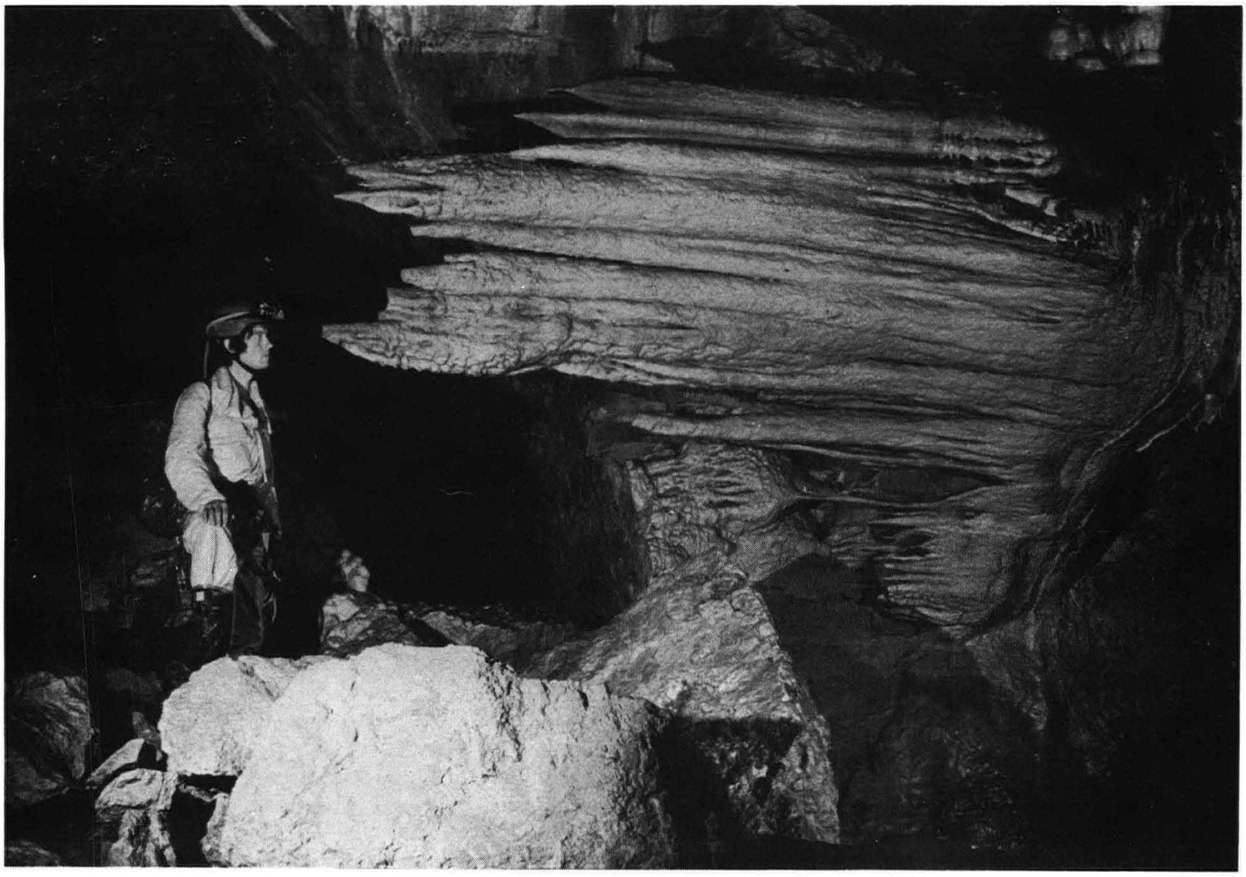
BCRA

TRANSACTIONS

BRITISH CAVE RESEARCH ASSOCIATION

Volume 6 **Number 3** **November 1979**



Grotte La Gournier, France

Man in Australian Caves
Cave Surveying Programs
Pe'ape'a Lava Cave

ISSN 0305-859X

TRANSACTIONS OF THE BRITISH CAVE RESEARCH ASSOCIATION

Volume 6 Number 3 November 1979

CONTENTS

Cover picture: Horizontal stalactites on a massive fallen boulder in Grotte La Gournier, France, by Jerry Wooldridge.

Published by and obtainable from

The British Cave Research Association

Brian Ellis
30 Main Road,
Westonzoyland,
Bridgwater,
Somerset TA7 OEB

Trans. British Cave Research Assoc., Vol. 6, No. 3, pp. 93-130 October 1979

MAN AND OTHER ANIMALS IN AUSTRALIAN CAVES AND SHELTERS: A REVIEW

by J.N. Jennings

SUMMARY

Big advances have been made in the last two decades in Australian prehistory and in associated vertebrate palaeontology. Caves have provided a high proportion of the sites for a number of reasons. A wide variety of geomorphological types of cave and rock shelter were used by the Aborigines. Nevertheless surprisingly little recording of their use of caves since European contact with them is to be found in historical and ethnographic literature. These records are reviewed under functional headings. Cave excavations have furnished the bulk of the evidence whereby the course of Aboriginal stone technology has been reconstructed and their sequences reach back in time nearly as far as open sites. Greater use of caves in the Holocene than in the Pleistocene depends on the rise of sea level to its present position and on improved coastal economy. Those human skeletal remains which have attracted most scientific interest have not come from cave sites and the general palaeoecological reconstructions crucial to the interpreting of prehistory have only been derived from caves to a subordinate degree. Topographic and ethnographic approaches to archaeology have led to a deeper understanding of cave as well as open sites. Caves are beginning to provide firm dates for parietal art. The effects of prehistoric use on the caves themselves are under investigation. Understanding the importance of caves for late Quaternary vertebrate history depends on solving questions of taphonomy, which have attracted the attention of Australian archaeologists and palaeontologists in recent years. The problems attaching to inferences of environmental change from Australian cave fauna are outlined, and the question of the extinction of giant marsupials touched upon.

INTRODUCTION

It would be hard to find in his time a speleologist who pursued to effect a more widely ranging interest in caves than Professor E.K. Tratman. Yet his study of human and animal remains in caves was dominant, and his original contribution in this direction in Britain was great. I am neither a prehistorian nor a palaeontologist but it seems appropriate to review, from the point of view of the speleologist, the role of caves in recent developments in Australian prehistory and vertebrate palaeontology. It was a privilege to have known Trat and this contribution is dedicated to his memory.

THE NEW LOOK OF AUSTRALIAN PREHISTORY

In the last two decades there has been a revolution in Australian prehistory brought about by a great increase in the numbers of trained specialists at work and the resources they command. This has accompanied a changed attitude towards the Aborigines amongst many white Australians. For a long time they were widely regarded as scarcely human, culturally barbarous and surviving precariously when Europeans took over their country. What would there be to study, what change could there have been in the past of such a brutish race as it was taken to be by many? Today, when the future of mankind seems at stake through risk of nuclear war, increasing numbers of people and exhaustion of resources, especially for energy, we look with different eyes at a society which was in close and balanced adjustment with its natural environment, conservatively regulating its numbers. With our materialist Western world in sore straits, we now recognise there may be something to be learnt from the social structure and discipline behind this more stable relationship with the land. In this context the Aboriginal past takes on an unexpected relevance.

A new picture has emerged as a result of this recent impetus in the study of Australian prehistory. Instead of having been in the continent for a comparatively short period of a few thousand years at the most as was thought previously, the Aborigines are now known to have lived here certainly for 32,000 years, probably for 40,000 years, and evidence of greater longevity of human occupation is expected. Although this antiquity means that they walked from New Guinea to Australia and thence to Tasmania in glacial low sea level times, it still implies familiarity with watercraft at very early times because deep sea troughs persisted between the Great Sunda Islands (Java, Sumatra and Borneo) and New Guinea throughout the glacio-eustatic oscillations. Notions of a pregnant woman drifting across on a log to found a continental population are demographically untenable.

Although bones of *Homo sapiens* have been dated at 25,000 B.P. in the earliest known cremation in the world at Lake Mungo in western New South Wales, the people buried at Kow Swamp in northwestern Victoria, who died only about 10,000 years ago, retain *Homo erectus* traits recollecting Middle Pleistocene man in Java. The meaning of the co-existence of different human strains as late as this has not yet found agreed interpretation.

As regards material culture, modern studies have shown much continuity in the fundamental 'chopper/flake' stone industry of the Aborigines but they have also revealed regional adaptation to different ecologies and significant technological evolution through time probably in relation to changing economy. Perhaps most unexpected has been the discovery of ground-edge, i.e. 'neolithic' axes as old as 22,000 B.P.

Although proof of hunting of former giant marsupials has not been established, the evidence is clear of overlap in time of the presence of man and of the extinct large animals. In consequence debate has arisen as to whether or not the megafauna was eliminated by human action as has been claimed elsewhere, for example, in North America.

On the other hand, there is ample evidence of historical and ethnographic nature showing that the Aborigines fired the 'bush' routinely both as a direct hunting tool and to promote the growth of grass for the game to multiply, a kind of primitive pastoralism. Pollen and charcoal counts from sequences of samples from swamp and lake deposits support the view that this has had drastic effects in the long run on natural vegetation. Thus at Lake George, New South Wales, it seems that sclerophyllous forest, essentially of *Eucalyptus* genus, has come to dominance late in the Pleistocene in association with a great increase and continuity in the presence of charcoal in the sediments, taken to be an effect of Aboriginal firing of the bush.

RESPECTIVE ROLES OF CAVES IN AUSTRALIAN AND EUROPEAN PREHISTORY

What part have caves played in arriving at this drastically different conception of Australian prehistory? Bowdler (1975) claimed that at least 75 per cent of sites investigated were in caves and rock shelters. This high figure warranted a check so Dr. J. Allen (Prehistory Department, Australian National University) provided a list of excavation sites up to early 1979; this is not claimed to be completely comprehensive but little will have escaped (Fig. 1). The result - 66 per cent - is very nearly as great. In McBryde's archaeological survey (1974) of the region of New England in northeastern New South Wales, eight cave sites were excavated for only one open one, whilst Bednarik (1977) in discussing the prehistory of part of the Pilbara region of northwestern Australia referred to only four open sites out of a total of sixteen. This is despite the fact that, in many areas at least, open sites are recognised to be the more numerous (Coutts, 1966).

This proportion of cave sites is thought to be higher than in European prehistory although similar data are not available. Various considerations bear on this comparison. For present purposes European prehistory may be taken to comprise the Palaeolithic, Mesolithic, Neolithic, Bronze and Early Iron Ages, during which the construction of habitations advanced substantially. Through this development, caves were bound to become progressively less important and their archaeological role to decline. It is perhaps an over-simplification to equate the whole of Australian prehistory with the Palaeolithic and the Mesolithic; nevertheless the difference in degree of technological evolution between Australia and Europe clearly leans towards a greater importance of caves in prehistoric archaeology in the former.

Moreover, since the study of Australian prehistory is at an earlier stage, there may be a greater tendency as yet to select for investigation cave sites because of the advantages they possess, with their generally thicker and denser deposits (Coutts, 1966). Bowdler (1975) points to the greater continuity of deposition in a cave whether by natural sedimentation


AUSTRALIA
0 kilometres 500
WESTERN
AUSTRALIA
NORTHERN
TERRITORY
QUEENSLAND
SOUTH
AUSTRALIA
NEW
SOUTH
WALES
VICTORIA
TASMANIA
ACT
DARWIN
PERTH
ADELAIDE
MELBOURNE
SYDNEY
CANBERRA
BRISBANE
HOBART
Melville I.
Bathurst I.
ARNHEM LAND
Yirrkala
Groote
Eylandt
Tandandjal
Ruined
City
Katherine
Beswick
Creek C
Cutta Cutta C
Yulirienji C
Ingaladdi
Gulf of Carpentaria
Buccaneer
Arch.
KIMBERLEYS
Windjana Gorge
Tunnel C
Derby
NAPIER RA
OSCAR RA
Fitzroy
Crossing
Fitzroy R
Limbunya
Victoria R
Bentinck I.
C York
Princess
Charlotte
Bay
Laura
Lynchs
Crater
Cairns
North Johnstone R
Townsville
Cape R
Keppel I.
Yuendumu
Alice Springs
Gosses Bluff
MACDONNELL RA
Ooraminna Rock Hole
Ayers Rock
MUSGRAVE RA
PIL
BARA
Fortescue R
HAMERSLEY RA
OPTHALMIA RA
GIBSON DESERT
WARBURTON RA
BROWNE RA
Puntutjarpa
Gascoyne R
Wilgie Mia
Cue
Northampton
Geraldton
THE
SOUTH
WEST
Wanneroo
Gwambygine C
Frieze C
The Humps
Avon R
Devils Lair
Mammoth C
Deepdene C
NULLARBOR
PLAIN
Koonalda C
Madura C
Albadakaroo C
Great Australian Bight
Lake Callabonna
FLINDERS RA
LOFTY RA
Yorke Pen
Koongarati C
Seton Shelter
Kangaroo I.
Devon
Downs
THE
SOUTH
EAST
Mt Gambier
Wyrie Swamp
Bunjils C
THE GRAMPIANS
WESTERN
PLAINS
Keilor
Kow Swamp
Cohuna
Lake Mungo
Lake Mitchie
Murray R
Murrumbidgee R
Darling R
Mossgiel
Louth
Wellington
Gulgong
NEW
ENGLAND
Timor C
Macleay R
Hunter R
Clarence R
Copmanhurst
Talgai
Kenniff C
The Tombs C
CARNARVON RA
BLUE MTS
Jenolan C
Wombeyan C
Bungonia C
Lake George
Currarong
Durras North
London Bridge
Yankee Hut
Den of Nargun
Conic Range C
New Guinea C
Buchan
Cloggs C
E. GIPPSLAND
Port Jackson
Bass Strait
Hunter I.
Rocky Cape
Montagu
Pleisto Scene C
Devonport
Beginners Luck C
Titans Shelter
Richmond
14°
20°
26°
32°
38°
112°
118°
124°
130°
136°
142°
148°
154°
Fig. 1.

or by accumulation of human refuse. Material gathering on a surface site is more exposed to natural processes spreading, removing or destroying it. The confinement of a cave is also likely to lead to more consistent superposition of human relics since a hunting group will more likely return to the precise focus of a cave than to an open camp which is a less well defined feature with more horizontal variation. The high middens on mosquito-ridden tropical coasts may be exceptional, height giving some relief from the insects. Some materials survive longer in caves than in open sites; for example, Merrilees (1975) cites the case of bone in the commonly alkaline conditions of a limestone cave. On the other hand predators are more likely to introduce their own food refuse and to complicate archaeological sequences in caves than in open sites (e.g. Dortch & Merrilees, 1971).

Then thereis the question of the effect of present-day activity on the discovery of archaeological sites. Cultivation, drainage works, excavations for buildings, road and railway workings, and other kinds of engineering have often led to the discovery of surface sites and these operations have been much more common and widespread in Europe than in Australia. Discovery of cave sites depends less on the intensity of economic activity. It may be that the extremely mechanised and low manpowered agriculture of Australia may destroy more sites than it reveals. Extensive stock farming without cultivation which predominates here will be less liable to lead to site destruction but even less likely to lead to their discovery. Because of its aridity, Australia has proportionately much less in the way of swamps, bogs, and infilled lakes and this almost excludes from Australia one class of open archaeological site common in Europe. There is only one of this kind as yet excavated here but its importance for the preservation of wooden tools, including boomerangs (Luebbers, 1975), is a measure of the significance of this absence. Disfavouring Europe as regards open sites, however, has been the frequent continuity of settlement at particular points so that many sites lie hidden beneath present-day villages and towns.

The reverse aspect of the matter is whether more actual use of caves was made in one continent or the other at equivalent stages of development. Some obvious factors point to Europe for troglodytes (Rosenfeld, 1969). Winter is more rigorous there than in Australia because of latitude and the greater continental extent of Eurasia; at various times in the Upper Pleistocene the comparison would have been even less favourable climatically to Europe. Another factor tending to a greater use of caves in Europe is the former presence of large carnivores capable of attacking man, a fire in the mouth of a cave offering excellent protection from this danger. The Australian Aborigines were not exposed to this risk. Why they used caves will be taken up below.

TYPES OF CAVES USED BY THE ABORIGINES

Compared with Europe and North America, Australia is poorly endowed with karst caves, not only because of its relative poverty in carbonate rocks but also because much of the continent is dry and lacks much relief. Despite this many caves and rock shelters give evidence of human use of one kind or another; a wide variety of cave was employed, most usages taking place within reach of daylight and requiring comparatively small space.

Shallow weathering caves or shelters in cliffs have provided by far the most sites and large areas of quartz sandstone and quartzite dominate in this group. The Triassic and Permian sandstones of the Sydney sedimentary basin, mainly more or less horizontal in attitude, abound in small caves and shelters, both along the coast and in the dissected plateaus inland such as the Blue Mountains. These have been in much use, both historically (e.g. Tench, 1789; Hunter, 1793; Collins, 1798) and prehistorically (e.g. David & Etheridge, 1889; Etheridge, 1891; McCarthy, 1948). The same is true of the vast plateaus of Precambrian sandstones in Arnhem Land (e.g. Spencer, 1914; Tindale, 1925-6; White, 1967a) and the Kimberleys (Grey, 1841; Love, 1936), and in areas between such as along the Victoria and Daly River systems (e.g. Basedow, 1907; Davidson, 1935; Mulvaney, 1975) where Cambrian and Devonian rocks are also involved. The steeply inclined quartz sandstones and quartzites (Cambrian and Ordovician) of the centre of the continent as in the Macdonnell Ranges (Stirling, 1896) and the arkosic Ayers Rock (Spencer, 1928; Mountford, 1965) also provided for the Aborigines. This is likewise the case with the Jurassic sandstones of the Carnarvon Range in central eastern Queensland (Mulvaney & Joyce, 1965) and of Cape York Peninsula (Trezise, 1971). This list could be extended widely.

Other kinds of sedimentary rock and some metamorphic ones yield serviceable weathering caves such as Precambrian slates in the Flinders Range (Tindale & Mountford, 1926) and Precambrian mica-schists in the Lofty Ranges (Hossfeld, 1926), both in South Australia. Limestone itself yields similar weathering caves as well as karst caves proper, e.g. in the Devonian Limestone Ranges of West Kimberley (Froggatt, 1888), in Tertiary beds as along the lower Murray River cliffs (Hale & Tindale, 1930; Mulvaney, 1960) and even in the walls of cenotes of the Southeast of South Australia (Tindale, 1974), and in Pleistocene dune limestone in Arnhem Land (McCarthy & Setzler, 1960).

Much of Australia is duricrusted where deep weathering profiles have developed in a variety of bedrocks, with resultant resistant horizons of ferricrete and silcrete overlying weaker kaolinitic horizons. Small caves develop beneath the hard caps of the 'breakaways', i.e. erosion scarps, in these ancient soil profiles, and some of these have been put to use by the Aborigines as, for instance, Tandandjal Cave in Arnhem Land (Macintosh, 1951). The nearby Beswick Cave (Macintosh, 1952) is probably another and other instances are to be found near the Warburton Range, Western Australia (Tindale, 1936a), in the northwest of South Australia (Basedow, 1914) and in central Queensland (McCarthy, 1960a). In all these cases it appears to be ferricrete which is the hard cap but Campbell (1914) specifies a silcrete roof over a shelter in kaolinised granite near Northampton, Western Australia.

Slopes of granite and other coarsely crystalline rocks are directly subject to cavernous weathering; the resulting tafoni have been large enough to attract human use as in the Musgrave Range of South Australia (Worsnop, 1897) and in Gwambygine (Dales) Cave in the Avon River valley in Western Australia (Serventy, 1952; Hallam, 1975). Perhaps it is more common to find such suitable shelters under large corestones of granite than in large faces of this rock, e.g. Frieze Cave in the Avon River valley, Western Australia (Hallam, 1975), the Humps Cave near Hyden, Western Australia (Serventy, 1952). These are not always due to the processes commonly associated with tafoni, such as granular disintegration beneath a case-hardened skin and internal exfoliation. Some hollows in corestones suitable for human purposes developed solely or partly as a result of induced tensile fracture (Ollier, 1978); a rock painting site at Yankee Hat, Australian Capital Territory, is of this type. So also appear to be Bunjils Cave, in the Black Range (Massola, 1969), and Conic Range Cave (Tugby, 1953), in northwest and northeast Victoria respectively. Tafoni in fallen sandstone blocks have also been proved to be archaeological sites in the Central Tablelands (McCarthy, 1964) and the Hunter River valley (Moore, 1970) in New South Wales. Massola (1964) cited shelters beneath sandstone tors which were occupied in the Grampians of western Victoria and many art sites in the Laura area in the Cape York Peninsula are in fallen slabs of sandstone below cliffs (Trezise, 1971).

Caves along watercourses might appear at first sight less likely yet some were in fact used as, for instance, a cave behind a waterfall in Palaeozoic sandstone at Ooraminna Rockhole in Northern Territory (Worsnop, 1897), and another in Proterozoic gneiss in a gorge in northern South Australia (Basedow, 1914). Stockton and Holland (1974) have excavated a similar site at Horseshoe Falls in the Blue Mountains sandstone, New South Wales. Howitt (1874) described graphically how his Aboriginal companions appreciated the possibilities of a cave, now known as the Den of Nargun, worn back in calcareous shales beneath a sandstone at a waterfall on Dead Cock Creek in East Gippsland, Victoria. Walls Cave, an archaeological site in the Blue Mountains, is an abandoned river meander cave (Stockton & Holland, 1974). The advantage of proximity to water can outweigh the disadvantages of dampness in much of Australia.

Inactive sea caves have proved to be important sites of human occupation in a variety of rocks. Those at Rocky Cape, northeast Tasmania, in Precambrian quartzite (Jones, 1966), Cave Bay Cave on Hunter Island, northwest Tasmania, in Precambrian siltstone (Bowdler, 1979) and Kongerati Cave south of Adelaide in Precambrian siltstone (Tindale & Mountford, 1936) are all emerged marine erosion caves. But that at Durras North, New South Wales, in Permian sandstone (Lampert, 1966) simply lies behind a prograded shoreline and no emergence appears to be involved; this may also be the case with at least one of the Triassic sandstone shelters used behind Dee Why Lagoon, north of Sydney (Etheridge, 1891). Temporary use of active sea caves has been suggested in connection with coastal fishtraps (Campbell, 1978a).

Massola (1969) stated that Aborigines made use of primary lava tunnels in the basaltic Western Plains of Victoria, though firm documentation of this was not found in preparation of this review.

Evidence for Aboriginal use of karst caves appears to be mainly archaeological but it incurs a wide range of rock type and age: highly crystalline limestones, Ordovician in inland Tasmania (Goede & Murray, 1977), Silurian in eastern Victoria (Flood, 1974) and New South Wales (Etheridge, 1893; Brennan, 1907), Devonian in West Kimberley (Froggatt, 1888; Playford, 1960), Cambrian in Northern Territory (Reay, 1962); in less compact Tertiary limestones in the Nullarbor Plain north of the Great Australian Bight (Wright, 1971; Milham & Thompson, 1976); in unequally consolidated Pleistocene aeolian calcarenite in the Southwest of Western Australia (Hallam, 1971; Dortch & Merrilees, 1973). A much used cave in Northern Territory, Yulirienji Cave (Mountford & Brandl, 1967) is a short, former river cave, modified by weathering, yet it is formed in siliceous cemented quartz sandstone; solution must have created it even if mechanical abrasion has enlarged it (Jennings, 1979).

THE HISTORICAL AND ETHNOGRAPHIC EVIDENCE ON CAVE USE BY THE ABORIGINES

The persistence of a hunter-gatherer people over a whole continent virtually to the present-day offered a great opportunity for documenting the human use of caves. However, search of the literature from the logs of 18th century sea captains following the coast, through the journals of the expeditions exploring the interior and the reminiscences of the early white squatters, to the formal accounts of anthropologists in this century where traditional tribal ways have survived in parts of the desert heart and the North does not prove as rewarding as might at first sight have been expected.

The Aborigines were nomadic though to different degrees; the richer the habitat the less frequently they needed to move to fresh food supplies so that in the most favourable circumstances movement might almost be reduced to a seasonal migration. Often they slept around their camp fires with virtually no protection from the elements. For these reasons, white observers rarely paid attention to their provision of shelter. It is symptomatic that, when in the second half of the 19th century it became urgent to gather information about Aboriginal ways of life and culture before these disappeared and questionnaires about the surviving tribes were sent out to various officials and settlers in South Australia (Taplin, 1879) and later through most of the country (Curr, 1886-7), in neither survey were questions put about habitations. Some other 19th century accounts are in response to J.G. Frazer's general questionnaire for world-wide use and it also overlooks this aspect of material culture. In her regional archaeology of New England, McBryde (1974) started with the 'proto-history' written by white settlers but she made no mention of 19th century Aboriginal use of caves, despite her overwhelming dependence on caves for excavation sites. Bowdler (1975) has been led to declare 'Curiously, very little can be gleaned from these sources pertaining to man's use of Australian caves. We are left, then, with a paradox; the type of site most sought after by the archaeologist was probably of least importance to the people who sporadically occupied it'.

For this review, 275 literary sources, which might be expected to yield something on this matter, i.e. they were not purely linguistic or sociological, were consulted. Considerably fewer than half, 116, included some mention, most commonly of the briefest, and the majority nothing, thus sustaining Bowdler's assessment. Poor though these sources may be, they are worth gleaning since it probably represents the best opportunity of this kind in the world. In doing this the wide range of uses to which caves are put by mankind must be borne in mind; they have served as dwelling-places, workshops, repositories, places of concealment, burial sites, ceremonial places, art galleries, mines, water and food supply points. The following table sets out the numbers of references on such

Fig. 1 Painting by Joseph Lycett of Aborigines sheltering from a storm in a sandstone cave on the South Coast of New South Wales c. 1820. (Reproduced by permission of the National Librarian, Australian National Library, Canberra).

Plate 1

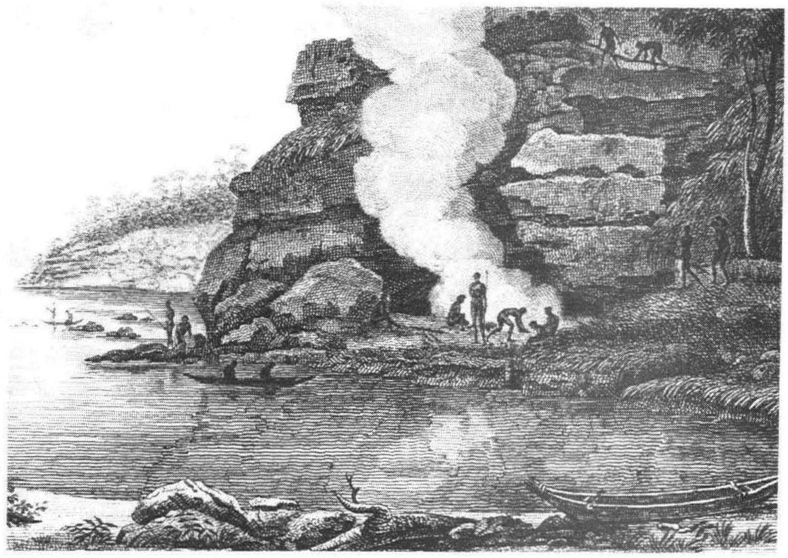


Fig. 2

Etching from a picture by Charles Alexandre Lesueur of Aborigines living in a sandstone cave on the shore of Port Jackson, New South Wales. From the second edition (1824) of the Atlas Historique of Péron and Freycinet's Voyages de découvertes aux Terres Australes. (Reproduced by permission of the National Librarian, Australian National Library, Canberra).

Fig. 3

Paintings in Linesman Creek Cave, Oscar Range, West Kimberley, W. Australia. The large figure represents the All Father, Nurunguni, of the Bunaba tribe's mythology.

Plate 2

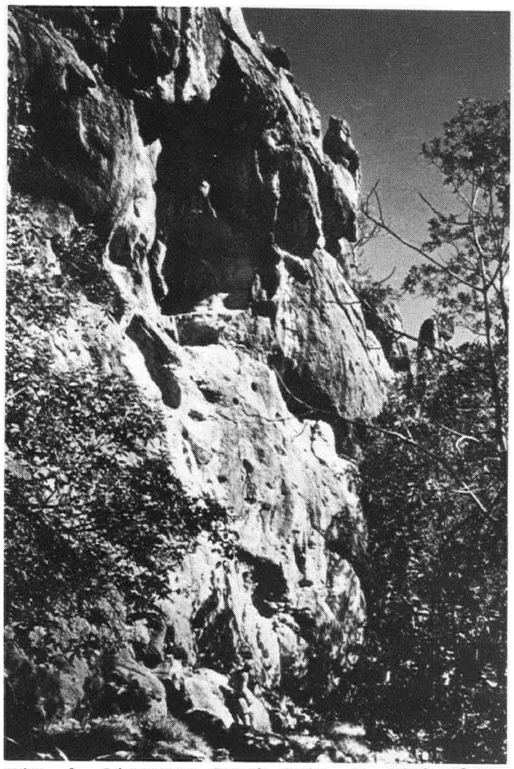


Fig. 1 Linesman Creek Cave, W. Kimberley. Entry into this karst cave from below is a difficult rock climb but there is an easier descent which the Aborigines used through darkness from the rugged limestone surface above. The figure of Nurunguni stands out impressively as one approaches.

Fig. 2 Looking out through the downstream portal of Winjana Gorge, Napier Range, W. Kimberley. In the wall of the gorge is a cave supposedly a retreat of the Aboriginal 'rebel', Pigeon, who hid from the police in this vicinity at the end of last century.

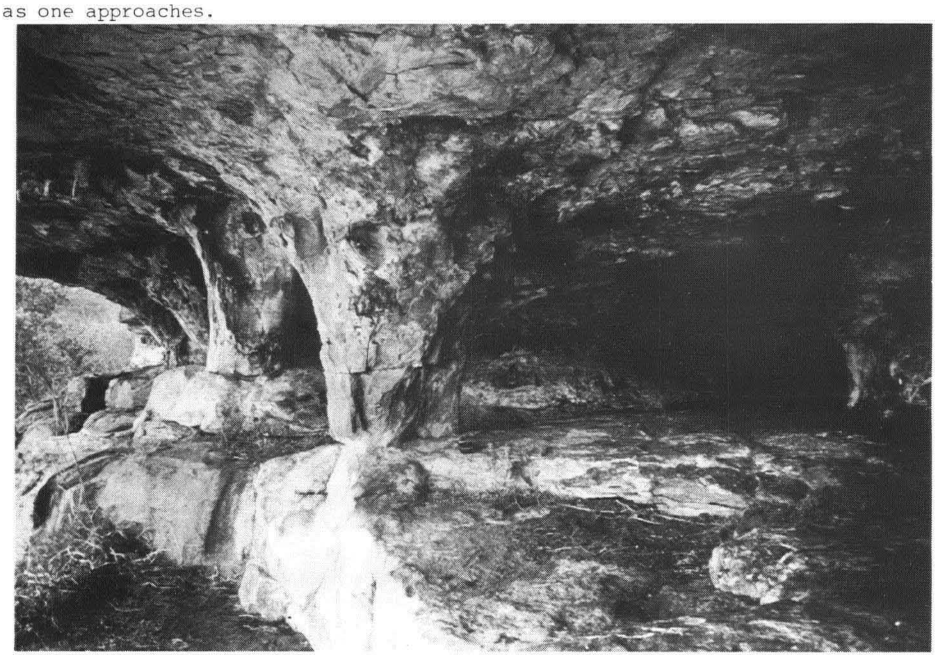


Fig. 3 Padypadiy is a weathering cave in Precambrian quartz sandstone high in a tabular outlier of the Arnhem Land plateau, N. Territory. The ancestors of the Kakadu people lived in this cave from about 3000 b.p. down to the present and painted its walls and roof.

functional basis but, of course, caves were frequently used for several purposes.

Use	Number of literary sources
Shelter/residence	51
Art	18
Ceremony	12
Interment	18
Storage	14
Refuge	7
Miscellaneous	12
In Legend	15

Shelter/Residence

A life of movement would have been conducive to taking advantage of ready-made shelter whenever this was wanted and conveniently placed so greatest recording of this function of caves is not surprising. The literature refers to a wide variety of such use from brief respite of the most adventitious kind to habitation as long-term as Aboriginal economies permitted. Collins (1798) at Port Jackson, Robinson (1829-34, in Plomley, 1966) in western Tasmania, Eyre (1845) on the River Murray, Lumholtz (1890) in coastal North Queensland, and Eylmann (1908) in central Australia, all described Aborigines sheltering from storms in caves. John Lycett depicted this recourse from the early days of settlement at Port Jackson, though the Aborigines had already acquired the supposed decency of apparel (Plate 1, Fig. 1). Scott (1963) found a family group stricken with sickness in a Sydneyside cave in 1789 and the frontispiece of Barrington (1798) showed in sentimental fashion a wounded Aboriginal and his sister prostrate with grief in the mouth of a cave near Sydney and it was to their normal home in a similar cave to which Barrington assisted them.

In the Sydney area the Aborigines made much long-term use of caves for dwellings. Tench (1793) said 'they depend less on them [constructed huts], than on the caverns in which the rocks abound' and this assessment is to be matched in Officer (1789), Hunter (1793), Collins (1798) and Barrington (1802). The scene (Plate 1, Fig. 2), pictured by Lesueur to illustrate Péron and Freycinet's *Voyages de découvertes aux Terres Australes* (in the 2nd Edition of the Atlas Historique, 1824) is thoroughly domestic, despite the fact that the female figures resemble more those of Parisian models than of Aboriginal women. Referring to the much later date of 1927, Hale & Tindale (1933-4) said of the life of the Aborigines of Princess Charlotte Bay, North Queensland, 'The only type of shelter to which the term "permanent" can be justly applied is that afforded by caves and rock shelters ... which, when commodious, are occupied by large bodies of natives, sometimes for long periods'. The natural food resources along the coast are, of course, concentrated enough for this to be possible in a way which does not apply to much of the continent. However with respect to the semi-arid Limestone Ranges of West Kimberley, Froggatt (1888) stated,'They build no mi-mis [bough shelters], as they obtain ample shelter in the numerous limestone caves'.

Many of the historical and ethnographic references to the use of caves verge on the inferential but usually convincingly as, for example, in Basedow (1907), 'At Blunder Bay, on the Victoria River, east of Endeavour Hill, a low cave, or rock shelter, was discovered in the quartzite range on the river frontage. The numerous mortars fashioned in slabs of rock for grinding ochre, utensils, soot-covered walls, and food remains showed that this cave has been, and still is, a frequent watering-place of the blacks'. Including such as these, more than fifty writings indicate the use of caves through much of Australia, though in this respect there are blanks on the map of diverse origins. Some of these blanks relate to an absence of caves in areas thickly populated for this continent with indigenes and comparatively well documented, e.g. along the middle Murray, the lower Murrumbidgee and Darling Rivers (Sturt, 1833, Beveridge, 1884). Here were built some of the best huts in Australia. By way of compensation, some areas which had caves were too unfavourable as human *oecumene* and were virtually uninhabited when white men came, e.g. the Nullarbor Plain north of the Great Australian Bight, which, however, had been peopled earlier. Caves at a distance from water in much of arid Australia would be of little use (Eylmann, 1908; Gould, 1968a). In yet other regions, the answer may rest in even more imperfect records about the life of the Aborigines than is generally the case. Apart from all these considerations, it would be a mistake to assume that all Aboriginal groups would behave in the same way given the same environment. Various writers, e.g. Oldfield (1865) and Basedow (1925), have referred to a fear of caves as haunts of evil spirits on the part of Aborigines. This may have been deliberately inculcated by elders for their own purposes but with some groups there may have been a complete tabu. Thus Campbell (1978b) considered the possibility that different hordes in neighbouring valleys of coastal New England behaved differently with regard to caves along the Clarence and Macleay Rivers, caves being used along the former but apparently not along the latter. Unfortunately, the literary record is inadequate for the effective pursuit of such questions.

The commonest reason given for the Aborigines living in caves is to get away from rain and the accompanying physiological cold, especially when accompanied by wind. In Hunter's words (1793), the Port Jackson Aborigines 'generally shelter themselves in such cavities or hollows in the rocks upon the sea shore as may be capable of defending them from the rain, and, in order to make their compartment as comfortable as possible, they commonly make a good fire in it before they lie down to rest; by which means, the rock all around them is heated as to retain its warmth like an oven for a considerable time'. Even in the arid heart of the continent, rain is erratically heavy. According to Winnecke (in Worsnop, 1897), large caves were relied on by the natives during excessively wet seasons in an area northeast of Alice Springs; in the Warburton Ranges, rock shelters are used as refuges during occasional torrential rains (Gould, 1968a). Tindale (1974) pointed to the additional reason of avoiding fires being doused by rain.

Greater use still has been made of caves in the wet season of the humid northern fringes of the continent as in Arnhem Land (Spencer, 1914; Gray, 1915; Tindale, 1925-6) and North Queensland (Hale & Tindale, 1933-4). This is also the hot season so along the northern escarpment of Arnhem Lane, 'there are long processions up the hills to occupy rock shelters at night; here they camp free from mosquitoes in comparative coolness, shifting from the northern to the southern face and *vice versa*, according to the direction from which the monsoonal winds are blowing' (Spencer, 1914). This protection against mosquitoes (no doubt supplemented by smoke filling the cave), mentioned by other authors, is complemented by the special modifications to huts made against insect pests by northern coastal tribes where caves are absent or not used, as in Melville and Bathurst Islands (Hart & Pilling, 1960).

This appreciation of the atmospheric elements suggested by the choice of slope in relation to wind exposure is reflected also in the habits of the coastal desert peoples from the Fortescue River to the Fitzroy River in Western Australia; according to Clement (1903), 'a day before the wiliwili (native name for a violent cyclone that usually comes in the month of February or March with torrential rains) the blacks go up into the hills and hide in caves and they are wonderful weather prophets'.

When water is more widespread in the wet season, it is easier to use caves than in the dry when only those near waterholes can be occupied for long (Basedow, 1904; Davidson, 1935).

Absolute cold is given by some authors to explain the use of caves in the southern half of arid Australia (Eyre, 1845; Tindale, 1974). However, a more persistent reason for spending time in caves in the centre and in the North is to obtain shade from the sun. Often bough shelters were used for shade during the day, not against cold in the night (Schulze, 1891; Wells, 1894), thus matching the use of caves for the same purpose. Reduction of body water loss is very important and bough shelters, though easy to construct, are not so effective in this respect as a carefully chosen cave (Basedow, 1904; Spencer, 1914). Basedow (1925) wrote 'in mid-summer months, when the heat of the sun becomes intense, he [the Aborigine] often finds his way to the same haunts to have the full benefit of the shade the solid walls of rock produce'.

Thus climatic factors can induce cave occupation at a particular season or during particular weather spells over much of Australia. Nevertheless it must be noted that there is minimal literary evidence for this practice from some of the wettest parts of the continent where the inducement might be expected to have been high. This is true of western Tasmania and parts of coastal Queensland where substantial huts were constructed, however.

Art

More human use of caves and rock shelters in Australia is registered by paintings and engravings than by other evidence (Plate 1, Fig. 3). The numbers of such caves certainly amount to many hundreds, probably thousands. In caves, more paintings are found than engravings, whereas the reverse is true with open sites. This may simply be a product of differential survival of engravings at the latter or possibly that the more elaborate engraving takes much time and so is more conveniently practised at open sites. Despite the great frequency of cave art, evidence of artistic activity taking place during the last two centuries does not emerge strongly from the literature. Many claims have been made that paintings seen were modern but it is not as easy to be sure of this as it is with relics of everyday living in caves which deteriorate more rapidly such as food.

However, a number of writers have actually observed painting in progress, though these accounts are chiefly of this century and so the occurrences belong to the desert or the North where traditional life persisted longest. Thus Gould (1968b) has seen both fresh paintings being made and older ones retouched by men of the Ngatatjara people near the Warburton Ranges in Western Australia. Engravings, however, were not seen in preparation. Brandl (1973) described painting going on in 1965 near the Cadell River in Arnhem Land. According to Edwards (1966) the Walbiri were still maintaining the decoration of caves near Yuendumu in Northern Territory. Tindale and Lindsay (1963) showed a photograph of a Pitjandjara man drawing on a cave wall in the Musgrave Range, South Australia, in 1933; and Hale and Tindale (1933-4) described people of Princess Charlotte Bay, Queensland 'as absorbed as children during their recreation' in this activity. In the early part of this century, Love (1917, 1936) watched hand stencilling and retouching of proper paintings by men in North Kimberley. So also did Dunbar (1943-4) remember from his youth hand stencilling being done in the central Darling River area of New South Wales; likewise it was reported in Curr (1886-7) that the Aborigines of the Cape River, Queensland, were making hand stencils.

Less direct evidence is accepted by many writers. Bennett (1895) and Mathew (1889) accepted the statements of other Europeans that they had seen natives painting caves in the Sydney area long after white settlement. Wilson (1946) depended on an Aborigine indicating a cave near Louth in western New South Wales in which members of his tribe used to paint. Macintosh (1952) and Crawford (1968) seemed to rely on learning about the social and territorial rules applying to painting as evidence of persistence of the practice in Northern Territory and the Kimberleys respectively. Stirling (1896) was told about painting methods by Aborigines in central Australia. Explanations of the meanings of paintings by Aborigines are cited by many authors but this is much less sure indication that these have been executed in the last two centuries. Mountford (1965) compared photographs taken in 1930 and 1940 at Ayers Rock to prove painting had gone on in the intervening decade, whilst at many places the inclusion of steamships, firearms, horses, goats, white man's hats, bicycles, motorcars, etc. have been used to prove the modernity of cave art (Mountford & Brandl, 1968, at Ingaladdi, Northern Territory; Crawford, 1968, in North Kimberley; Chaseling, 1957, at Yirkkala, Arnhem Land; Le Souef, 1907, near Mt. Peter Botte, Queensland; Tindale, 1972, in northwest South Australia).

There is divergence in the literature about the purpose of painting in this modern period. Much of it is undoubtedly recreational in nature, stimulated by aesthetic impulse. Mountford (1956) simply put much down to enforced leisure during the wet season in Arnhem Land and Basedow (1925) thought that sheltering from the heat of the day had the same effect. Stencilling of hands, feet and spear heads in a weathering cave in sandstone in the Ruined City in southeast Arnhem Land was dismissed to me as child's play by the guardian of this totemic area. According to Dunbar (1943-4), with the Ngemba tribe of the central Darling River, hand stencils were made by women and children, not by initiated men, and they had no tribal significance. However, other observers report that even hand stencils had important meaning. To one of Crawford's informants, they were a mark of belonging to that place (so of ownership in Aboriginal terms) and therefore could only be made in territorially appropriate places (Crawford, 1968). They relate to the individual's spirit which survives after death. According to aboriginal informants in Cape York Peninsula (Trezise, 1971), stencilling was involved in sorcery and hunting magic.

There is abundant evidence that many paintings represent parts of Aboriginal conceptions of the Dreamtime, when ancestral spirits created the world, including the striking physical features associated with the totems of the various sections of their societies. For example, there are the various paintings representing the All Father, such as the Winjina figures of the Kimberleys (Crawford, 1968). Crawford attributed the failure to maintain cave paintings to the decline of ritual in tribes there. So that much of the art is sacred or religious in nature. Conversely the maintenance of the paintings associated with Dreamtime stories helps in the perpetuation of the stories themselves (Tindale, 1972).

Closely associated with this is the probability that some of the art had magical purpose as, for example, to promote natural increase, both in the tribe itself and in the game which they hunted, and to bring rain (e.g. Macintosh, 1952). In contrast some pictures were involved in sorcery, aiming at killing breakers of tribal law (Hale & Tindale, 1933-4). As a consequence of these sacred and magical purposes, as distinct from the aesthetic pleasure of painting which was compatible with domestic use of caves, certain caves were forbidden to all but initiated males as in the cases of the people around Limbunya, Northern Territory (Meggitt, 1955) and of Princess Charlotte Bay, Queensland (Hale & Tindale, 1933-4).

Aesthetic feeling was, of course, just as likely to be a component of these more serious decorations as of those conceived in lighter mood. Grey's account (1841) of how he came across one of the best painted caves in North Kimberley reveals how successfully the native artist had positioned and drawn his Winjina paintings for dramatic effect. Similarly impressive is the life-size human figure looking down from a cave in Linesman's Creek, Oscar Range, West Kimberley (Plate 2, Fig. 1). Helms (1896) commented on the sensitivity with which Aboriginal artists incorporated natural shapes in the rock into their compositions.

Just as in some areas caves may not have been used for domestic purposes, it appears that there are similar gaps in artistic use of shelters. Thus McCaskill (1977) finds that all art in the upper Gascoigne River district is out in the open; the desert climate here, of course, favours survival of exposed art.

Ceremony/magic ritual

Despite the undoubted spiritual content of much of the cave paintings and engravings, there are very few references to ceremonies being carried out in the caves; indeed the literature makes it readily clear that corroborrees generally took place in the open, though this might sometimes be near painted caves. Thus in central Arnhem Land, there is a 'road' from a corroborree ground to a nearby cave (Arnt, 1962) and at Copmanhurst, New South Wales, the corroborree ground was in front of a cave (McBryde, 1978). However, Macintosh (1952) reported that Beswick Creek Cave, Northern Territory, was still in use for ritual and Hale and Tindale (1933-4) found that painted caves on Clack Island in Princess Charlotte Bay were employed by elders for sorcery; McCarthy (1960b) said the same for caves on Groote Eylandt in the Gulf of Carpentaria. Hambly (1936) stated from secondary sources that with the Aranda tribe of Northern Territory male initiation involves each young man sleeping a night in the entrance of a cave supposedly occupied by evil spirits.

Interment

Primary burial in caves is rarely reported in the Australian literature, though Froggatt (1888) wrote of West Kimberley 'The corpses of old men and children, however, are swathed in paper-bark and placed in clefts in the rocks out of reach of wild dogs. In some caves ... we found scores of these remains, many of the skeletons quite perfect'. Secondary interment of mummified skeletons or bundles of bones and skulls was widely practised and rooms and crevices in caves were used as well as clefts in cliff faces. This was true in the Buccaneer Archipelago, Western Australia (Bird, 1911); East Kimberley (Davidson, 1935); Northern Territory (Mathews, 1901; Tindale, 1925-6; Davidson, 1935; Chaseling, 1951; Mountford & Brandl, 1967); Keppel Islands, Queensland (Roth, 1901-10); southeast Queensland (Petrie, 1904); Yorke Peninsula, South Australia

(Tindale, 1936b); New South Wales (Bennett, 1834); Victoria (Massola, 1969); and Tasmania (Bonwick, 1870). At Groote Eylandt, thigh bones, shoulder blades, skulls, etc. were segregated in different caves (Tindale, 1925-6). These practices would, of course, enhance the ritual significance of such caves and might induce fear on the part of some Aborigines about visiting caves.

Storage

The same is true of the widespread practice of storing sacred ritual objects or *tjurunga* in caves, (e.g. Edwards, 1966, in respect of the Walbiri at Yuendemu in Northern Territory). These comprise a variety of objects from engraved ceremonial boards (Campbell, 1910), bullroarers (Meggitt, 1955), polished, smooth stones (Love, 1917) to lumps of calcite with supposed magical properties (Davidson, 1935). The entrances of such sacred storage caves were sometimes walled up (Spencer & Gillen, 1899). Strehlow (1970) reported the killing of an Aborigine who showed white men the whereabouts of a sacred cave of the Aranda tribe, Northern Territory; little wonder when on the Horn Expedition of 1895 the Director of the South Australian Museum removed fifty stone and wooden tjurunga from a cave in central Australia.

Caves were also used on occasion for the dry storage of profane objects such as bundles of native tobacco and of a poisonous plant, *Duboisia hopwoodi,* used in waterholes so as to stupefy emus and make hunting easier (Finlayson, 1935). Tindale (1928) described the storage of a yam knife in a dilly bag on a wooden frame in a Northern Territory cave; as it is made from the shoulder blade of a goat, it must belong to modern times. The Pitjandjara of the Western Desert store sticks and grass in caves for relighting fires which occasional torrential rains put out (Tindale, 1972).

Legends

Given the various uses for caves, especially those other than the domestic, it is not surprising that caves enter into many of the legends of the different tribes. These were not sought out in the literature and there is no doubt that many more sources could be found than the total of 15 enumerated above. However it puts the matter into better perspective to note that in only 5 myths out of 102 collected by Massola (1968) was mention made of them. A problematic legend including a cave comes from Bentinck Island, Queensland, where the cave is located on a tidal creek with no caves nearby in reality (Tindale, 1961a). For the caver, perhaps the nicest legend is that the Ngatatjara tell of their sacred cave, Kalkakutjara. The Two Men, totemic ancestors, travelled northeast in the Dreamtime and constructed a shade-shelter; this became a rainbow and turned into stone, becoming the granite archway to a large rockshelter (Gould, 1968b).

Water supply

Caves are commonly in other countries a source of drinking water where surface water is scarce at all times or seasonally. These conditions apply to most of Australia, and many accounts of white explorers reveal how skilful the Aborigines were at finding water. Nevertheless there is minimal reference in the literature to caves being used in this way by the native people. There is the notable exception of the limestone cave in an extremely dry stretch of the Canning Stock Route through the Gibson Desert in Western Australia where Carnegie (1898) found that the Aborigines descended by poles 9 m to Murcoolia Ayah Tenjah which he renamed Empress Spring. Massola (1969) said that the Aborigines of the basalt Western District of Victoria obtained water from lava caves, whilst the desert Aborigines of the Warburton Range, Western Australia, relied on a trickle of water at the back of a cave at Wiintjara (Gould, 1969). Tindale (1974) could be referring to the same cave when he figured a cave with a creek flowing through it in this area. According to Tindale (1974), Albadakarroo Cave in the limestone Nullarbor Plain means 'descending place of ants' and is so named because the Aborigines followed the indication that lines of ants gave to water below. Water was collected from cave driplines in the Laura caves in Cape York Peninsula during the wet season (Trezise, 1971).

Source of food, etc

Caves provide important food resources in some parts of the world such as edible birds' nests in southeast Asia and cave bats in the highlands of New Guinea where protein sources are not plentiful. Basedow (1914) found stone ladders built by Aborigines of the Mt. Gosse Range in northwestern South Australia to get into granite caves in which owls and insectivorous bats lived. It is surprising that no record could be found of the Aborigines hunting fruit bats in those tropical caves such as Tunnel Cave in West Kimberley where these bats live in the twilight zone, for they certainly used them on the surface as a food supply, taking them from trees. Another resource found in the threshold area of caves in the desert country is the most prized of the native tobaccos, which several tribes sought out in these places. 'In remote cave mouths they often glean a harvest of mingul (*Excelsior excelsior*), the native chewing tobacco, which grows best near the entrance to old caves and rock shelters, where enriched soils, shelter from the wind, and the higher humidity of south-facing cave mouths, enables the luxury plant to grow to perfection', writes Tindale of the Pitjandjara of northwest South Australia (Tindale, 1972).

It would be surprising if some ochre mining was not begun on the surfaces of natural caves in laterite profiles. However, there is no extant record of this and the large cavity of Wilgie Mia in Western Australia near Cue is entirely artificial and a remarkable testimony to the efforts of the Aborigines with their limited technology (Woodward, 1914).

Refuge

Finally there is the question of the taking of refuge in caves from men rather than the elements. Certainly the Aborigines retired to them promptly enough when contacts began to be made with white men. Flanagan (1888), referring to the early days of Port Jackson settlement, noted, 'On the approach of the military the women and children took shelter in a cave while the men came boldly forward', and Bonwick (1884) had a similar incident from Richmond, Tasmania, in 1827. In Eylmann (1908), a family is described as hiding from a police search in a cave near Gosse's Bluff Range in northern South Australia. Woods (1862) and other authors reported on a desiccated corpse in a Mt. Gambier limestone cave in the southeast of South Australia. Apparently the Aborigine had been one of a marauding group attacking white settlers, was wounded by the police and crept into the cave as a refuge where he died; 'When after a long time, his remains were discovered, the limestone had encased him in a stoney shroud! His next fate was to become an exhibit for a travelling showman'. At Windjana Gorge through the Napier Range, West Kimberley, a cave high in its wall is pointed out by local people as Pigeon's Cave (Plate 2, Fig. 2). This attribution may be doubtful since Serventy (1969) refers to Tunnel Cave some distance away in the same Napier Range as the refuge in question, but what is sure is that Pigeon, a police tracker who killed two white stockmen, retreated to these rugged limestone ranges with many caves in them, which he used as a base whence he and his band harried travellers on the Derby to Fitzroy Crossing track for two and a half years late last century (Buchanan, 1953). It is unlikely that the Aborigines only learnt of these advantages of caves when white men came. Tribal fighting was often rather stylised in pattern but in some circumstances the weaker fighting group might well have retreated to rough country with caves. Tindale (1914) wrote of the Wardibara retreating during tribal fighting to camp in inaccessible, forested gorges along the North Johnstone River, North Queensland. At the individual level, two young Aborigines, accompanying Howitt (1876), thought that the Den of Nargun in difficult East Gippsland terrain 'would be a splendid place to run off with one of the Aboriginal young women - a house already provided, plenty of wallabies and native bears, and a country unknown to other blackfellows'.

Verdict

The recording of Aboriginal traditional life since European encounter began and before its virtual destruction today has been generally inadequate. Nevertheless one cannot escape the impression that the limited account available of Aboriginal use of caves was in some degree a true measure of their relative degree of importance to this hunter-gatherer people and that the paradox, which Bowdler (1975) recognised between their modest real importance and great archaeological importance, does not arise from this general poverty of written record.

PREHISTORY FROM AUSTRALIAN CAVES

Despite the undoubted importance of cave sites in Australian prehistory, they were neither the first kind of site to be investigated nor do they reach farthest back in time. In 1788, Captain Phillip excavated an Aboriginal grave in the open at Port Jackson, almost immediately after founding the first British settlement there. This was an isolated effort and those early days saw chiefly the removal of thick shell middens from the sandstone caves around Sydney for lime burning and fertiliser (Hunter, 1793).

Stone technology

Some escaped this treatment, however, and the earliest scientifically conducted and recorded excavations were made in them by geologists familiar with the principle of relative chronology from superposition (David & Etheridge, 1889; Etheridge, 1891). Their example was not followed till 1929 when Hale and Tindale (1930) dug skillfully and productively in a weathering cave in the limestone cliffs of the River Murray at Devon Downs. The 6 m of deposits had artefacts throughout but could not then be given absolute dates. Employing distinctive tools as 'type fossils', Hale and Tindale considered the occupation of the site had passed through three successively older cultural periods, the Murundian, the Mudukian and the Pirrian. An open site nearby and open sites on Kangaroo Island led Tindale to add two older cultures, the Tartangan and the Kartan. On much the same basis from Blue Mountains sandstone shelters, McCarthy (1948) set up an analogous sequence of the Eloueran and the Bondaian, to which was added subsequently the earlier Capertian (1964). Tindale made Australia-wide correlations on the basis of his fivefold sequence (Tindale, 1961b). Thus these first efforts at establishing a cultural prehistory depended in large measure on cave stratigraphies.

The next major advances in Australian prehistory also came from such sites. Mulvaney (1960) excavated another Murray River cliff shelter at Fromms Landing notfar from Devon Downs. Both of these sites could now be dated by radiocarbon and both had an occupation span of about 5000 years from the present. The prime result was that the Pirrian, Mudukian and Murundian cultures could not be distinguished at Fromms Landing, where the sequence was interpreted in terms of local adaptations in a broad continuum. Whole assemblages of tools and associated stone material needed to be approached quantitatively and this Mulvaney did at Kenniff Cave in the Carnarvon Range, Queensland, which became the first site of any kind to prove without doubt that man had lived in Australia in the Pleistocene. Kenniff Cave, a rather elaborate sandstone cave, to which running water contributed as well as weathering, yielded the first long sequence of occupation to be investigated, lasting from 19,000 to 10,000 B.P., with a hiatus and then re-occupation from 5000 B.P. to the present. There was a great variety as well as a large number of tools, including most types already recognised, and cores and waste flakes (Mulvaney & Joyce, 1965). In this material, Mulvaney recognised two technological stages. The earlier stage, lasting virtually unchanged some 10,000 years, has since been designated *the core tool and scraper tradition* or industry. The later stage, whilst retaining the older tools, had various small tools as well - points, backed blades and other specialised tools, in effect both the South Australian suite of Tindale and the New South Wales suite of McCarthy. These came in rapidly about 5000 years ago and hafting of some of these tools was regarded by Mulvaney as distinguishing this phase, which later became known as the *small tool tradition*. The 'cultures' of Tindale and McCarthy, where validated by fuller artefactual analysis, fall into place as regional or local variants of one or other of these basic industries.

Today this assessment stands broadly confirmed by numerous workers, both at open and cave sites, though the date and order of appearance of the new tools of the small tool tradition have been shown to vary from place to place (Plate 2, Fig. 3). The most important revision relates to the sequence of non-hafted and hafted tools tied to the two major stages by Mulvaney. In three sandstone shelters near Oenpelli in Arnhem Land, White (1967b) excavated ground-edge axes, some grooved for hafting, at horizons dated preliminarily at greater than 20,000 B.P. - thus the oldest 'Neolithic' axes in the world. This was so disconcerting at the time that both I and M.A.J. Williams were asked to examine the stratigraphy from the point of view of the natural scientist to see if disturbance of some kind of the horizons could have caused a false dating of these finds. We found no such disturbance and could only recommend check dating in a different laboratory. This indeed confirmed the ages at between 20,000 and 25,000 B.P. Thus grinding and hafting have been shown to have been practised much earlier along the northern fringe than elsewhere in the continent where they have so far been found only in association with the small tool tradition.

Thus to the present times caves and rock shelters have contributed more than open sites to the history of the stone technology of the Aborigines.

Oldest evidence of man

The oldest human evidence yet known in Australia comes from open sites of contrasting kind. The more informative are occupation horizons in lakeshore beach and dune deposits of the former Lake Mungo and neighbouring playa lakes in semi-arid western New South Wales where there are stone tools and ochre lumps in horizons lower than one dated from freshwater mussels humanly gathered at some time in the range 34,100 - 37,400 B.P. (Mulvaney, 1975). River terrace deposits of the Maribyrnong River near Melbourne, which indlude humanly worked quartzite flakes, can only be dated by extrapolation from a younger radiocarbon-dated terrace, allowing for river deposition, soil formation and river incision (Bowler, 1976). This gives a reliable approximation of between 36,000 and 45,000 years B.P. When these surface discoveries were made, the record of cave occupation fell substantially short in the 20,000 to 25,000 year bracket. However, deeper and deeper digging in Devils Lair in the Pleistocene aeolian calcarenite of the Southwest of Western Australia has taken the oldest artefact horizon successively back from 12,000 B.P. (Dortch, 1974) to 25,000 B.P. (Dortch & Merrilees, 1973) and finally to 38,000 B.P. (Dortch, 1979). Devils Lair is a karst cave in the side of a collapse doline, with several metres of fill including rockfall, flowstone and surface soil entering by the present and a former roof entrance. There is the possibility of even earlier occupation because encrusted stones and bones in the lower layers are thought to come from reworked deposits older than 38,000 B.P. Six other caves have yielded evidence of human activity dating back to more than 20,000 years B.P. Two are in karst caves in the Nullarbor Plain and four are in sandstone shelters, two in Arnhem Land and two in New South Wales, of which one is near sea level on the South Coast and one high up in the Blue Mountains. There are only about the same number of open sites beyond this (arbitrary) limit of 20,000 years. Cave breakdown is encountered in many cave sites and some excavations in them have been halted by large rocks, e.g. Cave Bay Cave, Hunter Island, Tasmania (Bowdler, 1974), Koonalda Cave, Nullarbor Plain, South Australia (Wright, 1971). The older the cave deposit the more likely it will be that such an end to excavation will happen before the rock floor is reached. So it may be quite fortuitous that the oldest sites so far found in Australia are open ones.

Changing use of caves

Bowdler (1975) observed that Australian caves were less intensively used by man in the Pleistocene than subsequently and gave as a possible reason for this a former less dense population. The arguments in support are twofold. In the Sydney-South Coast of New South Wales, and in the coastal Oenpelli region of Arnhem Land, Northern Territory, many more cave sites were occupied in the last five thousand years than previously. Also for a number of caves, Devil's Lair, Western Australia; Seton Shelter, Kangaroo Island, South Australia; Cave Bay Cave, Hunter Island, Tasmania and Cloggs Cave, Victoria, it is claimed that evidence for cave occupation in the Pleistocene is meagre compared with that of thick, dense middens which accumulated in recent millennia at the Rocky Cape Caves on Tasmania's northwest coast and Cave Bay Cave itself. This explanation perhaps needs some amplification. The coast is preferentially favourable as a habitat for hunter-gatherers like the Aborigines, with fish and shellfish and coastal swamp plant products to be tapped as well as inland products. At the time of white settlement, the Aboriginal population seems to have been denser along the coasts than inland round much of the continent. Once the Pleistocene antiquity of man in

Australia was proven, most prehistorians (e.g. Mulvaney, 1964) have argued that the Aborigines crossed from southeast Asia during low sea levels in the Last Glacial period when New Guinea and Tasmania were linked by land to the continent. Bowdler (1977) in particular has gone further and postulated that colonisation proceeded preferentially round the coastline of that time. Whether this was so or not, there is nevertheless good reason to think that much of the population in the Last Glacial was concentrated on the then coastline and retreated with it during rising sea levels of the Holocene, which reached the present level about 5000 years ago. At that juncture the caves and shelters of the present coastal belt would have been subjected to much more pressure of use than before. However, these coastal tribes might well have been occupying at a similar intensity coastal caves along low sea level shorelines where such existed (cf. Beaton, 1978). This conception of Aboriginal prehistory satisfies Bowdler's arguments presented above without any increase in continental population in this sense of a Pleistocene low sea level 'greater Australia' and without any change in attitudes about cave use, even if there was a higher proportion of rocky coast in the Holocene than in the Pleistocene. This modified view needs itself qualifying in the light of Lampert and Hughes (1974). They have argued that improved fishing technology in the last 4000 years permitted a real increase in coastal population in this period. In addition they maintain that steady sea level is necessary for the geomorphic elaboration of coastal environments to provide a favourably diverse human habitat. This would not have happened during the rapidly changing sea level of the end of the Pleistocene and the early Holocene and an economically favourable environment along the coast before now would not have prevailed until one reaches back to the time of the Last Glacial maximum, perhaps 15,000 to 20,000 B.P.

Whatever the balance between these different factors affecting the intensity of coastal cave use in the Late Holocene, there is the separate question as to whether there have been changes in the proportions of open and cave site use with time. For example, Stockton and Holland (1974) think that there has been variation in the relative use of huts and caves in the Blue Mountains. A decline in cave use since 1000 B.P. is attributed to an increase in warmth and dryness but the improved tools available promoted this interchange, with edge-ground axes for hut construction and points for making skin cloaks. Analysis of the Australian chronological table in Mulvaney (1975) allows a crude approach to the problem in general, making the assumption that excavated sites are representative of all occupied sites in this respect.

Date of first occupation	Total number of sites	Ratio of open to cave sites
30 - 40,000 B.P.	3	2.0
20 - 30,000	10	0.7
10 - 20,000	14	0.4
5 - 10,000	17	0.3
0 - 5,000	20	0.5

This suggests little change in the relative use of the two kinds of site between the two times of stable sea level in the latter part of the Holocene and at the Last Glacial maximum. There is a change before that but the sample size is small so that the figures may not be significant. Differential preservation of the more vulnerable open sites might be expected to have led to a lower ratio for this early time rather than the greater one seen here. However, the table does suggest that it is not possible to explain the larger numbers of occupied cave sites towards the present in terms of progressive loss of sites by natural destruction.

Human skeletal remains

In some important respects caves have not contributed to Australian prehistory as much as the high proportion of excavated sites they have provided might suggest. Virtually all the fossil man sites, which have been subject to much discussion, are open sites - Talgai, Cohuna, Mossgiel, Kow Swamp, all with some primitive *H. erectus* skeletal characteristics and only the last one dated; Keilor, Green Gully, Tartanga, Lake Mungo, Lake Nitchie, all with modern *H. sapiens* characters and all but one dated.

This is despite the fact that burials have been encountered in several cave excavations - Kongerati Cave, South Australia (Tindale & Mountford, 1936); Balls Head, Port Jackson (Bowdler, 1971), Oenpelli, Arnhem Land, Northern Territory (McCarthy & Setzler, 1960); Gymea Bay, Port Jackson (Megaw, 1966); Fromms Landing No. 6, South Australia (Mulvaney, Lawton & Twidale, 1964). Many caves were, of course, stripped of skulls at an early stage without thought; thus Brennan (1907) noted a former stream cave in the limestone of London Bridge, New South Wales, as 'a veritable catacomb on a small scale. It was a limestone cave, wherein were found many hundreds of human bones and skulls, centuries old! I had several bags of them conveyed to Queanbeyan, where they were carefully inspected by three surgeons, including Coroner Morton, who pronounced them to be the skeletons of Aborigines of former times'. However, most of the bones lost to science in this way were probably not in stratified material and so their value for prehistory would have been limited. They might, nevertheless, have answered the question whether there is reality in arguing from the presently available evidence that the men with primitive physical traits did not inhabit caves in Australia. Some of the failure of excavated cave burials to have caused much scientific interest arises from the facts that most of them have been of children and women, less useful in terms of physical anthropology and that most cave burials are secondary interments, again less interesting than primary. Some of the interest in the open fossil men sites has derived from the burial practice as well as the anatomy of the bones.

Environmental archaeology

The discussion above which brought in eustatic movements of sea level is typical of much Australian prehistory in that there has been great concern to relate the human evidence to reconstructions of environmental history. As with human skeletal remains, however, cave sites have contributed only moderately to providing the context of changing habitat, which has come more from open sites. For instance at Lake Mungo and its neighbourhood in western New South Wales inorganic sediment sequences have revealed drastic changes of hydrology and climate over the last 40,000 years. At Wyrie Swamp in the Southeast of South Australia it is pollen analysis of peat and clay which has revealed the vegetation history over a similar period and here wooden artefacts have survived in the upper layers. Much of the late Quaternary envionmental history so far known in Australia has, of course, been reconstructed from evidence unrelated to any archaeology as, for example, Lynch's Crater in Queensland where the vegetation and climatic history of the last 120,000 years has emerged from pollen analysis of a former lake's deposits. By comparison, cave deposits have proven of much less promise for the working out of environmental history as opposed to the detail of the caves' evolution. Frank (1975) made a very close sedimentological examination of the deposits in caves at five areas in the western part of the Central Tablelands of New South Wales yet only very broad indications of the relative wetness and dryness of the surface could be derived and no indications of temperature regimes. Similarly Shackley (1978) could draw out little of general environmental import from the long sediment sequence in Devils Lair, Western Australia, though these sediments did contribute to the working out of the cave's own history substantially (Balme, Merrilees & Porter, 1978).

The Nullarbor Plain may be indicative in this matter. Frank (1971a) studied the sediments in a deep excavation in Koonalda Cave there but once again the changes were to be interpreted in local terms and the climate when surface sediment was washed in about 20,000 years ago could not be distinguished from that of the present. Frank pointed out that this may simply be because the processes preparing, transporting and depositing the mineral sediment may not have been very sensitive to climatic change. That there was a small degree of climatic change over this period was concluded by Martin (1973) from pollen analysis of the sediments in three archaeological digs in other caves in the area. From 18,000 to 9000 B.P. treeless shrubland extended nearer to the present coast than it does now and the present pattern had been established by 5000 BP. This is explained as a change from drier conditions than those holding now. Despite this sequence, Koonalda Cave was used by man during the earlier somewhat drier period and abandoned about 13,000 B.P.

(Plate 3, Fig. 1). This appears to be only indirectly due to climatic change through the loss of valuable tribal territory on the continental shelf as the sea rose rapidly between 16,000 and 12,000 B.P. (Wright, 1971). Lundelius (1976) recently claimed that a major climatic shift in climate is indicated by a change from clay deposition in Madura Cave, which prevailed between 22,000 and 16,000 B.P., to subsequent silt accumulation; the stratigraphy was described by Lundelius and Turnbull (1973). Lundelius did not state in which sense the climate is supposed to have changed, though he had earlier claimed that the presence of an extinct, large kangaroo of the *Sthenurus* genus in the older deposits indicated a more humid climate then than later (Lundelius, 1963). Thus in magnitude, sense and timing this claim is in disagreement with Martin's evidence and with Frank's cautious assessment, both of which must be preferred until Lundelius argues his case more fully.

Pollen from excavated sediments of Cave Bay Cave, Hunter Island, (Hope, 1978) showed sequences demonstrating amongst other things that grassland and shrubland prevailed around the cave in the Pleistocene between 28,000 and 15,000 years ago. With evidence from other sites this has been taken to mean that cold and dry conditions prevailed over the plain of the exposed Bass Strait, whereas previously it had been assumed that at that time dense forest would have occupied this plain and acted as a barrier between Victoria and Tasmania. Australian caves, even in limestone, have as yet failed to yield suites of fossil molluscs which have proved so valuable in many European caves as palaeoenvironmental indicators.

Tasmania approximates more closely to Europe latitudinally and some of its caves have come closer to matching European ones in the significance of their entrance facies. Thus in the Cave Bay Cave excavation angular roof detritus from roof fall looms large between about 18,000 and 15,000 B.P. and there is a corresponding decline in use of the cave at that time (Bowdler, 1979; Hope, 1978). Bowdler attributed this to the effect of frost wedging reaching into this shallow cave in this period (known in Tasmania from glacial and periglacial deposits to have been cold). More intimate interaction of changing natural processes with archaeological material has been found in Beginners Luck Cave, a karst cave in Ordovician limestone in the Florentine valley, the first inland Pleistocene archaeological site to have been found in Tasmania (Goede & Murray, 1977). Here are two sedimentary units, the lower consisting of high energy stream gravels fed in early in the Last Glacial stage. The second unit is of limestone breccia, which includes artefacts and bones that represent human food refuse. A minimal date of 12,600 B.P. was obtained from a bone tool. Humans lived in the cave mouth, perhaps only in summer for frost wedging was taking place as well; solifluction mixed and moved everything into the cave where later it was covered by flowstone and subjected to erosion in the Holocene. Goede, Murray and Harmon (1978) found a dolomitic breccia was similarly emplaced in Pleisto Scene Cave, a karst cave in Precambrian dolomite in northwest Tasmania, in the period 25,000 to 11,000 B.P., though this cave was never occupied by man.

On the mainland, Pleistocene glaciers were restricted to a very small area in the Snowy Mountains in southernmost New South Wales, but periglacial deposits are considered to reach to the Northern Tablelands in this state, with a rising lower limit northwards, of course. As yet no association between such deposits and human occupation in caves has yet been established, though frost breccias have been recognised in limestone caves in the Southern and the Central Tablelands. In the Capertee valley in the Central Tablelands, Walker (1964) was able to correlate sediments transported into sandstone shelters, which revealed occupation reaching back to 7600 B.P. (McCarthy, 1964), with the slope deposits of the hillside around with their sequences of K-cycles. These are alternations of instability when the soil mantle is eroded and transported and of stability when soils develop afresh in these mobilised materials. Three such cycles took place during the human occupation of the caves. Unfortunately the climatic interpretation of these soil cycles is still debated.

Farther north in the Carnarvon Range of Queensland, Joyce studied the sediments of sand and rock debris in the archaeologically important Kenniff Cave (Mulvaney & Joyce, 1965), which he regarded as weathering products of the sandstone roof. Dating of the occupation sequence revealed virtual cessation of such accumulation between 10,000 and 5000 B.P. and this he attributed to the climate being drier at this time, the inference resting on the need for a supply of moisture for flaking and

Plate 3

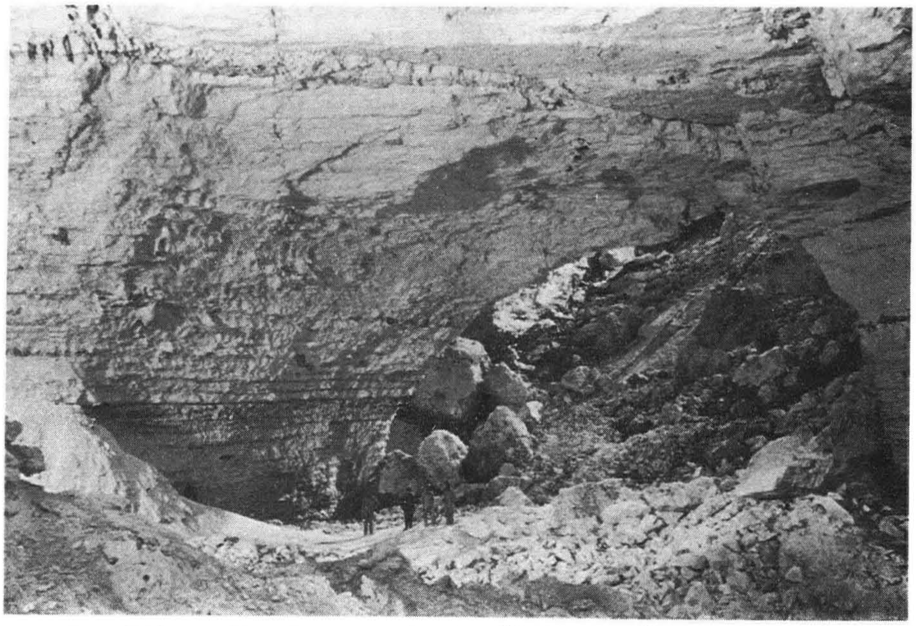


Fig. 1 Beginning of the northwest passage in Koonalda Cave, Nullarbor Plain, where there was active 'flint' mining from 22,000 to 13,000 B.P. Layers of black chalcedony can be seen in horizontally bedded Eocene chalky limestone. The scene is lit by flash powder; only faint glimmers of daylight reach the area down the entrance slope in the background.
Photo: H. Fairlie-Cuninghame

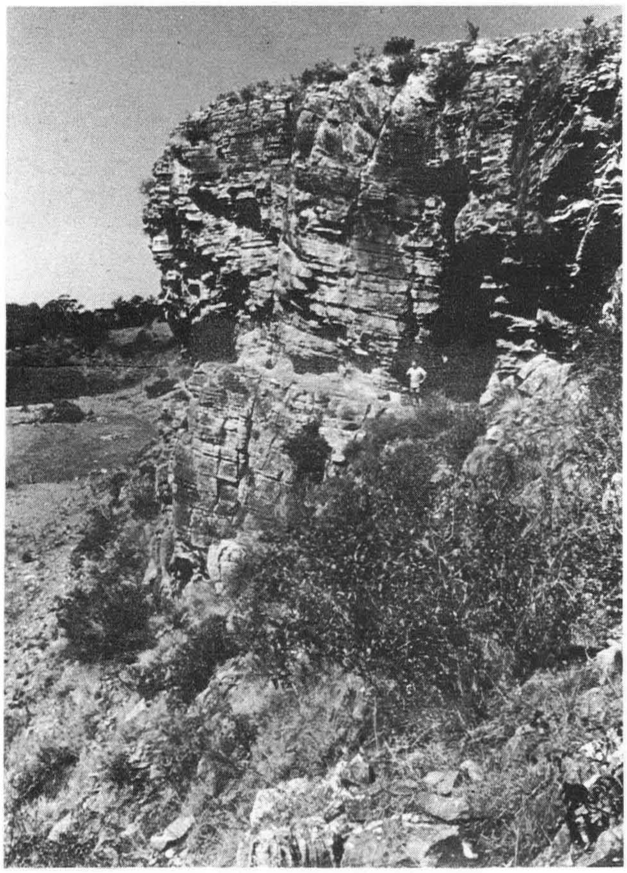


Fig. 2 Cloggs Cave, Victoria, in a northward-facing Devonian limestone cliff with a former channel of the Buchan R. at the foot. Aborigines occupied the inner part of this cave from 23,000 to 8000 B.P., then abandoned it but reoccupied the shelter on the ledge outside about 1000 years ago.

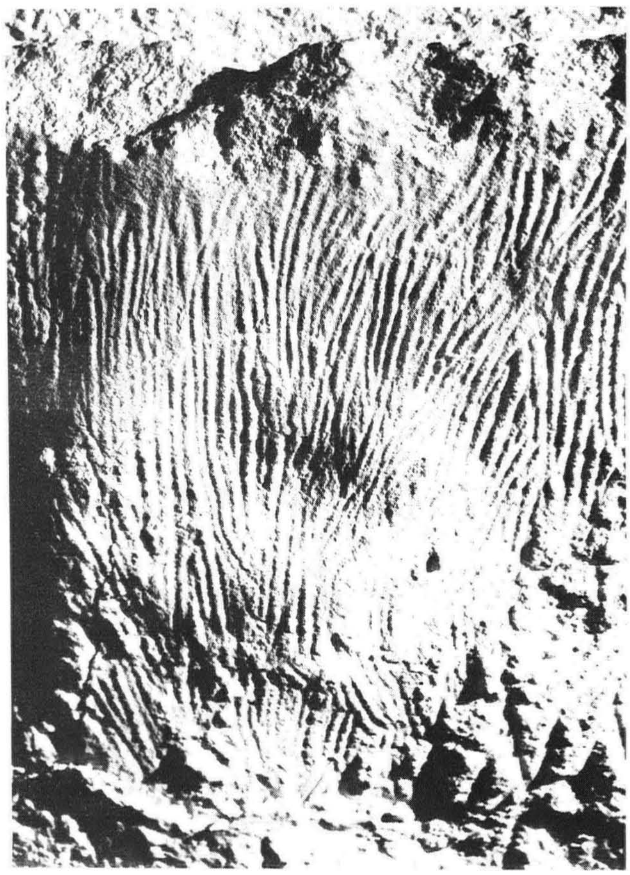


Fig. 3 Weathered finger markings on the wall of the Art Sanctuary in Koonalda Cave, Nullarbor Plain. Charcoal from brands used to illuminate the cave for this activity dated at about 20,000 B.P.
Photo: R. Edwards

Plate 4

Fig. 1 Prehistoric mining of chalcedony in the chalky limestone of Koonalda Cave. Most 'flint' was, however, obtained from debris fallen from the walls.
Photo: R.M. Frank

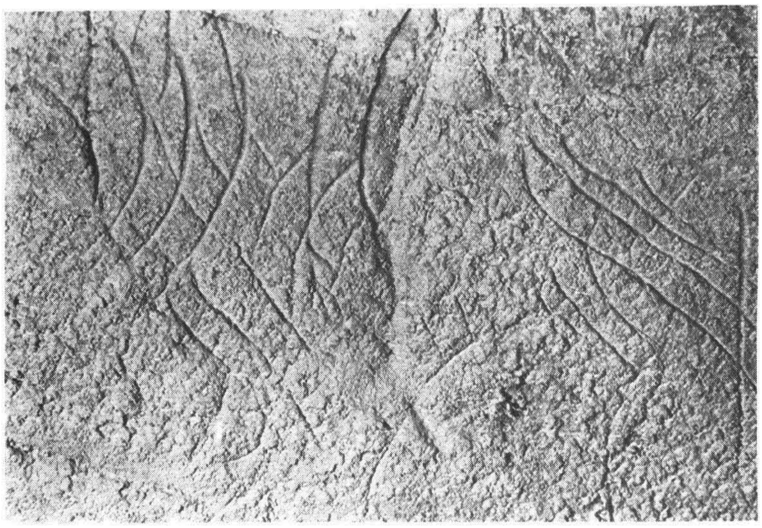


Fig. 2 Aboriginal engravings in the dark zone of New Guinea Two Cave, Snowy R., Victoria, an active outflow cave in Devonian limestone.

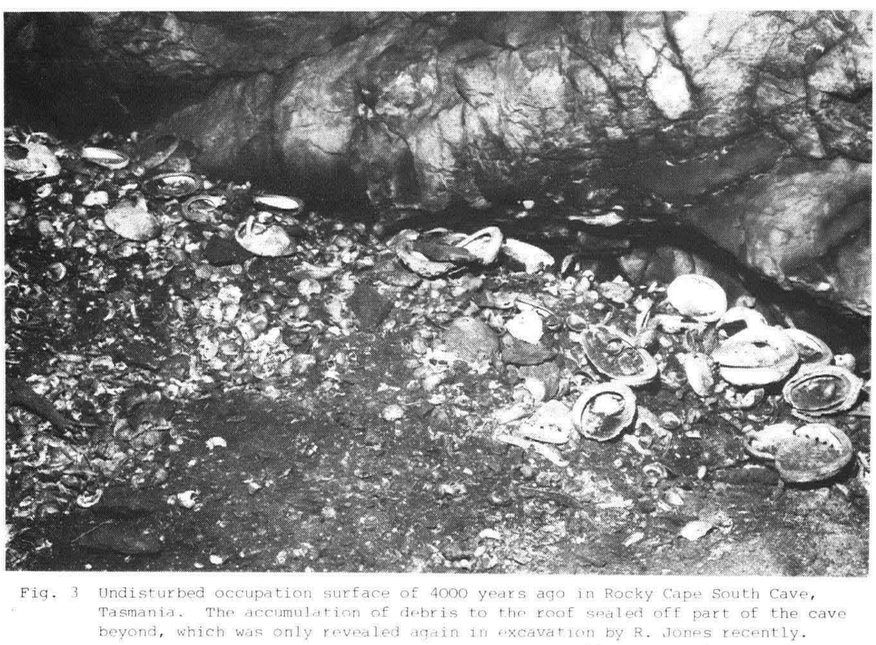


Fig. 3 Undisturbed occupation surface of 4000 years ago in Rocky Cape South Cave, Tasmania. The accumulation of debris to the roof sealed off part of the cave beyond, which was only revealed again in excavation by R. Jones recently.
Photo: W. Ambrose

granular disintegration of the roof. The fact that another cave in the area, The Tombs, had continued accumulation of coarse material at this time was not necessarily contradictory because the rock sequence was different in detail and rockfall was always more common through the last 10,000 years there than at Kenniff. However, evidence which has accumulated from the continent generally in the last 20 years contradicts this climatic sequence. Changes in the last 10,000 years have been small and the period of 25,000 to 15,000 years has proved to be the dry phase in the last 50,000 years. Kenniff Cave accumulation of the last 19,000 years does not agree with this sequence in terms of Joyce's hypothesis and the explanation may reside in a different direction altogether to be discussed below. It is also relevant to the argument that flaking and disintegration of limestone of sandy texture is known to take place prolifically in the karst caves of the semi-arid to arid Nullarbor Plain.

Several sea caves have already been mentioned as archaeological sites and sea level change has patently been important in Australian prehistory. The question follows as to whether these two records have impinged on one another as is true in a number of European caves. Rocky Cape South has the longest archaeological record of the three coastal caves which Jones (1966) excavated in northwest Tasmania, reaching back 8000 years, with angular rock debris, not beach boulders, at the base. This emerged sea cave well above sea level must have emerged in an interglacial sea level, perhaps the last one, but its human occupation begins when the rising Holocene sea level reached close enough to the bluff for it to be convenient for a coast-living people to occupy the cave there. Thus there is no involvement of the sea level and archaeological evidence with one another.

The story of another emerged sea cave, Cave Bay Cave on Hunter Island (Bowdler, 1979), has similarities to and differences from that yielded by the nearby mainland Tasmania coastal cave sites. For some millennia prior to 18,500 B.P., Aborigines used this cave which was then situated in the side of an inland hill overlooking a large open plain where now is Bass Strait. At that time they lived on inland products, including marsupials. There followed a period of slight use when climate was rigorous and rockfall more common in the cave. When next it came into use again, marsupials were not eaten in the cave but sea birds and shellfish were. Sea had risen to come close to the cave which was now on a peninsula. Finally Hunter Island became surrounded by the sea and for a time it was probably unused until the Tasmanians acquired the technique of reaching the island by boat. Then this and another cave, and open sites were occupied, the diet being mainly of coastal fauna and probably the use was seasonal coinciding with mutton bird breeding there. Thus once again there is no interplay in the cave record between sea level change and occupation but the use of the cave was much affected by the drastic geographical changes around.

The floor of a sea cave at Durras North, New South Wales, excavated by Lampert (1966), is at present sea level and here the occupation horizons rest on roof fall overlying pebble beach a metre down. The occupation only goes back 500 years and thus is much more recent than the time when sea level first rose to its present level in the Holocene. No sea level change need to be called in to explain the inhabitation, rock fall simply raising the floor to a level where this was possible. Lampert (1971) also excavated a sandstone cave on the shore of estuarine Burrill Lake nearby on this South Coast of New South Wales, with its floor only a little above sea level, and he found a sandy clay horizon wedging out backwards between sands into the cave. A mid-Holocene high sea level of a metre or two had long been claimed for this part of the Australian coast and it appeared at first to both Lampert and myself that this wedge might be an effect of it. The wedge did not, however, extend outside of rockfall from the cave lintel and the lagoon swamp deposits outside had nothing to relate to it (Jennings, 1971). This rejection of a Holocene marine interpretation for the clay wedge was later confirmed when radiocarbon dating showed it was Pleistocene in age. The clay was taken instead to have been washed down from the slope above the cave and deflected inside by the rockfall. Since artefacts reach down through and below the clay wedge, Lampert suggested that aboriginal firing of the forest might have been the cause of reduced ground cover and consequent soil erosion to provide the clay.

So no instance of intercalation of the sea level record and the archaeological record has yet been found in an Australian cave. There may never be such a find because no part of Australia has been subject to glacial isostasy as in Northern Europe nor does there appear to have been any rapid tectonic movement sufficiently late as in Mediterranean Europe. Bowler (1976) argued from the absence of any evidence of the Aborigines along known Last Interglacial shorelines and in the Golgol soil (probably Last Interglacial or late Penultimate Glacial in age) in the Lake Mungo area that the human occupation of Australia has taken place since Last Interglacial high sea levels.

Caves could play a more significant role in general environmental reconstruction in Australia if oxygen palaeotemperature and radiometric dating, especially uranium-thorium, work is done on speleothems. None of the former has yet been attempted in contrast with the situation in New Zealand and only two uranium-thorium dates have yet been published, though these do at least show that in some areas the uranium content is high enough for this technique (Goede, Murray & Harmon, 1978; James, Francis & Jennings, 1978). The potential importance of such studies rests on the fact that much of the evidence for environmental change is palaeohydrologic and in this dry continent high evaporation makes its climatic meaning difficult to determine with big differences between absolute and effective precipitation resulting. An independent thermal history is vital in this context and caves may provide it.

Topographic and ethno-archaeology

The explanation offered for the clay wedge in Burrill Lake belongs to another aspect of archaeological study, which Hallam (1977) called topographic archaeology, a concept which overlaps with that of ethno-archaeology but which stresses a regional geographical approach to prehistory where the patterns of all artefactual evidence (employing artefactual in the broadest sense) are brought to bear on the reconstruction of past human occupancy. The example Hallam employed in this paper to illustrate her theme shows how such regional archaeologies qualify the broad environmental approach already discussed above in a concept of dense coastal population and thin inland population. Her approach will reduce the interpretative imbalance that the present high proportion of cave sites in the total of excavations may have induced and subordinate the information from caves to the overall evidence, including the distribution and visible nature of all surface sites, not only excavated ones. This is to be seen in her book on the Southwest of Western Australia (Hallam, 1975), which is concerned above all to establish the importance and role of the burning of the bush by the Aborigines; every scrap of information and every reasonable inference is gathered from caves within the area but in fact the weight they lend to the whole falls to the modest dimension one might expect from the limited amount of reference to caves in the historical and ethnographic literature.

On the other hand, the recent shift in emphasis in Australian archaeology from the establishment of a reliable interpretation of the stone technology to an attempt to draw out a fuller picture of the life of the people registered in the artefactual evidence, which has attracted such names as ethno-archaeology, has meant that caves also have been made to yield more than they did before. A simple illustration was provided by Bowdler (1971). In a rock shelter at Balls Head, Port Jackson, there was a difference in the distribution of extractive and maintenance tools in the excavation, the former concerned with gathering food and other immediate needs, and the latter with the manufacture of extractive tools. The latter were relative more frequent round the back of the cave and the former in front. The cave appears to have been mainly a maintenance site where men made and repaired hunting gear at the back whilst the whole group subsisted at the front on shellfish readily gathered by the women along the nearby shore. This corresponds with descriptions of Sydney shelters at the time of white settlement, which indicate that the fireplace was in the outer part of the cave, an impression given by Lesueur's picture (Plate 1, Fig. 2).

Devils Lair in the dune limestone of the Southwest of Western Australia presents a different picture in the pattern of its occupation between 38,000 and 6500 B.P., perhaps with men alternating with owls and Tasmanian devils (carnivorous marsupials), which also left their food refuse in the cave (Dortch, 1979). Here the surrounding forests and woodlands provided the food and the eggshells of winter breeding emus, a significant human food item, suggest the season of human occupance. In winter today the cave roof drips and the prehistoric hearths and resting places lay close to the walls to avoid the worst of the drips. Flowstone layers presumably point to periods when dripping was even more pronounced than at present and the cave was avoided. It is inferred that the cave was used both as a residence and a workshop because of the finds of childrens' teeth and of maintenance tools and waste flakes.

In northwestern Australia cave aspect is considered by Bednarik (1977) to be important in selection of sites. In the Hamersley and Opthalmia Ranges all prehistorically occupied caves face east and northeast. This he attributes to the advantage of obtaining morning warmth from the sun, especially in winter, and avoiding its rays in the afternoon. Similar analyses have not been made elsewhere in the country but clearly the factors could be different, e.g. on the South Coast of New South Wales shelter from southerly and southeasterly sea winds might be the most important consideration as at Burrill Lake and Currarong shelters (Lampert, 1971). In the Sydney region it has been suggested (Megaw, 1974) that different caves were sought at different seasons, the more exposed outer shoreline caves giving place to others along the more sheltered estuaries in wintertime. In northern Arnhem Land, White and Peterson (1969) can make comparison with semi-traditional behaviour persisting among some Aboriginal groups. Here the wet season heralds a retreat from the flooded coastal plain into the inland plateau. In her prehistoric sites White found few stone artefacts and no stone waste in the shelters near the coasts but did find bone and wooden tools there. The converse applied to her inland sites. Thus it appears that the same seasonal migration was practised prehistorically as recently, stone tools being manufactured in the hills during the wet season.

Cloggs Cave in Buchan, Victoria, illustrates very well the skill of the Aborigines in appreciating cave attributes (Flood, 1974). It opens out into a ledge shelter about halfway up a north-facing limestone river bluff, with the river now 200 metres away on the other side of the floodplain, though it may well have been immediately below when the cave was first sought out (Plate 3, Fig. 2). A dimly lit but dry and smoke-free inner chamber was occupied from about 18,000 to about 9000 B.P. With glaciers in the Snowy Mountains not far away in this period the climate was harsher than now and this inner shelter provided highly desirable protection. It does not appear to have been used in the Holocene when conditions ameliorated whereas the sunny rock shelter outside was inhabited during the last 1000 years.

In the Western Desert the survival of traditional life style with the Ngatatjara people helped Gould (1968a, b, 1977) in his investigation of the Puntutjarpa rock shelter, continuously occupied the last 10,000 years. 'With regard to shade and protection from prevailing winds, this rock shelter is currently the most ideal location in terms of human comfort anywhere in the Warburton Ranges - Brown Range region' (Gould, 1977). The sun gets in in the cool morning hours. However, the nearest permanent water is now 4 km away so today it is not a long term habitation site. It is, nevertheless, visited for the wild figs growing at its entrance, and there is an inner, painted ritual site. Torrential rains also lead to its occasional use. Moreover the cliff above is employed as a game trap; animals are driven over its edge by fire and the hunters wait below by the shelter to finish them off. Excavation showed the main shelter has been used for 10,000 years but the occupation hearths suggest more persistent use than at present down to about 3000 years ago, since which time the more specific occasional purposes of the present have meant a lighter use. The cause of the change is thought to be evident in the west shelter where a pit was dug in the fill by the prehistoric ancestors of the present people. This pit can only be explained according to Gould (1977) as a collector for seepage water which would have permitted regular occupation. Failure of the seepage - the cave is dry today - would have brought about the change in use indicated by the archaeological record.

Prehistoric cave art

There is a wide range in freshness of colour and sharpness of outline of paintings on cave walls. Some times there are also changes in artistic style, range of content represented and in colour combinations employed. Superimposition of paintings may correspond with some or other of these differences. In some caves, sheets of roof or wall rock have fallen or weathered away, disrupting older paintings (Chaloupka, 1977), and in others mineral deposition such as calcite has overlain and partially obscured painting (Hallam, 1971). All these evidences testify to a long history of art in some Australian caves. At best, however, only a relative chronology can be established in this way.

Dating the human occupation of a painted or engraved cave in floor excavations only provides a possible time framework for the art unless definite links between the two kinds of use of the cave can be established. In Kenniff Cave, ochre was found right through the occupation levels back to 19,000 B.P. but this only proves the longevity of artistic activity in general, not necessarily of the stencilling on the walls above (Mulvaney, 1975). In an early excavation, Macintosh (1951) found that different coloured ochres characterise two successive occupation layers in Tandandjal Cave in southwestern Arnhem Land and he correlated these two horizons with two sets of paintings on the walls of differing degrees of weathering and colour combination. Unfortunately the depositional sequence was not dated by radiocarbon. In his excavation at Ingaladdi, Northern Territory, Mulvaney (1975) dug from a 5000 - 7000 B.P. level broken sandstone fragments with parallel linear grooves and 'bird's track' markings, whilst Dortch (1976) found much older engraved stones in Devils Lair from hearths dated to 12,000 and 20,400 B.P. These are certain proofs of the antiquity of Aboriginal art but not of the decoration of the cave walls, though increasing the probability thereof.

Such proof has come from a sandstone shelter, Early Man Cave, near Laura in Cape York Peninsula; dated occupation layers bury engravings on the cave wall to a level dated c. 13,000 B.P. (Rosenfeld, 1975).

Perhaps the most interesting site of all is in Koonalda Cave in the Nullarbor Plain where wall art was first discovered in 1957 (on the first expedition organised by the Australian Speleological Federation) over 100 m of passage some 150 m into the cave after a descent of 75 m and a climb of 35 m. It consists of meandering finger markings in soft chalk (Plate 3, Fig. 3) and linear grooves on harder limestone, made with sticks perhaps and including more definite designs than the finger doodling. What startled us most then was finding such marking above a 25 m drop, the former working ledge having dropped away. In 1966 I helped Richard Wright collect charcoal from brands in chalk dust beneath some of this art and on rockfall. This gave a date of about 20,000 B.P. (Wright, 1971). Masses of wall rock have fallen to cover wall markings. If superposition of fallen rock from that carrying the charcoal to that burying the markings could be demonstrated, some of the art must be older than that date. As it is, the association of mining and drawing is so close that the great age of the markings seems inescapable. Maynard and Edwards (1971) properly describe this activity as right on the boundary between art and non-art, the very beginning of artistic expression. They also argue from the fact that some mining was carried on at the more inaccessible art area as well as at the main mining area that there was a ritual connection between the two. Moreover the pattern of fine scratches on some smooth boulders indicates repetitive addition such as to suggest a participatory rite with each individual adding his own contribution (Sharpe & Sharpe, 1976).

The main flint mining area in Koonalda Cave, recognised in 1957 with considerable acumen and excavated with remarkable persistence by Dr. A. Gallus, is much nearer the front of the cave but it is still down a rough descent of 75 m and almost beyond the reach of daylight (Plate 4, Fig. 1). Here mining was proven to have gone on from 22,000 to 13,000 B.P. (Wright, 1971). Although many writers attribute to the modern Aborigines a great fear of darkness and a reluctance to penetrate deep into caves, the fact is that their ancestors were prepared to penetrate darkness underground for a deliberate purpose. At Koonalda Cave the main attraction was a valuable stone resource and the art was ancillary. In at least three other caves, the purpose was artistic. At Cutta Cutta Cave near Katherine, Northern Territory, and a cave at New Guinea, on the lower Snowy River, Victoria (Plate 4, Fig. 2), the art was performed in the dark but at Linesmans Creek Cave, Oscar Range, West Kimberley, a steep dark way led to a balcony entrance out of which the wall painting could have a startling effect on people approaching outside (Plate 2, Fig. 1). The explanation of an Aboriginal skeleton deep in a complex system of caves at Jenolan, New South Wales, is to be sought in the sheer accident of a fall down a shaft rather than in purposeful entry to this point (Etheridge & Trickett, 1904).

EFFECTS OF HUMAN OCCUPATION ON CAVES

The miners of Koonalda Cave did not have to dig their flint to any great extent because wall breakdown brought flint nodules and fragments down onto their working floor. That floor rose some 3 m from such breakdown and stream sediment inflow in the period between 22,000 and 13,000 B.P. Here men contributed little to debris accumulation but in other caves, especially coastal caves with shellfish middens, they added a considerable amount of material increasing the rate at which the floor rose. Rising floor level through accumulation of debris provided an archaeologically precious opportunity in Rocky Cape South in northwest Tasmania when it reached a part of the roof projecting downwards and sealed off some of the living area beyond. Thus when Jones (1966) removed this barrier, he saw the intact surface as its last occupiers had left it about 4000 years ago. Stereoscopic photography was employed to preserve a record of the valuable pattern of tools, food scraps, and fire surviving in this way (Plate 4, Fig. 3).

There are also less direct anthropogenic effects. At Fromms Landing, South Australia, Twidale (1964), a geomorphologist working with a prehistorian, Mulvaney, found a distinct relationship between the form of the bedrock floor and overlying deposits in two weathering caves. The earlier excavation of Hale and Tindale at Devon Downs in the same calcarenite River Murray cliffs also gave supporting evidence. As in many weathering caves, the floor rises inwards but it is also stepped, with the treads corresponding with thin, archaeologically sterile yellow sands, and the risers with occupation horizons including hearths and kitchen middens (Fig. 2). In Twidale's view weathering is concentrated at and proceeds fastest at the junction of bedrock, deposit and air, partly because water seeps out at this level. When natural weathering of the cave roof is operative alone, accumulation is slow and lateral extension at the back of the cave at this junction line can proceed almost uninterruptedly. However, when the cave was occupied by people, accumulation proceeded faster with the supplement of introduced debris and this cut down or halted extension at the level of the depositional surface. Using C-14 dates obtained for archaeological purposes, the rates of retreat of the backwall were calculated in the two Fromms Landing caves; these varied from 25 mm/100y to 300 mm/100y for various periods in the last 5000 years.

Hughes (1977, 1978) has pursued this question of human modification of caves used as habitations further on the basis of New South Wales sandstone shelters, mainly coastal. For the last hundred years there has only been natural weathering and this has left little debris on the middens of former aboriginal occupation. The present rate of material falling from the roof has been measured over several years. When this is compared with the rates of rooffall determined from the dated excavations, he finds the natural rate had been accelerated in the extreme as much as 20 times. As a result of bodily contact with those parts of the roof sufficiently low, pre-existing weathering crusts were knocked off. This exposed fresh rock prematurely to weathering and this in turn may have been accentuated by fires causing more pronounced temperature and humidity variations.

Occupation also reduces the escape of floor debris from the cave in various ways, e.g. by packing gaps between fallen blocks and keeping floors level by treadage and scuffage so that gravity action is reduced (cf. Stockton 1973). Using measures of intensity of human cave use based on the artefactual content of the fill, Hughes found that variations of rooffall rate and cave use corresponded, though there are complications because removal of prior crusts causes initially greater rates of accelerated rooffall than later and because rising floors bring different areas of roof within impact reach. To what extent this interesting interaction will apply to other weathering caves than these in weak rocks such as the Permian and Triassic sandstone of the Sydney sedimentary basin is being investigated. Hughes' hypothesis dovetails with Twidale's interpretation of the Fromms Landing shelters and could also provide a better explanation of the Kenniff Cave sequence than

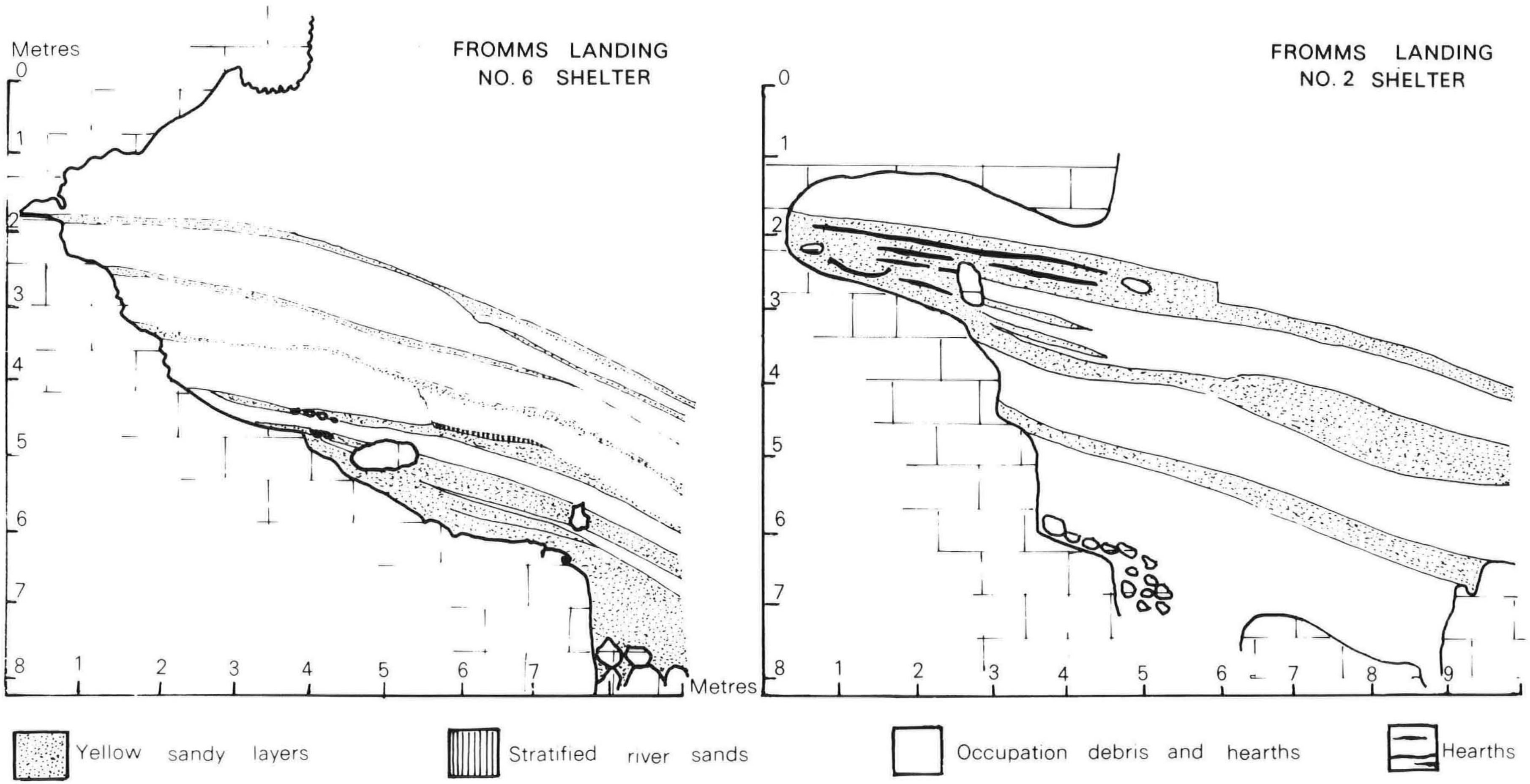


Fig. 2 Sections redrawn from Twidale (1964) through two Fromms Landing shelters in Miocene limestone cliffs along the R. Murray, S. Australia. Inward weathering of the backwall to widen the cave took place when people were not living in the cave; when they did, debris piled up too rapidly for this action to take place.

Joyce's climatic one discussed above.

CAVES AND THE BONES OF BEASTS

Caves have been important as sources of the remains of certain kinds of vertebrates just as they have in providing archaeological sites in Australia. This goes back to the beginning of such palaeontological work in this country with the memorable discoveries in Wellington Caves, New South Wales, in 1830 associated with the names of Sir Thomas Mitchell, explorer, in Australia and Professor Richard Owen, palaeontologist, in England. Recently there has been the fascinating turn in the case of *Burramys parvus* described by Robert Broom (of South African fame) as an extinct form of unknown habitat at Wombeyan, New South Wales, but now found living in the alpine country of the Snowy Mountains in New South Wales and in eastern Victoria so that it has acquired the common name of mountain pygmy possum (Dimpel & Calaby, 1972).

Many extinct taxa have been erected on the basis of cave bones and the following table is a crude measure of the relative importance of caves and other sites in this respect on the basis of the recent checklist of extinct mammalia by Mahoney and Ride (1975) (excluding the marine mammalia for the present purpose). There is a good deal of synonymy in this list, which the authors did not set out to eliminate, but there is no reason to think that this varies from one kind of type locality to another. The attribution to the Tertiary and the Quaternary is difficult as the high proportion of uncertain cases itself suggests but the results may be accepted as a coarse approximation.

TYPE LOCALITIES FOR AUSTRALIAN EXTINCT TERRESTRIAL MAMMALIA

	Caves		Other sites	
Quaternary	45	(49%)	47	(51%)
Tertiary	2	(6%)	34	(34%)
Uncertain	-	-	27	(100%)
Total	47	(30%)	108	(70%)

Thus nearly one third of all extinct mammalian species were first found in caves and this rises towards a half for the Quaternary on its own. The caves which have yielded the extinct mammals are all karst caves with one exception.

When living taxa are considered, caves have provided most of the fossil and sub-fossil material, though there is no ready way of supporting this with figures. In recent years archaeological excavations have provided many of the cave bones and as a result, sandstone shelters come into the picture significantly. Nevertheless karst caves loom larger amongst the whole range of caves and shelters as a source of bones than they do as archaeological sites. The reasons for this and for the general importance of caves for animal bones are several, falling into the realm of taphonomy, the post-mortem history of animal remains into which enter the causes of death, transport and burial mechanisms, and the course of bone decay (Baynes, Merrilees & Porter, 1975).

One aspect has already been touched upon, namely the conditions affecting bone decay. The anaerobic conditions of a waterlogged open site are at one favourable extreme but as already discussed for climatic reasons Australia as a continent is poorly endowed in this regard. The dryness often attaching to cave deposits restricts leaching also and when this is combined with alkalinity as in many caves in limestone and dolomite caves, be they superficial weathering cavities or deeper karstic hollowings, the other extreme optimum is reached. Indeed a remarkable degree of preservation over 4600 years has been found in a mummified Tasmanian wolf in Thylacine Hole in the Nullarbor Plain (Lowry & Lowry, 1967). As Hughes (1977) has pointed out, however, bone has survived in good condition in the calcareous deposits of Lake Mungo in semi-desert western New South Wales for as long as it has in the limestone cave of Devils Lair in the Southwest of Western Australia, namely into the 30,000 to 40,000 period. So this differentiating factor only applies in the more humid parts of the continent, and even there limestone caves have been shown to be more favourable in this regard than sandstone caves (Hughes, 1977).

Many causes of death in animals are not conducive to concentration of their remains in places where they are likely to be preserved. Falling into a shaft or through a daylight hole in a chamber roof is one that does, though death may not follow immediately from the fall but result from entrapment in this way. This pitfall function is one peculiarly the role of karst caves and not of weathering caves. The important collection of bones, including those of extinct, large sthenurid and diprotodontid marsupials, from Mammoth Cave in the southwest of Western Australia comes from deposits of this nature according to Merrilees (1968), though the stratigraphy and sediments were inadequately described when they were nearly completely dug away at the beginning of this century. Skull Cave in the same area is entered only by a 10 m drop down a shaft to the top of a 13 m debris pile. Most of the bones in and on the latter are the result of animals falling in (Porter, 1979). They include articulated bones and groups of bones close together attributable to the one individual. The tibia of one Grey Kangaroo were broken but articulated, the result of the fall.

When animals habitually spend time in caves for rest, parturition, hibernation or aestivation, there is a likelihood that a proportion of them will die there naturally, even if they forage outside. In Australia, this is true of various marsupials including wombats, rock-wallabies, native cats, the Tasmanian devil, possums, and some rodent-like species, of eutheria such as bats, some murids and the dingo, of some snakes and lizards, and of certain birds. Accordingly corresponding finds of bones in a subfossil and fossil state have been made widely in caves. The record about the Tasmanian wolf or tiger, the largest historically known carnivorous marsupial, is unclear, but it seems likely that it also was a habitual trogloxene. Whether extinct species related to these various animals, such as the large wombats (*Phascolonus*), behaved in the same way is a matter of speculation. It may be especially important in the case of *Thylacoleo carnifex*, the marsupial lion, the largest extinct Australian marsupial regarded as carnivorous.

The carnivores amongst these cave-frequenting animals are more important in the matter under consideration for the bones of their prey, which they leave in quantities in the caves they occupy as dens or lairs. In this way a variety of animals from the surrounding country can be represented in a cave deposit in much the same way as they can in a human cave occupation site. It may be that this particular taphonomic factor is the most important of all in making caves as important as they are in Australian Quaternary vertebrate palaeontology. For example, the well known Wombeyan Caves bone breccia in New South Wales, which included *Burramys parvus*, is now known to have been accumulated by owls (Ride, 1960). Tests with living Tasmanian devils were employed to demonstrate that a cave deposit from Wanneroo near Perth was a devil's lair (Douglas, Kendrick & Merrilees, 1966); and Merrilees (1979) argues that the most likely cause of a bone accumulation in Deepdene Cave in the southwest of Western Australia was the predation of a large snake, *Wonambi naracoortensis*.

Therefore archaeologists and palaeontologists have been much concerned to establish criteria for distinguishing between the food remains of the different predators so that the particular one can be identified and the related bias this puts on the faunal assemblage appreciated (Lundelius, 1966). The size of the food species, and its make-up in terms of adults and juveniles, can indicate the size of the predator and so narrow the choice. Similarly the habits of the prey species, whether ground or arboreal, for example, may help in the matter. Thus owls are able to take in small lizards, rodents, small dasyurids and bandicoots, but only juveniles of the small wallaby and rat-kangaroo species. The size and shape of any accompanying coprolites are significant evidence also. The degree of fragmentation of bones and characteristic teethmarks help in distinguishing not only between predators but also between the products of predation and of animals falling into or simply dying in a natural way in a cave. Falling does not usually lead to much bone breakage. However, owls also leave comparatively unbroken bones, whole skulls and even entire small carcasses, and dasyurids are likewise known to leave uneaten carcasses in caves so that mummified bodies of species too large to be brought in by owls may be the prey of native cats. Circular puncture marks and frayed edges to bones are characteristic work of Tasmanian devils (Douglas, Kendrick & Merrilees, 1966). One criterion may fail to distinguish between predators, e.g. dingo faeces contain bone broken to the same degree as in those of devils, but their coprolites are different. By a process of elimination, Archer (1974) arrived at the conclusion that the Tasmanian wolf, whose habits are poorly recorded, must have been responsible for a lair in Tunnel Cave, West Kimberley.

It is particularly important to distinguish human food remains from the rest and here additional criteria come in such as the charring of bone, the accompaniments of hearths and tools. Nevertheless difficulties may remain, for example, because the Tasmanian devil, which is a scavenger, probably ventured into caves used by men when opportunity offered and ate human refuse as well as mingling with it the food they brought in themselves. Baynes, Merrilees and Porter (1975) suggested this complication in the history of Devils Lair, Western Australia.

Further complexities in interpreting bones in caves arise from natural processes of transport introducing bones from the surface and redistributing bone from earlier cave deposits. As yet streams have not been shown to be important in introducing bone from outside, though some of the great body of fill in Wellington Caves is bedded and sorted by a stream (Frank, 1971b). A notable exception is the case of the limestone caves beneath the deep, alluvial fill of the Canadian Lead in the Gulgong Goldfield, New South Wales. These are completely filled with clay and gravels, the latter carrying gold and animal and plant remains. The whole deposit is regarded as Tertiary (Jones, 1940). Water washed much sand down a former shaft entrance into Devils Lair, forming a low angle cone in which were incorporated the bones of large, extinct, browsing kangaroos (*Sthenurus* spp.) that fell in. Later on owls brought in their smaller prey, which were also built into the accumulating cone. However, incoming water channelled the cone and reworked some of the older bone-containing sand to set old and new faunas side by side (Balme, Merrilees & Porter, 1978). In Titan Shelter in the Florentine valley, southern Tasmania, the accumulation of a carnivore's den was redistributed by water (Goede, Murray & Harmon, 1978).

Much more of the Wellington Caves' sediment was emplaced by mass movement, though Frank does not detail the mechanism involved. Murray and Goede (1977) specify solifluction for the emplacement of most of the bone-bearing deposit in Pleisto Scene Cave, a dolomite cave, near Montagu, northwestern Tasmania, in the Late Pleistocene. At much the same time debris flow moved the materials for a bone breccia from a former entrance deep into Beginners Luck Cave in the Florentine valley (Goede, Murray & Harmon, 1978).

Various claims for the extension of the ranges of living species have been made from cave finds, e.g. Lundelius (1957). Not all of these have much meaning, however, because the recording of animal distributions has been so inadequate that the natural range of many mammals when white men came is not properly known (Calaby, 1971). Therefore conclusions about environmental change, including climatic, from such evidence of range have not always been convincing. Indeed some inferences of this kind have been set aside in recent years by new discoveries of living animals which extend their modern range over a wide spectrum of habitats. Nevertheless there can be no doubt about some of these extensions to modern animal distributions by cave fossils. Thus Merrilees (1979) argued from the former occurrence of rock-wallabies (*Petrogale* sp.) in a number of caves in the southwest of Western Australia and their present absence from the area that there was proportionately more open vegetation formerly. The rock wallabies prefer rocky outcrops not heavily shaded by forest. Increasing rainfall may be the cause of the change.

Firmer environmental conclusions can come from the evidence for faunal changes through a sequence of cave deposits. Unfortunately as Ride (1964) stated, 'most of the early workers did not recognise the need for accurate stratigraphic localisation'. This is true not only for early excavations such as the crucial ones at Wellington Caves but for much later digging also. It is all the more regrettable because radiocarbon dating can be retrospectively applied to bones excavated in times past. Latterly, of course, appropriate stratigraphical studies have been made. Attempts to set up sequences in bones on the basis of colour due to weathering such as Wakefield (1967, 1972) attempted, not without difficulties arising, are now superseded by radiometric dating of the bones themselves and of interbedded charcoal and flowstone. However, it can still be a useful clue; contemporary bones are included in all horizons from the lowest excavated of about 38,000 years age in Devils Lair (Dortch, 1979) but included also are orange, sand-encrusted bones, which are reworked from older deposits still. Since fossiliferous cave fills have been cut across in quarries which are as old as Devonian (near Devonport, Tasmania), and since the geomorphic histories of cave areas are now being interpreted to imply that unfilled and unexhumed caves are as old as Palaeogene at Bungonia Caves, New South Wales (James, Francis & Jennings, 1978) and even Cretaceous at Timor, New South Wales,(Connolly & Francis, 1979) it is likely that mammal bones will be found in much older deposits than they have so far. In only one Australian cave have fossil mammals been found that are attributable to the Tertiary (Ride, 1971). Marsupials must go back even farther than the limit to which non-cave finds at present take them, namely the Oligocene-Eocene boundary, so Australian speleologists have reason to be on the alert for cave bone deposits of ancient aspect.

Even when bones are carefully related to stratigraphy and the whole sequence is dated radiometrically, the making of environmental inferences stays fraught with difficulty as Calaby (1971) demonstrates forcibly. Many species of animals responded rapidly and sensitively to European modification and destruction of habitats, some expanding as other contracted, so that the autecological basis for environmental reconstructions is uneven. Moreover many have wide ecological tolerances and species with widely different demands can live in close proximity because many regions consist of a mosaic of varying habitats. This would be especially true where Aborigines kept areas open within forested country by their burning practices. Selective predation may explain some presences and absences, camouflaging the full range of local conditions at a given time. Thus some climatic inferences from just a few changes in taxa from one time to another are uncertain because of possible alternative explanations as Calaby demonstrates from particular cases. When similar changes occur in different regions, the inferences develop more power. In the Mammoth Cave Pleistocene deposits, two bandicoots are present, *Isoodon obesolus* which prefers closed vegetation, and *Perameles bougainvillei*, which favours more open vegetation, but the latter had disappeared by modern times. Merrilees (1967b) argued from this that there has been a change in the southwest of Western Australia to more forested conditions and a wetter climate. On its own this might not fully convince but in the Seton limestone shelter in Kangaroo Island, South Australia, a sequence ranging from about 20,000 B.P. to the present shows *Isoodon* increasing relative to *Perameles* from the Pleistocene to the Holocene so Hope, Lampert, Edmondson, Smith and Yets (1977) infer increasing density of vegetation and drying of climate in this period, though they recognise other factors may have contributed. The two independent conclusions are strengthened by their agreement.

Larger assemblages of taxa may provide a number of parallel or reciprocal shifts which enable a single site's fauna to give substance to inferred environmental change. Thus in the latest palaeontological results from Devils Lair (Balme, Merrilees & Porter, 1978), the ratios of non-forest to forest mammals and of lizards to mammals increase first of all and then decrease through the last 35,000 years. The highest ratios are found between 17,000 and 13,000 B.P. This is inferred to be the driest part of the whole period, though other factors such as changing sea level are recognised to have had their influence also on the vegetation and faunal changes. This investigation is the most impressive so far in Australia in deriving environmental history from cave bones.

MAN AND THE MEGAFAUNA

The decline and extinction of animal species are not always going to be due to climatic change; competition between species is another mechanism which operates. Finds in Australian caves in the last two decades have shown that the Tasmanian devil, restricted historically to Tasmania, and the Tasmanian wolf, of which there are only two mainland records, both from Victoria and possibly zoo escapes, were present in widely separated parts of the mainland in the Holocene and earlier. The dingo has only been present in the last 3000 - 4000 years on the mainland and is regarded as an Aboriginal introduction. When these facts were appreciated, the proposition arose that the dingo ousted the other two by competition on the mainland whereas they survived in Tasmania which was not reached by the dingo. The issue remains in doubt; Calaby (1971) has pointed out that the dingo is almost omnivorous and unspecialised species of this type are not the sort to compete with other animals to the latters' extinction.

The extinction of the large marsupials - the largest, *Diprotodon*, was as large as a rhinoceros - has captured most interest. Early speculation was directed at a purely natural explanation and in this context it was assumed that these large animals needed the biomass of a humid climate, despite the fact that the largest living marsupial, the Red Kangaroo, flourishes in semi-arid land. A postulated 'Great Australian Arid' in the middle Holocene was called in to exterminate the large Sthenuridae and Diprotodontidae, especially after large numbers of *Diprotodon* remains were found in the arid playa, Lake Callabonna, South Australia, where their deaths were attributed to a shrinking water body. Latterly a more subtle and convincing explanation for such occurrences as this has been proffered, namely that animals of this size are more closely tied to water points than smaller animals which can more easily, cut down their water loss and so they necessarily eat out food supplies around the water points to the point of starvation (Horton, 1978). And even if evidence has accumulated to disprove the idea of any substantially drier period in the Holocene, it has at the same time established a widespread and severe aridity at the time of the last glacial maximum.

However, when radiocarbon dating became available and archaeological discoveries were made pushing human history in Australia much farther back in time, the possibilities of overlap between man and the megafauna fermented the idea of elimination of the large marsupials through 'overkill' by Aboriginal hunters (Jones, 1969; Merrilees, 1968). Much of the evidence, especially from surface sites, in this connection has proved debatable in one respect or another (Mulvaney, 1975) yet there is now no doubt from cave deposits that the large marsupials were still present after man had arrived. *Sthenurus orientalis*, an extinct browsing kangaroo, was found at the 23,000 B.P. horizon in Cloggs Cave, Victoria (Flood, 1973); in the late Pleistocene part of Tita Shelter sequence there are several large extinct species; there is a 14,500 B.P. date from a *Sthenurus* bone in Beginners Luck Cave but in deposits separate from those containing human artefacts; and in Pleisto Scene Cave the megafaunal remains fall into the 10,000 to 20,000 B.P. period. The three last sites are all Tasmanian (Goede, Murray & Harmon, 1978). At Devils Lair, Western Australia, the Sthenurus bones belong to those regarded as reworked from breccia older than the 38,000 B.P. base of the excavation but it is thought likely that some of the artefacts come from the reworked horizon also (Dortch, 1979). At two surface sites, there is unquestionable association of megafauna and human artefacts in the same bed; in the D-clay beneath the Keilor Terrace sediments on the River Maribyrnong near Melbourne (Bowler, 1976) and in the Older Fill of the Greenough River alluvium near Geraldtown, Western Australia, (Wyrwoll & Dortch, 1978). The dating of both these transported materials is inferential but there is little doubt but that they are very old, upwards of 36,000 and 37,000 B.P. respectively.

The questions remain whether artefacts and large marsupial bones occur in causal association and whether the ancestors of the Aborigines hunted these animals. For Tasmania, Goede, Murray and Harmon (1978) point out that, although there is contemporaneity over 10,000 years of man and the large beasts, the absence of extinct fauna from the human occupation sequences in the caves indicate that man was not a hunter of big game there. In Madura Cave in the Western Australian part of the Nullarbor Plain, *Sthenurus* bones are found along with human occupation debris; however, Milham and Thompson (1976) argue that the crucial bones may be *remanié* from older deposits. These questions are still open ones.

However, hunting is not the only role early man could have played to affect the large and other marsupials; their burning practices may have rendered particular areas unfavourable. The tendency of Australian archaeologists now is not to isolate the fate of the large from other extinct marsupials, to think of these extinctions as taking place over a long time in the late Quaternary and to call on as causes combinations of climatic change and Aboriginal burning of the bush, perhaps operating variously in different habitats for different species.

CONCLUSION

This review has shown that advances in Australian prehistory and late Quaternary vertebrate palaeontology have depended overall in significant measure on the evidence provided by caves, crucially in some directions, subordinately in others. Yet as regards archaeology, this disagrees with the modest importance of caves for the Aborigines as Europeans found them in so far as an admittedly imperfect written record permits this to be assessed. The special virtues of cave sites for the survival of the evidence in good order from the past and their ready discovery may go a long way to explaining this paradox. As the work of archaeological investigation goes on, this discrepancy may diminish. In this connection comparison between important surveys of the state of Australian prehistory by Mulvaney in 1966 and by White and O'Connell in 1979 is revealing. In the former, cave sites dominate the account whereas there is scarcely a reference to them in the more recent review. Despite this tendency for caves to match, as it were, their contribution to archaeological reconstruction with their modest role in the Aboriginal past, the prospect is that caves will continue to yield vital information to both fields of study considered here.

REFERENCES

Archer, M. 1974 New information about the Quaternary distribution of the thylacine (Marsupialia, Thylacinidae) in Australia. *J. Roy. Soc. W. Aust.*, vol. 57, pp. 43-50.

Arndt, W. 1962 The Nargorkun-narlinji cult. *Oceania*, vol. 32, pp. 298-320.

Balme, J., Merrilees, D. & Porter, J.K. 1978 Late Quaternary mammal remains spanning about 30,000 years, from excavations in Devil's Lair, Western Australia. *J. Roy. Soc. W. Aust.*, vol. 61, pp. 33-65.

Baynes, A., Merrilees, D. & Porter, J.K. 1975 Mammal remains from the upper levels of a late Pleistocene deposit in Devil's Lair, Western Australia. *J. Roy. Soc. W. Aust.*, vol. 58, pp. 97-126.

Barrington, G. 1798 *A Voyage to Botany Bay with a Description of the Country, Manners, Customs, Religion, etc. of the Natives.* Lowndes, London.

Barrington, G. 1802 *History of New South Wales...* Flint, London.

Basedow, H. 1904 Anthropological notes made on the South Australian Government north-west prospecting expedition, 1903. *Trans. Roy. Soc. S. Aust.*, vol. 28, pp. 12-51.

Basedow, H. 1907 Anthropological notes on the western coastal tribes of the Northern Territory of Australia. *Trans. Roy. Soc. S. Aust.*, vol. 31, pp. 1-62.

Basedow, H. 1914 Journal of the Government North-west Expedition (March 30th - November 5th, 1903). *Proc. Roy. Geogr. Soc. Australasia* (S. Aust. Br.), vol. 15, pp. 57-242.

Basedow, H. 1925 *The Australian Aboriginal.* Pierce, Adelaide.

Beaton, J. 1978 Archaeology and the Great Barrier Reef. *Phil. Trans. Roy. Soc.*, vol. B284, pp. 141-159.

Bednarik, R.G. 1977 A survey of the prehistoric sites in the Tom Price region, north-western Australia. *Arch. Phys. Anthrop. Oceania*, vol. 12, pp. 51-76.

Bennett, G. 1834 *Wanderings in New South Wales.* Bentley, London.

Bennett, G. 1895 *The aborigines of Australia: their habits and customs.* MS 115, National Library, Canberra.

Beveridge, P. 1895 Of the Aborigines inhabiting the great lacustrine and riverine depression of the lower Murray, lower Murrumbidgee, lower Lachlan and lower Darling. *J. Roy. Soc. N.S.W.*, vol. 17, pp. 19-74.

Bird, W.H. 1911 Ethnological notes about the Buccaneer Islanders, north-western Australia. *Anthropos*, vol. 6, pp. 174-178.

Bonwick, J. 1870 *Daily Life and Origins of the Tasmanians.* Low, Son & Marston, London.

Bonwick, J. 1884 *The Lost Tasmanian Race.* Low, Marston, Searle & Rivington, London.

Bowdler, S. 1971 Balls Head, the excavation of a Port Jackson shelter. *Rec. Aust. Mus.*, vol. 28, pp. 117-128.

Bowdler, S. 1975 Caves and Aboriginal man. *Aust. Nat. Hist., vol. 18, pp. 216-219.*

Bowdler, S. 1979 *Hunter Hill, Hunter Island.* Unpub. Ph.D. thesis, Australian National University.

Bowdler, S. 1977 *The coastal colonisation of Australia.* Pp. 205-246 in: *Sunda and Sahul Prehistoric Studies in Southeastern Asia, Melanesia and Australia.* Eds. J. Allen, J. Golson & R. Jones. Academic Press, London.

Bowler, J.M. 1976 *Recent developments in reconstructing late Quaternary environments in Australia.* Pp. 55-77 in: *The Origin of the Australians.* Eds. R.L. Kirk & A.G. Thorne. Aust. Inst. Abor. Stud., Canberra.

Brandl, E.J. 1973 *Australian Aboriginal Paintings in Western and Central Arnhem Land.* Aust. Inst. Abor. Stud., Canberra.

Brennan, M. 1907 *Reminiscences of Goldfields and Elsewhere in New South Wales.* Brooks, Sydney.

Buchanan, G. 1953 *Packhorse and Waterhole with the First Overlanders to the Kimberleys.* Angus & Robertson, Sydney.

Calaby, J.H. 1971 *Man, fauna and climate in Aboriginal Australia.* Pp. 80-93 in: *Aboriginal Man and his Environment in Australia.* Eds. D.J. Mulvaney & J. Golson. ANU Press, Canberra.

Campbell, V. 1978a *Two fish traps located on the mid-north coast of New South Wales.* Pp. 122-134 in: *Records of Time Past.* Ed. I. McBryde. Aust. Inst. Abor. Stud., Canberra.

Campbell, V. 1978b *Ethnohistorical evidence on the diet and economy of the Aborigines of the Macleay River valley.* Pp. 82-100 in: *Records of Time Past.* Ed. I. McBryde. Aust. Inst. Abor. Stud., Canberra.

Campbell, W.D. 1910 The need for an ethnological survey of Western Australia. *J. Nat. Hist. Sci. Soc. W. Aust.*, vol. 3, pp. 102-109.
Campbell, W.D. 1914 Description of a cave with aboriginal markings at Appertarra, and a cave and rock shelters at Willow Gully, Nonga and Norman Well, Northampton. *J. Nat. Hist. Sci. Soc. W. Aust.*, vol. 5, pp. 12-14.
Carnegie, D.W. 1898 *Spinifex and Sand.* Pearson, London.
Chaloupka, G. 1977 *Aspects of the chronology and schematisation of two prehistoric sites in the Arnhem Land plateau.* Pp. 243-259 in: *Form in Indigenous Art.* Ed. P.J. Ucko. Aust. Inst. Abor. Stud., Canberra.
Chaseling, W.S. 1957 *Yulenggor: Nomads of Arnhem Land.* Epworth, London.
Clement, E. 1903 Ethnological notes on the Western Australian Aborigines. *Inst. Arch. Ethnographie*, vol. 16, pp. 1-16.
Collins, D. 1798-1802 *An Account of the English Colony in New South Wales.* Cadell & Davies, London.
Connolly, M. & Francis, G. 1979 *Cave and landscape evolution at Isaacs Creek, New South Wales, Helictite;* vol.17, pp.5-24.
Coutts, P.J.F. 1966 Features of prehistoric campsites in Australia. *Mankind*, vol. 6, pp. 338-346.
Crawford, I.M. 1968 *The Art of the Aborigines.* O.U.P., Melbourne.
Curr, E.M. 1886-7 *The Australian Race.* Govt. Printer, Melbourne.
David, T.E.E. & Etheridge, R. 1889 On the examination of an Aboriginal rock shelter and kitchen midden at North Harbour, Port Jackson. *Rec. Geol. Surv. N.S.W.*, vol. 1, ''. 140-145.
Davidson, D.S. 1935 Archaeological problems of northern Australia. *J. Roy. Anthrop. Inst.*, vol. 65, pp. 145-183.
Dimpel, H. & Calaby, J.H. 1972 Further observations on the mountain pygmy possum. *Vict. Nat.*, vol. 89, pp. 101-106.
Dortch, C.E. 1974 A twelve thousand year old occupation floor in Devil's Lair, Western Australia. *Mankind*, vol. 9, pp. 195-205.
Dortch, C.E. 1976 Two engraved stone plaques of Late Pleistocene age from Devil's Lair, Western Australia. *Arch. Phys. Anthrop. Oceania*, vol. 11, pp. 32-44.
Dortch, C.E. 1979 Devil's Lair, an example of prolonged cave use in southwestern Australia. *World. Arch.*, 10, pp. 258-279.
Dortch, C.E. & Merrilees, D. 1971 A salvage excavation in Devils Lair, Western Australia. *J.Roy.Soc.W.Aust.*, vol.54, pp. 103-113.
Dortch, C.E. & Merrilees, D. 1973 Human occupation of Devil's Lair, Western Australia during the Pleistocene. *Arch. Phys. Anthrop. Oceania*, vol. 8, pp. 89-115.
Douglas, A.M., Kendrick, G.W. & Merrilees, D. 1966 A fossil bone deposit near Perth, Western Australia, interpreted as a carnivore's den after feeding tests on living Sarcophilus (Marsupialia, Dasyuridae). *J. Roy. Soc. W. Aust.*, vol. 49, pp. 88-90.
Dunbar, G.K. 1943-4 Notes on the Ngemba tribe of the central Darling River, western New South Wales. *Mankind*, vol. 3, pp. 140-148 & 172-180.
Edwards, R. 1966 The need for the preservation of Aboriginal cave art. *Proc. Roy. Geogr. Soc. Australasia* (S. Aust. Br.), vol. 67, pp. 9-19.
Etheridge, R. 1891 Notes on 'rock-shelters' or 'gibber-gunyahs' at Deewhy Lagoon. *Rec. Aust. Mus.*, vol. 1, pp. 171-174.
Etheridge, R. 1893 Note on an aboriginal skull from a cave at Bungonia. *Rec. Geol. Surv. N.S.W.*, vol. 3, pp. 128-129.
Etheridge, R. & Trickett, O. 1904 The discovery of a human skeleton at Jenolan Caves. *Rec. Geol. Surv. N.S.W.*, vol. 7, pp. 325-328.
Eylmann, E. 1908 *Die Eingeborenen der Kolonie Südaustralien.* Reiner, Berlin.
Eyre, E.J. 1845 *Journals of Expeditions of Discovery into Central Australia and Overland from Adelaide to King George's Sound in the Years 1840-1 ... Manners and Customs of the Aborigines.* Boone, London.
Finlayson, H.H. 1935 *The Red Centre.* Angus & Robertson, Sydney.
Flanagan, R.J. 1888 *The Aborigines of Australia.* Robertson, Sydney.
Flood, J. 1973 Pleistocene human occupation and extinct fauna in Cloggs Cave, Buchan, south-east Australia. *Nature*, Lond., vol. 246, p. 303.
Flood, J. 1974 Pleistocene man at Cloggs Cave: his tool kit and environment. *Mankind*, vol. 9, pp. 175-188.
Frank, R. 1971a *Cave sediments as palaeoenvironmental indicators, and the sedimentary sequence in Koonalda Cave.* Pp. 94-104 in: *Aboriginal Man and his Environment.* Eds. D.J. Mulvaney & J. Golson. ANU Press, Canberra.
Frank, R. 1971b The clastic sediments of the Wellington Caves, New South Wales. *Helictite*, vol. 9, pp. 3-26.
Frank, R. 1975 Late Quaternary climatic change: evidence from cave sediments in central eastern New South Wales. *Aust. Geogrl. Stud.*, vol. 13, pp. 154-168.
Froggatt, W.W. 1888 Notes on the natives of West Kimberley, N.W. Australia. *Proc. Linn. Soc. N.S.W.*, vol. 13, pp. 651-656.

Goede, A. & Murray, P. 1977 Pleistocene man in south central Tasmania evidence from a cave site in the Florentine valley. *Mankind,* vol. 11, pp. 2-10.

Goede, A., Murray, P. & Harmon, R. 1978 Pleistocene man and megafauna in Tasmania: dated evidence from cave sites. *The Artefact,* vol. 3, pp. 139-149.

Gould, R.A. 1968a Preliminary report on excavations at Puntutjarpa rockshelter, near the Warburton Ranges, Western Australia. *Arch. Phys. Anthrop. Oceania,* vol. 3, pp. 161-185.

Gould, R.A. 1968b Living archaeology: the Ngatatjara of Western Australia. *Southwest. J. Anthrop.,* vol. 24, pp. 101-122.

Gould, R.A. 1969 *Yiwara: Foragers of the Australian Desert.* Scribner, N.Y.

Gould, R.A. 1977 Puntutjarpa Rockshelter and the Australian Desert Culture. *Anthrop. Pap. Amer. Mus. Nat. Hist.,* vol. 54.

Gray, A.J. 1915 Geological reconnaissance of Arnhem Land. *Bull. N. Terr.,* vol. 14, pp. 20-31.

Grey, G. 1841 *Journal of Two Expeditions of Discovery in North-West and Western Australia.* Boone, London.

Hale, H.M. & Tindale, N.B. 1930 Notes on some human remains in the lower Murray valley, South Australia. *Rec. S. Aust. Mus.,* vol. 4, pp. 145-218.

Hale, H.M. & Tindale, N.B. 1933-4 Aborigines of Princess Charlotte Bay, north Queensland. *Rec. S. Aust. Mus.,* vol. 5, pp. 63-172.

Hallam, S.J. 1971 Roof markings in the 'Orchestra Shell' Cave, Wanneroo, near Perth, Western Australia. *Mankind,* vol. 8, pp. 90-103.

Hallam, S.J. 1975 *Fire and Hearth: A Stúdy of Aboriginal Usage and European Usurpation in South-western Australia.* Aust. Inst. Abor. Stud., Canberra.

Hallam, S.J. 1977 *Topographic archaeology and artefactual evidence.* Pp. 169-177 in: *Stone Tools as Cultural Markers.* Eds. R.V.S. Wright. Aust. Inst. Abor. Stud., Canberra.

Hambly, W.D. 1936 Primitive Hunters of Australia. *Field Mus. Nat. Hist. Chicago Lflt No.* 32.

Hart, C.W.M. & Pilling, A.R. 1960 *Tiwi of North Australia.* Holt, Reinhart & Winston, N.Y.

Helms, R. 1896 Anthropology of the Elder Exploring Expedition 1871-1872. *Trans. Roy. Soc. S. Aust.,* vol. 16, pp. 237-332.

Hope, G.S. 1978 The Late Pleistocene and Holocene vegetational history of Hunter Island, north-western Tasmania. *Aust. J. Bot.,* vol. 26, pp. 493-514.

Hope, J.H., Lampert, R.H., Edmondson, E., Smith, M.J. & Tets, G.F. van 1977 Late Pleistocene faunal remains from Seton rock-shelter, Kangaroo Island, South Australia. *J. Biogeog.,* vol. 4, pp. 363-385.

Horton, D.R. 1978 Extinction of the Australian megafauna. *Aust. Inst. Abor. Stud. Newsletter N.S.,* vol. 9, pp. 72-75.

Hossfeld, P. 1926 Aborigines of South Australia; native occupation of the Eden valley and Angaston districts. *Trans. Roy. Soc. S. Aust.,* vol. 50, pp. 287-297.

Howitt, A.W. 1876 Notes on the Devonian rocks of north Gippsland. *Rep. Progr. Geol. Surv. Vict.,* vol. 3, pp. 181-249.

Hughes, P.J. 1977 *A geomorphological interpretation of select archaeological sites in southern coastal New South Wales.* Unpub. Ph.D. thesis, University of N.S.W.

Hughes, P.J. 1978 *Weathering in sandstone shelters in the Sydney Basin and the survival of rock art.* Pp. 36-41 in: *Conservation of Rock Art,* Ed. C. Pearson. Inst. Cons. Cult, Mat., Canberra.

Hunter, J. 1793 *An Historical Journal of the Transactions at Port Jackson and Norfolk Island....* Stockdale, London.

James, J.M., Francis, G. & Jennings, J.N. 1978 Bungonia Caves and Gorge a new view of their geology and geomorphology. *Helictite,* vol. 16, pp. 53-63.

Jennings, J.N. 1971 *Sediments in the late embayment at the Burrill Lake site.* Pp. 72-75 in: *Burrill Lake and Currarong.* By R. Lampert. Dept. Prehistory, Aust. Nat. Univ., Canberra.

Jennings, J.N. 1979 An unusual sandstone cave from northern Australia. *Helictite* vol.17, 39-45

Jones, L.J. 1940 The Gulgong Goldfield. *Miner. Resour. N.S.W.,* vol. 38, pp. 1-134.

Jones, R. 1966 A speculative archaeological sequence for north-west Tasmania. *Rec. Qu. Vict. Mus.,* Launceston, vol. 25.

Jones, R. 1968 The geographical background to the arrival of man in Australia and Tasmania. *Arch. Phys. Anthrop. Oceania,* vol. 3, pp. 186-215.

Lampert, R.J. 1966 An excavation of Durras North, New South Wales. *Arch. Phys. Anthrop. Oceania,* vol. 1, pp. 83-118.

Lampert, R.J. 1971 *Burrill Lake and Currarong.* Dept, Prehistory, Aust. Nat. Univ., Canberra.

Lampert, R.J. & Hughes, P.J. 1974 Sea level change and Aboriginal coastal adaptation in southern New South Wales. *Arch. Phys. Anthrop. Oceania,* vol. 9, pp. 226-235.

Le Souef, W.H.D. 1907 *Wild Life in Australia.* Whitcombe & Tombs, Christchurch.

Love, J.R.B. 1917 Notes on the Wororra tribe of north-western Australia. *Trans. Roy. Soc. S. Aust.,* vol. 41, pp. 23-38.

Love, J.R.B. 1936 *The Stone Age Bushmen of Today.* Blackie, London.
Lowry, D.C. & Lowry, W.J. 1967 Discovery of a thylacine (Tasmanian tiger) carcase in a cave near Eucla, Western Australia. *Helictite,* vol. 5, pp. 25-28.
Luebbers, R.A. 1975 Ancient boomerangs discovered in South Australia. *Nature,* Lond., vol. 253, p. 39.
Lumholtz, C. 1890 *Among Cannibals.* Murray, London.
Lundelius, E.L. 1957 Additions to knowledge of the ranges of Western Australian mammals. *West. Aust. Nat.,* vol. 5, pp. 173-182.
Lundelius, E.L. 1963 Vertebrate remains from the Nullarbor Caves, W. Australia. *J. Roy. Soc. W. Aust.,* vol. 46, pp. 75-80.
Lundelius, E.L. 1966 Marsupial carnivore dens in Australia. *Stud. Speleol.,* vol. 1, pp. 174-180.
Lundelius, E.L. 1976 Vertebrate palaeontology of the Pleistocene: an overview. *Geoscience and Man,* vol. 13, pp. 45-59.
Lundelius, E.L. & Turnbull, W.D. 1973 The mammalian fauna of Madura Cave, Western Australia, Part I. *Fieldiana Geology,* vol. 13, pp. 1-35.
McBryde, I. 1974 *Aboriginal Prehistory in New England an Archaeological Survey of Northeastern New South Wales.* Sydney Univ. Press, Sydney.
McBryde, I. (ed.) 1978 *Records of Time Past.* Aust. Inst. Abor. Stud., Canberra.
McCarthy, F.D. 1948 The Lapstone Creek excavation: two culture periods revealed in eastern New South Wales. *Rec. Aust. Mus.,* vol. 22, pp. 1-34.
McCarthy, F.D. 1960a Rock art in central Queensland, Gracevale near Aramac. *Mankind,* vol. 5, pp. 400-404.
McCarthy, F.D. 1960b *The cave paintings of Groote Eylandt and Chasm Island.* Records of the American-Australian Scientific Expedition to Arnhem Land, vol. 2, pp. 297-414. Ed. C.P. Mountford. Melbourne University Press, Melbourne.
McCarthy, F.D. 1964 The archaeology of the Capertee valley, New South Wales.*Rec.Aust. Mus.,*vol.26, pp. 197-246.
McCarthy, F.D. & Setzler, F.M. 1960 *The archaeology of Arnhem Land.* Records of the American-Australian Scientific Expedition to Arnhem Land, vol.2, pp. 215-295 Ed.C.P. Mountford. Melbourne University Press, Melbourne.
McCaskill, D.L. 1977 *Schematisation in rock art in the upper Gascoigne district, Western Australia.* Pp. 184-197 in: *Form in Indigenous Art.* Ed. P.J. Ucko. Aust. Inst. Abor. Stud., Canberra.
Macintosh, N.W.G. 1951 Archaeology of **Tandandjal** Cave, south-west Arnhem Land. *Oceania,* vol. 21, pp. 178-204.
Macintosh, N.W.G. 1952 Paintings in Beswick Creek Cave, Northern Territory. *Oceania,* vol. 22, pp. 256-274.
Mahoney, J.A. & Ride, W.D.L. 1975 Index to the Genera and Species of Fossil Mammalia described from Australia and New Guinea between 1838 and 1968. *W. Aust. Mus. Spec. Pub.,* no. 6.
Martin, H.A. 1973 Palynology and historical ecology of some cave excavations in the Australian Nullarbor. *Aust. J. Bot.,* vol. 21, pp. 283-316.
Massola, A. 1964 Victoria Range shelters. *Vict. Nat.,* vol. 81, pp. 169-176.
Massola, A. 1968 *Bunjil's Cave Myths, Legends and Superstitions of the Aborigines of southeast Australia.* Lansdowne, Melbourne.
Massola, A. 1969 *Journey to Aboriginal Victoria.* Rigby, Adelaide.
Mathew, J. 1889 The Australian Aborigines. *J. Roy. Soc . N.S.W.,* vol. 23, pp. 335-449.
Mathews, R.H. 1901 Ethnological notes on the aboriginal tribes of the Northern Territory. *Qld. Gegr. J.,* vol. 16, pp. 69-90.
Maynard, L. & Edwards, R. 1971 *Wall markings.* Pp. 61-80 in: *Archaeology of the Gallus Site, Koonalda Cave.* Ed. R.V.S. Wright, Aust. Inst. Abor. Stud., Canberra.
Megaw, J.V.S. 1966 The excavation of an Aboriginal rock-shelter on Gymea Bay, Port Hacking, N.S.W. *Arch. Phys. Anthrop. Oceania,* vol. 1, pp. 23-50.
Megaw, J.V.S. (ed.) 1974 *The Recent Archaeology of the Sydney District.* Aust. Inst. Abor. Stud., Canberra.
Meggitt, M.J. 1955 Notes on the Malngin and Gurindji aborigines of Limbunya, Northern Territory. *Mankind,* vol. 5, pp. 45-50.
Merrilees, D. 1967a South-western Australian occurrences of *Sthenurus* (Marsupialia, Macropodidae), including *Sthenurus brownei,* sp. nov. *J. Roy. Soc. W. Aust.,* vol. 50, pp. 65-79.
Merrilees, D. 1967b Fossil bandicoots (Marsupialia, Peramelidae) from Mammoth Cave, Western Australia, and their climatic significance. *J. Roy. Soc. W. Aust.,* vol. 50, pp. 121-128.
Merrilees, D. 1968 Man the destroyer= late Quaternary changes in the Australian marsupial fauna. *J. Roy. Sox. W. Aust.,* vol. 51, pp. 1-24.
Merrilees, D. 1975 Ancient animals and man in caves. *Wildlife in Australia,* vol. 12, pp. 93-97.
Merrilees, D. 1979 Prehistoric rock wallabies (Marsupialia, Macropodidae, Petrogale) in the far south-west of Western Australia. *J. Roy. Soc. W. Aust.,* vol. 61, pp. 73-96.
Milham, P. & Thompson, P. 1976 Relative antiquity of human occupation and extinct fauna at Madura Cave, southeastern Western Australia. *Mankind,* vol. 10, pp. 175-218.
Moore, D.R. 1970 Results of an archaeological survey of the Hunter River valley. *Rec. Aust. Mus.,* vol. 28, pp. 25-64.

Mountford, C.P. 1956 *Art, myth and symbolism.* Records of the American-Australian Scientific Expedition to Arnhem Lane, 1. Melbourne University Press, Melbourne.
Mountford, C.P. 1965 *Ayers Rock: its People, their Beliefs and their Art.* Angus & Robertson, Sydney.
Mountford, C.P. & Brandl, E.J. 1967 Aboriginal cave paintings, Mountain Creek waterhole, St. Vidgeon, Northern Territory of Australia. *Rec. S. Aust. Mus.*, vol. 15, pp. 371-382.
Mountford, C.P. & Brandl, E.J. 1968 Aboriginal cave paintings and rock markings at Ingaladdi rock shelter, Willeroo, Northern Territory of Australia. *Rec. S. Aust. Mus.*, vol. 15, pp. 679-692.
Mulvaney, D.J. 1960 Archaeological excavations at Fromm's Landing on the lower Murray River, S.A. *Proc. Roy. Soc. Vict.*, vol. 72, pp. 53-85.
Mulvaney, D.J. 1964 The Pleistocene colonization of Australia. *Antiquity*, vol. 38, pp. 283-367.
Mulvaney, D.J. 1966 The prehistory of the Australian Aborigines. *Scientific American*, vol. 214, pp. 84-93.
Mulvaney, D.J. 1975 *The Prehistory of Australia.* Rev. Ed. Penguin, Harmondsworth.
Mulvaney, D.J. & Joyce, E.B. 1965 Archaeological and geomorphological investigations on Mt. Moffatt Station, Queensland, Australia. *Proc. Prehist. Soc.*, vol. 31, pp. 147-212.
Mulvaney, D.J., Lawton, G.H. & Twidale, C.R. 1964 Archaeological excavation of rock shelter No. 6 Fromm's Landing, South Australia. *Proc. Roy. Soc. Vict.*, vol. 77, pp. 479-516.
Murray, P. & Goede, A. 1977 Pleistocene vertebrate remains from a cave near Montagu, N.W. Tasmania. *Rec. Qu. Mus.*, Launceston, vol. 60.
Officer, An. 1789 *An Authentic Journal of the Expedition under Commodore Phillips to Botany Bay with an Account of the Settlement Made at Port Jackson and a Description of the Inhabitants...*Forster, London.
Oldfield, A. 1865 On the Aborigines of Australia. *Trans. Ethnol. Soc. Lond.*, vol. 3, pp. 215-298.
Ollier, C.D. 1978 Induced fracture and granite landforms. *Zeit. Geomorph. N.F.*, vol. 22, pp. 249-257.
Péron, F.A. & Freycinet, L.C.P. 1807-1816 *Voyages de découvertes aux Terres Australes.* Imprimerie Imperiale, Paris.
Petrie, T. 1904 *Reminiscences of Early Queensland.* Qld. Book Depot, Brisbane.
Playford, P.E. 1960 Aboriginal rock paintings of the West Kimberley region, Western Australia. *J. Roy. Soc. W. Aust.*, vol. 43, pp. 111-122.
Plomley, N.J.B. 1966 *Friendly Mission: The Tasmanian Journals of George Augustus Robinson, 1829-1834.* Tasm. Hist. Res. Ass., Hobart.
Porter, J.K. 1979 Vertebrate remains from a stratified Holocene deposit in Skull Cave, Western Australia, and a review of its significance. *J. Roy. Soc. W. Aust.*, vol. 61, pp. 109-117.
Reay, M. 1962 Notes on some rock paintings of the Katherine district, Northern Territory. *Mankind*, vol. 5, pp. 507-514.
Ride, W.D.L. 1960 The fossil mammalian fauna of the Burramys parvus breccia from the Wombeyan Caves, New South Wales. *J. Roy. Soc. W. Aust.*, vol. 43, pp. 74-80.
Ride, W.D.L. 1964 A review of Australian fossil marsupials. *J. Roy. Soc. W. Aust.*, vol. 47, pp. 97-131.
Ride, W.D.L. 1971 On the fossil evidence of the evolution of the Macropodidae. *Aust. Zoologist*, vol. 16, pp. 6-16.
Rosenfeld, A. 1964 The study and interpretation of archaeological deposits in caves. *Stud. Speleol.*, vol. 1, pp. 44-50.
Rosenfeld, A. 1975 The Early Man sites: Laura, 1974. *Aust. Inst. Abor. Stud. Newsletter N.S.*, vol. 3, pp. 37-40.
Roth, W.E. 1901-1910 *North Queensland Ethnography Bulletins.* Nos. 1-18.
Schulze, L. 1891 Aborigines of the upper and middle Finke River. *Trans. Roy. Soc. S. Aust.*, vol. 14, pp. 210-246.
Scott, J. 1963 *Remarks on a Passage to Botany Bay 1781-1792: A First Fleet Journal.* Angus & Robertson, Sydney.
Serventy, V.N. 1952 Cave paintings near York and Hyden. *W. Aust. Nat.*, vol. 3, pp. 121-130.
Serventy, V.N. 1969 *Australia's National Parks.* Angus & Robertson, Sydney.
Shackley, M.L. 1978 A sedimentolotical study of Devil's Lair, Western Australia. *J. Roy. Soc. W. Aust.*, vol. 60, pp. 33-40.
Sharpe, C.F. & Sharpe, K.J. 1976 A preliminary survey of engraved boulders in the Art Sanctuary of Koonalda Cave, South Australia. *Mankind*, vol. 10, pp. 125-130.
Spencer, B. 1914 *Native Tribes of the Northern Territory of Australia.* Macmillan, London.
Spencer, B. 1928 *Wanderings in Wild Australia.* Macmillan, London.
Spencer, B. & Gillen, F.J. 1899 *The Native Tribes of Central Australia.* Macmillan, London.
Stirling, E.C. 1896 *Report on the Work of the Horn Scientific Expedition to Central Australia. Pt. 4 Anthropology.* Dulau, London.

Stockton, E. 1973 Shaw's Creek shelter: human displacement of artefacts and its significance. *Mankind,* vol. 9, pp. 112-117.
Stockton, E. & Holland, W. 1974 Cultural sites and their environment in the Blue Mountains. *Arch. Phys. Anthrop. Oceania,* vol. 9, pp. 36-65.
Strehlow, T.G.H. 1970 *Geography and the totemic landscape in central Australia: a functional study.* Pp. 92-140 in: *Australian Aboriginal Anthropology.* Ed. R.M. Berndt. Univ. W. Aust. Press.
Sturt, C. 1833 *Two expeditions into the Interior of South Australia during the Years 1828, 1829, 1830 and 1831...* Boone, London.
Taplin, G. 1879 *The Folklore, Manners, Customs and Languages of the South Australian Aborigines.* Govt. Printer, Adelaide.
Tench, W. 1793 *A Complete Record of the Settlement of Port Jackson.* Nicoll & Sewell, London.
Tindale, N.B. 1925-6 Natives of Groote Eylandt and the west coast of the Gulf of Carpentaria. *Rec. S. Aust. Mus.,* vol. 3, pp. 61-134.
Tindale, N.B. 1928 Ethnological notes from Arnhem Land and from Tasmania. *Trans. Roy. Soc. S. Aust.,* vol. 52, pp. 223-224.
Tindale, N.B. 1936a General report on the anthropological expedition to the Warburton Ranges, Western Australia. *Oceania,* vol. 6, pp. 481-485.
Tindale, N.B. 1936b Notes on the natives of the southern portion of Yorke Peninsula, South Australia. *Trans. Roy. Soc. S. Aust.,* vol. 60, pp. 55-69.
Tindale, N.B. 1961a Geographical knowledge of the Kaiadilt people of Bentinck Island, Queensland. *Rec. S. Aust. Mus.,* vol. 14, pp. 259-296.
Tindale, N.B. 1961b Archaeological excavation at Noola rock shelter: a preliminary report. *Rec. S. Aust. Mus.,* vol. 14, pp. 193-196.
Tindale, N.B. 1972 *The Pitjandjara.* Pp. 217-268 in: *Hunters and Gatherers Today.* Ed. M.G. Bicchieri. Holt, Rinehart & Winston, N.Y.
Tindale, N.B. 1974 *Aboriginal Tribes of Australia, Their Terrain, Environmental Controls, Distribution, Limits and Proper Names.* ANU Press, Canberra.
Tindale, N.B. & Lindsay, H.A. 1963 *Aboriginal Australians.* Jacaranda, Brisbane.
Tindale, N.B. & Mountford, C.P. 1926 Native markings on rocks at Morowrie, South Australia. *Trans. Roy. Soc. S. Aust.,* vol. 50, pp. 156-159.
Tindale, N.B. & Mountford, C.P. 1936 Results of the excavation of Kongerati Cave near Second Valley, South Australia. *Rec. S. Aust. Mus.,* vol. 5, pp. 487-502.
Trezise, P.J. 1971 *Rock Art of South-east Cape York.* Aust. Inst. Abor. Stud., Canberra.
Tugby, D.J. 1953 Conic Range Rock Shelter: a preliminary account of rock paintings in north-east Victoria. *Mankind,* vol. 4, pp. 446-450.
Twidale, C.R. 1964 Effect of variations in rate of sediment accumulation on a bedrock slope at Fromm's Landing, South Australia. *Zeit. Geomorph. Suppbnd.,* vol. 5, pp. 177-191.
Wakefield, N.A. 1967 Preliminary report on McEachern's Cave, S.W. Victoria. *Vict. Nat.,* vol. 84, pp. 363-383.
Wakefield, N.A. 1972 Palaeoecology of mammals from Australian caves. *Proc. Roy. Soc. Vict.,* vol. 85, pp. 1-26.
Walker, P.H. 1964 Soil and landscape history in the vicinity of archaeological sites at Glen Davis, New South Wales. *Rec. Aust. Mus.,* vol. 26, pp. 247-264.
Wells, F.H. 1894 Habits, customs and ceremonies of the Aboriginals on the Diamantina, Herbert and Eleanor Rivers, in east central Australia. *Rept. Aust. Ass. Adv. Sci. Adelaide,* vol. 5, pp. 515-522.
White, C. 1967a The prehistory of the Kakadu people. *Mankind,* vol. 6, pp. 426-431.
White, C. 1967b Early stone axes in Arnhem Land. *Antiquity,* vol. 41, pp. 149-152.
White, C. & Peterson, N. 1969 Ethnographic interpretation of the prehistory of western Arnhem Land. *Southwest. J. Anthrop.,* vol. 25, pp. 45-67.
White, J.P. & O'Connell, J.F. 1979 Australian prehistory: new aspects of antiquity. *Science,* vol. 203, pp. 21-28.
Wilson, W. 1946 Albert, King of the Blacks, on the Darling River at Wangalara. *Walkabout,* vol. 12, pp. 33-34.
Woods, J.E.T. 1862 *Geological observations in South Australia.* Longmans, Green, Longmans, Roberts & Green, London.
Woodward, H.D. 1914 A geological reconnaissance of part of the Murchison goldfield. *Geol. Surv. W. Aust. Bull.,* no. 57.
Worsnop, T. 1897 *The Prehistoric Arts, Manufactures, Works, Weapons, etc. of the Aborigines of Australia.* Govt. Printer, Adelaide.
Wright, R.V.S. (ed.) 1971 *Archaeology of the Gallus Site, Koonalda Cave.* Aust. Inst. Abor. Stud., Canberra.
Wyrwoll, K.H. & Dortch, C.E. 1978 Stone artifacts and an associated diprotodontid mandible: from the Greenough River, Western Australia. *Search,* vol. 9, pp. 411-413.

MS Received 20th August 1979

J.N. Jennings,
Australian National Univ.,
Canberra.

Trans. British Cave Research Assoc., Vol. 6, No. 3, pp. 131-132 October 1979

CAVE SURVEYING PROGRAMS

by Nigel Dibben

Cavers unable to afford the Hewlett Packard calculators referred to by Ivan Young in his recent Transactions article (BCRA Trans. 5 (3) pp. 153-8) may be interested in the program described below for the Casio fx-201p. This calculator costs less than £50, has 10 stores, 127 program steps and is available (for added cost) with "permanent" storage similar to the HP-25c described by Ivan.

The purpose of the programme is to calculate the coordinates of points directly from the length, inclination and bearing starting from a chosen *base*. The base can be changed to the *last* point calculated or to a new value at any time during the program run. The *next* point to be calculated can be taken from the *base*, the *last* point, or, where the surveyor has taken a single leg off the main route (e.g. to the wall of a large chamber), from the *previous* point calculated. All this may sound a little complicated but if one draws a quick line sketch of the legs surveyed, the most efficient order of calculation can be quickly determined.

Using the data that is given in figures 3 and 4 of Ivan's article, the order of calculation would be:

set base (pt:0) to (0,0,0)	program	instruction	E = 3
calculate pt. 1	"	"	E = 2
Calculate pt. 2	"	"	E = 0
set base to pt. 2	"	"	E = 4
calculate pt. 3, then 4, and 5	"	"	E = 0 then 0, 0.
return to base			
calculate pt. 6 and 7	"	"	E = 2 then 0

The program uses 110 steps and if an owner of a Casio cannot see quite how it works, that is because there are a number of abbreviations in it which the instruction booklet with the calculator does not explain. In fact, the program would require 13 more steps according to the instructions. Using Ivan's test data (noting that there is no provision for correcting for clino errors) the results would be:

Leg	Northing (X)	Easting (Y)	Depth (Z)
0 t 1	86.60254	0	-50
1 to 2	86.60254	86.60254	0 (not 10^{-8}!!)
2 to 3	0	86.60254	
3 to 0	0	0	

Magnetic deviations are corrected by inserting the deviation in the space marked **** in the program. If bearings and inclinations are taken in opposite directions (back clino and forward compass) then a $\pm$ should be entered at the point marked @. Individual backward legs can be corrected by putting in a negative leg length; that has the effect of reversing the calculation.

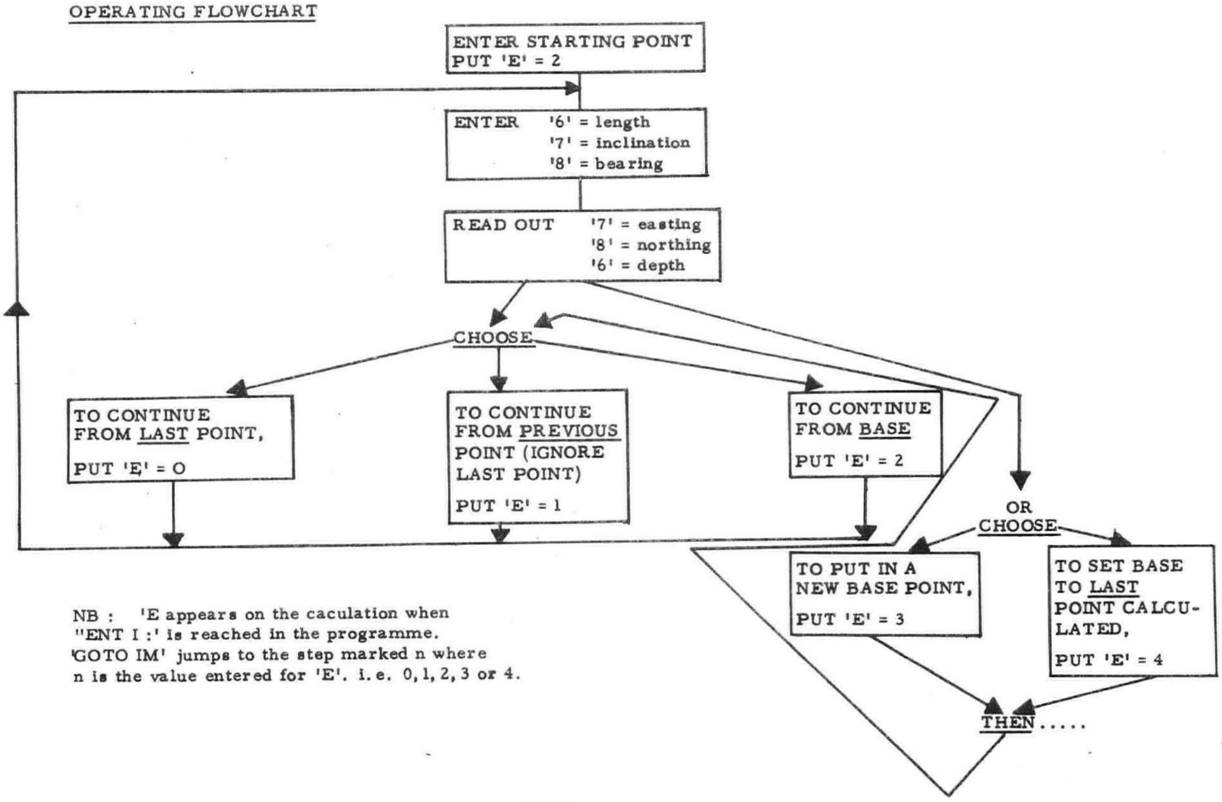
For the non-owner with some programming knowledge, the "Language" used is quite unlike the HP or Texas language and is rather similar to Basic or Fortran with the numerals 0 to 9 as stores. The program is written out in the form of operational statements, e.g.: GO TO 1: which uses three steps "GO TO", "1" and ":" which is an end of statement marker. Steps are marked by putting "ST 1:" etc. at the required point.

PROGRAM

```
ST 3
  ANS : 4 : 5 :                    Check or insert base coords

ST 5
  ENT I :                          Enter the choice of operation (see flowchart)
  GOTO IM :

ST 1
  MJ                               Enter length (6), inclination (7), bearing (8)
  ENT 6 : 7 : 8 :
  = - K ****                       Subtract the mag devn from (8) } See text
  9 = 6 x 7 COS @ :
  6 = 6 x 7 SIN + O :              (6) now becomes the depth
  7 = 9 x 8 SIN + 1 : ANS :        (7) now becomes the easting
  8 = 9 X 8 COS + 2 : ANS : 6 :    (8) now becomes the northing
  GOTO 5 :

ST 4
  = 7 :                            } This section sets the base (3, 4, 5) to the last
  3 = 6 :                          } point (6, 7, 8)
  5 = 8 :
  GOTO :

SUB O
  = 6 :                            } This section continues the calculation from the last
  1 = 7 :                          } point (6, 7, 8)
  2 = 8 :

SUB 2
  = 5 :                            } This section continues the calculation from the
  O = 3 :                          } base point (3, 4, 5)
  1 = 4 :
```

Nigel Dibben,
97 Worth Clough,
Poynton, Cheshire.

OPERATING FLOWCHART



NB : 'E appears on the caculation when "ENT I :' is reached in the programme. 'GOTO IM' jumps to the step marked n where n is the value entered for 'E'. i.e. 0, 1, 2, 3 or 4.

Trans. British Cave Research Assoc., Vol. 6, No. 3, pp. 133-142 October 1979

PE'APE'A LAVA CAVE, WESTERN SAMOA

by C.D. Ollier and P. Zarriello

ABSTRACT

A lava flow about 3000 years old descended from Mt. Fito (Western Samoa) along a narrow valley and spread out to form a lava plain. Just below the point of spreading is Pe'ape'a lava cave. This has a total length of about 1 km, with splitting and re-joining passages and several blind branches. The inside of the cave has several original volcanic features, including arcuate roofs and lava benches, but the floor is modified by a river that flows through the cave, cutting erosion grooves, scallops and plunge pools, and depositing shoals of pebbly alluvium. The lava plain has a hummocky surface suggesting the former existence of many more lava tubes which collapsed when drained. Cross-sections of the lava exposed in cliffs show large lobes which, if drained, could produce lava caves, but on balance the cave is thought to be formed by the thermal erosion of a continuous flow of lava beneath a solidified crust. Bats, swifts, eels and shrimps live in the cave.

Western Samoa consists of two main islands entirely of volcanic origin. The last eruption was on the western island of Savaii in 1905. The eastern island, Upola, has a national park on the southern side consisting largely of a lava flow that runs to the coast at O Le Pupu from Mt. Fito, the highest mountain on the island. The lava flow is prehistoric and is old enough to be eroded into cliffs and stacks at the coast, and into a series of waterfalls in its upper course, but young enough to retain much of the original lava surface, with details such as ropy lava almost intact (Fig. 1).

The Pala River flows over the Fito lava flow for much of its length, along a rocky bed eroded in the basalt, with smooth potholes, scallops and erosion grooves, and angular holes where joint blocks have been plucked out. In the lower reaches considerable tracts are floored by pebbly alluvium. At one point the river enters a large hole, 20 m across in the river bed - the Sink Entrance. The river flows underground through a lava cave known as Pe'ape'a Cave (the cave of the swiftlets), and emerges from the small Spring Entrance. The ground surface above the cave is continuous with the surrounding lava plain and there is no indication on the surface of the cave beneath.

We were unable to survey the long profile of the cave, but the numerous openings show it is roughly parallel to the ground surface which here has a gradient of about 1 in 25 (2^{o}). Topographically the cave is located near to, but not at, the point where the lava flow spreads from a confined valley flow into a delta-shaped lava plain.

In the dry season the cave carries very little water, but in the wet season much of it is flooded, and it is possible that in extreme seasons the river floods the cave and flows over the ground surface. There are indications of past river flow on the surface, but the life in the cave suggests that such flow is rare. In the dry season only a trickle of water emerges from Spring Entrance, but in the wet season the flow is so great that Spring Entrance is impassable.

FEATURES OF THE CAVE

Pe'ape'a Cave is unusual in having many original volcanic features, well preserved because of the relative youth of the lava flow, together with many features indicative of river erosion (Fig. 2).

1. Cave Plan

Some of the world's lava caves are confined to a single channel and in others a braided pattern is formed, with branching and anastomosing lava tubes. The Pe'ape'a Cave is slightly braided, with a division into two equal parts (Bat Chamber and the Stream Passage) for over 200 m, and many smaller tributary passages that are now blind alleys. The many collapse depressions described later indicate that there were many lines of lava flow originally, and suggest that braided lava flow was common on the original lava plain.

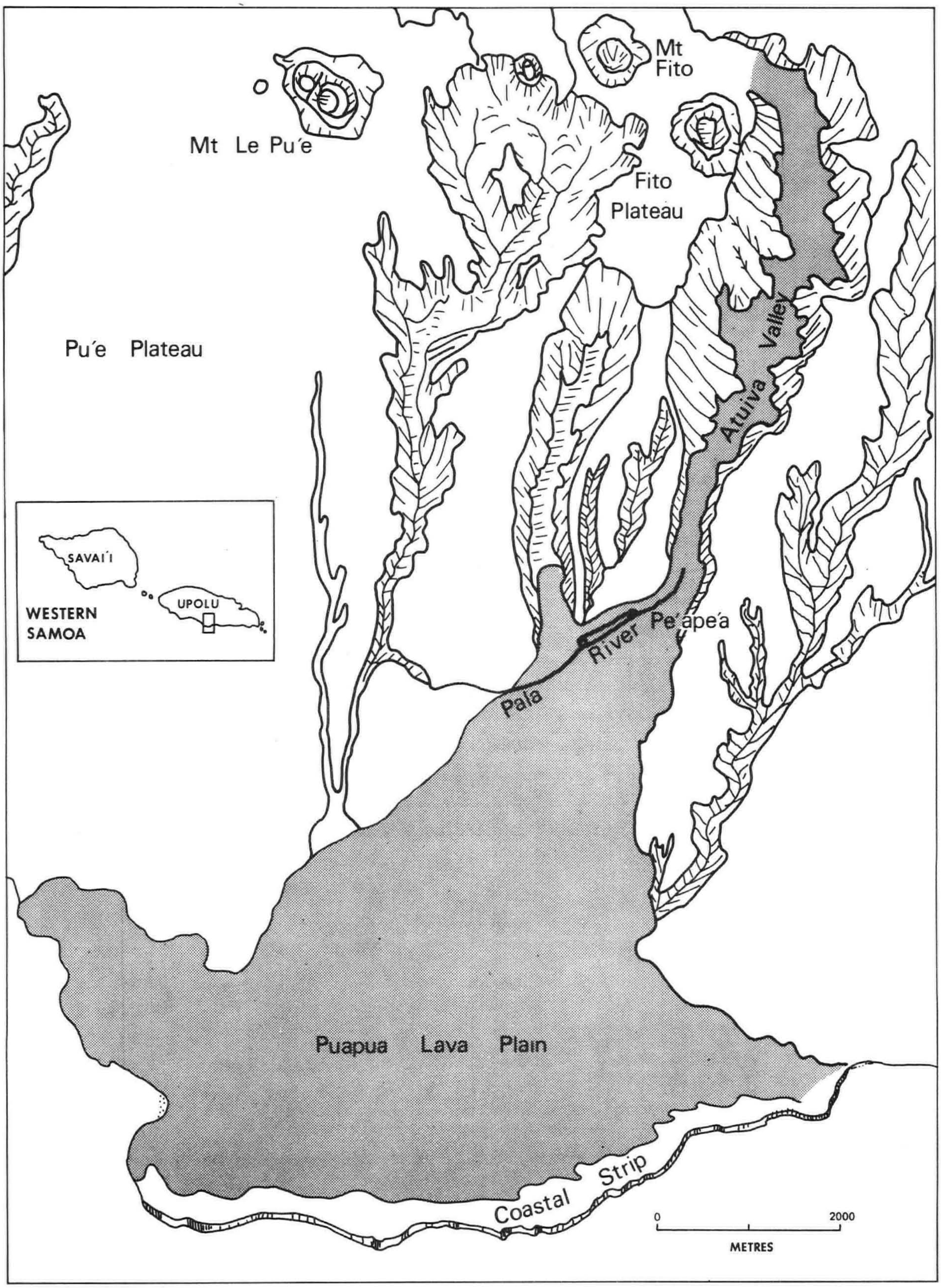


Fig. 1 The Puapua lava flow from Mt Fito and the location of Pe'ape'a Cave

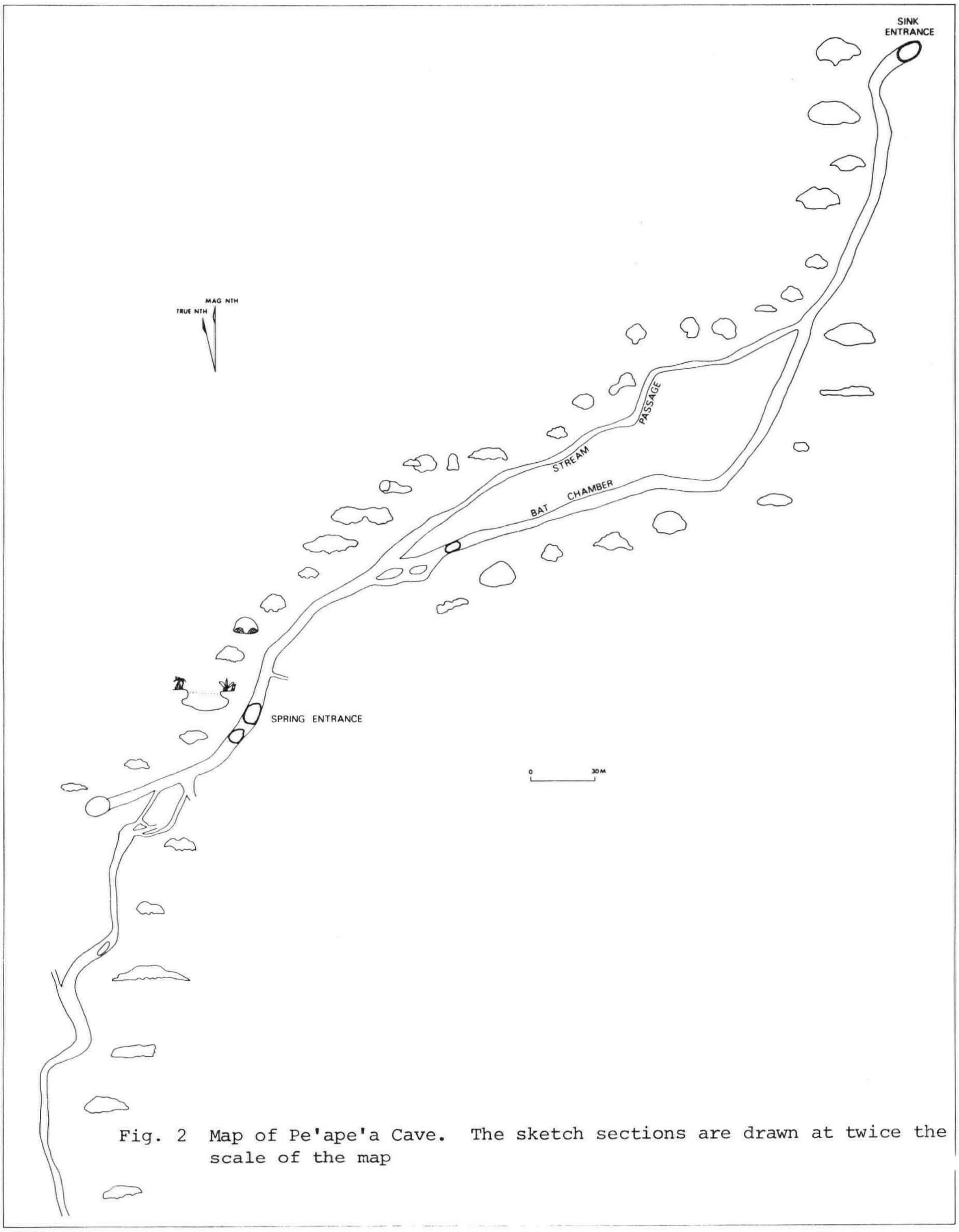


Fig. 2 Map of Pe'ape'a Cave. The sketch sections are drawn at twice the scale of the map

2. Cross-section

Studies of lava caves elsewhere in the world suggests that lava tubes are typically cylindrical, but as they seldom drain completely they usually have arched roofs and flat or irregular floors. Pe'ape'a Cave does not seem to have ever attained a high degree of circularity in cross-section, but the upper part of the cave is a rather rugged half circle in many places.

The cross-section of the cave, at its most perfect as in Bat Chamber, consists of three parts (Fig. 3):

a. The roof and upper walls, very roughly semicircular and irregular in detail;
b. Grooved lava and lava terraces on the lower walls of the cave;
c. A fairly smooth, concave upwards, cave floor formed by a crust about 30 cm thick.

Nowhere has the lava drained out completely to leave a circular section lava tube.

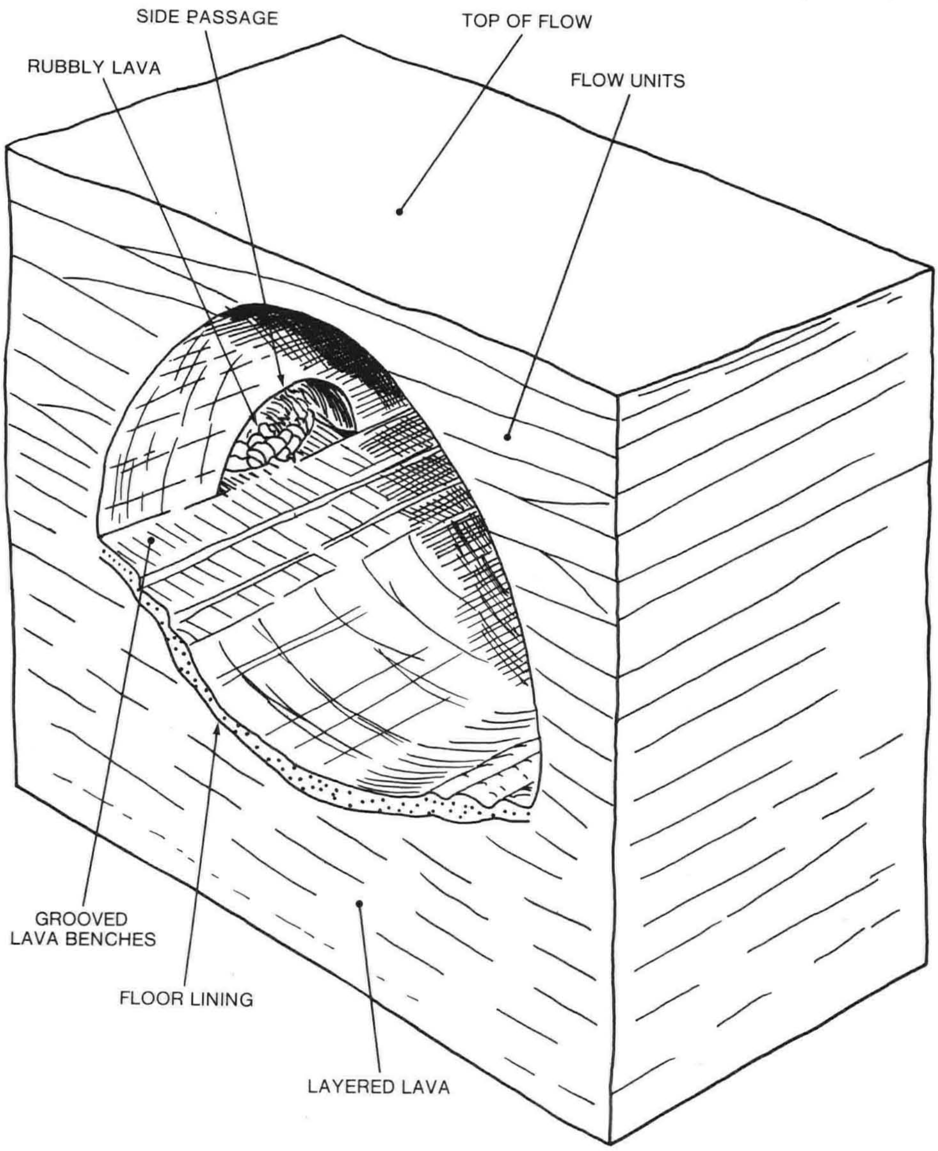


Fig. 3 Block diagram showing some features of the cave

3. Lining

Many lava caves have a lining of lava a few centimetres thick which covers much of the walls and roof of the caves. This may be the last bit of lava left behind when the lava drained out, or it may be made by re-melting the basalt of the cave roof and walls, after drainage of the lava but while hot gases occupy the cave. The lining has "flow" and "drip" structures and may have lava stalactites. There is no good "lining" on the upper half of Pe'ape'a Cave. Few lava stalactites have been seen in Pe'ape'a Cave, and no lava stalagmites on the cave floor have been found. These would not be preserved, if they ever did exist, because of the large amount of river erosion on the cave floor.

4. Benches

Benches and grooved lava are very extensively developed on the walls of the main passages, and are numerous - sometimes as many as seven benches. This seems to indicate that the channels functioned for a considerable time, with a slow fall in lava level by as much as a metre, after they were initiated by partial drainage (Plate 1, Fig. 1).

5. Minor side passages

The side passages, tributary to the main lava cave, have a different character from the main lava tube. They are not completely drained of lava and at the time the side passages solidified they were transporting a stodgy, rugged heap of rubbly lava. This does not extend into the

Plate 1

Fig. 1 Benches on the side of the lava cave. Each level marks a stable period during the draining of lava from the cave.

Fig. 2 A side passage with a solid floor remaining as a shelf after withdrawal of still-liquid lava from beneath. Rubbly lava is seen above the shelf. Pebbly alluvium has accumulated beneath.

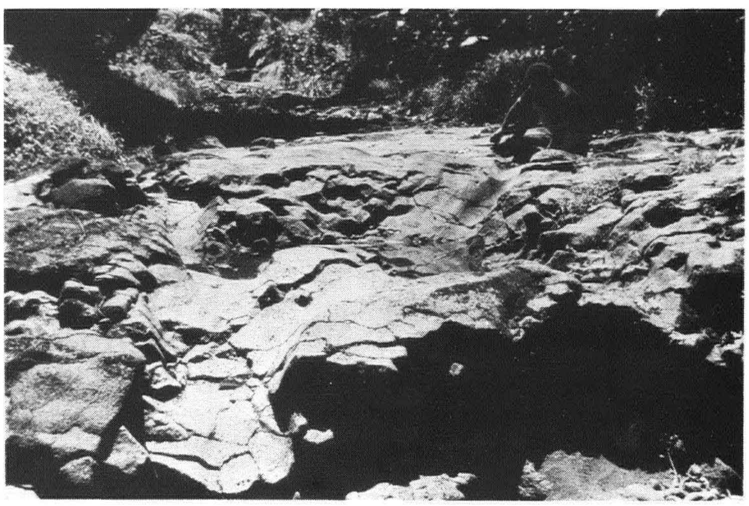


Fig. 3 Bed of the Pala River just upstream of the cave showing erosion grooves.

Plate 2

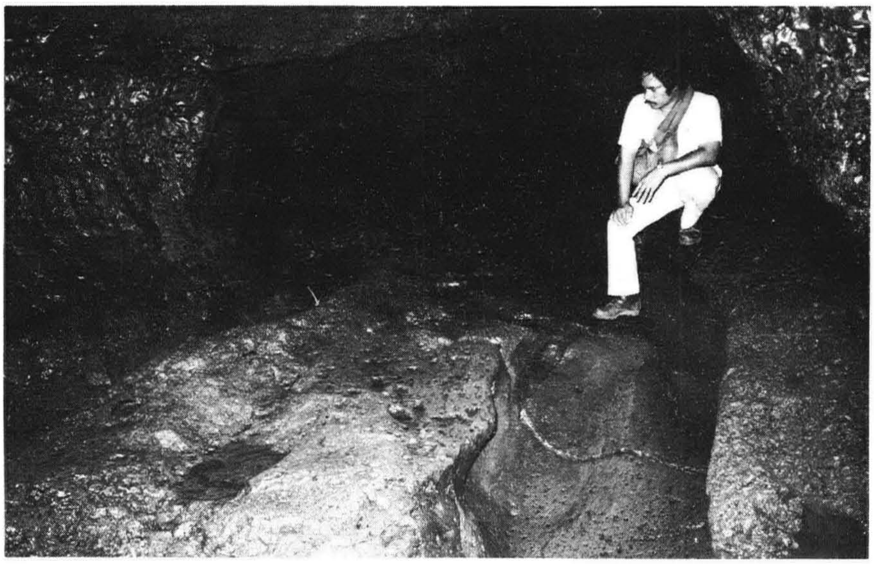


Fig. 1 The water-eroded floor of the lava cave, with potholes and erosion grooves.

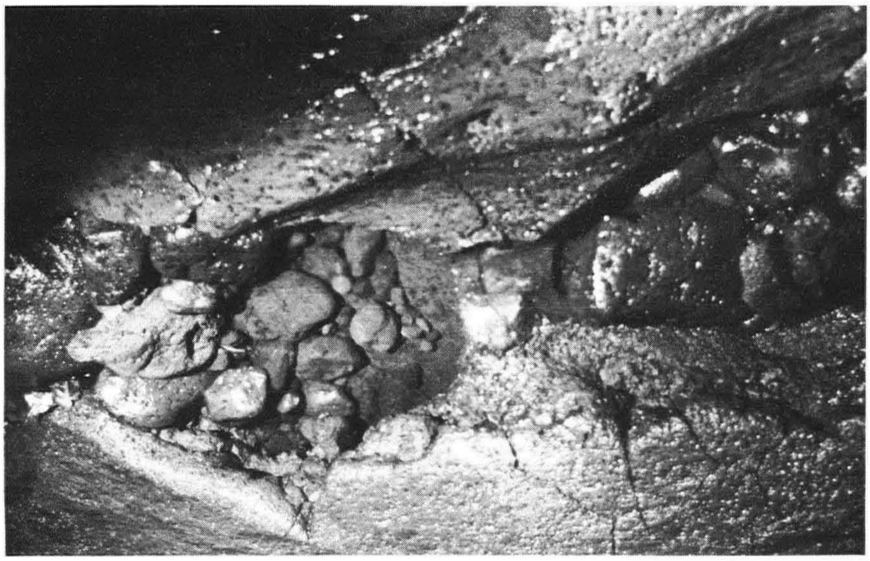


Fig. 2 Potholes and pebbly alluvium seen from above.

Fig. 3 A lava lobe seen in cross-section in a natural arch.

main cave, so any rough lava that reached the main cave was absorbed by the smoother lava of the main stream and carried away. But, since nowhere at all does the rubbly lava extend on to the floor of the main cave, it is concluded that the tributaries stopped flowing before the main cave. The lava in the main tunnel continued to flow for quite a long time after the tributary valleys ceased to flow, and at this stage the main lava cave was only about half full. In some instances the floors of the tributary caves had solidified over a still-liquid underlying lava, and then a fall in the lava level of the main stream allowed the underlying lava to drain out, leaving the old floor of the tributary cave as a small shelf (Plate 1, Fig. 2).

6. Layered Lava

Where pot holes and erosion grooves have cut through the floor-layer, the underlying lava is seen to be layered. Distinct partings such as those in the flow units above the cave roof are rare or absent, and the layering is mainly shown by vesicles aligned by shearing in the liquid lava as it flowed beneath the crust.

7. Collapse

Here and there the roof of the lava cave has collapsed, creating the openings to the surface at both ends of the cave and at a few places along the length of the cave. There are also places in the cave where bits of rock have fallen from the roof without making a hole right through to the surface. In most dry lava caves, such as the Byaduk Caves of Victoria, debris and fallen rocks can still be found on the cave floor beneath the corresponding scar on the cave roof, but in Pe'ape'a Cave the river carries all the fallen debris away.

8. River features

In flood times the Pala River flows through the cave. The south passage is relatively little affected, though it does carry some water, but the rest of the lava cave has many indications of stream erosion and deposition. Both in the cave and on the surface, river erosion takes three main forms.

In one kind of erosion the attrition of moving debris wears the basalt into rounded or fluted forms, such as scallops and erosion grooves (Plate 1, Fig. 3). In the cave erosion grooves are typically 20 - 50 cm wide, but the largest are a metre wide and a metre deep. The smaller abrasional features are about 10 - 20 cm across. The grooves and scallops intersect to form ridges that are generally rounded.

A second kind of erosion is joint-block quarrying. The basalt is divided into crude columns by vertical joints, and the columns are divided by incipient or actual cross joints - horizontal or slightly curved planes that divide the columns into blocks a few tens of centimetres across. These blocks fit tightly together, but as erosion grooves grow the blocks are loosened and eventually plucked out, leaving a new angular hole on the upstream side. This is then abraded, loosening another joint block, and so on.

The third kind of erosion is by waterfalls. Some layers of basalt are more resistant to erosion than the underlying basalt. In surface waterfalls the hard band is solid basalt with few joints, the underlying erodible layer is often rubbly, like the top of a flow unit. In the confined space of the cave it was not easy to see just why waterfalls occurred, because plunge pools and the waterfalls themselves made it hard to examine the rock, but distinct rubbly layers were not seen.

Pebbly alluvium accumulates on parts of the cave floor, with pebbles mainly about 10 cm across - all of course consisting of basalt. Shoals of alluvium perhaps 10 m long alternate along the cave with erosional stretches free of alluvium (Plate 2, Figs. 1 & 2).

WILDLIFE IN THE CAVE

Wildlife in the cave is limited primarily to two species, a bird and a bat, but these occur in large numbers. Furthermore each has adapted to navigating, roosting and breeding within the dark moist confines of the cave.

The White-rumped Swiftlet (pe'ape'a), a very small black bird with a white rump, is very common in the surrounding forest, where it feeds during the day on small flying insects. This bird never roosts or perches in trees. Instead at night (and sometimes during the day) it roosts inside the cave where it clings to the roof and walls. Nests are made of moss collected from tree branches, and are glued against the cave wall, or even the roof. Several thousand birds roost near the Sink Entrance.

The Sheath-tailed Bat (tagiti), a very small, greyish-black bat, feeds on small flying insects at dusk and at night, and during the day roosts in caves. Several thousand bats were roosting at the time of our visit, and many females had young clinging to their bodies.

Other animals in the cave include a fresh-water eel (tuna), a fresh-water shrimp (ula vai), and several species of flying insect.

It seems quite probably that the cave is occasionally flooded to an extent that would force out or destroy all the occupants, and it is possible that the cave may be re-colonized from other, undiscovered caves.

FEATURES OF THE LAVA FLOW

The first cooling of the hot, liquid lava surface forms a very thin skin, which is dragged along on the still-liquid lava beneath, wrinkled into tight folds, and moulded into festoons of ropy lava. Ropy lava is very well preserved on much of the flow surface.

Beneath the skin of ropy lava the crust of the lava flow, down to about a metre, has cooled into fairly dense lava with vesicles (bubbles) often arranged in horizontal layers. This crust is broken by cracks (joints) into crude columnar lava. Beneath this crust the lava may be massive, but is sometimes divided into layers by some sort of partings.

At the coast it is possible to see some features of the lava flow in cross-section, and one of the most interesting features is the lava lobe, which probably represents a unit of flow. At the front of an advancing lava flow, the lava often advances by extending a series of lobes. Each lobe forms a skin, and is like a plastic tube filled with hot lava. The skin is wrinkled into ropy lava and a crust of vesicular lava is beneath this. The lobes at the coast are full of dense lava that probably marks the top of an earlier unit in the lava flow.

If such a lobe were to drain, after the crust was solid enough to support its own weight, a lava cave might be formed. Interestingly, such a cave might have a semi-circular section from its inception, not as a result of partial drainage of a circular lava tube (Plate 2, Fig. 3).

It is much more probable that if liquid lava is withdrawn from beneath a plastic crust then the crust will not have the strength to support itself, but will collapse. Many instances of this are found on the Puapua lava flow. Linear depressions called collapse troughs probably result from collapse of the crust into a drained lava tube (Fig. 4).

In other places there are ridges where either the crust has been buckled up by pressure of lava derived from upslope, or remains as a remnant ridge when there is collapse on both sides (Fig. 5).

THE FORMATION OF LAVA CAVES

The origin of lava caves is controversial. As indicated for instance by the explanations given by Ollier and Brown (1965), Kermode (1970), Peterson and Swanson (1974), and Wood (1974, 1976). The Gruppo Grotte Catania organized and edited the proceedings of a Seminario Sulle Grotte Laviche (Seminar on lava caves) at which conflicting views were debated, and a forthcoming review attempts to show that lava caves are formed in several different ways (Ollier, in press).

There are at least four kinds of lava cave:

1. Minor partings and tubes, little more than very large vesicles
2. Caves formed by roofing over of initially open lava channels
3. Drained pahoehoe toes of flow units
4. Subcrustal caves in which continuing flow of lava beneath the crust first forms and then enlarges by thermal erosion a lava conduit beneath the crust. This becomes a cave if the lava in the conduit is drained out, at least partially, and the crust has enough strength to resist collapse.

The Pe'ape'a Cave is either type 3 or type 4.

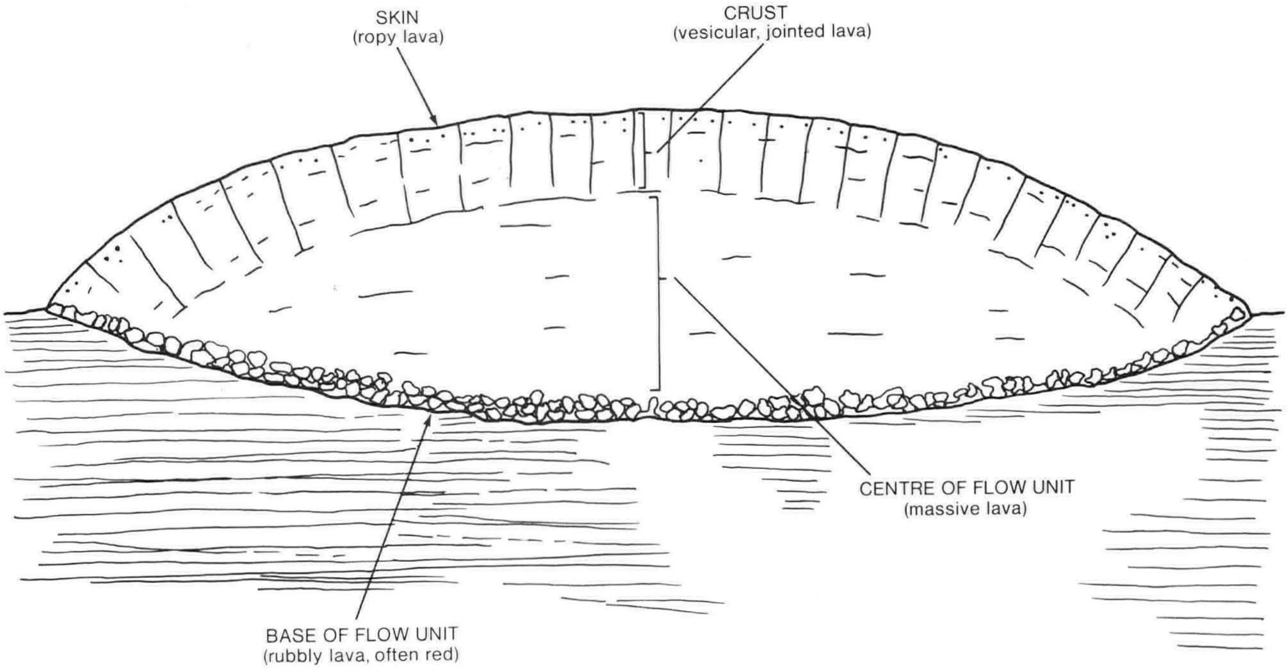


Fig. 4 Diagrammatic cross section of a typical lava lobe

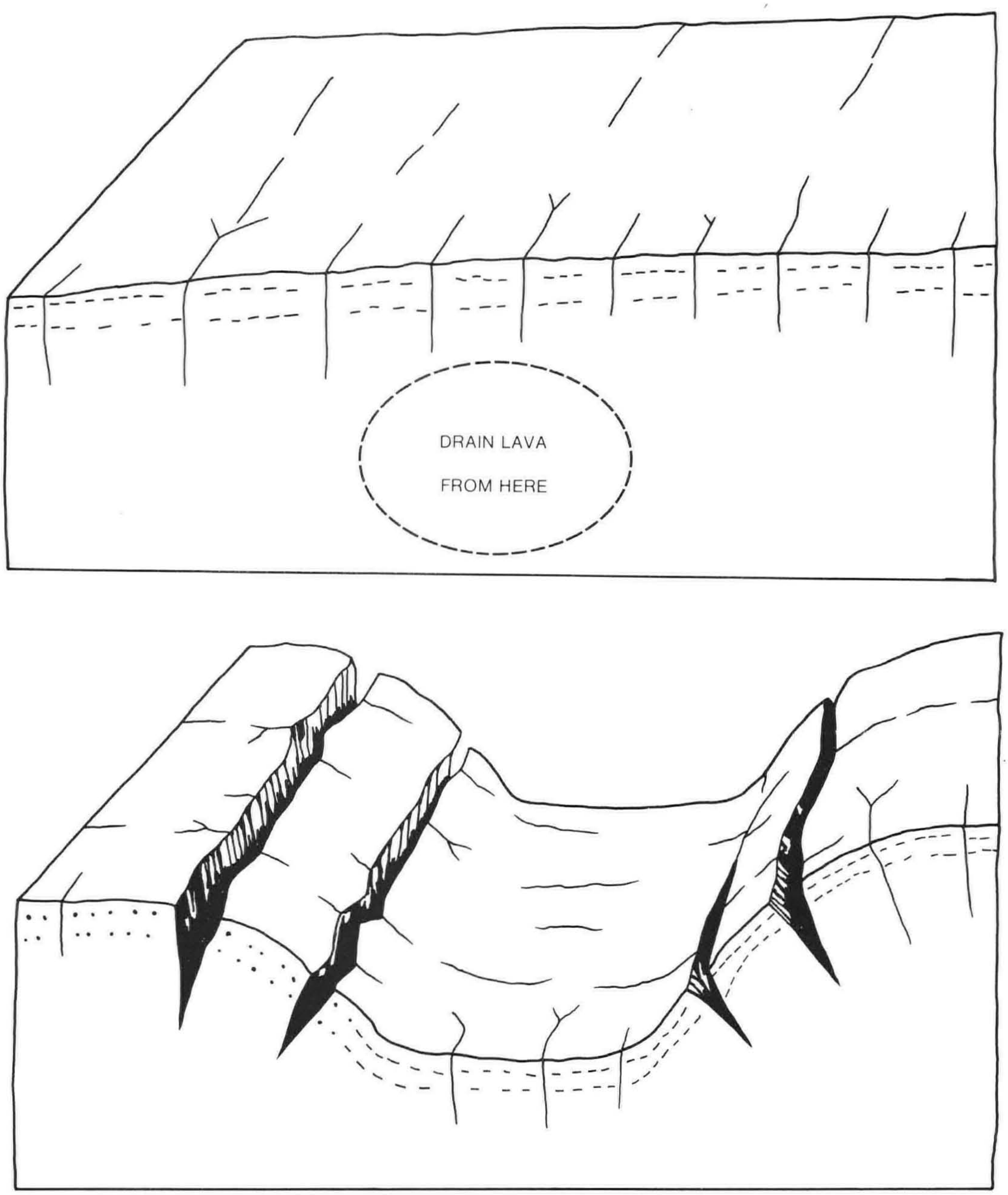


Fig. 5 Block diagram to show the formation of a collapse trough, an alternative landform to a lava cave

In favour of type 3 is the fact that flow units of about the right shape and size are present in the area. Cross-sections are visible at the coast, but we do not know what they are like in plan.

In favour of type 4 is the possible presence of layered lava, a feature commonly associated with this type of cave. The length of the cave lends some support to this idea, as does the braided pattern and the evidence of continued flow along the main stream for a considerable time, with the main stream continuing when tributaries had solidified, and flow going on long enough to form numerous lava benches.

On balance a type 4 explanation is preferred. One can envisage the lava pouring down from Mt. Fito along the Afuiva Valley and then spreading as a delta of lava on the broad plain behind the coast. At first the lava flowed by extrusion of individual lobes, but these coalesced to form a continuous lava plain. There would be many readjustments and alterations to lava flow patterns and in places flow units would be stacked one upon another. Eventually much of the flow would have a continuous crust and lava beneath the crust became confined to distinct conduits. When the supply of lava erupted from Fito stopped these conduits would initially be full. But if lobes continued to be extruded at the front of the flow they would be made of lava derived from the lava within the conduits, which were therefore partially drained.

On most of the lava plain this final stage of lava drainage led to the creation of collapse troughs and pressure ridges, but in one exceptional place the lava surrounding the conduit was sufficiently solid to resist collapse, and this became Pe'ape'a Cave.

REFERENCES

Gruppo Grotte Catania (eds) 1975 *Seminario Sulle Grotte Laviche.* Societa Speleologica Italiana, Catania.

Kermode, L. 1970 Lava Caves, their origins and features. *New Zealand Spel. Bull.*, vol. 4, pp. 441-465.

Ollier, C.D. (in press) *Lava Caves* In *Encyclopedia of Volcanoes and Volcanology*, J. Green (ed.), Dowden, Hutchinson and Ross, Stroudsville, Pennsylvania.

Ollier, C.D. & Brown, M.C. 1965 Lava caves of Victoria. *Bull. Volc.*, vol. 28, pp. 215-229.

Peterson, D.W. & Swanson, D.A. 1974 Observed formation of lava tubes. *Studies in Speleology*, vol. 2, pp. 209-222.

Wood, C. 1974 The genesis and classification of lava tube caves. *Trans. Brit. Cave Res. Ass.*, vol. 1, pp. 15-28.

Wood, C. 1976 *Caves in rocks of volcanic origin.* Chap. 4 in *The Science of Speleology*, ed. T.D. Ford & C.H.D. Cullingford, Academic Press, London, 593p.

MS Received August 1979

Professor C.D. Ollier,
Department of Geography,
University of New England,
Armidale, N.S.W. 2351,
Australia.

Mr. P. Zarriello,
93 Sand Creek Road,
Albany,
N.Y. 12205,
U.S.A.

The TRANSACTIONS OF THE BRITISH CAVE RESEARCH ASSOCIATION covers all aspects of speleological science, including geology, geomorphology, hydrology, chemistry, physics, archaeology and biology in their application to caves, as well as technological matters such as exploration, equipment, surveying, photography and documentation. Papers may be read at General Meetings held in various parts of Britain, but they may be submitted for publication without being read. Manuscripts should be sent to the Editor, Dr. T. D. Ford, Geology Dept., University of Leicester, Leicester LE1 7RH, who will be pleased to advise in cases of doubt about the preparation of manuscripts. The Transactions is normally issued four times a year to paid-up members of the British Cave Research Association. Subscriptions are due on January 1st annually.

Full Members £6 per annum

Corporate Members Clubs £7 per annum

Back numbers of the Transactions and other publications can be obtained from Bryan Ellis, 30 Main Road, Westonzoyland, Bridgwater, Somerset TA7 OEB