KEYWORDS: ***Limestone caves - Isotopic geochemistry - Rock art - Dating - South Australia***

Malangine and Koongine Caves, South Australia

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Abstract. Two caves with finger markings of a type observed at many other sites in western Europe, Papua New Guinea and southern Australia are described in this report. Malangine and Koongine Caves also contain other, more recent forms of petroglyphs, and this sequence of rock art is stratified by laminar ceiling deposits of travertine. These speleothems have provided preliminary dating evidence for the rock art, and they can be correlated to the sedimentary stratigraphy. The environmental setting of the caves is examined, particularly flora and climate in view of their effects on speleothem formation, and the archaeology as well as the sediment sequence are considered.

Introduction

THE 'discovery' in 1979 of Malangine and Koongine Caves in the course of a study of the known finger fluting sites of the world (Bednarik and Bednarik 1982) was a remarkably fortunate incident. Although research has since shown that the caves had been examined cursorily by several previous European visitors in recent decades (e.g. G. D. Aslin, R. Black, F. Glynn, L. B. Kurtze, T. McCourt), and no doubt by many settlers, graziers, rabbiters and others previously (and were known to the Aboriginal people for many thousands of years before), the extensive finger lines were apparently not identified and the significance of the petroglyph stratigraphy was not realised. None of the several archaeological studies of the Mount Gambier karst region had resulted in locating any of the many sites of cave art in the area.

The two caves in which rock art was first found are described here. They are located 6.7 kilometres south of Kongorong (south of Mount Gambier, South Australia), and almost four kilometres from the coastline at Nene Valley (Figure 1). In that region, three low ridges run parallel to the coast, constituting the southern continuation of the Woakwine Range. They are the Kongorong Range, Whawbe Range and, nearest to the sea, Long Gully Ridge. The last mentioned is generally only a few metres high, and terminates south of Kongorong in a group of prominent low rock ridges which contain two south-facing caves.

The caves are well known to local pastoralists but remain unnamed, according to statements from five residents made in 1980. Other informants have subsequently related the names 'Bat Caves' and 'Nunan's Caves'. The

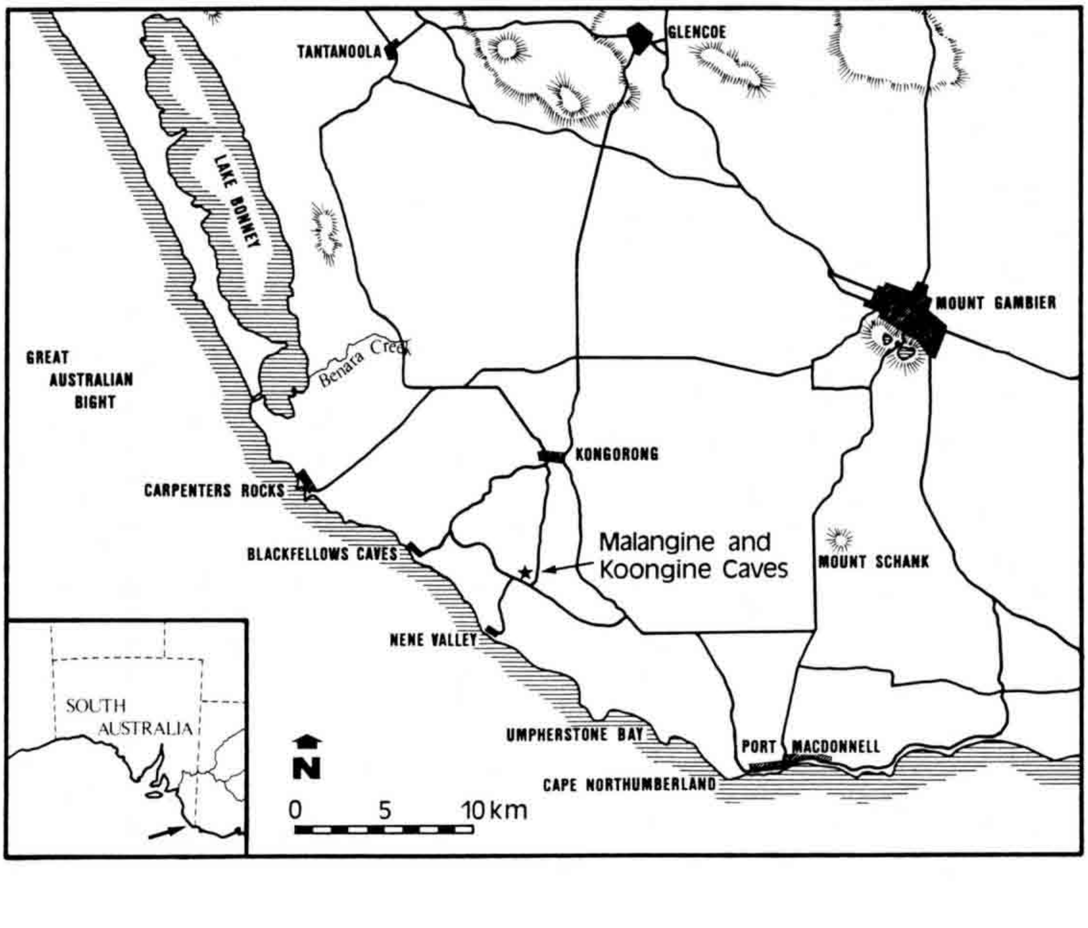


Figure 1.
Location map.

former name is considered inappropriate (there are numerous caves of that name, including in the near vicinity) and whilst the second would be of interest because it refers to the European settlement of the region, I decided that Aboriginal words are more appropriate, particularly in view of the complete extinction of the Boandik (Boandig, and other spellings), the most recent indigenous linguistic group to occupy the region. *Malangine* means 'my wife', and *koongine* means 'my son' (Smith 1880). These names are now well established in the scientific literature relating to Australian cave art and archaeology.

The purpose of the present paper is to introduce the sites Malangine and Koongine Caves, to indicate the variety of studies taking place there, and to explain how these are inter-related. The rock art in the two caves is described in a general form, and those features or characteristics of the caves that are directly related to the cave art are considered: the vegetational setting and speleo-climate (which are of significance to the isotopic geochemistry of the speleothems sandwiching the rock art, as well as to the conservation of the art), the archaeology and lithic sources (which provide background information), the cave precipitates (which are physically related to the rock art), and the nature of the rock art itself, its stratigraphy and its possible dating. Other aspects studied are not examined here, including the possible effects of volcanic eruptions on carbonate precipitates, the cave sediments, and the details of the excavations. Most of the latter have been published elsewhere, and the former are to be considered in future work.

Vegetational setting

Although most of the region has been converted to grazing land, interspersed with occasional plantations of *Pinus radiata*, it is still possible to reconstruct former vegetational patterns by examining remnant populations of native flora and through the accounts of early European residents.

Vegetation zones near the caves were determined by the closeness of the coast. The caves are only sixteen kilometres from Cape Northumberland, one of the closest locations along the entire Australian coastline to the 200-metre isobath. Nene Valley a small settlement on the coast nearest to the caves, is only twenty-six kilometres from that isobath, and about sixty-five kilometres from the 2000-metre isobath.

Parallel to the shore is a **coastal dune zone** usually of increasingly consolidated structure as one proceeds away from the beach (Figure 2). Although embryonic dune

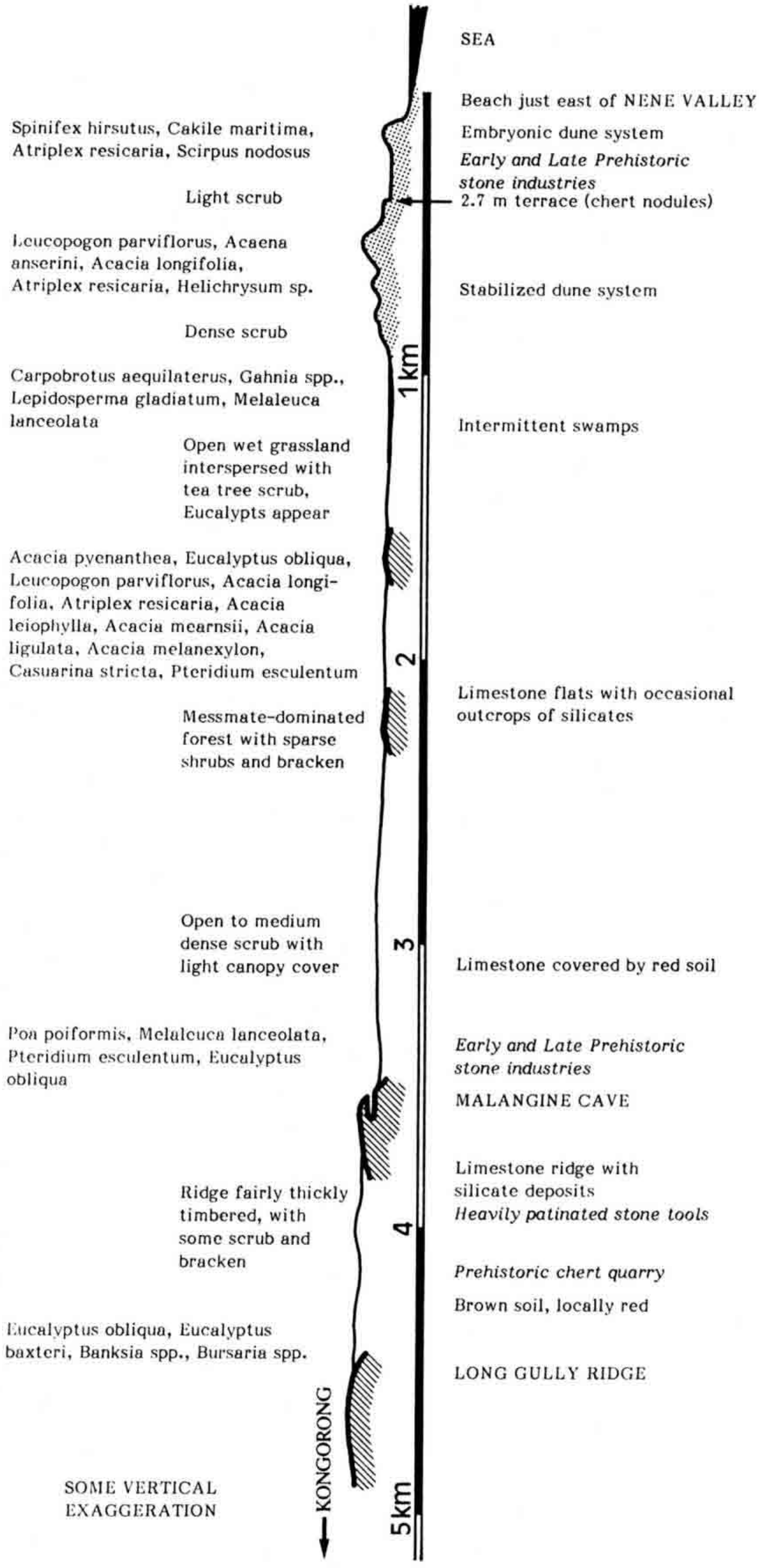


Figure 2. *Terrain section from Malangine Cave to Nene Valley beach, showing environmental detail.*

systems occur, most of the calcareous formations are well stabilised by vegetation in the vicinity of Nene Valley, first by hairy spinifex (*Spinifex hirsutus*), knobbly club-rush (*Scirpus nodosus*), sea rocket (*Cakile maritima*) and salt bush (*Atriplex resicaria*), and further on by light scrub. The scrub becomes very dense on the better stabilised dune systems that have been established a few hundred metres inland, and consists almost entirely of coast wattle (*Acacia longifolia*, var. *sophorae*), native currant bush (*Leucopogon parviflorus*), *Olearia axillaris* and a *Helichrysum* sp., often with a good ground cover of bidgee-widgee (*Acaena anserini folia*).

About one kilometre from the beach the dunes abruptly give way to **limestone flats** which are only a few metres above sea level. Silica seams are occasionally exposed, and ancient impact fractures in some places appear to bear witness of pre-Historic mining activities. There are several swamps where the surface approaches the aquifer table: Robertson's Swamp, Ashby's Springs, and the spring at Nene Valley Swamp. Although these swamps appear to be intermittent, water can be found there even in summer, and attracts water fowl such as ibis (*Threskiornis* sp.). The open wet grassland surrounding these localities is interspersed with tea tree scrub, whilst on the low ridges light, Eucalyptus-dominated forest with sparse shrubs and bracken has been established. This is of messmate (*Eucalyptus obliqua*), with Drooping She-oak (*Casuarina stricta*), wattles (*Acacia pyenanthea, leiophylla* and *mearnsii*), umbrella bush (*Acacia ligulata*) and blackwood (*Acacia melanexylon*), an undergrowth of the earlier-mentioned dune shrubs, with sword rushes (*Lepidosperma glatiatum*), Pigface (*Carpobrotus aequilaterus*), and tussock grasses (*Gahnia* spp.) in suitable locations.

At three to four kilometres from the coast, a **rocky ridge** rises to a maximum of about twenty metres above the flats. Here, the vegetation gradually changes to dry sclerophyll forest. Its light canopy and open to medium scrub abound with small bird life. Old dryland tea tree (*Melaleuca lanceolata*) stands occur with messmate (*Eucalyptus obliqua*) over a ground cover of gramineae such as blue tussock grass (*Poa poiformis*), and bracken (*Pteridium esculentum*) and herbs. In the past, the ridges were fairly thickly timbered, mostly with messmate forest, with the odd occurrence of brown stringybark (*Eucalyptus baxteri*). Woods (1862) also mentions the occurrence of *Banksia* and *Bursaria*.

Variations of open dry sclerophyll communities, alternating with heathlands, continued for about thirty to forty kilometres from the coast, where they faded into low to medium savanna, dominated by *E. camaldulensis* (for further details of former vegetation, see Costermans 1981; Crocker 1944; Dodson 1975; Eardley 1943; Welbourn and Lange 1968)

Geological and archaeological setting

From the Glenelg River estuary to south of Kingston, the South Australian coast consists mostly of a series of small, sandy bays separated by cliffs of recent aeolian sandstones (calcarenite). Very substantial deposits of chert nodules occur along the shore line and are particularly prominent between Blackfellows Caves and Carpenters Rocks, and east of Port MacDonnell. These white, cortex-covered clastics originate from the tabular deposits of the sedimentary silicas occurring on the sea bed (Boutakoff 1963: 20) and are cast up on the beach by a process described by Witter (1977: 52). The Oligocene limestone matrix is eroded in the coastal shallows (see Bednarik 1980: 59 for comments on the resultant coastal shingles), no doubt with the assistance of water turbulence which increases both chemical and mechanical erosion. The freed silica nodules are often adopted by kelp as anchors. During storms the plant appendages cause the cobbles to be propelled towards the high water line, where an embankment consisting entirely of chert nodules slowly forms.

In addition to the presently forming deposit, there is a second mound of such rocks, about 2.7 metres above the present high water mark, and extending for many kilometres where it is not covered by the recent, poorly stabilised dunes. For example, it extends over much of Umpherstone Bay, and is exposed intermittently east of Nene Valley, where it often has the appearance of an artificially built levee about a metre high. This formation no doubt indicates a geologically recent transgression, and could well be related to similar evidence I have observed elsewhere on Australian coasts (especially in the Dampier Archipelago, some 3000 kilometres away; refer also to comments by Virili [1977: 440]). It is archaeologically important in the Cape Northumberland area because deflated living floors occur frequently on the landward side of the dam-like features, but are lacking on the seaward side. As it is likely that the occupation debris is related to the raised sea level, a thorough investigation of this relationship appears a promising line of enquiry. Without doubt, the enormous chert deposits were extensively quarried by pre-Historic people, and were a significant asset to local groups.

Similar but less pronounced accumulations of chert cobbles indicate ancient shore lines further inland, as do the late Pleistocene dunes that dominate the topography for example north of Millicent (Blackburn 1966).

Geomorphologically, the Mount Gambier limestone karst forms the western half of the Otway Basin (Kenley 1971; Wopfner and Douglas 1971). These Miocene limestone strata have given rise by replacement process (Walker 1962) to a number of horizontal seams of silica which will be discussed later. The flat to low undulating relief almost totally lacks surface drainage. There is only one natural creek in the region, Benara Creek, merely eight kilometres long. The topography indicates that co-ordinated surface drainage was never established in this immature karst landscape. Ephemeral run-off channels drain subterraneanly, supporting marshy vegetation where they terminate. The aquifer is often only a few metres below the surface (Colville and Holmes 1972; Ward 1941), and the huge phreatic reservoir is frequently exposed in sinkholes and subterraneously, in caves.

The entire district is riddled with numerous cavities, with over 300 caves explored. Few of them are horizontally arranged, walk-in caves which would be suitable for habitation. Those close to the coast are without exception of small dimensions, Malangine Cave being the largest of them. Three very small caves have been excavated north of Beachport, two of them at the western shores of Lake George, and one just north of the small coastal settlement of Nora Creia. Piccaninnie Cave, thirty-seven kilometres to the east of the two caves considered here, is at a similar elevation, also facing the sea, and is of similar morphology. It may well have been formed by the sea at about the same time as Malangine and Koongine Caves. The marine erosion process responsible for these caves can still be observed in operation at Blackfellows Caves, a group of cavities just six kilometres due west of Malangine and Koongine. They are submerged at high tide and thus unsuitable for human occupation, but morphologically they are indistinguishable from the latter caves; their profiles and dimensions are very similar. The name derives from a massacre that took place there.

The region's enormous wealth of stone implements has been investigated by many writers, and the Beachport dunes, the Woakwine Range and the Kongorong Hills have been prime targets of stone tool collectors (McCourt 1975). Uncontrolled collecting of artefacts has somewhat reduced the research potential of many of these sites, but the damage is not as significant as is sometimes claimed. The sites are usually deflated occupation sites, or even reburied deflated floors. Archaeological investigation of these coastal sites is complicated by this lack of undisturbed deposits. Deflated floors, known locally as 'drifts', form when the unconsolidated sand between a number of occupational horizons is eroded by wind action which displaces the occupational debris both vertically and horizontally — besides causing several selection phenomena. This taphonomic process continues until a stabilised sediment is exposed, or until the composite surface layer (of lithic implements, *débitage*, bones, malacological remains) progressively formed by the process becomes so dense that it prevents further aeolian erosion. Obviously there is no great advantage in the excavation of such deposits, or in determining their statistical composition or the age of charcoal found with such remains (Bednarik 1989).

There has been relatively little comprehensive research, and published records are either not generally available (e.g. Campbell et al. 1966; Luebbers 1978; Clark 1979a), or are only cursory or preliminary (Witter 1977; Bednarik 1980). Archaeological research, or particular aspects of it, are described by Kenyon (1930), Daley (1931), Campbell and Noone (1943), Mitchell (1943, 1949), Campbell et al. (1946), Tindale (1957), McCourt (1975), Luebbers (1975) and Clark (1979b). Subsequent to the report of rock art from Koongine and Malangine Caves, Frankel undertook major excavations in these two sites as well as in Piccaninnie Cave (Frankel 1986).

The area's rich archaeological heritage suggests that it was densely populated in pre-European times. Whilst the outstanding wealth of flints probably tends to exaggerate this point somewhat (implement numbers, as well as implement sizes, are related to raw material availability, among many factors), it is quite probable that the region did support comparatively large human populations in the Holocene. The concurrence of various ecosystems (marine, lacustrine, swamplands, forests and open savanna) guaranteed some seasonal flexibility and suggests that only a modest energy input would have been required for subsistence extraction. Fresh water was no doubt amply available throughout the area during the Holocene.

An important archaeological observation concerns the distinct dichotomy in the stone tools Witter (1977) called the 'Early Prehistoric' period, and his 'Late Prehistoric' period. The accentuation, both in typology and patination state, is so profound that I have been tempted to suggest (Bednarik 1980: 64) that the apparent hiatus of concentrated coastal population might coincide with a period of lower sea level. Whilst this might imply a significantly greater antiquity of human occupation than that which is indicated by the few Early Holocene dates so far available from the Mount Gambier district, the same is rendered possible by the magnitude of the duration of the human occupation of Australia and the apparently early settlement of Tasmania.

The Holocene eruptions of Mt Gambier and Mt Schank (about 4830 and 1410 years BP, according to Blackburn 1966; however, the dating of the eruptions is far from established, cf. Prescott 1994) covered a wide area with a layer of volcanic ash. At Allendale East, seven kilometres south of Mt Schank, this measures 0.4 to 0.7 metres in depth, rests on large clastics, and is overlain by sand with clastics. At twice the distance from Mt Schank, on the coast east of Port MacDonnell (at Riddoch Bay), the thickness of the tephra horizon is only four to five centimetres, and very uniform. Where sediment sections can be observed, numerous occupation deposits occur below it. Tephrochronology (Pain 1982) would be a useful research tool in this region.

What would have been the effects of the eruptions on the environment of the area? The regularity of the ash stratum suggests that it was not subjected to subsequent fluvial or aeolian erosion. This presumably fairly continuous mantle of ejectamenta cloaking the landscape may have affected its hydrological regimes, prevented regeneration of the area for some time, and may have had a catastrophic effect on established ecosystems. There can be little doubt that the eruptions were witnessed by Aborigines, and there is even sound evidence of this in the little oral tradition that has survived. The local language group, the Boandik, became extinct some sixty-nine years after European settlement of the region began (McCourt 1975: 26). However, among the stories collected by Smith (1880: 14-15) last century we find the legend of Craitbul, the giant ancestor of the Buandik. Several geological events are described in it. Mt Muirhead and Mt Schank (two former volcanic centres) are described as Craitbul's ovens, and at both camps he was woken from his sleep and fled in great fear from an evil spirit, Tennateona. The second time, he determined that the evil spirit apparently was related to the proximity of the sea, so he moved north and camped in Mt Gambier, another crater. After a long time, the water in it rose and put out his fire, which happened four times, until eventually he moved into a cave high up on the hill, which still exists. We know that Mt Schank and Mt Gambier did not erupt at the same time (Barbetti and Sheard 1981), but are both younger than Mt Burr (Sheard 1978). A series of radiocarbon, palaeomagnetic and thermoluminescence dates remains inconclusive, except that the most recent eruptions in the region were clearly in the Holocene. The most recent status (February 1994) is that ambiguous ^{14}C dates cover the range from 1500 to 8000 BP, while the most satisfactory TL dates of 3000 to 5000 BP have been obtained from quartz sands overlain by lava flows. Other results suggest that a volcanic event occurred about 8000 years ago (J. R. Prescott, pers comm.). Although no dates are available for Mt Muirhead, it is evident that the most likely timing of the events apparently recounted in the Aboriginal legend, if

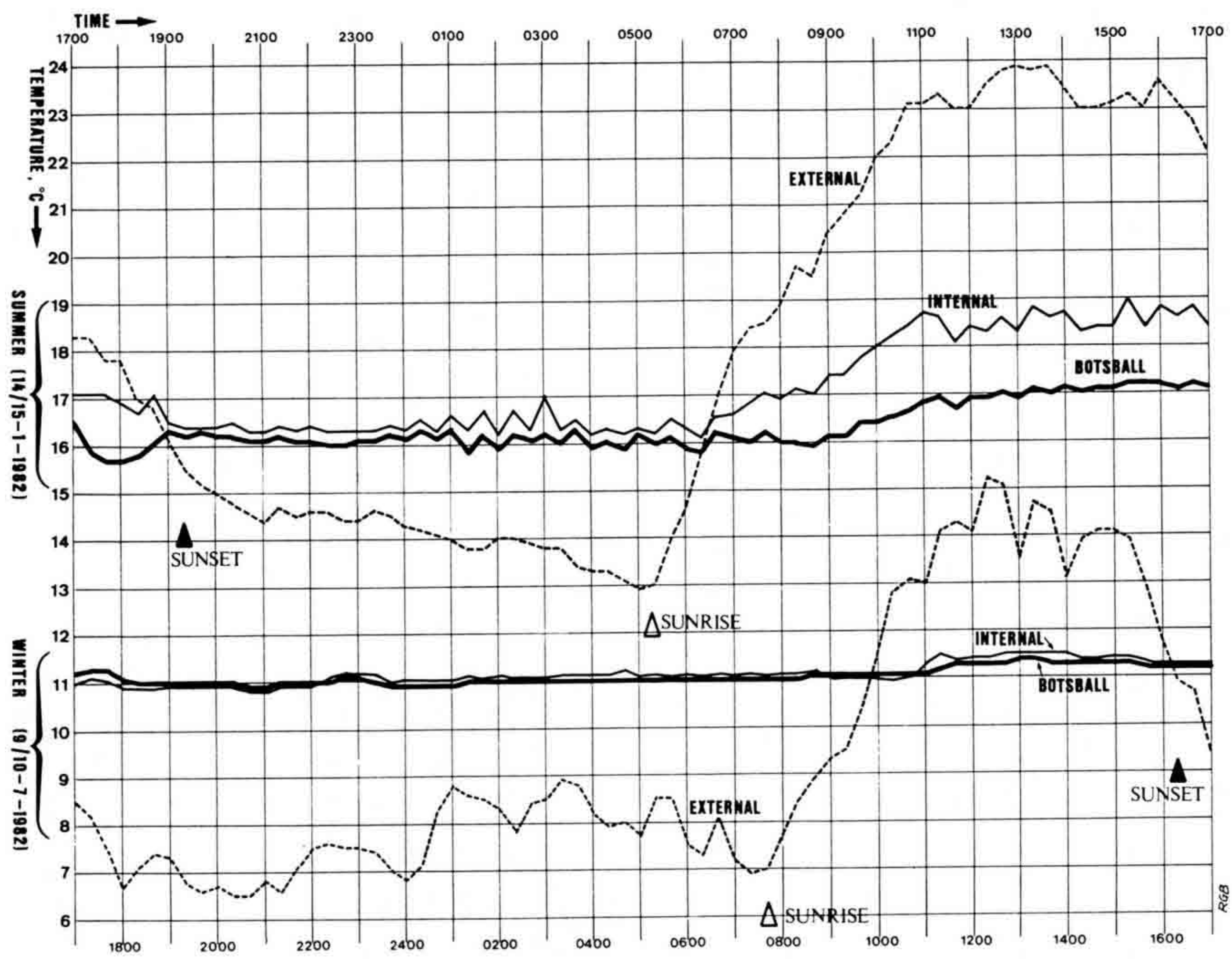


Figure 3. Thermal environment of Malangine Cave, as indicated by study results in 1982.

indeed they should relate to real events, would be the early Holocene. Neither Mt Schank nor Mt Gambier experienced marine erosion. Contrary to earlier views, Mt Gambier is not the result of large-scale volcanic collapse, but of steam-induced explosions (cf. Blackburn et al. 1982). This means that the aquifer level was perhaps similar to today's, which would exclude a late Pleistocene age. The karst region has a pronounced water table which would have been significantly lower at that stage. The description of the rising water level in the craters, of the threatening noise, the people being driven away, and the idea linking the threatening force to a specific region all seem to support the notion that the legend is based on first-hand observation. The occurrence of occupation evidence both below and above tephra strata leaves little doubt that the Holocene eruptions, at least, were observed by humans.

Macro- and speleo-climates

Just as the region's vegetation is greatly influenced by the proximity of the open sea, so is its climate. Both diurnal and annual temperature differences are less pronounced than they are further inland, and I have been unable to detect any significant differences between summer and winter relative air humidity ranges. Broadly speaking, the climate is one of temperate conditions lacking great extremes. The January average daily maximum surface temperature is just over 20°C, and is about 13°C for July. Average daily minimum temperatures rarely, if ever, fall below 7°C. Summer rainfall is about 200 millimetres, winter rainfall 490 millimetres, and these values are exceeded by the average tank evaporation for the summer months.

There are two reasons for investigating the microclimatic conditions within Malangine Cave itself. Firstly, such data are important to gaining a better understanding of the process responsible for producing the secondary limestone deposits that bear the rock art (of relevance to its dating and to its preservation). The second reason is to aid in evaluating the habitability of the cave, and to gain data for a speculative extrapolation from the present conditions to those of the past.

The work carried out at Malangine Cave was done within the framework of a major study of speleo-climatology, encompassing caves in vastly differing environments, and which is designed to find quantitative criteria to enable deductions concerning past climatic conditions within caves occupied during the Pleistocene. The centre of this study is the Gudenus Cave, the most important and oldest Palaeolithic occupation site known in Austria. There, a sequence of pollen spectra and a wealth of other palaeoclimatic data reaching back well into the Riss glacial are being used, together with the data gained from an intensive climatic investigation spanning about thirty years, to develop methods of assessing Pleistocene climatic oscillations and their microclimatic effects. This enquiry demands data from as many other caves as possible (to consider different macroclimates, cave configurations, rock matrices etc.); one of these auxiliary studies was carried out at Malangine Cave.

In Malangine Cave, a Botsball thermometer, an instrument not used in Australia previously, was employed to measure the human physiological response to the speleoclimatic conditions of two twenty-four hour periods, one in summer and one in winter. This instrument integrates convective temperature, thermal radiation, humidity, and air velocity into a single value, and relates these factors to the heat balance in a human body. It essentially measures comfort, or discomfort, experienced by people in response to their atmospheric environment (Botsford 1971). This is an important factor in the determination of the habitability of a cave. At twenty minute intervals, readings were taken from this instrument, as well as from hygrometers, anemometers and precision thermometers, both outside the cave and in its interior (Figure 8).

The only elucidation of the study's results of concern in the present context can be found in Figure 3. From it, the effects of the parietal environment on the air temperature can be illustrated by comparing internal and external conditions for random samples from the peak periods of summer an winter. The cave appears to exert considerable influence on the speleoclimate, despite its thin roof and comparatively small size. This observation is best demonstrated by the winter curves, which indicate that the internal convective temperature and the Botsball temperature are almost identical, both showing only negligible diurnal variation. Constancy of the combined factors determining the physiological environment is also demonstrated by the Botsball curve for the summer test period, and by the comparatively small difference between the summer and winter curves. Even annual variation is probably minimal: the diurnal net difference over the test period (commencing and ending at 5 p.m.) of 3.8°C only prompted an increment of 0.6°C in the Botsball reaction, indicating the considerable influence exerted by the speleo-environment.

The results of these studies demonstrate that the cave must be regarded as an excellent habitation. In addition to having a stable thermal environment, the cave is very dry throughout, with no measurable internal airflow.

Sedimentary silicas, stone artefacts and cave sediments

The convacuational spaces of both Malangine and Koongine Caves are quite low and were developed mainly along a north-south axis, following the horizontal rock bedding. (Convacuation space is the total cave volume, i.e. the evacuational space, minus the volume occupied by solid or liquid cave fill.) Cavities initially formed by marine erosion have been modified in places by rockfalls, the extent of which was determined by horizontal tabular masses of sedimentary silicas, and by the frequency of *Deckenkolke* (solution-caused domes in the ceiling, possibly dating from when the cave was water filled). As none of the tectonic adjustments (using the term in its correct sense) appears to postdate the Pleistocene, the caves seem to be structurally more stable than might be suggested by their roof thickness, which nowhere exceeds three metres (see longitudinal section, Figure 8). Vadose or phreatic solution has not played a discernible role in the genesis of either cave. The presence in the outcrop of further cavities is implied by numerous dolines, and by animal burrows entering at the level of the main silica seam that determined the caves' configuration.

The Miocene limestone accommodating Malangine and Koongine Caves consists mainly of fragmental material derived from bryozoa, corals, foraminifera and other marine organisms. It has locally undergone selective replacement by silica. Two modes of chert occur: randomly-distributed grey nodular deposits, and laminate formations of coalesced nodules, slightly lighter in colour. The latter are usually five to twenty centimetres thick and mostly horizontal, although the presence of a few vertical deposits (resembling sheet flint) is of geomorphological interest. Numerous formerly calcareous remains of organisms demonstrate the origin and genesis of these microcrystalline cherts (Bednarik 1980, 1992). The nodules are encased in a ten to twenty millimetre-thick veneer, of either incomplete silicification, or carbonatisation (some replacement reversal has evidently occurred; see Walker 1962). Flintmeal is generally absent in them.

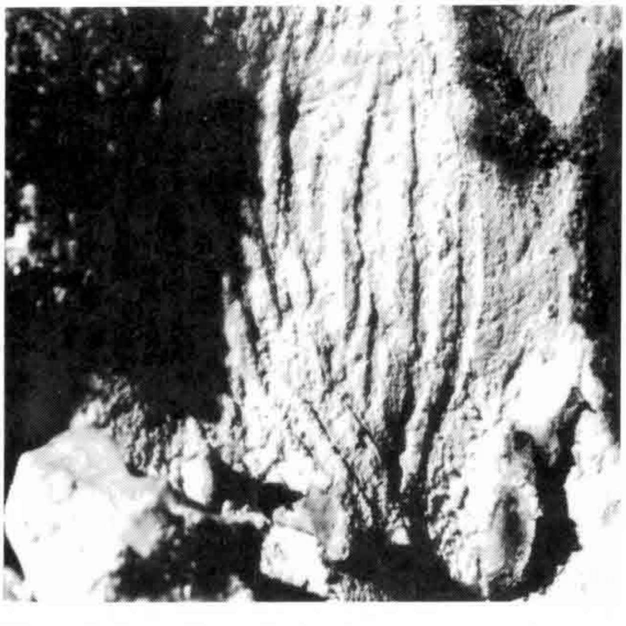


Figure 4. *Sets of finger flutings in recess next to impact fractured chert nodules, Malangine Cave*

The almost unbroken silica seam lacing the low cave walls protrudes into the cave spaces, but projecting portions have been artificially removed in places. Similarly, extraction of some of the random nodules appears to have been attempted or practised. There are rare instances of limestone gouging reminiscent of the mining activity in Koonalda Cave (Gallus 1968: 48; Wright 1971). However, chert mining was only of minor impact here as the mineral is of mediocre quality (Figure 4). Much the same applies at the remaining several subterranean chert mining sites in the Mount Gambier region (Bednarik 1992), and substantial deposits of excellent flint-like cherts were within the range of the local inhabitants. Indeed, there are unknapped allochthonous flint nodules strewn over the cave floor (Flint is a sedimentary silica whose properties fall within the spectrum of those of western European flint; Bednarik 1980: 48, 68-9, and references.)

Stone implements and *débitage* are present on the surface of the sediment fill in both caves and include, besides the indigenous grey chert, imported silicas: black flint, light grey to brownish cherts, and occasionally varieties of chalcedonic composition. Patination is only superficial (of types 1A and 4C; Bednarik 1980), especially in specimens of cryptocrystalline structure. Typologically the lithics resemble those of deflated littoral occupation sites in the region.

In contrast, the abundant quarrying debris from the surface of the low and barren limestone ridge harbouring the caves are without exception in an advanced state of leaching. But none of the external artefacts seem to be contemporary with the caves' latest habitation horizon, and many of the flakes lying exposed on the ridge are stained by iron oxide (patina type 4A, reaching Munsell 5YR 6.5/7), which suggests that they were once covered by soil.

Although the vagueness of the external assemblage's patina development does not necessarily impair the utility of the Porosity Index, the Patina Percentage was considered too unreliable a reference to express the intensity or progress of post-depositional alteration (for methodology and terminology of evaluating sedimentary silicas, see Bednarik 1980). Whereas some specimens would require the highest Patination Index to meet P = 100, others produce P = 65 even at $\alpha = 0.6$. In view of the reasonably uniform compositional and, presumably, environmental factors, it is difficult to accommodate this range within a single chronological unit, particularly considering cross-sectional characteristics of patinae. The matrix resulting from the patina analysis (Table 1) appears to manifest three clusters for β: one straddling 4, one ranging from 7 to 8, and one just slightly above 10 (a value indicating that granular disintegration has commenced). The surface industry from both caves is free of microlithic elements (Figure 5).

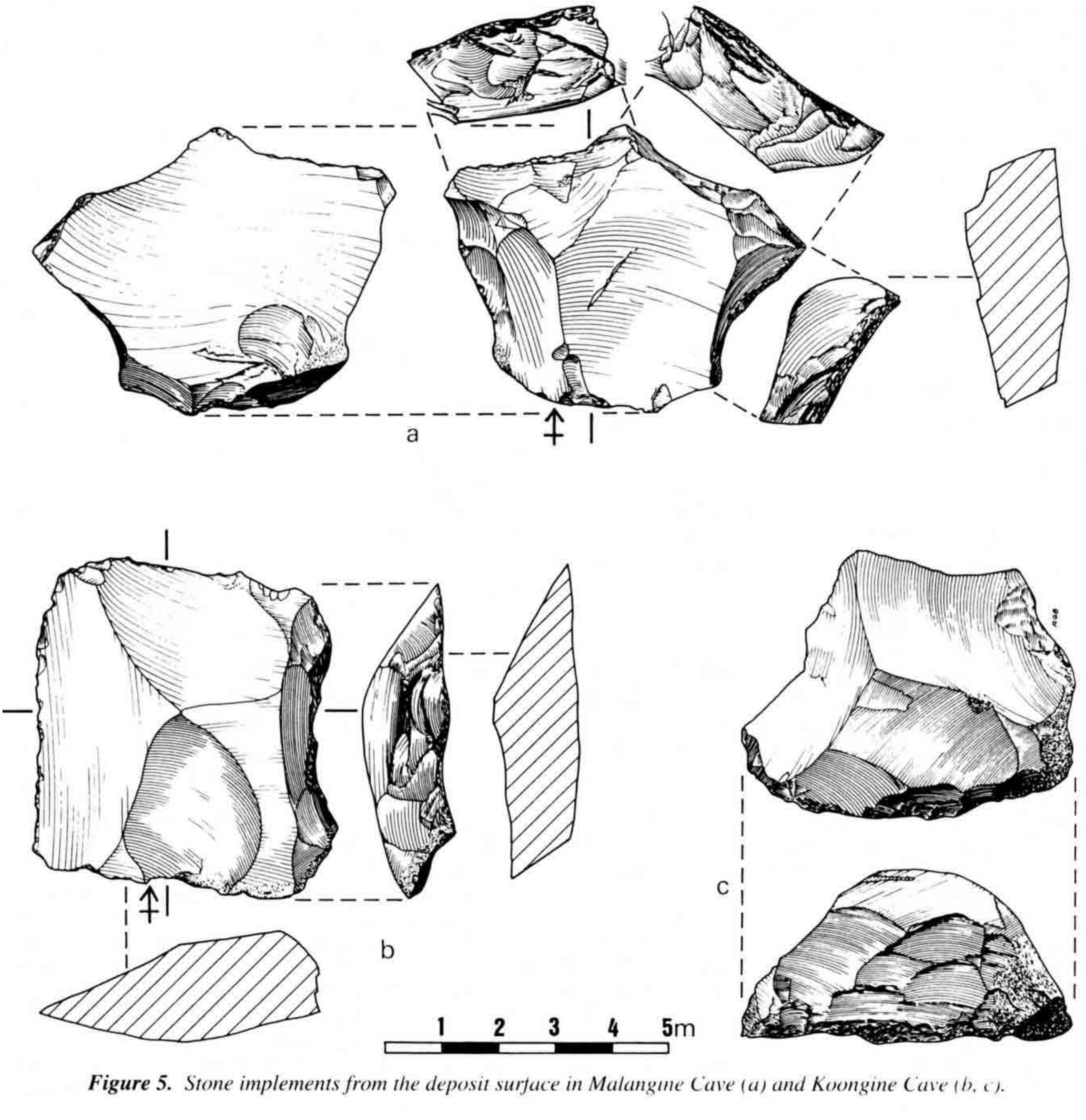


Figure 5. *Stone implements from the deposit surface in Malangine Cave (a) and Koongine Cave (b, c).*

No.	W	W_{90}	W_S	V	G_S	W_L	β	α	P
25	23.91	10.92	9.40	14.51	1.65	35.38	10.47	0.9	100
26	37.33	19.35	18.56	18.77	1.99	22.00	4.20		
27	9.57	4.58	4.01	5.56	1.72	32.51	10.25	0.85	100
28	14.36	7.99	7.71	6.65	2.16	15.33	4.21	0.6	65
29	16.02	8.41	7.79	8.23	1.95	23.68	7.53		
30	15.87	7.87	7.55	8.32	1.91	25.21	3.85	0.65	100
31	16.33	8.74	8.17	8.16	2.00	21.53	6.99		
32	9.37	5.14	4.88	4.49	2.09	18.17	5.79	0.8	58
33	5.64	2.99	2.76	2.88	1.96	23.16	7.99		
34	24.69	13.18	12.48	12.21	2.02	20.71	5.73	0.8	66
	MEAN				1.95	23.77	6.70		

Table 1. *Patina analysis indices for a surface sample of stone implements, collected in the vicinity of Malangine Cave. The variables used are explained in Bednarik (1980: 52-3).*

Criterion	Symbol	Reference	Unit	Min.	Max.	Mean
Mass	-	-	g	8.11	84.44	37.86
Relative thickness	RT	Collins 1970	-	14.0	50.8	25.3
Abplattungsindex	A_i	Cailleux 1951	-	1.77	5.50	3.72
Striking platform width	WID	Ohel 1979	mm	17	65	33
Striking platf. thickness	TSP	Ohel 1979	mm	2	21	10
Bulb thickness	BT	Ohel 1979	mm	0	2.8	1.4
Flaking angle	FLANG	Ohel 1979	degr.	111	137	125
Inclination	INC	Ohel 1979	degr.	101	130	114
Convex working edge roundness		Movius/Brooks '71	mm/mm	0.06	0.37	0.22
Concave workg. edge roundn.		Movius/Brooks '71	mm/mm	0.04	0.28	0.12
Working edge bevel angle		Clark 1979b	degr.	55	88	75
Linear retouch per mass		-	mm/g	0.56	3.40	1.63
Working edge profile		Movius/Brooks 1971	70%III, 20%I, 10%II			
Lamellar retouch proportion		Movius/Brooks 1971	70% 0, 20% 1, 10% 2			
Cortex proportion		Movius/Brooks 1971	20% 0, 75% 1, 5% 2			

Table 2. *Some elementary typological indices for the surface industry of Malangine and Koongine Caves.*

If the degree of modification by retouch is any indication, thick flakes appear to have been favoured. The sample is neither of adequate size to provide significant population variance data, nor does its common occurrence prove that it must necessarily relate to a single industry. Nevertheless, some basic data are offered in Table 2, in case they are useful for future work at the sites (see Note 1). Of particular relevance is the low retouch-to-mass ratio, which suggests that raw material was considered to be available in great abundance.

No excavation was conducted by me at the sites, but I extracted a sediment core column from the central part of Malangine Cave (Figure 8). Rock was struck at a depth of 2.21 metres. The entire 7.5 centimetre-diameter column has been subjected to an exhaustive analytical program, including the determination of grain size distribution, textural classes, sorting indices, carbonate void content, colour, plasticity, linear shrinkage, pH, particle density, as well as natural moisture content, organic matter, carbonate, ferric and ferrous oxides and charcoal. This was supplemented by a classification of quartz grain wear, morphometric analyses of coarse fractions, and the identification of osteal and malacological remains.

Two excavation programs were undertaken in both Malangine and Koongine Caves, the first being trenches across their entrances dug in 1982, by local field naturalists under the auspices of the South Australian Museum. This was to effect visitation control in the form of a steel grid that extended below ground level. Archaeological observations were conducted by G. D. Aslin, who reported that stone implements occurred down to the basal level, and that there was a distinctive change in typology and silica type, to coarser material with increasing depth. A comparison of these results indicates clearly a major divergence in the sediment sequence, between the dripline and the deep part of the cave: in the latter, sedimentation certainly commenced before the sea withdrew from the cave, and presumably long before any human presence in the region.

A few years after the installation of these protection grids, both sites were subjected to excavations by the Department of Archaeology at La Trobe University, under the direction of David Frankel (1986). This included a 2 by 2 metre area just in from the entrance of Malangine Cave, a trench outside its entrance, and several excavations in Koongine Cave. In contrast to the reasonably well stratified deposits in the entrance of Malangine and in the core I extracted deep in the cave, the large dig near the entrance exposed many rabbit burrows and extensively disturbed sediments. The work in Koongine was more successful, and several radiocarbon dates spanning the Holocene period were secured from charcoal. Nevertheless, these are not without problems: there is a significant anomaly with one date, and the remaining values suggest unlikely discrepancies in sedimentation rates. Most importantly, the proposed dating of occupation evidence is of limited relevance to the rock art, as there is no proof available to relate any occupation phase to any art phase. Most rock art sites offer no occupation evidence at all, and there is no reason to postulate that rock artists must have left archaeologically detectable evidence of their presence.

Precipitates

With the exception of minor stalactitic growth at Survey Point 3 in Malangine Cave, speleothems are restricted to more amorphous forms in both caves. Large portions of the ceilings are concealed by the pure-white, bulging exudations of a dry type of *montmilch*. In other areas, surface hardening, accompanied by discolouration, has stabilised the deposit. The more compact and smooth formations are distinctly laminated and are ten to fifteen millimetres thick. Annual sub-cutaneous moisture oscillations and the growth of efflorescence, assisted by gravity and biological interference, have already resulted in the exfoliation of about one half of the ceiling near Malangine Cave's entrance. It is archaeologically significant that both this travertine and the coarse rock it has formed on bear petroglyphs, which are thus physically separated by the speleothem lamina. Such a chronological relationship between cave petroglyphs and reprecipitated calcite is quite rare globally, but it has been subsequently found in three more caves in the Mount Gambier region.

The secondary carbonates' diversity may provide evidence for past variations in vegetation density, temperature, precipitation and humidity. Despite remaining a 'ferociously complicated subject (Collcutt 1979: 295; cf. Bednarik in press), limestone precipitate formation is widely accepted to be related more to the long-term availability of biological carbon dioxide than to any other factor (e.g. Bögli 1954; Franke and Geyh 1970). The resulting deposits are reliable environmental indicators, within limits.

In its 'fully developed' form, *montmilch* (for an explanation of this phenomenon, and the term I prefer to use for it, see Bednarik in press) is a white, amorphous, often dough-like mass that may be argillaceous. It is a common phenomenon in Europe, where it occurs in thousands of caves. In some Alpine regions it was used as an ophthalmic analgesic in Historic times. Several types of speleothems can be distinguished at the two sites considered here. Active, moist *monmilch* is white and bears no finger markings of the type described below, it clearly postdates them. The adjacent, richly decorated areas are of a dehydrated crust of 'cauliflower' or 'pearl travertine', still underlain by a subcutaneous zone of soft and slightly moist travertine. The range of more or less luxuriant travertine growth spanning these two extreme states illustrates the manner in which this deposition proceeds. The migratory carbonates determine the eventual contour of a finger line's cross-section, and groove width is demonstrably a function of precipitate density (Figures 6 and 7). The cross-section is also influenced by the degree of the surface's departure from the horizontal.

Figure 6. *Finger flutings on ceiling of Malangine Cave, Group 3, densely covered by travertine growth. The lowest portions bear a dark deposit of high organic content. The actual finger markings are a few centimetres from the surface, see section in Figure 7.*

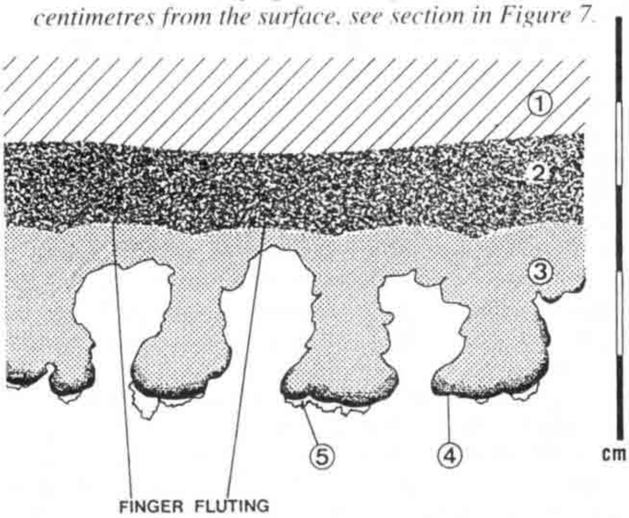


Figure 7. *Extreme form of speleothem development over finger fluting, seen in section: 1 - rock of cave roof; 2 - dehydrated* montmilch; *3 - pearly travertine exudations of calcium carbonate; 4 - brown organic stain, partly interstitial, but concentrated on surface (see Table 3 for analysis); 5 - yellowish-white efflorescence of sulphates (see Table 4 for analysis).*

Major components, as oxides	%	Trace elements	ppm
Fe_2O_3	0.041	V	11
MnO	0.01	Ba	66
Cr_2O_3	0.006	Sc	7
TiO_2	0.019	Ce	37
CaO	52.20	Nd	19
K_2O	0.011	Cu	70
SO_3	0.276	Zr	66
P_2O_5	0.018	Co	8
SiO_2	1.92	Y	7
Al_2O_3	0.25	Zn	13
MgO	2.42	Ni	35
Na_2O	0.19	Sr	727
L.O.I. (CO_2)	47.78	Rb	22
		Ga	17
	105.141	Cl	227

Table 3. *Chemical composition of brown deposit on speleothems in Malangine Cave.*

Two types of discolouration can be observed on these travertine formations. One consists of airborne matter, deposited on aspects facing the cave entrance. The other is a form of dark-brown patination which suggests a secretion of iron oxide. It is, however, almost free of iron and appears to derive its colour mostly from the organic constituents (Table 3; the Ca^{++} tabulated refers to the carbonate matrix and is of no relevance). Where there is most patination (e.g. in the deepest part of Malangine Cave) it is always restricted to the lowest portion of a speleothem (Figures 6 and 7). The partly interstitial deposit certainly predates the adjacent pure white *montmilch*. It is unlikely that the colouring matter has a secretionary origin; to explain its presence by a reversal of the conditions of high hydrogen ion concentration attendant to carbonate precipitation would require that the principal components be rendered mobile by such oscillations, and that there be a suitable solvent. It more probably indicates an accretion of combustion residues from hearth fires (thick deposits of unburnt resin occur on the ceiling of one of the two excavated caves on Lake George mentioned above).

A yellowish-white efflorescence of a homogeneous nature and with a 21.6 per cent moisture content is superimposed on this deposit, and obviously postdates it (Figure 7). Its chemical composition (Table 4) indicates that it is a combination of anhydrite and gypsum (both are frequently associated with bedded sedimentary strata), unless sulphurous vapours of a volcanic source have succeeded in converting $CaCO_3$ on a small scale (substantial eruptions are known to have occurred nearby during the Holocene, as noted above). Certainly, distinct environmental events or variations are recorded by both deposits described.

Major ion	%
Sulphate	52.4
Carbonate	10.8
Soluble silica	3.2
Calcium	20.3
Sodium	0.26
Magnesium	0.92
Iron	140 ppm
Potassium	67 ppm
Strontium	6 ppm

Table 4. *Chemical composition of yellowish-white efflorescence on speleothems, Malangine Cave.*

Descriptions of the markings

The abundant wall and ceiling markings in the two caves can be conveniently divided, on the basis of their sources, into three classes: volant species, large mammals and humans (Bednarik 1991, 1993, 1994a). Close examination has ruled out as highly improbable non-biological agents, such as selective granular mass exfoliation, solution or *Rillenkarren* formation, natural cross bedding and the like, in respect of virtually all features investigated.

Numerous swallow nests of mud are present in various recesses at both sites. The many scratches in their immediate vicinity are clearly discernible and their distribution relative to the nests suggests their origin. Primaries, claws and possibly mandibles of the airborne cave dwellers may also account for similar marks found sporadically elsewhere in the caves. Such lines are generally faint, straight, shallow and short.

A maze of very fine incisions found primarily on low ceiling portions is probably caused by the claws of bats frequenting favoured roosting sites. Around minor projections of hardened precipitate, some undercutting has occurred, perhaps indicating a considerable duration of the process responsible.

There are three varieties of markings that can be attributed to larger animals. First, grazes on some projecting ceiling bosses appear to have been made by livestock, because hair of domesticated species was found embedded in the deposit. A few engraved areas have already been damaged or partially obliterated. Second, some erratic deep lines in the north-west part of Koongine Cave were presumably caused by bovine horns. And finally, scratches and claw marks evidently fashioned by mammalian species such as macropods are present on near-vertical surfaces, for example in the major *Deckenkolk* in the back of Koongine Cave.

Our primary concern here are the humanly made rock markings. Several forms occur. They can be distinguished by their stratigraphical context, technique, spatial distribution and differing antiquity. There are sets of finger flutings similar to those found in many other Australian caves (Bednarik 1986, 1990); deeply engraved designs of the 'Karake style' (Aslin and Bednarik 1984; Aslin et al. 1985; Bednarik 1990); and shallow line drawings (Bednarik 1990). All of these predate some form of precipitate, at least stratigraphically, and there are instances where petroglyphs are actually separated from each other by a substantial, laminated secondary calcite deposit. Relative chronology can therefore be investigated without relying merely on immediate superimposition of art 'generations' themselves, but by examining the relationships of art forms to each other, and also that to other contents or aspects of the caves, especially speleothems.

Petroglyphs of greatly varying density and clarity cover about seventy-nine square metres in total. This area was divided into convenient panels for ease of description and study. Some of the groups were delimited arbitrarily or by using some natural demarcation; others are clearly separate. The following is a brief description of the individual panels:

Malangine Cave (see Figure 8):

Group 1. A large area of finger lines, masked to varying degrees by travertine growth.

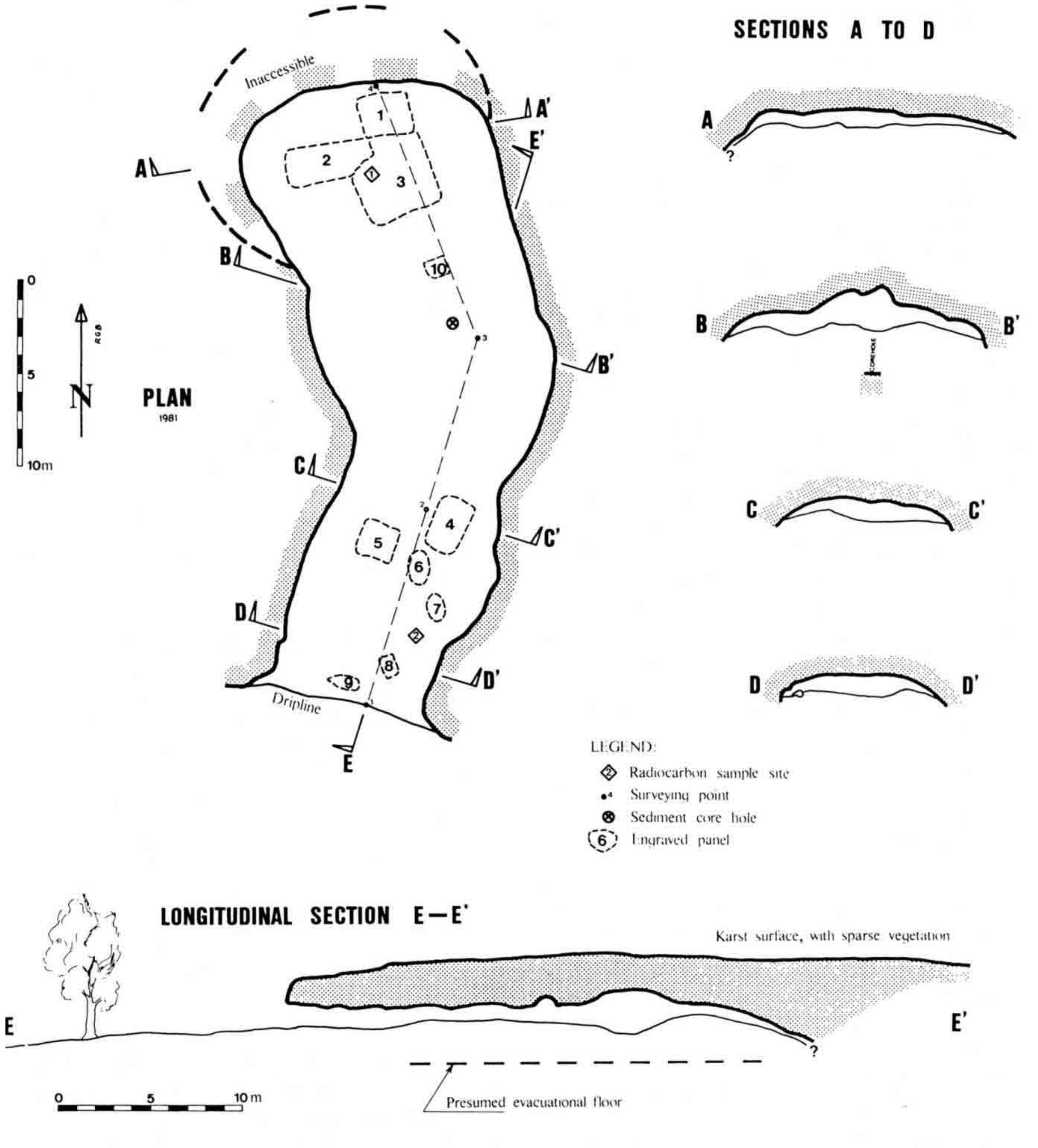


Figure 8. *Malangine Cave.*

2. Extensive finger lines with a heavy *montmilch* cover which intensifies towards the west. A few deep lines continue into two *Deckenkolke* in the southern section of this Group.
3. Adjacent to the westernmost *Deckenkolk*, a deeply carved 'convergent lines motif' (CLM) with three 'toes' is superimposed on the still abundant finger fluting. Further deeply furrowed lines appear also to be of artificial nature.
4. A dense concentration of finger fluting, mostly in short parallel sets, especially in niches, covered by a completely dry and pearly travertine.
5. Similar to Group 4, except that fluting is less dense.
6. Lines incised with implements, occasionally more than twenty millimetres deep. A dry and hard secondary deposit extends into the grooves. Most lines are intersected by others, either obliquely or at right angles.
7. Resembling Group 6. Short cuts appear to have been executed with some momentum.
8. Twenty-four CLMs are discernible; more may be obscured by a maze of intersecting lines. All are deeply engraved in the primary rock surface with the aid of tools. This group appears to have been covered by travertine deposit which was later shed through exfoliation. One small remnant of it bears three fine parallel lines resembling the post-lamina engravings in Group 9. Alignment and equal spacing of some of the three-toed CLMs suggests that they may be arranged in sequences, as in rows of 'bird tracks'.
9. Petroglyphs were executed both on the original rock ceiling, and on the secondary carbonate skin of which about half has remained in situ in the zone nearest the entrance. The former arrangements include seven CLMs, one apparent pair of foot prints of a macropod, a design reminiscent of the presumed vulva symbols found in many parts of the world, and an array of straight, short engravings possibly superimposed over these motifs. A remnant of the laminated deposit displays faint incisions and pitted lines on its hard and desiccated surface. This style is of outline figures (a club-like and a roughly circular composition can be discerned; Figure 10). Even these comparatively recent petroglyphs are coated by a film of speleothems.
10. Deeply cut marks of gash-like strokes resembling those in Group 9, but veiled by more extensive travertine growth; possibly contemporaneous with Groups 6 and 7.

Koongine Cave (see Figure 9), located 104 metres west of the site just described:

Group 1. A heavy concentration of corroded claw marks in a 1.5-metre diameter *Deckenkolk*. The lower portions of the ceiling bears finger flutings, but the upper part of the *Deckenkolk* was apparently out of human reach at the time.
2. Some short finger fluting is clearly discernible, but other arrangements seem to be predominantly of animal origin and are mostly masked by soft *Montmilch* formations.
3. Scattered sets of finger flutings are present in depressions, especially around silica nodules, where they resemble gouge marks.
4. Densely concentrated finger fluting extends into parts quite inaccessible now because of the high sediment level.
5. The density of finger lines rivals the heaviest concentrations elsewhere in Australia, but ridges are worn extensively by livestock in the more exposed locations, or destroyed by modern inscriptions.
6. Non-figurative incision marks, corroded and algae covered.

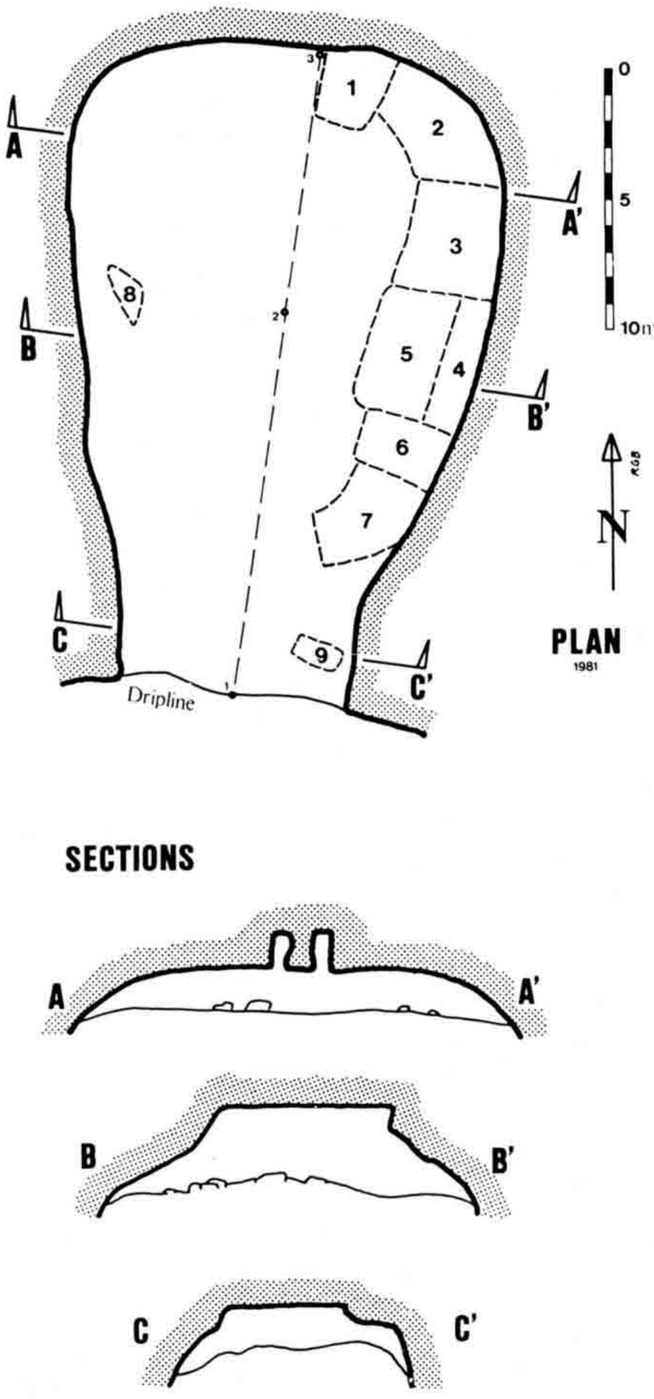
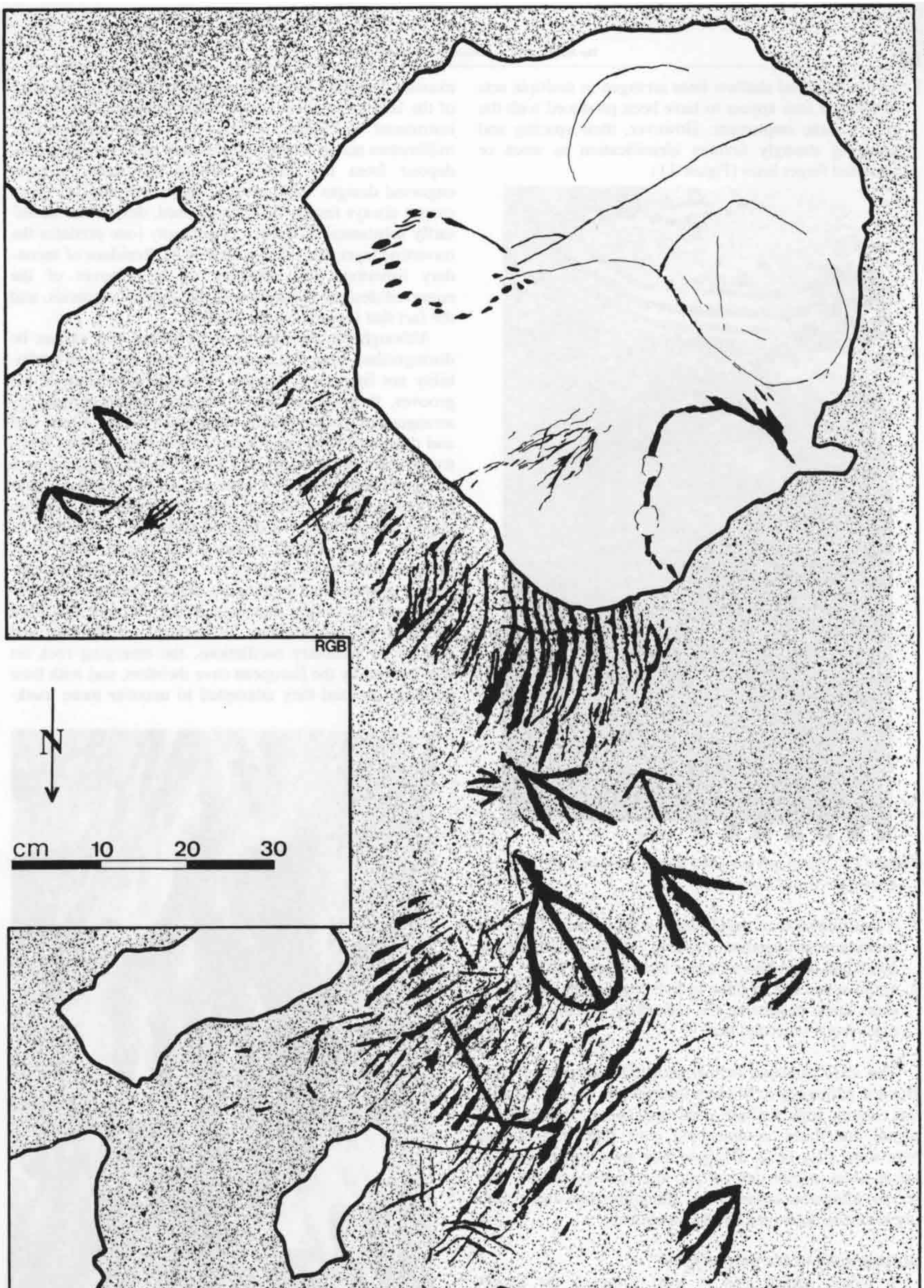


Figure 9. Koongine Cave.

Figure 10 (on the following page). *Petroglyphs in Group 9, Malangine Cave. The stippled area represents the coarse, re-exposed rock surface, the blank area indicates remaining travertine lamina.*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7. Several hundred shallow lines arranged in multiple sets of three or four appear to have been produced with the aid of some implement. However, their spacing and grouping strongly favours identification as worn or corroded finger lines (Figure 11).

Figure 11. *Worn or corroded finger markings in Koongine Cave, Group 7.*

8. A concentration of deeply carved short lines. The most prominent arrangement exceeds twenty millimetres in depth and resembles a human hand (Figure 12).
9. About seven sets of three to five convergent, deeply cut short lines, postdating the secondary deposit, which is extensively corroded here.

The cave contains further isolated examples of pre-Historic petroglyphs. Modern inscriptions are restricted to the central, high ceiling areas and consist generally of names and dates, commencing with 1906 and ranging over some fifty years. Because they are capable of facilitating some insight into surface alteration processes, they are not altogether unwelcome, although some digital fluting has been destroyed by this vandalism.

Stratigraphy of the petroglyphs

It would appear that at least some of the deeply engraved, short and straight lines of Group 9, Malangine Cave, are not contemporaneous with the incised figures of the same Group. This possibility was raised by the discovery that the lines truncated by the remaining portion of the travertine layer (Figure 10 upper part) do not continue under the lamina, as one would have expected. Those examined closely terminate abruptly just under the edge of the lamina, in holes whose shape indicates that a blunt instrument of circular section, measuring perhaps four millimetres across its end, was used to prize the secondary deposit from the ceiling. Where the lines intersect engraved designs they postdate them, but the two types cannot always readily be distinguished, despite the necessarily substantial difference in antiquity (one predates the travertine layer, the other postdates it). Residues of secondary limestone still adhering to the grooves of the engraved designs illustrate both the deposit's genesis, and the fact that it postdates the grooves.

Although the presumably more recent cuts cannot be distinguished from the apparently iconic (but in all probability not figurative) designs by colour or texture of the grooves, they can in many instances be recognised by arrangement, course (short, often much deeper at one end and thus cuneiform) and lack of travertine growth. Intuitively, the central panel of Group 9 could be seen as a disfigurement; its strokes appear to intentionally cut over earlier motifs and convey the impression of random gashes rather than well-directed incisions. A resident of the area, Mr F. Glynn, reported that 'in the early days, rabbiters used to live in the cave', and this recent occupation is substantiated by modern debris. Perhaps the exfoliation of the ceiling lamina near the entrance has been favoured by the influence of external temperature and relative air humidity oscillations, the emerging rock art was noticed by the European cave dwellers, and with their curiosity aroused they attempted to uncover more markings.

Figure 12. *Deeply carved arrangement of short lines forming a hand-like motif. Koongine Cave, Group 8.*

Further flakes of speleothem were removed in recent years, this time with much care, but without unveiling more carvings. The recentness of this activity is apparent from the contrast of colours. More petroglyphs are, however, unlikely to be uncovered by artificially detaching ceiling plates of travertine. This is because, firstly, the strength of the mechanical bond between the rock and the deposit will prevent a clean break between the two layers; these appear similar in their chemical and physical attributes, including cohesion, and only slow natural processes seem capable of gradually releasing the lamina and thereby revealing the petroglyphs intact. Secondly, the mode of secondary carbonate deposition outlined above applies also to the development of the compact laminar formations near the cave entrance. Selective precipitation maintains a groove by favouring its edges until the space between them is eventually closed laterally. The lamina thickness at this site is insufficient, however, to conceal the incisions completely via this process. Consequently, the petroglyphs still remaining under the travertine are largely discernible on the deposit's surface, appearing as Malangine Cave's Groups 6, 7 and 10.

The last proposition introduces another potential rendering of the artefact/speleothem sequence: some of the short, often cuneiform gashes in Group 9 could be contemporary with the Groups just named and thus predate the travertine. This alternative is considered only because the configurations of these Groups (and perhaps Group 8, Koongine Cave) resemble to some extent a portion of Malangine Cave's Group 9. The model thus formulated stipulates either that Group 9 gashes consist of two temporally discrete elements, or that lamina formations in this vicinity are of vastly differing antiquities. The latter alternative is hardly worth pursuing further, and the former has little evidence to its credit. No trace of secondary carbonate is present in the gashes and one of the CLMs in the Group even appears to have been fashioned with the lamina in situ — an assumption supported by the motif's conspicuously different execution and groove section. It may well be a copy of the ancient figures, effected by people observing them after their re-appearance.

To be objective we would have to consider all other potential interpretations of the petroglyph/speleothem sequence, and their respective merits. One model boldly proposes the contemporaneity of the faint outline figures in Group 9 with Groups 6, 7 and 10, by suggesting travertine deposition to have continued more vigorously farther from the cave entrance. This succeeds only in combining two incongruous stylistic elements, an unconvincing exercise. A variant may be more plausible: the gashes in Group 9 that are not explicitly modern could be included in the hypothetical generation, providing a stylistic link. However, this too faces difficulties. It is quite obvious from the condition of the most recent Group 9 outline grooves that they were made at a time when lamina formation was still incomplete, whereas exfoliation would conceivably not have commenced until dehydration of the mature crust had introduced progressive deterioration of the mechanical bond to the rock ceiling. Finally, the small engraved lamina remnant in Group 8 renders this version stratigraphically inconceivable.

The comparatively extensive finger fluting occurs mostly in the deeper parts of both caves, but fortunately there are some instances of superimposition by more recent petroglyphs. The finger lines certainly represent the oldest surviving generation of rock art in Malangine and Koongine Caves.

The radiocarbon dating of carbonate speleothems

Montmilch, pearly travertine, stalactites and cutaneous travertine laminae are all reprecipitated or secondary carbonates. Limestone (mainly of calcite) is dissolved by aqueous carbon dioxide, and travels to a new location (generally a cave surface) where it is reprecipitated (limestone is itself a precipitate) as a speleothem. The complex geochemistry of these processes (Bednarik in press) will not be considered here; suffice it to say that they result in the replacement of about 50 per cent of the carbonate's carbon with atmospheric carbon, whose radiocarbon component decays at the known rate. When I proposed in 1980 to date a mineral deposit by radiocarbon content, my paper was rejected by six archaeologist readers who did not believe that a mineral could contain radiocarbon. Yet the method I introduced in Australia had been developed in Europe thirty years earlier. Since then, Watchman has dated other mineral deposits, oxalates, through their radiocarbon (Watchman 1990). Earlier, the results of my own work, the first direct dating of rock art in the world, had to be published overseas (Bednarik 1984, 1985b). This led to my decision to create an independent forum of rock art scientists, which resulted in the formation of the Australian Rock Art Research Association in 1983, promoting the establishment of a scientific discipline. Since then, 'direct dating' methodology has decisively replaced traditional 'archaeological dating' of rock art.

This is not to suggest that the dating of reprecipitated carbonates is easy. On the contrary, it was clear from the beginning that it would involve considerable technical and interpretational difficulties. Most importantly, porous deposits such as those usually associated with cave art can be subjected to radiocarbon 'rejuvenation': the open spaces in a crystal lattice could be occupied by subsequent deposition of more solute, which must be 'younger' than the original precipitate. Hence dates derived from travertine should be regarded as conservative (Bednarik 1984), unless they are from very dense and crystalline deposits (usually best from stalagmites). Secondly, the method relies on the assumption that the atmospherically derived component of the carbon in the reprecipitated substance is of biological origin, i.e. respired by soil micro-organisms. This is largely the case (Hendy 1971) but there are exceptions, some of which can lead to distortion of the isotopic chemistry of the precipitate. Most importantly, gaseous volcanic emissions need to be considered here (Bednarik and Head in press). Finally, recent work has shown that the type of plant communities present above a cave at the time of reprecipitation can have a significant effect on the $\delta^{13}C$ value (Cole and Monger 1994). These plant communities may themselves be determined by atmospheric CO_2 levels, because the tolerance of various types of vegetation biota to such levels differs (Robinson 1994). Therefore we need to make some allowance for several potential variables in such dating results, and without even knowing the precise interplay and effects of these variables.

Some of these qualifications apply not merely to carbonate dating, they are relevant to all radiocarbon dating. They question archaeological credulity concerning the results of this method, particularly those of the Pleistocene. Practically all archaeological dating methods are subject to various reservations and qualifications, and any blind trust in the results of dating laboratories is misplaced. No such results provide certainty nor do scientists claim this (for comprehensive discussions of this topic, see for example Bednarik 1994b, in press; Bednarik and Head in press). In this sense, the use of reprecipitated carbonates for dating attempts is perhaps no more tenuous than a great many other indices currently used for such purposes. For all its shortcomings and significant problems, the method is certainly more viable than some other dating techniques applied to rock art, such as cation-ratio analysis which is known to be affected by at least two dozen variables (Dorn 1993: Table 3.3). Among the difficulties archaeologists experience with radiocarbon dating is their frequent neglect of the taphonomy of the dated substance (the age of charcoal is rarely the same as that of the event it is used to date; Bednarik 1989, 1994b), and their practice of comparing and juggling different dates as if they were finite numerical values. All radiocarbon dates are expressions of statistical probabilities, and in comparing two or more of them we reduce these probabilities accordingly.

Conclusions

The nature and genesis of the caves' dehydrated, mostly inactive *montmilch* has been considered in some detail (Bednarik in press), not only because of the palaeoclimatological connotations of such formations and the effects of their growth on incised linear markings, but also because they help us discern the stratigraphical relationship between the generations of petroglyphs. Though some detail remains open to alternative interpretation, the general petroglyph sequence in Malangine Cave appears to be as follows:

Initially, during a period of denser vegetation and, presumably, greater precipitation than today, extensive ceiling areas of the then moist and clayey travertine were marked by digital flutings (*sillons digitales*). Climatic conditions later yielded to at least one interval of markedly lower rainfall and sparser plant cover. Karake-style, deeply carved petroglyphs (Aslin and Bednarik 1984) were added after the growth of pearly travertine that covered most finger flutings in Malangine had ceased.

Some parallel, tool-made grooving may be contemporary with this art form. The CLMs or 'tridents', however, are clearly more recent. These forms are widely distributed throughout much of Australia including Tasmania, as part of the archaic linear petroglyph traditions (which were formerly included in a 'Panaramitee style'; Maynard 1979; cf. Bednarik 1985a, 1988; Rosenfeld 1991; Franklin 1993). Most of this second phase of ceiling decoration was restricted to the entrance-nearest portion of the caves and became concealed by a sheet of dense laminated carbonate precipitate, apparently during a phase of wetter climate. This lamina, in turn, bears on its surface a generation of incised and pounded outline figures, which were preserved only in a few places in Malangine Cave. They date from just shortly before the cessation of the deposition of the travertine lamina, bearing only minor subsequent speleothems.

The clear physical relationship between phases of rock art production and intervening speleothem deposition is not unique, it can be found at several other caves, in Australia as well as abroad. It offers an opportunity to determine minimum or maximum ages for the rock art traditions thus sandwiched between two carbonate speleothems, by estimating the ages of the latter. There are several methods potentially available to achieve this, including radiocarbon analysis of the carbonate, uranium-thorium analysis, oxygen isotope determination (only of limited use), radiocarbon determination of organic residues contained in the laminae, and archaeological correlation of exfoliated lamina fragments found in excavated and datable sediment strata. The speleothem medium of finger flutings and its isotopic geochemistry are crucial to such dating work, and have been thoroughly discussed elsewhere (Bednarik in press; Bednarik and Head in press).

Figure 13. *Set of four finger markings in a dome-shaped ceiling recess of Group 5 in Koongine Cave. The white* montmilch *is slowly dissolving and the darker primary rock re-appears.*

Dating work in some of the thirty-five known decorated limestone caves of the Mount Gambier karst is continuing, and its preliminary results should not be considered without a comprehensive discussion of the qualifications that apply to them. It will be presented in detail elsewhere. The dating information currently available might suggest that the shallow ceiling incisions in

Malangine Cave are of mid-Holocene age, while the deeply carved Karake-style motifs are probably of the early Holocene. This would agree with the occupation data by Frankel (1986), although I must emphasise that there is no proof whatsoever that any of the occupation evidence coincides with any of the art production. Humans were probably present in the region throughout the Holocene and late Pleistocene and they no doubt used the sites frequently. It would be naive to assume that each use of the caves has necessarily resulted in archaeologically detectable evidence.

The discovery of rock art in Malangine and Koongine Caves prompted a thorough survey of hundreds of caves across southern Australia, of which the Mount Gambier limestone karst was the focal region. The discovery of numerous further cave art sites and underground chert mines within a few dozen kilometres of Mount Gambier has added a fascinating aspect to the pre-History of Australia, and one that differs significantly from the more conventional archaeological evidence in this country. The recent discovery of similar cave art in Papua New Guinea (Ballard 1992) suggests, however, that such practices may have been more widespread, and that their past neglect by archaeology might be attributable to taphonomic factors and research biases.

Annotations and acknowledgments

Note 1: The variables used were deliberately chosen for their advantages in describing a lithic assemblage, not for their conformity with Australian preferences as current in 1982. This is because I believe that parochial and slavish adherence to an established set of variables, whilst no doubt conducive to forming established biases, is detrimental to the discipline. Lithic typologies are largely stylistic taxonomies, and thus fundamentally subjective: they are conceptual artefacts of archaeologists.

Malangine and Koongine Caves were closed by steel fences in 1983, at the request of the Millicent Naturalists Society, to protect them against uncontrolled visitation. This paper was written in 1983 and has been updated only to accommodate some new developments and bibliographical references. All illustrations are of 1983 or earlier. Most of the analytical work for this project was conducted by my own laboratory, Archaeological Soil Lab.

My gratitude is expressed to Professor M. A. Geyh, the then Director of the Niedersächsisches Landesamt für Bodenforschung in Hannover, for providing the radiocarbon dates. I also thank Messrs T. and F. Glynn, for permitting access to the sites on so many occasions; and Mr G. D. Aslin, for his valuable contributions to the history of the area, and his comments on my environmental data. Thanks are also due to Jörg Bednarik, for help with field work, and to Professor K. J. Sharpe, for his constructive criticism of the paper. I should also like to thank the anonymous local pastoralist, who mistook me for a cattle rustler while I worked at Malangine Cave at night, for shooting only into the air. Most of all, I wish to record my gratitude to my wife Elfriede, who not only suffered my enthusiasm with the usual patience, but who participated in nearly all of the field work of this project, over the past one and a half decades.

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