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## CONCERNING A CUPULE SEQUENCE ON THE EDGE OF THE KALAHARI DESERT IN SOUTH AFRICA

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**Abstract.** The Tswalu Reserve in the southern Kalahari is an arid place, the present occupation of which is only made possible by means of boreholes that tap patches of fossil water, while semi-permanent surface sources of ~65 m<sup>2</sup> extent are confined to three localities within an investigated area of over 1000 km<sup>2</sup>. Lithic evidence indicates that this vicinity was abandoned by humans during even drier Ice Age intervals, when rainfall fell at times to ~40% of present values, thereby providing a way to refer petroglyphs there to interglacials of known age and intensity in terms of regional and global palaeoclimatic data. By such means, together with microerosion measurements, it then becomes possible to identify three regional cupule production intervals: the earliest with cupules only at ~410–400 ka BP, the next with cupules and outline circles at ~130–115 ka ago, and the most recent, with cupules, geometric motifs and iconic images, at ~8–2 ka BP.

### Introduction

Cupules are manmade, roughly semi-hemispherical depressions, not normally more than ~8 cm in diameter, that were produced on hard rock surfaces by hammerstone percussion (Kumar and Krishna 2014), reportedly supplemented or replaced on softer stones by varying combinations of abrasion and incision (e.g. Clark 1958; Van Peer et al. 2003). The first account of their presence in sub-Saharan Africa occurs in A. A. Anderson's (1888) description of an isolated massive rock seen in 1867 near the confluence of the Notwane and Limpopo Rivers, the many petroglyphs on which included 'a small hollow of cup shape with two circles of the same round the centre one ...'. Since then, Africa south and east of the Sahara has produced many more cupule occurrences that a literature survey shows to be widely, but unevenly, distributed over its more than 18 million km<sup>2</sup> extent, based on cited data for the localities listed in Appendix 1.

Of these sites, only three have provided minimum or bracketing chronometric ages, beginning with Chifubwa Stream Shelter in Zambia, where excavations (Clark 1958) revealed a sequence comprising thin surface soil with a few shards, ~2 m of sterile yellow-orange sand, and up to 0.7 m of basal red sand containing Later Stone Age (Nachikufan 1) lithics (Clark 1950). The shelter wall then exposed, down to just 3 cm above that occupation level, was entirely covered by incised and then abraded petroglyphs that are dominated by vertical lines, inverted Us, with or without a central vertical line, and cupules which are mainly randomly placed. Only a single composite <sup>14</sup>C age was obtained

then, but the later dating of various regional sites (Miller 1971; Sampson 1974) placed the artefact level between ~25 and 13 cal ka ago (Weninger and Jöris 2008), and it is consequently considered probable that the Chifubwa petroglyphs were made at some time within that interval (Clark 1958).

Then, at Rhino Cave in the Tsodilo Hills of Botswana, fieldwork in 1995 and 2006 (Robbins et al. 1996; Coulson et al. 2011) probed an over 2 m deep deposit with Later Stone Age overlying Middle Stone Age in the ~94–66 ka range (Robbins et al. 2000; Phillipson 2007), that is flanked by a cave wall covered by over 300 fairly fresh to heavily weathered ground grooves and cupules (Coulson et al. 2011). A rock fragment with an artificial groove on its one face was found in the Middle Stone Age level (Coulson et al. 2011), and the organic coatings on two cupules have been dated to ~5 ka ago (Brook et al. 2011), with those findings here taken to indicate that the cupule ages are minimum estimates only, and that the marked mobiliary item was either discarded there, or had spalled off from the adjacent panel, in which case it predates ~66 ka BP. And lastly, albeit beyond present savannah bounds, is Sai Island on the Nile in northern Sudan (Van Peer et al. 2003), where a ~2.5 m deep sequence on bedrock contains Earlier Stone Age (Acheulian), followed upwards by Early Middle Stone Age (Sangoan) and Middle Stone Age. In the Sangoan strata, with bracketing OSL ages of 220–180 ka ago, were found three sandstone slabs, each with a single incised cupule, of which one is over 100 mm wide (op. cit. Fig. 3).

From this chronometric evidence it is apparent that

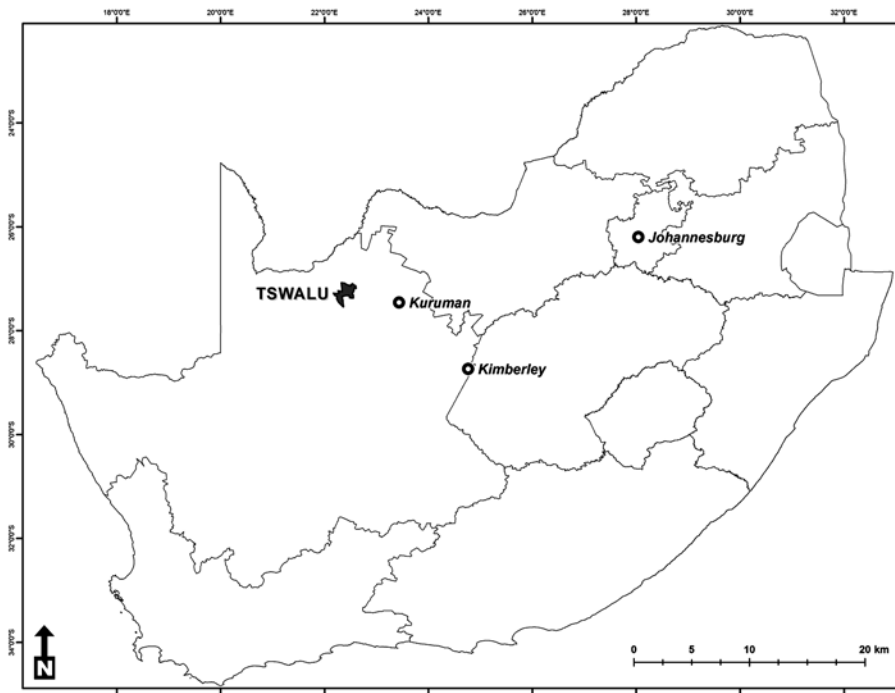


Figure 1. The location of the Tswalu Kalahari Reserve within South Africa.

African cupules were made over a timespan ranging back to before ~220 ka BP, and that they occur, on present evidence, in all Stone Age periods subsequent to the Earlier Stone Age. Furthermore, the absence of firm consistent evidence for extraneous organic residues in them, or that they were formed fortuitously (Walker 2008), does not support a utilitarian purpose for cupules, which are, rather, best taken to be a primal form of palaeoart (Bednarik 2007, 2008). However, cupules may also occur at the very point where the striking of rock gongs (Fagg 1956, 1957) results in a ringing tone, with the sometimes very weathered state of those surfaces suggesting that drumming (and music generally) may have very ancient beginnings (Goodwin 1957).

As for this article, its primary purpose is to document a cupule sequence made up of three phases, and to then utilise regional palaeoclimatic data to date them by way of the global oxygen isotope stage (OIS)



Figure 2. View to west from Klipbak hill of the sandy plains and the nearby hill on the far side of which lies Potholes Hoek.

record. Later Stone Age, Middle Stone Age, Early Middle Stone Age and Earlier Stone Age are henceforth abbreviated to LSA, MSA, EMSA and ESA, respectively. All  $^{14}\text{C}$  dates have been calibrated to calendrical ages by way of CalPal 2007 Hulu (Weninger and Jöris 2008), and rounded off to the nearest ka.

### Project setting

In early 2000 a rich cupule occurrence was found by staff members near the crest of a hill on the 103 000 ha privately owned Tswalu Kalahari Reserve, formed by the consolidation of 43 previous farms and farm portions, which is located ~100 km north-west of Kuruman in the Northern Cape Province of South Africa (Fig. 1). There, the

income generated by upmarket tourism and the sale of excess game is used to offset the costs of wildlife conservation, of returning the local biotope to its historical diversity, and the funding of a great number of pertinent projects by visiting researchers, of which this study, of cupules on and around Tswalu, is but one. Investigations commenced with a vehicle and foot survey of the broad vicinity, namely the south-eastern Kalahari, typified (Climate of South Africa 1986) by often high day temperatures (over  $30^{\circ}\text{C}$  for 4 months yearly) and a summer-centred annual rainfall of ~250-350 mm, of which 95% is soon lost, largely to evaporation (Turton 2013). The terrain (Fig. 2) is mainly covered by permeable orange-red Kalahari sands of Pleistocene age, sometimes in the form of linear dunes, but elsewhere there are the southward trending Korannaberg hills, comprised of indurated ~2-billion-year-old quartzites (Saggerson and Turner 1995; Visser 1998). Typical vegetation is a discontinuous cover of annual and perennial grasses, stunted shrubs that are mainly on the hills, and occasional trees with deep taproots, of which the most characteristic is the camel thorn (*Vachellia erioloba*).

### Petroglyph occurrences

Recording commenced at the initial find site, termed Klipbak 1 (i.e. the first locality found on the original farm of that name), a smoothed and heavily weathered  $17 \times 20$  m quartzite surface, flanked by a 2 m deep and up to 3 m wide pool, near the crest of a ~120 m high Korannaberg hill on Tswalu. Mapping there in 2001, by way of a  $1 \text{ m}^2$  grid, showed that this support was covered by ~720 cupules,

up to 80 mm (mean 30 mm) wide and 34 mm (mean 6 mm) deep (Appendix 2); ~40 outline circles, up to 230 mm (mean 70 mm) in diameter; ~30 rubbing areas; and ~5 meandering lines, all weathered, except for one or two reworked surfaces (Fig. 3). Over 80% of the randomly placed cupules fall into three clusters, two largely confined to cupules, and the other one with a far higher admixture of outline circles and rubbing areas, while the rest of the markings at this site are on other panels, including a vertical rock face near the pool. On close-by boulders are the hammered outlines of a 'giraffe' and three 'eland', and on a low outcrop at the lower end of the slope up to the pool are two outline human male images, one holding a 'staff', and an indeterminate 'antelope' lacking a head (Rifkin 2009).

The second mapped area, Potholes Hoek / Sunstroke 1, is a ~12 × 28 m smoothed sloping quartzite outcrop on the lower western flank of a saddle midway along another Korannaberg hill, ~10 km north-west of Klipbak 1, and also on Tswalu (Fig. 4). Within the grid there were a few dozen up to ~500 mm wide and 350 mm deep potholes of the conical floor variety (Gilbert 2000; Bednarik 2008), sans water when seen, a few outline circles and ~40 randomly placed cupules, from ~20–50 mm in diameter, of which the larger specimens are mainly on the eastern side of the panel.

The last mapped site was Nchwaneng (Rogers 1908; Wilman 1933; Fock and Fock 1984), ~20 km to the south of Tswalu, where the northern slopes of a Kalahari sand-encircled inselberg runs down to a ~45 × 70 m smoothed quartzite surface on the far side of which are a number of up to 2 m deep and 3 m wide rock pools flanking a low ridge (Fig. 5). Grid recording over its entire extent



**Figure 3.** A portion of the cupule-covered smoothed support flanking the small rock pool at Klipbak 1.



**Figure 4.** Northward view of the Potholes Hoek site on the footslopes of a hill on the original farm Sunstroke.



**Figure 5.** View to the north-west of the Nchwaneng site with its flanking pools on the farm Diep Druppel.



**Figure 6.** Potholes formed by localised subglacial meltwater action some 300 million years ago.

in 2001 documented ~1500 discrete hammered images of which ~80% show wind abrasion damage to an extent that, in some instances, render them barely perceptible 'on passing the finger over' (Rogers 1908). Cupules (~640) dominate, but also present are outline circles, lines, stars, crosses, triangles, U and V shapes, dots, blobs, and a few human images, with the ~5% balance being semi-naturalistic zoomorphs, usually in profile outline, and including 'eland', 'rhinoceros' and 'lion', that are all historically documented in this region (Skead 1980).

Other petroglyph occurrences seen on Tswalu are Klipbak 2, ~100 m upslope of Klipbak 1, where there are ~50 cupules, an outline circle, a meandering line, and an indeterminate animal image, all close to a shallow pool that has lost a part of its wall, and Gosa 1, where a few worn outline circles occur at a seepage point halfway up a valley east of the homestead there.

Localities seen beyond Tswalu are Steenkamp 1, on an adjacent farm, where outline circles and zoomorphs occur on a smoothed quartzite outcrop exposed in a gully close to the farmhouse; and Steenkamp 2, a few outline circles on hillside drainage-line rocks north of it.

### Support abrasion

It was soon seen that petroglyphs did not occur on normally rough and angular hillside rock surfaces, but were, rather, entirely confined to small smoothed

portions of it that were usually situated low in the regional landscape. Those patches were then noted to be further distinguished by the occasional presence of parallel rows of faint chatter/skip marks, the previously mentioned potholes, and ridge-flanked rock pools, the latter seemingly formed by the plucking out of bedrock slabs, all of which suggested past ice action (Fig. 6). That inference was confirmed during a visit by geologists M. de Wit and J. Ward, two authorities in this regard, who linked those features to southward glacial movement during Permo-Carboniferous times, 320–270 million years ago, when southern Africa, as part of Gondwana, was situated near the South Pole (du Toit 1937; MacRae 1999). Freshly smoothed localised rock surfaces were at that time covered by tillites and shales that have since been eroded away in the Tswalu region, with subsequent support re-exposure at differing times resulting in the heavy, moderate and light rock surface weathering seen at Klipbak 1, Nchwaneng and Potholes Hoek, respectively. This evidence therefore indicates that geological forces in the distant past fortuitously pre-adapted portions of the Korannaberg hills to much later Stone Age needs, by creating both the rock pools and potholes that are the sole source of essential surface water there, as also the smoothed adjacent rock surfaces which are ideal for petroglyph production.

An implication for palaeoart interpretation would be that cupule dimensions may well vary with differing support weathering state, as is suggested by depths of up to 34 mm at Klipbak 1, but of less than 10 mm at Potholes Hoek. As regards subsequent cupule surface weathering, two states are present at Klipbak 1 and Potholes Hoek, but three can be firmly identified in the westernmost pool vicinity at Nchwaneng, namely slightly weathered shallow cupules and other images on its upslope side, moderately weathered cupules and outline circles on an adjacent ridge, and severely weathered cupules next to that outcrop.

### Archaeological sites

Reconnaissance on and beyond Tswalu also located a number of LSA, MSA, EMSA and ESA lithic occurrences, with details being as follows, beginning as before with the mapped localities, and with an appended question mark indicating uncertainty as to their period ascription, usually because of low sample size.

Near the Klipbak 1 rock pool a sparse LSA scatter with ceramics is underlain by artefacts that eroded downslope exposures show to represent an extensive ESA (Late Acheulian) site. Then, at Potholes Hoek, the saddle slopes to the east have low density spreads of fresh MSA and lightly smoothed ESA? artefacts. Also, on the western edge of the support there, erosion has exposed a rubble-rich sand stratum with lightly patinated ESA? lithics. And at Nchwaneng, a test pit sunk in 1986–87 just west of the rock pools revealed two stratified LSA (Wilton and Swartkop) industries overlying MSA (Pietersburg / Mossel Bay) (Beaumont

and Vogel 1989). Inverted  $^{14}\text{C}$  readings indicate severe bioturbation of the sands there, thus rendering it unlikely that OSL can be used to accurately date the MSA stratum. Additionally, directly downslope of the rock pools, Kalahari sands overlie a rubble with EMSA (Fauresmith) (Fig. 7), while from the eastern edge of that locality come a few large handaxes of ESA ascription.

Other sites on Tswalu are Klipbak 2, where a sparse LSA spread overlies MSA? just north of the damaged rock pool, and MSA material underlain by similar lithics on a flat sand-covered platform on the otherwise steep slopes immediately east of it. At Tarkuni 1 an extensive area of low stone walling with associated Ceramic LSA occurs on a hillside west of the farmhouse, while at Tarkuni 2 a ~2 m deep warthog burrow hole exposed a rich ESA site below Kalahari sands on a hill slope close to the homestead. And near the Tswalu vehicle workshop is Witberg 1, an up to 4 m deep road gravel quarry has exposed a dipping level with ESA (Acheulian) below sparse similar material in calcified sediments. Sites seen beyond Tswalu are limited to Langkloof 1, a small (2 × 2 m) cave with surface LSA and ceramics in a gorge deep in the mountains on that farm.

#### Palaeoenvironmental information

A typological analysis of the above-cited LSA occurrences showed that all of them fall within the past ~12 ka, with none thus present in its longer prior timespan, that ranges back to ~48 ka regionally, based on OSL dates at White Paintings Shelter in Botswana (Robbins et al. 2000). This temporal mal-distribution is best taken to mean that the human presence in the Korannaberg region was highly pulsed, with heavy occupation in warm and wetter Holocene times, but virtually none during the prior cooler and drier Last Glacial (e.g. Beaumont 1986). The listed lithic data, as a whole, are, in terms of that inference, best taken to indicate single occupations during warmer and wetter periods, in the LSA, MSA and EMSA, plus one or more in the ESA (Acheulian), when water would have been available in close-by pools and ponds.

Amplifying this artefact-based evidence for past fluctuations in human population densities in the Korannaberg vicinity are regional palaeoclimatic findings, beginning with those from Equus Cave, ~200 km east of Tswalu, near the spot where the ~3 million-year-old *Australopithecus africanus* type specimen was found in 1924 (Dart 1925; McKee 1996). Adjacent road building there had exposed a section of 2.5 m deep deposits, the partial excavation of which, in 1978 and 1982, established a sequence of four natural



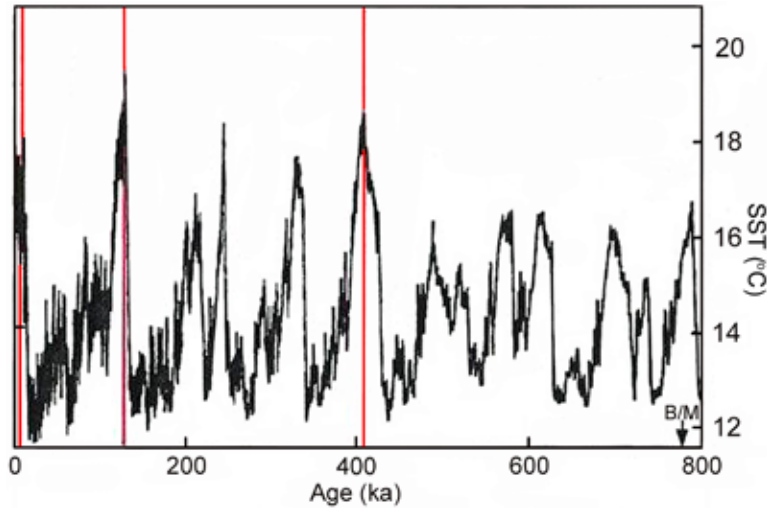
Figure 7. Two laterally retouched points and a handaxe from the Fauresmith occurrence at Nchwaneng.

levels containing a vast large mammal fauna (~50 species) that had resulted from the use of this site as a brown hyaena maternity den (Klein et al. 1991) over the past 35 cal. ka. Associated pollens (Scott 1987) show that Holocene-aged Stratum 1a formed under a modern-like grass and tree cover, preceding which is a shift to a grassland steppe in Stratum 2a, that spans the Last Glacial Maximum centred on ~18 ka, when temperatures in South Africa were ~6–7° C lower than presently (Talma and Vogel 1992). An isotopic study of stratified ostrich eggshell samples (Johnson et al. 1997) further shows that temperature decline to have been accompanied by an up to ~60% reduction in mean annual precipitation, thereby implying that rainfall in the Tswalu region at that time was a mere c. 120 mm, the effectiveness of which was likely further reduced by higher wind speeds and resultant evaporation rates then (e.g. Petit et al. 1981).

In close accord with those findings are OSL ages for presently vegetated linear dunes in the southern Kalahari (Fig. 8), which show that these were mainly emplaced ~28–12 ka ago, and that this manifestation of greater aridity and north-westerly wind intensity then can be traced back to at least 60 ka BP (Lancaster 1988;



Figure 8. A linear dune, now largely stabilised by vegetation, on the road between Tswalu and Nchwaneng.



**Figure 9.** Temperature fluctuations since 800 ka BP at Dome C in Antarctica, from Bard and Rickaby (2009), indicating the three occasions when the climate around Tswalu was as warm or warmer than now, and also that the Acheulian occupations there must predate that timespan.

Stokes et al. 1997; Bateman et al. 2003). Furthermore, data from the Beeshoek petroglyph site (Beaumont in prep.), ~110 km to the south of Tswalu, show that even small Holocene aridity increases, IRSL dated to ~4 ka ago, resulted in the re-activation of Kalahari sands locally, as a result of reduced vegetation cover and higher wind speeds at that time. And how those colder times impacted on past people in that region can be seen from the  $^{14}\text{C}$  and U-series calibrated artefactual record at Wonderwerk Cave, 110 km south-east of Tswalu, where there is a total lack of human occupation between earliest LSA there at ~12 ka ago and the youngest MSA stratum at ~80 ka BP (Beaumont and Vogel 2006). What this palaeoclimatic evidence, as a whole, therefore indicates, by reference to the global marine and ice

core archives (e.g. Shackleton 1995), is that the Tswalu region has been subjected to long intervals of Ice Age aridity since ~900 ka BP (Schefuss et al. 2003), when the few local water sources were dry and humans consequently absent.

Conversely, cupule patination states at Nchwaneng show that such colder times were broken by three episodes of interglacial magnitude, when the climate was as warm or warmer than the present, of which the youngest was the Holocene / OIS 1, and particularly its hypsithermal interval at ~6–5 ka ago (e.g. Iriondo 1999), as shown by microerosion readings of that order at Nchwaneng. The preceding interglacial, which was markedly warmer and wetter than now, with a global sea level up to ~8 m higher than at present (Kopp et al. 2009) is, by way of microerosion estimates of before 50 ka ago, confidently taken to be OIS 5e, during which peak temperatures occurred early in its 130–115 ka BP span (Kawamura et al. 2007). Placement of the earliest warmer and wetter than now interglacial was fortuitously established by field surveys in central South Africa by van Riet Lowe (Goodwin and van Riet Lowe 1929), and one of us (PBB) latterly, which indicate that by far the most common industry there between MSA and ESA times is the EMSA-aged Middle Fauresmith (op. cit.: 71–94). The high archaeological visibility of that industry, with bracketing ages of ~540–280 ka ago (Beaumont and Vogel 2006; Porat et al. 2010), is best taken to refer to a climatic amelioration linked to OIS 11 at ~410–400 ka ago, which would then make the Middle Fauresmith coeval with the Holsteinian of north-western Europe, the warmest interglacial there prior to OIS 5e (Jöris 2014).



**Figure 10.** A loose rock slab with a cupule on it from the edge of the smoothed support at Klipbak.

In terms of this temporal framework for the Tswalu region (Fig. 9), the Middle Fauresmith is ~410–400 ka old, the Pietersburg / Mossel Bay refers to OIS 5e, and the Wilton lithics at Nchwaneng would be of mid-Holocene age, while the Ceramic LSA and Acheulian assemblages would seem, on present evidence, to owe their presence to the water sources, rather than be connected to the adjacent palaeoart.

#### Microerosion estimates

Despite the intensive search, no mobiliary palaeoart in dateable stratified sediments, such as those at Sai Island (see Introduction) could be found, with the closest approach being on the western margin of Klipbak 1, where cupule-covered fractured pieces of the support edge were seen on the surface (Fig. 10). It may thus be that similar occurrences exist, perhaps in deep deposits there and

elsewhere, like those flanking the steeply sloping outcrop at Potholes Hoek, but checking on that possibility would require extensive excavation, with no assured success, which was not deemed a viable current option. Fortunately, the consequent lack of temporal data was breached in 2009 when a microscopic study of the three mapped localities provided a number of microerosion readings. These were, in the absence of a calibration curve for the southern Kalahari, based on secure values for a climatically reasonably similar region, the Spear Hill petroglyph complex in the eastern Pilbara of Western Australia (Bednarik 2002a, 2002b).

That study again commenced at Klipbak 1, where the hammered grooves outlining an indeterminate 'antelope', sans head, are 10–15 mm wide, and generally quite shallow, with the figure's rear end formed by its deepest (up to 2 mm) portion, which offered the best prospects for microerosion analysis. Numerous suitable edges in a small area yielded 35 micro-wane measurements varying from 4–12 microns (mean 7.1 microns), that, using the Spear Hill calibration values, provide an age of  $E1600 + 1090 / - 700$  years BP. Several outline circles that were checked provided no suitable surface, with the questionable exception of one in the main cupule concentration, which offered a very diffuse micro-wane of 280 microns length, from which 7 micro-wane width values with a mean of 67.4 microns (range 60–72 microns) was obtained. This would, on calibration, correspond to an age of  $E15\ 080 + 1660 / - 1020$  years BP, but, in view of the lack of other suitable surfaces on the cupule and outline circles that were examined microscopically, it seems likely that this age refers to its subsequent re-working. In general, as with a nearby 18-mm-deep cupule, the exposed quartz grains, although of inherently angular shape, have rounded 'domed' surfaces, and entirely lack detectable impact traces (conchoidal features, battering, internal fractures), on the basis of which an antiquity of less than 50 ka for either the outline circles or the cupules at Klipbak 1 are most unlikely.

At Potholes Hoek, rock surfaces among the potholes and extending down to a certain elevation, perhaps marking a past maximum level of stagnant water, are evenly covered by a very thin (~5 microns) brown patina, which also covers two (or more) discrete episodes of petroglyph production that are readily distinguishable by their microscopic weathering characteristics. Younger phase petroglyphs on the lower end of the smoothed support include some small cupules, outline circle motifs from ~60–100 mm across, and uncompleted outline circles delineated by widely spaced blows, which are whitish in



Figure 11. RGB conducting microerosion analysis at Nchwaneng.

colour, due to the 'blistering effect' caused by light reflection in very thin, weathered cutaneous microfractures. Further north are a few dozen cupules of two types, small shallow specimens ~20–30 mm in diameter, and others 40–50 mm across and up to 7 mm deep, that are perceptibly more worn than the former. Near the western margin of the sheet are other small cupules and an outline circle motif, upslope of which are four more cupules of the larger and older type, two of which have been truncated by a later fracture of the support panel. Both show virtually no microscopic relief, with both the cupule floors and the fractured surface being weathered far beyond the range of the microerosion method.

Last examined was Nchwaneng, where three phases of petroglyph production are evident, but only the youngest offered adequately preserved fractures to permit a quantitative microerosion assessment (Fig.

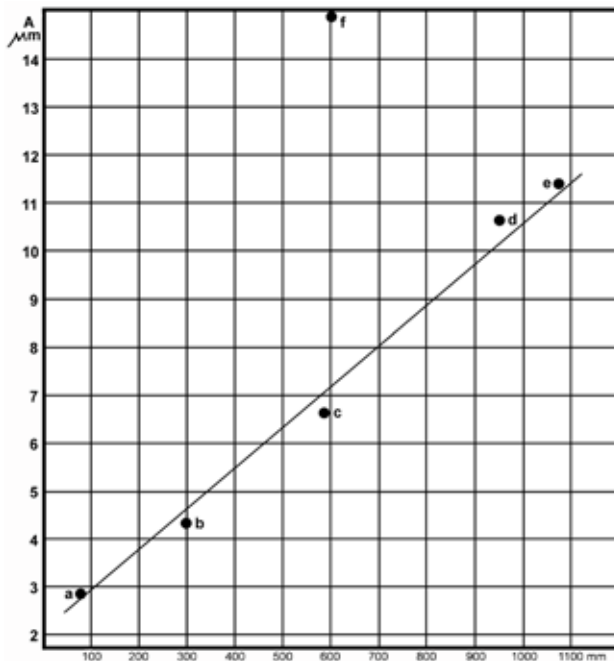


Figure 12. The semi-naturalistic ~E5.1 ka-old 'rhinoceros' image at Nchwaneng.



**Figure 13.** A closer view of the ~E1.9 ka-old patterned cupules next to a 'giraffe' image at Nchwaneng.

11). The two earlier phases are clearly beyond the ~50 ka range of that method in this environmental setting. Of the several motifs of the youngest group checked to secure regularly angled fractures, three were found to provide conditions suitable for microerosion analysis. On the first, a semi-naturalistic 'rhinoceros' image (Fig. 12), the area of the horn yielded five micro-wane measurements averaging 23 microns (range



**Figure 14.** Microerosion coefficients of Ha'il (a), Spear Hill (b), Deyunshan (c), Grosio (d), Vila Real (e) and Besov Nos (f) as the function of respective annual precipitation data. The Russian value is anomalous because the site is frequently washed over by the lake. Based on an annual average rainfall of 330 mm at Tswalu, a coefficient of about  $4.8 \mu\text{m}$  can be predicted for the sites described here.

21–26 microns), that, by way of the Spear Hill calibration curve, would result in an age estimate of  $E5144 + 670 / - 450$  years BP. Then came a group of very shallow, geometrically arranged cupules near a 'giraffe' image (Fig. 13), which yielded eight dimensions at  $90^\circ$  ranging from 7–10 microns (mean 8.5 microns), that, using the same calibration curve, would correspond to an age of  $E1900 \pm 340$  years BP. And lastly was an 'eland' figure that offered one split quartz crystal, the right hand edge of which was unsuitable, but the other provided seven micro-wane width determinations ranging from 25–29 microns (mean 27 microns), that, using the same calibration curve, provided an age estimate of  $E6060 + 425 / - 470$  years BP.

One way to circumvent the lack of a local calibration curve for microerosion analysis is to estimate the predicted microerosion coefficient on the basis of relative precipitation, determining its position on the curve of reliable measurements elsewhere. This is attempted in Figure 14, on the basis of precipitation vs microerosion coefficients at sites in Saudi Arabia, Australia, China, Italy, Portugal and Russia. The mean annual rainfall measured at 33 sites in the Tswalu Kalahari Reserve in the ten years 2001 to 2010 is 329.6 mm. If this value is placed in the median curve of Figure 14, it corresponds to a microerosion coefficient of about  $4.8 \mu\text{m}$ . That permits the application of a correction factor of  $4.316 / 4.8 \approx 0.9$  to the above-listed mean, minimum and maximum age estimations, to arrive at probably more realistic datings.

Petroglyphs of the second group at Nchwaneng comprise cupules and outline circles that are of significantly greater age, as indicated macroscopically by weathering condition and patination state, while microscopically those surfaces show low relief among crystals, with negligible retreat of the cement. An exhaustive search yielded no evidence of surviving fracture edges and, on that basis, those petroglyphs may be safely attributed to a timespan beyond the effective range of the microerosion method, considered to be in the order of 50 ka (Bednarik 1996).

The oldest petroglyph phase at Nchwaneng is significantly earlier again, as shown by the almost flat microscopic relief where the motifs are well preserved, with surviving examples linked to just two occurrences: at the foot of some vertical panels next to the large western-most pool, and on its opposite margin. Some of the upright rock slabs there have broken and become displaced previously, so that the base of one of them partially conceals one of the horizontal cupules, while nearby, two of the severely weathered earliest cupules have begun to exfoliate by way of a pattern previously observed on cupules elsewhere (Bednarik et al. 2005; Bednarik 2008). In this process a surface layer of up to 1 mm thick within the cupule has been



rendered more resistant to weathering than the underlying rock, and, as the latter was subjected to slow dissolution, the cupule floor resisted. However, in this particular case, the more resistant cutaneous layer has also begun to exfoliate, with the emerging 'cupule shadows' seen to be retaining the shape of the cupule floor faithfully. Although unproven, it is likely (Bednarik 2008: 88) that the resistant layer relates to the collective kinetic energy released by the tens of thousands of hammerstone blows that are required to produce a cupule of such size on hard quartzite (Kumar and Krishna 2014). The conversion to tectonite is thought to be attributable to crystallisation of the syntaxial quartz overgrowths on quartz grains that constitute the cement component of quartzite, through a tribological process metamorphosing the protolith (Bednarik 2015).

#### Data summary

The three phases of cupule production identified by microscopic study at Tswalu in the previous section can be linked to coeval warmer and wetter intervals of interglacial amplitude and related lithic industries as follows:

First phase: relatively large, well-made deeply hammered cupules that occur in unstructured clusters on largely horizontal panels and which can be tentatively referred to a marked warm and wet interval at ~410–400 ka ago (Fig. 15). Likely associated lithic assemblages belong to the Middle Fauresmith with distinctive small and somewhat thick handaxes, of which specimens have been found immediately downslope of the earliest cupule occurrence at Nchwaneng. The Fauresmith occupation of the site clearly predates the brief interglacial at ~225 ka BP (see Fig. 9). This phase is represented at the plotted sites Potholes Hoek and Nchwaneng.

Second phase: usually smaller and often shallower cupules that tend to be in smaller unstructured groups (Fig. 16), together with well-shaped, typically ~70 mm wide circles with outlines 10 mm or more thick (Fig. 17), and occasional meandering lines. Such petroglyphs certainly refer to the Last Interglacial at ~130–115 ka BP, and are linked to a rather bland MSA assemblage of Mossel Bay / Pietersburg type, of which the lowermost industry from the excavation just west of the Nchwaneng pools is typical. This phase of petroglyph production has been observed at all of the mapped localities.



Figure 15. Some of the ~40 extremely weathered Phase 1 cupules at the base of rock slabs at Nchwaneng.



Figure 16. Surviving moderately weathered Phase 2 cupules on a disintegrating rock face at Nchwaneng.



Figure 17. A distinctive Phase 2 broad outline circle, dating to ~120 ka ago, from Klipbak 1.



**Figure 18.** The relatively fresh Phase 3 geometric patterns of Holocene age at Nchwaneng.

Third phase: much more recent petroglyphs, in terms of patination and weathering state, that feature often still smaller and shallower cupules, usually in structured groups (e.g. rows), or as part of larger motifs; also circles with outlines ~4–8 mm thick, together with variable complements of iconic images (Fig. 18). It undoubtedly refers to the Holocene, as shown by the microerosion readings, and is related to lithics belonging to the LSA, and more particularly the Wilton occurrence in the excavation at Nchwaneng. This phase is represented at plotted sites Klipbak 1 and Nchwaneng.

### Concluding comments

Cupules are a palaeoart form that has been recorded from every continent that early humans have occupied, and the finding of a three phase sequence of them showing systematic changes in mean dimension, group structure and associated motifs is therefore significant. Of additional heritage interest is that the ~400-ka-old cupules at Potholes Hoek and Nchwaneng are the earliest yet found worldwide, with the possible exception of undated Lower Palaeolithic-linked occurrences at Auditorium Cave and at Daraki-Chattan in central India (Bednarik 1993, 1996, 2001; Bednarik et al. 2005).

The ~130–115-ka-old broad outline circles, if taken together with sub-Saharan marked mobiliary finds postdating ~100 ka ago (Beaumont and Bednarik 2012, 2013), indicate the presence in southern Africa of a sequence of non-representational geometric motifs that continue up to historical times (e.g. Goodwin 1936). A future challenge is the location, description and dating of localities where such images occur in petroglyph form further north (Cole 1954), whence their makers would have retreated during Ice Age times, of which an example may be markings on flat outcrops in Angola that consist of 'concentric circles, cup markings and ... curvilinear motifs' (Clark 1959: 269).

Lastly, the only major change in sub-Saharan palaeoart context came with the advent of iconic images, currently by ~32 ka BP at Apollo 11 Cave (Beaumont and Bednarik 2012, 2013) during the LSA, which appears in central southern Africa at ~48–44 ka ago (Robbins et al. 2000; Villa et al. 2012). From there the LSA onset can be traced northwards to its beginnings at  $60 \pm 2$  ka BP in east Africa (Gliganic et al. 2012; Beaumont and Bednarik 2013), that was then the continental focal point of genetic and cultural transformation (e.g. Watson et al. 1997; Quintana-Murci 1999).

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### APPENDIX 1

#### Published cupule sites in sub-Saharan Africa

Sai Island, northern Sudan. The excavation of a ~220–180 ka old stratum at site 8-B-11, between the 2nd and 3rd Nile cataracts, exposed three sandstone slabs, each with a single cupule on it (Van Peer et al. 2003, 2004).

Unnamed village, central Sudan. A locality on the west bank of the Nile, north of the 6th cataract, comprises a single stone, perhaps a rock gong, with a number of cupules on it (Fagg 1956).

Datsen Mesa, north-central Nigeria. At the base of a hill near Birnin Kudu, south-east of Kano, are rock gongs with cupules on them (Fagg 1956; Goodwin 1957).

Datsen Murufu, north-central Nigeria. At the base of a hill near Birnin Kudu, south-east of Kano, are rock gongs with over 50 cupules on them (Fagg 1956).

Bokkos, central Nigeria. A locality to the south of Jos, where a rock gong has cupules on it (Fagg 1956).

Old Oyo, south-western Nigeria. Near this abandoned town, north of Ibadan, are rock gongs with cupules on them (Goodwin 1957).

Bidzar, northern Cameroon. This locality near Guider comprises a ~2.5 km long occurrence of calcareous marble with cupules on a number of its outcrops ([www.bradshawfoundation.com/central.africa/cameroon.php](http://www.bradshawfoundation.com/central.africa/cameroon.php)).

Nsengezi, south-western Uganda. A steep rock face, close to and on the north bank of the Kagera River, was seen to be covered by a great number of cupules that resembled a 'star map' in overall design (Wayland 1938; Cole 1954).

Ufuvu, northern Tanzania. On the crest of a hillside overlooking the Mruma Mission School were a dozen or more granite slabs pocked by from 4 to 53 irregularly placed cupules ~50 mm across and ~10–20 mm deep (Fosbrooke 1954).

Londergess, north-central Tanzania. Lying between an ancient well and habitation site in central Masailand was a single stone with ~6 cupules on it (Fosbrooke 1954).

Engaruka, north-eastern Tanzania. A few slabs found in the ruins of this old city were marked by irregular lines and cupules (Leakey 1936; Fosbrooke and Marealle 1952; Cole 1954).

Samunge, north-eastern Tanzania. In the vicinity of this village was found a stone with irregularly spaced cupules on it (Fosbrooke 1938; Fosbrooke and Marealle 1952; Cole 1954).

Kilimanjaro, north-eastern Tanzania. On its lower slopes were four stones covered by meandering lines and cupules, but all of the latter are here considered suspect (Fosbrooke and Marealle 1952; Cole 1954; Clark 1959).

Chifubwa Stream Shelter, northern Zambia. This small shelter ~6 km from Solwezi had its back wall, and up to 2.4 m below the deposit floor, covered by rubbed petroglyphs, including vertical lines, inverted Us, usually with a central vertical line, and shallow randomly placed cupules, except for two short lines of them (Dart 1931, 1953; Clark 1958, 1959).

Child 1, Tsodilo Hills, north-western Botswana. An open site on the western side of Child Hill with 33 cupules (Walker 2010).

Child, Tsodilo Hills, north-western Botswana. A cave on the western side of Child Hill that contains 32 cupules (Walker 2010).

Near Sex, Tsodilo Hills, north-western Botswana. An overhang on the northern end of Female Hill with two cupules on it (Walker 2010).

Rhino Cave, Tsodilo Hills, north-western Botswana. A fissure-formed tunnel on the northern end of Female Hill has one of its walls largely covered by over 300 ground cupules and vertical grooves up to 0.5 m long (Robbins et al. 1996, 2007; Walker 2010; Brook et al. 2011; Coulsen et al. 2011).

White Cow Shelter, Tsodilo Hills, north-western Botswana. This painted site on the northern end of Female Hill also contains three cupules (Walker 2010).

Chokxam Cave, Tsodilo Hills, north-western Botswana. In this deep cave on the northern end of Female Hill there are 42 cupules on vertical faces (Walker 2010).

Unnamed site, Tsodilo Hills, north-western Botswana. A steeply sloping rock face on the eastern side of Female Hill that is partly covered by rubble has 129 cupules on it (Rudner 1965).

Cleft, Tsodilo Hills, north-western Botswana. A rock crevice on the eastern edge of Female Hill that has 20 cupules in it (Walker 2010).

Eastern, Tsodilo Hills, north-western Botswana. This locality on the eastern edge of Female Hill yielded a few cupules (Walker 2010).

Depression Shelter, Tsodilo Hills, north-western Botswana. This vertical rock wall on the eastern side of Female Hill is partly covered by over 1000 closely spaced cupules, and, although excavated, the trench, which exposed LSA overlying MSA, did not reach bedrock (Rudner 1965; Robbins 1990; Walker 2010).

Nqoma East Shelter, Tsodilo Hills, north-western Botswana. In this small shelter towards the southern end of Female Hill

there are 28 cupules and a rock-gong (Walker 2010).

Origins, Tsodilo Hills, north-western Botswana. An open site towards the southern end of Female Hill with three cupules (Walker 2010).

Hidden Valley Shelter, Tsodilo Hills, north-western Botswana. This shelter towards the southern end of Female Hill has 151 cupules in it (Walker 2010).

Well, Tsodilo Hills, north-western Botswana. A valley entrance open site near the southern end of Female Hill with a single cupule (Walker 2010).

Female East Shelter, Tsodilo Hills, north-western Botswana. In this small shelter on the southern foot of Female Hill two paintings and 32 cupules were noted (Walker 2010).

Female Cave, Tsodilo Hills, north-western Botswana. A ~6 m deep open cave on the southern foot of Female Hill has a floor largely covered by rock slabs, on some of which 193 randomly placed cupules occur, including one slab with 37 specimens, ~30–80 mm across and 3–25 mm deep (Rudner 1965; Walker 2010).

Kudu Horn Shelter, Tsodilo Hills, north-western Botswana. This overhang on the western side of Male Hill has 152 cupules in it (Walker 2010).

Ancestors Cave, Tsodilo Hills, north-western Botswana. A small cave on the western side of Male Hill has 78 cupules on a vertical face and on a loose floor slab at its main entrance (Campbell et al. 1994; Walker 2010).

Watercleft, Tsodilo Hills, north-western Botswana. On the western side of Male Hill is a large flat exfoliated slab, resting steeply against other rocks, that has 28 shallow cupules scattered over it (Rudner 1965; Walker 2010).

Male Cave, Tsodilo Hills, north-western Botswana. This large cave on the southern end of Male Hill has two cupules at its mouth (Walker 2010).

Dead Goat Shelter, Tsodilo Hills, north-western Botswana. This small shelter on the southern end of Male Hill contained six cupules (Walker 2010).

Corner Cave, Tsodilo Hills, north-western Botswana. This small cave on the southernmost side of Male Hill has over 200 cupules on horizontal slabs, with the results of a test pit in the shallow deposits there taken to suggest that the cupules resulted from the making of spheroids during MSA times (Walker 2008, 2010).

Hill Ruin at Khami, south-western Zimbabwe. A few granite slabs with petroglyphs on them from this locality ~21 km west of Bulawayo include one having a herringbone pattern with a cupule at its midpoint, and another with a diamond motif that has a central cupule (Robinson 1953).

Plumtree, south-western Zimbabwe. An illustrated boulder from this town shows grooves and ~2 dozen cupules on its sides and upper surface (Cooke 1964).

Ghaub, northern Namibia. An old photograph records that the petroglyphs on the floor of a river bed there comprised hammered footprints, and cupules (Rudner 1965; Rudner and Rudner 1968).

Twyfelfontein, western central Namibia. Over a hundred petroglyph-covered sandstone slabs that occur within 3–4 km of the Ai-Ais spring. These include Symbol Rock, where there are rows of small circles of cupules with a central cupule; Prancing Kudu Slab, that also has circles of cupules with a crescent-shaped marking in the middle; and a shelter where cupules occur on its side walls (Viereck and Rudner 1955; Rudner and Rudner 1968).

Great Dome Ravine, central Namibia. This rich petroglyph site includes iconic depictions, designs and cupules (MacCalman 1963; Rudner and Rudner 1968).

Kamkoes, central Namibia. Petroglyphs on a granite floor

there comprise deeply hammered animal tracks, a human figure, and a ladder design with an adjacent cupule (Rudner and Rudner 1968).

Northern Tuli Game Reserve, eastern Botswana. A survey, mainly between the Motlatse and Shashe Rivers, found 25 localities with petroglyphs that include grooves and cupules (Forssman 2013).

Mochudi, south-eastern Botswana. Noted in 1866, near the Notwane – Limpopo confluence, was a large rock with petroglyphs that included a small cupule with circles around it (Anderson 1888; Wilman 1933).

Riverslee, south-eastern Botswana. Fieldwork at a sandstone pavement around a small pan on this farm ~8 km from the Limpopo River located 8 panels; with cupules on Panel 1, which had 7 specimens 30–40 mm across and 10–20 mm deep; Panel 3, where 6 of similar size formed a square; Panel 4, which had three rows of them; and Panel 8, where 35 were found (Van der Ryst et al. 2004).

Basinghall, south-eastern Botswana. An inspection of an outcrop of flat sandstone slabs ~300 m from the Limpopo River on this farm identified 4 panels; with 4 cupules on Panel 3, 3 of them in a row; and two cupules on Panel 2, of which one was shallower and less patinated than the others (Van der Ryst et al. 2004).

Schroda, northern South Africa. Found on this farm just south of the Limpopo River was a large loose rock with petroglyphs of animal tracks and randomly placed cupules (Schoonraad 1960).

Mapungubwe, northern South Africa. On this large inselberg, ~2 km south of the Limpopo-Shashe confluence, there are cupules, including some at the base of a small hilltop rock pool (Schoeman 2006).

Rhodes Drift Hill, northern South Africa. A domed sandstone hill, ~10 km west of the Limpopo-Shashe confluence, with 15 cupules near its crest (Schoeman 2006).

EH Hill, northern South Africa. The examination of this sandstone hill, ~7 km south-west of the Limpopo-Shashe confluence, recorded 72 scattered cupules, except for two small clusters (Schoeman 2006).

M35 Hill, northern South Africa. Fieldwork at this sandstone hill, ~8 km south-west of the Limpopo-Shashe confluence, found 37 scattered cupules, including one in a pool below excavated Iron Age debris (Schoeman 2006).

JC Hill, northern South Africa. A survey of this sandstone hill, ~10 km south-west of the Limpopo-Shashe confluence, identified 49 scattered cupules, mainly near water sources (Schoeman 2006).

Lydenburg, north-eastern South Africa. Diabase boulders with petroglyphs on them, located ~4 km north-west of this town, include some with cupules only, and others that have cupules surrounded by circles (Pijper 1919; Dart 1931).

Cyferfontein, central South Africa. The examination on this farm in the Parys district of a rock gong, revealed two

cupules, ~100 mm across and ~25 mm deep on its south side, four smaller ones on the north end, and several more at other places, with the sounds those emitted when struck being recorded by a musicologist (Malan 1959).

Gestoptefontein, central South Africa. Outcrops of a soft slate-like rock (wonderstone) on this farm ~1.5–2.0 km north of Ottosdal are covered by petroglyphs that include unpatterned cupules (Hollmann 2013).

Driekuul, central South Africa. Petroglyph-covered outcrops of wonderstone on this farm ~1 km north of Ottosdal include unpatterned cupules (Hollmann 2013).

Bernau, central South Africa. On this glacially striated diabase pavement just east of Vryburg are petroglyphs that include small cupules, about 30 mm in diameter and 15 mm deep (Fock 1969; Fock and Fock 1984).

Potholes Hoek, central South Africa. On the western side of a hill near the north side of Tswalu is a smoothed rock sheet with a few outline circles and ~40 randomly placed cupules on it (Beaumont and Bednarik 2012, 2013).

Klipbak 1, central South Africa. Near the crest of a hill on the northern end of Tswalu is a rock pool and flanking rock sheet with petroglyphs dominated by irregularly spaced cupules, but also including outline circles, meandering lines and rubbing areas, while nearby are less weathered hammered human and animal images (Beaumont and Bednarik 2012, 2013).

Klipbak 2, central South Africa. A hundred metres or so upslope of Klipbak 1 is a pond that has lost part of its walling, next to which are ~50 cupules, an outline circle, a meandering line and an indeterminate zoomorph (this article).

Nchwaneng, central South Africa. The petroglyphs on the northern footslopes of this low inselberg ~20 km south of Tswalu were noted, in 1907, to include 'small conical hollows two inches wide and one deep' (Twelfth Annual Report of the Cape of Good Hope Geological Commission, 1908) and subsequent studies there were undertaken by Wilman (1933), Fock and Fock (1984), and one of us (PBB) in 1986–7 and in 2000–1.

Beeshoek South, central South Africa. A linear outcrop of a white, talc-like rock in this iron ore mine just west of Postmasburg was covered by animal images, concentric circles and circles with a central dot or deep cupule (Wilman 1933; Rudner and Rudner 1968).

Bushman Fountain, Klipfontein, central South Africa. Boulders on a low hill flanking a fountain on this farm, now part of the Rooipoort Nature Reserve, are covered by petroglyphs that include a cupule at the centre of concentric circles, surrounded in turn by radiating lines (Wilman 1933).

Kalk Gat, central South Africa. An illustration features two large diabase boulders straddled by an unpatinated 'python' image, in the Britstown area, but no mention is made of the hundred or more irregularly spaced cupules that are present on the lower rock (Wilman 1933: 37).

## APPENDIX 2 : Cupule dimensions at Klipbak 1

Cupule width (5 mm intervals)									
mm	10 & 15	20 & 25	30 & 35	40 & 45	50 & 55	60 & 65	70 & 75	80 & 85	90 & 95
N = 723	58	309	231	78	35	10	1	1	0
%	8.0	42.7	32.0	10.8	4.8	1.4	0.1	0.1	0
Cupule depth (1 mm intervals)									
mm	1 & 2	3 & 4	5 & 6	7 & 8	9 & 10	11 & 12	13 & 14	15 & 16	17 & >17
N = 723	30	152	220	141	90	38	19	8	35
%	4.1	21.0	30.4	19.6	12.4	5.3	2.6	1.1	4.8

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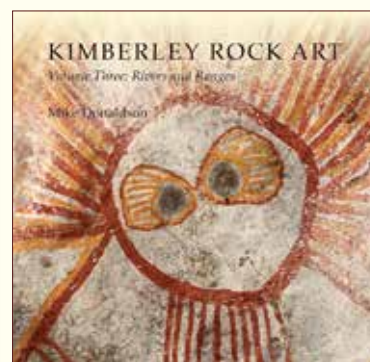
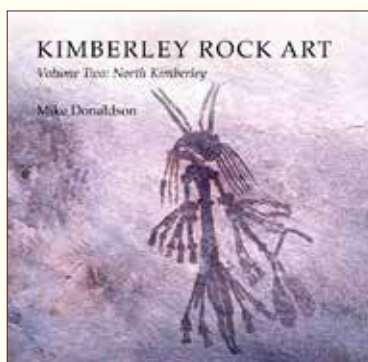
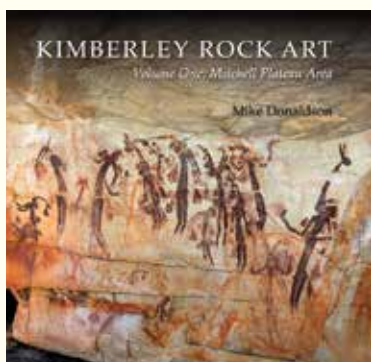
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