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THE TECHNOLOGY OF CUPULE MAKING

Robert G. Bednarik

Abstract. Cupules may seem simple features requiring little technological explanation, until one examines them in their wider context or in scientific detail. The technology of cupule making is considered in an introductory format, leading to a reassessment of the ideas researchers have formed about their significance. Parameters for replication experiments in making cupules are proposed, based on work already undertaken in recent years. The acute need for empirical recording data is identified, leading to a listing of the elements of a scientific system of quantifying cupules in the course of field surveys.

Keywords: Cupule, Replication, Percussion, Hammerstone, Mur-e, Recording standardisation

Introduction

If we exclude what has been written about the distribution of cupules (which is limited and biased), their purported meanings (which is almost universally pure conjecture; see chapter on interpretation in this volume) and futile speculation about their age, we find that the residue of the available literature on this topic is rather limited. This literature has accumulated for much longer than two centuries (consider Abel 1730), and yet it comprises very little in the way of sound scientific information. We have misidentified a host of natural rock markings as cupules and considered them together with authentic ones (see my chapter on discriminating cupules from other markings, this volume); we have invented many idiosyncratic names, cultural roles and attributed cupules to many cultures, usually without evidence. We have speculated about their antiquities and meanings for centuries, and we have without sound data theorised about how they were made. We have created a rich tapestry of cupule mythology, and very little in the way of scientific information.

For instance we have failed to attempt a comprehensive review of the rock types cupules occur on, so we were unable to consider the interdependence of lithology, technology and taphonomy of cupules, which would be a benchmark in their scientific study and a precondition to any valid attempt of etic interpretation. We have severely neglected to secure more ethnographic or emic data relating to them, which of course is an almost universal malaise in the archaeological study of global rock art. We have conducted almost no controlled replication work. Since we failed to develop a standard methodology of surveying cupules empirically, we have no credible statistical and metrical data on cupule morphology, and the published record on the study of work traces in cupules can fairly be described as pitiful. Our endeavours of investigating the gestures involved in the production of cupules are clearly inadequate (de Beaune 2000 being a rare exception), yet without such studies and the introduction of contextual studies our rampant speculations about meanings are mere noise. Archaeologists have even questioned whether cupules should be studied together with other forms of rock art. I contend that rock art science is much better equipped to deal with rock art generally, and with cupules specifically.

Inadequate technological research of cupules (as well as other petroglyphs) has led to numerous assumptions and assertions concerning the way they were made. In particular, many authors have assumed that cupules were produced through indirect percussion, grinding or polishing. For instance, Walsh (1994: 35) contends that some Kimberley cupules are what he terms 'pebraded', i.e. first pecked and then abraded, 'to create a very smooth recess and perimeter'. Although he acknowledges the very great investment of time and energy in making cupules, he goes on to suggest that they were made before the sandstone had fully metamorphosed. This implies that he misunderstood both the technology and the relevant petrography. Taphonomy ensures the preferential survival of cupules on the hardest rocks, which it would be impossible to abrade in the fashion Walsh imagines. The 'abraded' appearance he observed is the result of the pounding action: as the crystals or grains are literally crushed into fine dust particles, the cupule surface and its rim take on a macroscopically polished appearance. But under the binocular microscope, no evidence of abrasion has so far been observed in any genuine cupule anywhere in the world. Not only is the term 'abraded' clearly inappropriate here, the term 'pecked' (Maynard 1977) is so also. There is,

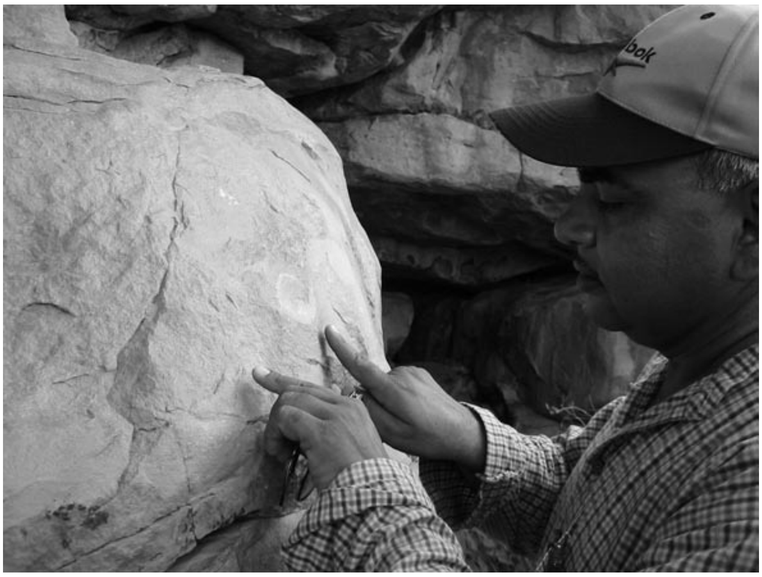

Figure 1. *G. Kumar with two replicative cupules near Daraki-Chattan, central India, which were created by Kumar and associates.*

as noted, no evidence that cupules were made by pecking (Keyser 2007 notwithstanding).

Until refuting evidence becomes available we may assume that all cupules on hard rock (hardness 4 to 7 on Mohs scale) were created by direct percussion, or pounding, and the type of tools used were those observed in ethnographic petroglyph production as well as in all replication work and relevant excavations to date (Bednarik 1998). Technologically, cupules on very soft rock are perhaps more interesting because in favourable circumstances, good traces of their production have remained intact. The softer the rock is, the greater the chance of detecting such traces, increasing the potential of securing valuable technological data. The softest rock on which cupules have been recorded is moisture-containing limestone in caves (Bednarik 1990), which is of hardness 1 to 1½. At one Australian site, hundreds of cupules have been observed on mudstone (hardness 3) with extensive, perfectly preserved work traces (see my chapter on lithology, this volume). Such instances show that indirect percussion has often been used on soft types of rock, but apparently with tools other than lithics. In particular, cupule-like pits in cave walls are the subject of a study by Yann-Pierre Montelle and myself, examining not only tool traces on limestone, but also the gestures involved in the making of these features. The results of this forensic work will be reported in a future paper.

Replication of cupules

In reviewing the technology of petroglyphs generally, I have briefly considered the replication of cupules I conducted and suggested parameters for standardising such experiments (Bednarik 1998: 30, Fig. 5). Since then, Kumar (see his chapter in the present volume) has undertaken more detailed replicative research (Figure 1) into the production of cupules at Daraki-Chattan, India (Bednarik et al. 2005: 168; Kumar 2007). He recorded the details of the hammerstones used (including their wear) in five experiments, the precise times taken for each cupule and the number of impact strikes counted. The first cupule created under his supervision, in 2002, was worked to a depth of 1.9 mm, using 8490 blows in 72 minutes of actual working time. Cupule 2 required on the first day 8400 blows in 66 minutes and reached a maximum depth of 4.4 mm, after which the maker was exhausted. He continued on a second day for another 120 minutes, achieving a total depth of 7.4 mm (total number of blows not recorded). Three more cupules were made in 2004, taking respectively 6916 blows to reach 2.55 mm depth, 1817 blows to achieve 0.05 mm (abandoned), and 21,730 blows (over 2 days) to reach a maximal depth of 6.7 mm. The experimenters suffered fatigue and physical pain and often had to interrupt their work to rest. Their cupules tend to be larger than those in nearby Daraki-Chattan Cave, illustrating lower striking precision relative to the Palaeolithic cupule makers who, we may safely assume, were also of much greater physical strength (consider traces of skeletal muscle attachments on fossil remains) and endurance (Figure 2). At the time of writing (December 2008), Kumar's continuation of his replication studies sought to determine how to keep the diameter of experimental cupules as small as that of the Lower Palaeolithic specimens.

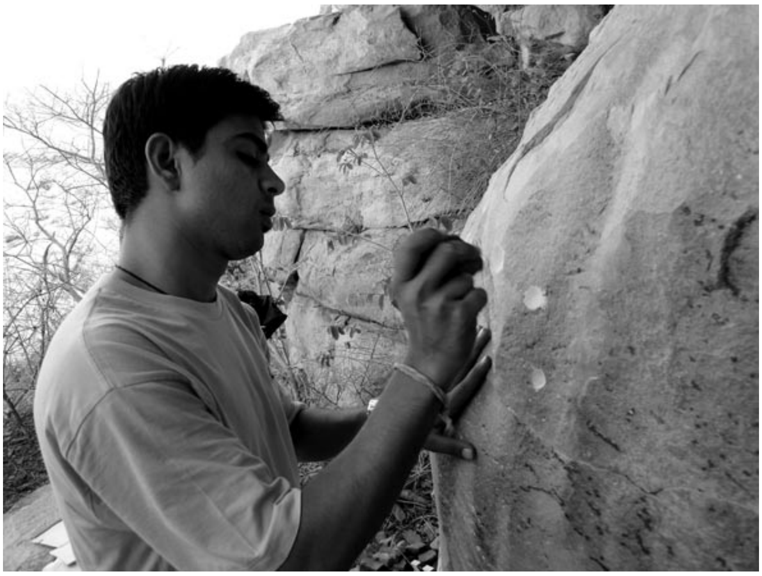

Figure 2. *Replication of cupules by Ramkrishna Prajapati, June 2009, at the location shown in Figure 1. Photograph by G. Kumar.*

Kumar's precise observations show dramatically that an incredible physical effort was required

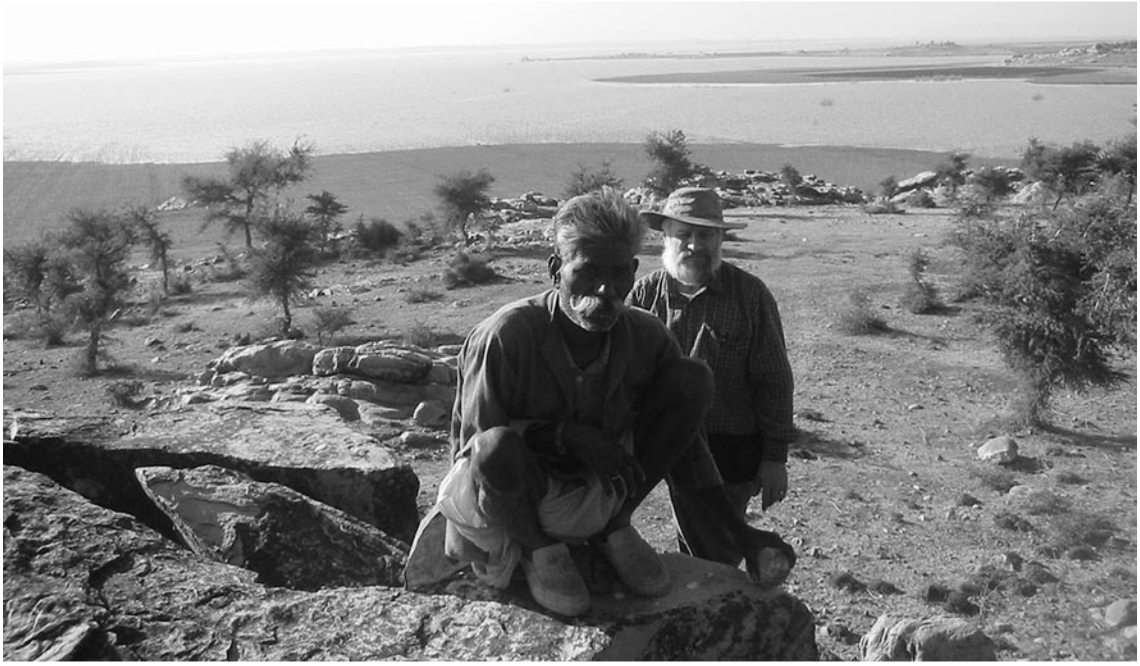

Figure 3. *Ethnographically observed production of a cupule, at Pola Bhata, Madhya Pradesh, India, in 2004.*

to create the Daraki-Chattan assemblage of more than 540 cupules on this extremely hard, almost unweathered quartzite. Additionally, two significant points must be considered. Firstly, the progress of depth relative to time or number of blows is not a linear relationship; as the cupule becomes deeper, progress slows down. Secondly, the smallness of all Palaeolithic cupules at this site is extraordinary. The modern replicator finds it difficult to match the precision in striking the rock that is so clearly and consistently demonstrated by the Palaeolithic operator. Most of the site's cupules are under 40 mm diameter, yet many are in excess of 6 mm deep. In the most extreme case observed at Daraki-Chattan, a cupule of only 25.5 mm diameter is worked to a depth of 9.2 mm. Kumar's fifth experimental cupule of 6.7 mm depth measured 77.7 mm × 59.0 mm, and had to be struck a staggering 21,730 times. We can reasonably assume that the ancient cupule of 9.2 mm depth required well in excess of 30,000 blows, and these were delivered with a precision that is almost certainly not achievable by a modern human. Thus the actual skill and sheer persistence of the ancient cupule makers is hard to fully appreciate.

It has often been suggested that petroglyphs were made by indirect percussion, and the same has been said about cupules. (Some archaeologists have even claimed that cupules were made by grinding or abrading.) If we assume, conservatively, that on average it took 10,000 blows to create each cupule at Daraki-Chattan, and if these blows had been delivered via an intermediary tool (a chisel or punch), such tools might have been struck, say, 5.4 million times. If we further assume that each chisel had been worn to a slug after being struck, say, 100 times (in reality the number would be much lower before they would need to be discarded), there would have to be at least 54,000 discarded stones with very distinctive bipolar wear at the site (unless someone had removed them intentionally). If each of these discarded chisels had weighed, say, 80 g, I would expect to find over four tonnes of them in the floor deposit. Not a single such implement has been found in the entire excavation, but a good number of mur-e (direct percussion hammerstones) has been excavated (Bednarik et al. 2005). It is also relevant that all petroglyph (including cupule) production observed ethnographically involved direct percussion, or pounding (Figure 3), and not pecking (sensu Maynard 1977); and that those who have conducted controlled petroglyph replication work (Crawford 1964: 44; McCarthy 1967: 19; Sierts 1968; Savvateyev 1977; Bednarik 1991, 1998; Weeks 2001; Kumar 2007) uniformly regard indirect percussion as impracticable or impossible to use effectively.

The production of cupules on extremely hard rock types was therefore a lengthy process demanding great physical power, accuracy and dedication. I note in passing that the deepest cupule measured on very hard rock in India (at Moda Bhata), occurring on pure white quartz, is about 100 mm deep (Bednarik et al. 2005: 181). The number of percussion blows or the amount of time and effort lavished on just this one cupule must be staggering (Figure 4).

Standardisation of experiments

On the other hand, in trying to establish a standardised approach to replicative experiments in petroglyph production, I have nominated 12 mm depth as the standard for cupules, and reported that on well-weathered Gondwana-type sandstone, it takes only about two minutes to create such a cupule (Bednarik 1998: 30). I have worked on

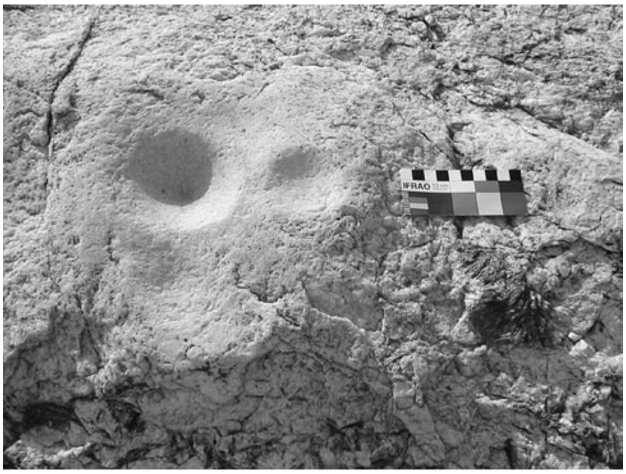

Figure 4. *Cupules on crystalline white quartz at Moda Bhata, Rajasthan, India.*

such stone in all present major sections of Gondwana (southern Africa, north-western Brazil, northern Australia and India), except in Antarctica. Quartzite is chemically and morphologically very similar to sandstone, except that this sedimentary rock has been metamorphosed (i.e. recrystallised). There is in fact a continuum between the two types of rock, with respective characteristics determined by the degree of metamorphosis. It is obvious that to create a cupule of 12 mm depth on the Daraki-Chattan quartzite would take several days and presumably result in severe RSI (repetitive strain injury). This provides a basic appreciation of the importance of lithology, which is discussed in a separate chapter of this volume.

The study of cupules could be improved significantly by standardising both the descriptive surveys of cupule sites and by adopting specific guidelines for conducting replication experiments. Since my proposal of 1998 remains the only one offered so far, I suggest that it could be adopted to render all such work fully compatible. Accordingly, as a measure of how hard it is to create a cupule on rock of today's weathering condition, one would produce a cupule of the smallest possible size of a depth of 12 mm, using a typical hammerstone (mur-e) of the kind used by traditional cupule makers (Figure 5). This would be a cobble of hard stone, such as quartzite, quartz or granitic stone of roughly 100 to 200 g mass, i.e. about fist size. The stone would not be pre-shaped or trimmed, but there would be a preference for a cobble of slightly elongate shape, perhaps with a somewhat pointed end (Figure 6). The rock would be struck in a rhythm of blows timed to the natural rebound of the tool, the duration of the process would be timed, and perhaps the number of blows would be counted. Thus the diameter of the finished cupule can be measured, but the crucial variable in the experiment is its depth, measured with the help of callipers (it is preferred to use plastic-type callipers rather than metal ones in measuring any dimensions of petroglyphs, so as not to scratch crystal facets or surface features). The depth is measured from the deepest point to a line bridging the cupule rim, perpendicular to that line. The smallness of the cupule diameter is considered to be a function of the accuracy of blows and the skill of the operator.

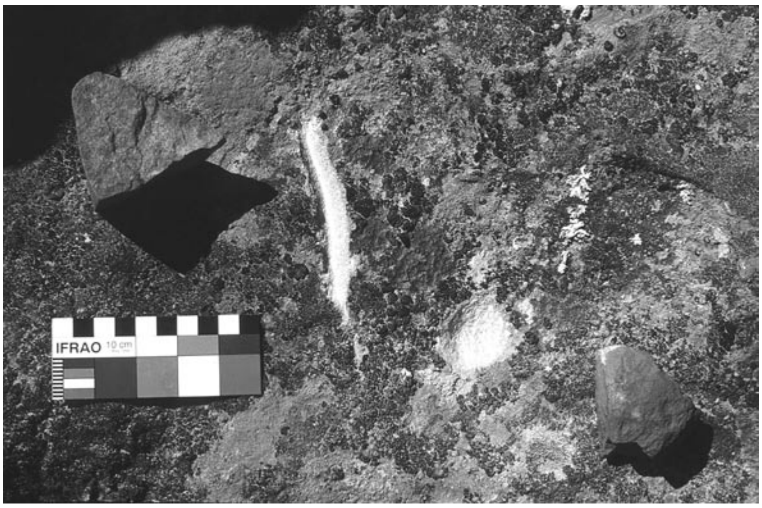

Figure 5. *First recorded replication of a cupule, near Toro Muerto petroglyph site, Mizque, central Bolivia, in 1987 by the author. The linear groove and the cupule were made with the respective hammerstones placed next to each mark.*

The results of such experiments will show that the time it takes to make such a standard cupule of 12 mm depth can range from a few seconds (on rock of hardness 1 on Mohs Scale) to several days of actual working time (on rock of hardness 7), i.e. it varies dramatically depending on the rock's hardness, by a factor of up to over one thousand times.

Conversely, the second form of 'standard petroglyph' I have proposed is a groove of 10 cm length and 10 mm depth, to show the times required to create grooves on various lithologies (cf. Figure 5). Little work of this type has been conducted so far.

There is also a great deal of scope for further development of replication experiments with cupules to provide much more comprehensive technological information. This is essential for their systematic study, and needs to become part of general recording procedures. As in any scientific pursuit, there needs to be standardisation of methods, in the case of cupules ranging from replication studies to all aspects of their recording.

Defining cupules scientifically

The principal condition for effectively studying the technology of cupules is the availability of comprehensive empirical descriptions. These are generally lacking at the present time, essentially because no universal recording standard has been proposed. Such a standard would need to facilitate technological and taphonomic studies of cupules, which should determine its nature and scope. However, limitations of time, resources and competence may impair the comprehensiveness of the recording work possible to any recorder, therefore it seems preferable to introduce two sets of guidelines. I first list the absolute minimum requirements, as I perceive them, and then those I would hope to see met in studies professing to be comprehensive:

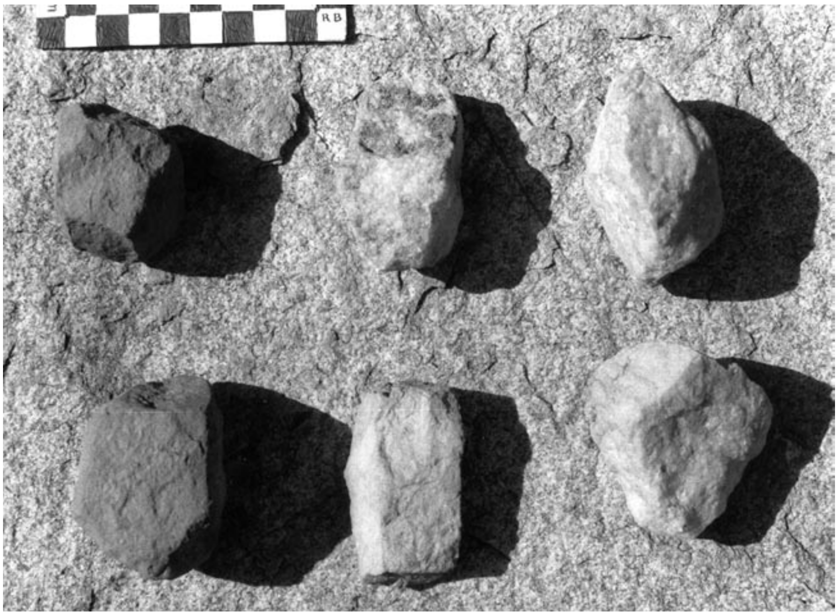

Figure 6. *Typical hammerstones used in direct percussion to produce cupules.*

Minimum level: petrology, surface condition, rim diameter, maximum depth, ratio of diameter to depth, rim inclination, spatial relationship with other cupules (layout) and other site aspects; for details see corresponding entries for comprehensive level recording.

Comprehensive level:

1. Petrology: type of rock, hardness.
2. Weathering condition of adjacent rock surface.
3. Surface condition within cupule (e.g. accretionary deposit, weathering, lichen).
4. General orientation of the cupule.
5. Maximum rim diameter (vertical dimension in case of vertical panel).
6. Rim diameter measured at right angle to the maximum diameter.
7. Maximum depth.
8. Ratio of maximum rim diameter divided by maximum depth.
9. Inclination of a plane formed by the rim, relative to horizontal plane.
10. For cupules on vertical or steeply inclined panels, vertical distance between the deepest point and the projected geometric centre of the rim plane (d^v, expressing the 'sagging' section), see Figure 7.
11. For cupules on vertical or steeply inclined panels, horizontal displacement of deepest point from the geometric centre of the rim plane (presumed to indicate handedness of maker).
12. Definition of overall shape of cupule (e.g. by measuring the diameter at an arbitrarily selected distance from the deepest point).
13. Presence and nature of tool traces in the cupule and on its rim.
14. Any indications that the cupule has been retouched subsequent to a much earlier production.
15. Spatial relationship with other, nearby cupules (e.g. appearance of geometric arrangement, alignment, or random).
16. Presence of other markings (impact, scraping) in the immediate vicinity of the cupule.
17. Exposure of the cupule to precipitation and insolation.
18. General description of the group of cupules.
19. Any indications that the cupules are of similar or different ages.
20. General description of site morphology, archaeology and location.

If possible, a microscopic examination of the cupule floor should also be attempted, and its results recorded. Field microscopy is one of the most important methods in rock art science (Bednarik 2007a: 170–2), and yet it is significantly under-utilised. In the case of cupules it is likely to provide the most important types of empirical information for clarifying the phenomenon's status, especially the following:

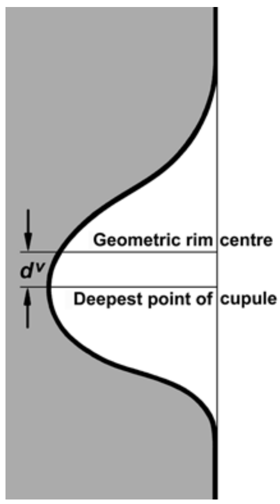

Figure 7. *Typical section through the majority of cupules on vertical panels, showing the vertical displacement of the deepest point below the geometrical centre.*

a. Presence, nature and condition of impact-damaged crystals or grains (Bednarik 1992).
b. Presence of truncation facets caused by abrasion of crystals or grains (Bednarik 2000).
c. Presence of microscopic striae on abrasion facets (Bednarik 2000).
d. Degree of microerosion on edges of crystal fractures or truncation planes (Bednarik 1992).
e. Weathering state at the microscopic level (Bednarik 2007b).
f. Condition of alveolar erosion patterns (Bednarik 1995).
g. Nature, condition and extent of any accretionary deposit (Bednarik 2007b).

These variables can be decidedly crucial in determining such aspects of cupules as their authenticity, technology and age, but they can also be of great significance to basic recording issues. Most obviously, the specialist will in a recording report look for indications that there are at least remnants of the original surface (i.e. the surface when the cupule was last worked) remaining, which in some cases may well be just a few grains. This information is absolutely essential in determining whether an attempt to apply microerosion analysis is worthwhile. It cannot be recorded without at least careful examination with a magnifying glass (10× or 20×), which is one of numerous reasons why the second-most important implement in a rock art researcher's toolkit (after a colour calibration device, such as the IFRAO Standard Scale) is indeed a good magnifying glass.

It is only through the provision of such detailed and systematic empirical data that the study of cupules generally, and more specifically that of their technology, can expect to attain scientific status. With some very rare exceptions, all information so far provided for cupules is inadequate to initiate a scientific study of this phenomenon. Only the most basic information is usually available, it is unreliable, and distorted by countless epistemological issues, such as preconceived interpretations. On that basis it is clear that the scientific study of cupules remains in its embryonic state, which by extension can be said about most other rock art also. It is up to researchers to change this incipient state of the discipline.

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