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The Paroong Cave Preservation Project

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Abstract. The planning and execution of the first Australian project of cave art preservation is described, emphasising the rationale and methods of the project. Generic issues of cave art conservation and site management are engaged. The paper covers most of the conservation aspects likely to be encountered in limestone caves containing ancient rock art.

1. THE SITE

1.1 Description of the site

1.1.1 General description

Paroong Cave was described as 'unnamed' in 1971 by Fred Aslin, surveyed, and given the CEGSA Number S-188. In 1982 it was re-surveyed by Peter Horne, under No. L 135 and the name 'Glenhuntly Cave'. It is located in a grazing paddock forming part of Glenhuntly, a grazing property owned by John Hunt near Mt Gambier, South Australia. The area consists of undulating grassland, formerly covered by dense stringybark forest, and is characterised by low, sub-parallel ridges of Tertiary limestone deposits that are rich in caves, cenotes and other karst phenomena. Drainage is entirely subterraneanly; i.e. there are no rivers or creeks in the region.

The cave consists of a single linear horizontal passage formed mostly along a vertical fault, oriented roughly east–west (Fig. 1). It reaches the phreatic water level at several points, all of which lie in complete darkness. There are presently two entrances from the surface above and land owners during the early part of the 20th century have attempted to fill in both of them with boulders and agricultural refuse. This was a common practice throughout the Mt Gambier region (cf. Aslin and Bednarik 1984a: 44). In the case of Paroong Cave, one opening was successfully closed—the western entrance. The eastern entrance was only partly obscured by rocks, and the amount of farm garbage present in it was minimal. The historical infill in the eastern entrance had several effects. It closed off access to the western part of the passage and thus influenced micrometeorology profoundly; it allowed soil sedimentation in the entrance, as well as the establishment of vegetation; it indirectly affected the hydrological regime; and it concealed some rock art.

As a result of this deposition of boulders and refuse, human access has not been possible into the cave's western part during much of the present century. The speleological surveys carried out earlier have only considered the eastern part of the cave, and only 50 or 60 m of an obviously larger cave system had been explored until January 1988.

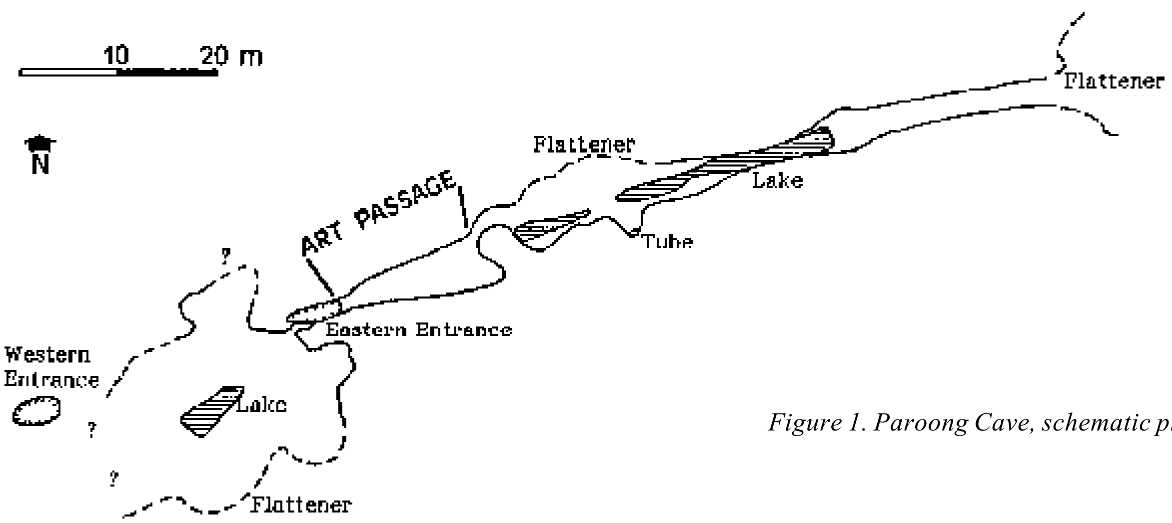

Figure 1. Paroong Cave, schematic plan.

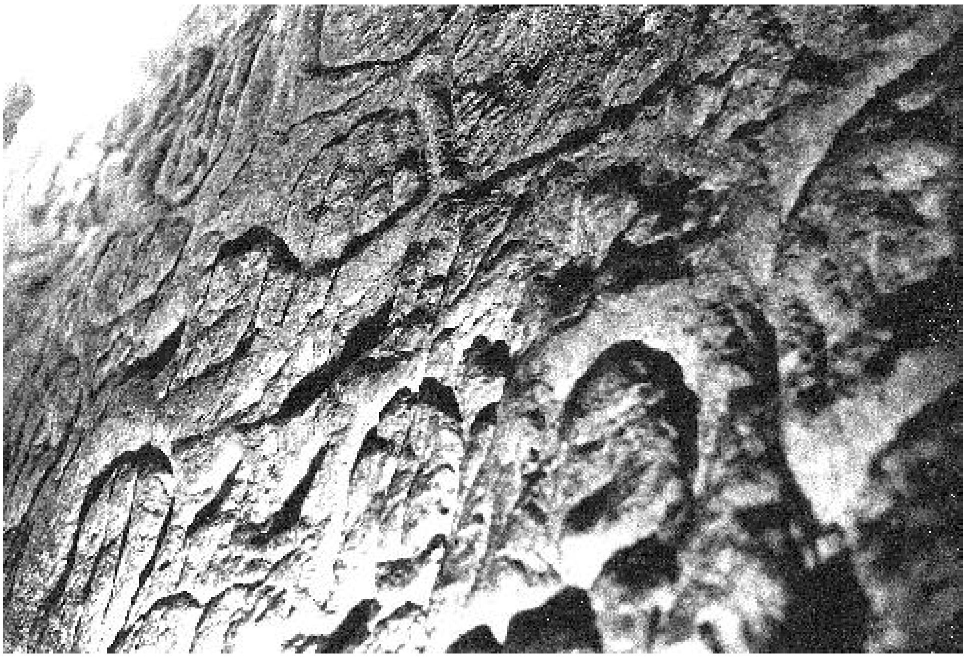

Figure 2. *This wall in Paroong Cave is densely and completely covered by deeply carved petroglyphs to a height af about 4.5 m from the floor.*

1.1.2 Cave morphology

Paroong Cave owes its existence to a fault line that is not apparent from the surface, and is oriented 16º south of west, to 16º north of east. Where accessible the width of the cleft is generally under 1 m, any wider spaces are either due to subsidence of a block, as in the Art Passage, or solution by atmospheric water, or solution by phreatic water. At a level of between 3 and 5 m above the present water table, solution has produced extensive horizontal widening, both in the eastern and western part of the cave, which extends up to 25 m laterally in the western part (Fig. 1). Much of this space is quite low, however, and some of it does not permit human access. In these low solution spaces, animal scratches are extremely numerous, the vast majority being of great antiquity. Their arrangements (Bednarik 1991) indicate that the cave served as a water supply for many species, including megafaunal ones.

It is assumed that the floor in the Art Passage, which is over 10 m below the surface, is a false floor, and that air spaces exist beneath it. In 1982, heavy rains caused water to rush into the eastern entrance, removing within a short time about one metre of soil sediment in the western part of the Art Passage, according to the landowner. Remains of the former sediment occur in wall recesses and it is clear from the floor channels that substantial voids must exist to accommodate fluvially transported material. However, the absence of vadose water and the lack of discernible flow in the area's massive phreatic reservoir raise the question of what caused the intensive solution activity above the present water table. The most likely explanation is that Pleistocene pluvials have been instrumental in this solution, as is being assumed for the deep caves of the Nullarbor (cf. King 1950; Jennings 1963). Paroong Cave in its present form is a comparatively stable cave: it has not experienced any tectonic (structural) adjustments at least during the Holocene; its waters are near-saturated with carbonate and, in the absence of turbulence or a new supply of CO_2, would be unable to accept any further solute. In addition it is possible (if tentative approximate dating of the cave art is accepted) that the cave survived the considerable lowering of the water table during the late Pleistocene without any significant tectonic adjustments.

While the eastern part of Paroong Cave is almost free of major speleothem formations, the western part, which is somewhat wetter, contains extensive stalactitic carbonate decorations, including short straws. Cauliflower-shaped formations are frequent, and much of the speleothem population remains active, slowly encroaching upon the cave's convacuation space. In summary, Paroong Cave is a morphologically stable, 'mature' to 'old' cave; it has entered the regressive phase of its life cycle, having peaked sometime during the Pleistocene.

1.1.3 Environment

The Gambier Limestone is of Oligocene and lower Miocene age. The area's macro-hydrology is characterised by its upper aquifers. At Paroong Cave the water table is about 8 m above sea level (Holmes and Waterhouse 1983), and drains in a due southerly direction. The soils in the vicinity of the cave entrance consist of dark rendzina-type sediment (for analyses refer below) overlying in places a reddish deposit that may be related to terra rossa-like horizons in the region (Bednarik 1980; Witter 1977). The mean annual rainfall lies between 700 and 750 mm (Commonwealth Bureau of Meteorology data), and the predominant wind direction in January, the month during which this project was conducted, is SE, accounting for about 30% of duration followed by SW. During January 1988, a wind speed of 8 m/sec was not exceeded near the entrance of the cave.

The vegetation zones in the coastal region south of Mt Gambier prior to European occupation have been described in Bednarik (1994) and further vegetational information can be found in Luebber's (1978: 37-8) thesis. In the vicinity of Paroong Cave, substantial stands of *Eucalyptus baxteri* or *obliqua*, interspersed with *Casuarina* sp.,

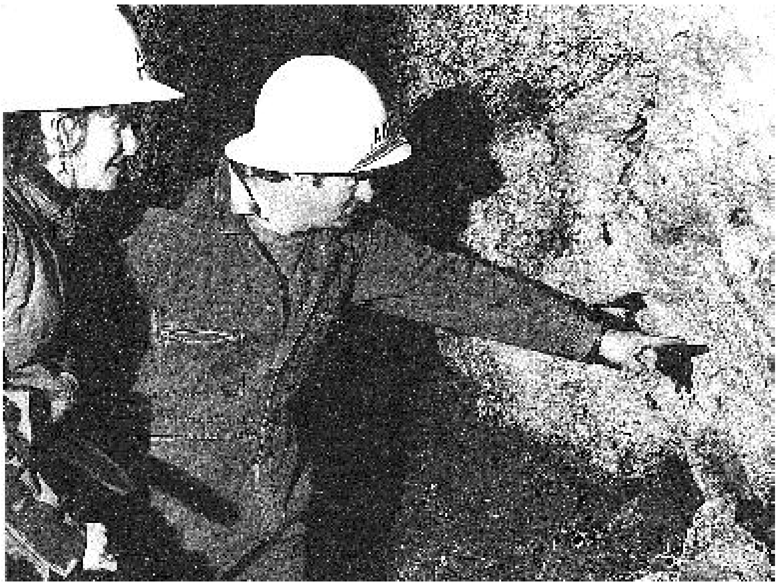

Figure 3.
The discoverer of the Paroong cave art, Geoffrey Aslin, showing one of the authors (EB) some petroglyphs in the Art Passage ofParoong Cave in 1984.

are reported to have existed (J. Hunt, pers. comm.), and a remnant of them still occurs as a grove just a few hundred metres to the south-east. Original casuarina trees (*C. stricta*) also still occur in the hills around the cave.

1.2 History and exploration

1.2.1 Historical information

Less than 100 m west of Paroong Cave, on the crest of the nearest ridge, are the crumbling remains of a small building that was constructed of limestone blocks. According to the son of its former occupants, the now blocked western entrance of the cave was used by his parents to obtain water from Paroong Cave. It would thus appear that the blocking of that entrance (and presumably also the attempt to block the eastern entrance) only took place during the 1930s or 1940s. Furthermore, it can be assumed that access to water was reasonably easy via the western entrance, at least in recent centuries.

Water was pumped out of the eastern part of the cave, via the entrance (several rotting logs still straddled the entrance up to January 1988 and are said to have supported the pipe). There are two deep saw cuts into the rock, and the narrow passage east of the Art Passage has been artificially enlarged, presumably to improve access to the eastern exposures of the water table. Furthermore, there is a borehole above this water, connecting to the surface above. It must be assumed that this phase of water use postdates the closure of the western entrance, because it would seem to have been easier to exploit the water source there.

Within the Art Passage there are a few historical inscriptions, but fortunately none actually deface any pre-Historic markings. There are also patches of recent wall damage where the dark, heavily patinated rind of the limestone wall has been broken through, and the pale-yellow rock is exposed. For instance, such a scar occurs within the petroglyph considered by some to be the site's dominant motif—a large circle with internal lozenge lattice, 40 mm deep engraved. Such recent damage may be attributable to rubble or boulders that have tumbled down over the entrance chockstones, or have been thrown down, or possibly to intentional damage. Fortunately only a few instances of this have been noted.

1.2.2 Exploration history

Early European settlers have obviously known Paroong Cave, and they have exploited its water deposit in various ways. We are not aware of a published reference to the cave prior to 1985 (Aslin, Bednarik and Bednarik 1985), however. A plan of the eastern part was produced by Fred Aslin and Ian Lewis on 5 August 1971 which seems fairly accurate (No. 5L135-CEG 1087). A second survey, by Peter Home, includes more detail, especially of the evacuational space below the water table, but is not accurate, and particularly its Section is unsatisfactory. This was produced on 25 September 1982. It is amazing that both surveys failed to notice the dense petroglyph concentra-tions in the Art Passage, which demonstrates an urgent need to make cavers better aware of the range of phenomena they could conceivably encounter on their excursions.

The Parietal Markings Project (Bednarik and Bednarik 1982; Aslin, Bednarik and Bednarik 1985; Bednarik 1988a) has been concerned with archaic cave art since the mid-1970s. In 1980 it began to focus on the Mt Gambier limestone region, and was joined three years later by Geoffrey Aslin. Aslin soon commenced a systematic search of caves, locating petroglyphs in nearly two dozen caves between 1983 and 1986. This survey led him to Paroong Cave in 1984, and he immediately discovered the rock art of that cave. In line with the Project's established practice he used an Aboriginal word in naming the cave. Paroong is derived from *paroong kar-li-e*, meaning 'abundant' in the language of the last indigenous language group that inhabited the South East of South Australia, the now extinct Buandik (Smith 1880). It refers to the abundance of the markings in this cave. It is in no way intended to suggest that the most recent indigenous occupants of the area, the Bunganditj (Tindale 1974), used the cave.

Aslin began in January 1985 to record the rock art of Paroong Cave (Aslin, Bednarik and Bednarik 1985: Fig. 1), after a thorough examination had revealed that, in addition to the hundreds of deeply engraved motifs, finger lines also occurred. They have managed to survive only on a few square centimetres of rock surface at the eastern end of the Art Passage.

1.2.3 Preamble to preservation measures

Members of the Parietal Markings Project immediately recognised the significance of Paroong Cave, and the threats to its art (see below). In their 1985 report, the principal researchers noted:

> In order to ensure the continued preservation of the visually spectacular markings we have requested the closure of this important cave (Aslin, Bednarik and Bednarik 1985: 72).

In his response, a letter that was published in *Rock Art Research* (Volume 2, p. 91), the former Manager of the Aboriginal Heritage Branch of South Australia, said:

> With reference to your letter of 30/11/84 concerning the screening off of Koongine and Paroong Caves I am to advise that funding can be made available from the National Estates Grants Program to undertake site protection works. … Before we can instigate any protection works at these locations it will be necessary for the Site Conservation and Management officer of the Aboriginal Heritage Section to inspect the site and formulate a proposal. It would be appreciated if a member of your Association would contact Mr R. Muegge of this office to arrange a suitable time for such a site inspection which should also involve the relevant property owners.

Two meetings were held on site, and a grant of $5000 was made available from the National Estate Grants Program, for ‘Minor protection works, gridding and security at various caves in the South East of South Australia’.

In November 1986, one of us (RB) made application on behalf of the Parietal Markings Project, for funding from the Australian Institute of Aboriginal Studies Rock Art Protection Program. A grant of $4200 was to cover purely materials and plant, all labour was to be voluntary.

1.3 Significance of the site

1.3.1 Australian cave art

The large corpus of Australian rock art has traditionally been thought to be entirely restricted to rockshelters and open air sites. Until the late 1960s it was believed that pre-Historic Australids had not normally entered caves. The reluctance of Aborigines to venture into caves—sometimes even into deep rockshelters—is attributable to a mythology describing them as the dwelling places of a variety of beings. Since most Australian rock art studies until the mid-1960s were tied firmly to iconological and ethnographic interpretation, neglecting the possibility of great time depth, the apparent absence of cave art only seemed to verify what ethnography suggested. No thought was given to the possibility that Pleistocene Australians could have held cultural concepts akin to those of Upper Palaeolithic Europeans. The first site of Pleistocene cave art to be located in Australia was Koonalda Cave (Gallus 1968), followed by New Guinea 2 Cave (found in 1977). Our investigation of Orchestra Shell Cave in 1978 revealed that these markings, too, were finger markings, and closely resembled those at Koonalda and Buchan.

Between 1980 and 1986, a total of 26 further sites of cave art were located in Australia, all except one in the Mt Gambier district. Here, the cave art was found to be far more varied, and several phases were soon recognised. One of them has been named the Karake style, and is particularly well exemplified in Paroong Cave.

1.3.2 Rock art in Paroong Cave

Not all parts of Paroong Cave have been explored, even those accessible as of February 1988. More specifically, it is highly likely that there are anthropic markings inside the western entrance which remains concealed beneath tonnes of fencing wire, rubble, boulders, refuse and bones of domestic species.

The rock art presently known in Paroong is entirely restricted to the Art Passage, although other traces of pre-Historic activity have been located elsewhere in the cave. The Art Passage consists of an elongate chamber with a slightly sloping floor, which begins from the cave’s eastern entrance, where it is under 1 m wide and opens up into the chimney forming the entrance. The floor is between 10 and 12 m below the surface, and as one proceeds away from the entrance the chamber widens to over 3 m. It is between 4 and 6 m high, has a comparatively flat ceiling and near-vertical walls, which means that its cross-section is roughly rectangular. After about 15 m the passage is almost completely closed, and access to the easternmost part of the cave is via a squeeze at the eastern end of the Art Passage.

About three-quarters of the vertical wall surfaces within the Art Passage are covered by deep petroglyphs, and markings also occur on part of the flat ceiling. The most conspicuous of the petroglyphs are the numerous circles, most of them with internal designs, especially vertical barring. But there are many other, less obvious types of markings, representing a variety of motifs, as well as markings of less formal graphic content. In particular, there are hundreds of blow marks that have obviously been produced with a heavy and possibly hafted implement, presumably a large stone tool. Many of these impact marks show that the blows penetrated several centimetres deep into the rock. It is clear from the arrangements of these traces (which occur also in several other caves) that these activities had no vandalistic intent, as they have in general not damaged any petroglyphs. There are also dozens of large pits, 10 to 20 cm in diameter and about as deep, on the walls, which were apparently fashioned by similar blows with heavy tools. These markings remain mysterious, although they have already prompted some inte-resting hypotheses.

The north wall is the more densely engraved of the two main panels, and on its western half practically all available surfaces are marked. The art extends to more than 4 m above the present floor in places, and to about 3 m practically throughout the rest of the chamber (except the back wall, which is unmarked, apart from a tiny remnant of finger flutings). Dim day light reaches into the Art Passage and although natural light is not adequate to perceive most of the motifs, none are actually in complete darkness, as in many other caves in Australia. The positioning of many motifs indicates a sense of aesthetics, a conscious strategy, in some cases they seem to emphasise the ambience of the chamber (Steinbring 1987). Individual petroglyphs are unusually deeply carved; most grooves are between 30 and 40 mm deep.

1.3.3 Significance

Besides being a major concentration of Australian cave art, Paroong Cave is an art site that is stylistically close to the Mt Cameron West site in north-western Tasmania. It had already been suspected before the discovery of Paroong that the Karake Style existed at both sides of Bass Strait:

> The recent discovery of 'Tasmania-style' petroglyphs at Karake Cave opens new avenues. The site is located quite close to Cape Northumberland which could have been a kind of springboard, a landmark for trans-Bassian migrants ... If it was introduced to Tasmania, this tradition would necessa-rily have to be of Pleistocene antiquity (Aslin and Bednarik 1984b).

But it was Paroong Cave that decided the matter: its art is so similar that anyone doubting a connection with Tasmanian art would find it difficult to explain away the remarkable stylistic parallels. Therefore Paroong Cave should become a cornerstone in any future attempt to formulate a continental synthesis for early Australian rock art.

The cave art found along the southern coast of Australia, from Perth to Buchan, is now one of the two largest concentrations of mostly Pleistocene cave art in the world. Mt Gambier, with some forty sites within a radius of 40 km, possesses the world's largest regional concentration of cave art sites. The Karake Style corresponds with the earliest part of what used to be called the 'Panaramitee style'; it is totally noniconic and seems to lack animal tracks. Elsewhere this style has been dated to over 28 000 BP (Bednarik 1999), and while we do not know the age of the Paroong Cave art, it may well belong to one of the oldest traditions of rock art in the world. We contend that it was produced by a people lacking the concept of iconicity, who probably possessed a model of cosmic order quite different from that which was held by Holocene humans. While this art occurs at many sites, Paroong is one of the most outstanding among them. Seen in this perspective, it is most worthy of preservation.

2. CONSERVATION PROBLEMS

2.1 Water

2.1.1 Surface run-off

Both entrances to Paroong Cave lie at the bottom of a depression forming a gentle gully that drains towards NW. The entrances are only about 20 m apart, and a pronounced drainage depression has formed around each opening. Precipitation occurs almost entirely as rain, and during each rainfall some run-off enters the cave through the openings. It is obvious that the petroglyphs on the north wall once extended right to under the chimney opening of the eastern entrance, they now peter out where the wall experiences run-off. The surface water, having had the opportunity to absorb some CO_2 before entering the opening, has corroded the wall to such an extent that only faint traces of petroglyphs remain. The water then would have run straight down to the cave floor, but since the partial filling of the cave entrance some decades ago its path would have changed. Placement of several boulders and smaller rubble enabled the retention of a considerable amount of soil which soon covered several engraved motifs that had until then not been subject to any threat. Noting that this dark rendzina soil, which had itself been washed in from the vicinity of the cave entrance, seemed to have the ability to retain moisture for a very long time we collected samples of it for analysis. We had also noted that where the prolonged moisture presence in the soil had maintained a high interstitial moisture level in the rock it was in contact with, the rock surface had become so soft that its hardness on the Moh's Scale was be below 1. Furthermore, the high level of moisture, well within the reach of daylight, had permitted the establishment of a luxuriant growth of mosses. This in turn had created a vicious circle: the plant growth, through the micro-organisms it supported, produced carbon dioxide which attacked the limestone rock, the moss cover assisted in retaining moisture longer, and the byproducts of the microchemical attack of the rock probably further assisted in keeping moisture from evaporating. To make matters worse, the partial filling of the cave entrance had somewhat reduced the opening size, thereby impeding convective temperature exchange slightly. Perhaps more importantly, this assisted in maintaining higher air humidity near the cave floor, which assisted the moss community to survive the dry summer months easily. Observations during several visits at different seasons clearly showed that the mosses in the upper part of the chimney were struggling to survive through part of the year, and became so dry in summer that they could easily be brushed off. Near the artificial infill, however, especially in a zone of 20 or 30 cm above it, the mosses thrived throughout the year. Their success was encouraging the establishment of other plant species already, and even *Graminae* were beginning to settle the slope.

The recent deposit covered an engraved panel (several motifs extended beneath it), and micro-organisms would have accompanied the root systems of the establishing plant colony. These, naturally, produce carbon dioxide, which forms carbonic acid with moisture, which dissolves limestone readily. So while the surface run-off would normally not have posed any significant threat to the art, it certainly did so in combination with the alterations that had taken place in the cave entrance as a result of the attempt to fill it in.

Bearing in mind that heavy rains were capable of producing flash floods in the cave and removed a good deal of sediment, such as had occurred in 1982, we conducted a survey to determine the actual catchment area to which the eastern cave entrance served as a drainage. We determined that the approximate catchment area is 18 150 m^2, most of it consisting of a long hill slope to the NE.

2.1.2. Insterstitial or capillary moisture

Most rocks contain interstitial moisture, and the Tertiary (Miocene) limestone at Paroong Cave, being very porous, certainly does so under any conditions in nature. Provided that this moisture content remains within a certain range it should not have any adverse effect on the rock. But if the moisture between the grains or crystals rises above a critical level the mechanical strength of the limestone becomes seriously impaired. While the latter seems to return with desiccation, prolonged water logging results in increased porosity, and permanent mechanical weakening. The rock then becomes so frail that it can be easily ground to dust between fingertips. This tendency created a serious conservation problem in the entrance-near part of the Art Passage of Paroong Cave. To reach the cave's floor visitors had to climb over the boulders that had been deposited recently, and lower themselves with the help of a rope (Fig. 4). In doing so they had to climb past a dense concentration of petroglyphs and were virtually unable to avoid rubbing against some of these. The high content of interstitial moisture has rendered the wall utterly soft, and where the boots of visitors have rubbed against the petroglyphs, even the most moderate frequency of visits has within three years resulted in the almost complete obliteration of deeply carved motifs.

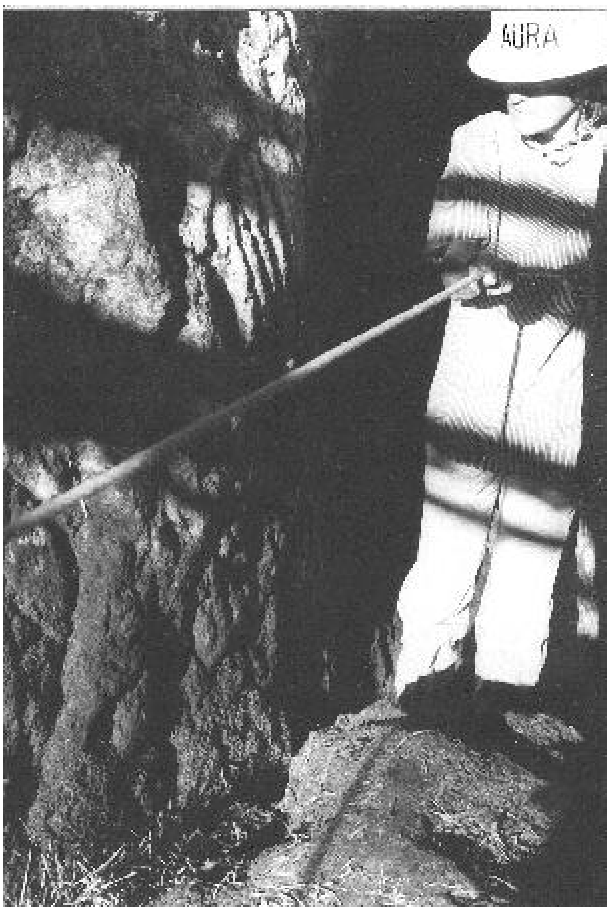

Figure 4. *Descent into the lower part of the entrance shaft. Deeply carved petroglyphs are clearly visible.*

In order to establish why the rock was so highly absorbent we analysed samples and found that it could absorb an average of 27.6% of its own bulk weight in 24 hours. By determining the bulk volume (wax coating method) and assuming a s.g. of 2.7 (for limestone) we found that the rock only accounts for about 49.2% of the volume (ignoring impurities), which means that water occupied 36.7% of the volume, suggesting a 73.1% moisture penetration of pores after 24 hours. The rock's porosity is extremely high but the bulk of the interstitial spaces are readily accessible, so the problem was hardly one of waterlogging. It seemed more likely that the high moisture level was being buffered by the soil among the boulders, which appeared to be very moist and fine grained. We conducted a standard analysis on a sample of soil covering the decorated wall, which produced the following results:

Natural water content: 33.40% of total mass, or 50.15% of soil mass.
pH: 7.6
Natural colour: Munsell 10 YR 3/1.5 wet, 10 YR 3/2 dry.
Colour after removal of organic content: 7.5 YR 4/5 (wet), 7.5 YR 5.5/5 (dry)
Plasticity: 0.4-0.5 mm
Linear shrinkage: 14.8%, yielding slight curling and fracture of column
Organic matter content: 4.1% of mass
Morphometric analysis: sample unsuitable
Particle size distribution and sedimentation analysis: the coarser sand fractions consist almost entirely of calcium carbonate, and nearly all the particles under 6.5 mm are fossil casts. A thin silica spall was observed in the 2-4 mm fraction, and a few ferruginous grains in the 4-6.5 mm fraction. From 0.63 to 2 mm, the carbonate still accounts for 99% of the sample, and a ferruginous component only becomes prominent at 0.4 mm. A qualitative spot check of the smallest sand fraction indicates that nearly all iron present is of the ferric valence, with only a faint trace of ferrous matter present.
General character of soil: it belongs to the family of rendzina (or rendsina) soils, which are of dark-grey to black colour, owing to the formation, between humus and excess calcium carbonate (they always overlie limestone or calcareous sediments), of water-insoluble calcium humates. In seasonally dry climates, as in this region, calcium carbonate that has been mobilised may rise in the soil profile by capillarity. In the Mount Gambier region, rendzinas occur extensively in low-lying areas, and are subjected to water logging. The sample's natural water content is extremely high, bearing in mind that, (a) there had been no rain in the days preceding collection, and (b) a content of 33.4% of mass, at soil s.g. = 2.6, means that an incredible 56.6% of the sediment's actual volume is occupied by water. This is particularly surprising in view of the quite modest clay fraction (about 15%) and the very marked steepening in the cumulative grain size distribution curve in the fine sand fraction, from 0.055 to 0.225 mm. Judging by the particle size distribution alone, one would expect no susceptibility to prolonged moisture retention. The organic content is also moderate, but it is the very high linear shrinkage index that reveals the sediment's extraordinary moisture retention characteristics. The absence of drying cracks in the cave suggests that the soil has not experienced significant desiccation. Its natural moisture content is periodically replenished by surface run-off, it is

maintained by the soil's character, and it is probably buffered by the high relative air humidity of the cave atmosphere. Its permanently high moisture content maintains the moisture level in the rock it covers, and it represents a serious conservation threat to the petroglyphs on this rock surface.

2.1.3 Condensation

The dew point is the temperature at which air becomes saturated and dew is precipitated. Condensation occurs on a cave wall if air humidity is high, close to saturation point, and the rock face temperature is lower than the ambient air temperature. Air humidity is high in most caves, and limestone caves frequently have a relative air humidity of 95% to 99%. This is particularly so if they contain bodies of water or 'active' speleothem formations. Despite these frequently very humid conditions, condensation on a large scale is a comparatively rare phenomenon in large limestone caves. The reason for this is that in a large cave system, air temperature is buffered by rock temperature and thus very stable. There is practically no convective temperature exchange in caves of a high air residence rate, and the temperature differences necessary to induce condensation do not exist. To some extent this can even apply to the entrance part of a cave, as demonstrated by the example of Paroong Cave.

The micrometeorological study at Paroong Cave that formed part of this project was not as sophisticated or comprehensive as that which was conducted at nearby Malangine Cave (Bednarik 1994), but it produced sufficient data to understand the site's basic speleoclimate, and it did benefit from the Malangine study. Over the duration of the actual conservation works, which were conducted from 3 to 22 January 1988, the air temperature near the floor of the cave, immediately below the eastern entrance, never strayed outside the range from 11ºC to 14ºC. During these twenty days, the relative air humidity just 10 m from external conditions remained continuously above 97%. Both temperature and humidity showed only negligible diurnal changes, if any. For instance, the external air humidity just outside the entrance ranged from 30% to 43%, but just one metre below the ground line, in the upper part of the entrance chimney, a reading of 52% was taken on 20 January at 6 p.m. Below, near the cave floor, the relative humidity remained static at 97% to 99%.

External conditions (unaffected by the cave) were characterised by diurnal oscillations: morning temperatures (at 9 a.m.) averaged 20ºC, those at 3 p.m. 25ºC, while the corresponding values for relative air humidity were again lower than those taken just outside the cave entrance, averaging 21% and 18% respectively.

Whenever wind speed values were taken, no discernible air movement could be recorded a few metres into the entrance chimney. While no wind speeds greater than 8 m/sec were actually observed during the work period, experience at other sites suggests that even much stronger winds would be ineffective in producing an air flow in the cave. The relative stability of the cave meteorology just a few metres below the entrance is probably the result of the following factors: closeness of the water table prevents any intake of warmer air, the cool air is trapped. It is buffered by both the water body and the rock mass, allowing its humidity to remain equally stable. As soon as this equilibrium is threatened by convective heat in the entrance, the evaporation rate there would increase; evaporation would effect a lowering in temperature and thus protect the cool air below. In this system equilibrium is maintained permanently, and condensation does not occur.

We should add, however, that we do not regard condensation as a serious threat to petroglyphs in limestone caves. Rock art conservators fear condensation water when it occurs at painting sites, and when the paintings are comparatively recent there is indeed cause for concern (Schwartzbaum 1985). Where the art is very ancient, conservators should think carefully before implementing measures to modify the microclimate. In particular, condensation water by itself will not damage engravings on limestone or the limestone surface as such. It consists of distilled water, which has to be charged with carbon dioxide before it can dissolve the rock. In a speleo-environment, the CO_2 can be introduced by human visitors (Fernandez 1986), or by micro-organisms (which may also be introduced by humans). Thus condensation moisture becomes a conservation problem for cave petroglyphs when human visitation occurs.

In well-ventilated cave systems (such as those with multiple entries, vertical passages, particularly if located at a hillside) condensation can occur in abundance. For instance, in the new part of Orchestra Shell Cave, near Perth (which one of us discovered in 1984; Bednarik 1987), a large panel of finger flutings has become calcified after production and is now completely hard. It attracts large-scale condensation, and can be assumed to have been subjected to it for a very long time, yet we noticed only minor corrosive damage that could have been caused by this moisture.

2.2 Biological factors

2.2.1 Mosses and algae

The occurrence of a luxuriant growth of mosses in the entrance chimney of Paroong Cave has been mentioned above. No attempt was made to identify the species concerned, as this did not seem relevant to the preservation work. Mosses require daylight for their growth and are therefore restricted to the immediate entrance zone of a cave. The same applies to algae but some species can cope with very low light conditions. This can be observed in any moist cave: green algae growth is usually found much further from the entrance than most other vegetation, specifically mosses and lichens.

The deteriorating potential of mosses has already been touched upon. Algae, too, tend to concentrate and retain moisture, but their corrosive effect on rock does not seem to be pronounced (Bednarik 2001: 95-6). They seem to be using the rock merely as support, fixing the atmosphere's nitrogen and carbon dioxide. Indeed, if they act as an absorbent of the latter they might even be conducive for rock art conservation in a limestone cave.

Lichens occur in the entrance region but not in close vicinity of rock art, as far as could be ascertained. They require direct daylight for their growth, and do not seem to particularly favour the limestone in the region.

2.2.2 Fungi and bacteria

Fungi, or moulds, lack chlorophyll and therefore require no light for their growth. They range in form from a single cell to a body mass of branched filamentous hyphae and feed on organic matter. Fungi can penetrate deeply into a cave system, but do not seem to have a major effect on limestone. However, some species are known to produce oxalic acid (which may form calcium oxalate) and fungal growth is of course unsightly. In the absence of precise data about the interaction of fungi and calcium carbonate within caves it seems prudent to keep such growths away from decorated areas.

Fungal growth is comparatively easy to control within a cave, by the removal of all organic matter, notably wood and other vegetable matter.

We have no expertise in identifying bacterial decay and did not attempt to assess whether any was apparent in the cave. However, if bacteria have been active in the vicinity of the rock art, then any effect would have been on a very small scale over the many millennia it has survived. In comparison to other conservation threats, which clearly did exist, the threat of bacterial damage seems negligible, provided there are no significant environmental changes.

2.2.3 Speleofauna

Paroong Cave does not appear to accommodate a bat colony, as many other caves in the area do. Bats tend to damage cave walls and ceilings in two ways: (a) by scratching soft surfaces while they are airborne, with their wings and perhaps with their digital claws; (b) with the claws of roosting animals, produced as the bats hang from the ceiling. Both types of damage are minute but their cumulative effect over long periods of time can be severe for a rock surface. These fine lines have been described as the most numerous animal marks in caves (Bednarik 1991, 1994, 2001). Another type of effect bats are believed to have on rock has been described by King-Webster and Kenny (1958) who suggested that 'bat erosion' was responsible for dome or bell-shaped ceiling pockets in a cave in Trinidad. Hooper (1958), who identified the phreatic origin of these phenomena quickly challenged their view, however. Our own observations in Caribbean caves remain inconclusive: while local speleologists are adamant about the effectiveness of 'bat erosion' in this tropical area, the ceiling cavities in question resemble those in other regions, which are called *Kolke* and are a widespread speleogenetic phenomenon in caves that were once water filled.

Birds cause a second type of cave marking produced by volant species. A variety of birds are known to enter caves, for instance owls preying on bats penetrate deeply in pursuit of their quarry (Bachofen-Echt 1931). The damage such occasional visitors could conceivably cause would seem to be most minimal. But where birds actually inhabit the twilight zone of a cave it is a different matter. Australian caves, especially in the Mt Gambier area, are commonly occupied by the Welcome Swallow (*Hirundo neoxena*) and Fairy Martin (*Cecropis arie1*), both of which construct nests of mud pellets on the walls and ceilings. At present or former nesting sites, a small area of wall may be densely covered with vertical grooves. Their distribution in relation to the nest suggests that the primaries, claws and perhaps mandibles of the cave dwellers caused them.

Swallows have certainly inhabited the Art Passage where one old nest was observed. A further conservation problem relates to the corrosive effect of bird faeces in the vicinity of nests, and to the threat of fungal growth from organic matter.

Certainly the most conspicuous animal markings in caves are the scratch marks of animals with claws, and they have been discussed exhaustively (Bednarik 1991, 1993). Numerous species have been identified or suggested as potential producers of such markings, and animal scratch marks are known to have survived for many tens of thousands of years in caves. Several morphologically different types of animal scratch marks are now being distinguished, and such markings occur in all countries possessing mammalian or reptilian species with claws. (They may be absent in New Zealand, for instance.) They rank in size from the huge markings of the Cave Bear (*Ursus spelaeus*), which occur in vast numbers from Europe's Pyrenees to the Urals, or the wide-spaced marks of Australia's *Thylacoleo carnifex* which occur in the Mt Gambier region, to the tiniest rodent markings that are often barely perceptible.

Ancient animal scratch marks occur among the rock art of Paroong Cave. There is one prominent concentration of them immediately adjacent to the entrance shaft, in the uppermost part of the art panel. Elsewhere in the cave, particularly in the vicinity of water, animal scratches are very conspicuous and number many thousands. However, all of them are patinated and corroded, no recent markings were observed. It is therefore assumed that mammalian species did not frequent the cave much during its recent history, if at all, and do not pose a threat to the art.

None of the animals mentioned so far are true troglobites, i.e. they do not live wholly and permanently in the dark zone of caves; they are trogloxene species. Troglophiles (which live in the dark zone permanently, but may also be found outside) and troglobites also occur in caves. They include various aquatic species (fish, and in this region especially crustaceans) and a great variety of insects, spiders, snails, centipedes and worms. Among the most common in the South East are the poorly pigmented cave crickets, which do occur in Paroong Cave. The small invertebrate species found in these caves have inhabited them for a long time and would have been present before the rock art was produced. There is no evidence that they had a significant effect on the art and they are not considered to pose a threat to it.

2.2.4 Domestic animals

The introduction of agriculture to the South East of South Australia, during the mid- and late 1800s, resulted in significant changes to the district's environment, and in a complete transformation of the ecological system. Near Paroong Cave, the dense stringybark forest with bracken cover was replaced with grazing pasture, and the formerly sparse native fauna with a dense population of livestock, particularly sheep and cattle. Cultivation in the district has remained limited, the most conspicuous being pine silviculture. Nearly the entire district has been adapted as pastureland, and since the area has a reliable rainfall and a large supply of subterranean water, relatively high densities of livestock exist. This has had a profound effect on the level of nitrates in the phreatic reservoir, which constitutes the region's water supply.

2.2.5 Human visitation

The human visitation of caves, specifically of decorated caves, is a complex subject. Most of the relevant research has been conducted in Europe, but some Australian work on site management and visitor control is also relevant (Gale 1985; Gale and Jacobs 1986). We mention briefly a few aspects we consider relevant to the present conservation project.

The human visitor can contribute to the deterioration of cave art in several ways. Man is the only organism capable of damaging art consciously. The psychology of vandalism is again a very complex subject. Vandalism may be purely utilitarian (e.g. by a land owner who wishes to keep out outsiders, or prevent land claims from being raised), or it may have some psychological condition as its basis, which, at the simplest level, may be religious (e.g. Christian missionaries in South America or Muslim activities in western China) or cultural (e.g. the action of the man who destroyed an art panel at Rio Tinto Pass, Pilbara, with gelignite because he resented Aboriginal culture), but it may alternatively be far more complex (Freeman 1987; Brunet et al. n.d.). Since man is able to carefully plan any such destruction the only way it can be prevented is by complete and effective control of access.

There are various types of vandalism: the superimposition of inscriptions, caricatures, copies of rock art; the 'enhancement' of art, mostly for the purpose of photographing it (rubbing, chalking, dousing with water or motor oil, etc.); the calculated action of destroying it; and the attempted or successful complete removal of individual motifs (several instances in western Europe, many in North America; cf. Bednarik 1988b). If one were to try countering them by individual measures it would be quite impossible to do this effectively, and since there are several other arguments in favour of cave closure this is certainly the preferred measure.

Humans also cause deterioration of cave art involuntarily, a problem that has been investigated in depth in western Europe; it is summarised in Dragovich (1986) and the debate accompanying that paper. Briefly, the presence of human visitors raises the temperature, relative air humidity and carbon dioxide level in a cave's atmosphere. Visitors also introduce pollen, seeds, spores and bacteria into the speleo-environment. The effects of artificial lighting in tourist caves have been devastating in some cases, while the effects of brief episodes of torchlight and frequent photographic flashes on painting pigment are not yet understood. Human visitors are likely to brush against rock art in narrow spaces, or touch it with their fingers intentionally when inadequately supervised. The tendency of visitors to touch art has been commented upon in detail by Gale and Jacobs (1986).

In certain caves rock art is also likely to suffer from human traffic through the dislocation of rocks from a steep slope, that may then graze decorated panels as they tumble down; or from the damage occasioned by equipment brought into the cave, such as diving equipment, in the case of caves containing water. One of the most obvious threats to the art in Paroong Cave is attributable to the narrowness of the entrance chimney where it connects to the Art Passage, and where petroglyphs already occur, particularly on the north wall. Here, the passage narrows to about 70 cm. This is also where the wall is moister than elsewhere, and the petroglyphs are more fragile. Prior to 1988 cave divers entered the cave occasionally and each time they had to bring their equipment through this narrow, wet and slippery part of the passage.

As mentioned above, the mere presence of humans in a cave space has an effect on its microclimate. Air temperature rises within minutes, and it is an interesting observation that children give off more heat than adults do. Similarly, air humidity rises quickly, and if it is already very high initially saturation is reached, and precipitation occurs as mist. But more importantly, humans exhale carbon dioxide. This gas, being heavier than air, drifts to the ground and drain away through openings. Where the convacuational space of a cave rests on an exposed water table—as it does in Paroong Cave—the ability of the system to permit the gas to drain away readily is impaired. Where such a cave is narrow and well sealed (by dense, fine-grained sediments, by speleothem growths, or moisture) and lacks lateral escape possibilities, the carbon dioxide residence rate may be quite high and poses a serious threat to limestone rock that contains substantial quantities of interstitial water. Such water is always present in porous limestone close to the water table, and it certainly is so in the rock of the Art Passage in Paroong Cave. While the level of water content can be somewhat reduced by control of the hydrological regime, it could never be reduced to a very low level, nor should it be, because this would quite likely lead to mechanical weakening of the rock structure. So we have to accept the presence of this moisture, and the only remaining means of avoiding the formation of carbonic acid on the rock surface is a strict control of carbon dioxide sources. Human visitors are such a source, which means that frequency and duration of human visits must be kept to an absolute minimum.

2.3 Potential conservation problems

2.3.1 Physical weathering

Rock art conservators at open air sites and rockshelters have to deal with a variety of physical weathering processes, notably insolation (Bednarik 1979), freeze-thaw cycles (Tricart 1969; Schmid 1958), *Salzsprengung*, spalling through bush fires (Emery 1944) or lightning (Laudermilk and Kennard 1938), aeolian erosion (attrition by wind-blown sand grains) and capillary moisture. They may all contribute to the deterioration of rock art in such places, but have no effect, or very little effect, on cave art. Crystal wedging or Salzsprengung merits a mention because limestones, particularly the bedded sedimentary strata of Tertiary limestones, do contain a variety of salts, notably anhydrite, gypsum, nitrates and chlorides. However, we have found that where there is an abundance of interstitial moisture, salts that become mobile are simply flushed through the system. They often appear as precipitates on the cave ceilings (such as the sulphates in Malangine Cave, or the nitrates in Koonalda Cave, to name some examples we have analysed).

Tectonic adjustment is far more relevant in the area of cave art conservation. Structural changes may be seismic, or they may be responses to stresses within the rock structure. Such responses are frequently subsidence or roof collapse, and they may be due to factors such as major changes in the level of the water table, or other adjustments in the aquifer, or to changes in the load of load-bearing components within the cave tectonic. Alternatively, they may be due to seismic activity, or such activity may at least be responsible for the release of structural stresses. Tectonic adjustments can be massive, and in general it is well beyond the means of the rock art conservator to prevent or alleviate them, or often even to understand them. However, it is the conservator's responsibility to ensure in his planning that no undue tectonic stresses are placed on a cave structure as the result of his work. Rocks cannot simply be removed or relocated at will, and when placing protective structures or plant at or near a cave entrance it has to be first established that this will not impair tectonic soundness of the rock structure, nor impair tectonic movement where the possibility for it exists. For instance, if there is a potential for two rock masses (such as the two bodies along a fault line) to change their relative position in the future then it is futile to install a man-made structure across the two, fastening into both. This would be like installing a solid wall across one of the expansion joints that exist in any large building. Such a mistake could cause considerable damage to the cave.

2.3.2 Summary

The above examination of individual conservation problems has shown that a variety of them do exist at Paroong Cave. However, in order to draw up a plan for their alleviation it was necessary to summarise and synthesise them so as to produce the basis for a practical conservation plan, and, in view of the severely limited resources, design from this basis the most cost-effective work plan.

It has emerged from the above that the most immediate danger to the rock art in the cave existed in the western part of the north wall panel, particularly where the deposition of rocks had enabled the establishment of a sediment deposit resting against the engraved panel. Samples of this deposit have established its outstanding ability to retain moisture, and rock samples have confirmed the suspected high porosity. Moss growth tended to aggravate the significant mechanical weakening of the rock by facilitating even more extended moisture retention, as did the decreased opening size of the cave. Every visitor had to pass through this narrow passage, and as this was during the steep descent over the recently placed rocks which was generally conducted with a rope, visitors at that point tended to be more concerned with their personal safety than with the need of preserving the petroglyphs. In addition, the south wall is slightly overhanging in the crucial location, forcing the visitor towards the engraved north wall. My observations suggested that about four in five visitors brushed or leaned against the petroglyphs at that point, some in fact used an engraved depression as a foothold on the moist rock, despite all admonishments. Within two years of the discovery of the markings by Aslin, the moist, soft rock in this vicinity had become extensively worn by the boots of descending and ascending visitors, and it was obvious that similar wear would soon spread further. It was clearly imperative that this problem had to be eliminated effectively.

Several other factors posed minor conservation hazards, such as algae, fungi, speleofauna and livestock, but the principal threat remains that of damage by humans, and by excessive moisture in the entrance part.

3 PRESERVATION MEASURES

3.1 Development of conservation management plan

The perhaps most important rule in rock art conservation is that any measure that is adopted must be reversible. This means not just that cures such as transparent 'miracle coatings' are unacceptable, but also those alterations to the rock itself should be avoided, whenever possible: fixing holes or rock anchors for protection grilles, for instance. The destruction of archaeological deposits in the course of installing protection structures is to be rejected for the same reason. Unless there are very strong grounds to do otherwise, the micrometeorology of a site is to be maintained. In the case of a deep cave this means that closure of the entrance must never impede airflow. (Besides, the access of bats should be maintained.) Direct chemical or physical interference with the art face itself is unacceptable in nearly all cases. Most particularly, when dealing with very ancient rock art it should always be remembered that usually humans pose the only threat to such art, be the threat a direct one, or indirectly, through external environmental changes. In the case of Pleistocene art all conservation measures should be designed to merely modify environmental imbalances caused by man, any other 'conservation work' is really indefensible for art that has survived for such huge time spans. In our opinion, the environmental conditions under which the continued survival of such ancient art can be best guaranteed are those it has experienced throughout most of its existence. In the case of Australia, these existed prior to the event of European occupation, which introduced significant changes to vegetational, faunal, hydrological and micro-meteorological regimes.

3.2 Practical measures

3.2.1 Control of surface run-off

The reported effects of flash floods within Paroong Cave may not in themselves amount to a serious threat to the cave art, but they are not desirable. Furthermore, the high rate of moisture retention in the cave entrance certainly is a serious conservation problem, and it is obvious that the eucalyptus forest with undergrowth that existed prior to European settlement would have soaked up most precipitation then. Run-off into the cave entrance would have been significantly less under identical climatic conditions. In fact there may have been hardly any at all. It is therefore desirable that a substantial reduction be effected in the amount of surface water that may drain into the eastern entrance at any time. Not only would this eliminate the potential of large-scale sediment transport in the entrance region and in the Art Passage, it would probably re-establish the earlier hydrological conditions, and would conceivably result in a moderate lowering of moisture in the entrance chimney. In the absence of major run-off, externally derived water would cease to influence hydrology and moisture levels, which would then be maintained almost entirely by cave meteorology and capillary moisture. They would therefore be rendered far more stable, and would be subjected only to marginal annual variations instead of the present erratic, episodic and excessive changes, which are due to a combination of the effects of denudation and modification of the cave entrance.

Stabilisation of moisture levels in the rock and cave atmosphere would contribute significantly to the conservation of the art, quite apart from the other positive effects it would have. It is well known that fluctuating moisture levels constitute a conservation hazard not only for rock art, but are a main consideration in conservation science generally. In the case of rock, fluctuations in moisture may lead to swelling and contraction, hydration, the formation of subcutaneous salt deposits, the breakdown of crystal lattices, oxidation or reduction, the formation of corrosive weathering products which will themselves accelerate weathering, and other potentially harmful processes. Indeed, rock hydrology may be the most important single factor in rock art conservation apart from humanly induced deterioration processes.

The above considerations led to the decision that the natural catchment area of the cave entrance should be reduced by approximately 98%, from about 18 150 m^2 to about 345 m^2. This was to be achieved by constructing a shallow drainage channel and levee, to collect the run-off and redirect it into the gully that drains towards NW.

The size of the remaining catchment area, i.e. the area enclosed by the proposed drainage channel, was determined by the cave space below, and more specifically, by first projecting the plan contour of the Art Passage onto the surface. It was then assumed that lateral diffusion of water percolating through the rock would not extend significantly beyond 45º from the vertical. Since the cave's roof thickness is not substantial it was decided that the surface area from which external run-off should be excluded should be of roughly elliptical shape, measuring approximately 25 × 18 m. This was considered adequate to exclude the possibility that moisture from the drainage channel would reach the cave space below. In addition, the accumulation of water within the channel was to be prevented by providing it with a continu-ous fall over its entire length.

A 73-m-long channel was constructed mechanically (front-end loader), forming a shallow groove about 15 cm deep and a metre wide. The spoil was deposited along the channel's lower side, to form the levee (Fig. 5). To prevent erosion of this dam it was reinforced with rocks removed from the cave entrance along a critical stretch. This structure is presently up to 80 cm high, but once it settles it will project 30 to 50 cm above the adjacent channel.

Figure 5. *South-eastern section of the drainage channel constructed. The stock fence to enclose the reserve is also under construction.*

The rough ellipse formed by the channel in plan, which is open only where a natural rise prevents the ingress of surface water, drains rainwater towards its two western ends, and discharges into a natural gully. As a further control of subterranean water the landowner has planted two rows of trees around the drainage channel. These are very effective in absorbing water with their root systems. In addition, they also counter any impact aeolian erosion might have, and they provide the general locality (within a large, barren grazing paddock) with some welcome visual relief. The trees are located far enough from the Art Passage to prevent root penetration into the cave, and to prevent any of the carbon dioxide that will be produced by the micro-organisms of their root systems from reaching the Art Passage.

3.2.2 Control of interstitial/capillary moisture

To summarise some of the relevant points made in earlier chapters: within reasonable limits, interstitial moisture is essential for maintaining the mechanical strength of the highly porous limestone at Paroong Cave. There are no data to tell us what these limits might be, but it should be 'safe' to assume that the type of hydrological and microclimatic conditions that existed prior to European settlement should be the ones that are the most conducive to the continued survival of the art. Furthermore, since there is ample moisture available from the cave atmosphere, and perhaps also from capillary action, it seemed best to strive for the near-complete exclusion of external moisture sources. This should achieve a pronounced stabilisation of moisture, probably resembling the pre-European hydrology, which we know has facilitated long-term survival of the rock art. However, in the entrance shaft and the immediately adjacent western part of the Art Passage, substantial quantities of recently deposited soils resting against the art panel retained moisture throughout the year, and were capable of absorbing a large water content. Through their contact with the rock wall these soils not only maintained high moisture content in the same, they also supported a luxuriant growth of moss on the rock. Clearly the soil presented a major conservation threat, but it seemed impossible to remove it without also removing the boulders among which it was lodged. While these rocks should also be removed, being recent infill, it was far from certain that they could be dislodged without damage to the rock art that was evidently concealed by them. In fact our concern about the expected difficulties of such an operation led us to investigate alternative possibilities. One that we considered seriously was the use of a high-pressure water jet to dislodge the soil, leaving the chockstones in position. However, there were three arguments against this: (1) it could not be guaranteed that no more soil would be washed into the cave, which means that the deposit might be re-established in future years; (2) it seemed possible that some of the boulders were not actually resting against both rock faces of the shaft, which means that the washing out of the soil would cause them to drop and become truly wedged, possibly damaging concealed petroglyphs in the process; and finally, but most importantly, (3) there was another reason to remove the infill, to do with visitor access (see below). It was therefore decided to attempt complete clearance of all recent deposit in the entrance shaft.

It was quite clear that the boulders, packed tightly with soil in this narrow passage, immediately next to rock art, could not be moved by sheer muscle power. Not only was there no adequate space for this, the rock art would have fared badly. Mechanical means were to be used, and two options were considered: the construction of a frame to which a Tirfor or a block and tackle could be attached; and the use of a mobile crane. While the former would probably provide better control, the latter was preferred as being more cost-effective, efficient, and because of a crane's jibbing ability. Besides, the lifting ability of the former method is relatively limited, whereas that of the crane is only limited by its rated capacity.

Normally the removal of chockstones from a cave must be preceded by a tectonic study of the effect of such action, but in this case it was obvious that the removal of recently placed rocks could have no structurally significant effects. We still had to decide upon the precise location where the crane was to be positioned relative to the cave entrance and morphology, to ensure that there would be no danger of structurally overloading the rock. After examining the rock and considering the possible presence of concealed cave spaces we decided that the crane would be soundly positioned south of the entrance, with its rear outriggers about 6 m from the fault line, and its axis at a right angle to the same.

In planning the technique of removing the boulders wedged into the shaft we considered the possibility of drilling a hole into each above its (presumed) point of gravity, setting a rock anchor, and using this to attach the rock to the crane. However, several factors prompted us to discard this idea: it would create a slow, costly process; the rocks were water logged and fragile; the point of gravity could not be reliably determined because much of each boulder was concealed; and the method therefore offered no particular benefit.

The mobile crane was reversed into the predetermined location (to realise its full lifting capacity such a crane has to lift over its back), and hoisted hydraulically onto wooden blocks. For the lifting of the boulders, cloth-covered, flexible slings were used, to avoid any damage to rock surfaces. The removal of soil and rubble was done with a 44-gallon steel drum, which was lowered to the base of the entrance shaft where it is widest.

The larger boulders were first dislodged by attaching a sling over some protruding part, and applying force in a direction that would tend to rotate the block away from the decorated wall. A slight movement in the rock was sufficient to establish its size and approximate shape, and to insert a wooden spacer. Some blocks had to be moved several times before sufficient space became available underneath them to permit the insertion of a sling, and proper and balanced slinging. Throughout this delicate and dangerous operation there was only space for one person to work within the shaft (RB) and wooden spacers were inserted whenever the opportunity arose, to space the rock under strain from the decorated wall. Once a boulder became freely suspended it could be slowly raised, but it continued to be guided by hand until it reached the upper part of the shaft. The removed rocks were then deposited along the course of the planned drainage channel, to provide the levee with some stability against erosion.

Five major boulders were removed in this manner, the largest weighing about 750 kg, and when adequate quantities of soil and rubble became accessible, the steel drum was lowered and three workers proceeded to fill it manu-ally. The space was so restricted that tools were of limited use. Besides, their use was considered to create a danger for the petroglyphs. In all, some four to five cubic metres of soil and rock were removed. Throughout this operation, rusty bits of barbed wire, glass, bones of domestic species, pieces of wood and ceramic fragments were observed in the deposit, confirming its recent age.

When it seemed that no further petroglyphs were concealed we also began to have doubts that the remaining deposit was still part of the recent infill. Every effort had to be made to avoid removing any rock or soil that may have been deposited prior to 1850, because of the archaeological potential of such a deposit. So we decided at that stage that excavation was to be discontinued.

This operation has resulted in the clearance of most of the deposit in the entrance shaft. All of the soil that had endangered rock art has been removed, but the formerly concealed petroglyphs were left covered by a thin layer of soil. Brushing away the moist soil would have damaged them, so it was decided to let them dry out slowly, and, bearing in mind the abnormally high linear shrinkage index of this soil, it was expected that it would flake off naturally.

The removal of the soil deposit means that the source of the abnormally high interstitial moisture content has been completely eliminated. The buried petroglyphs have been exposed to the cave atmosphere (as they were until earlier on the 20th century), and the conditions of human access into Paroong Cave have been considerably improved. Not only is it now very much easier to reach the floor of the Art Passage, human traffic itself no longer poses a danger to the site's main concentration of art. Within two weeks of the removal of the soil deposit we could perceive a slight reduction in moisture, and it was expected that within one or two years interstitial moisture levels will have returned to normal, pre-1900 conditions.

Concern that dislodging of the larger boulders might cause extensive damage to both exposed and concealed petroglyphs was no doubt justified, but even in this respect the operation was a complete success. Only one of the blocks slightly bruised a small patch on the wall, but without removing any rock matter, and without damaging any petroglyphs. The subsequent installation of a steel grille ensured that large rocks could no longer be thrown into the entrance.

3.2.3 Control of biological factors

It is expected that the measures described in 3.2.1 and 3.2.2 will result in a deterioration in the living conditions of the rich moss growth in the cave entrance. In the upper part of the shaft the moss was so dry even before we commenced our work that it appeared to be dead. It was possible to remove some of this by brushing, detaching individual fronds. Upon drying out of the wall, in one or two years, we will remove all dry moss by this method, except on petroglyph motifs. Here, the damage that might be caused to the rock surface would not be acceptable. We have not yet decided how to remove moss from the art, if at all, but the method we would most likely use is the application of a weak ammonium hydroxide solution. The use of fungicides seems pointless, as this is not a question of killing the growth, but one of removing it. For the former we prefer the natural method, of withdrawing adequate life sources. The use of complex chemicals is always to be avoided.

We have already mentioned that we do not regard lichens as presenting a threat to the rock art in Paroong Cave. Algae do occur in the vicinity of the art but again we have not observed evidence of an adverse effect. Moreover, both algae and lichens would have existed there for many millennia, and could in fact have been present already before the art was produced.

Fungi are dependent on the presence of organic matter, which may of course have been present in the cave in past ages, but probably on a fairly intermittent basis, whereas much of the wood present has been thrown in as part of the attempt to close the entrance. In addition, the dense plant growth at the entrance has resulted in quantities of grass stems and seeds to be blown in. We decided to collect all the vegetable matter visible on the floor of the Art Passage and in the entrance shaft, and remove it from the cave. Furthermore, we cleared away most of the dry plant growth surrounding the entrance. These measures have dramatically reduced the material available for fungal growth and bacteria.

One old swallow nest was also removed from the wall in the Art Passage, and it showed some mould growth. It is assumed that the steel grid now in place will discourage swallows from flying into the cave, considering that even before its installation the site was not a popular one for nesting. Bats, on the other hand, are likely to negotiate the grid without difficulties. Surface wear by bats has not been identified on the rock art panels, and we have observed that bats tend to follow established 'flight corridors' (Bednarik 1991) when flying within a cave. Bats should therefore not be prevented from frequenting the site, but we have never observed any in Paroong Cave.

Larger species are of course no longer able to enter the cave, thanks to the steel grid. In particular this applies to livestock. One bovine skeleton lies at the eastern end of the Art Passage, suggesting by its location that its former owner must have entered the cave live. Cattle and sheep occasionally plunge into sinkholes in the South East, and stock fences are not always successful in preventing a thirsty animal from trying to reach the water it knows to exist in the cave. (All of these natural animal traps contain huge quantities of bone remains, often of extinct species.)

The erection of a stock fence around the entire cave complex would have been a useful conservation measure, but it had not been included in our management plan, nor would our budget have allowed such a further expenditure. The then South Australian Aboriginal Heritage Branch, Department of Environment and Planning, decided at a meeting on site to make available the necessary funding to install a fence, and authorised the land owner, John Hunt, to proceed with this work. The fence was erected concurrent with the steel grid, and completed in three days (Fig 5). It encloses both entrances of Paroong Cave, the drainage channel and levee, and the trees that are to be planted. It now forms the perimeter of the Reserve and most of the known cave passages lie below that area. The fenced-in area consists of an irregular quadrangle (Fig. 6), the four sides of which are of the following approximate dimensions: 66, 22, 64 and 37 m. A standard gate has been provided on the north-west corner, with a clear width of 244 cm. The fence is equipped with an electric wire, and it effectively excludes livestock from the protection area. This is important as the entire new catchment area draining surface run-off into the eastern entrance lies within the Reserve. It is expected that natural vegetation levels will be established within a decade.

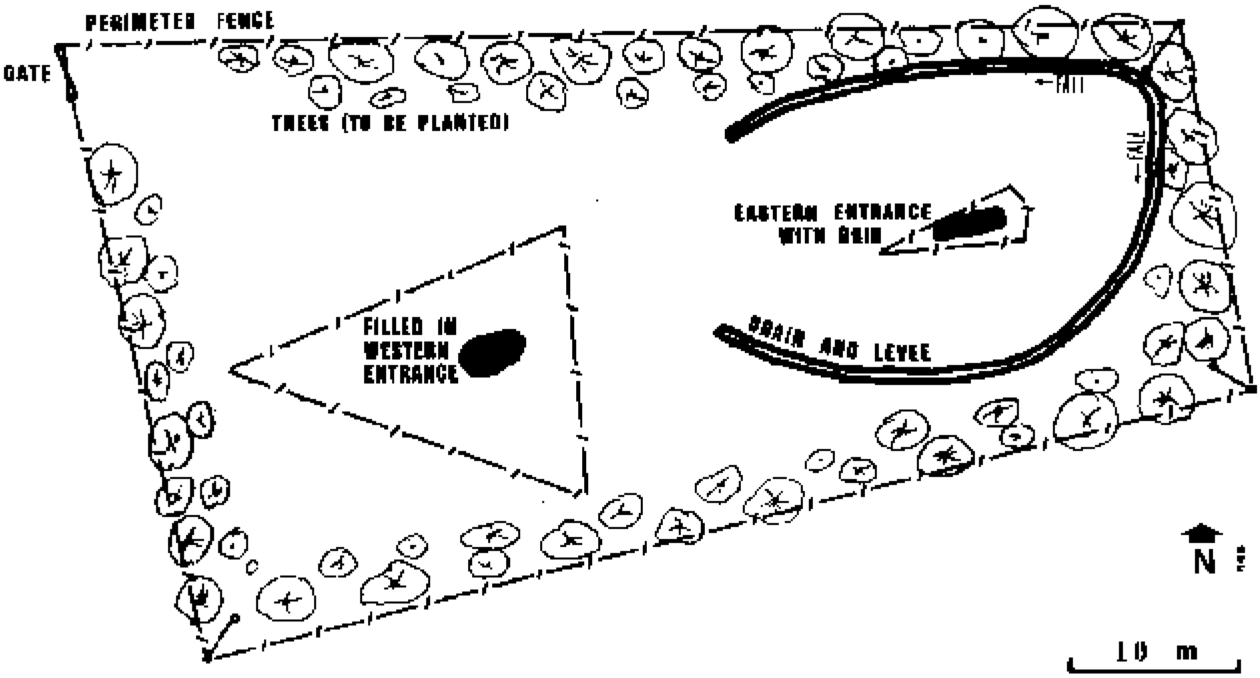

Figure 6. *Sketch plan of the reserve surrounding the two entrances of Paroong Cave.*

3.2.4 Active visitor control measures

At a site that is not permanently attended by a custodian, active visitor control can only be provided by effectively enclosing the site with a physical barrier preventing human access. In the case of a cave this means generally closure of the entrance(s).

Before effecting the closure of a cave one needs to consider several aspects. While the only objection that is being raised when a rockshelter is provided with a protective screen, is that it destroys the site's aesthetic integrity, the objections are far more severe when a cave is closed. This is because cavers and potholers consider caves as having to remain accessible them. Some cavers regard the closure of caves for archaeological or other reasons as an infringement of their rights and tend to react accordingly. While the majority of cavers are responsible people who are prepared to accept that in rare instances their right of access to a cave has to be foregone in the interest of conservation (usually of archaeological, palaeontological or rock art contents), in Europe there are those,

> akin to the clandestine diggers, who force their way into caves and do accidental or wilful damage. They refuse to be kept out, and constantly break locks or even doors in their efforts to gain entry. As soon as a door is installed at the entrance to a French decorated cave, one can confidently expect it to be broken within a couple of weeks. Many cave doors need replacing several times a year. Crowbars, cutting equipment, oxyacetylene torches and even explosives have been used by the trespassers (Bahn 1986).

Bahn then goes on to describe the kind of damage the cave art has suffered. Our own observations in French caves corroborate the picture he paints. An example is the important site of Baume Latrone, which was severely vandalised, despite being located over 200 m in from the entrance. Now there is a 75-mm thick strongroom door, located over 100 m from the entrance, which is likely to withstand even the more determined efforts of vandals. The story is very much the same at other unattended caves. In Australia this extreme stage has not yet been reached, but the S.A. Aboriginal Heritage Branch has attempted to close Koonalda Cave, yet illegal visitors still manage to gain access, with the result that the extremely fragile finger flutings continue to deteriorate at a frightening rate. Only one Australian site of cave art has been protected by effective means prior to 1988: New Guinea 2 Cave, near Buchan, has been closed by a grid of rail tracks. It is not a particularly attractive structure, but it certainly is functional.

In the case of Paroong Cave concern was already expressed about the indignant response of some cave divers to the prospect of closure. The potential for forced entry certainly exists at that site, but it is tempered by the fact that the landowner, himself conservation conscious, lives only a short distance away (just under 1 km from the cave). The proximity of his property means that potential trespassers would be unlikely to resort to one of their more determined methods. Nevertheless, the protecting structure would have to be sufficiently substantial to deter any attempt to tackle it with hand tools. Another requirement was that it had to support a substantial steel ladder permitting direct access to the floor 7 m below, and that it had to carry the weight of people who were going to walk on it. Furthermore, preference was to be given to a design that did not require any fixings into the rock, as conservation work should not effect the rock of the site, and because the structure would straddle a fault line which could be subjected to tectonic adjustment. To ensure that trespassers could not lift or displace the structure it had to be heavy enough to eliminate that possibility. And finally, to prevent it from being dragged away with a vehicle it could be built in such a manner that it would fit snug into the recesses of the uneven rock base: this 'tailor-made' aspect, together with a substantial weight, would render fixing to the rock unnecessary.

During the second half of 1987 we decided in favour of an essentially simple model, consisting of infrastructure, beams, decking and superstructures. All were to be solidly welded in situ, into a single mass of steel, with the exception of the access ladder, which was to be detachable. Constructing the grid in a single piece would satisfy the requirements for a substantial weight and ruggedness, and it would provide the possibility of lifting the entire structure with a crane, should that ever be necessary. Obviously such a custom-built structure, dimensioned to fit exactly to the shape of the cave opening and the rock contours around it, could only be constructed on site; its effectiveness would depend on its accuracy. With an anticipated weight of over one tonne the construction of it promised to be quite a challenge. Since the site is located remote from any services and sources of help it was necessary to plan every detail of the engineering workshop we had to set up in the field.

The design of the grid we proposed to build consisted of the following elements:

(1) *Infrastructure*: this part would rest immediately on the solid rock surrounding the entrance opening, and would be shaped so as to be in contact with the rock in the greatest possible number of places, to distribute the load evenly rather than cause excessive point loads to occur. Our mechanical load model required that no load be applied in the eastern or western part of the frame, i.e. above the fault line. The load had to be entirely borne by the tectonic blocks forming the fault, and no load was to be applied close to the edge of the rock to preclude the danger of shearing or spalling. We therefore decided to place two pre-shaped 100 mm pipes about 50 cm from the rock edge on either side of the entrance shaft, attempting to follow the rock contour, and then sweeping over the depression at the western end. These two load-bearing runners were to be connected by free-hanging braces at either end, still of 100 mm pipe. The entire infrastructure was to be completely sealed to prevent internal rusting.

(2) *Beams*: the infrastructure would follow the rock shape, and therefore be quite irregular. Nevertheless, it would still have an overall horizontal aspect, and using cross beams of different cross-sectional dimensions could compensate for some of the irregularity. The functions of the beams would be to provide the infrastructure with additional rigidity and bracing; to provide supports for the ladder and the entrance trap door; to provide the supports for the grid decking itself; and to contribute a large portion of the final weight of the structure. By compensating for some of the infra-structure's irregularity the beams would also have the function of facilitating the installation of the decking.

(3) *Decking*: it would form the grid that would prevent access by unauthorised persons. To ensure the required stability it should be welded solidly wherever crossing or touching other members of the structure. Any protruding lengths that could invite attempts to bend them because they are only fastened on one side were to be reinforced by suitable cross-members (Fig. 7).

(4) *Superstructures* would include the trap door and locking facilities; the sign stand and support rail leading to the door; the suspended steel ladder and its support brackets; the vertical grille extension at the western end to prevent excavation under the grid; and any members found necessary to install where openings remained.

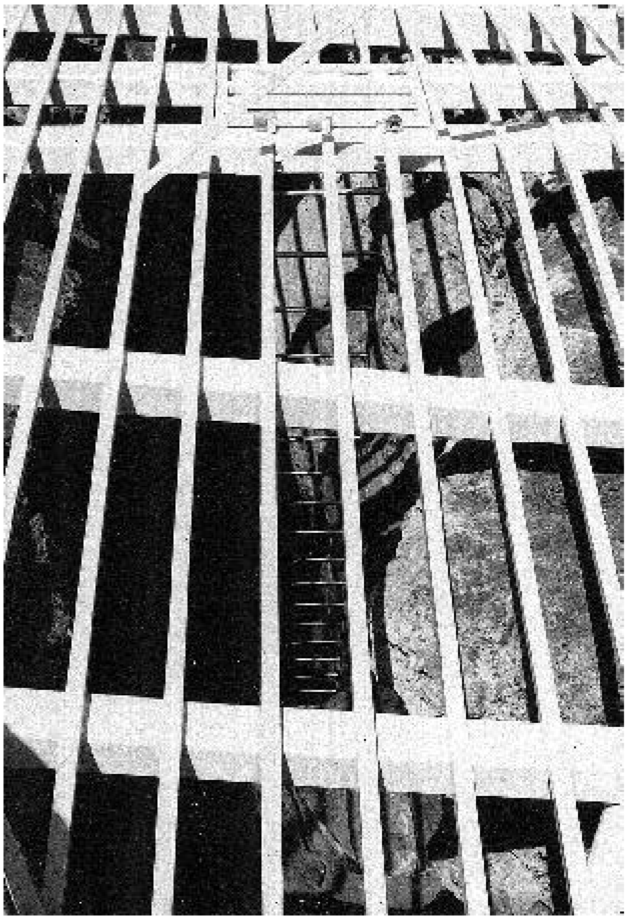

Figure 7. *Partial view of the the entrance grid, looking down the entrance shaft. The access trap door and the suspended access ladder are visible.*

The first stage of site works for the installation of the entrance grid was to expose the rock ledge around the cave entrance. It was found to be covered by rubble (dating from the partial infill earlier this century), water-transported soil and dry vegetation. The deposit was removed to form a strip 60 to 90 cm wide, over which the solid rock was fully exposed. The precise shape of the proposed structure could now be determined and a material list was drawn up. We established the necessary details, quantities and dimensions and then canvassed three commercial steel suppliers in Mount Gambier. They tendered prices and we inspected their stores to ensure that suitable materials were readily available. Upon finalisation of an order with the selected supplier the steel was transported to site by semitrailer. It was unloaded by crane and tightly stacked well above ground, as close as possible to the work site. Since it had to be stored until we finalised the construction plan and procured plant and supplies it was completely covered with protective plastic sheeting.

Once all preparations were complete and all plant was on site, the actual construction work commenced. It continued for seven days without interruption. As one of us was without help during this period, difficulties were encountered through the need to handle heavy components (of around 100 kg) and to manoeuvre them into position right above the entrance shaft. The lack of an assistant also meant that RB had to continuously be alert for any fire danger, and had to tailor the program so that most of the welding, oxyacetylene cutting and abrasive cutting could be done early or late in the day. Fire fighting equipment was stationed at the work site throughout the operations, having been provided by Mr John Hunt.

Construction of the entrance grid proceeded in four stages, according to the above-listed elements of the structure. We had hoped that the infrastructure could be shaped hot but in the absence of any assistance we had to opt for segmented (mitred) and welded bends at every change of direction, beginning with the two runners, and manufacturing them away from their final site. Upon completion they were placed correctly, and the two end braces were inserted. Next, the completed infrastructure was raised from its position for treatment with rust inhibitor and zinc-chromate primer. This painting process was complicated by the need to leave the areas untreated, where the cross beams would be attached later. Much of the upper part of the infrastructure was therefore left bare. In all, seven protective coats were applied, three of rust inhibitor and four of primer.

Upon completion of the surface treatment the infrastructure was eased into its position, and the five beams were placed on it. They had already been manufactured away from the entrance, their ends had been sealed by steel plate and they had been surface treated. As planned, the unevenness of the infrastructure was partly compensated for by the way in which the beams were placed. While this still did not succeed in providing a flat surface for the decking, it did render the unevenness manageable, and the two beams intended to support the door came to occupy the same plane, which was clearly necessary. The position of the central beam, which had to support the suspended steel ladder, was determined by the proposed position of the ladder, and it in turn determined the position of the second beam supporting the door, which had to be parallel to it.

The beams were all welded into position at high current, and welds were treated with rust inhibitor. Next the decking, consisting of 32 × 32 mm square section steel tubing, was commenced (Fig. 7). Beginning from the sides of the proposed door opening, the tubing was first tack welded into position, formed and bent into the required shape, and then each rung was welded solid on both sides at each beam it crossed. The emerging shape was that of a high part in the middle section, from which the decking sloped down towards both ends, i.e. towards east and west. The lateral spacing of all rungs is uniform, at 160 mm centres, which means that the voids are 128 mm wide over the entire grid area. It had been decided that this spacing would be a suitable compromise between providing maximum protection on the one hand, and avoiding obstruction of airflow on the other. It means that the completed entrance grid area accounts for some 23% of the effective cave opening area. (We had earlier decided that the proportion should be kept below 25%, on meteorological grounds.)

Both ends of each decking rung were closed, and sealed by welding, to prevent the ingress of air or moisture. After welding all slag was removed, the steel degreased, brushed clean, and coated with rust inhibitor. After two coats of this, two further coats of red zinc-chromate primer were applied to all surfaces above the infrastructure.

Having completed the decking the various infra-structures were added. The trap door, located immediately above the ladder, consists of a rectangular frame with two internal rungs, of 32 × 32 mm steel, hinged along one long side, with three locking provisions along the other. Two galvanised pipes, one inserted into the other, were used to manufacture the hinge, which is welded solidly over its entire length. The door opening has an effective clearance of 600 × 400 mm. To keep future visitors from guillotining their fingers, the trap door hinging was constructed in such a manner that the door will remain stationary in any position, including a near-horizontal one. Three sets of nibs for the locks were welded into position, and drilled to accept three locks.

At the southern perimeter of the grid structure, a vertical sign stand of 1.8 m height was erected, bearing a rectangular, pre-drilled steel plate. Decking rungs projecting beyond the westernmost and the easternmost beams were at that stage only supported and secured on one side. To provide them with full rigidity a cross member, also of 32 × 32 mm steel, was shaped for each end of the decking, and welded into position.

Along the northern and southern margins, the grid structure rests directly on the rock, and along the eastern side the reinforced decking approaches the rock face to within a few centimetres. But the western part of it projects over the upper part of the recent deposit, and could be tunnelled under by people attempting to force their way in. Prepainted stakes were driven into the soil vertically with a sledgehammer until they would go no further, along the reinforcing member aligning the decking in that area. They were then cut off level with the decking, sealed, and welded solid. To reinforce the vertical grille so formed a horizontal member was attached to it, about 30 cm below the level of the decking, and also sealed at both ends. A diagonal bracket then closed one remaining small opening near the eastern end of this grille.

While the rest of the steel structure was to be corrosion protected by painting, the ladder, which would be subjected to much more frequent wear from visitors, was protected by hot dip galvanising. The 7-m-long steel ladder had been manufactured from two flat bars, and rungs of 16 mm diameter solid round steel. The bars were drilled, rungs were inserted, and secured by welding. The finished item was galvanised. Just west of the door opening, two substantial angle brackets were welded to the side of the central beam. To permit later withdrawal of the ladder, three of the decking rails had been stopped short of the beam, and raised above it (or rather, not bent into the shape of the other rails). They had been secured via a cross-member to the two adjacent rungs on either side. The ladder could now be inserted through this opening, between the two support brackets. Its precise positioning had been determined earlier, and upon insertion into its place four fixing holes of 20 mm diameter were cut through the support brackets. The suspended ladder was then tightly secured.

The 30-cm-wide access ladder is so positioned that it can be comfortably reached through the door opening, and it descends at an angle allowing easy descent and ascent (about 15 degrees from the vertical; see Fig. 8). It is rigid enough to carry 3 or 4 persons easily.

Figure 8. *The access ladder in the cleared part of the entrance shaft. Prior to the project visitors had to climb past the petroglyph panel on the right to reach the floor of the cave.*

Upon completing the priming of the entire entrance grid structure, it was painted with one coat of enamel. Its colour was selected to blend in with the light khaki of the dry grass. It was decided not to apply a second coat of finishing paint, but to permit the first one to weather for one or two years, and to repaint the structure then.

The completed entrance grid at Paroong Cave is 6.02 m long and 2.44 m wide. It has an overall height of nearly 9 m, including the access ladder, and weighs approximately 1070 kg.

3.2.5 Passive visitor control

The research of Professor Gale and others has demonstrated that passive control of visitors while they inspect a site can be very effective, and passive visitor control planning formed part of this preservation project. While active visitor control has secured the complete exclusion of uncontrolled visitation from the site, a limited number of visitors would still be entering the cave, and it seemed important to design measures to control their conduct.

Passive visitor control can be achieved by such means as low barriers, defined paths or board walks, thorny or prickly bushes, in fact any type of strategically placed vegetation, or by the placement of ropes or other types of 'token' divisions. In general, passive visitor control measures are far less obtrusive than all active control measures. The latter, after all, include such conspicuous barriers as transparent screens (as in Font de Gaume, France) or complete cages over the art (at many Spanish and Australian sites, for instance), while the former are often barely noticeable, if at all, because they function primarily at the psychological level. Weldmesh and other grilles at rockshelter sites have often been condemned as being unsightly or as having an adverse impact on a site's aesthetic integrity. It is also true, however, that no 'person or agency would want to be responsible for removing the grilles and installing barriers which may be less obtrusive but not entirely foolproof' (Gale and Jacobs 1987: 74). The entrance grid at Paroong Cave has no real effect on the aesthetics of the Art Passage. Only a very small part of the art is visible from the grid. It does of course not protect the art from the visitor who has gained access, and different measures had to be adopted here.

It was assumed that, as a result of limiting any future visitation to those people who would have a genuine interest in the art, there would be no need to provide any active visitor control measures other than the entrance grid. Since it had also been decided that all future visitors would be supervised (refer 3.2.6) there would be no threat of wilful damage. The knowledge of visitors that they are being closely monitored would be adequate protection for the art. Therefore only one source of possible physical danger remained: involuntary damage, by accidental contact or through negligence.

The removal of boulders had achieved a substantial change in the lower part of the entrance shaft. The section of the petroglyph panel on the north wall that had previously been subjected to wear from the boots of visitors was now 1.5 m above the floor of the passage, almost out of the reach of the visitor. Whereas the visitor had previously entered the cave by climbing down over a steep and slippery boulder slope, past dense concentrations of petroglyphs, barely able to avoid brushing against engravings, often slipping and seeking support on the decorated wall, and generally making his way the best he could, he was now confined to the access ladder. He could neither step onto the rock ledge forming the entrance, nor enter the unstable slope, or reach most of the wall area forming the entrance shaft. The formerly threatened petroglyph motifs could now only be reached with difficulty (Fig. 8). While descending the ladder, one's path of motion is totally controlled. Upon reaching the floor of the cave the visitor would tend to seek support on the two walls, so it was important to level the floor for the next few metres. Sediment removed to locate the ladder was used to fill in uneven parts of the floor, forming a gentle slope.

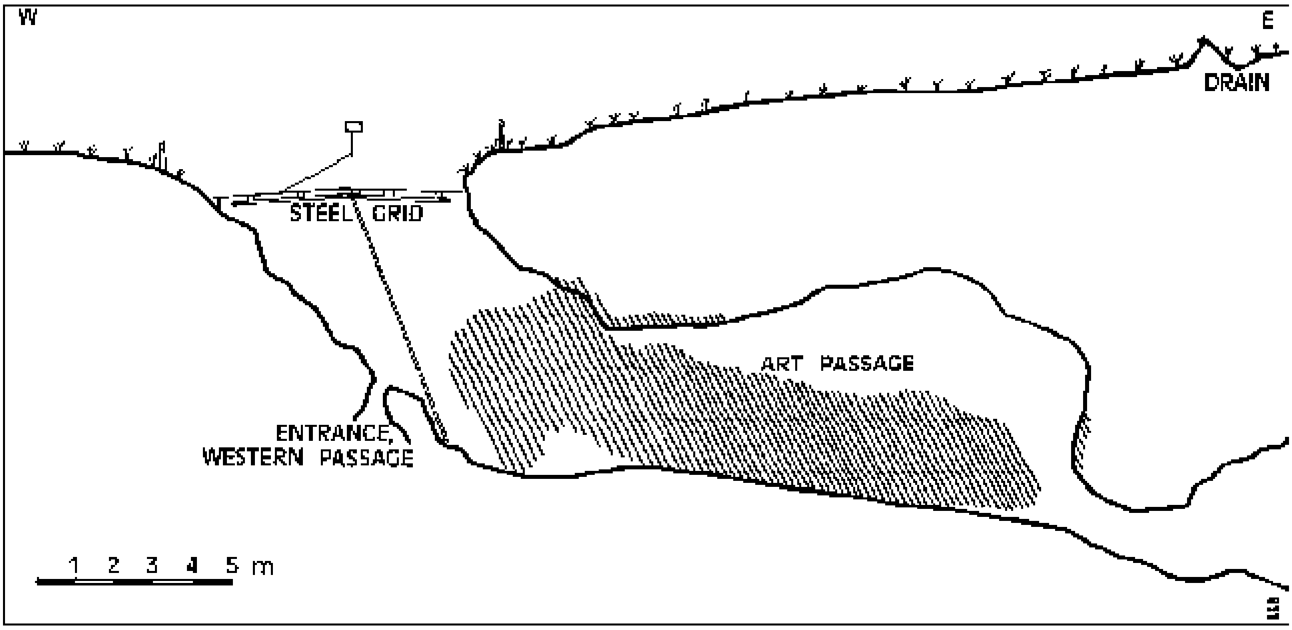

***Figure 9.** West-east section of the Art Passage, looking north. The extent of petroglyphs is indicated by hatching. While in this illustration the entrance appears to be spacious, this effect is due to the direction of the section, which follows the fault line. The cleft is in fact under 1 m wide in parts. The western passage is not shown.*

Several measures were employed to urge the visitor away from the wall in the still comparatively narrow western part of the Art Passage. A soil embankment resting against the north wall, a remnant of an earlier floor deposit, was left untouched, and nearby, the floor was so shaped that a slight rise towards the decorated wall tends to 'force' the visitor away from it. Further on in the Art Passage, flash floods had formed channels along both walls, and these were cleared and emphasised, inviting the visitor to prefer the raised central part of the floor—again tending to encourage him to keep clear of the walls. Depressions in the preferred path were filled with soil and rocks, not only to prevent the visitor from stumbling, but also because we believe that the cave visitor generally prefers to follow a path he subconsciously perceives as the safest and least arduous. It is therefore quite possible to 'goad' him into following a preferred path, if necessary by placing obstacles of 'natural' appearance (jagged rocks, depressions etc.) in areas not to be entered. This is an effective form of passive visitor control and can also be considered at rock art sites other than caves, although it would be far less effective in full daylight. But there, the strategic positioning of a thorn bush or, in the Americas, a cactus or poison oak, can effect miracles in the service of rock art conservation, without affecting aesthetics.

3.2.6 Monitoring of visitors

Sullivan (1984) has considered the advantages of visitors' books at rock art sites. Such books may provide information about visitor population and response, and may contribute to site preservation. Unfortunately the information they provide will always remain selective, as we have observed in Europe and the United States. In the case of a site with controlled access introducing a compulsory record of visits can easily rectify this. The use of a visitor form has the added benefit of being a potential means of impressing upon the visitor the need for strict conservation measures, and of conveying the rules of conduct governing the visit. The data from such forms would provide reliable statistical information.

We therefore resolved to design a suitable form, produce it, distribute and collate the sheets and to utilise their statistical potential for future conservation/preservation designs. In this manner, all future visitors of the site will be monitored on paper. The second aspect of monitoring them concerns their control and supervision at the site.

No category of visitors is categorically excluded. Cave divers are welcome to apply for access, they will observe the same rules as other visitors, and they will need to guarantee that their diving equipment will not be handled close to decorated areas. Other rules are the complete banning of smoking, and the banning of combustion engines (e.g. those of generators), in the cave as well as within the carbon dioxide catchment area surrounding the cave entrance. No fires are to be lit within the entire protected zone (within the stock fence), and vehicles are restricted to the area immediately inside the gate. No organic matter (other than clothing) is to be taken into the cave, and no rock wall is to be touched at any time. Groups permitted to enter the cave are restricted to no more than five people, excluding the wardens, and children must be strictly supervised. The duration of visits is to be kept to a minimum, and after each visit the cave atmosphere must be given time to recover.

6. SUMMARY AND RESULTS

The purposes of the Paroong Cave Preservation Project were essentially to alleviate conservation hazards that had been introduced by the European occupation of the district, to halt the deterioration they were causing to the cave art, and to effect measures of active and passive visitor control. To achieve these ends a number of basic guidelines or ground rules had to be observed: no structural changes to the cave, nor any modifications of the rock mass, were to be undertaken; all adopted measures had to be fully reversible; costs were to be kept within the limited funding available for materials; the results of the project had to be monitored in the long term; and preference was to be given to conservation measures that would control the environment by indirect or natural means rather than by calculated direct intervention. Each measure adopted had to be carefully considered before implementation, and its effects, or potential effects, on other measures forming part of the program had to be assessed. Preservation measures had to be compatible with the landowner's perceived management plan, and in addition had to have the approval of the Aboriginal Heritage Conservation Branch. They had to be within the capability of a very small work crew, and they had to be conducted without the danger of accident. Furthermore, the design of the program had to be based on scientific, quantitative assessment of any crucial factors, not on mere opinion or guesswork.

The Paroong Cave Preservation Project has met all of these conditions. To begin with, it was based on long-term observation, analytical work, and extensive experience both abroad and in the limestone region of Mt Gambier. The final site management plan was designed by carefully reviewing the various options, and how they could be integrated into a realistic, economic whole. While all adopted preservation measures are fully reversible we consider it extremely unlikely that the need to reverse any will arise. No alterations to the rock structures and surfaces were undertaken, nor was the rock art in any way interfered with, and only natural and subtle means of restoring the environment were employed. All work was conducted in full consultation with the landowner, and the protection proposal had the approval of the appropriate government agency. Our planned monitoring program will ensure that there will be the kind of feedback of information that is so much needed from projects of this type, not only to observe the effects of preservation measures in the long term, but also to facilitate the planning of future projects. Finally the project costs were kept within the budget available, although it must be emphasised that the actual cost of the Paroong Cave project exceeds the grant provided by far. If the project had been budgeted on the basis of all associated costs, including a paid work force, costs of research, planning and monitoring, a vastly greater grant would have been required (about $30 000, of which the AIAS grant accounts for 14%). Therefore this project demonstrates forcefully the benefits to be gained from accommodating conservation work within the framework of some existing major project, particularly if the same is privately funded. Perhaps the most important lesson to be gained from this project is that, in future, applications for rock art protection funding that contain budget components relating to surveying fees, architect fees, various other consulting fees and such items, perhaps ought to be reviewed more critically. Funding available for rock art conservation is very limited, and every effort must be made to stretch them as far as possible. One way to do this is to favour projects for which the scientific and other support work can be funded from alternative sources.

The principal conservation problem at Paroong Cave had been created by the placement of boulders in the entrance shaft earlier this century, because this had permitted the establishment of a deposit of soil. Through its outstanding moisture retention ability, the soil maintained a high level of interstitial moisture in the petroglyph-bearing wall it covered, which had become so soft that it was being worn rapidly by visitor traffic. Rock art elsewhere in the cave, while not at such an immediate risk, was subject to slow deterioration from various agents, especially moisture, plant growth and visitors, all of whom caused both physical and chemical breakdown of the porous limestone into which the petroglyphs had been carved.

Of the various preservation measures forming part of this project, the most important were:

The modification of the hydrological regime to re-establish conditions resembling those of the pre-European period, through reducing the surface run-off into the entrance, and through removing the moist soil deposit in the entrance.

Modification of access through the entrance shaft, to keep visitors away from the petroglyphs, by removing the boulders; and determining a visitor's path.

The effective control of visitation, through the installation of an entrance grid, and the introduction of a visitor monitoring system.

The removal of the recent deposit in the entrance shaft has resulted in a major spatial change, which is clearly visible in Figure : the concealed rock art has been exposed, allowing it to desiccate, and the access ladder has been positioned well clear of the rock art. This separation of the visitor from the art is particularly well illustrated in Figure 8: the petroglyphs on the right are over a metre from the ladder. Externally, changes are more subtle, but no less effective. The entrance grid is not very obtrusive, being well below the surrounding ground level, except for the sign. Its colour blends in well with its surroundings.

It may seem premature to discuss the effectiveness of the measures, but there are some observations that can be safely made. Visitor control at this site should be most effective, and for most of the art there is no longer any danger of contact with visitors. We can therefore reasonably expect that there will be no further deterioration through them. Furthermore, the hydrology has certainly been influenced profoundly, and the predicted effect is a fairly rapid return to pre-1850 hydrology and micrometeorology. These factors alone should have a dramatic effect on the art's survival chances. As a result of this preservation project, the priceless petroglyphs can confidently look forward to the next millennium: their perpetual survival seems assured. We therefore contend that the Paroong Cave Preservation Project has been a complete success.

7. ACKNOWLEDGMENTS

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We also express our gratitude to Mr John Hunt, on whose land Paroong Cave is located. His enthusiastic co-operation and interest were crucial to the project's success. Mr Geoffrey Aslin, who also has a very personal interest in this site, has expressed this by participating in the project, for which we thank him sincerely. The co-operation and encouragement of Mr Ross Muegge are also gratefully acknowledged.

9. REFERENCES

ASLIN, G. D. and R. G. BEDNARIK 1984a. Karlie-ngoinpool Cave: a preliminary report. *Rock Art Research* 1: 36-45.

ASLIN, G. D. and R. G. BEDNARIK 1984b. Karake Cave - a preliminary report. *The Artefact* 8: 33-5.

ASLIN, G. D., E. K. BEDNARIK and R. G. BEDNARIK 1985. The 'Parietal Markings Project' - a progress report. *Rock Art Research* 2: 7 1-4.

BACHOFEN-ECHT, A. 1931. Fährten und andere Lebensspuren. In 0. Abel and G. Kyrle (eds), *Die Drachenhöhle bei Mixnitz*. Speläologische Monographien, Volumes 7-9, Vienna.

BAHN, P. G. 1986. Comment on Dragovich 1986. *Rock Art Research* 3: 144-6.

BEDNARIK, R. G. 1979. The potential of rock patination analysis in Australian archaeology - part 1. *The Artefact* 4: 14-38.

BEDNARIK, R. G. 1980. The potential of rock patination analysis in Australian archaeology - part 2. *The Artefact* 5: 47-77.

BEDNARIK, R. G. 1987. The cave art of Western Australia. *The Artefact* 12: 1-16.

BEDNARIK, R. G. 1988a. The cave art of Australia. *American Indian Rock Art*, Vol. XII, ed. H. Crotty. Proceedings of the 1985 ARARA Symposium in Santa Barbara.

BEDNARIK, R. G. 1988b. No pictograph at end of Rochester Creek rainbow. *La Pintura* 14(2+3): 14-17.

BEDNARIK, R. G. 1991. On natural cave markings. *Helictite* 29(2): 27-41.

BEDNARIK, R. G. 1993. Wall markings of the cave bear. *Studies in Speleology* 9: 51-70.

BEDNARIK, R. G. 1994. Malangine and Koongine Caves, South Australia. *The Artefact* 17: 43-60.

BEDNARIK, R. G. 1994. The discrimination of rock markings. *Rock Art Research* 11(1): 23-44.

BEDNARIK, R. G. 1998. Direct dating results from Australian cave petroglyphs. *Geoarchaeology* 13(4): 411-8.

BEDNARIK, R. G. 2001. *Rock art science: the scientific study of palaeoart*. Brepols, Turnhout, Belgium.

BEDNARIK, R. G. and E. K. BEDNARIK 1982. The Parietal Markings Project. *Bulletin of the Archaeological and Anthropological Society of Victoria* 3: 3-4.

BRUNET, J., P. VIDAL and J. VOUVE, n.d. Conservation of Rock Art. Volume 7 of Studies and Documents on Cultural Heritage. Unesco.

DRAGOVICH, D. 1986. A plague of locusts, or manna from heaven? *Rock Art Research* 3: 141-58.

EMERY, K. O. 1944. Brush fires and rock exfoliation. *American Journal of Science* 242: 506–8.

FERNANDEZ, P. L. 1986. Natural ventilation of the paintings room in the Altamira cave. *Nature* 321: 586–8.

FREEMAN, P. 1987. The psychology of aggression as it relates to rock art vandalism. Paper presented at the ARARA Symposium in St George, Utah.

GALE, F. 1985. Monitoring visitor behaviour at rock art sites. *Rock Art Research* 2: 112–8.

GALE, F. and J. JACOBS 1986. Identifying high-risk visitors at Aboriginal art sites in Australia. *Rock Art Research* 3: 3-19.

GALE, F. and J. M. JACOBS 1987. *Tourists and the National Estate*. Australian Heritage Publication Series No. 6, Canberra.

GALLUS, A. 1968. Parietal art in Koonalda Cave, Nullarbor Plain, South Australia. *Hellctite* 6: 43—9.

HOLMES, J. W. and J. D. WATERHOUSE 1983. Hydrology. In M. J. Tyler et al. (eds), *Natural History of the South East*. Royal Society of South Australia Inc.

HOOPER, J. H. D. 1958. Bat erosion as a factor in cave formation. *Nature* 182: 1464.

JENNINGS, J. N. 1963. Some geomorphological problems of the Nullarbor Plain. *Transactions of the Royal Society of South Australia* 87: 41-62.

KING, D. 1950. Geological notes on the Nullarbor cavernous limestone. *Transactions of the Royal Society of South Australia* 73: 5 2-8.

KING-WEBSTER, W. A. and J. S. KING 1958. Bat erosion as a factor in cave formation. *Nature* 181: 1813.

LAUDERMILK, J. D. and T. G. KENNARD 1938. Concerning lightning spalling. *American Journal of Science* 25: 104-22.

NOBBS, M. F. and R. I. DORN 1988. Age determinations for rock varnish formation within petroglyphs: cation-ratio dating of 24 motifs from the Olary region, South Australia. *Rock Art Research* 5: 108-46.

ROSENFELD, A. 1985. *Rock art conservation in Australia*. Australian Heritage Publication Series No. 2, Canberra.

SCHMID, E. 1958. *Höhlenforschung und Sedimentanalyse*. Basle.

SCHWARTZBAUM, P. M. 1985. The role of conservation techniques in rock art preservation. *Rock Art Research* 2: 65-70.

SMITH, C. 1880. *Booandik tribe*. E. Spiller, Adelaide.

STEINBRING, J. 1987. Rock art site classification. *La Pintura* 14(1): 8-9.

SULLIVAN, K. 1984. Monitoring visitor use and site management at three art sites: an experiment with visitor books. In H. Sullivan (ed.), *Visitors to Aboriginal sites: access, control and management.* ANPWS Canberra.

TRICART, J. 1969. *Geomorphology in cold environments*. London.

TINDALE, N. B. 1974. *Aboriginal tribes of Australia*. Australian National University Press, Canberra.

WITTER, D. 1977. The archaeology of the Discovery Bay area, Victoria. In P. J. F. Coutts and R. A. Brooks (eds), *A collection of papers presented to ANZAAS 1977*. Memoirs of the Victorian Archaeological Survey 2.

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