting with a mixture of white clay and ground charcoal.

As a general rule, each technique appears separately (monochrome). However, on some occasions, all four techniques appear simultaneously (bichrome).

Classification (Fig. I)

'Occuli' and Circular Motifs (Fig. I.1): Circles 1(a), concentric circles 1(b), 'occuli' 1(c), circles with spokes or rays 1(d and e), in charcoal (monochrome). Circle 1(f), circle with rays 1(g and h), two circles joined by a horizontal bar 1(i), and concentric circles 1(j) in finger dotting or painting (monochrome). Circular motifs are the most common of all the motifs and occur frequently throughout the cave.

'Embryo' motif and Irregular Triangle Motif with two Projections (Fig. I.2): Triangular shaped motif with projections in monochrome finger dotted white clay 2(a). Motif of similar style 2(b) in bichrome charcoal and fingerpainted white clay. Motif in similar style 2(c) in monochrome finger dotted and painted white clay. Variations of these motifs appear some six times throughout the cave. (Fig. II, 1, c was described by P.J. White (1964) as follows, "Possibly an embryo figure; a complex but enigmatic design".)

Anthropomorphs (Fig. I.3): A diverse group of anthropomorphic figures appears throughout the site. Forms 3(a to e) are executed in white clay, the form of the figure 3(d) being filled-in in grey (bichrome). Forms 3(f) to 3(j) are executed in charcoal (monochrome). Forms 3(a), 3(b), 3(f) and 3(g) appear to have exaggerated male sexual characteristics whilst 3(c) is possibly female. Form 3(a) appears once (section C-D), form 3(b) twice (section E-F), and form 3(c) appears once on the roof (section F-G) and once elsewhere (section N-O). There are five variations of 3(d), 3(h) and 3(i) which appear in sections D-O. Form 3(g) appears once in section I-J, and twice in section AA-AB (see cave survey). Form 3(f) appears once in the passage area of entrace 1, and form 3(j) appears once in section AA-AC.

Zoomorphic Figures (Fig. I.4): A monochrome zoomorphic figure in charcoal, of unknown meaning and origin, occurs twice in section C-D and five times in an alcove in section E-F.

'House-like' Motif (Fig. I.5): This motif is drawn in charcoal (monochrome) and appears five times in the southern chamber (sections U-O). Although the form appears to be of recent origin, on at least two occasions it appears under other obviously old drawings, thus indicating its antiquity. The origin and meaning are unknown.

General

Fig. II shows a female form drawn in charcoal which appears on the east wall of the small alcove on the western side of the outcrop; a short distance to the right and slightly above this appear the forms shown in Fig. III which are executed in white clay and charcoal. Fig. IV is an enigmatic design painted in white clay and occurs immediately above 'E'. Fig. V(b) is a further enigmatic design drawn in charcoal and appears 0.5 m right of 'P'/ Fig. V(b) which is drawn in white clay appears in section 'AH-AI' and Figures V(c), (e) and (f), which are drawn in charcoal, appear 2 m to the right of 'C'. The meaning of (c) remains an enigma whilst (e) and (f) obviously represent female and male genitalia. The form in Fig. V(d), which is drawn in charcoal and appears approximately 1 m to the right of 'T', appears to be a 'legless' anthropomorph.

Fig. IV is a detail of the wall in section 'J-K' showing two anthropomorphs outlined in charcoal and filled in with a mixture of white clay and ground charcoal; these figures are surrounded by geometric and linear designs drawn with charcoal. A white clay finger dotted pattern, of no apparent form, is superimposed over the anthropomorphic and charcoal designs.

RECORDING METHODS

The drawings and paintings were photographed using a 35 mm through-the-lens single reflex camera and 400 ASA black and white film. An electronic flash device was also used. Where photography proved to be impracticable, the grid method of copying was applied. The cave was surveyed with a compass and inclinometer to the nearest degree and with a non-magnetic tape to the neareat centimetre (C.R.G. Grd 4).

CONCLUSIONS

The Aibura art style differs greatly from the art style of the Kundiawa sites (Wilde 1974) with the exception of some similarities between circular motifs and some anthropomorphs. Dating is as always difficult, but as previously mentioned, it is reasonable to assume that at least some of the paintings and drawings were executed by the people who occupied and used the site during the second phase of habitation (1000-600 BP). It is possible but very doubtful that some art has survived from the first phase (4000-2000 BP). However it is more reasonable to assume that the majority of the art is attributable to the second phase and that the older art lies hidden beneath the smoke stains. There are, however, two distinct stryles and techniques which may indicate cultural differences in the artists themselves. Much of the art appears to be associated with childbirth and fertility and the site apparently fulfilled this purpose until very recent times.

CONSERVATION

As with many of the other parietal art sites throughout the highlands, Aibura has been vandalised by local youths. It is obvious that sites lacking in 'tambus' are abused by village children and in some cases by Europeans too. Perhaps schools could be made aware of the catastrophic destruction of this aspect of local culture? Students should be made aware of this tragedy and be educated towards preserving these unique, valuable and beautiful assets of their cultural heritage.

References

CSIRO, 1970 Lands of the Goroka-Mt Hagen Area, New Guinea. *Land Res. Ser.*, 27,60.

WHITE, J. Peter, 1972 "Ol Tumbuna" Archaeological Excavations in the Eastern Central Highlands, Papua New Guinea. *Terra Australis*, 2, 51-74. (Dept of Prehistory, School of Pacific Studies, Canberra.)

WHITE, J. Peter, & WHITE, Carmel, 1964 A New Frontier in Archaeology: Rock-Art in Papua New Guinea. In *The Illustra ted London News*, Nov.14, pp.775-777.

WILDE, K.A., 1974 Notes on Rock Art and Burial Caves of the Singganigl and Kwinigl Valleys of the Chimbu District. *Niugini Caver*, 2(2), 163-180.

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APPENDIX I

General Description of Art

For ease of description the walls of the cave have been divided into sections from convenient survey points and are marked from A - X and AA - AH.

SECTION A - B - C: The wall and ceiling of section A - B to a point 2 m after B - C shows mainly white clay, finger drawn or dotted 'occuli' and circular motifs of the type shown in Fig. I, 1, f-j. Also present are a number of charcoal 'occuli' and circles similar to those shown in Fig. I, 1, a-e. Near the entrance are four variations of Fig. I, 3, f. Also at the entrance and at a height of approximately 2 m are a group of recently executed charcoal figures. Local informants say that this group was drawn by village children. Almost the entire roof of these sections consists of white clay, finger dotted, circular patterns of no apparent form to the writer; the roof also has a number of circular motifs of the type shown in Fig. I, 1, f-j.

SECTION C - D: Above 'C' there is a motif of the type shown in Fig. I, 2, a, and a centrally placed anthropomorphic form (Fig. I, 3, f); surrounding this form is a white clay, finger dotted pattern of no apparent form. Approximately 2 m to the right appears an isolated anthropomorph (Fig. I, 3, a) and below this and slightly to the right are a number of faded, old, linear charcoal drawings (Fig. V, c, e and f). A further 2 m to the right and 0.5 m above the floor is a faded, double zig-zag design 0.8 m long and 0.2 m high. A number of scratched lines of a geometric form also appear but are most likely of recent or accidental origin. No drawings or paintings appear on the smoke blackened roof of this section.

SECTION D - E: Has a number of motifs and drawings in charcoal including two anthropomorphs and two zoomorphic forms as in Fig. I, 4; a number of circular and 'occuli' motifs (Fig. I, 1, a-e) and some linear charcoal designs. The roof of this section is clean and high with no drawings.

SECTION E - F: Immediately above 'E' appears an enigmatic design (Fig. IV). The design is finger painted in white clay upon dark brown, smoke stained rock. In an alcove. almost at ground level, appears a design of 'complete' and 'incomplete' zoomorphic forms of the type shown in Fig. I, 4. These are drawn in charcoal. Approximately 3 m above the floor and to the right of 'E' is an anthropomorphic form of the type shown in Fig. I, 3, b. Above the group of zoomorphic forms, drawn upon calcite flow, are a number of white clay, finger dotted designs which are faded and almost indistinguishable; and another anthropomorph of the type shown in Fig. I, 3, b. 0.3 m to the right of this is a white clay, finger dotted design consisting of a double circle with three upright, dotted lines between the two circles; the design is 0.3 m high.

The roof of sections E - F, F - G, H - I, and I - J forms an 'archway' which is smoke blackened; upon this 'archway' appears a complex circular and geometric design covering the whole roof and overlapping on to the walls. The design is finger dotted in white clay; a 'kidney' shaped motif appears to have been recently retouched. Near to SP 'G' is an anthropomorphic form similar to Fig. I, 1, c; a similar but dotted anthropomorph appears adjacent to this, a triangular design similar to Fig. I, 2, a, and a variation of form I, 2, c also appear in this section.

Entrance area 2 has a fallen rock slab across it with a number of faded and almost indistinguishable charcoal designs.

SECTION H - I: On the wall immediately adjacent to SP'H' are a number of recently executed charcoal drawings. No original drawings appear on the wall of this section.

ANTHROPOLOGY - K.A. Wilde

SECTION I - J: Beneath the 'arch' there are a number of older charcoal drawings, including an anthropomorph. A short distance before SP 'J' and 0.75 m above the floor is a white clay, finger dotted anthropomorph similar to Fig. I, 3, e. Immediately above SP 'J' are a number of recently executed charcoal drawings (probably drawn by juveniles). Amongst these are a number of the 'house-like' motifs (Fig. I, 5) which casts some doubt on the antiquity of the design. However, in other areas of the cave the motif appears underneath old white clay paintings. It is possible that the ones in this section are recently made copies of older ones.

SECTION J - K: This section has a complex group of drawings in both charcoal and white clay. Amongst the drawings are two variations of the anthropomorph in Fig. I, 3, d; these two forms are outlined in charcoal and filled in with a mixture of charcoal and white clay. Charcoal drawings are predominant with superimposed white clay dots (Fig. VI).

SECTIONS K - L, L - M and N: This section has little in the way of drawings or paintings with the exception of a number of very recently executed charcoal drawings which local informamts say were drawn by children from the village. There are a number of old and faded and no longer recognizable drawings beneath these.

ALCOVE: On the western side of the outcrop near entrance 3 is a small alcove or cave. This small cave has a number of monochrome charcoal drawings and bichrome charcoal and white clay paintings. Fig. II, an obviously female form appears on the east wall and a short distance to the right and slightly above it is the 'embryo' motif and anthropomorph that appear in Fig. III. The female form is drawn with charcoal and the 'embryo' motif is painted with white clay and outlined in charcoal.

SECTION N - O: This section continues with recent, juvenile drawings superimposed over old and faded charcoal drawings. To the right of SP 'N' and 3 m above the floor is an anthropomorph similar to Fig. I, 3, d but in charcoal outline only; the form is over one metre high and is faded and possibly old. The right hand extremities of the figure are obscured by calcitic flow and algae. One metre to the right of SP 'O' is a white clay, finger-dotted anthropomorph similar to Fig. I, 3, c with a white clay, finger painted 'loop-like' design superimposed over it. Below this are a number of charcoal limear, zig-zag, curvilinear and rectilinear drawings which are faded and almost indistinguishable and above a dry inlet by the ceiling is a further 'loop-like' painting similar to, but older in appearance than the previous one.

SECTION O - P: There are no drawings in this section, with the exception of some faded, linear, charcoal drawings and a heavily drawn group of sweeping, charcoal lines left of SP 'P'.

SECTION P - Q: Half a metre from SP 'Q' is a white clay, finger-dotted anthropomorph similar to Fig. I, 3, e and below this appears a linear charcoal design (Fig. V, a) to the right of this is a faded and indistinguishable white clay, finger-dotted design and a linear charcoal design, also indistinguishable.

SECTION R - S: This section is smoke blackened above 0.9 m leaving a group of linear charcoal designs only partly exposed. At SP 'S' is a circular charcoal motif as in Fig. I, 1, e and a faded, linear, charcoal pattern which is almost completely indistinguishable.

SECTION S - T: Immediately to the right of SP 'S' is a faded group of bichrome motifs, smoke stained and very difficult to distinguish in any detail. There is a clearer group of white clay paintings left of SP 'T'.

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SECTION T - U: To the right of SP 'T' and 1 m above the floor is a concentric circle motif drawn in charcoal (Fig. I, 1, b) and 1 m to its right is a legless anthropomorph (?) 0.7 m high, also drawn in charcoal (Fig. V, d). 1.3 m to the right is a group of faded, linear, charcoal designs and above them is a white clay, finger-dotted curcular motif of type Fig. I, 1, f on the roof of this section is a white clay, finger-dotted pattern, similar to the entrance areas 1 and 2, but almost completely obscured beneath smoke stains.

SECTION U - V: Open area (entrance 4) with no drawings.

SECTIONS V to Z: No drawings.

SECTION Z - AA: This section has a number of recently executed charcoal drawings (presumably drawn by village youths) which are superimposed over old and faded charcoal designs. In a hollow in the roof is a white clay, finger-dotted pattern similar to previous roof patterns.

SECTION AA - AB: A number of faded, charcoal, limear designs and white clay, finger dotted patterns; circular motifs, rectilinear designs and an anthropomorph similar to Fig. I, 3, e.

SECTION AB - AC: Has a faded enigmatic, linear charcoal design too complicated to describe here in detail and, left of a calcite flow in the centre of the section, is a charcoal anthropomorph as in Fig. I, 3, f, and a faded, linear charcoal design. Two metres left of SP 'AC' are a number of faded, linear, charcoal designs partly obscured by smoke staining.

SECTION AC - AD: In this section are a number of charcoal drawings and white clay, finger-dotted paintings but above 0.9 m the roof is completely smoke blackened, leaving little of the drawings exposed to view.

SECTION AD - AE: Linear, charcoal drawings are visible on a clean wall up to 1.4 m above the floor, with the remainder smoke blackened and indistinguishable. White clay designs are partly visible through the smoke stains.

SECTION AE - AF: One metre from the floor and in the centre of this section appears a number of faded, linear, charcoal patterns; approximately 2.5 m left of survey point 'AF' is a charcoal circle motif and faded linear, geometric designs. One metre to the right and 1 m above the floor is an anthropomorphic form with a rectilinear drawing below it.

SECTION AF - AG: Here is a circular charcoal motif which appears 0.5 m right of survey point 'AF' and 1.7 m above the floor; it is similar in appearance to Fig. I, 1, d and is 25 cm in diameter. 1.5 m across from SP 'AF' is a white clay, finger-dotted pattern of no apparent form to the author but similar to previous ones; left of this is a linear charcoal design.

SECTION AG - AH: This section has a number of old and faded indistinguishable, white clay, finger dotted patterns similar to previous ones.

SECTION AH - AI: Has a white clay, finger dotted 'flower-like' motif (Fig. V, b) which is 40 cm across and continues with white clay, finger dotted patterns similar to previous ones; some circular motifs also appear.

SECTION AI - A: Entrance 1.

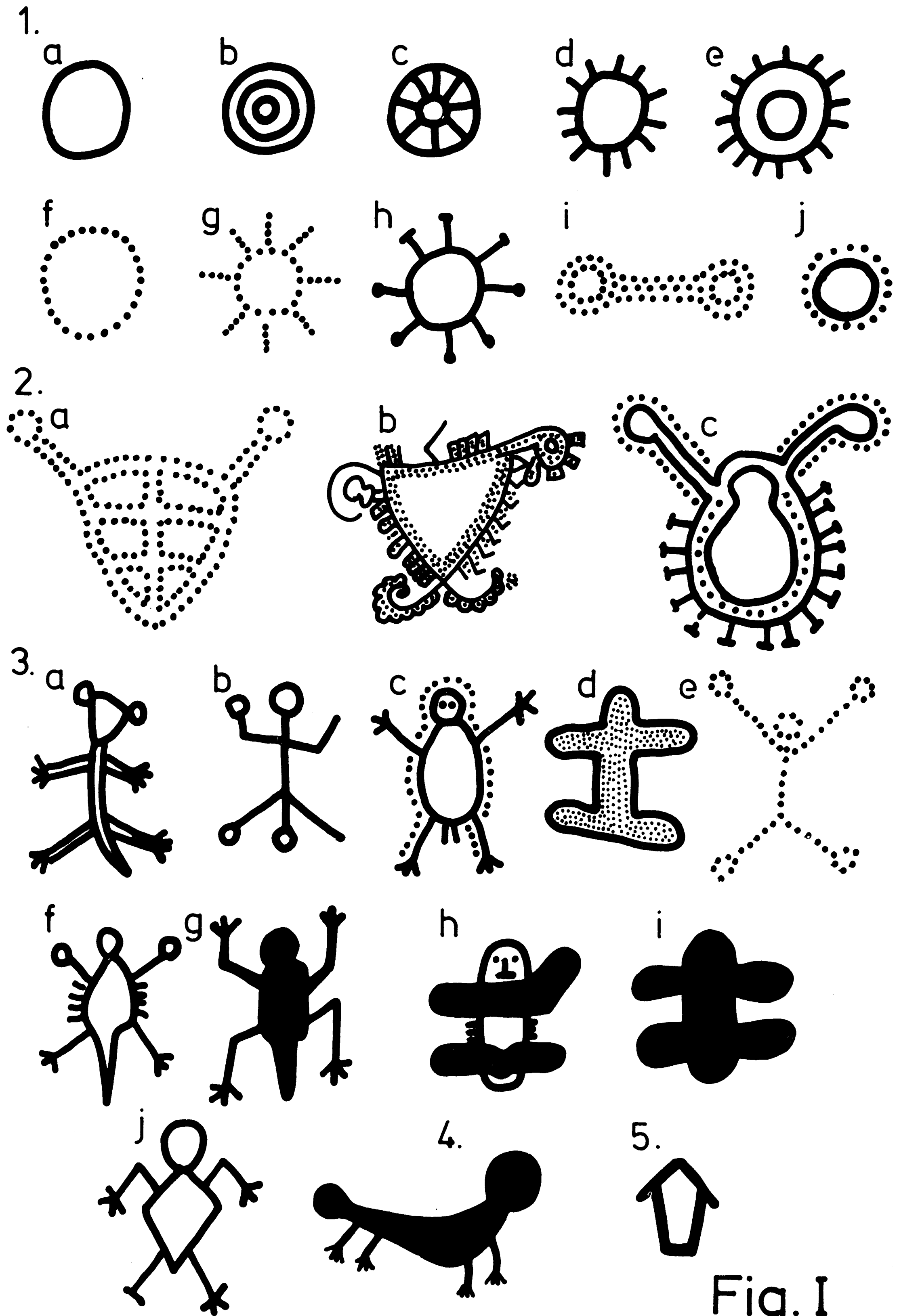
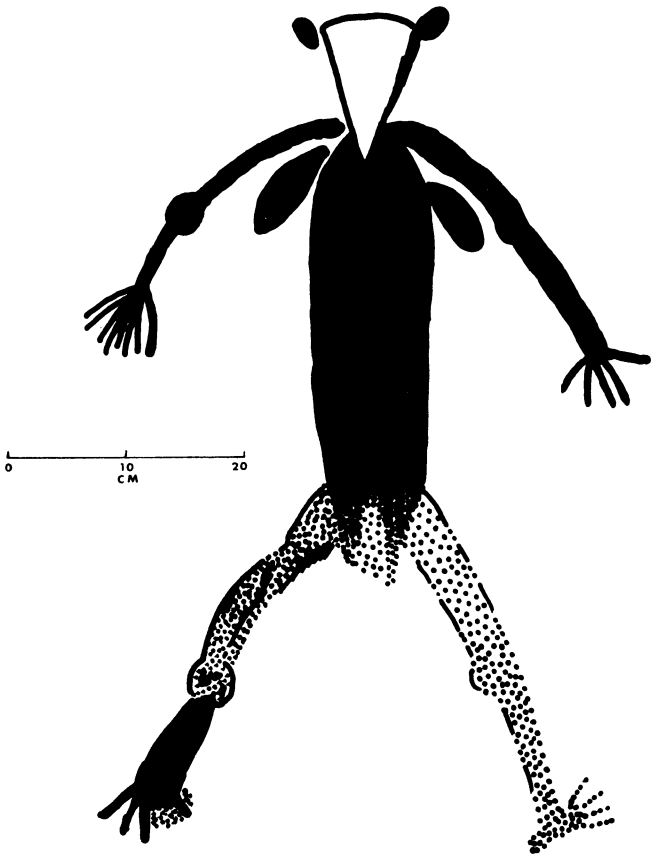


Fig. I

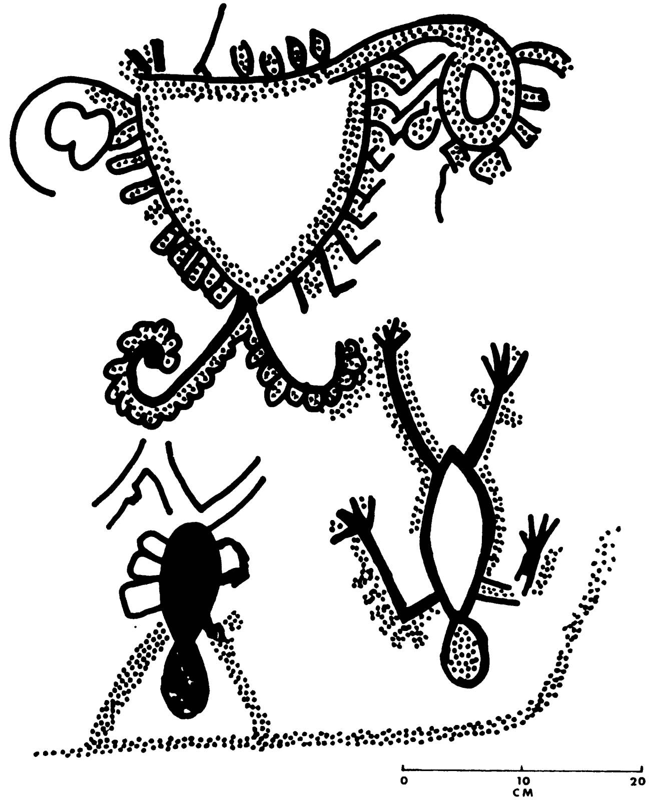
Fig. II

smudged areas with some outline



'female figure west alcove'

Fig. III



white clay
charcoal

Embryo motif & anthropomorphs

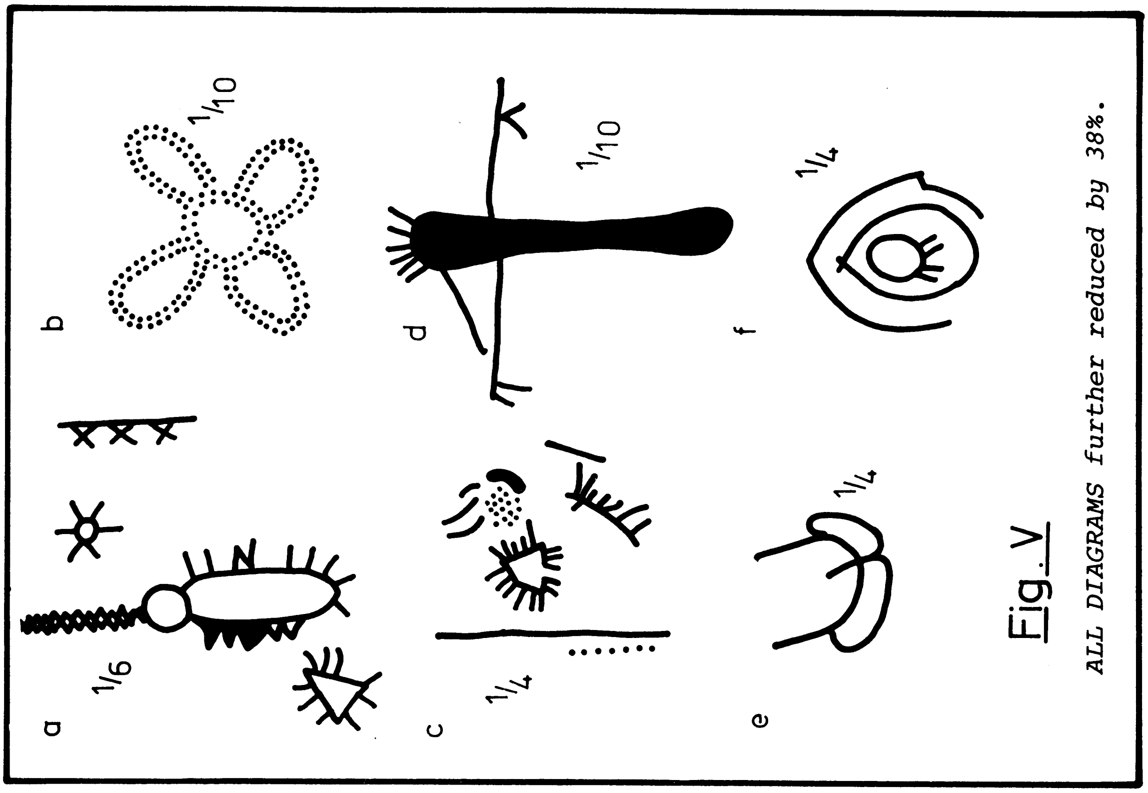


Fig. V

ALL DIAGRAMS further reduced by 38%.

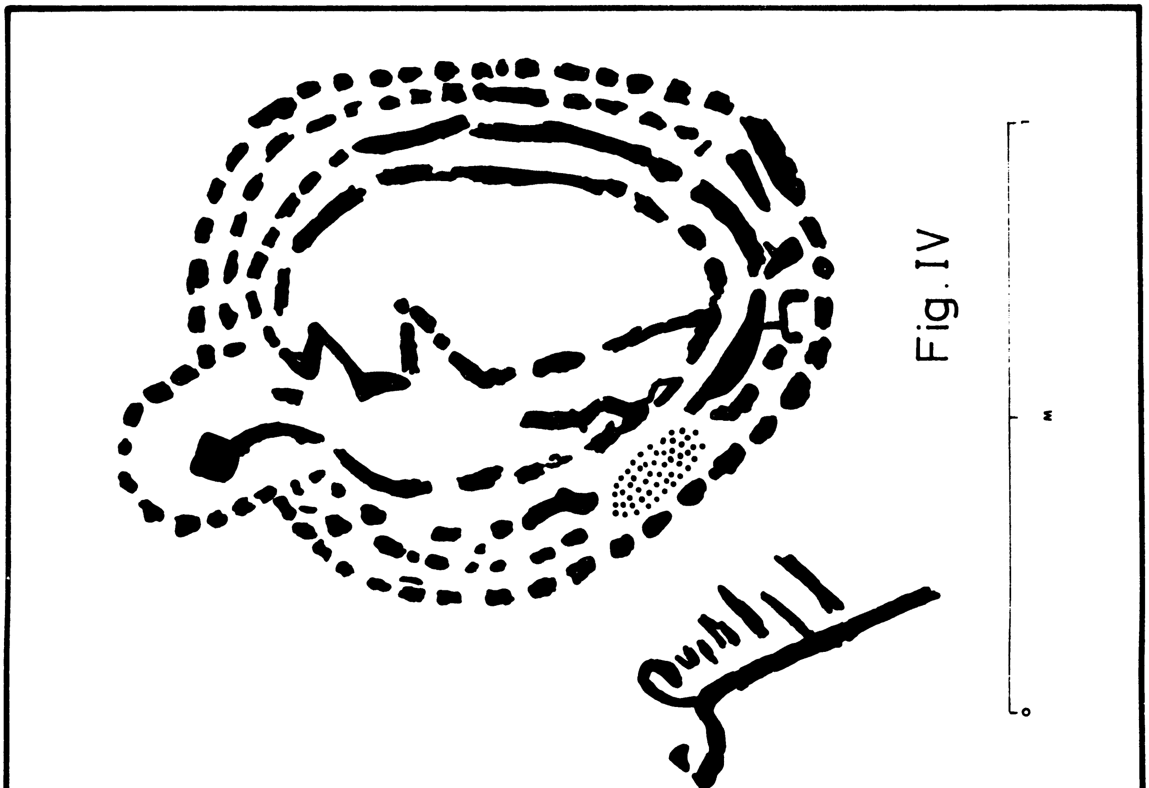


Fig. IV

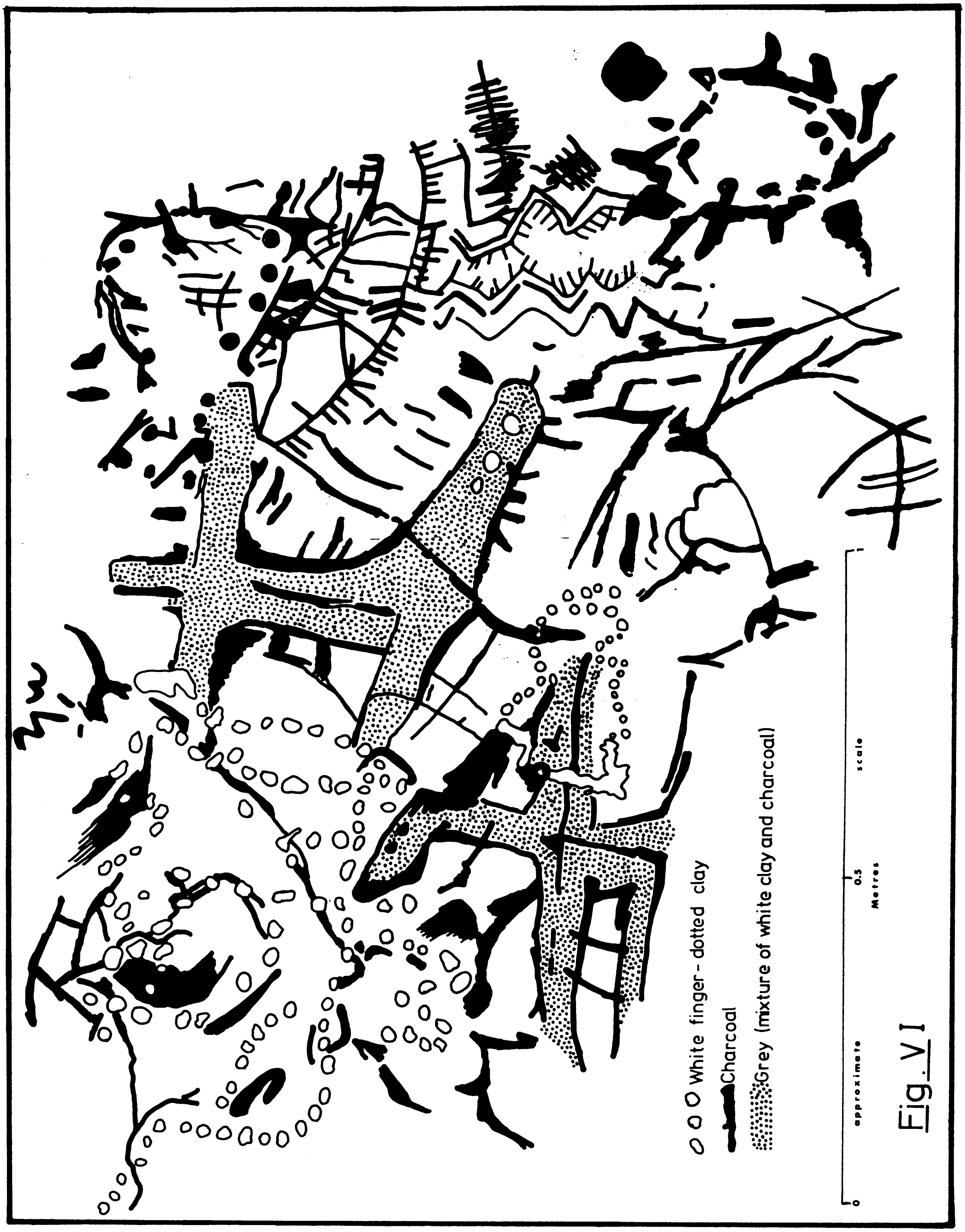
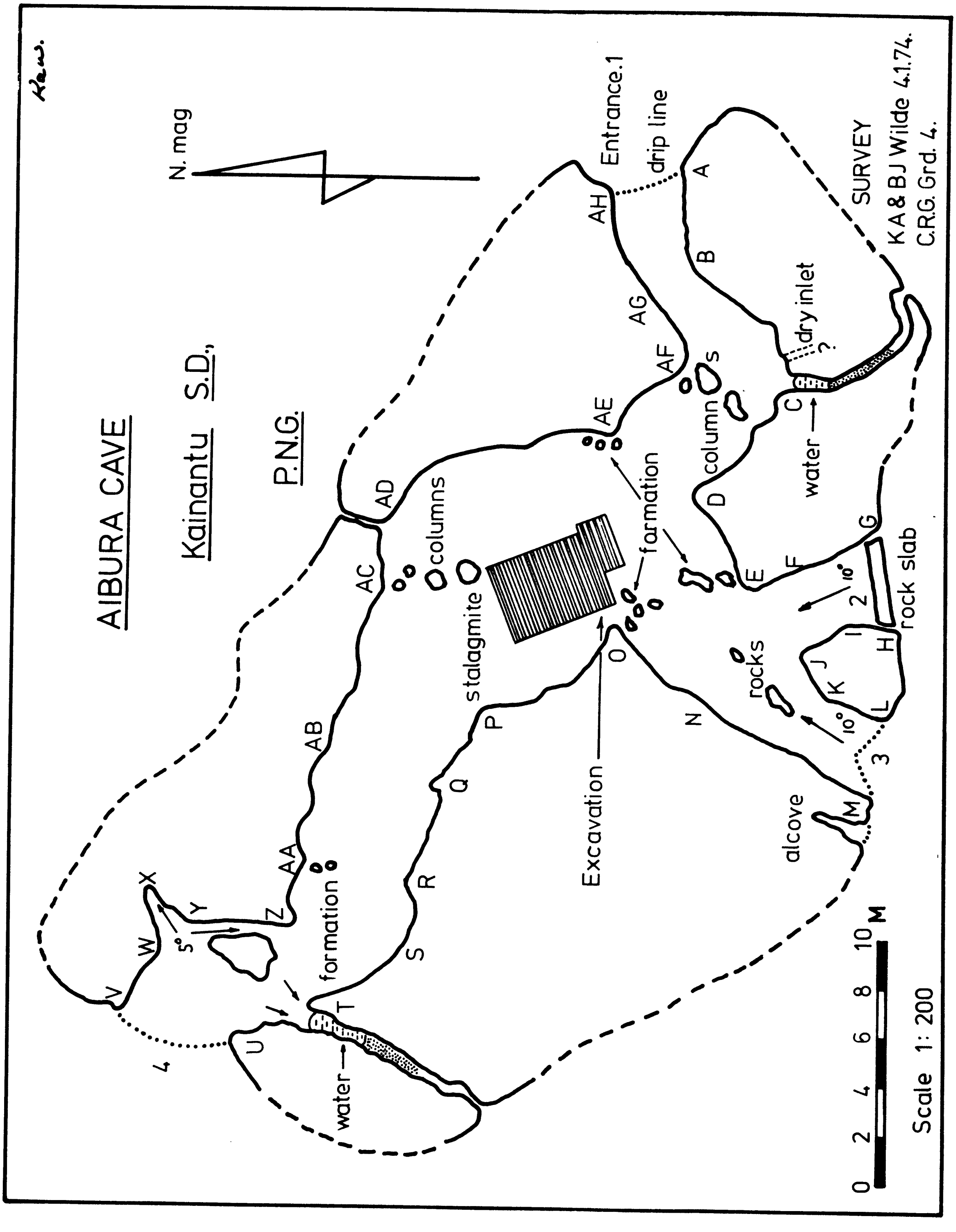

White finger - dotted clay
Charcoal
Grey (mixture of white clay and charcoal)
approximate scale
0
0.5
Metres

Fig. VI


AIBURA CAVE
Kainantu S.D.,
P.N.G.
N. mag
Entrance.1
drip line
SURVEY
K A & BJ Wilde 4.1.74.
C.R.G. Grd. 4.
dry inlet
?
water
column
columns
stalagmite
formation
Excavation
rock slab
rocks
alcove
water
formation
Scale 1: 200
0 2 4 6 8 10 M

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SECTION 4
CHILLAGOE - AREA, AIMS AND ACTION

OBSERVATIONS OF THE GEOMORPHOLOGY OF THE CHILLAGOE LIMESTONES

P.A. Wilson*

INTRODUCTION

Because Chillagoe is distant from the centres of population most of the scientific work of a purely academic nature carried out in the area, has been done by interested amateurs. And this is how I see myself, as I have no formal qualifications in geomorphology. My main contribution to the study of the geomorphology of the area is that I have been able to spend two years in Chillagoe making observations.

Chillagoe lies at the southern end of the Cape York Peninsula and is approximately 130 km west of Cairns. This is hilly country where the Great Dividing Range sweeps down to the Gulf of Carpentaria towards which the area drains. The height above sea level is 390 m. The mean annual rainfall is 800 mm and the seasonally arid climate exhibits very well defined wet and dry seasons. The wet season lasts from the end of December until the beginning of April.

FEATURES OF THE MAIN LIMESTONE OUTCROPS

The limestone lies in a belt about 5 km wide in places and 45 km long and is bounded in the east by the Almaden Granite and to the west by the Palmerville Fault. It is often fossiliferous and represents coral reef deposits of Upper Silurian or Lower Devonian age (De Keyser and Wolff, 1964). The bedding is at first difficult to determine but can be seen in highly contorted, vertically bedded chert bands, found for example near the Donna Cave. In one instance north of Mungana the dip is approximately 70^{o} and to the north-east. The bedding is always steep and can vary from east to west in direction.

Large masses of dark grey limestone protrude from the plain in tall vertical towers rising up to 65 m high. These are usually lens-shaped or boat-shaped in plan, aligning themselves approximately N.W. - S.E.; thus an apt description is "an aligned tower karst". Interleaved with the limestone towers are steep rounded hills of cherts and quartz greywackes often over 100 m high, and again, the bedding where seen (2 km west of Zillmanton rail crossing, 0.3 km east of the Donna Cave), is dipping between vertical and 60^{o} and is highly contorted and faulted.

The main towers to the west rise up sheer in places to sharp needles of rock. There is a considerable amount of collapse, producing scree slopes at the bases of the towers and fallen blocks of rock on top of the towers. Jointing is always well defined but variable; some areas with more joints appear to have more collapse. Solution along the joints has produced grikes and corridors varying from a few centimetres in width to the really large grikes in the Queenslander area which are 10 m wide and 30 m deep. Box valleys occur in a few instances such as in the Royal Arch area, and smaller raised box valleys with level floors some 10 to 15 m above the general plain level are common - behind the Donna Cave, at the Disney Cave and the Spring Cave.

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SURFACE SOLUTION FEATURES

The usual tropical Karren solution features are well developed. The Rillenkarren of about 1 - 2 cm across drain down the tower faces into Rinnenkarren up to 30 cm deep and 30 m long. Flat solution pans, or Kamenitsa, are very common on the tops of the towers and these always have a Karren-type outlet draining down the outside of the tower or into fissure caves.

Limestone pavements occur, and vary from narrow pediments (approximately 20 m wide), covered with scree material, at the bases of the towers (Royal Arch area), to large pavements which can be seen further to the east. A large pavement at Zillmanton is an undulating surface drained by two surface streams (in the wet season) and strongly dissected by grikes. Pavements can also be seen along the railway line by the smelters and at Dome Rock, (the Lion's Head Rock referred to by Danes). On many of the pediments the results of solution within the soil cover can be seen. By the aboriginal paintings at Mungana, owing to poor surface drainage, the water table rises above the surface of the limestone pediment in heavy wet seasons. The water lying in the large pool formed thus attacks the bases of the towers and has in three cases caused small towers to topple over.

THE DEVELOPMENT OF CAVES

The larger caves are in general highly complex tight systems, often developed along parallel joints. The survey of the Queenslander system (Chillagoe Caving Club 1973) demonstrates this very well. In many cases caves consist of interconnected daylight chambers or sometimes open solution corridors. On examination, phreatic features are common, even at the tops of the tallest towers, though they are often disguised by collapse and large quantities of formations and cave coral. Contrary to the implications in Danes' paper (1911), vadose development is limited mainly to Karren-type formations on cave walls although some scalloping was found at the bottom of Christmas Pot.

Cave floors are generally fairly flat and consist of cave earth, guano, tree roots and accumulations of bat bones and snail shells. The water table often rises above the cave floors in the heaviest wet seasons and these obviously lie within the para-phreatic zone. That there is an active phreatic zone between depths of 10 m and 120 m is suggested by De Keyser and Wolff (page 66) in the statement:

"The presence of supergene sulphides at a depth of 400 feet, although ground-water level is only 30 feet below the surface, may be explained by the *free water circulation afforded by solution channels in the limestone*." (my italics).

This is further born out by local contractors who claim that drilling companies have encountered large water-filled cavities at considerable depths. Despite the obvious phreatic origins of the caves only three caves (Ti-tree Cave, Narahdarn Cave, Christmas Pot) are known to descend into the phreatic zone. Of these Narahdarn Cave was dived to a depth of 15 m without a floor being reached.

Direct solution in the paraphreatic zone is also an important contributor to cave development. Examples of partly redissolved cave coral and other formations are common. The extent of solutional activity below the cave floors remains to be investigated.

THE CONTRIBUTION OF FLOODWATERS IN HEAVY WET SEASONS TO CAVE DEVELOPMENT

Observation of the behaviour of moving water in the heaviest wet seasons is important to an understanding of how the caves develop. Hamilton-Smith suggests that scree rubble dams back accumulated infiltration waters from within the towers (Jennings 1969). Jennings (1966) suggests that the "impounding of flood waters behind these barriers might be the cause of the formation of the network of caves". However the piles of scree material are not a significant barrier to the movement of floodwaters. Water is able to flow out of, for example, the Royal Arch Cave underneath the scree and within the solid pediment.

The main controlling factor over water movement appears to be the levels of the surface streams which are always lower than the flat earth floors of the caves. Chillagoe Creek, Redcap Creek and Ryans Creek all flow, in part, all the year round, and in the driest periods, source in springs in the limestone bedrock. The water probably derives from the main mass of water stored in the phreatic zone. In the wettest periods rain water pouring into the caves raises the water table into the paraphreatic zone and this water attempts to find its way out to the main surface drainage. The only real variable is the rate at which it does this.

In the Royal Arch system water reaches the cave floor only two or three minutes after the onset of a storm and at least half the system drains towards the entrance. In a normal wet season it lies in still pools while gradually seeping downwards into the mud. However in the very heavy wet season of 1974 when 1950 mm of rain fell, the water in the entrance chamber was 2.5 m deep and the water flowed through small passages under the scree into a tributary of Chillagoe Creek outside the cave. The cave emptied in about three weeks.

In the Donna Cave in 1974 a different situation occurred when the water in the main chamber reached a depth of over 9 m by mid-March, and it did not empty until 14 weeks after the rain ceased. For about half this time water seeped out of the base of the tower on the opposite side to the Donna's entrance. Chillagoe Creek flows on limestone some 800 m away and the intervening country is a silt-covered plain.

Other caves near Mungana gave similar indications: The Markham (often referred to in the past as "The Mungana Caves"), the Ryan Imperial Cave and the Giant Causeway Cave all still had water to a considerable depth 20 weeks after the rain had stopped. In each case local surface drainage is almost non-existant. However the Ryans Creek Cave had completely drained by before June 15th - 13 weeks after the rain had stopped; and the New Southlander and the Cathedral Cave (Queenslander system) had almost drained by this date. The Ryans Creek Cave has excellent local surface drainage and the Queenslander/New Southlander area has moderate drainage.

The obvious inference is that the proximity of local surface drainage directly affects the rate of outflow of water from the paraphreatic zone.

THE LITHOLOGY OF THE CHILLAGOE LIMESTONES

While exploring the limestones around Chillagoe I have noticed considerable variation in limestone types which, for convenience, I have classified into four general groups. As each type of limestone has physical characteristics peculiar to itself it is clear that any further study of the geomorphology must include a study of the lithology. I shall follow with a brief description of the four types.

1. Sparite

This is a dark grey, compact, hard crystalline limestone which occurs mainly (but not exclusively) on the western side of the limestone belt. It is often fossiliferous. It produces tall, pinnacled towers with very well developed Karren solution features and collapse. To quote a tourist (in bare feet) - "The rocks are sharp, aren't they?". Pediments, where they occur, are small in area and often feature small towers. This type of limestone is responsible for all the really large cave systems and most of the other caves.

2. Banded limestone

This is a paler, blue/grey striped limestone which is moderately hard and crumbles under hammer blows. The stripes produce a pretty effect inside the Donna Cave. It produces low, rounded towers of smooth appearance although Karren solution features do develop. An important mode of weathering is exfoliation. The only sizeable caves known to occur are the Donna and the Trezkinn and in fact the largest outcrop is in this area, close to town. Quite large pavements occur (at Zillmanton) and also outcrops of highly contorted chert bands.

3. Sugarstone

This is an aptly named white limestone which crumbles easily into separate calcite crystals in a fashion similar to decomposed granite. Patches of Iceland Spar occur and bands of large crystals betray the bedding in an otherwise massive rock. It outcrops to the east of the limestone belt, following the railway line from town to Dome Rock. Also a junction between this and the banded limestone can be seen on a tower 1 km north of the smelters. The rock exfoliates and only occasionally are Karren features found. The only caves to occur are small phreatic tubes and widened joints. It mainly forms large pavements and well rounded outcrops.

Neither the banded limestone nor the sugarstone contain fossils.

4. Limestone breccias

Several different types of breccias can be found both inside and outside caves. The most noticeable type consists of a whole range of cave breccias having a matrix of calcified cave earth, or of tufa, containing limestone boulders of varying size which are often, surprisingly, well rounded. Also contained in the matrix are bat bones, snail shells and sometimes angular chert fragments. However there is another breccia (on the surface at the Walkunder Cave, The Ramparts and 1 km north-west of the racecourse, and underground in the Ryan Imperial Cave, the New Southlander and Rift Pot). This is a matrix of pink limestone containing angular pieces of grey limestone which usually match each other very neatly. There is never any observable differential weathering between the matrix and the contained boulders. De Keyser and Wolff (1964, page 22) propose that "The limestone breccia-conglomerate .... is here regarded as a wave-platform breccia overlying local unconformities and disconformities", although the appearance of the breccias shown in cave walls suggest that they are collapse breccias formed within already existing cave passages.

Clearly the origins of breccias deserve further study and accurate dating may reveal much information about rejuvenation and earlier karst phases.

THE GEOMORPHOLOGY OF THE DOME ROCK AREA

To conclude this paper I shall discuss a proposal by Danes (1911) that "the Lion's Head (Dome Rock) and its surroundings owe their shape to the vigorous action of running water in some remote period". He refers to the bed of a "short ancient river". He bases his arguments on the smooth surface rock and, in his later paper, on the existence of "fluvial potholes" (Jennings 1966). However the limestone here is of the sugarstone variety which exfoliates, accounting for the smooth surfaces. The "fluvial potholes" have the appearance of solution tubes aligning themselves along joints, and in a random sample of 24 holes, 11 disappeared out of sight, 13 contained leaves and rounded pieces of sugarstone and 1 also contained fragments of gossanous ironstone probably derived from a small outcrop some 5 m away, uphill. I crawled into one large tube which led into a small phreatic cave developed along two joints.

A list of caves referred to in the text

Cathedral Cave	CH15
Christmas Pot	CH144
Disney Cave	CH45, CH112
Donna Cave	CH2
Giant Causeway Cave	CH78
The Markham	CH10
Narahdarn Cave	CH34
The New Southlander	CH81
The Queenslander	CH51, CH55, CH85
Rift Pothole	CH127
Royal Arch Cave	CH9
Ryan Imperial Cave	CH4
Ryans Creek Cave	CH123
Spring Cave	CH12, CH60
Ti-tree Cave	CH43, CH101
Trezkinn Cave	CH14

References

DE KEYSER, F., & WOLFF, K.W., 1964 The Geology and Mineral Resources of the Chillagoe Area, Queensland. *Bur.Miner.Resour.Aust.Bull.* 70.

DANES, J.V., 1911 Physiography of Some Limestone Areas in Queensland. *Proc. Roy.Soc.Qld,* 23, 75-83.

JENNINGS, J.N., 1966 Jiri V. Danes and the Chillagoe Caves District. *Helictite,* July 1966, 83-87.

JENNINGS, J.N., 1969 Karst of the Seasonally Humid Tropics in Australia. *Supp. Vth Internat.Spel.Cong.,* Stuttgart, Academia Brno 1969.

WILSON, P.A., 1974 Record Wet Season Floods Chillagoe Caves. *J.Syd.Spel.Soc.,* 18(5), 112-114.

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VISITOR ACCESS AND FACILITIES

CARLSBAD CAVERNS (U.S.A.) AND CHILLAGOE CAVES (QLD.)

H.S. Curtis*

ABSTRACT

Carlsbad Caverns in the United States contain some excellent features in the work done to provide visitor access and facilities and especially in the standard of illumination provided. Some aspects of this work are discussed. Mention is also made of work being done at the Chillagoe Caves in Queensland.

CARLSBAD CAVERNS

The Carlsbad Caverns National Park, over 70 square miles in area, is located in south-eastern New Mexico in the United States. Some 13 miles of caverns have been explored of which about 3 miles are open to the public. The largest chamber is 2,000 feet long and up to 200 feet high.

I inspected the Caverns in 1972, firstly going through just as a member of the public to gain a general impression and then returning later with the Park's Electrician who explained and showed me the work which had been done. Two features of this work impressed me greatly -

.. The full length of the pathway is illuminated and visitors are permitted to walk through at leisure, thus being free from the sense of regimentation which is inevitable with supervised guided groups.

.. In the total length of over 3 miles of pathway, at no point was any of the wiring or the actual lights themselves directly visible.

Protection of Cave Formations

It was pleasing to note a complete absence of any obvious signs of damage to the natural formations of the cave. Park visitation for 1968 was 668,401 and no doubt has been increasing. To achieve such a high standard of protection without obvious constraints on visitor freedom is a major achievement. Constructed paths with smooth surfaces are provided with minimum illuminations sufficient for a person whose eyes have become dark-adjusted to walk in comfort and safety. The cave floor away from the path is kept dark and this in itself is sufficient to discourage people from leaving the pathway. All visitors are briefed at the entrance so that they know what to expect, where to go, what to do - and what not to do. Rangers are on continuous patrol throughout the cavern.

Visitor Safety

This is achieved through such obvious measures as avoiding danger spots in the initial location of the path, and provision of safety rails, hand rails, steps etc., but also through the initial briefing and the presence of the Rangers on patrol, and adequate emergency lighting.

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CHILLAGOE - H.S. Curtis

Park Interpretation

Apart from the initial explanation at the entrance, the patrolling Rangers provide an excellent interpretative service. One never has long to wait, or far to walk, to find a Ranger to answer questions and explain what the visitor is seeing. Where at particular points certain descriptive information is considered appropriate this is provided by means of back-illuminated signs, produced after considerable research, to be easy to read but to not affect the visitor's dark-adjusted vision as would a normal sign illuminated from the front.

Cave Illumination

This has been done superlatively well and reflects great credit on the park service, and especially the Chief Electrician, Horace T. Morelli and his staff.

For the most part the whole cave is illuminated by a soft diffuse light giving a most beautiful effect. Special lights are then used for cave formations of particular beauty or interest. A variety of lights - fluorescent tubes, floodlights, blue "daylight" bulbs etc., are used and are chosen and placed with great care to give the best and most natural effect.

And again I wish to emphasise that nowhere is any of this work directly visible from the pathway. It was only when Mr. Morelli took me on a tour of inspection and we moved from the path that I could see under his direction where wiring had been concealed and the actual fixtures that were providing the light. Every effort was made to place wiring in naturally concealed positions but where this was not possible, loose material from the cave floor was cemented into place with such care, - artistic care is perhaps the right description, - that only when it was pointed out to me did it become noticeable.

Emergency Lighting

An obvious problem under the system of unescorted visitation is that of a failure in the power supply. This is covered in three ways -

- firstly throughout the cave there is a system of battery operated emergency lights. The batteries are kept charged by the normal power supply and the emergency lights come on automatically if there is any failure of the main lights.
- secondly the park maintains a complete emergency generating plant with sufficient capacity to run not only all the cave illuminations but also all the ancilliary park service facilities, staff residences and a neighbouring village.
- finally all Rangers in the cavern carry flashlights.

CHILLAGOE CAVES

A number of cave systems in the Chillagoe/Mungana area have been afforded National Park status and consolidation and expansion of the present parks is under active consideration, though it is unlikely that anything approaching the Carlsbad Caverns National Park area of 46,000 acres could be achieved (at Carlsbad not only the area encompassing the caverns, but a viable sample of the desert landscape with its plants and wildlife are included).

Although the Chillagoe Caves have long been known, there has been a major expansion of interest in them in recent years. In no small measure this has been due to the interest and initiative of Mr. V. Kinnear who, initially in a purely honorary capacity, guided people through some of the caves, tidied up the worst of the litter and generally helped to protect the area. Later he was employed in a care-taker capacity by the Department of Forestry and then as active work to provide visitor facilities got under way he was permanently employed to take charge of the operations.

The work done to enable visitors to inspect the caves had consisted mainly of the construction of pathways and steps, largely of concrete, and the provision of ship-type ladders, handrails and safety rails. In a few cases narrow passageways between caverns have been enlarged to facilitate access. Some details of the work done may be of interest.

Royal Arch Caves located some 6 kilometres from Chillagoe has a system of caverns extending for about 3,500 metres. The section open to visitors takes in 21 caverns, and a full tour involves a distance of approximately 1,000 metres. To provide this walk in comfort some 600 metres of concrete path has been constructed, 15 ladders, 9 bridge walks with hand rails and some 120 metres of hand and safety rails installed. Caverns are up to 50 metres long, 20 metres wide and 25 metres high.

Donna Cave about 2 kilometres from Chillagoe, is a smaller cave system with a total tour distance of about 600 metres. A steep descent from the entrance to the bottom level of the cave has been provided by means of 86 concrete steps. Seven ladders and six bridge walks have been established. There is also a concrete path and handrail of about 45 metres from car park to cave entrance.

Ryan Imperial Cave is some 18 kilometres from Chillagoe not far from the old town of Mungana. The toured distance in the cave is relatively short but again includes a bridge walk, ladders and concrete steps. Outside the cave, about 700 metres of walking track takes the visitor to the balancing rock.

<u>Tourist Industry</u>

For reasons of public safety and to prevent vandalism the entrances of the developed caves are closed off, and guided parties are taken in by National Parks staff. At present no charge is made for these guided tours but it is likely that eventually this will have to be done.

Interest in the caves is growing rapidly - approximately 13,000 visitors came to the Chillagoe area during 1972/73 financial year and 10,808 visitors were taken on guided tours of the caves.

During the last 5 years major business expansion has occurred in Chillagoe. The Imperial Hotel has been rebuilt and has had motel accommodation added. The Chillagoe Caves Lodge has been established providing a shop, cafe, cabin and motel type units as well as caravan and tent accommodation. The old Post Office Hotel continues to operate. A caravan park has been established as well as a new store, a new butcher shop and a Community Hall. Reticulated electric power has been connected to the town and the main street has been sealed. Major improvements in the road access to Chillagoe are being undertaken with complete new road construction in the Almaden/Chillagoe section since the 1974 floods. Road improvements are expected to make Chillagoe more accessible to tourist buses.

The Department of Forestry has constructed two residences in Chillagoe for its staff. Additional residences and administration headquarters, including visitor information facilities, are likely future developments.

The Department has had reticulated electric power extended to Donna Cave and an electrician is permanently employed to install and maintain cave illumination. In this work valuable advice and guidance have been given by the Electricity Board.

It is pleasing to note that private enterprise, the Mareeba Shire Council, the Cairns Regional Electricity Board, the Department of Main Roads and the Department of Forestry are all combining to cater for the ever-growing stream of visitors to this interesting region.

AUSTRALIAN SPELEOLOGICAL FEDERATION
PROCEEDINGS 10TH BIENNIAL CONFERENCE

CAVE EXPLORATION AND CAVING POTENTIAL IN THE CHILLAGOE AREA

T.W.L. Robinson*

In the closing decade of the last century, a noted English botanist and painter, Mrs. Ellis Rowan, visited the area under review, as guest of the pioneering Atherton family on Chillagoe Cattle Station. Later in her book "A Flower-hunter in Queensland and New Zealand" published by John Murray - London in 1898, she recorded the following impression:

"I was driven there in a small one horse trap, the material of which needed to be of the strongest for the road was an exceedingly rough one, being for the most part over broad beds of rock and pebbly ground. The whole country is a vast undulating plain, dotted with rugged masses of curiously outlined limestone ridges rising to many hundreds of feet straight out of the ground, giving the landscape a stern and oppressive grandeur. The deep fissures of these towering walls are filled with gnarled and hoary trunks of trees, striking and grasping the massive fragments with their rootlets and creeping and twisting in and out of crevices. Below, the huge blocks of stone are overgrown with an intricate wilderness of shrubs and creeping plants, while high above, these dark and towering walls are destitute of any living thing, and their stricken, shattered looking peaks, networks of sharp pinnacles with needle like points, stand grey and arid looking against the intense blue of the sky".

Today, after three-quarters of a century of mining and pastoral activity, the visitor to Chillagoe can still experience the thrill and fascination of this unique landscape and also the discomfort of that rough road which still has sixty miles of unsealed surface with numerous creek fords and corrugations. Few who make the journey go away dissatisfied. Chillagoe can offer something for everyone.

Apart from the scenic grandeur, the follower of history can fossick around the old derelict mines and smelters or browse through the museum at the Post Office. The geologist can study the multi-stratered and mineralised rocks of the Palmerville Fault and ponder the explosive influences which gave birth to the topography of the area. The "rock hound" can find specimens and those interested in fossils can have a field day among the remains of the inhabitants of a long lost Silurian-Devonian sea, or the bone breccias of the more recent past in some of the caves.

Camped by Chillagoe Creek, the holiday maker can just relax and enjoy life far from the rushing crowds of the cities.

The speleologist can have a field day!

Here we have a limestone belt some 60 km long, with a width of 1-6 km, broken in places with granite intrusions and beds of chert. The area is dotted with bluffs, some large, some small, and the general belief is that few lack caves. Because of the inaccessibility from major centres of population, the area from a caving point of view is still relatively unknown. Many of the more accessible bluffs have been looked at superficially by interested people but records were seldom kept. In the mining boom days guided tours of a few of the major caves were organised for keen tourists who bumped over the road to see them. Some attempt was made to improve access by walking tracks, but with the collapse of the mining period, and the decline in the population of the area, most fell into disrepair, and with the exception of one or two caves, visitors seldom reached some of the more impressive areas.

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One of the major tasks for a speleological club here will be that of rediscovery and documentation. Even so there is still plenty of virgin territory to be opened up by using more sophisticated methods of scaling, laddering and of course the opening up of "digs".

Following representations, National Park status was given to parts of the area in 1943. Honorary rangers were appointed to establish the locality of caves and by 1966, the Forestry Department, National Parks division recognised the need for a full time ranger and appointed Mr. Vince Kinnear, to co-ordinate development work in and around the National Park and to organise conducted tours of selected caves for the growing tourist traffic.

The geology of the area has unfortunately provided a conflict of interests with other governmental departments, notably the Mines Department, and because mining is not allowed on a National Park, the park as we know it today consists of isolated parcels of land, containing the more impressive limestone bluffs. Between them lies land subject to mining leases. Extension of the park boundaries will come as a result of exploration and co-operation in research by the government departments concerned and in this field of discovery and documentation of cavernous areas, speleological clubs can play a vital role.

Such documentation was begun early in 1960 by a few interested individuals and the Queensland Forestry Department, National Parks section. Apart from the job done by Mr. Vince Kinnear, mentioned earlier, recognition must also go to the assistance given by Frank Trezsise, Peter Freeney, John McKeegan and Allan Cummins for much of the early work. Then, between 1966 and 1970, the Sydney Speleological Society visited the area and produced several maps, including a limited area map from aerial photography, and also an Occasional Paper "Communications No. 3". Surveys were also done of several of the major more accessible caves, including the Royal Arch, the Donna, Markham, Spring, Haunted and the Ti-tree. The latter contains a very interesting bone breccia from which the remains of the extinct Diprotodon have been recovered. The formation of the Chillagoe Caving Club in 1973 enabled local cavers to co-ordinate their efforts.

Club membership is drawn from a wide range of age groups, and includes some with overseas caving experience, and others with disciplines of a nature which add expertise and guidance for the less experienced. Seasonal and road conditions have posed problems. The area was inaccessible for five months during the last wet season. Because of the problems of getting there, members prefer to have as long a stay as possible.

The longer holiday weekends in Queensland all fall in the wetter half of the year when planned meets are liable to be washed out by impassable roads or flooded caves. During the drier season locals are generally too busy with occupations of a seasonal nature which limit time away from the job. Meets at Christmas and the May-June period have been the most popular, while individual members have made visits whenever they could spare the time during the rest of the year.

Co-operation with the Forestry Department has been excellent. All are keen cavers and the major office bearers of the club. Since its formation the club has built up a supply of electron ladders and ropes for use by members and visitors. A limited supply of helmets are available but in the main,head gear, foot gear and lighting are a personal responsibility. As 240 volt mains supply of electricity is now available at Chillagoe the charging of accumulator type batteries is no problem, provided of course that you camp in Chillagoe!

Prior to the establishment of the club, the index of known caves stood at 120. Despite adverse seasonal conditions the index has now been increased to 150, while numerous entrances have been found to previously known caves. Work has begun on extending the area map produced by the Sydney Speleological Society to include the magnificent bluffs on Rookwood Station continuing to the Walsh River at the N.W. end, and to the Ootan-Almaden area in the S.E.

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Surveying has been carried out in conjunction with exploration and has aided greatly the discovery of new caves and extensions. Thirty surveys have been undertaken using CRG 5 as a standard, and they have exposed an interesting series of geological fractures, where a preferred 15^{o} - 20^{o} of fault has occurred in widely separated bluffs.

The chief areas of interest have been the Royal Arch Bluff at Chillagoe and the Cathedral Bluff at Mungana. However because of possible mining activity in and around bluffs not as yet on a National Park reserve, attention was focussed on the Ryans Creek and Suicide Bluff areas to prove what was at risk.

Both bluffs were found to be cavernous and beautifully decorated, Ryans Creek CH 123 (4 entrances) containing some of the largest shawls yet discovered in Chillagoe, and with ease of accessibility, this cave would make an ideal "tourist" cave in the future.

Representations have been made to have this area declared a National Park and attached as an extension to the Spring Bluff Reserve.

Suicide Bluff provided somewhat a surprise and continues to be quite a challenge. By means of laddering techniques, vertical descents have been made in excess of one hundred feet into vast, beautifully decorated chambers some of which contain permanent water. Here in Christmas Pot (CH 144) as in Narahdarn Cave (CH 34) in the Carpentaria Bluff, a species of colourless shrimp has been discovered, part of the interesting eco-system of the Chillagoe area. Christmas Pot also contains a swiftlet colony of considerable size and the clicking and chirping of these unique birds can be heard as they navigate, using a method of sonar in the darkness.

In the Royal Arch Bluff area several new caves have been added to the index. Discovered and surveyed by Paul and Hazel Wilson in 1973, Rift Pot (CH 127), with its delicate decorations and its animal life is a beautiful cave which will delight any visitor. The bluff area housing the Disney (CH 45), shows great promise of extension and could eventually link with Kirkies Cavern (CH 48) by way of an interesting series of grikes. This area awaits a survey to supplement the exploration.

Chinese, Concave and Compass Caverns (CH 138, 134, 143) and Uncle Ron's Cavern (CH 135) all have been discovered and surveyed by club members in the area in the past year. In the Piano Bluff area, "Big Hole 66" discovered by Ralph Page in 1973, introduces the caver by way of a series of vertical descents, into a highly fossiliferous area where the entire walls of caverns consist of masses of crinoids, corals, bryazoans and brachiopods, some of which because of weathering have a three dimensional effect. Notwithstanding all these interesting finds, the major club project has been and will continue to be for some time, the exploration of the vast cave complexes within and what was formerly referred to as the "Cathedral Bluff" at Mungana, but which has now been called "The Queenslander".

"The Cathedral Bluff is a very promising area". So stated the Sydney Speleological Society as an end piece to their description of the old Cathedral Cave (CH 15) in "Communications - Occasional Paper No. 3". Situated half a kilometer to the north of the Chillagoe-Mungana Road and about one kilometer from the site of the old Mungana itself, the bluff is rather impressive with pinnacles towering in excess of 200 ft over the plain. Relatively compact in shape with a perimeter of approximately two kilometers, the bluff can be subdivided into five regions.

The north-west section contains what was originally the Queenslander with its many extensions, including the old Cathedral Cave (CH 15), linked by the Club in July 1973. To its east lies a large central area of collapse, actually a large doline which rises with a most impressive north-eastern wall as yet to be explored. To the south of the collapse and extending to the south-east like a giant backbone is a region of high bluff which has been called Super Grikeland.

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Here we have a region of giant grikes exceeding thirty metres in depth, carpeted with ferns and the occasional stinging plant and fig tree, interconnected by numerous passages. This section contains the New Southlander (CH 81), discovered by Sydney Speleological Society, Broadway (CH 148), Epi Frenetic (CH 84), and Fox Hole (CH 145), which were linked in November 1974, and all of which lie parallel and adjacent to the old Queenslander complex.

In the S.E. corner we have the junction between the N.E. wall and Super Grikeland, an area yet to be looked at, this region terminating in a low ridge containing Hair Cave (CH 95, 96 and 97).

A feature of this bluff to date is the large number of apparently parallel fractures, evidence of its explosive genesis, along which cave systems have developed. Over twenty surveys in this bluff alone are laying bare the secrets and aiding in the exploration of what is a system of great size. The compilation of our bluff map has been the end result of a lot of hard work by club members, and without this team work the Queenslander would still be an unknown quantity. Although large areas still remain unexplored, Saturday, December 14th, 1974 was a red letter day for the club when Fred Hipworth, one of a party exploring an area of the Queenslander, dropped down a passage from high on a cave wall and found himself on familiar ground in Fox Hole, Super Grikeland, thus linking and extending the Queenslander to include the known caves of that area, Fox Hole (CH 145), Broadway (CH 148), Epi Frenetic (CH 84) and the New South Lander (CH 81).

The very nature of this cave system makes the survey difficult and the compilation of cave footage a question mark. In order to get the job underway it has been necessary to take the more direct route and the lineal survey footage is doubtless, only a fraction of the actual cave footage available by way of rockfall, solution tunnels, avens and numerous areas of tiered flowstone floor all of which are so common and characteristic of this bluff.

Present surveyed lineal measurement of the Queenslander stands at 3,440 metres (11,300 ft), which can be expanded to 5,000 metres (16,500 ft). Exploration is by no means complete, and there is every possibility of extending the Queenslander further into blank areas on the survey map or into the remaining third of the bluff yet to be looked at. To date it is the largest known system in the Chillagoe-Mungana area, possibly the largest in Queensland and must be one of Australia's top class caves.

In the near future an attempt is to be made to photograph areas of great beauty in this cave. In fact the area lends itself to the photographer both above or below the ground. Many very spectacularly decorated caves are easily accessible with minimum risk of damage to equipment. However, the size, colour and lighting pose quite a challenge to the photographer.

The immense area of limestone in the Chillagoe-Mungana area will make documentation and exploration a challenge for years to come. But the belt of limestone does not end at the Walsh River. Rather it disappears below a layer of sandstone to reappear again some 60 kilometres to the north at the Mitchell River. From here a chain of impressive looking bluffs march north for some 50 kilometres to the Palmer River.

From the air they look equally as impressive but ground access by road is difficult and it will take a well equipped and supplied expedition to further explore the area. Members of the Sydney Speleological Society visited portions of this area in August/September 1972 and their report can be read in their journal (See *J.Syd.Spel.Soc.*, 17(3), 64-67).

The overall area is of great scientific interest. The bluffs themselves give rise to a unique eco-system differing from the surrounding plains and the botanist and zoologist are attracted by their relatively undisturbed state.

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Every year sees a procession of scientific individuals to the area and the general comment is that much more research needs to be done in many fields. Questions rather than answers seem to be the rule. It is of vital importance to the area that this research be done before any large scale developmental activity be undertaken. This does not necessarily mean that mining or quarrying should be eliminated, rather a co-operative approach should be undertaken so that the area's uniqueness as a plant and animal habitat can be preserved, together with its scenic charm above or below ground, for future generations of mankind to enjoy.

Achnowledgements

Mrs. Ellis Rowan "A Flower-hunter in Queensland and New Zealand" published 1898 John Murray, London.

The Sydney Speleological Society. "Communications" Occasional Paper No. 3.

AUSTRALIAN SPELEOLOGICAL FEDERATION
PROCEEDINGS 10TH BIENNIAL CONFERENCE

SECTION 5
THE NATURAL RESOURCE AND CONSERVATION

HOW WELL OFF IS AUSTRALIA FOR CAVES AND KARST?

A BRIEF GEOMORPHIC ESTIMATE

J.N. Jennings*

ABSTRACT

The cave provinces of Australia are discussed in terms of the geological, physiographic and climatic factors which limit karst development. The optimum terrain for karst is mountainous, wet and with abundant limestone. Australia is dry, flat, and generally deficient in limestone, hence caves are comparatively rare. This overall scarcity of caves makes proper conservation all the more necessary.

In the *Report of the National Estate* (1974), an impressive document despite the short time allowed for its preparation, it is stated on the basis of writing of mine (Jennings 1967) that "Australia generally is poorly endowed with caves, although Tasmania perhaps reaches the world average". I understand that this assessment does not tally with some at least of many submissions made to the Federal Government's Committee of Inquiry by speleological organizations. Therefore I think it will not be out of place on this occasion to defend and explain my conservative standpoint, though I will enlarge its scope to comprise karst rather than caves alone. This extension will not invalidate consideration of the matter since most of our caves are in fact in karst, indeed in carbonate rock, for evaporite karst is virtually absent from our country.

Of course a proper quantitative analysis is impossible at the moment. Inventories of caves are by no means generally available nor are they uniform in basis where available. Where there are many big caves, small caves will go unrecorded; in areas poor in caves, the tendency will be to list them all. In any case numbers alone provide an inadequate basis for comparison; dimensions are clearly necessary. In this latter respect information is even more incomplete and unequal. On the world scale at the moment, cave cadasters probably more closely reflect the distribution of speleological activity than that of caves themselves. Referring to submissions about caves by speleological organisations, the *Report of the National Estate* makes the remark that "this aspect of the National Estate is therefore probably better documented than any other". Australian cavers may take some pride in that. Nevertheless factors of knowledge and ignorance affect assessment of caves and karst in Australia as much as in many other parts of the world. Many caves remain to be discovered in karst areas remote from the main centres of population. I need only remind you that the Nullarbor is some 2,000 km by road from Sydney, the centre of gravity of Australian caving activity, and the Limestone Ranges of West Kimberley some 5,000 km; these are the two largest karst areas in the continent.

Nor is it possible to approach the matter by comparison of proportions of karst rocks to total area in different parts of the world. Although geological maps are now available for the whole world at least on small scales, these represent geological formations which frequently comprise many types of rock within their

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sequences and which commonly change in facies laterally. What are needed are lithological maps and these are much less complete in coverage. Thus maps showing the distribution of limestone and dolomite are not available for most of Australia. Moreover even if we had such maps, they would furnish a weak basis on their own since different karsts vary very much in caves per unit area for many reasons. So one is forced to approach the question inferentially and to a substantial degree subjectively. This is the best that can be done now; if my arguments can be proved wrong, I shall of course be as pleased as anybody by the implication of my errors.

Of the several reasons why there is less karst and why there are fewer caves in Australia than in most other continents or subcontinental areas of equivalent size, the most important is geological structure. Much of the western half of the continent consists of Precambrian Shield, of ancient crystalline basement. Indeed as a whole the continent tends to be older than others. Many of its rock systems antedate significant life forms and much carbonate rock depends for its formation on the calcareous skeletons of marine organisms. On the average the older the rock system the less the proportion of carbonate rocks. From Cambrian times onwards, this may be due mainly to the greater solubility which characterises them and makes them more likely to be removed into the sea during denudation than most other rocks; the older the rocks the more likely it is that this will have happened.

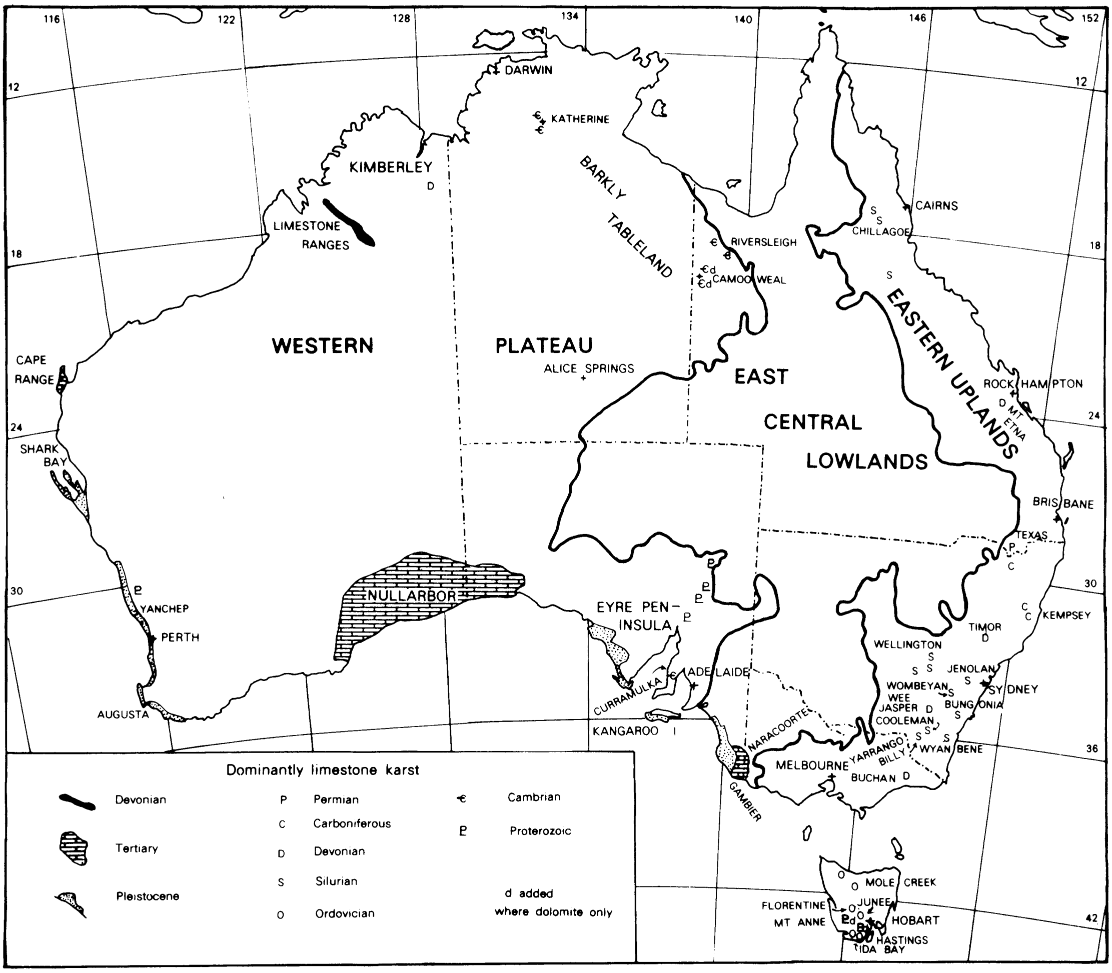

Figure 1. Distribution of Karst in Australia

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Moreover the older the rocks the greater the proportion of dolomite to limestone amongst the carbonate rocks. Primary dolomites are of course particularly important in early geological times but even more voluminous are secondary dolomites due to dolomitisation of limestones. The older the rock formation the greater the chance of this having happened. Of course dolomites are not without caves and other karst features as Buchan in Victoria (Sweeting 1960) and Camooweal in Queensland remind us forcibly. Nevertheless proportionately they are not as rich in caves and other karst features as limestones because they are not so readily soluble and dolomite sand is a cause of blockage of incipient caves.

Tertiary orogenic belts are often, though not universally, rich in limestones and so in karst and caves. Australia is the only continent without such tectonic belts. The accident some 5-6,000 years ago of the flooding of the shallow continental shelf between Australia and New Guinea which created Torres Strait has resulted in Australia being an incomplete continent tectonically, incomplete in a disastrous way for speleologists. Of course this is a narrow nationalistic way of looking at things.

From New Guinea to New Zealand, folded mountain ranges lie within a reasonable distance of this country in terms of modern travel and these ranges have a higher proportion of carbonate rock outcrop than is true for Australia as a whole. There is thus a geological basis for the rapidly growing activity of Australian cavers in this nearby island chain.

Of course not all carbonate rock will form karst and caves even when other necessary conditions are satisfied. High mineral purity and adequate mechanical strength are required for the kind of geomorphic action and response involved. It is hard to make an overall subjective assessment of Australian carbonate rocks in these respects. One may hazard the guess they are as a whole at least up to the world average.

It is not sufficient that a suitable rock shall be present for karst development. Other conditions must be satisfied, notably the availability of water, which can fashion the surface by solution and may develop underground circulation, initially capable of corrosive action alone but later acting corrasively as well when movement becomes sufficiently free. In this regard, there is the blunt fact that, setting aside Antarctica, Australia is the driest continent. Two-thirds of the continent is arid or semi-arid. To speak of the dead heart of Australia is as relevant for the speleologist as it is for other students of nature. Of course, ancient karst features and caves may survive into the present from former times more favourable in terms of water availability, whether this be by dint of increased precipitation or reduced evaporation. Inheritance of this type certainly contributes to the array of caves in this country. This is true, for example, of the Nullarbor karst where present signs of active cave formation are negligible in the presence of some substantial systems. Nevertheless we must be careful not to overstress this factor of inheritance. From the same region comes evidence of prolonged aridity. Whereas Permian sandstones in the Great Victoria Desert immediately to the north are well lateritised, indicative of former marked soil water movement and so of at least seasonally humid conditions, the Colville Sandstone of the adjacent northern part of the Eucla Basin is unlater-itised (Lowry & Jennings 1974). This registers dominantly arid conditions since the sandstone emerged in Middle Miocene times. The dead heart of the continent has been so a long time.

The third major factor governing the development of karst and caves is relief to promote active circulation of underground water and also to permit more cave to develop per unit area by storeys. Australia is basically unfavourable in this respect also. It has the lowest mean elevation and the lowest maximum elevation of all the continents. The continent is one of plains and plateaus, rather than of mountain ranges. It is true, of course, that the largest cave system in the world by far, the Flint Ridge-Mammoth Cave system of Kentucky, of over 250 km, belongs to plateau karst. However as antidote we need only remember how long

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Switzerland's Hölloch maintained the greatest length record with some 78 km of length squeezed into a horizontal area of some 5 km by 2 km. It is of course not absolute altitude that signifies but local or relative relief in carbonate rocks. If Hannel's Spur from the Swampy Plain River to Mt. Townsend summit in the Snowy Mts. with its 1,700 m of relative relief had happened to be developed in limestone, there would have been the chance for this continent to have held the world's depth record for a time at least. Nevertheless even in this matter of relative relief, Australia on the average falls behind other continents.

Given these overall drawbacks, what is the pattern of Australia's caving world and what is its nature in general terms? The pattern is to quite a marked extent peripheral. Though precipitation (and the location of speleologists) is similarly peripheral, the prime cause of this marginal distribution of karst is structural. The Eastern Uplands from Cape York Peninsula to Tasmania have formed from Palaeozoic geosynclines. In similar structural conditions have developed the important karsts of eastern U.S.A. and of Britain. The Western Plateau of Australia mainly comprising the Precambrian Shield has important peripheral sedimentary platforms and basins of various ages where the shallow seas of continental shelves have overlapped onto the crystalline basement of the continent from time to time. The East Central Lowlands from the Gulf of Carpentaria to the Murray R. mouth also rest for the most part on similar sedimentary basins but for the most part these lack adequate relief and also carbonate rocks. The one exception to this is South coastal.

Let us now consider the essential features of these peripheral parts from the point of view of karst.

The Eastern Uplands, including Tasmania, consist of dissected plateaus. The former mountain ranges created here by several Palaeozoic orogenies from geosynclinal sediments were all planated by the end of Mesozoic time and then in the Cainozoic these erosion surfaces were uplifted epeirogenetically with some faulting to yield the highest land in the continent. Unfortunately the geosynclines and associated continental shelves were not rich in carbonate sediments, still less in evaporites. This was probably due to great oceanic depths close into the continent (K. Crook, personal communication) and presents a remarkable contrast with the modern presence of the Great Barrier Reefs off Queensland, the biggest reef system in the world today. Nevertheless from time to time small patches of carbonate sediment were deposited amongst the vast bodies of clastic sediment of non-karstic nature in the seas margining the east of the continent and these were successively incorporated into the land by eastward continental drift and mountain building through crustal plate collision.

From these patches have come our many but small impounded karsts of generally steeply dipping Ordovician, Silurian and Devonian carbonate rock, of limestone, dolomite and marble, from southern Tasmania to the north of the Atherton Tableland. Rarer are older Cambrian and younger Carboniferous and Permian karst rocks. Mostly they are exposed in the valleys and gorges which incise the tablelands, rather than on the plateau surfaces themselves, because on the whole they are less resistant to denudation than the impervious rocks. Despite their small sizes of a few km^2, these karsts are frequently furnished with many caves and a variety of karst surface forms , though naturally larger features such as poljes are lacking and uvalas rare. Also because of their small size they are much influenced by surface drainage from surrounding higher impervious rocks with their usually quite unsaturated waters and their gravel and sand armoury. Cooleman Plain in southern New South Wales, which forms part of the upland surface over most of its area illustrates the vital role that rejuvenation of the rivers through uplift has on the underground water circulation in the karst rocks and so on cave development. Away from the gorges still invading this karst there are tiny caves or none at all. A significant theoretical implication is that true phreatic cave formation with slow moving water beneath a planation surface is of modest importance.

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Where the karst rock has been subject generally to dissection and (apart from flooring the valleys) forms barriers across them (e.g. Jenolan, Sussmilch & Stone 1915) or benches along them (e.g. Yarrangobilly), one of the most characteristic attributes is the alternating sequence of quasi-horizontal epiphreatic levels and vadose canyon development. This alternation reflects varying rates of plateau uplift and inversely correlated stream erosion. Today along active cave streams, free surface stream passages may alternate with water-filled sections showing how intimately related these two fast-flowing but different hydrodynamic conditions are (e.g. at Wombeyan). Highly unreliable climates in terms of precipitation such as prevail almost everywhere in Australia still further blur the distinction between vadose and epiphreatic stream activity though frequent wide variation in water levels. Abandoned levels of these caves in the Eastern Uplands in N.S.W., Victoria and Tasmania are commonly very rich in speleothems, perhaps most distinctively in the variety and proportion of eccentric decorations, though this is not to say that all active stream passages are devoid of decoration.

Usually cave streams flow out from passages at or close to valley floors but Bungonia is remarkable for the high level at which springs occur above the gorge bottom; here rejuvenation has proceeded so fast that karst preparation of the lower levels of the limestone has been unable to keep pace (Sydney Spel. Soc. 1972). The caves here show marked vertical developments in part of the same cause, though the greatest mainland cave depth has passed to Yarrangobilly (Pavey 1974). However Bungonia retains certain other distinctions, notably the breaching by the main underground stream of a barrier of impervious rocks (Jennings & James, in press) and much higher carbon dioxide levels in cave atmosphere than is common for Australia, with consequences of great interest, particularly in terms of cave sediments (J.M. James, pers. comm.).

The northern and southern extremities of this eastern belt of uplands require separate comment. In Tasmania, Ordovician limestones dominate the karst scene and a higher proportion of carbonate rocks appears to have accumulated in this southernmost part of the Palaeozoic geosynclinal belt. With this passive factor favouring karst is combined the dynamic factor of higher absolute precipitation and even higher effective precipitation because of lower temperatures on most of Tasmania's karsts. The net result is greater karst and cave development proportionally in this state than in others. It is no accident that the largest known cave system is Exit Cave in wet, cool, rain-forested southern Tasmania. Generally the Ordovician limestone is just as recessive in the relief as N.S.W. and Victorian karst is but resistant dolerite caps preserve it at times high up valley sides and on plateau flanks so that the Australia depth record has long resided in Tasmania from the days of Growling Swallet to the present reign of Khazad-dum. Whatever happens to the length record where sheer area of karst can intervene, the depth record is virtually bound to stay in Tasmania. Corrasional activity is more positively in evidence in some Tasmanian caves than elsewhere in the continent with boulder trains in active transit through them, e.g. Marakoopa Cave, Mole Creek.

Another special character best developed in the southernmost state (and on Cooleman Plain at 1,200 m in southern N.S.W.) is the role of cold climate effects in karst development. Pleistocene proglacial and periglacial conditions seem to have led to conflicting influences on cave development. On the one hand such loads of sediment were set in movement in more ways than one that they led to the blocking of caves and their entrances, with the restoration of surface runoff in karst; on the other hand snow and ice meltwater could be of such volume and so directed onto limestone that cave development was promoted (Jennings & Sweeting 1959; Goede 1969; Goede 1973; Jennings, in press). In this connection it is important to note that permafrost is apparently absent; the cold periods were not sufficiently rigorous.

The Mole Creek karst in Tasmania is somewhat more extensive in area than most in the Eastern Uplands and here our nearest relatives to poljes are found, as well as an indubitable hum in Dog Hill.

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But it is not surprising that we must turn to the northern part of the Eastern Uplands to find a dominance of residual karst forms. At Mt. Etna and nearby, practically on the Tropic of Capricorn, the residual hills are more like hums than tropical sinoids or towers but the density of cave development and the frequency of daylight holes in them is more reminiscent of tropical humid karst (Shannon 1970). In the Chillagoe - Walsh River area of N. Queensland (Sydney Spel. Soc. 1969) there is however a typical tower karst if of modest relative relief (no more than 100 m at the most). These intricately sculptured castles of limestone are separated by pedimented plains chiefly truncating steeply dipping interbedded impervious rocks. Network caves with many light holes are developed at plain level almost entirely. Decorations have a dry aspect but are active in the wet season.

In the Southeast of S. Australia, overlapping slightly into western Victoria, is the one karst area of the East Central Lowlands. This is developed in the Oligocene Gambier Limestone, permeable in the mass as well as along joints and horizontally disposed. This is a free karst, reaching to the Southern Ocean. Its most distinctive attribute in the Australian context is the occurrence of fine cenotes, largely water-filled collapse dolines. Some of them extend well below sea level and underground circulation during glacial low sea level times in the Pleistocene probably played an important part in their formation, though the arguments of Galloway (1970) maintaining that these periods were too short for the development of coastal drowned valleys, may apply also to these deep cenotes and Late Tertiary tectonoeustatic sea level changes may also be involved. Interesting cave systems at Naracoorte are not waterfilled and may relate in development either to faultlines or to buried former marine clifflines in the Gambier Limestone.

The Tertiary faultblock terrain of South Australia, comprising the Mt. Lofty-Flinders Ranges and Yorke Peninsula and the intervening gulfs of the sea, is successor to folded mountain ranges of a Precambrian geosyncline and orogeny. Incorporated in these structures are some Precambrian limestones and dolomites. It is possible that prolonged semi-aridity in the Flinders Ranges has hindered cave development there though a few presently inactive caves are known. Evaporites involved in the Blinman diapir have long since been removed. At Curramulka in Yorke Peninsula in horizontal Cambrian limestones there is the striking three-tiered maze complex of Corra-Lynn Cave, perhaps as clearcut an example of joint control of true phreatic solution as is to be found anywhere in this country.

In contrast with these small occurrences of tough, ancient carbonate rocks in complex geological structures comes the huge extent of virtually horizontal, weak Eocene and Lower Miocene limestones of the Nullarbor karst straddling the S.A. - W.A. border, an enormous free karst of some 200,000 km^2. Lowry & Jennings (1974) have recently reviewed the characters of this karst retarded by aridity prevalent since it emerged from the sea in Middle Miocene times. Minimal surface erosion has taken place; instead deflation of an insoluble residual soil cover over most of its extent is one of the more striking geomorphic events. Water action is minimal today in the caves which appear to be largely the work of solution during low sea levels of glacial times when also precipitation was more effective though absolutely less than at present in all probability. This solution has been followed by substantial upward stoping to produce cave forms largely representing equilibrium collapse shapes. Though large and deep caves are few for the area, they are nevertheless voluminous and recent successful diving of waterfilled sections gives promise of extension to what may prove to be very great lengths of which there are surface clues. Particular traits of distinction are halite speleothems and atmospheric weathering of cave walls through salt crystallisation. In these and many other respects the Nullarbor karst bears the stamp of aridity.

From Cape Leeuwin to Shark Bay, W. Australia is fringed practically continuously by a narrow seam of limestone of a kind more extensively developed in Australia than in any other continent. This is Pleistocene dune limestone or aeolian calcarenite. Even though this kind of limestone is found at intervals from N.W. Tasmania through to Cape Leeuwin, reference has been delayed until this juncture because it is in the main Western Australian belt that karst characteristics become most pronounced. Beach sand dominantly of calcareous nature and of biological origin has been blown inland in more than one phase, from at least 100,000 years ago (Teichert 1967); various degrees of induration have since been achieved through surface leaching of calcium carbonate and reprecipitation at lower levels in the profile. Karst and cave development may proceed in part concomitantly with this process of diagenesis, i.e. we have, to a degree, syngenetic karst. Though some karst features such as solution pipes of a rather special kind may occur more or less everywhere through this long coastal limestone belt, more elaborate features including collapse dolines and caves are confined to particular parts (not necessarily the rainiest), from Kangaroo Is. and Eyre Peninsula in the east to the Southwest of W. Australia between Cape Leeuwin to Cape Naturaliste and between Yanchep and Aramall Lake. In these weak materials, still in process of lithification terrestrially, collapse and rockfall are very prominent in the caves but this has not prevented a wide array of speleothem construction from beautifying many of them. Eccentric decorations can be important and the exceedingly long straw stalactites of Jewel and Strong's Caves in the Southwest are outstanding at the world level. Gorges of construction, well represented by Deepdene in the same Southwest, are also peculiar to this special kind of karst.

Though karst development is modest as yet, the Miocene limestone of Cape Range in the Exmouth Gulf area of W. Australia warrants brief mention because it has been folded into an anticlinal ridge of 300 m height by Late Tertiary orogenic movements. Limited times and aridity have combined to restrict cave development to potholes no more than 20 m deep (Cook 1962).

There is far from a poverty of karst forms in the semi-arid but much older karst of the Limestone Ranges of W. Kimberley. Here Devonian limestones have been exposed to terrestrial attack at least through the whole of the Tertiary but probably for a much longer period than that, perhaps back to the beginning of the Mesozoic. They form low ranges up to 100 m high and 30 km wide over a stretch of country some 290 km long, transected by fine gorges of superimposition of rivers extending from the rugged heart of the Kimberleys. Thus this karst is not recessive but stands up in the landscape as at Chillagoe. Minor surface sculpture is developed to an incredible degree and the larger landforms constitute a scenically fantastic and scientifically most interesting sequence from an initial undissected Tertiary planation surface. First this is cut up into "giant grikeland", networks of closed corridors up to 30 m deep and 10-15 m across, hundreds of metres long. From these develop small poljes and rectangular valley systems of box cross-section. Gradually these are pedimented away by lateral retreat of wall-like margins or reduced to a tower karst resembling that of Chillagoe. Cave systems tend to be fragmented by openings to the surface in the giant grikes but the largest system as yet incompletely mapped must consist of some 5-6 km of fissure passage in network array at the levels of the pediments around (Lowry 1967). One great problem attaches to this karst. Is it a product of the very modest rainfall of a short wet season of about 3 months when a few but intense storms occur, supporting but a meagre vegetation? Or is it a karst inherited from wetter climate in the Pleistocene or even the Late Tertiary (Jennings 1969)? As yet the only evidence of climatic change in the area points to drier conditions than at present. Pedimentation reaches its greatest perfection in semi-arid climate and certainly the pediments here are as perfect as any.

Horizontal Cambrian carbonate rocks occur sporadically from the Daly River basin in Northern Territory through the Barkly Tableland into northwest Queensland. Of all substantial areas of potential karst rock these are the least studied in the continent. In the Katherine area limestones, only shallowly dissected or undissected, show limited surface karst attributes, though cave systems of some length, up to 2-3 km, are known, horizontally developed not far below the surface. Like the W. Kimberley caves, they alternate between a long dry season of inactivity and a short season of sharp flooding. Recent stripping of a former sandstone cover may explain much of the nature of this karst.

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Around Camooweal, dolomites give rise to much the same kind of karst, though here the caves reach more deeply - up to 100 m below the surface in some of their horizontal development. Though recent exploration chiefly by the University of Queensland Speleological Society has shown the caves here to be more extensive than previously realised, an old problem (Danes 1916) remains unsolved. Where do the waters of these caves emerge? No large springs are known in the Georgina drainage to the south. It is true that some of the supposed lacustrine limestones of Tertiary age here are more likely to be valley trains of stream origin (P.W. Williams, pers. comm.) and these could relate to past periods of greater spring activity than at present, in part fed from the Camooweal area. Or do these waters pass northwards into Cambrian limestones in the rugged northern fall of the Barkly Tableland in the Riversleigh area where amongst low, dissected karst, some of it consisting of modest towers, large springs are the perennial sources of rivers such as the Gregory flowing to the Gulf of Carpentaria? If the Camooweal caves can be shown to feed the Gulf of Carpentaria in this manner instead of flowing to the Georgina and the L. Eyre basin, it would indeed be a long distance karst hydrological system of considerable interest.

The purpose of this brief, highly selective and subjective survey of Australian karst has been first to sustain a general assessment that quantitatively this continent is by no means rich in caves and associated karst features. This is offset only marginally by a comparative richness in volcanic karst and caves in western Victoria (Ollier 1963) and in several parts of Queensland (Graham 1971). Secondly this survey has tried to illustrate the point that despite this comparative poverty in number and size, there is scenic variety and scientific value of considerable qualitative importance. Rather than diminishing the importance of a proper conservation policy with regard to this portion of the national estate this estimate renders the need for and the wisdom of such conservation both more urgent and more powerful. We must urge this outside the ranks of cavers. Withal let us not distract ourselves by such high sounding phrases from the unpleasant truth that the activity of cavers itself is the biggest danger to this part of our national heritage.

References

COMMITTEE OF INQUIRY INTO THE NATIONAL ESTATE, 1974 *Report of the National Estate*. Aust. Govt Publ. Service, Canberra.

COOK, D., 1962 Caves of the Cape Range, North-west Cape, Western Australia. *J.W. Aust.Spel.Grp*, 1962, 4-1.

DANES, J.V., 1916 Karststudien in Australien. *Sitz.Kgl.Bohm.Ges.Wiss.*, 7, 1-75.

GALLOWAY, R.W., Coastal and shelf geomorphology and late Cenozoic sea levels. *J. Geol.*, 78, 603-610.

GOEDE, A., 1969 Underground stream capture at Ida Bay,Tasmania, and the relevance of cold climatic conditions. *Aust.Geogr.Stud.*, 7, 41-48.

GOEDE, A., 1973 Hydrological observations at the Junee resurgence and a brief regional description of the Junee area, Tasmania. *Helictite*, 11, 3-24.

GRAHAM, A., 1971 A preliminary note on a cave in basalt. Bunya Mountains National Park, Queensland. *Helictite*, 9, 73-76.

JENNINGS, J.N., 1967 Some karst areas of Australia. In *Landform Studies from Australia and New Guinea.* Ed. J.N. Jennings & J.A. Mabbutt.

JENNINGS, J.N., 1969 Karst in the seasonally humid tropics in Australia. Pp.149-158 in *Problems of the Karst Denudation Brno 1969.* Ed. O.Stelcl. Brno.

JENNINGS, J.N., (in press) History of a dry valley on Cooleman Plain, N.S.W., Australia. *Proc. 6th. Int.Spel.Cong.*

JENNINGS, J.N., & JAMES, J.M., (in press) Rejuvenation and Australia's deepest mainland caves. *Proc. 6th. Int.Spel.Cong.*

JENNINGS, J.N., & SWEETING, M.M., 1959 Underground breach of a divide. *Aust.J.Sci.*, 21, 261-262.

LOWRY, D.C., 1967 The Cave Spring Cave system, Kimberley Division of Western Australia. *Helictite*, 3, 15-19.

LOWRY, D.C., & JENNINGS, J.N., 1974 The Nullarbor karst Australia. *Z. Geomorph.*, 18, 35-81.

OLLIER, C.D., 1963 The lava caves of Victoria. *Helictite*, 1, 69-71.
PAVEY, A., 1974 The first UNSWSS Yarrangobilly expedition. *Spar*, 33, 4-16.
SHANNON, C.H.C., 1970 Geology of the Mt. Etna area: Cave descriptions. Pp.11-35 in *Mt. Etna Caves*. Ed. J.K. Sprent.
SUSSMILCH, C.A., & STONE, W.G., 1915 Geology of the Jenolan Caves district. *J. Roy.Soc. N.S.W.*, 49, 332-384.
SWEETING, M.M., 1960 The caves of the Buchan area, Victoria. *Z. Geomorph.Suppl.*, 2, 81-89.
SYDNEY SPELEOLOGICAL SOCIETY 1969 Chillagoe. *Occ.Pap.* 3, 46.
SYDNEY SPELEOLOGICAL SOCIETY 1972 Bungonia Caves. *Occ.Pap.* 4, 230.
TEICHERT, C., 1967 Age of coastal limestone, Western Australia. *Aust.J.Sci.*, 30, 71.

AUSTRALIAN SPELEOLOGICAL FEDERATION
PROCEEDINGS 10TH BIENNIAL CONFERENCE

MT. ETNA CONSERVATION - A HISTORY OF ARBITRARINESS

A.L. Brown*

ABSTRACT

The caves of Mt. Etna and Limestone Ridge in Central Queensland, collectively known as the Mt. Etna Caves, are being quarried for limestone by Central Queensland Cement Company. The case for the inclusion of Mt. Etna and Limestone Ridge in a National Park is briefly outlined. The history of quasi-protection, pseudo-protection, proposed protection, promised protection, and destruction of this cavernous area is traced. Though originally gazetted as Recreation Reserves, mining leases now cover these areas. In 1968 a Queensland State Government Committee recommended a National Park over 31 acres of Mt. Etna. Present indications are that a National Park may soon be announced over at least part of Limestone Ridge but that Mt. Etna will be destroyed. The arbitrary basis of this action is challenged.

The conflict is not insoluble, but no solution can be contemplated which would allow any further violation of either of Mt. Etna or Limestone Ridge.

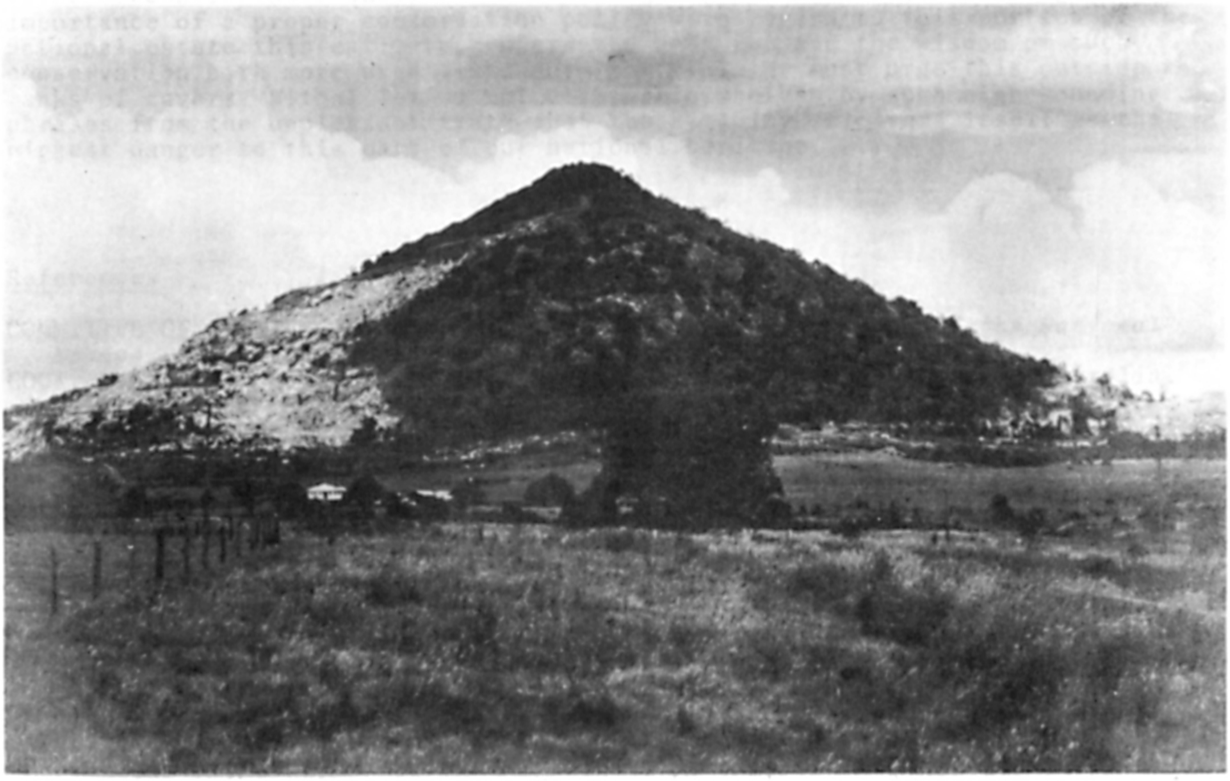

Figure 1. Mt. Etna, viewed from the northern side.

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JUSTIFICATION OF NATIONAL PARK PROPOSAL

The photograph, Figure 1, shows what we want included as a National Park. Depending on one's point of view, it might be regarded as either a rather good quarry, or as the scarred remains of what was once a very prominent cone - in its context as proud a feature as its namesake Mt. Etna in Sicily. Obviously from this photograph, Central Queensland's Mt. Etna is no longer in its natural state. Its aesthetics appear to have been rather drastically destroyed. The proposal then, that Mt. Etna still be proclaimed as a National Park (or included in a larger National Park) needs more than a little justification.

Geographical Unity

Firstly, Mt. Etna can not be considered alone. It is one part of a larger geographical unit including Limestone Ridge and several other limestone outcrops in "The Caves" region. Destruction of Mt. Etna would destroy something around a third of the known caves in the area. Its preservation is essential to the integrity of the region; geologically, biologically, visually - and if you allow speleological hopes to run a little high, the possibility of a cavernous connection to Mt. Etna underneath the plain should not be discounted. This geographical relationship will be discussed later.

Superficiality of damage

Secondly, despite the superficial damage, Mt. Etna and its caves are basically intact. Figure 1 shows the northern face of Mt. Etna with the eastern quarry on the left. A road passes under the northern face and leads to another major quarry on the western flanks. The Central Queensland Cement Co. began mining in the eastern quarry in 1967 and extended operations to the western quarry in 1971. The area in the middle - the northern face - is the significantly cavernous area. Actually the whole of the Mt. Etna cone is not limestone, only the northern half. There are 40 known caves on Mt. Etna, and another half dozen or so opened by quarrying operations. To date Central Queensland Cement has breached 5 of the known caves, three on the eastern quarry, and two on the western. We have information of their breaking into, and subsequent destruction of, several previously undiscovered caves as well. Damage to formations in the breached caves is extensive, and though structural damage has occurred in these and other caves near to both quarry faces, the vast majority of caves are by no means destroyed. Not yet - that is!

The western quarry can not be extended eastward without the destruction of major caves, and similarly, the eastern quarry is in dangerous proximity to Main Cave, Winding Stairway and Bat Cleft. It is Bat Cleft - the maternity cave for Central Queensland's *Miniopterus* sp. - which is the cause for most concern.

Any claim that Mt. Etna has been too badly damaged to be protected as a National Park shows an excessive concern for the superficial scarring of the surface, and little understanding of the cavernous nature of the mountain. Most of the caves are as yet intact, but those which are not, will, given time and the immediate cessation of blasting, generally be able to disguise much of any blast damage they have sustained. Even the quarried surface could be subject to restoration. A few months "cleaning up" action by the cement company could round off the contours, and a long term and difficult program of revegetation begun. Two old quarries on adjacent Limestone Ridge show that scars become less blatant with time - even though in these cases their revegetation has been undertaken by lantana.

Biological value

The third warrant for inclusion of the scarred Mt. Etna in a National Park is the need to protect the biologically important Bat Cleft. Bat Cleft is the maternity colony supporting an estimated 400,000 *Miniopterus* species in the Mt.

Etna area, and it is highly unlikely that an alternative to the traditional maternity site would be found by the species in the area if this cave were destroyed. As mentioned earlier, Bat Cleft is precipitously close to the eastern quarry and it has sustained some structural damage. There has been no measurement of the size of the bat population since 1970, and it is hoped that one can be made soon, so that an accurate indication of the effect of the blasting on the numbers of the bats inhabiting Bat Cleft can be obtained. (See footnote).

Those three points; the geographical unity of the area, the fact that Mt. Etna's caves are intact, and the irreplacibility of Bat Cleft as a maternity site, provide the basic justification why Mt. Etna must be included in a National Park despite its surface scars.

Initially, this discussion has been concentrated on Mt. Etna alone, because it is the limestone outcrop at present subject to mining, but as mentioned, the mountain is not to be considered in isolation. Limestone Ridge and Mt. Etna are shown in Figure 2.

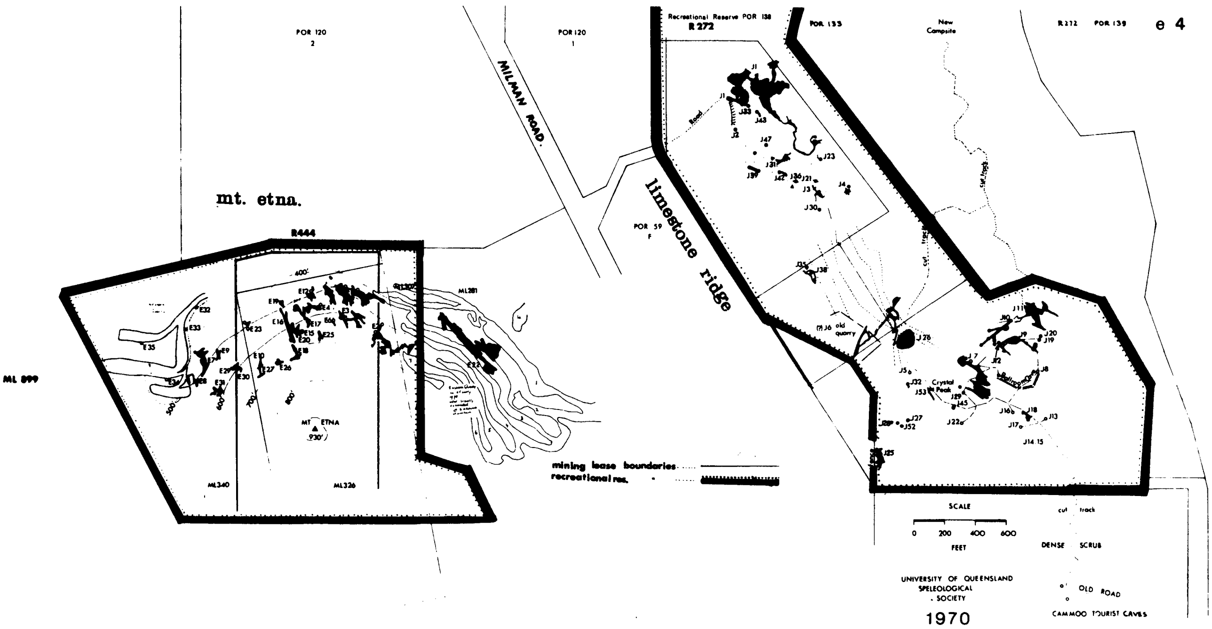

Figure 2. Part of parish map, showing Mt. Etna and Limestone Ridge.

Limestone Ridge is less than 500 metres across a valley from Mt. Etna. Mount Etna is situated on a portion of land known as Recreation Reserve R444, and Limestone Ridge is on Recreation Reserve R272. The area would be most widely known from the two show cave developments, Olsen's Caves, and Cammoo Caves and "The Caves" township which is situated on the main north coast highway and rail link, 22 km north of Rockhampton. Recreation Reserve R272 consists of two portions of land separated by an area known locally as "The Valley", which contains no limestone. Several other smaller outcrops of cavernous limestone are scattered throughout this area.

Figure 2 does not include all the most recent caves found, but it does give some indication of the distribution of caves on Mt. Etna and Limestone Ridge. In particular, it can be seen how the eastern and western quarries on Mt. Etna have, to date, avoided the most cavernous area.

The case for the inclusion of both Mt. Etna and Limestone Ridge in a National Park has been argued in depth in the book *Mount Etna Caves*, and there is little need to reiterate that case here. Today, no one - except perhaps the cement company - would argue against the legitimacy of a National Park in the area, but what is in question is which portions will be protected, and which will be thrown to the wolves. We are confident that there will eventually be a National Park over at least some of the area. In fact an announcement of a National Park over only Limestone Ridge before the recent State elections was expected. But what no one is confident of, is the processes by which the boundaries of the park will be determined, or more probably, have already been determined. This author's thesis is that arbitrariness, rather than any legitimate form of enquiry is the chief factor in the Queensland Government's forthcoming National Park decision. This arbitrariness, with a significant component of insincerity, has characterised Government attitudes over the long history of the Mt. Etna caves dispute.

Throughout the years, the area has been afforded quasi-protection, psuedo-protection, proposed protection, temporary protection, and most recently promised protection. One would hope that any forthcoming permanent protection in a National Park might be the result of a rational investigation, and, hopefully have more luck than any of the preceding forms of "protection" in preventing the destruction of the Mt. Etna Caves by limestone quarrying.

HISTORY OF "PROTECTION" OF MT. ETNA AND LIMESTONE RIDGE

Quasi-protection

"Quasi-protection" was afforded Mt. Etna in 1920 when it was gazetted as Recreation Reserve R444. Limestone Ridge was similarly gazetted as R272 in 1934. A Recreation Reserve is defined as land set aside for public recreation. The wording of the 1934 Order in Council was "shall be permanently reserved and set apart for Recreation purposes." These Recreation Reserves stand today. The only hitch, of course, was that mining leases could cover such reserves, and there will be precious little left to recreate on when the miners have finished on Mt. Etna. The spirit in which both of these Recreation Reserves were declared can be honoured today only by re-gazetting them as National Parks.

The history of guano and limestone mining leases on the two Recreation Reserves is long, and is adequately documented in *Mount Etna Caves*. In fact, 1975 will be the fiftieth anniversary of the first application for limestone mining on Mt. Etna. Until late this year (1974), the situation was that Central Queensland Cement held leases over the whole of Mt. Etna, and the southern half of Limestone Ridge, while Mt. Morgan Ltd held the lease over the northern end of the Ridge. The leases have recently been relinquished over Limestone Ridge, presumably in preparation for a National Park, but all leases over Mt. Etna are still operational.

Pseudo-protection

The late 1960's saw the "pseudo-protection" of Mt. Etna's caves - the elusive "66 foot" agreement. After many representations, it was learnt that an agreement had been made by the Cement Company and Mines Department, not to mine within a 66 foot radius of known caves. This has been variously worded as "*66 feet from any known cave entrance*" and "*66 feet from any known cave which is a habitat of Macroderma gigas*". Questions have been asked in Parliament about breaches of this agreement, with a reply in March 1970 by the Acting Minister for Mines..... "*....if these promises have been breached inadvertently, there can be no legal redress and the actual distance of encroachment which allegedly occurred is not relevant.*" In any case, the concept of providing a 66 foot barrier around only the entrance of a cave is a negative one. Virtually the whole of the cave could be destroyed while still maintaining this barrier. Neither does such an agreement provide protection for caves which will be discovered in the future by normal speleological activity.

Surveys existed for at least two of the caves broken into by quarrying operations. Also as late as 1972, the Mines Department forwarded the Society a plan of Mt. Etna showing only 6 cave entrances, and one chain barriers around these six entrances. This has been typical of the Mines Department and Central Queensland Cement Company's refusal to recognize the extent to which the limestone outcrop is cavernous. The 66 foot agreement has been meaningless in the past, and is obviously going to remain meaningless in the future.

Proposed Protection

Then came the "proposed protection". In November, 1967, in a reply sent to the University of Queensland Speleological Society by the Minister for Local Government and Conservation, it was stated that "approval was given for a Departmental Committee consisting of officers of the Lands, Forestry and Mines Departments to investigate the future of the Mt. Etna caves system and the question of mining thereon."

In 1968 this interdepartmental committee recommended: ".......*Having regard to all the facts, both from a mining and a conservation viewpoint.....*

1) That the Mines Department approach the lessee Company to obtain the surrender of about 31 acres (on Mt. Etna).....

2) That upon completion of the surrender action, the area be proclaimed a Scenic Area under the Forestry Acts, 1959 to 1964."

(Scenic area was the former nomenclature for a National Park less than 1,000 acres. The 31 acres referred to is some of the as yet untouched northern face of Mt. Etna).

It is understood that this approach was made by the Mines Department, but Central Queensland Cement Company refused to relinquish its leases. Apparently nothing more has been done, and the proposed protection has never been implemented.

In summary, a Queensland Government interdepartmental committee has recognised that Mt. Etna is of National Park status even despite the scar of the quarry. It is regrettable that this recognition has not resulted in more definite action (However, the University of Queensland Speleological Society regards the proposal of only 31 acres for a National Park as inadequate).

Temporary Protection

The northern face of Mt. Etna, between the eastern and western quarries, has only remained inviolate because of an agreement between the cement company and the Queensland Government Mines Department not to mine part of Mt. Etna for a three year period while investigations of alternative limestone deposits were made by the Mines Department. That agreement, made probably about 1969, has long expired, and the company is now free - if in fact it was ever bound by such a gentlemen's agreement - to join up their eastern and western quarries and completely obliterate Mt. Etna's caves. It is understood that Central Queensland Cement has recently agreed to relinquish its mining leases held on Limestone Ridge, adjacent to Mt. Etna, on the understanding that it be allowed to quarry all the limestone on Mt. Etna. As a result it is envisaged that an attempt will be made by the company in the immediate future to extend their operations into the most cavernous areas. Such a move to quarry the northern face of Mt. Etna would have to be construed as an attempt by the company to despoil as much of the surface as quickly as possible, rather than a legitimate need to extend the quarry. In the western quarry being worked at present, a conservative minimum of 20 years supply of limestone is available by downcutting in an already destroyed area. Should political and legal methods fail to prevent the unwarranted despoilation of any more of the surface of Mt. Etna, this author believes that direct action would have to be contemplated at the first sign of any attempt to extend the quarry.

Promised Protection

The latest protection - promised protection - for Mt. Etna and Limestone Ridge was offered by the Queensland Premier, Mr. Bjelke-Petersen, at a political meeting in Rockhampton in May 1974. The Premier promised that Mt. Etna Caves would be protected. A few weeks later the Rockhampton National Party candidate affirmed that the Premier's promise meant protection of both Mt. Etna and Limestone Ridge. The performance of the Premier's promise is eagerly awaited, but this author believes that the promised protection will have the same fate as all the other bogus protections.

Limestone Ridge and Mt. Etna were gazetted as Recreation Reserves early this century; recognized by Queensland Government officers as possessing requisite National Park qualities in the 1960's; in part temporarily protected from mining (which further illustrated recognition of these qualities); subject of political promises of protection in early 1970's - but the fate of Mt. Etna and Limestone Ridge is still undisclosed.

However, this author believes that the arbitrary decision has been taken to mine Mt. Etna and propose a diminutive national park on Limestone Ridge. At no time has any recreational or biological study of the Mt. Etna-Limestone Ridge complex been undertaken by the Queensland Government. Their decision will be based solely on the results of an economic geology survey.

The arbitrary and short-sighted basis of this decision is deplored.

Footnote (February 1975):

Since the 10th Biennial Conference, there have been further developments.

(a) Counts of the number of bats in Bat Cleft in January 1975 indicate little change in the numbers using the maternity colony. Despite continuous blasting over many years (a rockfall has occurred in Bat Cleft) the tenacious hold that the species has on this single cave indicates their inability to locate or develop an alternative maternity site.

(b) In January 1975, the Queensland Mines Department Minister officially announced that the mining leases on Limestone Ridge had been removed, and that the Queensland Government intended to make Limestone Ridge a National Park. Central Queensland Cement is to be allowed to continue to mine Mt. Etna, implying Mt. Etna, all its caves, and the bat colony are to be destroyed.

But the issue is not closed. To date there have been 13 years of conservation activity centered on this area. The battle for Mt. Etna is only warming up.

AUSTRALIAN SPELEOLOGICAL FEDERATION
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SECTION 6
CAVE DOCUMENTATION

THE NUMBERING OF CAVES NOT FOUND IN SPECIFIC CAVES AREAS - THE NEW SOUTH WALES SYSTEM

P.B. Toomer+
and
B.R. Welch*

ABSTRACT

Following active interest in the caves of the smaller limestone deposits and the non-limestone caves of New South Wales, a new numbering system was devised to encompass this development.

A series of "General Caves Areas" has been created, with the boundaries of each 1:250,000 topographic sheet delineating the area. The area codes are derived from the map identification number.

The numbering of each General Caves Area will be controlled by interested individuals and the N.S.W. Cave Numbering and Nomenclature Committee will over-see general administration.

The numbers will be allocated arbitrarily in each General Caves Area with specific emphasis on grid references for the location of caves.

This system is sufficiently flexible to be used throughout Australia and it is for this reason that it is brought to the attention of the Federation as a whole, in the hope that others may see in it the solution to their problems.

INTRODUCTION

The system has been instigated so that numbers may be allocated to all caves not found in specific cave areas. The system is based on the principle of General Cave Areas, delineated by the boundaries a 1:250,000 map, each general cave area is given a prefix drawn from data given on the map. Numbers for each cave within a general cave area are allocated by the co-ordinator of the area who is responsible to the Convenor of the N.S.W. Numbering and Nomenclature Committee.

THE AUSTRALIAN TOPOGRAPHIC MAPPING SYSTEM

For mapping purposes, the Central Mapping Authority has subdivided Australia into areas of six degrees of longitude, by four degrees of latitude, and each of these areas is covered by a 1:1,000,000 international map. Each of these is designated by an alpha-numeric code number, as well as a name. (See appendix 1) For example, the Sydney 1:1,000,000 sheet is designated SI 56.

The alphabetic part of the map reference number is drawn from the alphabetic

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labelling of each division of four degrees of latitude, starting with 'A' for the band 0^o - 4^oS and so on. Each letter is prefixed with the letter 'S' to designate that it is in the Southern Hemisphere.

A similar numerical system operates with longitude, the division being every six degrees, starting at 180^o (approximately the International Date Line), and moving eastwards round the earth. Thus Australia and Papua New Guinea fall into zones SA - SK for latitude, and 49 - 56 for longitude.

Each 1:1,000,000 sheet is further divided into sixteen 1:250,000 sheets. These are numbered 1 - 16, in four rows of four, and each sheet has a name also. For example, the Sydney 1:250,000 sheet is designated SI 56-5. (See appendix 1)

PREFIXES FOR GENERAL CAVES AREAS

As mentioned earlier, the prefixes for General Caves Areas are derived from the alpha-numeric reference number of each 1:250,000 sheet.

Since Australia is obviously in the Southern Hemisphere, it is felt that the 'S' can be deleted without confusion. Similarly, since the maps of Australia have longitude codes 49 - 56, and therefore all sheets except a small part of Western Australia west of longitude 114^o are prefixed by a '5', and since the figure '9' does not appear in any of the other longitude designators, the 'tens' digit has also been dropped.

Since confusion could arise from using the numbers given to each 1:250,000 sheet by the C.M.A. (i.e. numbers 1 - 16, see appendix 1), it was decided instead to use the corresponding letter of the alphabet. For example, instead of SI56-5, which is the code number of the Sydney 1:250,000 sheet, the Area Code for the Sydney General Caves Area would be I6E.

This system is totally compatible with the format required by the ASF Cave Summary Form No. DOC2/403PGM as the field 1.2 is able to take three characters. The state prefix although superfluous should still be used in documentation as an aid to initial location, for example 2I6E.42.

IMPLEMENTATION

This system facilitates the ready numbering of any cave or other karst feature, or in fact any feature of speleological interest. The number given will have significance as to the location of the feature and the area code may be readily deduced from the 1:250,000 map covering the area, and similarly the reference number of the map may be calculated from the area code. The actual boundaries of each area are irrefutable and thus far superier to any arbitrarily assigned boundaries. This system does not require profound genetic decisions to be made as to whether the cave is a sea cave, limestone or non-limestone and thus many of the often pedantic arguments which have opposed systematic numbering of caves not found in specific cave areas do not arise.

The field where this system will find immediate use is the numbering of sea caves, and the area codes for the NSW coast are, from North to South, as follows:-

Area Code	Area Name/Map Name	Map Code
H6C	Tweed Heads	SH 56-3
H6G	Maclean	SH 56-7
H6K	Coffs Harbour	SH 56-11
H6N	Hastings	SH 56-14

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Area Code	Area Name/Map Name	Map Code
I6B	Newcastle	SI 56-2
I6E	Sydney	SI 56-5
I6I	Wollongong	SI 56-9
I6M	Ulladulla	SI 56-13
J5D	Bega	SJ 55-4
J5H	Mallacoota	SJ 55-8

It should be noted that the above areas also cover most of the other known caves not found in specific cave areas, for example, Kincumber, Basin Cave, Hilltop, Nangwarry. Thus there is no further need to proclaim a new Specific Cave Area to cover one cave, even if it is limestone, as it may be readily numbered in a General Cave Area, thus maintaining the simplicity of the Specific Cave Areas in existence.

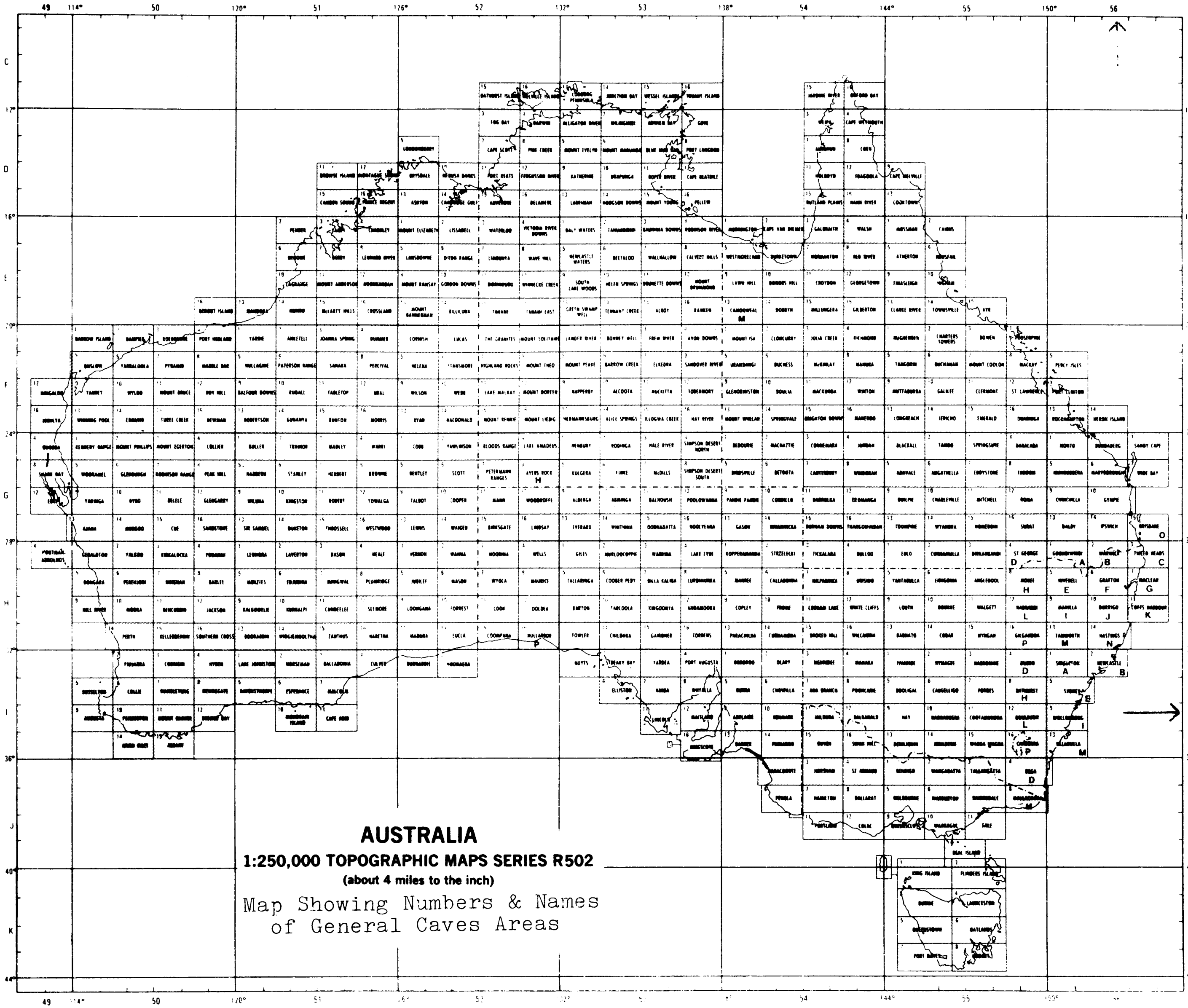
NUMBERING & TAGGING

Numbering within each area is arbitrary, but the grouping of numbers is encouraged. For example, the numbering and tagging of sea caves of the Sydney General Caves Area is being conducted by P.S.G. commencing with 16E 1 in the North and numbering all caves sequentially Southwards.

Tagging is carried out under the supervision of the area co-ordinator, and if a cave is found the co-ordinator is contacted and a number allocated; or if a group is intending to investigate an area where caves have been reported, a block of numbers is allocated immediately with the understanding that a description and location of each cave tagged is given to the co-ordinator along with any unused numbers.

As previously mentioned, the co-ordinator is responsible to the N.S.W. Cave Numbering & Nomenclature Committee.

APPENDIX 1


AUSTRALIA
1:250,000 TOPOGRAPHIC MAPS SERIES R502
(about 4 miles to the inch)
Map Showing Numbers & Names
of General Caves Areas

AUSTRALIAN SPELEOLOGICAL FEDERATION
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SECTION 7
PUBLICITY AND PROMOTION

THE PRODUCTION OF A CAVING MOVIE

A.J. Pavey
and
John Carmichael

ABSTRACT

The University of New South Wales Speleological Society produced a 25 minute 16 mm colour caving movie of a general nature, showing most aspects of cave exploration and with a conservation biassed commentary. Production techniques and the many problems encountered during shooting "The Crystal Kingdom" are discussed in detail.

INTRODUCTION

Due to a fortuitous set of circumstances in Orientation Week at the University, several University of New South Wales Speleological Society members managed to interest Opunka, the University Film Group at UNSW, in the production of a caving movie. The original proponents of the idea, Chris Fisher and John Carmichael called a meeting of interested persons and subsequently UNSWSS formed a sub-committee to control production of the film and agreed to some financial support for the proposal. Opunka finally agreed to provide 270 m (900 ft) of 16 mm colour film, half the processing costs and use of camera, lens, tripod and film editor for a nominal hire fee.

Later the University Union was approached for a direct grant and this was provided from the Cultural Affairs section. It did not however, cover all the costs, but did enable purchase of another 130 m of film.

PLANNING

Although no one had any previous experience in movie making, quite a few good ideas were proposed at the initial meeting and finally Andrew Pavey, who had the most photographic and caving experience, was commissioned to produce a script, and was also nominated as Director. Chris Fisher took the job of cameraman and John Carmichael the onerous coordination task of Producer. Graeme Pattison was nominated to look into lighting and generator hire. From the host of applicants ("volunteers"), three were finally selected as "stars". The criterion was photogenic trogs and one female female. Keith Oliver, Rosalind Dall and David Perkins were the elected stars.

A number of caving areas were discussed and the final decision was to stick to one caving area where access to the caves was easy, and reliable. The caves had to be easy to move a large film crew, lights, cameras etc. through. Further, all possible locations had to be within a reasonable distance of the entrance to minimize the electric cable required as lighting was to be by portable generator situated at the entrance location,

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Cliefden Main Cave was finally selected. There was an excellent variety of speleothems close to the entrance, and although the cave was muddy it was an easy walk-through cave. Also, as a result of a recent intense interest in Cliefden, many members of the Society had a good knowledge of the cave. (Carmichael1974 a,b,c, Pavey 1974).

THE SCRIPT

The script was essentially the scenario for each shot. It was written roughly in order of the scenes as they might occur and each scene was numbered and verbally described. Also "in a majority of cases" the location of camera and crew etc., was carefully spelled out. In most scenes it was not necessary to drastically alter any of the specified location and shots. This was only possible because of Andrew Pavey's very accurate recollection of the cave and firm idea of what should appear on the final film.

After the basic script had been written and approved by the sub-committee, it was broken up into convenient days of shooting each in a specific part of the cave, and in the order in which it would be easiest to shoot them. The minimum number of camera set-ups is essential to completing filming in a reasonable period.

Any scenes which proved unworkable in the cave were scrubbed or combined with others in somewhat arbitrary decisions. A number of "saving" shots of formation and actors were made on the last session and proved valuable in the long run.

TECHNICAL

Lighting

Caves are dark holes in the ground and muddy walls absorb a lot of light, so in preliminary discussions with other movie producers and with some arm-waving caving fudge factor analysis, it rapidly became obvious that at least 4-8 500w photo-flood lamps would be required. It was found that a 5 kVA portable generator could be hired and that either 800w or 2kw Quartz Iodine lights were also available. After considering the budget it was decided to purchase 4 x 500w photofloods and hire one 2kw QI light. In retrospect we need not have bothered with the photofloods - surprisingly enough they produce almost negligible lighting in the cave as far as movie-making is concerned. The 2kw light comes on a portable stand but this was rapidly abandoned as impracticable in the cave. All lights were mainly hand held.

200m of electric extension cable was acquired as long extension leads and a small distribution box with a number of power outlets, plus a few short extension leads were used to distribute the light at the chosen location. Mud in the power sockets was not a problem although the generator was run at a slightly higher than normal voltage to allow for any potential drop along the cables. Two photo-floods were rather spectacular victims of drips and we considered that we were very lucky not to lose more. Various methods were used to hold the bulbs, the most useful being a large bucket and DMT traffic light reflectors.

The Generator

A portable 5kw generator is not very portable (weight 50-80kg!) and it was necessary to borrow Bruce Dunhill's tractor and trailer to transport the generator to the cave entrance. For the first two of the three weekends of underground shooting, a telephone line was rigged through the cave and a couple of brave (but bored and often wet) trogs minded the generator, starting and stopping it as required between scenes. The generator only consumed about 4 gallons of petrol during a weekend, so on the final weekend it was left running continuously. Transport of the generator from Sydney was a bit of a bind but thanks should go to Bill Gamble (CEGSA), Joe Minney (OSS) and S. Wheatly (UNSWSS). Although the available light in the caves was adequate, a larger cave or greater distance from the entrance may not be feasible. Certainly any larger generator would prove almost completely unmanageable. We recommend moving extension cables through the cave on spools as it avoids messy, muddy tangles!

Film and Exposure

The lights had an effective colour temperature of 3200K so Ektachrome EHB stock was used. The normal film speed is 125ASA but it was rated up one stop at 250ASA. This proved adequate in most caverns with the lowest stop used being f2.8. The majority of shots were taken at f4 or higher. Exposure was determined from incident light readings taken on a Lunasix light meter. After the first "rushes" were viewed, it was decided to use the light meter at 200, not 250ASA in order to effectively uprate the film by an additional 1/3 f stop. Exposure was quite acceptable in medium sized chambers but in larger caverns more exposure (especially of the background) would have been desirable.

The above ground shots proved to be more of a problem than was initially imagined An 85B filter had to be used to correct the colour balance of the tungsten balanced film. The camera speed is fixed at 24 frames per second on the electric motor, which means an effective exposure of 1/60th sec. This low shutter speed, combined with "pushed" high speed film stock and bright sunny days resulted in light meter readings of f45, which were not available. A compromise had to be made and on one shot the clockwork motor was used at 64fps but was not highly successful as the mechanism only runs for 8 sec. The other main surface pan was shot at 24fps and f16 and with the hope that it would not be too overexposed (it wasn't). A pair of two-way walkie-talkies proved to be useful in co-ordinating camera and actors in the above-ground sequences.

The Camera

The camera used was a Bolex with a three lens turret and reflex viewing. The three lenses were a 16-80mm zoom lens (f4.5), a 25mm f1.1 macro lens and a 10mm f2 wide angle lens. All lenses were used in the cave on many occasions. The tripod was fitted with a Miller (fluid) pan-tilt head which ensured very smooth pans. The tripod is absolutely essential. A couple of shots pan-zoom required two people to operate the camera but otherwise Chris managed the job on his own admirably. The fancy (but solid) camera case provided by Opunka unfortunately did not fit through the entrance so the camera and lenses were carried around the cave in a plastic garbage bag in a frameless pack (not really recommended)!

A number of problems were encountered with the camera - the first weekend it chewed film about 20m into the first roll of film. The tear was repaired with insulation tape and then filming continued. Later there was a definite misalignment in the camera which scratched quite a bit of film stock and caused some focus problems in the film gate. For a while a lens was mislaid in the cave, but it was safely found the next day! In general, the camera survived quite well and didn't get very muddy at all. All the gear was washed at the end of each weekend - a major, messy task, but essential. It is very important for the cameraman to wear gloves in the cave to keep his hands clean for operating the camera.

Continuity and Location Shooting

When a film is shot in an order different to that which will finally appear on the screen, several difficulties arise. In a cave the foremost of these is the muddiness of the trog suits. It is not good to have the stars enter the cave in white trog suits, emerge from a rockpile with very muddy ones, and then appear later on in clean white ones again. A continuous and careful check must be kept on items like, "who's wearing the red helmet" or "carrying the pack". A tribute to our efforts in this item is the lack of serious discontinuity in the final product. Some of the production hassles centred around getting all three actors together on any given weekend. Every scene was rehearsed several times before filming in order to minimise film wastage and cut costs. Reshooting scenes is both expensive and annoying.

After a session of six or eight hours of filming, much of which seems to be spent standing around and getting things moved and organised, the whole crew showed signs of fatigue, bitchiness, bouts of "let's tell the Director what to do". and even the occasional mud fight. As a study in group psychology this is no doubt very interesting but it didn't help get the film "in the can".

Editing and the Concept of the Film

Editing the film is a long, slow job and in this case we had 400m of film of which about 300m was finally used. Basically, all the film is cut up into lengths of one scene and these are then arranged in the required order and stuck together. A print of this is then made for projecting purposes. It is normal practice to run a copy of the raw film stock and use the copy to work out all the ideas before cutting the original... Unfortunately, our finances did not run to this and so a number of scenes appear in the film which would now, on second thought, be cut out.

The basic idea was to just make a caving movie in the first place. Later it developed that it would be aimed at several audiences:
a) the general outdoor loving public who know little about caving;
b) the speleos who would like to see a movie about caving;
c) internal audiences in UNSWSS, e.g. freshers who would be shown the film as an introduction to caving.

The film essentially tells the simple story of a party of three cavers exploring a cave, and shows scenes of wandering around in the cave, looking at formations and climbing a ladder; - with a conservation message at the end. Originally it was considered that three different sound tracks would be made. One for each of the three audiences, but all using the same film sequence. This turns out not to be very practical, although it could be done.

The voice-over commentary was written whilst watching the film and then recorded separately and transferred to the magnetic strip on the print. For the first few showings, only a roughly synchronised cassette tape was available as soundtrack. The final soundtrack incorporated music specifically written and selected for the film.

Titles

The film titles were shot in the School of Physics from black and white slides of the lettering. Some of the close-up crystal shots were also done from colour slides in the same way. This panning across still shots can be quite effective and enables images to be presented which would almost be impossible to get with the movie camera because of its size and weight i.e. movie cameras just aren't compatible with confined spaces!

Credits

Producer:	John Carmichael
Director/Script Writer/Editor:	Andrew Pavey
Cameraman:	Chris Fisher
Cast:	Keith Oliver/Rosalind Dall/David Perkins
Lighting:	Brad Jones, Paul Tapp, Graeme Pattison, Paul Woodbury
Continuity:	Bev Riley

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Clapper:	Robyn Wilson
Sherpas:	Helen Wallis, Bill Gamble, Richard Katsch, Trish Peterson, Phil Ireland, Joe Minney, Steve Wheatley, Alan Wrild, John Leonard, Tony Heat, Brian Cooper, I. Bowron, Dave Lowry, J. Gordon, S. Banks, T. Ball, R. Daniels
Equipment:	Opunka Film Group
Financial Backers:	University Union, Opunka Film Group, UNSWSS.

Budget

To give an idea of costs and items required, we present here a detailed budget for the movie. This budget does not show the actual cost to us, as short cuts and grants were available; it is intended to give interested persons an idea of the costs which do arise.

(early 1974 prices)

Equipment	Purchase Price	Hire Cost
16mm Bolex and lenses		$30 per day
Tripod		$5 " "
2 kw light (Blondie)	$132 each + $26 globe	$7 " "
800w light (Red Head)	+ $8 globe	not worth hiring
240v extension cable		$1 per 100ft per day
5kv generator		$10 per day
petrol	consumes about $2 per day	
Insurance on above	7½% of hire cost + Stamp Duty	
Telephones + cable	?	
Two-way radio	?	?
Distribution box	To make - about $10	
Generator transport	Allow petrol expenses for private transport	
Film		
16mm H.S. Ektachrome film	$26/400ft	
Processing original	6.4 cents/ft	
Forced developing (to 250ASA)	25% per stop	
Light corrected work print (recommended)	18 cents/ft	
Answer print	20 cents/ft	
Magnetic stripe	10 cents/ft	
Spool + storage case	Approx. $8	
Other Facilities		
Editing	?	?
Sound recording + mixing		?
Letraset & title slides	approx. $10	
Copyright for music	?	
Fee for narrator	?	
Colour correction filters	approx. $5	
Contingency	10% is conservative	

Total estimated expense to produce a 25 minute 16mm colour movie with sound on magnetic stripe, and using 1 camera, 1 2kw light and equipment hire for six days is approximately $700 (minimum).

PUBLICITY - A.J. Pavey and J. Carmichael

SCREENING ENQUIRIES

"The Crystal Kingdom" and at a later date "Kubla Khan" are available to ASF member societies for a nominal hiring fee. Enquiries should be made to the Producer, John Carmichael C/- U.N.S.W.S.S., Box 17, The Union, The University of New South Wales, Box 1 P.O., KENSINGTON. N.S.W. 2033.

CONCLUSION

"The Crystal Kingdom" is a 300m, 25 minute film about a simple caving trip with a conservation theme. The total amount of man hours involved in the production was about six hundred. Our costs were about $700. As a first effort we were fairly pleased with the result and certainly learnt a lot about the practical difficulties of shooting a movie in a cave. As a result of this we were successful in applying to the Arts Council's Experimental Film Fund for a $2,700 grant to make another film in "Kubla Khan", using experimental lighting (Diprotodon), and also making a video programme about the making of the film.

References

CARMICHAEL, J., 1974a Film Making at Cliefden. *Spar*, 35, 6.
CARMICHAEL, J., 1974b More Film Making at Cliefden. *Spar*, 35, 7.
CARMICHAEL, J., 1974c The Third Filming Session at Cliefden. *Spar*, 37, 13.
PAVEY, A., 1974 Final Filming Trip. *Spar*, 37, 13.

Additional exposure data

At Bungonia, Ektachrome EH (160ASA) was used with a 16x neutral density filter. For the gorge, which is in shadow and very "blue", an experiment using an 85B filter to correct the colour was tried. However it proved to be a bit too strong and a faintly orange gorge results.

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SECTION 8
OVERSEAS RECONNAISSANCE

PRELIMINARY SPELEOLOGICAL RECONNAISSANCE OF FIJI & TONGA

John R. Dunkley*

ABSTRACT

The literature on limestone deposits and caves of the Fiji and Tonga Islands is sparse, difficult to obtain and in general quite old. There appears to be nothing in the speleological literature. In January 1974, the author made a brief reconnaissance of some caves and karst in the South Pacific Islands. The best potential appears to be on Tongatapu and 'Eua Islands in Tonga, and in the Lau Group in Fiji, although small areas with good potential and relatively easy access are reported on Viti Levu.

FIJI

The main islands of Fiji, Viti Levu and Vanua Levu are considerably older than most of the Pacific Islands, the earliest rocks being of mid-Eocene age, intruded by grandiorite dated as early as 54 million years.

Two types of cavernous limestone and dolomite deposits are found in Fiji:
1. localised deposits and small lenses up to a few square kilometres, ranging from Pliocene to Eocene in age, found on Viti Levu and Vanua Levu.
2. extensive quaternary reef and atoll limestones, sometimes froming thin crusts on thick bedded, older limestones, located mainly in the Lau and Yasawa Islands.

For logistical reasons, reconnaissance was restricted to Viti Levu, and descriptions of other areas have been obtained from the literature. Two major areas, Wailotua and Singatoka River Valley were investigated on Viti Levu.

1. Wailotua 178°24'30"E, 17°46'S "Caves" marked on geological map.

Situated about 70km north of Suva on Kings Road, Local villagers conduct visitors through caves by hurricane lamp for 50c. Active river system, at least 1500m long and chambers up to 80m high. Extensive guano deporits used for fertiliser. Good decoration. Excellent exploration prospects. Grade 2 map prepared. Resurgance of river examined 1km away, no entry possible. Very extensive limestone deposits marked on geological sheet a few kilometres north of Wailtoua, not investigated but map shows sinking streams.

2. Singatoka River Valley

A reconnaissance was made of all but one deporit reported between the coast at Singatoka and the village of Ndraimbe at the end of the road.

Singatoka: Tertiary and Quaternary limestones exposed along coast west and east of Singatoke. Several small closed depressions observed on side of Queens Road but local enquiries failed to locate any caves.

Lawai & Naroro: 177°32'E, 18°7'30"S. Not checked. Could be the location of the "Singatoka River Cave" mentioned by Sawyer & Andrews (1901).

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OVERSEAS RECONNAISSANCE - J.R. Dunkley

Mata-Ni-Vatu: 177°37'E, 17°59'S, 40km up valley road. Extensive but discontinuous outcrops, extensively faulted, several square km. Impressive dolomite (?) cliffs up to 350m high, unfortunately on opposite side of river were examined with binoculars and are spectacular. Residents at village of Rounitogo said that largest cave was a few hundred metres long but no serious attempts at exploration. Underground water and blind fish reported.

Tuvu: 177°42'E, 17°56'S. On west side of road 1.5km north of Tuvu. Village chief said caves used for burial and could not be entered but did lead to entrance. Not promising at all.

Yaloko Creek: 177°43'E, 17°54'S. Outcrop 1 km long examined by binoculars from road 0.5km away. Small cave reported locally.

Saweni: The Singatoke Valley road ends ar Ndraimbe where enquiries were made about deposits and caves upstream. Two caves are reported on side of Mt Talenalawe (177°48'E, 17°54'S) 2km east of Saweni village, bearing 104°Mag from end of road. One cave at river level, one on hillside, both easy walk through reported.

Korovou: 177°47'E, 17°55'S. Not examined. Maluwa Cave reported on Nasikawa Creek, said to be easy walk through.

Upper Singatoka Valley: Several long narrow lenses (?) are marked for at least 12km on west side of Singatoka River near Korolevu and Namoli villages. Caves reported, but reports were vague, near Mt Korovunima.

3. Vanua Levu (not examined)

Several mostly quite small outcrops are marked on the geological maps of the island. The most promising appear to be in the Upper Pliocene (?) Tuatua Limestone near Lambasa, and Ibbotson (1967) notes that "solution cavities are usually filled with limestone debris but there are a few extant caves which have been used as burial chambers" (p. 12). Access by air from Suva.

4. Lau Islands (not examined)

The Lau Islands lie some 250km east of Viti Levu, extending over a 500km length, and are accessible only by ship. Major cave systems are reported in the literature on the islands of Mango, Thithia, Lakemba, Nghillanghillah, Bai Vatu, Vatu Leile, Katavanga, Naitamba, Gamia, Tuvutha, Vanua Vatu, Yangasa and Yangava. Some of these are raised atolls and at Wangava a central tidal lagoon exists, completely shut off from the sea by high limestone cliffs on all sides. An active stream cave 500m long is reported on Mango, the surface of which is said to be virtually impassible because of the sharply fretted and deeply scoured limestone.

5. Yasawa Islands (not examined)

The only reported limestone is on Sawa-i-lau. Several large caves are known, including one entered underwater, and one of archaeological importance.

TONGA

Caves are reported on the main island of Tongatapu, and on Vava'u and 'Eua Islands.

Tongatapu: The island is a coral atoll 30km x 15km on which has been deposited volcanic debris from Vava'u to a variable depth averaging 10m. The island is therefore virtually flat, the heavy rainfall disappears quickly into the porous soil and there is apparently no surface drainage. A large cave near the village of Haveluliku , 20km from the capital of Nuku'alofa, is open to tourists and consists of a formed path along which visitors are conducted with torches or hurricane lanps. Opening from the back of attractive Anahulu Beach, the cave is well decorated with stalactites, stalagmites and small helictites and, although only 50m from the sea there is a deep, slow moving body of fresh water inside. According to local guides, the cave can be followed, partly by swimming and wading, and partly by high level traverses, for approximately 8km to the village of Mua where it reportedly comes out underwater in the lagoon near the monument to Captain Cook. Now this sounds very much like the usual local exaggeration, however in the light of the origin of Tongatapu, caves of similar nature reported on Mango and Wangava in Fiji, the absence of surface drainage and the undoubted presence of a substantial fresh water lens, this is a lead well worth following.

Vava'u: About 300km NNE of Tongatapu, partly volcanic origin (Port of Refuge Harbour is an extinct caldera similar to Pago Pago). Tourist information folders describe tours to Swallows Cave on Kapa Island, a milticoloured chamber which is a sanctuary for thousands of swallows, and can be entered by boat. Tours are also available to Mariners Cave ... "guides take divers through the heart-shaped entrance into the mystical blue lit cavern". Not visited. Access by air or ship from Nuku'alofa.

'Eua: Access by scheduled light aircraft or ship from Nuku'alofa. This island consists of a low Late Tertiary coralline limestone fringing a more elevated backbone of Eocene foraminiferal limestone on a base of older volcanic rocks, and overlain in places by Miocene tuff. The author had only one day on 'Eua and in this short time traversed the shoreline for several kilometres north of Ohonua, and walked across part of the Central Valley. Local enquiries about caves were fruitless and in the Cantral Valley none of the "numerous shallow sinks" mentioned by Hoffmeister was seen.

According to Hoffmeister, the higher parts of this island contain large depressions. Some of these must be subjacent as they are described as being entirely in the Miocene tuff, and some contain water for short periods. Some of these depressions are said to be much deeper the others: Lister (1891) describes Ana Aha or Smoky Hole as being a funnel shaped shaft 30 x 13m in size and swallowing a stream which plunges straight down as a waterfall for about 60m. The top 2 metres is in volcanic material, the remainder in limestone, and "in all probability the bottom of the shaft represents the real volcanic basis of the island and the water of the stream follows along the limestone-volcanic contact through subterranean channels until it reaches the sea... the top of the shaft is about 550 feet above sea level" (Hoffmeister p. 21).

Another spectacular local feature (not visited) is the Matalanga, evidently a very large collapsed sea cave 80 metres deep.

'Eua is an absolutely splendid anachronism which will rapidly be spoilt following completion in 1974 of a dirt air strip. There are no cars, only one road, and a few trucks. Transport locally is by horse or foot, and there is a primitive but comfortable licensed lodge where horses and canoes can be hired. Details can be obtained from the proprietor, a New Zealander, who would no doubt be able to arrange exploration parties to the interior of the island: Mr Lance Collins, Taha-Kae-Afa Lodge, P.O. Box 12, Ohonua, 'Eua, Kingdom of Tonga.

Obviously a week at least would be required to explore the speleological potential of 'Eua, and if no worthwhile caves were found, it's a marvellous place for a holiday, at least until with the recent mainland air link, the tourists find it.

Selected References

Only those works referred to in the text are included here. The author has a more extensive bibliography which may be obtained by those interested.

OVERSEAS RECONNAISSANCE - J.R. Dunkley

ANDREWS, E.C., 1900 Notes on the Limestones and general Geology of the Fiji Islands with particular regerence to the Lau Group. *Bull.Mus.Comp.Zool.Harv.*, 38, 1-50.

HOFFMEISTER, J.E., Geology of 'Eua, Tonga. *B.P. Bishop Mus.*, *Bull 96.*

LISTER, J.J., 1891 Notes on the Geology of the Tonga Islands, *Geol.Soc. London, Quart.Jour.*, 47, 590-617.

SAWYER, B., & ANDREWS, E.C., 1901 Notes on the Caves of Fiji, with special reference to Lau. *Proc.Linn.Soc.NSW*, 26, 91-106.