SUMMARIES OF PROPOSED ROCK ART MONITORING STUDIES

Introduction

Listed below are summaries of the studies that have been endorsed by the Burrup Rock Art Monitoring Management Committee. These studies are the outcome of discussions between the Committee, researchers and the local Aboriginal and broader community following a Rock Art Monitoring Workshop in Dampier in March 2003.

In accord with Government procedure these studies are being finalised in terms of arranging contracts and engaging qualified consultants/researchers (external to government) to undertake and report on scientific findings. This process has followed a formal government tender process, which commenced with advertising for tenders in July 2003. The successful consultants for these studies were announced in February 2004 with commencement of field work expected in late April or early May following monitoring site establishment.

The Committee expects regular updates on the monitoring studies with six-monthly and annual reporting to the Committee. These reports will be made available on the Web (*www.doir.wa.gov.au*). The Committee will continue to provide updates on the progress of the rock art-monitoring program and will report to, and consult with the community annually.

Following completion of studies and peer assessment of the work of the consultants, the Committee will produce a final report to government and the community. It will then make recommendations to the Burrup conservation area management body for the ongoing preservation and conservation of the rock art, whether further industrial development on the Burrup Peninsula proceeds or not.

Study 1 - Air monitoring of ambient concentrations of air pollutants

Monitoring required:

- NO_2, SO_2, NH_3, BTX

Monitoring locations:

- Six locations selected (1 each at northern Dolphin Island and northern Burrup Peninsula and 4 within the industrial area of King Bay-Hearson Cove).
- Note: SO_2 and NH_3 monitoring (1 control and 1 industrial location only).

Monitoring timeframe:

- Initially for 1-year period with possible extension following annual review of monitoring results.

Proposed sampling system:

- Each sampling site to have anodised aluminium sampling lid fitted with a rail with passive gas samplers for NO_2, SO_2, NH_3. BTX samplers to be housed under the same lid and secured with metal clips. Aluminium casing to be attached to a metal or treated pine pole.
- Passive gas samplers to be mailed to a central location for exchange drop-off and pick-up by trained technician.
- Exposed samplers to be removed and placed in the vials and new samplers installed into the housing.
- Record sheets to be used by operators to record time and date of sampler installation and removal, serial number on the vial, average temperature and any additional observations/comments.
- Exposed samplers to be placed in pre-addressed envelopes supplied by researchers and posted to researchers for analysis.

Sampling period:

- Monthly sampling periods.

Study 2 - Microclimate and deposition study

Monitoring required:

- Temperature;
- Relative humidity;
- Wet deposition - amount and chemical composition;
- Dry deposition - amount and chemical composition;
- Bulk deposition - amount and chemical composition;
- Chemical composition (including pH) of dew on rock surfaces on exposed and protected/shaded faces.

Chemical composition shall include sodium, chloride, iron, total nitrogen and sulphur.

Monitoring locations:

Six locations selected (1 each at northern Dolphin Island and northern Burrup Peninsula and 4 within the industrial area of King Bay-Hearson Cove).

Monitoring timeframe:

- Initially for 1-year period with possible extension following annual review of monitoring results

Site establishment
(equipment to be co-located with passive samplers)

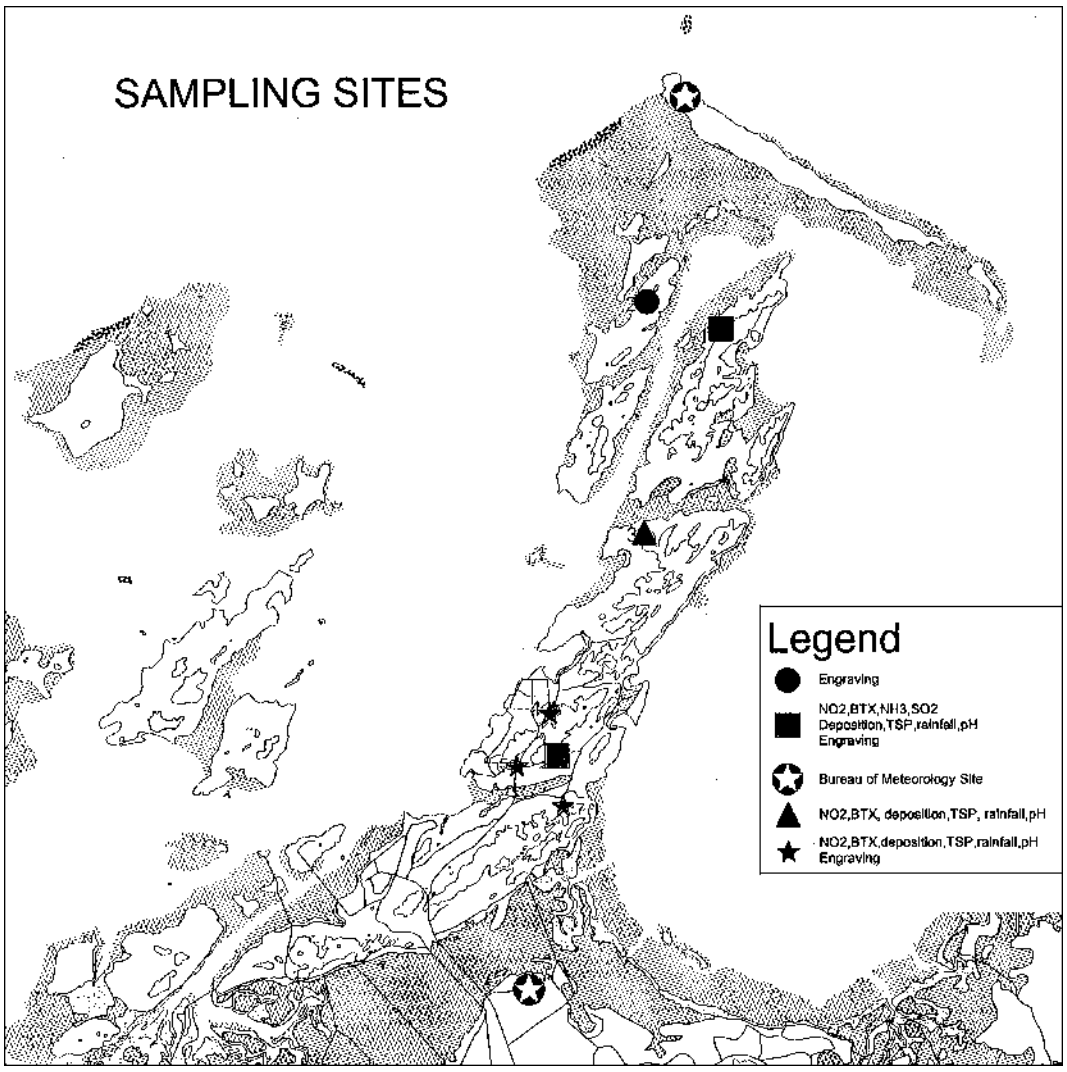
- Consists of a rainwater sampler, total suspended particulates (TSP) particle sampler, a deposition sampler and temperature and humidity meters.
- Rainwater and TSP particle samplers to be bolted to a free-standing concrete slab and placed in an appropriate position.
- Temperature and humidity will be measured electronically with a sensor mounted in a screened enclosure approximately 1.5 m above ground, powered by a gel cell battery.
- During each visit the technician will download data to a notebook computer and e-mail the file to researchers. Notebook computer can be supplied by researchers if required.

Sampling period:

- No greater than monthly sampling for wet, dry and bulk deposition.

Sampling and analysis methodology:

- Rainwater samples to be collected monthly using Ecotech Model 200 'wet only' rainwater samplers. These will be supplied with solar panels to charge the battery. To counteract effects of bacteria consuming some species such as organic acids, ammonia and sulphate thymol (a biocide) will be added to the sample bottle prior to field installation.
- At end of each month sampling period, data stored in the data logger will be downloaded to the notebook computer and the data file e-mailed to researchers for chemical analysis.
- Dry deposition to be collected using Ecotech Microvol 1100 samplers configured to collect TSP. They are fitted with a solar panel to charge a battery.
- After sampling the filters will be returned to researchers, extracted with high purity water and analysed for species as for rainwater.
- For measurement of amount and chemical composition of bulk deposition, a pre-cleaned plastic funnel and bottle at each site exposed for monthly periods will be used. At end of each month, high purity water will be used at the site to wash particles deposited on the funnel into the bottle.
- Dew samples will be collected from rock and surrogate surfaces using pre-cleaned pasteur pipettes. Samples to be transferred to glass vials, sealed and sent to researchers for analysis as for rainwater.



The sampling sites of the Burrup Rock Art Monitoring Management Committee

- In all cases, record sheets will be provided by researchers to the field technician to record sampling times, dates, volumes and any observations or comments.

Summary of joint proposals

- Six sites for NO_2, BTX, wet deposition, dry deposition and bulk deposition measurements.
- Two sites (1 control and 1 industrial site location) for NH_3 and SO_2 measurements.
- Sampling for gases, rainwater and particles at monthly intervals.
- Sixteen dew samples at each site during the year.
- Sixteen dew samples are on the basis of 4 samples/site unshaded and 4 shaded and a similar number on a surrogate surface such as Teflon.
- Number of rainwater samples is estimated at 10 per year per site based on data from Bureau of Meteorology.

Study 3 - Field studies of colour changes

Monitoring required:

- There is a need to assess whether there is a loss of colour contrast between rock art/petroglyphs and adjacent rock surfaces, and to establish a scientifically valid baseline for future assessments. Physical assessments are required at a number of monitoring sites to assess whether colour changes are occurring and if these are occurring at a greater rate than that due to normal weathering.
- It is expected that due to the small changes expected, monitoring of the same sites would only be needed annually over the four-year period study period.
- Any monitoring would need to ensure that there were controlled or carefully characterised conditions so that comparisons are reproducible.

Monitoring locations:

- Six monitoring locations (2 at northern Dolphin Island and 4 within King Bay-Hearson Cove).

Monitoring timeframe:

- Annual monitoring over a 4-year period, with possibility of extension following review of the monitoring results.

Proposed sampling system:

- The proposed methodology demonstrated an understanding of the need for a reproducible, reliable approach through the use of a BYK-Gardner portable spectrophotometer with natural light being excluded using a compressible collar. Such an instrument has a range of standard illuminants, including those for natural light. It does not have the capability to provide readings for light in particular spectral intervals. It would, however, provide detailed comparable information about changes in colour in standard natural light as perceived by the eye.
- The measuring head measures a diameter of 4 mm, which would allow for measurement of contrast between engravings and surrounding rock faces.
- Contrast in colour between engravings and adjacent rock faces

would be in terms of Delta E, the standard CIE colour difference method.
- Each petroglyph would be monitored at three points with three adjacent points on the rock surface, each an average of 7 readings — 42 readings per petroglyph.
- In order to relocate the instrument, digital photography with a macro lens will be used to relocate to within a millimetre.

Sampling period:
- Annual

Study 4 - Artificial fumigation studies of rock surface changes

Monitoring required:
- In order to gain some indication of the types of changes to be expected from prolonged exposure to existing and possible future industrial emissions it is considered that there may be value in conducting fumigation cabinet studies of typical rock samples with weathered surfaces from the Burrup Peninsula.
- Fumigation trials of nitrogen dioxide, sulphur dioxide, ammonia, xylene, benzene and toluene would be needed at a range of concentrations to provide a dose-response assessment but in the above proportions with realistic Burrup temperature and humidity conditions. The fumigation trials should examine the gases in combination for existing and future industry scenarios and multiples of those concentrations to assess any physical, mineralogical or chemical changes.

Monitoring timeframe:
- One-year period, exercisable at the absolute discretion of the Rock Art Committee.

Proposed sampling system:
- The proposed 8 cycles per day of dry/wet/dry transitions over 3 months would be equivalent to some 7 years of climatic cycles
- Further acceleration is proposed through 'a combination of adjusting temperature and pollutant dosage (to an extent limited by the need of not distorting the damage mechanism' leading to obtaining 'an equivalence of 20 years of climatic cycles'.
- Consideration will be given to assess possible damage over a longer period than 20 years, it would be necessary to identify early indicators of damage. These may be chemical changes in desert varnish or specific mineral structure alteration, identified by analytical tools such as XRD or XPS.
- Possibly conduct a preliminary assessment to decide on the number and conditions of test cycles.
- There is also a proposal for a limited study using extreme exposure doses to assess the early indicators of chemical or mineral change mentioned above.
- Analysis will be done using SEM and XPS by the relevant researchers.

A recipe for failure

ROBERT G. BEDNARIK

The Dampier rock art monitoring program by the Western Australian government was initiated in response to my paper 'The survival of the Murujuga (Burrup) petroglyphs', in *RAR* 19(1). In that paper I had reported detecting quantifiable degradation of the ferruginous mineral crust in the Dampier Archipelago, on whose preservation the rock art depends for its continued existence. Having measured changes in colour and crust degradation since the late 1960s, I had observed a marked deterioration since the late 1980s. In extrapolating from these empirical observations I predicted that the proposed three-fold increase in acidic gaseous emissions would cause widespread loss of colour contrast among the massive petroglyph corpus over the course of the 21st century.

I have therefore every reason to welcome the initiative of the government. Moreover, our knowledge base of the effects of atmospheric acidification on mineral patinae remains woefully inadequate, and any work that is designed to improve this is more than welcome. However, if the full potential of such an opportunity is not realised, it is just an opportunity lost, and it is for this reason that we need to examine the above proposals critically.

It seems to be agreed that the primary purpose of this exercise is to (a) determine the precise nature of the processes causing deterioration, and its secondary purpose is (b) to use this information to design ways of alleviating these effects. From a scientific perspective, the first purpose is the more valuable, because it will enrich our generic understanding of threats to rock art. However, from a purely pragmatic point of view, only the secondary purpose (b) is of ultimate interest, for the possible implementation of palliative measures. Nevertheless, it is obvious that, in order to design such measures, it is imperative that the basic research be conducted under optimal conditions. The terms of reference make it clear enough that this project will fail to deliver the optimal information we require.

The main reason for this lies in the central assumption that the deterioration processes are very slow and *gradual*. This is no doubt acceptable for Study 3, where colour changes are to be examined. These occur over a long period of time and the proposed four-year period may in fact be inadequate. Moreover, none of the studies is concerned with the key issue to be addressed: the physical degradation of the mineral accretions that are the very centre of this preservation problem. Instead we have monthly monitoring of four pollutants, which will offer vaguely relevant background information; we have monthly sampling of some factors of atmospheric deposition, which is much more relevant but is incompletely covered; the colour monitoring program; and simplistic accelerated weathering experiments.

Dampier is a locality of climatic extremes, where most precipitation occurs within a few weeks in the year. Gaseous emissions by themselves are not likely to dissolve the crusts, they would become operative in the presence of moisture. Unless dew has an effect, which remains unknown, we could reasonably assume that the deterioration only takes place in the course of a few weeks, essentially in the cyclon season. Obviously what we need to know more than anything else is what happens at the rock face when it rains. What I would like to know most is this: does solution take place only during rain, does it proceed evenly or does it peak, for instance in the first ten minutes of rain, when radicals in dormant solids are activated by the water? Or perhaps it takes a certain time of rainfall before the micro-erosional front becomes fully active? At this stage, we cannot claim to understand the processes of mineral accretion deterioration at all, therefore any study must commence without unwarranted assumptions. It is quite probable that most of the deterioration of the crusts is by the reaction of NO_2 and rainwater in the atmosphere, yielding nitric acid, but how does its effectiveness vary as a function of duration of the precipitation event? We have no idea about these crucial details, and the most obvious aspect of the proposed study project is that it cannot possibly provide such details. The simplistic design of the project prevents the acquisition of the most important data, and instead meaningless data are likely to be collected.

It would have been much more appropriate to determine the variation of rainwater pH at the atmosphere/lithosphere interface

and to plot it against time over the duration of a rain episode. The most relevant study would be a direct observation of the process under a binocular microscope, visually observing the physical mobilisation of material. The detailed recording of just one such event would tell the judicious analyst far more than four years of unfocused and purposeless gathering of probably meaningless data. Moreover, such observation results would quickly lead to the formulation of alleviating measures. For example, if it were found that most of the degradation occurred in the early part of a rain episode and is attributable to a flushing with nitric acid, then it would be possible to avoid most damage simply by closing down emissions several hours before rain. Since most rains occur during a brief spell in the monsoon period, Woodside could easily schedule this period for annual maintenance shut-down, or for the periodic repairs or construction works entailed in the normal operation of such installations.

I am of course not suggesting that this is the correct solution, I merely use this example to show that we must not make assumptions about the relevance of specific empirical indices. All we know with certainty is that there was deterioration of the accretions since the late 1980s, because this has been monitored over decades and is quantifiable. We also know, from my work, that the micro-morphology of the accretionary deposits in the Pilbara is heavily influenced by precipitation. The core issue, then, is one of geochemistry. Emissions are the most obvious culprit, but it seems perfectly possible that factors or catalysts we have not even considered are contributing, or are even crucial. In science the solution to a problem can come from even the most unexpected direction. If we work from the assumption that only long-term average exposures are relevant, as the terms of reference in this project stipulate, we may not just be limiting the effectiveness of the project (if the short-term event peaks were the problem), we may render the entire project ineffective. And we may miss a rare opportunity to conduct badly needed basic research into this generic subject area of iron-rich mineral crust deterioration resulting from industry.

There are still other objections to the research proposal. The accelerated weathering study ('fumigation') is likely to lead to severely misguided pronouncements about the effects of exposure to various gases. It does not simulate the natural exposure conditions, but will extrapolate from the probably negligible effects of fumigation at multiples of concentration. If the gaseous emissions have little or no effect in the absence of water, as may be the case, what is the point of demonstrating that they have also little effect at twenty times the predicted concentration?

Of particular concern is the proposed methodology of monitoring colour changes in the accretionary ferromanganous deposits. As indicated in the above terms of reference, it is proposed to use a BYK-Gardner spectrophotometer with a 4 mm aperture opening for this purpose. Therefore the instrument proposed is the 45/0 model, catalogue number CB-6807. This instrument is designed for manufacturing processes, e.g. of plastics products. It is highly sensitive to extreme conditions of temperature and relative air humidity, and cannot be operated either above 42°C or above 85% relative humidity — conditions that both occur commonly in the Dampier region. Moreover, the instrument is very imprecise, with a spectral interval of 20 nm, over a spectral range from 400–700 nm. Hence it does not even cover the full range of visible light. Indeed, Gardner call it a 'colour guide', a much more appropriate description than 'spectrophotometer'. The impression that an unsuitable methodology has been proposed is reinforced by the description of how the sampling site will be re-located (not 'relocated'): digital photographs will guide this process. Yet the baffle surrounding the aperture is of about 12 cm diameter. First, it will be physically impossible to re-locate the baffle so that the original sampling site is targeted 'to within a millimetre', as stated. Second, it should not be approximately re-located, or within a millimetre, it must be precisely re-located, otherwise the result can only be imprecise, if not meaningless.

What amazes me most about this methodological blunder is the fact that a vastly more accurate method of colorimetry is available. It was designed precisely for measuring changes in rock art, it has been published, and has been used in the Dampier Archipelago for many years. The colorimetric method I have developed specifically for rock art is much more accurate, simpler and cheaper, and I have used it not only at Dampier, but also elsewhere in the Pilbara (notably on repatinated inscriptions at Spear Hill) as well as on red pigment in Mladeè Cave, Czech Republic, on petroglyphs in Saudi Arabia, and elsewhere. In this method with its spectrum of over 16 million colours, the spatial sampling accuracy is well under 100 microns. It requires no expensive American gadget and measures colour change with much greater precision, by relying on aliquot readings rather than single but questionable values. Moreover, because calibrated photographic records can be included to determine earlier colour changes, the duration of the monitoring period can be extended to the earliest such records we have. They are in this case of 1968, so in 2008 they will provide coverage of the highest accuracy for a total of forty years, whereas the results of this government endeavour will cover just 10% of that duration, at vastly inferior accuracy, at massive cost (hundreds of thousands of dollars), and yield results which I can only reject: I remain unconvinced that the Gardner instrument is even remotely suitable for this task.

Why, then, this unfortunate choice of methodology? The answer is simple. This Rock Art Committee does not include a single rock art researcher, or even a specialist in accretionary mineral crusts. This is despite the fact that such expertise would have been available in Perth, and amply available in the eastern states of Australia. The committee is unaware of previous attempts to measure rock art deterioration by spectrophotometry or spectrometry, which were unproductive or inconclusive, and which were the very reason why I opted for digitised colorimetry a long time ago. The exclusion from this project of rock art specialists is deliberate, as shown by the simple fact that all four studies were awarded to a single government agency (CSIRO) that, significantly, has no previous track record in rock art research or rock art conservation. Having conducted all previous analytical work on the Dampier rock art, and having prompted this project, I find it sad that I was not consulted on any aspect of its design. Its mistakes were all avoidable.

Therein lies the problem: this is not an attempt to resolve the issue, but a political whitewash and a measure to procrastinate further. I predict that the results of this project in 2008 will be inconclusive and unreliable, and that the main finding will be that CSIRO will require further funding to continue the work. Meanwhile the government expects to continue its destruction of the Dampier rock art, bulldozing many more sites, and permitting the huge petrochemical industries to belch out ever more acidic emissions, at the rate of tens of thousands of tonnes per year. And all the while, the alternative Maitland Industrial Estate remains unoccupied.

Footnote: the International Federation of Rock Art Organisations (IFRAO) will this year expand the monitoring and inventorying program I began in the 1960s, and prepare the documentation and data required for the establishment of a National Park in the Dampier Archipelago.

Please visit the Save the Dampier Rock Art site at
http://mc2.vicnet.net.au/home/dampier/web/index.html