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About the Age of Pilbara Rock Art

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Abstract. – The largest concentration of petroglyphs in the world is reputed to be that of the Pilbara, a mountainous arid region of northwestern Australia. The first credible age estimations of a few individual motifs of this major rock art corpus are presented here. They were made possible by the discovery of a series of historical inscriptions in the region, which were utilized in the establishment of a calibration curve for microerosion dating. The initial results confirm that some of the most spectacular figures, those of the "Woodstock" genre, are quite recent, being only a few centuries old. They also confirm that there is a substantial body of Pleistocene petroglyphs in the Pilbara, thought to consist of hundreds of thousands of motifs. *[Australia, Pilbara region, Pleistocene petroglyphs, rock art]*

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Introduction

The rock art of the Pilbara region in northwestern Australia (Fig. 1), reputed to be the world's largest concentration of petroglyphs, has attracted the attention of Europeans for at least 160 years (Wickham 1843; Richardson 1886; Withnell 1901). But in comparison to the research of similarly impressive corpora of rock art elsewhere, very little sustained effort has been lavished on this massive body of petroglyphs. The Frobenius Institute of Germany conducted brief expeditions to three localities – Abydos, Port Hedland, and Depuch Island – which resulted in some preliminary descriptions (Fox 1939; Petri 1954; Petri und Schulz 1951). Davidson's visit in 1938–39 is reflected in his opinions about similarities with other Australian rock art (Davidson 1952), but the first study of substance was the work of another German researcher, Father E. A. Worms. After conducting fieldwork in 1931 and in the early 1950s, he presented his findings in this journal (Worms 1954). His observations, especially in the Abydos area, led him to suggest that many petroglyphs there were connected with the Kurangara cult, introduced from the east and originating in Arnhem Land.

More detailed reports only began to appear in the 1960s, first the studies of F. D. McCarthy of Depuch Island (1961) and at Port Hedland (1962), soon followed by the first study that made use of scientific and analytical procedures, by a team from the Western Australian Museum (Ride and Neumann 1964; see especially Trendall 1964). The principal limitation of all research efforts up to the mid-1960s was, however, that they dealt with individual sites or site complexes and were the result, generally, of rather brief visits. They also lacked in-depth consultation of Australoid informants, which has severely limited the amount of authentic ethnographic information available about Pilbara rock art. It was only with the work of Wright (1968, 1972) and myself during the 1960s that the true magnitude of the Pilbara petroglyph corpus began to become apparent. Wright was the first to conduct broadly based intersite studies over a wide section of the region, and to thus define this distinctive rock art province. Indeed, his quantitatively descriptive study, extending over two years and then intermittently into the early 1970s,

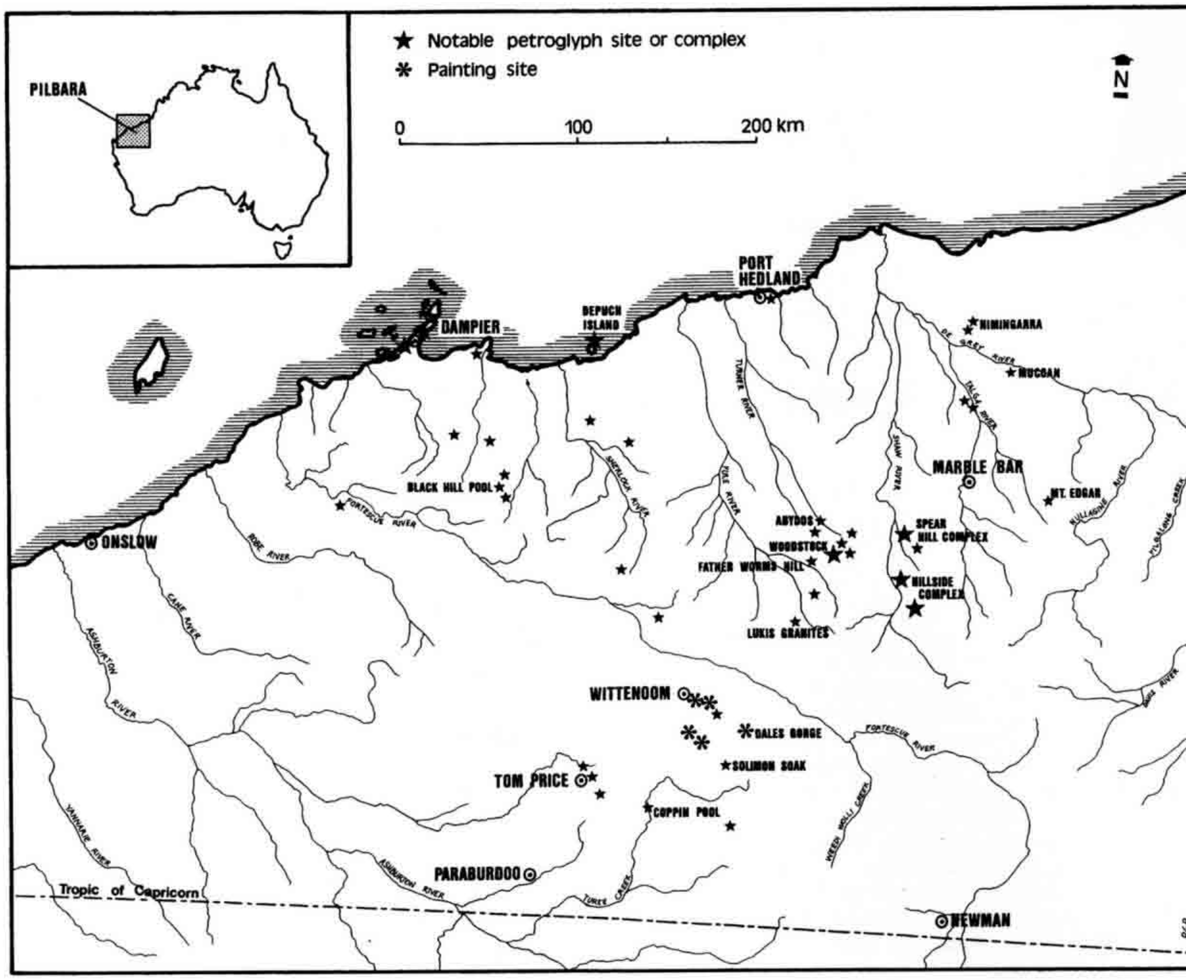

Fig. 1: Map showing the principal rock art sites of the Pilbara region, Western Australia.

has not been bettered to the present time, even though much better funded projects have been undertaken during the subsequent three decades. Wright kept interpretation of the rock art to a minimum and endeavoured to provide comprehensive initial descriptions, particularly of the significant and spectacular anthropomorphous component of the region's rich iconography. Because his recordings were derived from a meticulous photographic record, on which the early component of the art tends to be invisible due to repatination, he only registered the more recent technological traditions in most instances, as had also been the case with all previous research endeavours. Geographically, Wright focused broadly on a region spanning from Roebourne to the Upper Yule River area.

My own study of Pilbara petroglyphs, commenced in 1967 (Bednarik 1973) and still continuing into the 21st century (Bednarik 2000b), differs from previous work in the region in various aspects. It is a long-term attempt that began with a period of several years during which, like Wright, I was a permanent resident of the Pilbara. Its recourse to archaeology had no precedent in the region, and I conducted the first systematic study of lithic artefacts (Bednarik 1977) as well as the first archaeological excavation (at Tom Price site 4) not only in the Pilbara, but in the entire northwestern mainland quadrant of the continent (Bednarik 1977: 69 f.). I succeeded in identifying the early petroglyph traditions at many sites, and introduced the use of scientific methods in examining the petroglyphs and their context, focusing on the presentation and testing of refutable propositions. In practical terms this meant that I ignored notions of iconographic content or "meaning" as much as possible, treated variables of distribution and manifestation as functions of taphonomic effects, and concentrated my efforts on topics that were readily susceptible to refutation. For instance, I conducted analytical work on patination and weathering processes (Bednarik 1979) and petroglyph technology (Bednarik 1998b). Motivated by wanting to place the rock art into an archaeological context rendered it essential to focus particularly on the question of the art's antiquity, because it can only become an archaeologically meaningful resource if its age is known – at least approximately. However, I also managed to interview in detail several Aboriginal elders who were born in the 19th century and had undergone full traditional initiation prior to the settlement of autochthons on pastoral stations, which had led to a rapid decline of tribal society. An important outcome of my work is the discovery of vast numbers of entirely repatinated motifs at many sites that are very difficult to discern, to note the distinctive stylistic differences between these and the more recent traditions, and to render it possible to identify the earliest surviving (and probably Pleistocene) component of this massive art body.

By about 1969, Wright's painstaking site recording program, especially in the eastern Pilbara (involving close to 100 sites in total), and my addition of several hundred more sites in the western Pilbara (about 570 sites just on the Burrup Peninsula, which had not been surveyed before I commenced my project) had demonstrated that the Pilbara contains the largest assemblage of petroglyphs in the world. In sheer number of motifs it eclipses the seven other major concentrations, those in northern Africa, the Middle East, the European Alps, northern China, Siberia, the American Southwest, and the central Andean region (I have examined most of these). While I reject some of the more enthusiastic estimates, such as the suggestion that there are 500,000 petroglyphs just on Burrup (Lorblanchet 1986), I do concede that preliminary estimates such as those of Wright are excessively conservative because the majority of motifs were not recorded due to their age and near-invisibility. Certainly the number of petroglyphs now known in the Pilbara is in the hundreds of thousands, with perhaps in the order of 2,000 sites known, many of which number in excess of 1,000 motifs.

Once the magnitude of this corpus became apparent it attracted new interest, and in particular the Burrup site complex I had discovered became the subject of several studies (Virili 1977; Lorblanchet 1983, 1992; Vinnicombe 1987). These research projects were usually connected with industrial developments and were therefore often well funded, but they were also biased in favor of specific localities and corporate or governmental preoccupations. Elsewhere in the Pilbara, little further research took place as there developed a tendency to treat the rock art as an integral part of the archaeological landscape (Maynard 1980; Brown 1987). Instead of confronting the need to date rock art to achieve its integration, there were no efforts towards the creation of such a bridge. Since Wright's first tentative but inconclusive forays into the question of antiquity, almost no opinions have been offered, and no hard evidence at all. Concerning Burrup rock art, Clarke (1978) stated his opinion that it must be in excess of 17,000 years old, based on his assumption that the patina found on some of it, which he thought to be desert varnish, formed during a very arid phase at about that time. However, much of the patina is not of the varnish type, nor does that kind of accretionary deposit necessarily indicate arid conditions. Indeed, the term "rock varnish" has since replaced the name "desert varnish".

Lorblanchet is the only archaeologist who presented an effort to establish a time depth for any Pilbara rock art through his intensive study of two Dampier sites. However, his endeavours at Gum Tree Valley and Skew Valley have only succeeded in relating inconclusive evidence (Lorblanchet 1992). Indeed, that rock art is most likely of the Holocene, rather than in excess of 18,000 years old as Lorblanchet sought to demonstrate. He based this on a single, questionable radiocarbon date from a marine shell collected from the surface, when at the time in question the shore was over 100 km out to the sea. Radiocarbon analyses show that occupation evidence at these sites begins with the establishment of the present sea level in the early Holocene, because before that time they would have been on inhospitable boulder piles, far from water supplies and food resources. Thus Lorblanchet's elaborate chronology of Burrup rock art is probably false.

While some researchers had long suspected that Pleistocene rock art does occur in the Pilbara, no credible evidence to that effect has been offered so far, and experience elsewhere suggests that Pleistocene occupation centres are most likely encountered along major river courses or at water holes and springs, because favourable sites of the former coastal zones are now all below the sea. Coastal settlement evidence is much more likely to relate to the Holocene than the Pleistocene, and is always dominated by shell middens and rock art imagery of maritime creatures.

About the Dating of Petroglyphs

It must be appreciated that until the 1980s, no scientific methodology for the age estimation of rock art had become available to archaeology (Ward and Tuniz 2000). Previous rock art dating claims had been based on nontestable criteria. My early research in the Pilbara reinforced my belief that methods yielding testable data needed to be developed. Having experimented with lichenometry and the use of a variety of geomorphological products in the 1960s, I focused on weathering rinds, rock varnish, and other accretionary mineral deposits as potential agents of dating information in the following decade. Realizing the open nature of the carbon system in rock varnish and other ferromanganeous accretions (Bednarik 1979: Fig. 3), I abandoned the hope of using them effectively for carbon isotope analysis and by 1980 turned my attention to reprecipitated carbonates. Having discovered a major series of deep limestone caves near the southern coast of Australia, which contained evidence of several phases of petroglyph production that were in some instances physically separated by speleothem skins, I secured radiocarbon and uranium series results from these deposits in two caves (Bednarik 1984, 1990). Not satisfied with them myself (cf. Bednarik 1996, 1998a for most recent self-critiques) I experimented with several other potential approaches, which in 1989 led to the development of microerosion analysis.

Rock art occurs in two forms, as pictograms (paintings, stencils, drawings, beeswax figures), i.e., the results of additive processes; and as petroglyphs, i.e., the results of reductive processes. Obviously dating approaches differ significantly between these two classes: pictograms provide the analyst with a substance that was prepared at the time the art was produced, and that may yield analytical data concerning its age. No such substance is available from petroglyphs, which can therefore only be dated by analysing a physically related feature that either pre- or postdates the art (lichen, accretionary skin or crust, biogenic deposits, etc.) and thus provides minimum or maximum ages; or by estimating the age of the petroglyph surface itself. Obviously the second approach should be preferred (Dunnell and Readhead 1988), but so far only one such method, microerosion analysis, has been proposed and applied.

Traditionally, it has been sought to determine the ages of petroglyphs from their perceived iconographic content, style, or technique; from proximity to archaeological evidence and by excavation; or from superimposition, patination, and weathering. Iconographic interpretation is not falsifiable in most instances (but cf. Macintosh 1977, which demonstrates that such interpretation by alien researchers is likely to be invalid), and stylistic constructs, while possibly comprising some valid elements, are not a sound basis for dating rock art, as has been demonstrated time and again in various continents. Not only are such mental constructs of researchers untestable, they tend to reflect modern Western perception more than historically valid variables. The technique of petroglyph execution is rarely a reliable chronological marker, and proximity to occupation sites is almost irrelevant in this context. Excavation, either of in situ rock art[1] or of detached and stratified fragments of petroglyphs[2], can only provide minimum ages, and is dependent upon the validity of a chain of unfalsifiable deductive arguments relating to the taphonomy of both the excavated sediments and the dated material (e.g., charcoal). Superimposition of motifs certainly provides reliable data for relative sequences, but is not always reliably determined without the use of field microscopy and does not yield actual age estimates.

Indeed, of the traditional methods of estimating the ages of petroglyphs, only the study of subsequent patination and weathering promises testable data, and although it was perhaps the first to be considered (Belzoni 1820: 360 f.), it has not been applied in a rigorous or systematic fashion up to the present time. Instead of pursuing the development of a scientific methodology to date petroglyphs, archaeology has for the greater part of two centuries opted for an "archaeological methodology," which consists of nonquantifiable speculations, unexplained perception of invented styles, and nonfalsifiable propositions. The use of these untestable and thus nonscientific approaches continues to the present time, and is sometimes vigorously defended by archaeologists.

The alternative approach is by "direct dating," the use of direct physical relationship of art and dating criterion, and the presentation of falsifiable propositions concerning this relationship for the purpose of estimating rock art age (Bednarik 1996). While many of the possible methods have not so far been tried, those currently in use include radiocarbon analysis of mineral accretions

1 Rosenfeld et al. 1981; Steinbring et al. 1987; Crivelli Montero and Fernández 1996; but see Abreu and Bednarik 2000.

2 Hale and Tindale 1930; Mulvaney 1969: 176; Thackeray et al. 1981; Lorblanchet 1992; Fullagar et al. 1996; Roberts et al. 1998.

(carbonates and oxalates), radiocarbon analysis of organic inclusions in accretions, microerosion analysis, luminescence dating (especially of optically stimulated luminescence), erosion retreat analysis, uranium-series dating (such as thorium-uranium analysis), measurement of macro-wanes, analysis of weathering rinds and patination variations, radiocarbon dates from paint residues and beeswax figures, amino acid racemization of paint residues, and the determination of cation leaching and cosmogenic radiation nuclides (the last two are considered to have failed; for a comprehensive critique of all these methods see Bednarik 2001).

Of these methods, only microerosion analysis seeks to estimate the age of petroglyphs, others attempt to determine the age of materials occurring in direct physical relationship with the rock art. The rationale of this technique is that, after a new rock surface has been created, by either natural or anthropic agents, it is subjected to chemical weathering processes. This applies especially in unsheltered locations, and it results in cumulative effects that are a function of time, among other factors. While this is a fairly self-evident principle, the difficulty in using the results of such processes to estimate the age of a rock surface is that our understanding of them, of their effectiveness on different rock types, and of their susceptibility to environmental factors remains limited.[3]

For the time-spans we are concerned with in dating petroglyphs, only comparatively erosion-resistant rock types are suitable for microerosion analysis, because sedimentary rocks, especially, weather so fast that very soon no remnants of the surfaces created at the time a petroglyph was made are likely to survive. The principal technique used so far is the measurement of micro-wanes on fractured crystals (Bednarik 1992, 1993a). The "radius" of wanes (strictly speaking, wanes are not equicircular in section, but hyperbolic) increases as a function of age. In wane formation (Fig. 2), the ratio $h : r$ is constant for any angle α, irrespective of distance of retreat of the faces and the edge. Ratio $x : z$ is a function of α, and at $\alpha = 60°$, $x = 2z$. Dimension x can be expressed in algebraic fashion:

$$x = \sqrt{\left[\left(\frac{z}{tan\ 0.5\alpha}\right)^2 + z^2\right]} \quad (1)$$

3 Cf. Acker and Bricker 1992; Busenberg and Clemency 1976; Lin and Clemency 1981; Oxburgh et al. 1994; Rimstidt and Barnes 1980; Williamson and Rimstidt 1994.

This leads to the prediction of β, the angle expressing the rate of wane development relative to surface retreat:

$$\beta = 2\ sin^{-1}\left(\frac{r}{x + h + r}\right) \quad (2)$$

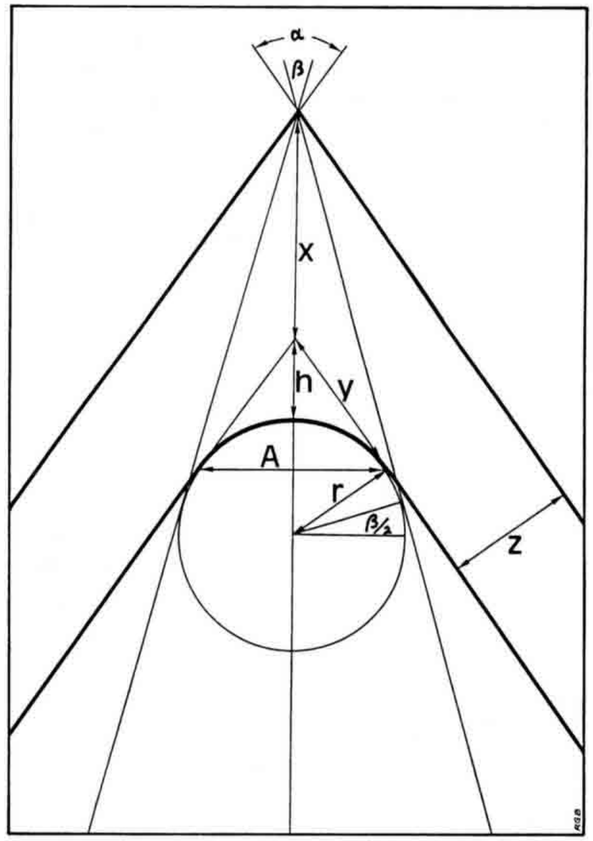

Fig. 2: Diagram depicting the laws of wane formation in a simplified form.

The relationship wane width A with age, irrespective of actual retreat, is ultimately determined by the ratio $\alpha : \beta$, which must be established empirically. It follows that the dimensions A, r, z, and angles α and β are all related geometrically and algebraically, and that the variables A, r, x, z, and h are all proportionally equivalent, and increase linearly with age. Of these, A is most easily measured physically. It is therefore the variable used in micro-wane measurement. The analyst scans the rock surface microscopically to locate crystals that have been truncated (either fractured by impact or truncated by abrasion) by the event to be dated (e.g., the petroglyph production). A statistically significant sample of micro-wane widths along the edges of such truncation surfaces is recorded and placed in a calibration curve. Age estimates are prefixed with a capital E, indicating that the result is erosion derived.

The precision of the method is probably poor at this early stage, because it depends entirely on the number and precision of calibration points. The principal potential variables in microerosion are temperature, pH, and moisture availability. The first two are regarded as unimportant: variations in mean temperatures were probably minor, even as far back as glacial peaks of the Pleistocene; they would not have affected solution rates appreciably. Variations in pH would certainly apply back through time, but in the case of both amorphous silica and quartz, there is almost no change in solubility below pH 9. For alumina it is negligible in the central region of the pH scale, which coincides with most natural conditions. Precipitation would have varied in the past, but it is expected that significant changes in moisture availability would affect component minerals differently, and should thus be detectable by calibration. Therefore, it is preferred to apply the methods to two different component minerals, say, quartz and feldspar.

While microerosion analysis is not thought to provide great accuracy, it is probably more reliable than most alternative methods of dating petroglyphs, and it is certainly cheaper, simpler, and more robust than most. It requires no laboratory backing; the results can be determined in the field. It provides not a single result, but clusters of age-related values (the micro-wane widths) that can be converted into various statistical expressions – a luxury not available to all other dating methods. Importantly, it does not attempt to determine the age of some accretion or other feature somehow relatable to the rock art, it focuses on the age of the actual petroglyph, the "target event" of Dunnell and Readhead (1988). No other method currently available does this. Microerosion analysis does satisfy the demand of Dunnell and Readhead for methods that are applicable directly to the feature about which chronological information is sought. Moreover, it is the only dating method that offers a means of internal checking, that is, of checking the validity of the result without recourse to another method (although luminescence dating does have a limited feature of this type, i.e., the possibility of checking whether the uranium and thorium decay chains are in equilibrium). Finally, microerosion analysis involves no removal of samples, or even contact with the rock art, being a purely optical method. The valid arguments *against* microerosion analysis are that we have inadequate calibration curves for it, that its accuracy is limited by its inherent coarseness, that it can only be applied to certain rock types (principally those permitting the preservation of microscopic crystal surface features for the time span concerned), and that it is unsuitable where the rock surface may not have been continuously exposed to precipitation (i.e., where it may have been concealed in the past by sediment, mineral accretion, etc.). These are significant limitations, but they are outweighed considerably by the benefits of this method.

The microerosion method by micro-wane measurement has been used on petroglyphs in six blind tests now, in Russia, Italy, Portugal, and Bolivia (Bednarik 1992, 1993a, 1995, 1997b, 2000a). Archaeological expectations were matched in all cases except one, where, however, results matched those of other scientific analyses (Bednarik 1995; Watchman 1995, 1996). Calibration curves are now available from Lake Onega (Russia), Vila Real (Portugal), Grosio (Italy), Qinghai (China), and eastern Pilbara (Australia), and the technique has also been applied in India and South Africa. The method's practical time range on crystalline quartz from 0 to perhaps 50,000 years BP renders it particularly suitable for rock art.

Microerosion Calibration Curve for the Pilbara

Although my early endeavours to address the dating issue of the Pilbara petroglyph traditions remained unproductive, they were instrumental in the formation of my conviction that dating was the crucial link in rendering rock art archaeologically relevant, in my view that such dating would eventually be achieved by micro-geomorphological and geochemical means, and in my coining of the term "direct dating" of rock art. Twenty-two years after commencing my research in the Pilbara, my development of the microerosion method in 1989 seemed to render Pilbara petroglyphs datable at last. Unfortunately there remained a stumbling block: in Australia, and most especially in the remote and very thinly populated northwest of the continent, there are few rock surfaces of historically known ages available to establish calibration curves. The great wealth of rock-made structures, quarries, gravestones, and glacial abrasions in Eurasia whose age is either known historically or can be ascertained with reasonable accuracy renders that region far more amenable to this method, which I applied first in Karelia, later in Italy and Portugal, before attempting uncalibrated estimates in South America and Africa. I sensed that the calibration curves I had secured in more temperate areas would be greatly inappropriate in a hot and arid region such as the Pilbara, so I avoided making uncalibrated predictions in Australia, considering instead to attempt calibration in one of the few Saharan granite regions with petroglyphs. But dated inscriptions are extremely rare in the Sahara and I know of none on quartz-bearing rock. In July 2000 I managed to locate a large series of engraved dates on one of the four major granite facies of the eastern Pilbara, which at long last provided me with the means of securing calibration values for this important rock art region.

While surfaces of historical structures (Roman bridges) and glacial striae from the end of the last stadial have been utilized in Europe, dated inscriptions of the last two centuries seem to be the only available option in Australia. I had already used dated inscriptions in Europe very profitably (at Besov Nos, Lake Onega, Russia; and at Panóias, Vila Real, Portugal), but in the case of Australia, the exceedingly short time range covered by such dates would introduce a higher level of imprecision. This, however, I had to reconcile myself to if the method was to be used with any confidence in this country, because the potential imprecision imposed by an arid climate could be considerably greater than that of very short-range calibration values. The series of dated inscriptions my search has located in the Pilbara includes, amazingly, an apparently authentic example from 1771 (Fig. 3), which is in fact part of the earliest known nonindigenous rock art composition found in Australia (Bednarik 2000b). Unfortunately this date was engraved on a basaltic dolerite, free of quartz and feldspar, and could therefore not be utilized for microerosion analysis; its mineral constituents have not as yet been subjected to such studies. The remaining dates surveyed range from 1881 to 1997, and they were all located on AGL granite, a well foliated, fine to medium-grained biotite adamellite representing remobilized older granitic rocks. Eight dates were surveyed with a specially adapted field binocular microscope, six near the peak of Spear Hill site 7 (Fig. 4), one from a site on the hill's western flank, and one from nearby Spear Hill site 9 (McNickle 1985). Six of these inscriptions provided quantifiable micro-wane width readings from 90° fracture edges on crystalline quartz (see Bednarik 1992, 1993a), with samples ranging from four to thirty-two measurements per inscribed date (Table 1).

Fig. 3: Four historical petroglyphs in the eastern Pilbara, apparently dating from 1771. Currently the oldest known historical inscription in Australia.

Table 1: Microerosion Calibration Values from Eight Engraved Dates at Spear Hill, Pilbara, in Microns, for Crystalline Quartz.

Date	No. of determinations	Min. width	Max. width	Mean width
1938	15	0.1	0.4	0.233
1941-A	8	0.2	0.3	0.237
1980	Micro-wanes are slightly <0.1 micron			
1997	Micro-wanes too small to measure effectively			
1964	4	0.2	0.3	0.275
1941-B	32	0.2	0.4	0.259
1881	8	0.4	0.7	0.537
1917	8	0.3	0.7	0.412

The calibration curve derived from these values (Fig. 5) differs considerably from those secured from temperate to subarctic sites, and while this was to be expected, the difference is not as great as might have been predicted. What might keep microerosion rates low is not just the low precipitation of an arid climate, but also the relative duration of surface moisture, which is determined by the lengths of rainfall periods and evaporation rates. In that sense, the Pilbara with its regime of frequently cyclonic precipitation and very low rel-

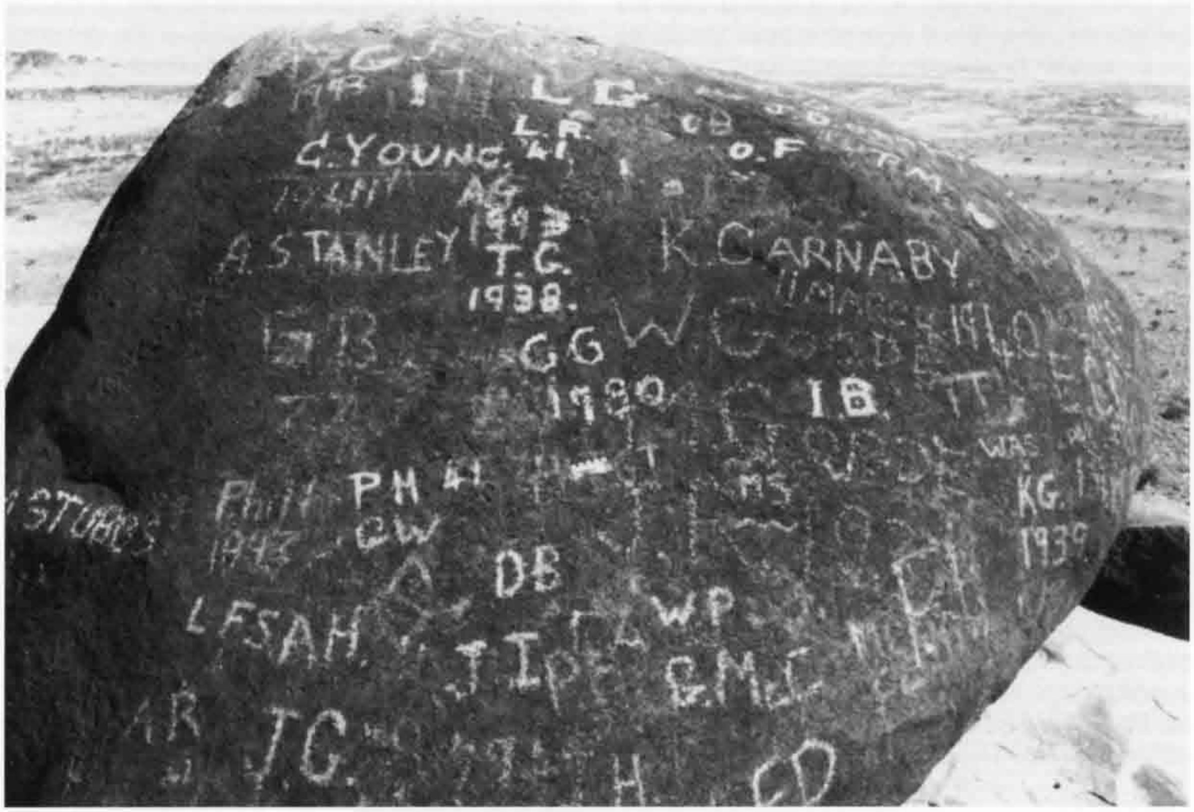

Fig. 4: Large granite boulder near the peak of Spear Hill site 7, bearing numerous dated inscriptions, some of which were used for dating calibration.

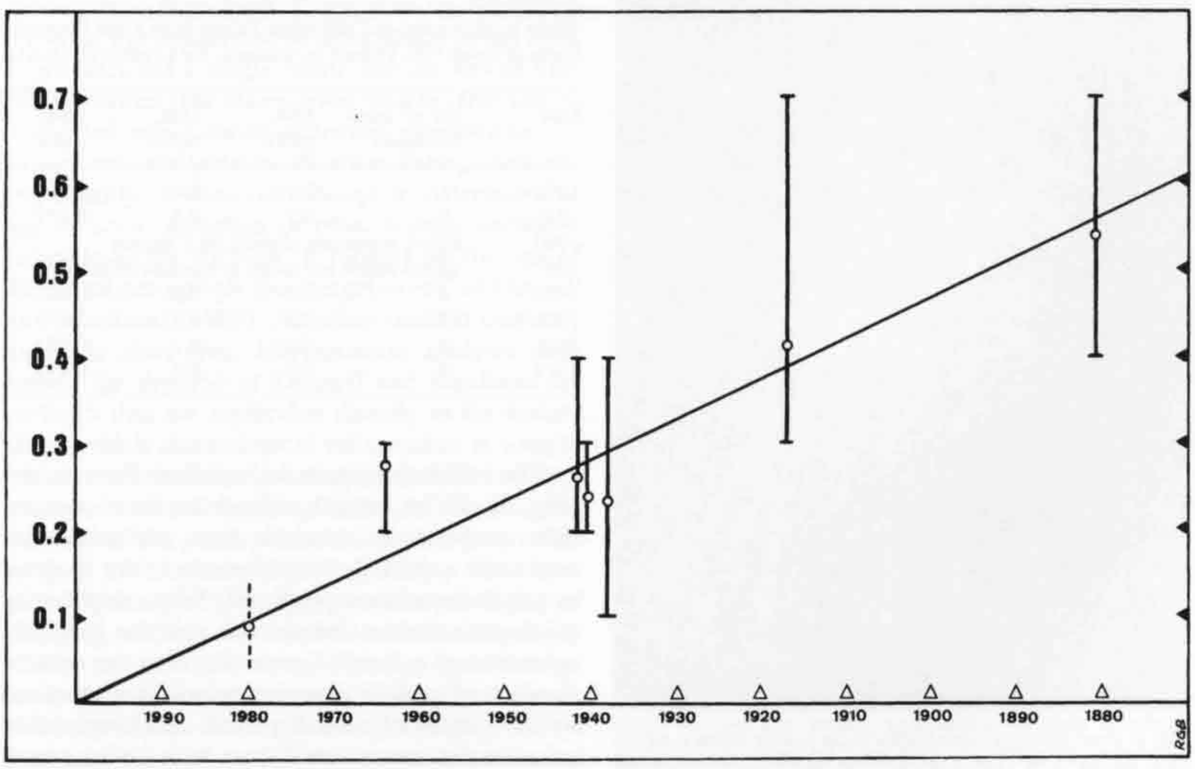

Fig. 5: Microerosion calibration curve for quartz, Spear Hill rock art complex.

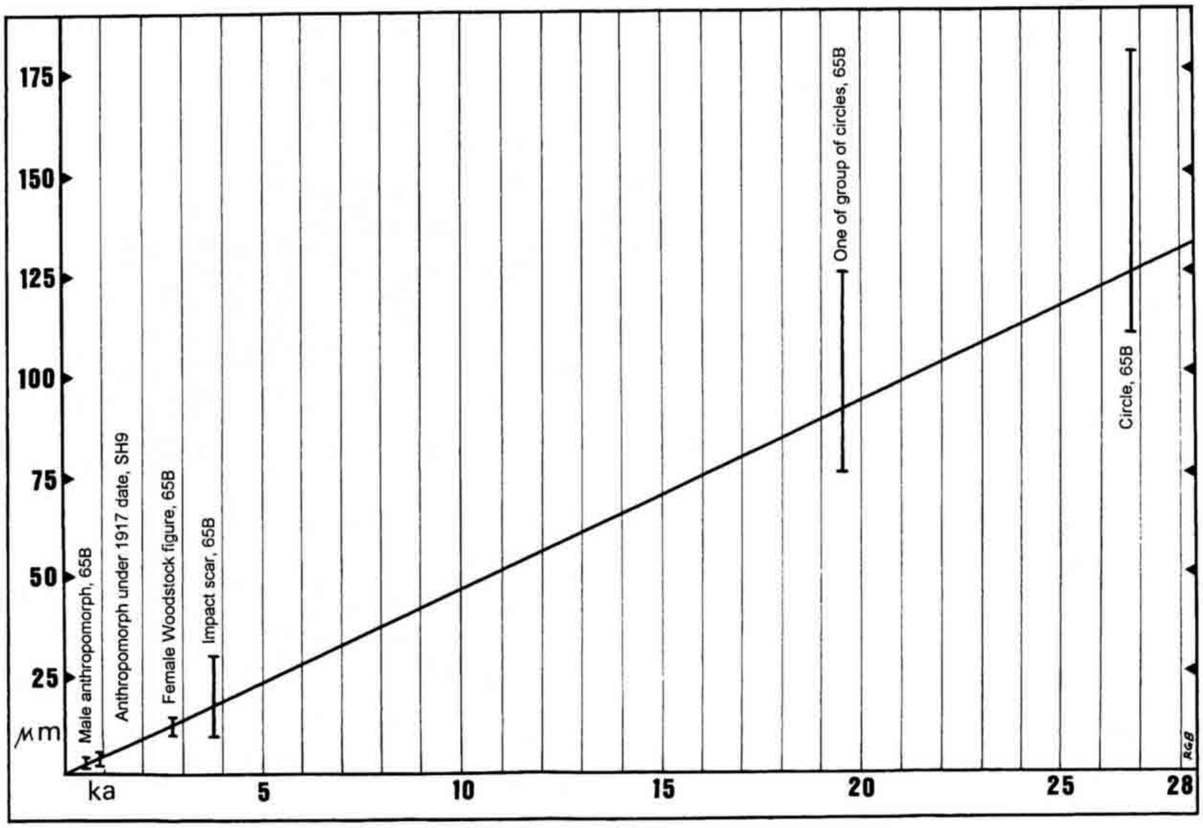

Fig. 6: Age estimates of six petroglyphs of the eastern Pilbara, based on microerosion indices.

ative air humidity and vegetation cover is probably fairly close to the extreme end of the spectrum, as far as mineral solution rates are concerned. Another result of these conditions are the ubiquitous iron-rich accretions of the entire region, which have previously been interpreted as autochthonous conversion products, but which are largely (though certainly not entirely) the outcome of inadequate flushing of dissolved minerals.

Two points need to be emphasized here. First, this calibration curve lacks in precision, for a number of reasons, especially the short range of the calibration values it is based on. Second, it would be better to back it up with a curve for feldspar, which is certainly possible to do but which has so far not been attempted. This first determination for the Australian Pilbara is, therefore, best regarded as preliminary, subject to refinement and testing, and its purpose is merely exploratory: to gain a very first inkling of the time depth represented in the rock art of the region.

The First Datings of Pilbara Petroglyphs

Within days of securing the Spear Hill calibration curve, it was applied to several selected petroglyphs in the region, at three sites: Woodstock 65B, Spear Hill 7, and Spear Hill 9. Fractured quartz crystals that had remained free of accretionary mineral deposits and possessed edges of between 85° and 95° were selected, and the micro-wanes developed on these were measured in accordance with standard microerosion analysis (Bednarik 1992, 1993a). While the results of this very first foray into the direct-dating of Pilbara rock art (Fig. 6) were perhaps not particularly unexpected, they are nevertheless of significant value, particularly as they probably herald the acquisition of many more results, and hopefully the general development of the methodology.

Woodstock site 65B is located near the long abandoned Abydos station, on AGM granite, a fine to coarse, even-grained biotite adamellite, biotite granodiosite and, less commonly, biotite tonalite, well-foliated and often gneissic. Morphologically, the area is dominated by boulder piles, roughly conical hills consisting almost entirely of mul-

Fig. 7: Circular designs of Karake style on right, and much more recent anthropomorphs on left. Woodstock site 65B, eastern Pilbara.

tifaceted, rounded granite boulders rising up to about 100 m above the alluvium or pediplain. On the western slope of site 65B large boulders have formed a distinctive shoulder, where petroglyphs of clearly very different antiquities occur in close vicinity, even on the same panels. They include circle motifs of a quite specific genre thought to be of the Pleistocene elsewhere in Australia, occurring here on four panels. The upper surface of a small elongate boulder bears several deep impact scars (Munsell 10R 4.5/7) and an almost fully repatinated pounded circle, together with faint linear marks that may also be of former circles. Twenty quartz micro-wane widths (*A*) were measured in one of the impact scars, yielding a mean value of 17.25 μm (range 10–30 μm). When placed into the newly constructed calibration curve, this corresponds to an estimated age of E3670 (+2713 –1543) years BP. (The "E" in front of the age estimate indicates that this dating is erosion derived.)

Next, the immediately adjacent circle was examined (Munsell 7.5R 4/6) and an area of suitable accretion-free quartz edges was located in it. This led to the determination of a mean wane width of 125.74 μm (range 110–180 μm, N = 14), which corresponds to E26753 (+11 545 –3349) BP. Clearly, then, the impact marks are very significantly younger than the circle, and they were probably a reaction to it.

Just two metres to the south of this boulder, a well-rounded, larger boulder bears a weakly patinated male anthropomorph, whose quartz cleavage faces appeared quite fresh under the microscope and whose ~90° edges produced a mean value of only 2.0 μm (range 1–4 μm, N = 10). Consequently this figure, which could be considered to be of typical Woodstock style, is only E425 (+426 –212) years old.

Some 10 m to the east is a large flat boulder, about 6 m long. Most of its upper surface has experienced massive laminar exfoliation of 3–5 cm thickness, but near its northern end, one square metre of patinated crust is still present, bearing the remains of a design of multiple circles arranged in the Karake style (Aslin and Bednarik 1984). Four circular designs and an elongate, bisected outline remain visible, although heavily weathered (Munsell 10R 4/5, on 10R-3/5 background), and there is also a patch of heavily abraded area. A sample of fourteen micro-wane widths taken from

Fig. 8: Female anthropomorph at foot of Spear Hill site 7, west side, c. 350 years old.

the east side of the largest circle yielded a mean value of 91.07 μ (range 75–125 μm). They are therefore E19376 (+7219 –3419) years old. The ground area, about 70 cm across (Munsell 5YR 8/4, but very speckled), is significantly younger, in fact it is about the same age as the Woodstock figure just mentioned: wane sizes of about 2 μm are consistent, although no quantitative count was attempted.

Some of the most prominent petroglyphs at site 65B occur about 30 m north of the locality so far considered, on a widely visible dark boulder. The numerous motifs include female Woodstock figures. One of them, with distinctly S-shaped torso, exhibits wane widths of 10–15 μm, and is therefore between E2130 and E3190 years old. The southwest wall of the large boulder bears at least 82 cupules, typically of 25–40 mm diameter and 5–10 mm depth. Unfortunately they are so heavily coated by accretionary deposits that microerosion assay could not be attempted. They appear to have continued on the upper surface of the rock, and there could be taphonomic selection based on relative orientation evident. Several Karake-style circular designs on the northwest side appear to be of intermediate age (Fig. 7). Although the cupules are not datable by the method used here, there can be little doubt that they are by far the earliest component of the rock art present. This is clear from their alveolar erosion patterns, which are well in excess of the condition observed in the c. 27 000-year-old motif.

Finally, two petroglyphs were examined at sites of the Spear Hill complex. The "1917" date included in the calibration curve, located at site No. 9, is just marginally superimposed over a non-Woodstock anthropomorph. The latter provided a series of twelve micro-wane width measurements which yield a mean value of 4.25 μm (range 3.0–5.0 μm). This corresponds to an age estimate of E904 (+160 -266) years BP. At the western base of site No. 7, a prominent group of three female anthropomorphs includes one particularly recent example (Fig. 8), which proved to be about three times as old as the nearby "1881" date, i.e., about E350 years (no quantitative data collected).

Discussion

A quest to determine the antiquity of Pilbara petroglyphs commenced in 1967 has at long last led to the development of a method capable of producing credible age estimates for this rock art corpus.

Table 2: Quartz Microerosion data from Seven Petroglyphs, Sites 65B and Spear Hill 7 and 9, Eastern Pilbara. Micro-Wane Dimensions in Microns.

Motif	Wanes	Min. *A*	Max. *A*	Mean *A*	Age, years	Tolerance
Female SH7		No measurements taken			c. E350	–
Male 65B	10	1	4	2.00	E425	+426, –212
Anthropomorph SH9	12	3	5	4.25	E904	+160, –266
Female 65B		Micro-wanes range from 10–15 microns			E2127–3191	–
Scar 65B	20	10	30	17.25	E3670	+2713, –1543
Circle 65B	14	75	125	91.07	E19376	+7219, –3419
Circle 65B	14	110	180	125.74	E26753	+11545, –3349

This was made possible by three factors: the early appreciation of the need to exploit geochemistry and micro-geomorphology, the development of the theory of micro-wane formation in 1989, and the discovery of numerous historical engraved dates in 2000. These three stages were crucial in developing a standardized method for routine age estimation of individual motifs in the Australian Pilbara, particularly in the granite-dominated eastern Pilbara. This paper describes the establishment of the first Australian calibration curve, followed by the initial seven practical applications. These comprise a fairly random selection, although a conscious effort was made to primarily focus on very young and very old examples, to acquire an initial appreciation of the time depth represented by a very few sites in the world's greatest concentration of petroglyphs.

Several qualifications and considerations are therefore immediately apparent in the data presented here, and bearing in mind how frequently archaeologists misinterpret or overinterpret direct-dating evidence (Bednarik 1994, 1996, 2001; Watchman 1999), it is important that these qualifications be considered:

1. The spread or distribution of these preliminary dates is of little consequence. Much older dates are expected to be secured in due course, and these few determinations tell us nothing about population densities, artistic trends, "styles," or any of the other archaeological interpretations such data are usually subjected to.
2. The calibration curve they are based on is to be regarded as tentative, and may need to be refined. There is, however, very little prospect for such refinement in Australia, and it may come in the form of comparative data from similar arid regions in other continents. Such potentialities are currently under investigation.
3. In reliable microerosion analysis the use of two or more parallel calibration curves (from two or more component minerals) is desirable and has already been demonstrated. In the present case it is strongly recommended that a calibration curve for feldspar be established.
4. Crystalline quartz occurs in different forms, and while it is not expected that their solution characteristics differ sufficiently to affect the rather coarse resolution this method supports, for the sake of rigor it is desirable to test this assumption, through analyses targeting diverse quartz surfaces of historically known ages.
5. A large part of Pilbara rock art occurs on plutonic or extrusive igneous rocks such as gabbro, dolerite, and basalt, which renders the development of expertise in the microerosion behaviour of pyroxene, augite, and olivine very useful for an expansion of the dating program now begun. It is planned to attempt this shortly.

Nevertheless, it might realistically be possible to speculate that the adverse climatic conditions introduced by the last Glacial Maximum around 18 000 years ago effected depopulation of economically marginal regions, such as much of the Pilbara, and that there may be a dearth of rock art from the last part of the Pleistocene, essentially until rising sea level and a climatic amelioration brought about an increase in the human population of the land area presently exposed. At this stage, however, the few age estimates presented here are certainly most inadequate to test such speculations. Once some hundreds of randomly derived dates are available such theories may be developed, and the time of this may be relatively close at hand. Now that a calibration curve is available, the estimation of petroglyph ages in the eastern Pilbara has become a routine procedure, and it is perfectly possible to acquire a few hundred dates in a matter of some weeks of intensive fieldwork.

The present paper does establish clearly the presence – indeed, the ubiquity – of Pleistocene rock art in the Pilbara, because the types of petroglyphs now shown to be of such antiquity occur widely and in massive numbers, as had been suspected by me of being the case since the 1960s. They are especially cupules and "geometric" line motifs, all of them nonfigurative to European perception. Very similar patterns and a variety of traces of quite specific mark-producing behaviours have been shown or suspected to be of the Pleistocene in parts of southern Australia, so this is far from unexpected. Bearing in mind that there are probably well over a million motifs in the Pilbara region, and considering further that at least twenty per cent of these figures (and possibly a much higher percentage) can be expected to be of the Pleistocene, it is apparent that this corpus of surviving Pleistocene rock art is numerically dozens of times greater than that of the entire Upper Palaeolithic cave art of southwestern Europe. Moreover, all of this rock art is associated with a technology that must be defined as essentially Middle Palaeolithic – irrespective of the great reluctance of Australian archaeologists to condone this term. Undeniably the first human settlement of Australia was by seafarers of a Middle Palaeolithic tradition, most probably from Timor or Roti, where a maritime tradition had been established since the Middle Pleistocene (Bednarik 1997a, 1999; Bednarik und Kuckenburg 1999), and the archaeological record of the continent implies that this technology persisted there for the remainder of the Pleistocene (and in Tasmania to European contact). In Europe, only one occurrence of Middle Palaeolithic rock art is widely known, the set of eighteen cupules from burial No. 6 in La Ferrassie (Peyrony 1934: 33–36, Fig. 33). Interestingly, the oldest known rock art in the world, in India, also consists primarily of cupules (Bednarik 1993b). The Pilbara evidence clearly supports the contention that there is more surviving "Middle Palaeolithic" rock art in the world than "Upper Palaeolithic." This is a refutation of the major pillars of wisdom concerning Europe's cave art: that it is the oldest art, and that it documents the origins of art. The Pilbara Pleistocene rock art certainly does not document the beginnings of palaeoart, but it is a lot closer to them than the Franco-Cantabrian corpus could possibly be. Yet to the end of the 20th century, it has remained profoundly neglected, and has never been any part of the discussion of universal art origins. We possess no inventory of this corpus, we have made no rigorous attempt to divide it into spatial or chronological traditions, and until now we have presented no credible evidence of its antiquity.

Hopefully, this paper can lead to a more balanced consideration of the issues it addresses, and also to an increased use of microerosion analysis. The development of this technique is entirely contingent upon its frequent use in many different climates and lithological contexts, so that more calibration curves can be secured to develop greater precision, and a better understanding of the variables affecting microerosion.

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