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A SCIENTIFIC STUDY OF A NEW CUPULE SITE IN JABILUKA, WESTERN ARNHEM LAND

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Abstract. Cupules (engraved pits) have been observed on every continent with the exception of Antarctica, and cover Lower, Middle and Upper Palaeolithic contexts. Despite this remarkable spatial distribution and the perceived antiquity of these petroglyphs very few detailed scientific studies have been conducted at cupule sites, with fundamental aspects of morphology, manufacture and function poorly understood. In Australia, lack of detailed recording has led to differential classification and disputed identification. In this paper we review literature for Australian cupule sites and present detailed archaeological results from a new site in western Arnhem Land. By applying metric, use-wear and residue analysis we reassess these issues, providing insight into cupule classification, function and intra-site complexities.

Introduction

Cupules are human-made cup-shaped petroglyphs formed through percussion. Cupules can be distinguished from grinding hollows and natural potholes, being more numerous, uniform shaped/sized and often located at natural boundaries (e.g. lines and cave entrances) in the rock (Bednarik 1993a, 2008: 68; Taçon et al. 1997: 943). In Australia, they are commonly closely and regularly spaced, on vertical and sloping (as well as horizontal) rock faces and may directly relate to other petroglyphs and/or painted art.

Cupules are thought to have been made during both Pleistocene and Holocene periods (Bednarik 2008; Taçon et al. 1997: 945). Pleistocene contexts include La Ferrassie in France (Peyrony 1934); Auditorium Cave in India (Bednarik 1993b), Daraki-Chattan, in India (Kumar 1996: 38), Sai Island in Sudan (van Peer et al. 2003), Kalahari sites in South Africa (Beaumont and Bednarik 2012), and probably also Rhino Cave in Botswana (although radiocarbon and thermoluminescence dates remain 'problematic' for this site) (Coulson et al. 2011: 23). A Pleistocene antiquity has been argued for Australian examples based loosely on oral histories (Chaloupka 1993a: 235) and extensive studies of art superimposition across Kakadu and Arnhem Land (Taçon and Chippindale 1994: 215) and the Kimberley region (Walsh 1994; Welch 1992; 1993: 101). Direct dates from oxalate salts overlying cupules in the Kimberley and Keep River regions suggest a short chronology of >6600 years ago (Aubert 2012; Watchman 1997, 2004; Watchman et al. 1997). This is supported by AMS dates (<3000 years ago) from cupules in the Laura River Region, Cape York (Cole and Watchman 2005), and a buried cupule surface at Jinmium in the Keep River region (Roberts et al. 1998a). A charcoal sample associated with buried cupules at the Leichardt site, Arnhem Land was dated to 5180 ± 130 BP (SUA-244) (Kamminga and Allen 1973: 88).

The function/s of cupules remain poorly understood (Bednarik 2010). Utilitarian and/or symbolic motivation for cupule production was suggested, with artistic activities indicated by the small size (i.e. impractical for processing food/ochre), position on sloping or vertical surfaces, dense clustering and frequent association with significant natural features (e.g. cave entrances, lines in the rock) (Bednarik 2008; Parkman 1986; Taçon et al. 1997). Artistic motivation for the production of cupules is, however, rarely visible in the archaeological record (Bednarik 2008: 72). A notable exception is Rhino Cave in Botswana where a 'massive quartzite outcrop' was decorated with rock paintings, in addition to over three hundred overlapping 'grooves and depressions' (Coulson et al. 2011: 20). Ritual activity was suggested based on excavated materials (ochre, large quantities of exotic MSA points, grinding stones and an exfoliated piece from the cupule panel), evidence for intentional lithic burning and breakage and observations based on site context and lighting (Coulson et al. 2011: 50).

In America, cupule function has been examined through analysis of residues (e.g. Buonasera 2012: 65–82; Schneider and Bruce 2009). Results frequently support non-utilitarian use (Buonasera 2012), however, plant and animal residues have been recorded, suggesting some cupules may have had utilitarian roles

(Schneider and Bruce 2009; Zepeda-Herman 2012). No detailed use-wear/ residue analysis has, thus far, been reported for cupules in the Australian context where interpretations utilise ethnographic records. For example, Charles Mountford (1976: 22) recorded that cupules in the Musgrave Ranges (South Australia) were made to 'propagate the creative powers of an Ancestral Being and thereby increase the population of the natural species associated with that Being'. A ceremonial role was also identified for cupules (and associated painted rock art) at a Green Plum Dreaming site near the Mann River in eastern Arnhem Land (Taçon et al. 1997: 947).

Pecked circles and pits have been recorded throughout Australia, concentrated in the Kimberley, Keep River, Victoria River, Kakadu/western Arnhem Land and Cape York areas of northern Australia (Chaloupka 1993b; Cole and Watchman 2005; Donaldson 2007; Edwards 1979; Flood 1987, 1997; Graham and Mulvaney 1995; Gunn 1989; Jones and Brockwell 1990; McNickle 1991, 1993; Sullivan and Haskovec 1986; Taçon et al. 1997; Walsh 1994; Watchman 1997, 2004; Watchman et al. 1997; Welch 1992, 1993). Cupule sites have also been found through the Chillagoe, Hervey and Expedition Range regions of central Queensland (Bednarik 1993a), Victoria (Bednarik et al. 2003; Bednarik 2008), central and southern Australia (Flood 1997; Franklin 1991; Maynard 1976, 1979; Mountford 1976), Tasmania (Bednarik et al. 2007; Brown 1991; Sims 1977, 2008) and Pilbara in Western Australia (McNickle 1984, 1985). These petroglyphs are found in rockshelters and on boulders, occasionally also at the bottom of vertical rock faces (e.g. Bond Bay, Tasmania).

Understanding the spatial distribution of cupules in Australia is problematic given the scarcity of detailed written records and scientific studies (i.e. use-wear and residues), with results 'often limited to their incidental occurrence in photographs together with other motifs' (Bednarik 2008: 84). This has influenced differential classification (Donaldson 2007 vs McNickle 1991; Rosenfeld 1999: 31 vs Taçon et al. 1997) and disputed identification (Bednarik et al. 2007 vs Field and McIntosh 2009). Cupules in Tasmania and South Australia (e.g. Bednarik et al. 2007; Cosgrove 1983) have elsewhere been termed 'cup and ring motifs', 'pits', 'circles', 'mine markers' or 'natural hollows' (e.g. Field and McIntosh 2009; Flood 1997: 149, 238; Mountford 1976). Taçon et al. (1997: 960) suggest that detailed documentation of cupule sites may assist assessment of 'long-range settlement and migration patterns for the earliest periods of north Australian prehistory' and enable better understanding of 'how people were articulating and expressing their relationships to landscapes'. In this paper we present fine-grained archaeological analyses (including use-wear and residue analysis) from recently re-discovered cupules in western Arnhem Land and reassess distribution and function of known cupule sites in Australia. This paper has three specific research questions:

1. Can use-wear and residue analysis, including newly developed techniques for PSR polarisation (Stephenson 2011), provide insights into the purpose of cupules in northern Australia?
2. How does the Djawumbu cupule site relate to its wider cultural landscape?
3. Are there similarities and differences between the Djawumbu cupule site and others recorded in the region?

The Djawumbu (Djawumba) site complex

A large cupule site recently recorded within the Jabiluka leasehold area, western Arnhem Land, provides a further opportunity to study northern Australian cupules. The site is located on the Djawumbu Massif, an isolated sandstone outlier on the eastern margin of the Magela flood plain. It was located and recorded in 2012 during survey conducted as part of the Mirrar Rock Art Project.

Oral and written histories suggest Mirarr, Dadjbaku and Bunidj communities used Djawumbu to 'get away from mosquitoes and for ceremonies' (Chaloupka 1978: iii; Toby Gangali and Dolly Yarnmalu cited in Layton 1981: 12–13; Kamminga and Allen 1973: 53). Elder Jimmy Galareya Namarnyilk, identified this outlier as a ceremony ground that continued to be used in the contact period but was now 'dead' (pers. comm. 2010). Toby Gangali includes Djawumbu in his description of walking routes, in particular a route between the historic sites of Oenpelli and Baroalba Timber Camp (Layton 1981: 19, Table 4; see also Kamminga and Allen 1973: 44, 53). While he is describing walking routes used in the contact period, many such routes would have followed earlier, pre-contact seasonal movements and made use of known rockshelters and water sources.

Extensive surveys on and around Djawumbu were conducted by Kamminga and Allen (1973), Morley and Lovett (1980) and, to a much lesser extent, Cundy (1982). Kamminga and Allen (1973) recorded six rockshelters along the edge of the massif (Djawumubu 1–6; Kamminga and Allen 1973: iv). Chaloupka (1975) also worked in the Mirrar-Gundjeihmi clan estate and identified over forty sites of significance (including rock art, archaeological deposits and Dreaming sites). In 1978, two important site complexes were recorded: Boywek Bagolui-Almudj (which connected Wirrmuyurr Swamp with the eastern escarpment) and Djawumbu-Madjawarrnja (Chaloupka 1978; Keen 1980). In 1997, Chaloupka carried out site surveys with Senior Custodians and Northern Land Council employees, confirming the importance of the Boywek-Bagolui Almudj sacred site complex. Pancontinental Mining Ltd soon afterwards commissioned their own rock art study of the Jabiluka leasehold area with work undertaken by company employee A. W. Morley (Morley and Lovett 1980). Systematic surveys revealed approximately 189 sites from the Magela Creek series and Djawumba Massif, including archaeological deposits, rock art panels, and burial sites but no 'mythological sites' (Morley and Lovett 1980: 2). All of these studies

Figure 1. *The western entrance to the cupule site (fissure to left of photo) and surrounding site complex, including stone arrangements and rock paintings (in natural recess near fissure, at base of outlier). Photo DW.*

combine to reveal important cultural associations for the Djawumbu complex.

The most famous of the Djawumbu sites, Malakunanja II (known as Madjedbebe by Mirarr Custodians), has been the focus for three major excavations (Kamminga and Allen 1973; Roberts et al. 1990). Cultural activity was radiocarbon dated to 24 000 – 20 000 BP, with shell middens containing human remains postdating 7000 years ago (Kamminga and Allen 1973). Pieces of red/yellow ochre and haematite were associated with Pleistocene deposits, and three grinding stones (one impregnated with ochre) dated to approximately 20 000–18 000 BP (Kamminga and Allen 1973: 48–49; Mulvaney and Kamminga 1999: 138). Subsequent sand auger and excavation allowed Rhys Jones and colleagues to re-date Madjedbebe (Roberts et al. 1990; 1998b). Thermoluminescence dates were used to interpret occupation from 61 ± 10 ka (Roberts et al. 1990). TL dates were criticised by some archaeologists due to large standard errors (Hiscock 1990) and stratigraphic observations (Bowdler 1990; Hiscock 1990).

The Djawumbu cupule site is one of only two within Mirrar country and only just under a dozen recorded from central Arnhem Land to the southern end of Kakadu National Park.

Its exact location is restricted at the request of Mirarr traditional owners; however, it is located near Madjedbebe and at the top of the Djawumbu Massif. The outlier is approximately 3 km long, 1 km wide (at widest point), located between the Oenpelli-Jabiru road (to the west) and Jabiluka tailing dam (to the east). The top of Djawumbu varies between a sparsely vegetated, boulder-strewn plain in the south/centre to a maze of eroded passageways, chambers and rockshelters in the north and west. The latter area contains a large quantity of cultural sites, including rock art, stone arrangements and grinding hollows.

A substantial open corridor, located in the northern portion, provides access to a large opening containing many cultural sites (painted art, circular stone arrangement, grinding hollows and lithic scatters). A small enclosed corridor, formed by two boulders leaning against each other to make a rockshelter, is located at the edge of this opening, running east-west (261°) and emerging at the top of the outlier (Fig. 1). On the right side of the western outside entrance to this enclosed corridor/shelter, in a natural recess in the cliff, is a painting of a large 'human' figure with arms outstretched, alongside a large 'macropod' and 'fruit bat' (Fig. 1). The 'human' figure is unlike others in the local area and the wider Kakadu region in terms of its great size and the length of its limbs. The 'fruit bat' is also unusually large. Ground red haematite and yellow ochre were observed beneath these figures. The northern side of the enclosed corridor is broken, 12 m from the entrance, by a large hole that opens into a small cave before diminishing to a narrow crevice. On the far side of the boulder the crevice opening has a range of paintings

Figure 2. *The main panel (panel 1) on a vertical wall opposite the cave entrance and running along the south side of the passage way, including cupules chosen for residue analysis. Note: petroglyphs below cupule C are enclosed by natural lines. Photo PT.*

The passage is shaded for much of the day, best lit during the late afternoon at which point the conglomerate lumps of quartz give the impression of glistening drops of rain. Half-way along the passage (on the south side) there is a vertical rock face (max. length = 7.8 m, max. height = 1.5 m) on the south wall, facing the mouth of a narrow cavity (max. length = 1.8 m, max. height = 1.8 m). The vertical rock face contains 177 cupules (Fig. 2; henceforth panel 1), adjacent to and downslope from the cavity entrance but not continuing deeper into the passage. At the top of the vertical rock face is a horizontal platform (max. length = 7.8 m, max. width = 2.3 m) containing a further 122 cupules (panel 2; Fig. 3). On the north wall an additional 15 cupules (panel 3) skirt the western edge of the cave entrance (max. length = 0.6 m, max height = 0.4 m) making a total of 314 cupules. Two shallow cup-shaped hollows are located on the cavity floor.

In all cases, cupules (and adjacent rock surfaces) appeared smooth and weathered, giving the impression of considerable age. Some cupules on panel 2 were covered in algae and lichen while others (mainly panel 1) have a patinated appearance. Panels 1 and 2 contained dense clusters of cupules which often skirt (but rarely overlap) natural grooves or contours in the rock (Fig. 2). The density of cupules on panel 1 was so great that superimposition occurs. Breaks in the panel often correspond with large quartz nodules in the sandstone, suggesting either avoidance of time-consuming harder rock or deliberate inclusion of these natural anomalies in the rock panel.

A sub-sample of cupules from panels 1, 2 and 3 (20, 20, 10 respectively) were measured in order to better understand cupule variation (Table 1). There was considerable diversity in diameter and depth of all cupules (particularly those in panel 1 which range from 3.5–13 cm and 0.4–3.2 cm respectively) suggesting consistency was not a major consideration during production. Combined, the average diameter and depth was similar for panels 1 (8.3/1.9 cm) and 2 (8.0/1.4 cm), while cupules from panel 3 were small and shallow (averaging 6.0/0.6 cm). This suggests diameter and depth of cupules was not determined by surface orientation (i.e. vertical vs horizontal walls), however, the deepest cupules correspond with the most populated (and from passage entrance, most visible) panel. The vertical orientation of this wall and cramped position of some cupules at the base of the panel suggest that manufacture was not influenced by ease of access.

Figure 3. *Panel 2 facing west towards the entrance with features chosen for residue analysis. Photo PT.*

Cupule #	Diameter (1)	Depth (1)	Diameter (2)	Depth (2)	Diameter (3)	Depth (3)
1	13	1.5	8.5	0.9	10	1.8
2	10	2.5	8	1.1	8	0.3
3	9.5	2	6	0.7	7	1.1
4	11	2.9	6	0.8	5.5	0.8
5	11	3.2	9.5	1.4	4.5	0.6
6	8	2.5	10	1	4.5	0.2
7	3.5	0.4	8	1.8	5	0.3
8	7	0.6	6	0.8	5	0.2
9	10	2.2	8.5	2.5	6	0.3
10	11	2.8	8	1.2	4	0.2
11	5.5	0.8	7	1.2		
12	9	2.89	9.5	1.5		
13	5	0.8	9	2		
14	6.5	5	8	1.2		
15	9	1	6	1.3		
16	9	2	6.5	1.7		
17	5.5	0.7	6	2		
18	9	1.9	10	2.3		
19	5	0.9	11	1.1		
20	9	1.1	9	1.3		

Table 1. *Raw data on cupules from all panels.*

Residue and use-wear analysis

Use-wear and residue analysis was conducted on cupules from panels 1, 2, a cup-shaped hollow (D) in the cave mouth and one of the three feature lines observed on panel 1. Use-wear analysis was conducted in the field using a hand-held Dino-Lite (AM413T USB digital microscope) at a magnification of 50 times. In broad terms, the microscope was used to examine evidence for surface modification (e.g. changes in surface

***Figure 4.** Janet Davill assisting with pipette extractions on the cupule wall (cupule A, panel 1). Photo BS.*

topography, modifications of individual rock matrix grains, striations and polish) (see Stephenson 2011 for details). Lifts were performed to extract samples (including residues) from the matrix of the investigated surface using a variable volumetric pipette. The pipette delivered 20 μl aliquots of ultra-purified water to a porous area on the investigated surface (a crack or pitted section; Fig. 4). The solution was left to soak and then the process was repeated over a 10 to 15 minute period. Water from a second pipette was then used to agitate the lift surface area and draw back a sample of matrix from the lift section. The samples containing residues were then placed in eppendorf tubes, sealed, labelled and transported back to the laboratory for residue analysis. The lifts were transferred to microscope slides and dried before undergoing a series of biochemical staining using picrosirius red (PSR) and phlorglucinol (see Stephenson in prep. for details).

Control lifts were taken from nearby cupule surfaces and provide a baseline for comparisons of lifted residue densities, types and combinations. It was assumed that quantitative variation between control lifts and cupule samples would differentiate between use-related residues as opposed to those present due to environmental processes (see also Atchison and Fullagar 1998: 121; Barton et al. 1998: 1233). Vegetation and soil samples were collected in the field to establish a comparative reference collection for the study area.

Panel 1 cupules

To obtain a representative cross-section for panel 1, three cupules located within different areas of the main frieze were selected for sampling (Fig. 2). Cupule A is located towards the east end of the wall, immediately below an undulating natural line. Cupule B is immediately above a natural crack towards the base of the east end of the main cupule wall. Cupule C is located towards the western end of the main cupule wall. Its position is independent of any natural lines.

Use-wear observations (Fig. 5) were similar for each cupule which suggests that consistent production techniques were used. The uneven surface profile, high presence of irregular matrix grains is consistent with pounding. A number of grains displayed small amounts of polish which might be indicative of minor grinding component. Grinding is likely to have occurred during a late stage of cupule production, however, it is uncertain whether this reflects use of cupules for utilitarian tasks after production or part of the engraving process.

A low density of plant residues (including an isolated starch grain and some bordered pits) were observed across cupule A. While starch residue was absent across the control lift a similar frequency of plant residues was recorded. Grinding studies have shown that processing starchy materials generally results in starch clusters and/or the spread of granules and plant residues across a worked area (Stephenson 2011). As such, the presence of an isolated starch granule is likely to relate to environmental influences rather than cultural activity.

Residues noted across the worked surface of cupule B include a low density of carbonised plant materials (plant fibres and amorphous cellulose predominate). Similar observations were recorded across cupule C. The frequency and type of plant and carbonised residues observed across the worked surfaces of cupules B and C were likewise noted across the control surface lifts. As such use-relatedness of these residues cannot be established.

Mineral residues (pounded rock matrix grains) were observed across all lifts on panel 1. The density of mineral residues, however, was considerably lower across the control compared with the three cupules lifts, where a medium mineral density was noted. It is reasonable to assume that the minerals therefore relate to the forces involved with cupule manufacture leading to mineral dislodgment and crushing.

The panel 1 cupules cluster between three clearly defined lines (Fig. 2). Macroscopic examination suggested that these lines were natural; however, use-wear analysis was used to test for manipulation during cupule production. A section of the major top line was studied using the Dino-lite at a magnification of 50× to identify evidence for human modification (i.e. broken rock matrix, damaged crystals). The matrix grains were intact and unmodified with no fractured or sheared surfaces as would be expected if the line had been modified.

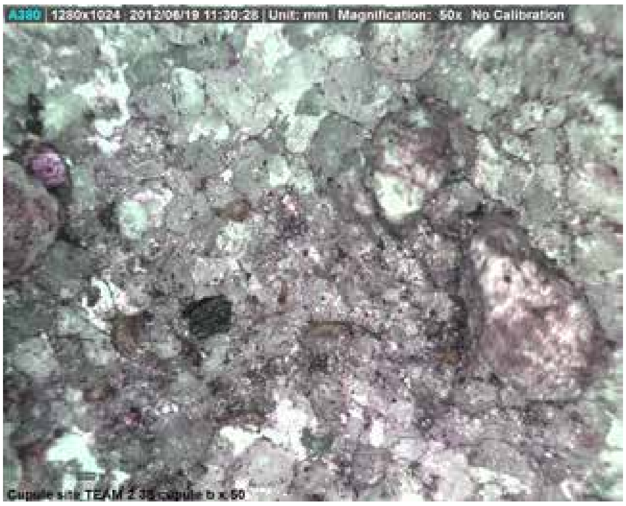

Figure 5. *Centre of cupule B. Use-wear 50×. Note uneven surface with raised crystals, missing grains and unmodified areas. Photo BS.*

Figure 6. *Centre of cup-shaped hollow D. Use-wear 50×. Note polish and rounded grains. Photo BS.*

Panel 2 cupules

A single cupule (E) was sampled from the horizontal panel (Fig. 3). This was located at the western edge of a dense cluster of petroglyphs. Although there was no visible patterning of cupules in this area, it adjoins a shallow west-east line which culminates at a natural north-south water-worn channel running down the middle of panel 1. A lichen growth was associated with the channel suggesting presence of water. The growth was sparse higher up the slope and prominent in the low lying areas. Although cupule E was some distance away from this channel, it is expected to have experienced significant water flow during the wet season.

Use-wear observations were similar to those noted for panel 1 with evidence for pounding (see above). A variety of plant residues, including bordered pits (i.e. vascular plant tissue), fibres and cellular material along with a low density of collagen (protein found in animals) fibres of varying thickness (consistent with animal processing) were found across the surface lift of Cupule E. In contrast, a low density of plant material was noted across the control lift and collagen was absent. This result indicates that the presence of these residues is likely to relate to cultural activity (e.g. pounding or grinding meat). Given the location of the horizontal cupules and the possibility of significant water impacts during the wet season taphonomic influences cannot be eliminated.

Other tested features

A cup-shaped hollow D is located on the floor of a crevice, opposite the main cupule wall. The hollow is associated with sparse sediment and animal droppings. Its diameter and depth (5/0.3 cm) fits with tested cupules; however, it differs through separation from the main body of petroglyphs and variation observed in use-wear (i.e. level/polished rather than uneven/irregular surface profiles). The absence of striations suggests a natural pothole (cf. Bednarik 2008: 65) or a heavily eroded grinding hollow. Natural formation is supported by paucity of mineral inclusions observed in surface residues.

Summary

A study of the three panels on Djawumbu provides important information about the spatial patterning and potentially also the function of cupules:

1) Cupules inside an enclosed corridor/rockshelter mark/accentuate an internal cave entrance that runs through one wall of the shelter.
2) Cupules cluster in rows and dense groups on all panels.
3) Some cupules are contained within natural lines in the rock (i.e. they are localised within a panel or panels).
4) Cupule diameter range, depth and quantity of petroglyphs is far greater on the most accessible and visible vertical wall (when viewed from the main passage entrance).
5) Cupules on the horizontal surface are shallow and uniform, much less visible than those on the vertical panel.
6) Cupules were primarily formed through pounding, with a possible small grinding component.
7) Organic residues (in quantities that are greater than observed in the control sample) were found in a cupule on the horizontal panel. These were absent from all other cupules and the grinding hollow.
8) The more easily accessible entrance to the shelter where the cupules are located is marked with highly unusual figurative rock paintings.

Discussion and conclusion

A visible discrepancy exists in the classification of 'cupules' in Australia. This situation is partly due to inherent ambiguities in the word (encompassing as it does all cup-shaped petroglyphs), but also mistaken classification based on the absence of detailed records for these sites. The outward appearance of grinding hollows, mine-markers and natural features may be similar to cupules, particularly when found on horizontal panels (cf. Bednarik 2008). The Djawumbu cupule site provides a rare scientific study of Australian cupules (including metric, residue and use-wear). Use-wear analysis confirmed differential production (i.e. pounding, with a small grinding component). It further identified intra-site variation, with a natural (or potentially ground) hollow located within a site dominated by cupules (Figs 5 and 6). Following Bednarik (2008: 68) we emphasise the value of microscopic examination of features, prior to classification. Portable microscopes are inexpensive and generally allow for the ready differentiation between pounded and non-pounded surfaces (Figs 5 and 6).

Residue analysis has also provided useful information. A single cupule tested on the horizontal surface (panel 2) showed evidence of possible use-related collagen and plant residues. This result may support utilitarian or ceremonial use of horizontal cupules for processing animal and plant materials during the recent period (cf. Coulson et al. 2011; Taçon et al. 1997: 947; Zepeda-Herman 2012). In contrast, use-related residues were absent across the three cupules investigated on the vertical panel and from the grinding hollow on the cave floor, suggesting non-utilitarian/artistic purpose for these features. Residue analysis suggests inter- and intra-site complexities exist in terms of the role of cupules for the Aboriginal people who made and used them, and, that at different times, there may have been ritual and secular functions, especially for horizontally placed cupules. As grinding was observed on all cupules (not only those with collagen/plant residues), this appears to be evidence for production rather than secondary use.

While no ethnographic information exists in Australia for the use of cupules for pounding plant/animal products it is interesting to note that grindstones have been used to pound (as opposed to grind) pieces of kangaroo tail, goannas, small rodents, small mammals and cooked lizards (see Hayden 1979: 141; Yohe et al. 1991: 660). Similarly, grinding slabs were used to pulverise and grind the vertebrae of reptiles, rabbits and feral cats to assist consumption.

Based on residue and use-wear analysis it appears that cupules were a product of their own manufacture (i.e. non-utilitarian petroglyphs, potentially emphasising an important cultural site). Previous experimental studies suggested cupule production was a lengthy process (cf. Bednarik 2008: 68), indicative of protracted activities at the Djawumbu site. It is likely that a subsequent, potentially temporally discrete, phase of grinding occurred at which point animals/plants may have been ground or pounded onto horizontal cupules.

A key factor in understanding the Djawumbu cupule site is its place in the wider cultural landscape. While we cannot know whether the surrounding rock art, stone arrangements and archaeological deposits are contemporary with the cupule site, the density of sites within the Djawumbu region (including painted rock art and a ring of stone boulders near the entrance to the cupule passageway) suggests this was an important complex. Moreover, paintings used to mark the main entrance are considered unusual (the large 'human' figure is unique) in the Kakadu region. Broadening the focus, it is clear that the Djawumbu Massif has a high density of painted rock art, along with stone arrangements and pounded areas in sandstone bedrock (e.g. Chaloupka 1975; Kamminga and Allen 1973). Madjedbebe, at the base of the outlier was occupied during both Pleistocene and Holocene periods with evidence for burial activity within the past 7000 years (Kamminga and Allen 1973; Roberts et al. 1990). Oral histories further identify the socio-ceremonial significance of Djawumbu for multiple Indigenous communities (Chaloupka 1978: iii; Jimmy Galareya Namarnyilk pers. comm. 2010; Toby Gangali and Dolly Yarnmalu cited in Layton 1981: 12–13; Kamminga and Allen 1973: 53). The 2012 re-discovery of a large cupule site (one of only two such sites recorded within Mirarr country, with the second found in July 2013 on top of a neighbouring massif) further cements Djawumbu as a highly significant locale in the pre-contact cultural landscape.

The Djawumbu site supports a northern Australian cupule tradition. As with other documented sites, cupules are pecked and pounded into vertical and horizontal walls, appearing to cluster around natural boundaries (i.e. lines) and features (i.e. the cave mouth). Following Taçon et al. (1997: 961) this pock-marked form of petroglyph 'has strong "natural" roots, indicative of an early coming to terms with and marking of the landscape'. The frequent link with geological features suggests cupules were visual markers for culturally significant sites, structuring human movement through country.

As with all rock art, we will never know the exact or many varied meanings cupules may have had for the people who made them. However, by studying cupules from scientific perspectives, such as use-wear analysis, residue analysis, landscape placement and relationships to geological features, we can advance our knowledge of their mode of production, function and use. Unfortunately, the Djawumbu cupules are not amenable to dating with our means but when this is also possible a temporal dimension can be added. All of this leads to more robust interpretations based on science rather than speculation.

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