The following annotated text is an extract from the paper entitled ‘Finger lines, their medium and their dating’, written in 1980 and slightly modified in 1981. The paper is in the AURA Archive, a repository of thousands of rock art publications and recordings. It is of historical significance in the sense that it contains the first mention of ‘direct dating of rock art’, defining this as an alternative to the methodology traditionally applied by archaeology. As a result of archaeological opposition to the introduction of such scientific methods this paper was never published, but its rejection led to the establishment of the independent Australian Rock Art Research Association in 1983, and of the International Federation of Rock Art Organisations in 1988. In the late 1990s, similar archaeological opposition to scientific dating of rock art in Portugal caused the destruction of the credibility of state archaeology in that country. This paper therefore foreshadows the major developments in rock art dating over the following decades. It is presented here unedited and unchanged, primarily for its historical interest to the field of rock art dating.

THE INTRODUCTION OF DIRECT ROCK ART DATING IN 1980

Robert G. Bednarik

Past attempts at dating Australian rock art

The question of the age of rock art is one of the queries most commonly directed at archaeologists, and it is also one of the most agonising. At present there is no method for directly dating isolated examples of rock art. In Australia, no rock paintings or petroglyphs have been firmly dated; in fact, there are very few whose age has been determined with even remote credibility. In Europe, there is a clear association of petroglyphs with occupational floor deposits in only a few cases (Bednarik 1979: 14) whilst the bulk of parietal art is only dated by such criteria as style, method, and the presence of occupation debris in the vicinity.

Since G. Belzoni (1820: 360–1) first considered the possibility of determining the ages of petroglyphs from their varying degrees of patination, many methods have been brought to this task. The most successful attempts at establishing chronological frameworks for regional sequences of rock art have been made by E. Anati (1960; 1961; 1963; 1968; 1975; 1981; and numerous others). He subjected rich regional sequences from the Val Camonica (Italy), the Negev Desert and central Arabia [1], to intensive investigation of such factors as superimposition, method of execution, patination, style, motifs or identifiable and illustrated objects, and written characters (from proto-historic and historic periods).

The abundance of rock art in the Val Camonica is rivalled by that in some Australian regions, notably in the Pilbara (Worms 1954; Wright 1968; Bednarik 1973, 1977; Virili 1977; Crawford 1964) and in northern Queensland (Trezise 1971; Rosenfeld, et al. 1981). But ‘stylistic’ sequences with clues for dating are almost completely lacking in Australia. Generally, only *minimum* ages have been proposed for non-portable Australian art, as deduced from the stratigraphical context of detached rock fragments found at excavated sites, or from dated sediment layers which conceal petroglyphs. These will be discussed below.

The only attempts of delimiting a *maximum* age of Australian rock art of which I am aware are by M. J. Morwood (1981) for Ken’s Cave, and by J. M. Beaton and G. L. Walsh (1977) for Cathedral Cave (both sites are in Queensland). Beaton and Walsh have ‘strong stratigraphic reasons to believe’ that the paintings at Cathedral Cave are ‘no older than the date for the bottom of the latest occupation level’, but they omit to mention these (Beaton and Walsh 1977: 47). However, one can dispute Morwood’s interpretation of his sediment section at Ken’s Cave (Morwood 1981: Fig. 7). His illustration shows the engraved boulder resting on Layer 1 (this relationship has been confirmed by Morwood, pers. comm.), which is overlain by Layer 2a, apparently consisting of later infill material. I am unable to see on what basis we should assume the rock-fall to postdate ANU-2118, which came from Layer 2a, and Morwood has offered no explanation for this discrepancy (pers. comm.). The age of ANU-2118 is not a maximum age for the deposition of the boulder; it in fact represents a minimum antiquity for this event. The nearest radiocarbon sample, ANU-1853, does predate the rock-fall, and could thus provide a *terminus ante quem* date for the rock art, provided we accept Morwood’s view that the boulder was not engraved before it came to rest in its present position. Since his paper contains numerous technical errors or shortcomings, particularly on sedimentary matters it may be judicious at this stage to consider the evidence for rock art dating at Ken’s Cave as inconclusive.[2]

Minimum ages have been ascribed to the petroglyphs of several Australian sites, on the basis of marked rock fragments that later became detached and buried by the floor sediments. It has been stressed elsewhere that the minimum ages derived from charcoal associated with the buried rock fragments are of limited utility (Edwards 1971: 363; Bednarik 1979: 30), because they merely record the time when the clast became dislodged, even though the petroglyphs themselves may have been executed eons earlier. This remark is strengthened when one considers that petroglyphs would more than likely not be fashioned on an already disintegrating rock surface. Such minimum ages have been provided by the fallen slab at Devon Downs (Hale and Tindale 1930: 208–11), the several engraved fragments from Ingaladdi (Mulvaney 1975: 184–9), a piece of sandstone possibly bearing an artefactual design from a layer of core and thick flake implements near Santa Teresa Mission (Stockton 1971: 57–8), and a supposedly incised limestone slab from Koonalda Cave (which is probably not an artefact).

A novel method of dating rock art advanced by N. W. G. Macintosh (1965: 93–4) attempts to correlate, via colour, paintings at the Mt Manning Shelter with ochre fragments from stratified and dated occupation floors. However, this method is unlikely to produce adequate evidence; both the hue and the chroma of ochre are functions not only of its redox state, but also of its capillary and adsorbed water content, and no judicious investigator would propose that this had remained identical in the two samples compared (one having been subjected to a subterranean environment, the other to an atmospheric one). At the Mt Manning Shelter, the colour of the lower of the two ochre strata (apparently haematitic sandstone detritus) could, for instance have been significantly affected by a reduction of ferric matter from a lack of aeration. A painting’s pigment, by contrast, may have undergone such processes as oxidation, an admixture of fixatives, or even have been treated by fire, which would modify the hydrous iron oxides and convert some of the iron to the lower valence. These theoretical considerations find support in the findings of Morwood (1981: 22), who detected no correspondence between the excavated pigments and the colours of the rock art. At Turtle Rock, he found that the distribution of pigment fragments does not reflect the sequential colour pattern discerned for the rock art of the region.

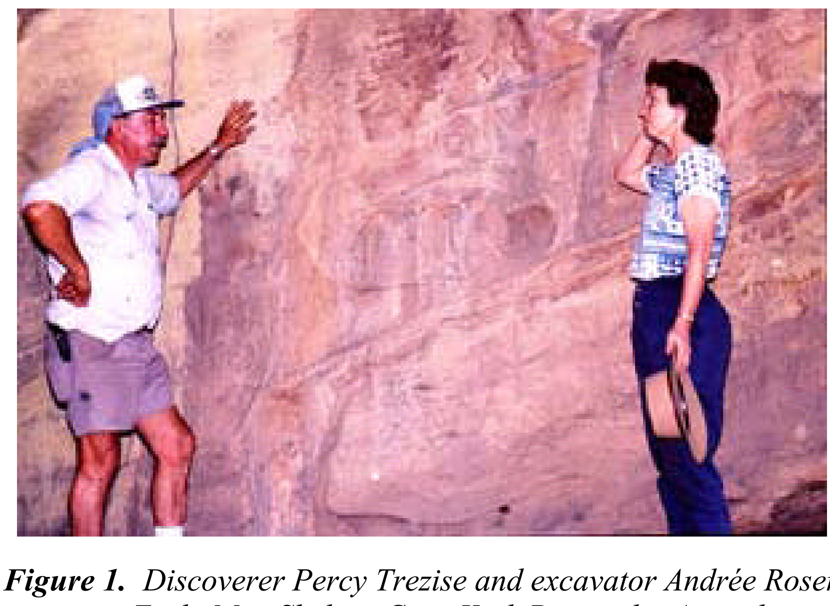

Figure 1. *Discoverer Percy Trezise and excavator Andrée Rosenfeld at Early Man Shelter, Cape York Peninsula, Australia.*

The most impressive Australian evidence for rock art chronology that has so far been produced is from the Early Man Shelter (Rosenfeld 1975; Clouten 1977; Rosenfeld et al. 1981). Assisted by a well-defined stratigraphy and an apparently very consistent rate of sedimentation, Rosenfeld has been able to assemble a chronological framework and relate it to aspects of the art sequence. Most importantly, a substantial frieze of petroglyphs extending virtually to the base of the sediment deposit was uncovered by the excavation. The strata covering the lowest peckings yielded several fairly consistent radiocarbon dates suggesting an antiquity of at least 15 000 years for the petroglyphs, although Rosenfeld et al. (1981: 30) only propose a minimum age of about 13 000 years—apparently cautious not to rely on the very small sample ANU-1567.

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[1] Actually, Anati never studied the rock art of Arabia first hand, his comments about its chronology were made purely on the basis of other people’s photographs.

[2] In fact the dating argument presented by Morwood is fallacious.

Mere association through stratigraphical context is not an entirely satisfactory basis for rock art dating, because it involves the assumption that every link in a chain of deductions is reliable[3]. An element of uncertainty will always accompany the results of these attempts.

Direct rock art dating

Heedful of the uncertainties of dating rock art by its associations alone, I have long considered the possibility of alternative dating approaches[4]. Short of extraordinarily fortunate circumstances (e.g., the discovery of a 'reduced scale pattern' from which the rock art was clearly copied), the most reliable means for determining the antiquity of rock art remains the investigation of features related to the art itself, which either date it (e.g. paint residue), predate it (e.g. the rock art's medium, or the particular surface it was executed on), or postdate it (e.g. later cracks dissecting a motif, or precipitates deposited over the rock art)[5].

I have suggested (Bednarik 1979) a method combining patina analysis with a sequencing of insolation fractures as having potential; the latter are very common in regions of north-western Australia which also abounds in outstanding petroglyph galleries (Bednarik 1977). Unfortunately, this method would be extremely laborious and has little chance of success. Rock patination by itself is an unreliable indicator of antiquity, and whilst one can readily accept that patina formed within an engraved or pounded groove is younger than the petroglyph, there are several difficulties in evaluating this fresh patina. For instance, does the adjacent, unmarked patina skin influence the rate of patina reformation within the groove? Climatic factors and pH have considerable influence and can accelerate, delay or completely inhibit patina formation (Bednarik 1979: 29–30).

However, fractures and patination are not the only things found in a direct chronological relationship with rock art. In Canada, a method has been investigated for dating which seeks to determine the rate of lichen growth, and to estimate from the size of a lichen thallus a *terminus ante* date after which a petroglyph could not have been executed (Dewdney 1970: 24). But owing to the many known and unknown variables, lichenometry offers at best limited hope. The microscopic carbonate laminae Canadian researchers have found within haematite pigment (Myers and Taylor 1974; Taylor et al. 1974; Wainwright and Taylor 1978) is capable of providing convincing minimum dates, but the severe restrictions on sample sizes prevent dating with the apparatus currently available. Another possibility is to establish the relative chronology of generations of pictograph painted on the same surface by the microscopic study of cross-sections (Wainwright, pers. comm.). Australian rock art is occasionally found covered with a skin of silica and J. M. Flood (1981: 65) suggests that a method to determine the age of such a skin be sought.

Perhaps potentially the most convincing dated sequence of dates for rock art may be from a site where generations of petroglyphs or paintings occur between laminae of reprecipitated carbonate which were superimposed, the more recent over the earlier layers. Not only would the 'stratigraphical relationship' of the artefacts (in the sense of Anati 1961) be a physical, indisputable stratigraphy of rock art, but the intervening carbonates are datable by several absolute and relative dating methods. Let me give examples. If a 'generation' of markings lies chronologically between the dates of the two contiguous travertine laminae (secured either via radiocarbon, or uranium-thorium), one above and one below, it can hopefully be allied to a specific occupation layer in the cave—which can be dated, for example, via its charcoal. Secondly, if fragments of the travertine happen to have fallen from the ceiling, they will also be stratified within the sediments. Furthermore, the climatic oscillations responsible for the speleothem formations may even be perceivable in the sedimentary record. And, finally, if the speleothem sequence also includes some organic deposit, an absolute date can be secured for it. Thus, this comprehensive framework of interrelated features may produce a securely dated artistic sequence.

Dating the rock art in Malangine Cave

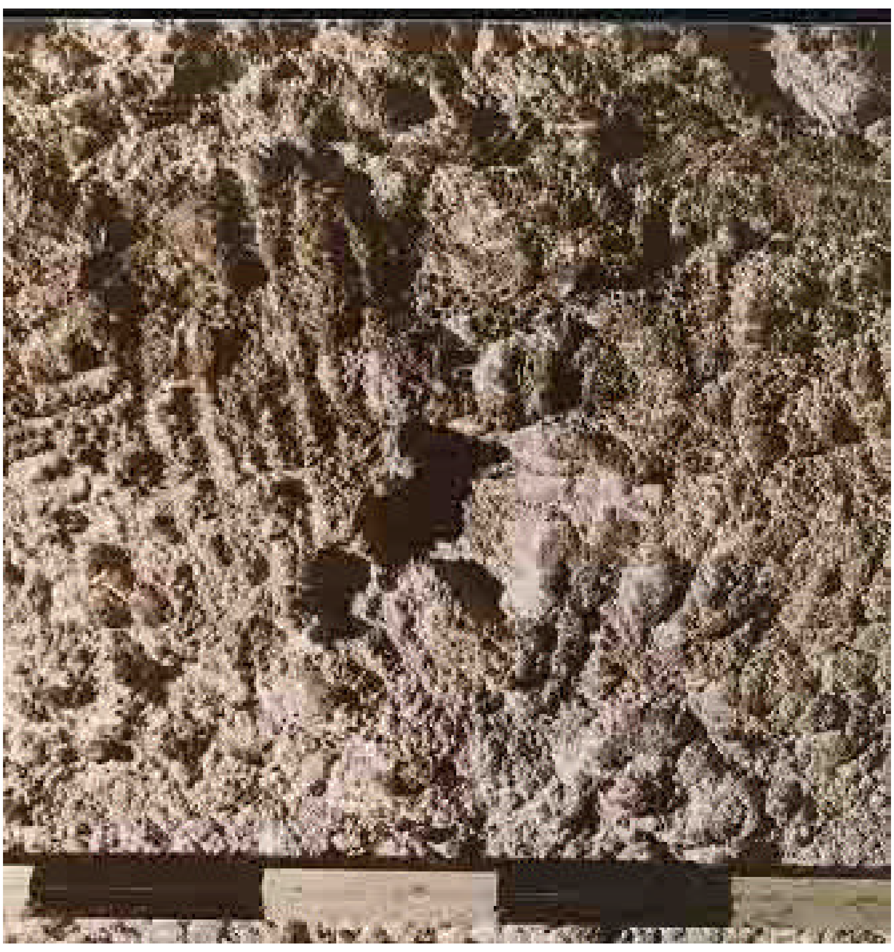

Figure 2. *Deeply carved CLM in Malangine Cave, Group 3, showing its sequential position relative to the here heavily masked finger flutings. Photograph taken in 1980, scale in dm.*

A site possessing all the above ideal characteristics is Malangine Cave, the rock art sequence at which I re-discovered in 1980. The art series commences with *Montmilch* finger fluting, followed by deeply carved figures of apparently noniconic motifs. In the southern part of the cave, the latter motifs precede the main travertine deposit, itself bearing line figures which were executed shortly before the deposit matured. Digital fluting occurs mostly only in the deeper parts of both this cave, and nearby Koongine Cave, but fortunately there are some instances of superimposition by later artefacts. The solitary trident in Malangine Cave's Group 3 [6] cuts through five finger lines, completely truncating most of them (Figure 2). It was sculptured in by then comparatively hard rock. One part is carefully scooped out, and fine lines at the base of the groove indicate the effort required to execute this particularly deep figure. Only minor subsequent travertine formation has occurred in the engraving.

By contrast, the preceding finger fluting[7] requires a soft *Montmilch* which was of a clayey consistency at the time of its execution, but which is now adorned with a luxuriant 'pearly' travertine. The patina colour of the two petroglyph generations also varies, although the difference can probably be attributed to the inability, in general, of higher ceiling recesses to attract patination matter. The discolouration may, in fact, postdate all the art forms at this site.

Identification of the digital fluting as the oldest petroglyph element at Malangine and Koongine Caves—although adequately resolved by the stratigrapby of travertine laminae—is further demonstrated by the lack of finger lines on the surfaces exposed by the ceiling collapse in Koongine Cave, despite the adjacent ceilings being extensively decorated. The younger surfaces seem to be free of secondary limestone deposits and have not been enveloped in *Montmilch*. The rock-fall, therefore, appears to provide a convenient *terminus ante quem* for the finger flutings in Koongine Cave. The moisture retreat postdating the *Montmilch* / digital fluting period could, in fact, have contributed to the collapse by further weakening the already structurally-unsound roof which had earlier been riddled by many pressure solution cavities. The collapsed mass of rock is now buried under some one to two metres of sediment, and its lower portions may still bear traces of finger fluting. A datable occupation floor is

[3] Here we can observe the author's early scepticism concerning the deductive reasoning of indirect dating methods, which he developed much further twenty years on.

[4] In fact the author has examined this issue since 1963, when he was faced with having to estimate the age of the petroglyphs at Kranichberger Höhle in Austria, developing his alternative methodology especially from 1967 to 1970, when he conducted extensive studies in the Australian Pilbara.

[5] This definition of 'direct dating' was subsequently formulated with more precision by the author, to ' the dating of rock art by direct physical relationship of art and dating criterion, and falsifiable propositions concerning this relationship'.

[6] See Bednarik (1994) for a detailed description of the site.

[7] The term 'finger fluting' or 'digital fluting' was abruptly rejected by archaeologists at the time, before being adopted by specialists.

hopefully concealed beneath it[8].

The considerable sediment deposited after the rock-fall suggests a great antiquity for the earliest finger markings. This concept can only receive more support by the gradual reduction in parietal sedimentation rates as the cave's convacuation space decreases. The sediment sequence records no major interruption and certainly no degradation phase, and thus, although sediment thickness is of limited chronological relevance (Bednarik 1977: 69), a Holocene age is quite implausible for the middle portion of such an evenly graded column of deposit which represents a complete record since the time of the sea's final retreat from the cave.

There is other evidence that the digital fluting was executed at a time when the cave floor was at least one metre below its present horizon. Some of the decorated ceilings are clearly too low for access nowadays, and at points fluting extends beneath the floor level, especially along the east wall of Koongine Cave. In Malangine Cave, extensive spaces at present less than thirty centimetres high will become accessible upon excavation, and promise to feature further ceiling petroglyphs.

A relative chronological framework for the petroglyphs, calcite deposits, sediments and the associated lithic assemblage will be attempted elsewhere[9]. The concepts that emerged have yet to be bestowed with the added depth that only numeric dating can provide. By virtue of their containing a remnant of the radioactive carbon isotope, speleothems can be dated by the radiocarbon method. The bicarbonate required for their formation was obtained from an intake of biological carbon dioxide. Although the ensuing ratio of carbon isotopes is somewhat complex (to render the limestone soluble an excess of carbon dioxide is necessary, causing less than fifty per cent of the bicarbonate's carbon to be derived from the carbonate, and thus be practically ^{14}C free), it is possible to estimate the proportion of ^{14}C that should have been precipitated in a travertine at the time of its formation. The method was conceived by Franke (1951a; 1951b) shortly after Libby's inauguration of the radiocarbon method. Subsequent research (Franke and Geyh 1970; Franke et al. 1958; Geyh 1969; Hendy 1969) suggests an encouraging reliability for samples from stalagmites; the duration of growth can be determined with great precision. However, numerical ages (which have been obtained up to 45 000 years) are burdened with a potential error (Münnich and Vogel 1959: 170) because the initial ^{14}C concentration is not derived from the atmospheric $^{14}C/^{12}C$ ratio alone:

$$x CaCO_3 + H_2O + (x + y)CO_2 \circ x Ca(HCO_3)_2 + y CO_2 \qquad (1)$$

A close scrutiny of this reaction reveals that a surplus of carbon from the atmosphere is necessary, and since this surplus may theoretically be up to one hundred percent, an error of about 5000 years has to be reckoned with. Fortunately, since the carbon content ranges only from seventy to eighty-five percent in natural bicarbonate solutions (Franke et al. 1958: 4), the potential error is reduced to less than 1500 years. Even this can be diminished dramatically if the $^{14}C/^{12}C$ ratio in the modern vadose water is determined.

Isotope exchange by the infiltration of younger vadose solution would render this dating method ineffective. To test this and at the same time to obtain dates which may enable a later correlation of the rock art to the occupation layers, two samples from Malangine Cave were analysed for their ^{14}C content. One was from the laminated and dense travertine that separates the two basic art styles present near Malangine Cave's entrance (Figure 3). Processed as Hv-10241, it yielded an adjusted age of 5550 ± 55 years BP, which is best described as a *minimum average age* for the entire lamina. Cutaneous speleothems of this type require substantial time spans for their formation and, assuming a minimal post-depositional rejuvenation from younger solutions, it may be that precipitation commenced well prior to 6000 years BP. Pertinently, the 'absolute ages' for several occupation deposits in the region are from the early Holocene (Luebbers 1978: 113–34; Tindale 1957: 110) and therefore coincide in their order of magnitude with the implied age of the pre-lamina engravings. More accurate dating of the deeply-incised figurative petroglyphs will be possible once excavation has secured suitable organic remains from the related habitation floor.

***Figure 3**. The lamina of dense travertine on the ceiling near the cave entrance is visible in the upper part of the image, Where it has become exfoliated, petroglyphs concealed by it have reappeared.*

The second sample processed, Hv-10240, is also from Malangine Cave, and was collected from the pearly travertine that formed on digital fluting. The radiocarbon age of 4425 ± 75 years BP does not contradict the value for Hv-10241. The highly porous *Montmilch* excrescence has in all probability remained moist for most of its existence; its subcutaneous stratum has retained a significant content of water up to the present time. The absence of any evidence of exfoliation suggests that full dehydration may have, in fact, not occurred at all. Generally, greater moistness is apparent in inscriptions, even in those only seventy years old, in the travertine. It may be that present conditions have been influenced by the effects of pastoral land clearing, such as reduced moisture conservation and carbon dioxide production. Isotope exchange has possibly resulted, not so much from the persistence of moisture, but rather from its fluctuations and from variations in the availability of biological carbon dioxide; thus the sample's ^{14}C content of 57.7 ± 0.5 p.m. of modern may, in part, be the result of post-depositional enrichment. But a second factor presumably also had a reducing effect on it. The sample contained brown colouring matter that is almost entirely organic. Since this must be radiometrically younger than the surface on which it lodged, there must have been further rejuvenating contamination of the sample.

The preliminary nature of this dating attempt must be emphasised. Considerably more dating work is being undertaken and contemplated [10], and it is anticipated that a convincing radiometric dating for the entire sequence of rock art will be achieved eventually.

Two other radiometric methods are available for determining the approximate age of carbonate speleothems. It seems possible to infer fairly accurate palaeoclimatic data if the isotope ratio of $^{18}O/^{16}O$ is measured in reprecipitated calcite. This ratio is a sensitive index of the temperature at the time of deposition (Franke 1953; 1958; Hendy and Wilson 1968; Urey 1948); because parietal travertine grows in an environment where the temperature is buffered by a large mass of rock, the temperature at deposition will closely reflect the mean annual temperature of the region. Therefore this method, while not providing an absolute dating, can detect climatic oscillations and optima, from which one may infer an antiquity, or check the results from alternative dating methods.

Finally, D. Thompson (1973) recently developed a method for obtaining age estimations of speleothems via an isotopic analysis of their uranium and thorium content. The uranium-thorium to helium-lead method has been previously used to date a small range of minerals, particularly magnetite. The method involves various chemical purification processes and controlled re-precipitation. After final purging, the U and Th are plated onto metal disc so that the activities of the various isotopes (^{230}Th, ^{232}Th, ^{234}U and ^{238}U) may be measured by alpha spectrometry. The recorded $^{230}Th/^{234}U$ activity ratio is then employed to determine the absolute age.

Minute traces of uranium isotopes are usually present in calcium carbonate lattices, and their decay state (isotope activity ratio) can, with this method, provide apparently reliable dating information. It is presently being used by several specialists (e.g., H. P. Schwarcz, Canada; R. Harmon, U.S.A.; H. H. Veeh, Australia) and its accuracy and utility will presumably be clarified once a larger number of age estimates has become available, especially if they can be cross-checked by other dating methods. The two radiocarbon-dated samples from Malangine Cave described above are currently being subjected to this method.[11]

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[8] The sediment was subsequently partially excavated by D. Frankel, but without reaching the levels predating the roof-fall. However, Frankel's sediment dates do establish that the roof-fall probably pre-dates the Holocene, which would mean that the finger fluting must be of the Pleistocene.

[9] See Bednarik 1994.

[10] See Bednarik 1994 and 1998.

[11] The result of 28 000 ± 2000 BP from the dense travertine skin covering the Karake-style petroglyphs implies that this samp le may have experienced much more carbon 'rejuvenation' than the author had suspected.

It is hoped that the approximate order of antiquity determined for the various generations of petroglyphs can be tied to specific occupation horizons, which in turn can be dated as securely as possible. It may be that a comprehensive and convincing dating for the art sequence may result. The most archaic tradition of rock art known, not only for Australia but for the world, may be represented at this site (Figure 4). This Pleistocene style is succeeded by one closely resembling that found at the Early Man Shelter (Final Pleistocene, at least 13 000 to 15 000 years old; Rosenfeld et al. 1981), in Tasmania (sundered from the mainland around 11 000 BP; Sims 1977), and at other sites considered to be among the most ancient Australian art sites (e.g. Yunta district, Flinders Ranges, Pilbara). This second style consists of engraved trident motifs and similar groups of converging lines, circles, parallel lines, rectilinear mazes or grids, cupules and radial shapes. At Malangine Cave, this tradition has already been demonstrated to be of at least the early Holocene, and of possibly a significantly greater antiquity.

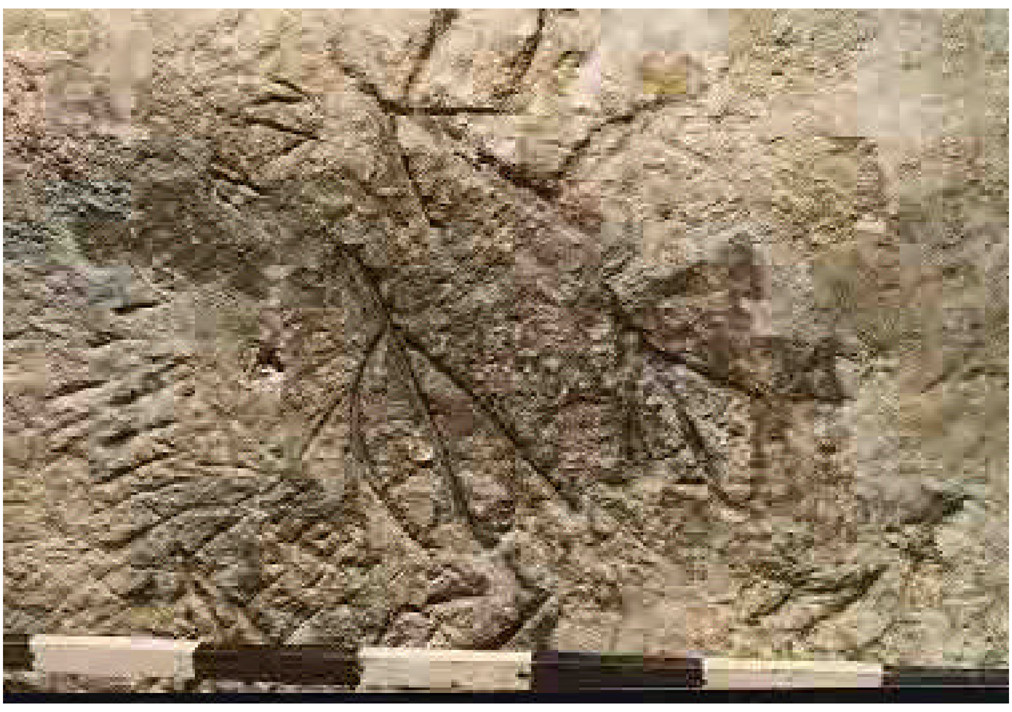

Figure 4. *Probably Pleistocene petroglyphs in Malangine Cave, postdating the finger flutings by a substantial margin.*

The subsequent generation of Malangine petroglyphs, shallow engravings, appears to be younger than 5500 years, and was executed shortly before the cessation of the deposition of the speleothem lamina on which it was incised. To suggest that the eruptions, supposedly about 4800 years ago, of nearby Mount Schank and Mount Gambier, which blanketed much of the region with volcanic ash and perhaps affected its ecology and hydrology, were related to this cessation, is certainly precarious—albeit very interesting. If it were so, the antiquity of the third generation of art would be defined with considerable accuracy to within a few centuries of 5000 years. While the merits of such an estimation may be debatable at this early stage of investigation, it is tempting to raise it, if only to see whether it might be falsified later by the results of a more comprehensive dating.

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