KEYWORDS: *Conservation – Termite – Methodology – Rock painting – Torres Strait*

ROCK ART CONSERVATION AND TERMITE MANAGEMENT IN TORRES STRAIT, NE AUSTRALIA

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Abstract. In the late 1960s, a small termite nest was documented at the base of the Kabadul Kula rock art site, on the island of Dauan, northern Torres Strait, Australia. Sometime between 2000 and 2004 the nest grew dramatically — advancing approximately a third of the way up the north face of the boulder and wholly or partially covering several highly significant and unique rock paintings. In response to concerns of the Dauan community, a joint project involving archaeologists, a professional fine art conservator specialising in the preservation of rock paintings, and a CSIRO termite specialist was undertaken to remove the nest and re-expose the fragile rock paintings. Building on the work of earlier researchers, we describe a detailed removal methodology as well as eradication methods to deal with this well-known problem. Among the key outcomes from this project was the successful recovery of previously documented motifs as well as other, unknown motifs, covered by the nest prior to recording in 2000.

Introduction

Rock art is faced with a host of natural and anthropogenic threats. Attempts to conserve rock art in the face of such threats has taken many forms such as artificial driplines (e.g. Gillespie 1983; Lambert 1989), artificially controlling climate (e.g. Brunet et al. 1995; Schwartzbaum 1985), developing methods for removal of graffiti (e.g. Bostwick and Dean 2000; Ford 1995; Thorn 1991a, 1991b) and lichen (e.g. Tratebas and Chapman 1996), construction of shelters or houses for open air sites (e.g. Wainwright et al. 1988; cf. Bahn et al. 1995), and restricted or complete closure of sites (Bednarik 2001: 102). Conservation and management of Australia's rock art sites has remained an important priority for many groups, especially Indigenous communities and heritage managers. The success of programs such as the Australian Institute of Aboriginal and Torres Strait Islander Studies (AIATSIS) *Rock Art Protection Program* (Ward 1992; Ward and Sullivan 1989) and important contributions by researchers such as Rosenfeld (1985), Pearson (1978), Ward and Ward (1995), and Thorn and Brunet (1995) into the nature of various forms and remedies in the deterioration process have been critical to the conservation of many threatened and deteriorated sites across Australia (and elsewhere around the world). However, the last decade has seen a relative lack of published advice on physical conservation of sites compared to the 1980s and early 1990s (see Hall 1999). In particular, little detailed attention or guidance has been provided to those seeking effective, or fine-grained solutions to problems caused by mud-daubing insects (e.g. termites and mudwasps).

This paper re-orients attention towards methods involved in the conservation of rock art by presenting the results of a conservation project aimed at removing a large termite nest attached to a painted rock face at the Kabadul Kula rock art site on the island of Dauan in far north-east Queensland. A request from the Dauanalgaw community to preserve the rock paintings (many of which had become obscured as a result of the nest) resulted in a comprehensive methodological approach incorporating archaeologists, a professional rock art conservator and a CSIRO (Commonwealth Scientific and Industrial Research Organisation) termite specialist. As rock art sites in many parts of the world continue to be faced with damage caused by mud-daubing insects, this paper provides a detailed methodology for rock art researchers, heritage managers and Indigenous communities to consider when dealing with issues of termite encroachment at rock art sites.

Rock art and termite management research

Partial or full concealment of rock art as a result of mud structures created by mud-daubing insects such as termites and mudwasps is well-known to rock art recorders, conservators and site managers. While the scope of this paper is restricted to dealing with damage caused by growth of a termite nest at a rock art site in tropical far north-eastern Australia, the methods for dealing with this problem have important implications for other termite-infested sites around the world (see Bednarik 2001: 105–106). In northern Australia, concerns for painted panels covered by termite nests (including runways or 'runners') at well-known rock art sites in Kakadu National Park and south-eastern Cape York Peninsula have been voiced for over two decades (e.g. Hughes and Watchman 1983; Naumann 1983; Rosenfeld 1985; Rowland et al. 1992; Watson and Flood 1987). Three key concerns associated with termite damage are: (1) termite nests (or mounds) and covered runways completely or partially concealing painted panels; (2) disturbance of potential archaeological deposits directly below the nest (cf. Watson and Abbey 1986); and (3) placement of paintings over runways which collapse with termite removal or disuse over time.

Early conservation work at rock art sites in northern Australia provides few details into effective methodologies for the removal of nests created by mud-daubing insects — in most cases these methods result in damage to rock paintings. For example, at Ubirr in Kakadu National Park, it was found that some mudwasp nests could be 'removed whole leaving very little residue and without lifting any pigment or rock', while others 'may leave extremely hard residues or even detach paint and rock' (Hughes and Watchman 1983: 50). Naumann's (1983: 179) research into removal strategies for termites (also at Kakadu rock art sites) consisted simply of locating and destroying the central nest 'with the aid of pesticides', while mudwasp nests could be removed 'during the humid months, when they are the softest'. Naumann (1983: 183) suggests '[w]ater plus detergent is most effective in further softening nests, but its use may damage art' (the use of detergent is no longer considered necessary or sensible by the current authors as it leaves a residue on the rock wall that will become apparent over time).

Watson (of the CSIRO Division of Entomology) and Flood (1987) provide the most detailed (and most commonly cited) study into damage caused by termites based on work at Green Ant Shelter 1 in the Koolburra Plateau, Cape York Peninsula. In their paper, they recount instances where termite nests attached to rock walls were removed: '[w]here mounds of *C. acinaciformis* had been removed from the rock faces, as at Green Ant Shelter 1 (K1), it was evident that any paintings that had been present behind them had been destroyed, although engravings had survived' (Watson and Flood 1987: 22)[1]. They also noted how one small nest built by *Termes cheeli* rapidly 're-established itself in the centre of the decorated back wall at Green Ant Shelter 1 between July 1981 and 1982', although they continue to note that this was 'probably due to the fact that the nest had not been properly destroyed' (Watson and Flood 1987: 25). Watson and Flood provide the only published methodology for the removal of termite nests: (1) remove all mounds (nests) near to the rock face and destroy the queen; (2) destroy all nests present in trees within 50 m of the site; (3) revisit the site one year later to check for re-establishment; (4) repeat inspections every two to three years; and (5) do not remove runways as this might encourage new runways that further obscure the images (see Watson and Flood 1987: 21 for details). Chemical barriers consisting of insecticidal emulsion were discounted owing to their toxic nature, cost and environmental impact (cf. Bednarik 2001: 99). However, as we discuss below, a range of new methods to control termite infestations, including removal strategies first used in another context by one of us in 1988 (Thorn 1991b; see below), supersede these earlier methods.

The major problem associated with any nest removal technique is the potential for damage to fragile rock paintings (i.e. removal of paint). Watson and Flood (1987: 26) commented that '[f]ortunately removal of termite nests is not a difficult task nor does it require any technical knowledge, although of course every care must be taken that neither the rock art nor any other artefacts or occupation deposits present are damaged in the process'. We agree with Watson and Flood that damage to cultural artefacts (e.g. rock art), and occupation deposits should not occur during the process of removing a termite nest; however, we would argue that a high degree of technical knowledge, understanding, and skill associated with the delicate task of removing the carton and residue attached to paintings is of critical importance to the preservation of painted matter on the rock surface.

Torres Strait rock art and termite damage

Detailed documentation of western and central Torres Strait rock art began in 2000. Since then, over sixty known and previously unknown rock art sites have been recorded as part of collaborative, community-based research projects with individual Islander and Aboriginal communities (e.g. Brady 2005; David et al. 2004; McNiven et al. 2004).

Unlike the Koolburra Plateau, where Watson and Flood (1987: 17) state that termites were the main conservation issue affecting rock art, only two rock art sites in western and central Torres Strait (on the islands of Dauan and Badu) have been documented with a termite nest attached to the rock face, although several other sites (e.g. on the islands of Pulu, Badu and Mua) feature termite nests located in close proximity (less than 1 m) to painted rock walls. Termite 'runners' have yet to be recorded damaging any rock paintings in the archipelago. The other major forms of damage are natural (e.g. algae/lichen/fungus growth, granular

1 If any paintings had been present behind the mound prior to removal in 1982, no record of them exists. During their work in the Koolburra, no attempts were made by Watson and Flood to pull off, or remove, any nests that were partially obscuring painted panels or where nests were covering known or previously documented paintings (Flood, pers. comm. 2009).

disintegration, mudwasp nests, dust, salt and water damage, and heavy weathering due to the harsh coastal tropical climate).

Dauan Island and the Kabadul Kula rock art site

Dauan is located in the Top Western Group of islands and is situated approximately 10 km south of the Papua New Guinea coastline (the Australian border runs immediately to its north) (Fig. 1). The island's landscape is dominated by a granite boulder-strewn mountain with a village situated on the north-east coast. Geologically the island comprises part of the Badu Suite of granites of Late Carboniferous – Early Permian age (Von Gnielinski et al. 1997).

Kabadul Kula (Dauan 1) is the northern-most rock art site documented in Australia (Fig. 2). The site is a large biotite granite boulder (length = 8 m; height = 5.5 m) situated on a flat, grassy area approximately 30 m from the coastline, and a five-minute walk north of the village. The site has been recorded sporadically since the 1950s by anthropologists (Beckett 1963; Laade 1971; Lawrie 1970), archaeologists (Vanderwal 1973) and schoolteachers (Teske 1990).

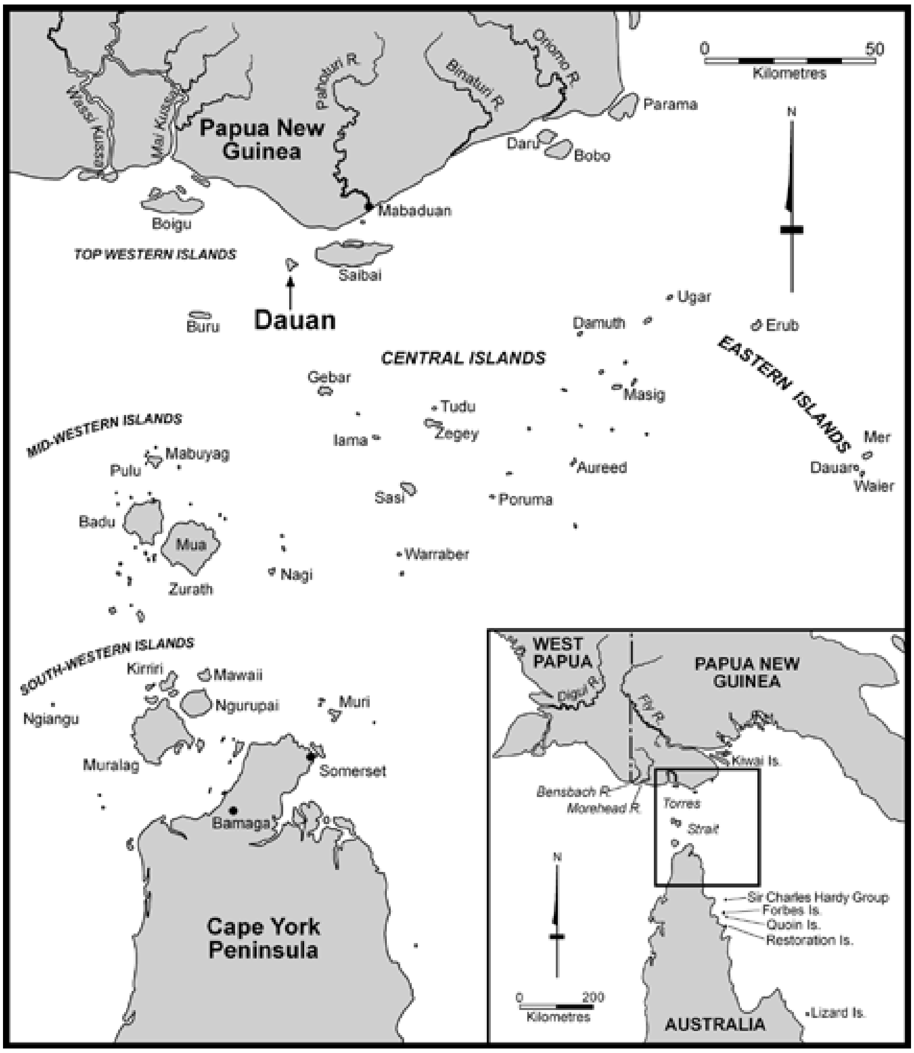

Figure 1. *Map of Torres Strait, north-east Queensland.*

The site was systematically documented in April 2000 by Ian McNiven, Bruno David and John Brayer as part of a recording project using digital photography and computer enhancement techniques. This initial study revealed a total of 44 red paintings (McNiven et al. 2004), although re-recording of the site in 2004

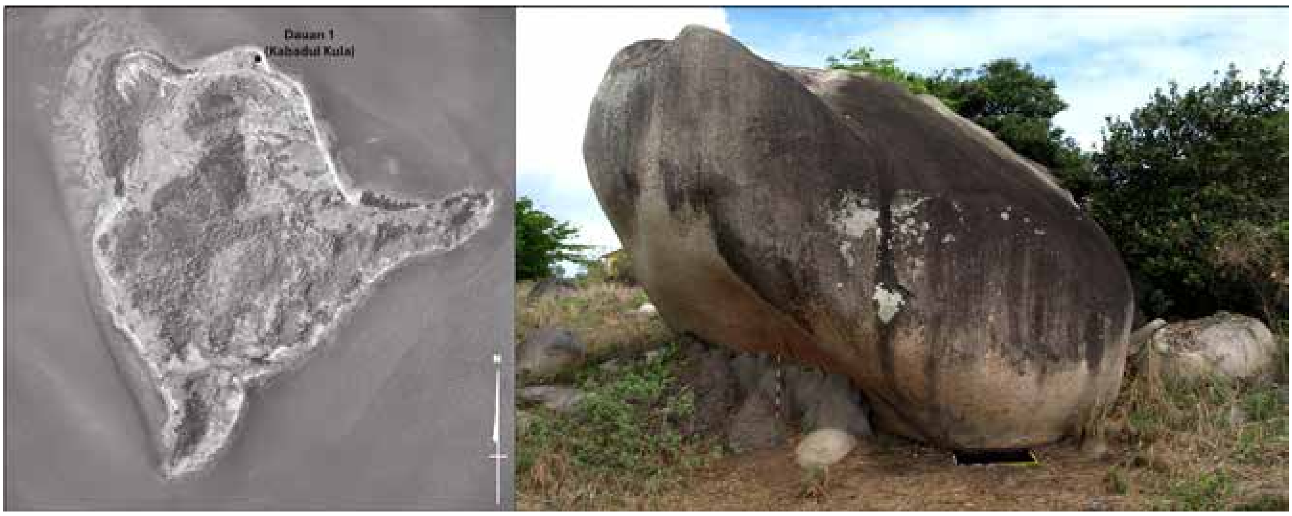

Figure 2. *Left: aerial photograph of Dauan; right: Kabadul Kula rock art site (excavation pit located in bottom right of photograph).*

***Figure 3.** Left: Theo Evans collecting termites from the nest during removal; right: close-up of termites from the nest.*

using a higher-resolution digital camera (see below) detected three additional, heavily deteriorated red paintings, bringing the total number of images to 47 (Brady 2004, 2005). Two panels of paintings have been recorded on the northern and north-western faces of the boulder (under overhangs 3.5 m deep and 0.5 m deep, respectively) associated with a low-density surface scatter of quartz artefacts, and *Anadara antiquata* and *Polymesoda erosa* shell fragments. Damage recorded at the site in 2000 included exfoliation, lichen growth, rainfall runoff, vegetation abrasion and fire, natural weathering, and a termite nest at the base of the northern rock art panel (McNiven et al. 2004).

Kabadul Kula is significant at two levels: (1) to the local Dauanalgaw community; and (2) as a key site for studying the cultural history and interconnectivity of islands and mainlands in the region. McNiven et al. (2004: 230) recently noted that members of the Dauan community consider Kabadul Kula to be 'a special place' and one which has 'strong cultural significance for the entire Dauan community'. Furthermore, during discussions surrounding this conservation project, Dauanalgaw Elders stressed the importance of this site as a part of their cultural history, and reiterated their desire to see the rock paintings preserved for future generations. Today, Kabadul Kula continues to be engaged with by Dauanalgaw through regular visits, and more recently through a special dance, performed by schoolchildren, commemorating dramatic historic events that took place at the site.

The site is one of the only rock art sites in Torres Strait linked to oral tradition. In 1968, Margaret Lawrie recorded a narrative about headhunters from Kiwai Island (at the mouth of the Fly River of Papua New Guinea to the north-east) painting pictures on Kabadul Kula while waiting for dawn to launch a raid on the village (see Lawrie 1970: 143–147 for details). While this narrative does not provide any indication as to *which* paintings the Kiwai produced, it does shed light on the origins of some of the paintings at the site, and the credit of authorship of some images to a Papuan group.

From an archaeological perspective, Kabadul Kula's rock paintings yield key data regarding interregional connections with neighbouring islands and mainlands. Artistic links involving distinctive design conventions such as a four-pointed star design, concentric circle eyes tapering to a sideways-facing triangle, concentric ellipse-shapes, and fish headdresses have been found in painted motifs from Kabadul Kula, and decorated material culture objects and scarification designs from Papua New Guinea and Torres Strait (e.g. Brady 2005, 2006, 2008; David et al. 2001, 2004; McNiven et al. 2000, 2002, 2004).

Termite nest

The termite species most likely responsible for the nest at Kabadul Kula is *Nasutitermes magnus* — one of several closely-related species which share a very similar biology and are all capable of building nests and causing the same sort of damage (Fig. 3). This species differs from *Nasutitermes gravelous* which Watson and Flood (1987: 22) noted 'was the most common termite on the Koolbura rock art, being present in eighty-seven percent of the shelters examined in the entomological survey'. *N. gravelous* is a wood-eating species that builds nests in the branches of trees[2], while *N. magnus* is a grass-eating species that builds ground nests (see below). The size of the nest observed at Kabadul Kula suggested that the species was *N. magnus*. The workers (one of several castes in a termite colony evolved to specialise in different roles, e.g. soldier = defence, nymphs = reproduction, workers = foraging, building and care for dependents; see Watson and Flood [1987] for a detailed discussion on the biology/habits of termites) are responsible for foraging and building the

2 Hence the recommendation by Watson and Flood (1987: 24) to 'destroy any nests of *Nasutitermes gravelous* present on trees within approximately fifty metres of the artwork, including trees on ground above the rock face'.

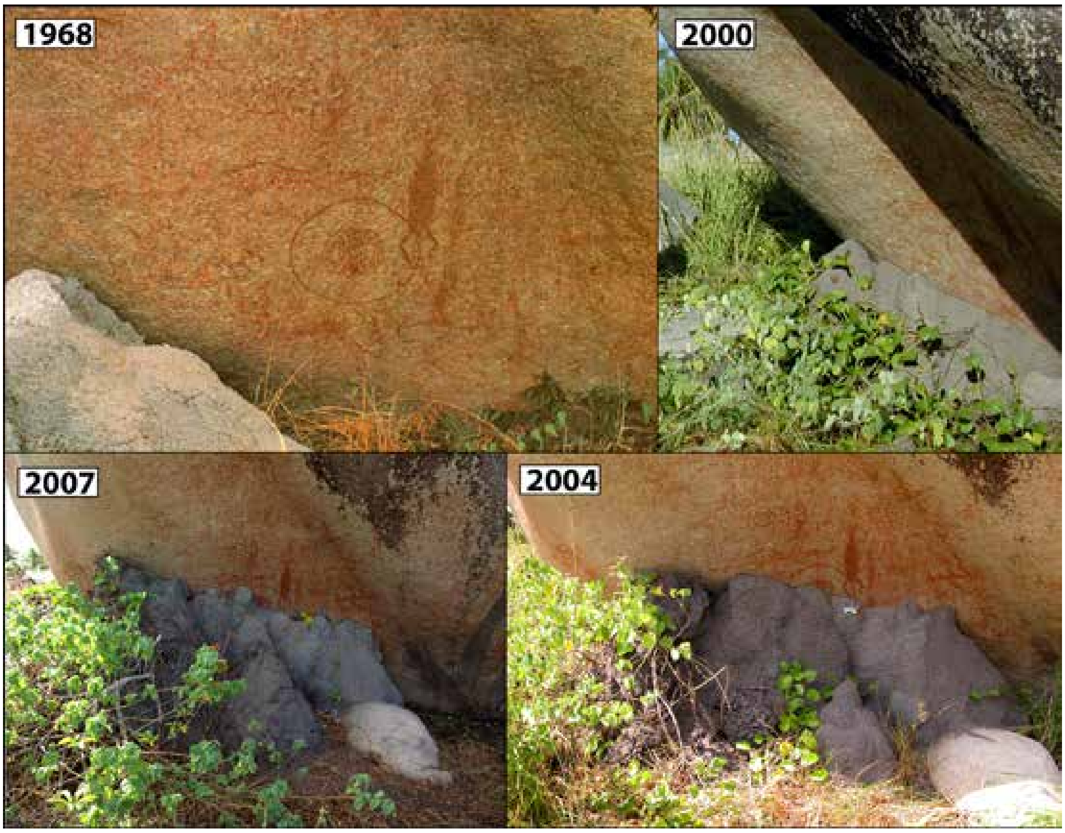

Figure 4. *Development of the termite nest: (clockwise from top left) 1968 Margaret Lawrie photograph (1970: 145) (reproduced courtesy of the John Oxley Library); 2000 photograph during first systematic recording by McNiven et al.; 2004 photograph; 2007 photograph prior to removal of the nest.*

nest. *N. magnus* workers are grass harvesters (viz. they eat dead grass leaves) and build epigeal ('upon earth') mounds constructed of loamy material with faeces and saliva as adhesive.

Growth of the termite nest can be tracked for the past 40 years using photographs (Fig. 4). Analysis by McNiven et al. (2004: 250) of the 1968 Margaret Lawrie photographs (1970: 145–146) revealed that 'while well formed, [the nest] was set out a little from the wall and may have only been touching the wall midway between the *dogai* … and the concentric circle painting'[3]. No paintings appeared to be affected by the nest at this time. Subsequent photographs of the site and nest over the next three decades reveal slow growth, although there is a lack of any close-up photographs of the nest itself. By April 2000, McNiven et al. (2004: 250) reported that the nest had grown 'considerably along its W side' and had 'expanded some 30 cm to make contact with the wall' and become perilously close to the visually dominant motifs on the northern panel. They also noted the rapid growth of the nest in a follow-up visit in August 2000 by stating that '[a] new addition to the surface of the nest since our recording visit 4 months before had resulted in burial of an area of painting approximately 10 cm × 1 cm' (McNiven et al. 2004: 250).

The most intense period of growth occurred between 2000 and 2004. A return visit to the site in April 2004 revealed a massive growth resulting in a substantial portion of the lower third of the northern panel being covered by termite nest (Figs 5a, 5b and 6). The light grey-coloured nest had expanded to completely cover a number of significant paintings: three anthropomorphs drawn 'standing' on a curved line, two smaller linked anthropomorphs, a mushroom-shape, and a set of parallel lines. In addition, the nest partially covered several other images: the large concentric ellipse-shapes contained in a circle-variant, an anthropomorph and other indeterminate designs. Upon visiting the site in November 2007, a new phase of nest building had begun eastwards towards the distinctive *dogai* painting (c. 15 cm from the fingers on the right hand). Overall, the nest measured c. 1 m high × 3.75 m wide.

After consultation with Dauanalgaw Elders regarding conservation options for the site, funding was obtained from the Department of the Environment and Water Resources through its National Indigenous Heritage Program to begin conservation work at the site. In conjunction with the conservation work, an excavation was carried out directly below the north-western panel to learn more about the history of the

3 A *dogai* is an ugly and potentially dangerous female spirit figure with big ears and features prominently in the oral traditions of Torres Strait Islanders (see e.g. Lawrie 1970).

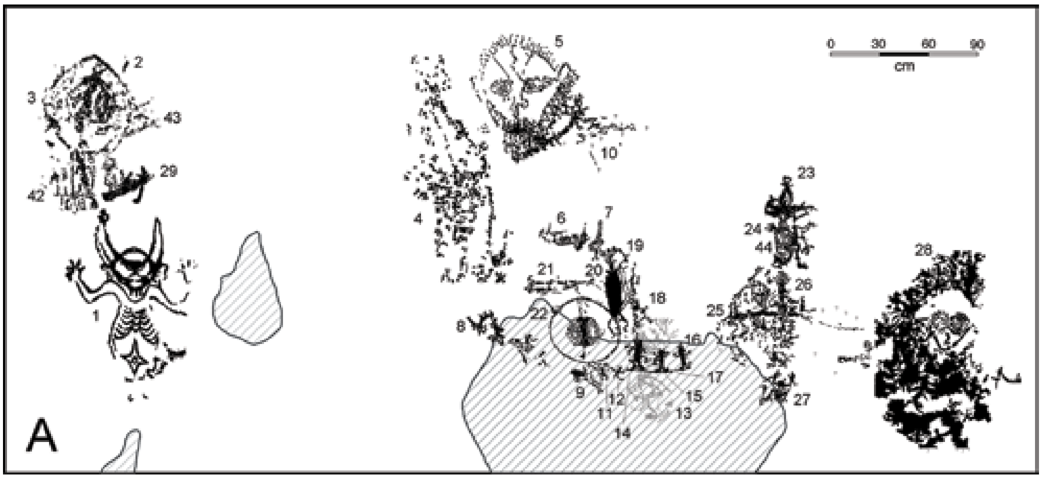

Figure 5a. *Northern panel indicating locations where termite nest was attached to the rock-face.*

Figure 5b. *Nest attached to the rock-face: (left) eastern end; (right) western end.*

site and possible antiquity of painting production (see McNiven et al. in press).

The conservation process

The conservation of Indigenous rock paintings and petroglyphs follows standard internationally-adopted procedures for the care of cultural heritage places (AICCM 2002; Australia ICOMOS *Burra Charter* 1999). The current conservation project is shaped by the two equally-matched guiding tenets of the conservation profession: (1) intervention shall be minimal; and (2) no action shall be undertaken that is considered damaging to, or compromising, the surviving integrity of the cultural material.

Minimal intervention applies both to preservation procedures, in this case the removal of the termite nest, and to how the painting is ultimately presented to the viewer. Minimal intervention ensures that only those processes required to recover or preserve the image are implemented and that other, more cosmetic considerations such as the removal of dust or accretions that do not obscure or confuse the reading of the image are not undertaken without a sound basis. In a museum context, presentation of images not produced on rock often involves reintegrating missing parts of an image to make sense of the creative intent. However, such actions are rare in the conservation of rock art and can usually only be justified when traditional custodians or others entrusted with the maintenance of such sites wish to see a whole image restored — this is not a decision that is made by the conservator[4].

The conservation profession is bound by codes of ethics (AICCM 2002; Australia ICOMOS *Burra Charter*

4 In 1994–5, Thorn undertook the removal of displaced pigment obscuring underlying paintings at Yuwengayay in Kakadu National Park. The decision on what constituted wash and what was original painting was decided by the custodian who directed the entire procedure. Displaced pigment was first removed only from outside distinct images. Once this was completed the custodian directed that select inner surfaces be worked on further where displaced pigment lay directly over original paint.

1999) to ensure that any treatment is not damaging to the cultural artefact and in this aspect a judgement must be determined of what constitutes acceptable damage. *If fragile paintings covered by a termite nest cannot be returned to a readable state, then under the conservation profession's guiding principles they should be left covered until more advanced technologies are developed*.

As part of the treatment proposal a complete condition survey of Kabadul Kula was undertaken by the conservator. This survey addressed environmental and physical impacts, documenting the overall condition of the visible rock paintings while working closely with archaeologists and community members to gain an understanding of the extent of paintings and the recent spread of the nest. This condition survey ensured that the removal process operated within a broader understanding of the condition and constraints of the whole site and its surroundings. The need for this broader view of the site is illustrated by the location of a helicopter pad approximately 25 m southwest of the site (and its potential impact for dust accumulation) and vegetation cover. Ignoring the close proximity of air transport to the site may have led to pointless dust removal, especially if the dust was immediately blown back into the site during the next landing. There was a similar joint consideration when assessing sun impact at the site affecting the stability of the rock. Not only will a proposed shade canopy reduce hydrothermal impact but also provide more comfortable natural viewing conditions for the community. The conservation process also involved community engagement where community members were informed of the removal process, and the progress of the work, as well as other discussions regarding future management options for the site.

Figure 6. *Close-up of termite nest covering large circle variant motif.*

Removal method

Very little guidance has been published for the removal of termite nests but it is a familiar problem to the conservator. The removal of termite tunnels (covered runways), mudwasp nests, bound dust, displaced pigment and charcoal has been undertaken at many sites in Victoria, Western Australia, Queensland and Kakadu National Park in the Northern Territory. The general principle developed — and applied at Kabadul Kula — is common to all types of loosely bound granular material (Thorn 1991, 2006, 2008).

The sequence of decision making and implementation followed was:

1. Method confirmation
2. Method refinement
3. Pilot of full process on confined area
4. Remove bulk of nest to within 50 mm
5. Dry removal of remaining cell wall structure to expose attachment layer
6. Removal of remaining carton layer using acetone/water mixture
7. Dry brushing of exposed rock and painting to remove all excess loose dust
8. Wet brushing of surface to remove all remaining bound carton

Method confirmation

Previous work has determined two approaches useful to the removal of loosely-bound materials at rock painting sites:

(1) The 'rolling poultice' or moist swab technique (Thorn 1991a) involves the use of a moist rolling swab to pick up particulate matter without applying any sideways abrasive movement (Fig. 7). Water has a very high surface tension (polarity) and can act as a very strong 'magnet' for such particles. To trap and lift the particles, a cotton wool wad is formed on a chopstick to make an oversized cotton bud. The bud is dipped in water just enough to moisten it but not to the point where water flows

Figure 7. *'Rolling poultice' or moist swab technique.*

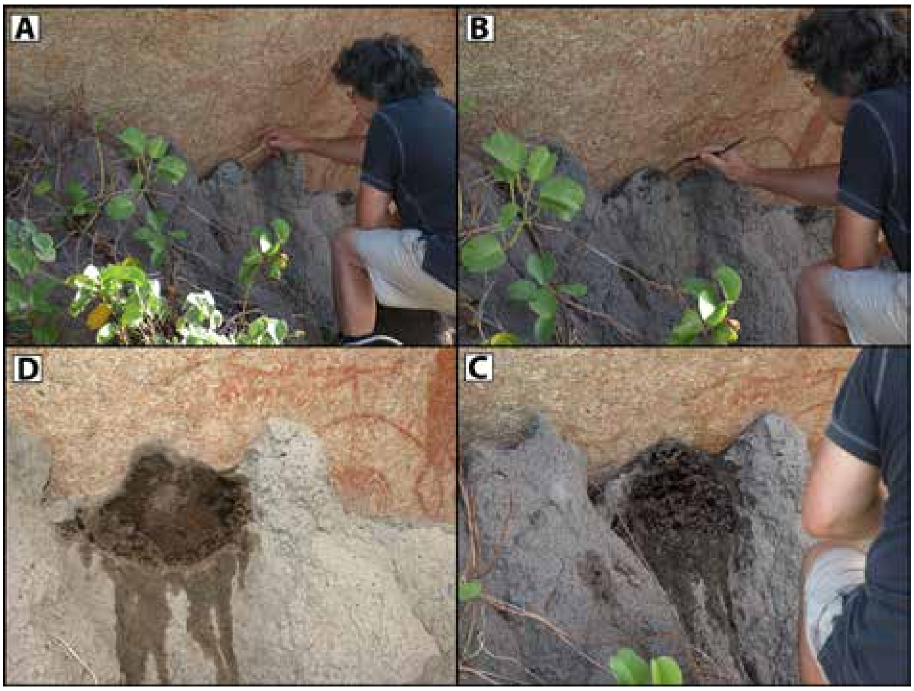

Figure 8. Method assessment (clockwise from top left): A, applying the solvent using a disposable pipette; B, removing a small section of the nest with small trowel; C, inner honeycomb structure after soaking with solvent; D, remaining dark, thin attachment carton level.

from the cotton when applied to the surface. This is a critical requirement as any released water has the ability to redeposit displaced particles into the surface or into new areas not previously covered by residues in such a way that they can no longer be picked up by the moistened cotton wool. This technique has been used for the cleaning of fragile paintings for many years, and has been developed by one of us (Thorn) for broad-scale use on rock paintings for the removal of powdery graffiti, charcoal, displaced pigment, and various other loose materials. This technique has been used to remove an unauthorised repainting of Bunjil's Shelter, Victoria (Thorn 1991b) and for the removal of displaced original paint at the Yuwengayay site in Kakadu National Park (Thorn 2006).

(2) The second method relies on the ability of mildly diluted acetone to break down termite carton and other mud nests into a crumbly consistency, which lessens the mechanical action on the underlying paint. The technique applies particularly well to termite carton and has been developed by Thorn through repeated practice in removing termite tunnels from rock paintings in Kakadu National Park and larger mud-insect nests elsewhere. Using water alone to try to break down termite carton creates a slurry that is drawn further into the surface of the underlying rock. Alternatively, acetone is a highly volatile solvent and alone will evaporate from the carton very quickly, especially in tropical conditions (although at present there is no immediate explanation for how this works). However, when acetone was diluted with approximately 10% water evaporation remained slow, and the nest remained friable until it could be removed with a blunt dental pick. The slight water content did not create a slurry but kept the carton in the desired friable condition. In this state the carton crumbles from the wall with slight pressure and the tool rarely makes contact with the rock surface. Too much water in earlier trial mixtures resulted in a slurry of mud forming — a situation that must be avoided for reasons described above.

A small section of the complete nest comprising the light-grey thick outer casing, darker-grey inner honeycomb/carton structure (bulk of the nest), and thin dark-brown attachment carton level was removed to confirm the full method (Fig. 8). The attachment carton has been characterised as different from all other aspects of the nest by being much darker in colour and in particular, to be far more bound to the rock surface by means of termite faeces and saliva binders (see for example Fig. 10, left).

The only sections of the paintings that were unstable were some brighter red spots located near the eastern end of the nest (close to the *dogai*), which have the characteristics of more recently applied paint. These were the only sections requiring the rolling poultice approach. The rest of the surface was considered durable enough to withstand both water and brushing in the manner described below.

During the mechanical removal of the carton within the trial area, careful attention was paid to confirm whether any of the nest had bound-in pigment. This was assessed visually with the aid of a handheld microscope with 30× magnification. It was inevitable that the initial dry removal of carton down to the darker attachment layer would cause the outer carton to break away from the surface. This action could easily pull the painting away but this was not observed during the removal process. As a consequence there was no need to consolidate the painting during the removal process.

Method refinement

Once the method was successfully trialled, further refinements were required as the work proceeded. This was the case with the solvent ratio, and in particular the following sequences of dry brushing and wet brushing.

Figure 9. *Bulk removal of the nest: (left) eastern end; (right) main bulk of nest under the northern panel.*

Figure 10. *Removal of the inner 50 mm protective buffer zone with small hand tools down to the thin layer of attachment carton (see also Fig. 9, left picture).*

Pilot of full process

Two areas were worked to full completion to demonstrate the final result and ensure that the proposed sequence of work was appropriate and could be scheduled in the right order. One of these trial areas revealed the unstable nature of the brighter red areas at the eastern end of the nest, and these were partitioned off for future, more careful treatment using the moist swab technique (see Fig. 7). These areas were so unstable that the pigment itself was only lightly cleaned, although the surrounding, unpainted surface covered by the nest was given a thorough cleaning.

Bulk removal of nest

Once the process was established clearly, the bulk of the termite nest was carefully removed with shovels and trowels to ground level. Penetration of the ground surface was not attempted to ensure that any cultural deposit below ground remained intact. While aware of the extremely high likelihood of the deposit being disturbed by termites, there was no need to do any further damage. Nearly three tonnes of removed termite nest was disposed of at a location 30 metres west of the site. The nest was reduced to a thin layer c. 50 mm thick, which remained attached to the painted surface (Fig. 9). There was no risk to the painting or rock surface during the bulk removal due to the very friable nature of the inner honeycomb structure.

Removal of the inner 50 mm

The use of a shovel was considered safe during the bulk removal phase, provided this 50 mm-thick inner protective buffer zone was maintained. The remaining thin wall, which consisted of the innermost honeycomb structure, was then removed down to the thin black layer of attachment carton using smaller hand tools (e.g. small trowels) (Fig. 10). This last remaining black layer could not be removed dry without risking pigment loss.

Removal of attachment layer with solvents

Perhaps the key to a successful result has been the understanding that even well-bound carton can be softened and removed quite safely if first soaked with acetone. Dilution with water slows the evaporation dramatically and a final mixture of 9 parts acetone to 1 part water gave the desired soaking time. Soaking with this mixture caused the whole nest material to become quite friable and yet when dental tools were applied to remove the residue it was already moderately dry and unlikely to become absorbed into the rock surface (Figs 11a and 11b).

The solvent was applied through a small disposable pipette and while this made for slow application, it ensured there was no excess of solvent applied to the surface. Normally the residue is picked from the surface using bamboo satay skewers or similar soft instruments but a steel dental tool was found quite safe. More firmly attached flecks could be removed with a scalpel.

Dry brushing

The final process in removing the absolute maximum of loose particulate matter is to either use the moist swab technique or rinse in a controlled manner. Prior to this step the whole surface, which still remained a powdery grey with the images obscured, was brushed using a short bristle brush (Fig. 12). A range of brushes is required as the exact stiffness needed to remove such powder can only be determined through experimentation. This

Figure 11a. Fine-grained removal of thin attachment layer using dental tools and acetone solution.

Figure 11b. Close-up of fine-grained removal of thin attachment layer.

process was applied twice across the whole 'ghost' (previously nest-covered surface) of the nest and made the previously obscured images substantially more visible.

Wet brushing

The pilot cleaning showed that the rolling moist swab provided the best clarity to the surface. However, on a larger scale it was found that this technique was time consuming and provided no better results than a more water-intensive rinse using a spray bottle and brushes. This revised technique of wet scrubbing using 15-mm-wide bristle brushes, once shown to be safe over all paint surfaces, was carried out twice over the nest 'ghost' area (Fig. 13). A third effort resulted in no change to the surface and no grey rinse water. Isolated areas were further picked off with a scalpel and rolling swab.

Figure 12. Dry brushing with a short bristle brush.

Final result

The final result was a measured success to the extent that no motifs were lost or damaged and all were clearly visible. The term 'measured success' is used in view of the fact that when no more nest residue could be extracted from the surface the outline remained faintly visible (Fig. 14). The previously nest-covered surface remained visibly greyer than surrounding granite surfaces, however, the overall impression of the site was that all images were now visible again. From a distance of 4–5 m (the normal viewing distance), the grey shadow of the previously covered area was not immediately discernible and certainly not disturbing, even at close range.

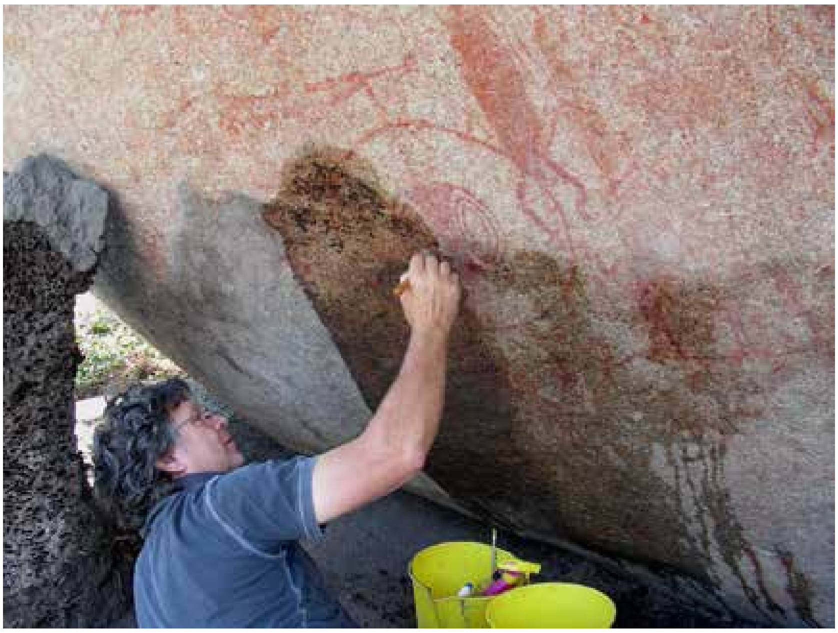

Figure 13. Wet brushing using spray bottle containing water and bristle brushes.

Figure 14. Final result illustrating removal of the nest, with a faintly visible outline that is expected to revert back to its natural colour with further exposure to sun and washing.

Figure 15. Left: preparing the ground surface for application of termiticide; right: discussing the application procedure with Dauan AQIS officer, Kevin Akiba.

Termite control and insecticides

While it is uncertain whether or not the king and queen termites (the primary reproductives in the colony necessary for the nest to be re-built) were killed during the project, there is a very high likelihood they were either killed or removed during the bulk removal process. Regardless of their status, application of the termiticide (below) would prevent any re-building of the nest.

Prior to the mid-1990s, efforts at preventing termite infestation and damage at rock art sites involved use of organochloride insecticides as soil-based barriers — the dominant termite control method at that time (e.g. Chaloupka 1978: 78). Watson and Flood (1987) discounted the use of chemical barriers using organochlorides owing to the toxic nature of the chemicals, cost and environmental impact (organochlorides were deregistered in 1995). However, at the time of their publication, Watson and Flood were unable to provide any recommendations regarding insecticides, since CSIRO were at the time undertaking experiments to provide safer and more environmentally-friendly alternatives to organochlorides.

Today, synthetic pyrethroid (SP) products are used widely to control termites and are based on natural plant insecticides (see Lenz and Evans 2003 for further details of methods to control termites). Pyrethrin, an organic compound, is derived from the seeds of a daisy (*Chrysanthemum cinerariaefolium*). Synthesising new products based on pyrethrin allowed the possibility of more desirable properties: more powerful insecticidal action (requiring lower quantities); and greater persistence (from days to years) due in part to better binding properties (e.g. to soil and timber) and resilience to ultraviolet light. Additionally, SP products have high insect and low vertebrate toxicity (meaning they are among the safest insecticides on the market today), and are both toxic and repellent to insects. Thus, when the dose degrades below a toxic level, it is still likely to remain repellent.

After the complete removal of the nest a diluted solution of water and Biflex® Ultra-Lo-Odour termiticide was applied to the ground surface of the site to create a residual toxic barrier around the site to prevent any re-infestations or re-growth of the nest (Fig. 15). Five square metres extending from the base of the northern panel were treated. The surface of the soil was roughened to a depth of c. 5 cm using a shovel (a rake can also be used) so the termiticide solution could penetrate the soil easily. Each square metre received a 5-litre-dose of diluted Biflex solution (ratio: 75 ml Biflex concentrate to 5 l of water). Rubber or vinyl gloves were used when mixing the solution, and the solution was applied to each square metre using a watering can. The termiticide will degrade to ineffective levels, perhaps as early as in five years and certainly by ten years, and then re-treatment required. The degradation rate is dependent on actual heat and rainfall experienced by the treated soil (faster in hotter/wetter and slower in cooler/drier conditions). Once the termiticide has been applied it is recommended that the site be monitored for any further termite activity (below).

Figure 16. *Left: heli-pad situated south-west of the site (rock art site located directly behind the tall bushes); right: helicopter taking off from heli-pad.*

Why was there a rapid growth of the nest?

The most plausible scenario for the rapid growth of the nest between 2000 and 2004 involves an increase in resource availability to the termite colony due to the construction of a concrete heli-pad foundation in close proximity to the site. The heli-pad was constructed in a grassy area c. 25 m south-west of the site, sometime between August 2000 and April 2004 (Dauan Island Council's [2000] Management Plan indicates it was targeted for construction in 2001, but there remains uncertainty as to the final completion date) (Fig. 16). This grassy area was prime termite habitat due to the large quantity of food (*N. magnus* is a dead grass harvester); it is highly likely one or more termite colonies were present in this area prior to building of the heli-pad. Construction of the heli-pad would have destroyed these colonies, thus removing the established competitors for the grass, and so allowing other nearby termite colonies to expand. Nearby colonies protected from human interference included the termite colony at Kabadul Kula. The short distance to the grass at the heli-pad area was well within the 50 m foraging limit for termite workers and soldiers, thus creating a high likelihood that the Kabadul Kula nest benefited from the heli-pad construction. Now that the termite colony at Kabadul Kula has been destroyed, a new competition vacuum for dead grass leaves has been created. Return visits to the site are planned over the next few years to establish whether another termite colony will benefit from this vacuum, thus testing this scenario.

Recovered images and computer enhancement

Following the successful removal of the termite nest, the entire boulder was re-recorded using an Olympus E-410 digital SLR camera (10 megapixels). Three sets of paintings were revealed:

(1) Those previously recorded in 2000 and that had become wholly or partially obscured by subsequent nest building.

(2) Those covered by the nest prior to the systematic recording by McNiven et al. (2004) and where no record exists of these images.

(3) Images not obscured in any way by the termite nest, but could not be recovered/discerned using older, lower-resolution digital cameras during the 2000 and 2004 recordings (3.34 megapixels and 5.1 megapixels, respectively).

Despite having carton and residue attached to the paintings for over three years, a detailed inspection of the first group of paintings indicates they remain in a relatively good condition. Images that could be discerned with the naked eye in 2000 were still easily visible, while those recovered using computer enhancement could still be retrieved using this technique.

The second group of paintings consists of six 'new' images: an anthropomorph, a complex linear design, a circle variant, a curved line, an infilled non-geometric and an indeterminate design (see Brady 2005 for definitions of terms). All images were heavily deteriorated (although it is unknown whether this was a result of differential weathering or due to the effects of carton and residue attached to the paint for approximately 35 years) and could not be identified without computer enhancement. Of particular note is the anthropomorph depicted in profile (Fig. 17), bent at the waist and the knees, and 'standing' on a curved line. This is the second occurrence of anthropomorphs on a line at the Kabadul Kula site, the other instance located c. 55 cm west and featuring three anthropomorphs in frontal view decorated with various 'dance ornaments' (e.g. rattles). McNiven et al. (2004) previously noted this distinctive design convention on a painted sago frond collected by Seligman (1905: 161) from Goaribari (Aird River delta, 125 km NE of the Fly River estuary) depicting anthropomorphs dancing on a line, and a pencil drawing by Sunday of Mabuyag of a composition of dancers drawn on a curved line.

A total of three paintings (a circle variant, a set of parallel lines, and an indeterminate design) constitutes the third group and were documented on the northern panel, bringing the total number of recorded images from the site to 56. The heavily deteriorated nature of these images and our inability to document them using earlier recording techniques indicates the importance of re-recording sites in-line with developments in technology, but also illustrates the considerable differential weathering of images on the northern panel.

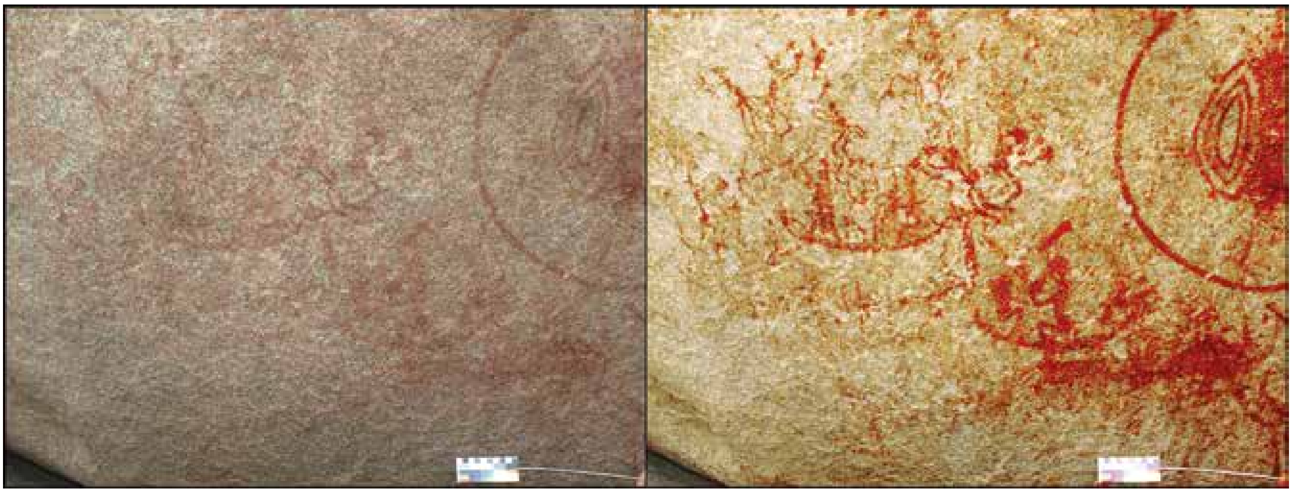

Figure 17. *Computer enhancement of images covered prior to 2000 recording and recovered after removal of the nest (original photo at left).*

Discussion

Conservation, archaeology and entomology

This project has been undertaken with four groups interested in the termites and their impact on the site:

(1) Dauanalgaw: concerned about the loss of previously visible images, and further threats to remaining visible and partially visible images.
(2) Archaeologists: protection of rock paintings, keeping cultural deposits intact and overall archaeological value of the site.
(3) Entomologist: concerned with ensuring that once removed, the termites do not re-colonise the site and cause further damage.
(4) Fine art conservator: concerned that the nest be removed from the rock with the least amount of damage to the painted surface; part of this process has required a risk assessment of damage already done, and potential for further damage that may be caused through the removal process.

Were the needs of each of the various groups met? And were there any potential conflicts between any of the four groups as the project was carried out?

The removal of the termite nest to expose the full extent of the painted surface has been determined to be of greater importance than any potential for gaining information directly from the rock paintings. If the community requests more information regarding dates for the Kabadul Kula rock paintings, there are many images which have not been directly impacted by the nest removal process. The application of water and acetone is unlikely to contaminate the surface to any extent through the deposition of carbon. This would normally only occur if residual materials such as waxes, resins or soaps are applied. One of the key benefits of using the moist swab technique, and all other techniques applied to Kabadul Kula, is that there is no organic residue left (see Thorn 1993 for a discussion of this issue in relation to preserving archaeometric evidence).

With regard to the archaeological sediments, there is an extremely high likelihood of termites disturbing or compromising cultural deposits located below the northern panel. However, as noted above, the excavation requested by the Dauanalgaw and undertaken by McNiven and Brady (McNiven et al. in press) prior to the conservation work can be used to shed more light on cultural activity (including painting activity) at the site.

From an entomological perspective, general health and safety issues are factors in this project — proper precautions must be taken (e.g. rubber gloves when preparing the termiticide). There is also a slightly negative aspect of soil disturbance with preparation of the ground surface for application of the termiticide. In some areas it may be advantageous to apply the termiticide by injection at the required spacings rather than raking or tilling the surface to a 5 cm depth. Furthermore, the application of chemicals into the soil will compromise the archaeological record and thus two issues must be considered: (1) excavations must be completed prior to any treatment and possibly some excavations that may not otherwise have a high priority may be initiated; and (2) the residual effect of the chemical must be known, both in treatment effectiveness terms and for deposit contamination reasons.

Pigments and stability

Previous researchers have commented on the stability of pigments in the context of weathering or fading. For example, Cook et al. (1990) have discussed the possibility that red paintings today may have originally been produced in yellow and subsequently changed colour through exposure to weather (this potential mutability and colour change of ochres was first proposed in Bednarik 1987, however), while Chippindale and Taçon (1998) remarked that red ochre (haematite) is usually one of the most stable and enduring pigments. Yellow ochres are not as chemically stable, while white (kaolin clay) pigments are the least stable on the rock-face and are usually the first to flake or fade away (cf. Clarke and North 1991; Thorn 2005). However, the issue of long-term fading and deterioration should not be confused with ease of damage.

From a conservation standpoint, the assessment phase of the treatment process is crucial in identifying stable or unstable pigments. Any unstable pigments would be dealt with by the conservator in a manner that would keep them in situ. If unstable pigments were present at Kabadul Kula prior to being covered by the termite nest, they must be preserved or the removal process abandoned until such time as they can be preserved. The conservator's assessment at Kabadul Kula did note that there was some grain loss but this did not weaken the appearance of the red pigment. Alternatively, if kaolin clay pigments had been observed detaching from the rock surface during the assessment phase, this would have necessitated a different conservation strategy with different outcomes (e.g. reattaching the paint before full removal of the nest). Thus, while the behaviour of certain pigments can contribute to our understanding of weathering processes (e.g. Chippindale and Taçon 1998), proper assessment of the stable/unstable nature of the pigments by a trained conservator is a key factor in their conservation.

Changing attitudes to insect structures

Robert Bednarik (2001: 106) pointed out that over the last decade, our 'attitude to insect structures at rock art sites has changed dramatically' from banishing them for aesthetic appreciation, to instead using them as a tool to gain better understandings of the antiquity of some rock paintings (e.g. Roberts et al. 1997). However, in this case, the decision to remove the nest for aesthetic purposes was made by the Dauan community. As noted above, the Dauanalgaw consider this site to be a 'special place', and one where the images have strong cultural significance for the entire community. As such, the concealment of several significant images necessitated the careful removal of the nest to ensure this aspect of Dauanalgaw visual heritage was not lost, but instead preserved for future generations.

Conclusion

Building on Watson and Flood's earlier work, this paper has provided a fine-grained/detailed removal methodology incorporating new strategies and remedies in dealing with damage caused by mud-daubing insects. This research has also illustrated how images that were wholly or partially obscured by a rapidly advancing termite nest can be successfully recovered. Thorn's research into dealing with the effects of, and solutions to, removing loosely-bound granular material over rock surfaces over the past two decades has highlighted the crucial role played by a trained professional fine arts conservator in the preservation of fragile rock paintings. While the method described here was a success, it must be emphasised that this was a delicate task and *should not be undertaken without proper professional advice and training*.

A key difference between our work and that of Watson and Flood's is the nature of the rock art sites studied and applicable recommendations (Kabadul Kula: a single, easily accessible and well-monitored site; Koolburra: 163 remote area sites with no ready vehicle access and located on private property). Whereas monitoring, and if necessary follow-up conservation work can be arranged fairly easily at Kabadul Kula, remote area sites such as those in the Koolburra are much more difficult to monitor/assess. Flood (pers. comm. 2009) recently commented that in 1982 they carried out the first two of their published recommendations (1: remove all termite nests/mounds from the area immediately surrounding the rock face; 2: destroy nests present, located in trees within 50 m of the site; see Watson and Flood 1987: 24) at all Koolburra rock art sites. However, owing to the remoteness of the sites, no known follow-up conservation work has ever been done. As such, future rock art conservation studies should consider re-visiting these sites as part of comparative conservation investigations.

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