KEYWORDS: *Cupule – Pothole – Ethnography – Antiquity – Technology – Interpretation*

# CUPULES

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**Abstract.** Cupules may seem simple features requiring little technological explanation, until one examines them more closely and in their wider context. Before they can be considered effectively, their identification needs to be clarified and the many similar phenomena they have been confused with are considered here. A review of the secure ethnographic interpretations shows the extremely limited availability of scientifically based explanations, and also that these cannot be archaeologically evident. The incredible longevity of the phenomenon of cupule production, which spans from the Lower Palaeolithic to the 20th century, is then reviewed. Their world-wide ubiquity is considered, and a basis for their scientific study is formulated. This involves primarily issues related to lithology, technology of production, the role of taphonomy in effecting the extant characteristics of the evidence, and redefining the category and its distinguishing characteristics in that light. A simple standard methodology is then proposed to define the surviving global corpus empirically. The paper offers no interpretations of meaning, it merely presents an epistemological framework within which to make scientific propositions about cupules and test them.

**Introduction**

Fifteen years ago I introduced the term 'cupule' into the archaeological vernacular of Australia, describing briefly some aspects of the phenomenon (Bednarik 1993a). It was a new term only for Australian archaeologists; it had been in use in specific parts of the world for over a century, especially in the Americas and parts of Europe. In Australia, a number of colloquialisms had previously been used to describe a vaguely defined phenomenon in rock art, although some practitioners had questioned whether it should even be included under the general rubric of rock art. Such previously used archaeological terms had included 'pits', 'pit marks', 'hollows', 'cups', 'cup marks', 'simple cups', 'pitted rocks', 'dots' and, interestingly enough, 'potholes'. This trend to idiosyncrasies also pertained in the jargons of much of the rest of the world, with words such as cupels, cup stones, *Näpfchen*, *Näpfe*, *Schalensteine*, *Schälchen*, *Schalen*, *Opferschalen*, *Kuppeln*, *pierres à cupules*, *ecuelles*, *tacitas*, *puntos acoplados*, *punctates*, *molcajetes*, *lakouva*, *ythrolakkos*, *bljudce*, *erime tavasi*, and so forth, all apparently designed to describe the same general phenomenon.

However, just as there were almost as many terms in use as there were influential researchers engaged in investigating such features, there was also a wide spectrum of rigour applied to such work. Most importantly, numerous commentators have found it difficult to discriminate between natural rock markings resembling cupules, humanly created features that look somewhat like cupules (or large versions of them), and those features the word 'cupule' is intended to describe. I shall therefore initially focus on these difficulties, because unless we can be certain that we include in our studies only those instances or phenomenon populations that we intend to deal with, any further elaboration, interpretation or discussion seems pointless. For instance, there would seem to be no value in considering the orientation of natural rock hollows to determine their astronomical function.

Once we have mastered the distinction between natural and 'cultural' rock markings, and have determined that what we are considering are indeed non-utilitarian features of quite specific and distinctive morphological characteristics, we have secured a viable working basis from which to explore our subject productively. Most practitioners in the field will agree that cupules do constitute quite distinctive phenomena that should be readily definable. Such definition will be attempted here.

**What is a cupule?**

Generically, the term cupule (in English pronounced *kyoo'pyool*, not *ka'pool*) refers to a small, cup-shaped feature, structure or organ, such as, for example, the cup at the base of an acorn or one of the suckers on the feet of certain flies. The word derives from Late

Latin *cūpula*, 'little cask'. It is translated as *cupule* (French), *Kupule* (German), *copella* (Italian), *чашевидное углубление* (Russian) and *cúpula* (Spanish) (Bednarik et al. 2003).

The roughly hemispherical features that we are concerned with here, pounded into horizontal, inclined and vertical rock surfaces, probably constitute the most common motif type in world rock art. They occur not only in every continent other than Antarctica, it appears they have been produced by many of the rock art traditions, transcending all major divisions of human history. Cupules are found in some 'Lower Palaeolithic' traditions, they are very common in 'Middle Palaeolithic' contexts, some have been reported from Upper Palaeolithic times, and they occur in numerous Holocene traditions around the world. For instance, cupules are said to appear very commonly in Neolithic and Bronze Age contexts, but also in those of Iron Age antiquity, and in Europe they were still frequently made in the Middle Ages. In some parts of the world, notably in Australia, the production of cupules only ceased in the 20th century. In short, this perhaps simplest of all petroglyph motifs is so ubiquitous that its surviving representatives can be expected to outnumber all other motifs found in the world's rock art.

Yet despite this ubiquity, cupules are among the least investigated forms of rock art, as well as among the least understood. They have been subjected to a variety of over-interpretations based on very inadequate evidence, and there has been an incredible number of misidentifications. In a sense cupules offer a test-case for the probability that our interpretations of rock art generally may be valid, because if we have such obvious difficulties dealing effectively with one of the arguably simplest forms of rock art, it does not bode well for our more sophisticated explanatory attempts in rock art research. Indeed, some authors have even challenged the notion that cupules should be considered as rock art. Rosenfeld (1999: 31), for instance, has argued that 'pitted rocks', as well as a number of other rock markings usually treated as rock art, should be excluded from rock art and defined as 'rock markings'. This proposal is particularly interesting, for several reasons. For instance, most 'rock markings', such as taphonomic marks, animal scratches in caves, solution phenomena, xenoliths and countless others (Bednarik 1994a), will not be regarded as 'rock art' by most commentators, even though there are almost countless examples on record of researchers having identified them as rock art. Rock markings also include many kinds created by humans, such as bulldozer scratches, steel cable grooves, machine tool marks, all of which have also been misidentified as petroglyphs, and of course utilitarian rock markings, such as axe grinding grooves or grooves made to drain water from grinding surfaces. Moreover, rock markings can be expected to occur not only on this planet, but can also be found elsewhere in the solar system and elsewhere in the universe (e.g. one type has already been detected on Mars). Obviously, non-'art' rock markings greatly outnumber 'art' rock markings; glacial striations alone would outnumber petroglyphs many times over. Not only do we need to be circumspect in identifying them, the term 'rock markings' is obviously inappropriate here. Of course petroglyphs are all rock markings, as are pictograms, animal body polish on rock, *Rillenkarren* and thousands of other types. But what is more important about Rosenfeld's comments is that she expresses a particular view of what art is, and that she seems to imply that what she regards as rock art is art. This is a highly problematic position to take. Firstly, we lack an agreed scientific definition of what art is, and non-scientific views of the nature of art vary greatly. Many if not most artists would argue that a row of house bricks laid out in a line by an artist constitutes art, as does the killing and the carcass of a cow slaughtered by an artist at the entrance of the Melbourne Art Gallery. We could profit from looking at the issue of the definition of art more carefully before attempting to define what is art in rock art. Certainly the definition that might refer us to the Eurocentric concept of the Fine Arts is not relevant here, nor is rock art to be considered art in that superficial and philosophically as well as scientifically unsatisfactory sense. But to make arbitrary decisions about what constitutes art in the entirely emic human past is certainly beyond the brief of a troubled discipline such as archaeology, already so tainted by its association with the state and other hegemonies. Archaeology as we know it serves Occidental interests by creating Western constructs of the human past, facilitating cognitive neo-colonialism, and legitimising contingent political, social and religious ideologies in the ways it moulds its explanations of the past. It should not decide what is or is not art.

It has demonstrated that it also cannot determine what rock art is, as there are far too many erroneous identifications on record to trust archaeology with this (Bednarik 1994a). Twelve fundamental types of rock markings have been identified, of which only two are humanly made, all others are natural markings. One of these two humanly made groups of anthropic rock markings does not constitute rock art; the second comprises intentionally made anthropic rock marks of apparently symbolic content. Among the countless examples in the literature of archaeologists having defined several of the ten types of natural rock markings or the utilitarian anthropic markings as rock art (or vice versa), there are many examples relating to cupules. Some of the natural rock markings that have been misidentified as cupules are reviewed next.

## Natural features resembling cupules

### *Potholes*

These are fluvial abrasion hollows caused by the

*Figure 1.* *Potholes at Chutu Kollu, near Tarata, central Bolivia.*

grinding action of clasts caught in rock depressions, scouring the bedrock in eddying or swirling water (Fig. 1). They range in shape from cylindrical to hemispherical and sub-conical or test-tube shaped, and they can vary considerably in size (Gilbert 2000), but are most commonly in the order of 5 cm to 20 cm diameter. Except for the smallest specimens, their depth usually exceeds their diameter. The largest reported pothole in the world, Archbald Pothole in Pennsylvania, is 18 m deep, larger examples reported are the result of other processes. These phenomena occur especially along turbulent rivers of high kinetic energy, but they can also be found along marine and lacustrine shorelines. Kayser (1912) distinguishes between *Flusstöpfen* (fluvial potholes), *Gletschertöpfen* (glacial potholes) and *Meermühlen* (marine potholes). Morphologically, he divided these phenomena into three types: shallow with a *Weinflaschenboden* (convex floor), deeper with a flat floor, and very deep with a bowl-shaped floor and spiral-shaped furrows in the wall. Fluvial potholes develop preferentially in rock channels, at waterfalls and at rapids, and they can only begin to form where an initial hollow exists that retains swirling sand or clasts (Elston 1917–1918). Rehbock (1917, 1925) initiated the complex study of hydraulic energy in potholes. Richardson and Carling (2005) limit the term explicitly to round depressions eroded by approximately vertical vortexes and through mechanisms other than plucking, thereby excluding one of the two types Rehbock had established experimentally. The convex floor pothole (Fig. 2) is thought to result from the centrifugal force of the abrasive material (*Schleifmaterial*) (Ljungner 1927–1930).

Springer et al. (2005, 2006) have examined the potholes on streambeds using empirical analyses of field data and geometric constraints. They report that radius and depth of such features are strongly correlated, using a simple power law which they explain. Erosion efficiencies within small, hemispherical potholes (Fig. 3) must be high if the potholes are to survive in the face of streambed fluvial incision. As potholes deepen, the necessary efficiencies decline and increasing concavity through growth imposes stricter constraints. Thus hemispherical potholes are gradually converted to cylindrical potholes, the geometries of which favour enlargement while they

*Figure 2.* *Convex floor pothole (Weinflaschenboden) at Rocas Rio Milloma, near Tarata, central Bolivia.*


*Figure 3.* *Small hemispherical pothole at Punku Cocha, near Tarata, central Bolivia.*

***Figure 4.*** *Cylindrical pothole at Rocas Rio Milloma, central Bolivia.*

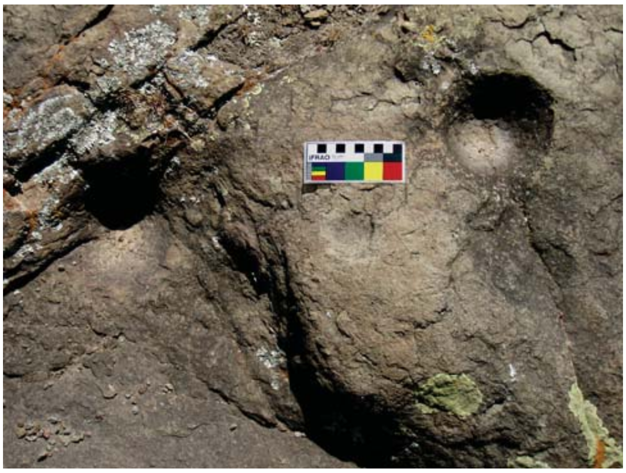

***Figure 5.*** *Potholes (natural erosion phenomena) co-occurring with cupules near Karakara, central Bolivia.*

are small. More substrate is eroded by volume from cylindrical pothole walls during growth than from cylindrical pothole floors (Fig. 4). Clasts acting as grinders (called 'tools' by pothole researchers) play a secondary role to suspended sediment entrained within the vortices that occur in potholes.

Marine potholes (Swinnerton 1927: Note 5) are found in places where the bedrock is exposed in the zone of wave action, chiefly due to the breakers' action. The favoured locations in the formation of fluvial potholes are the upper levels of waterfalls, but the perhaps most important prerequisite is the presence of relatively soft bedrock (particularly sedimentary rocks, even those lightly metamorphosed) and the involvement of very hard abrasive clasts, sand and silt (e.g. quartz). The identification of these rock markings is particularly difficult when they are found high above a present river course, and heavily weathered corresponding to their great antiquity. For instance at Hoover Dam in the United States, 'fossil' potholes occur in a palaeochannel 275 m above the present Colorado River bed (Howard 2004). However, even relatively recent and unweathered examples have often been misidentified as anthropic markings by archaeologists.

Of particular relevance is that potholes sometimes co-occur with cupules, and in such cases it is reasonably assumed that it was the very presence of the potholes that prompted the production of the more recent anthropic markings (Fig. 5). This raises interesting issues concerning the functional context of the latter, but it also demonstrates that the discrimination between the two forms of rock markings is well outside the domain of archaeologists who have misidentified the potholes as mortars, *tacitas* or cupules in many cases. Examples are the extensive concentrations featuring cupules, other petroglyphs and potholes at El Valle de El Encanto and El Valle del Sol (Iribarren 1949, 1954; Klein 1972; Ampuero and Rivera 1964, 1971; Ampuero 1993), or the potholes in the Coquimbo Region (Gallardo Ibáñez 1999), all in Chile (see also Gajardo-Tovar 1958–59). The issue, as far as I have been able to ascertain, seems to have its origins in Menghin's (1957) pronouncements. Similar cases of misidentification can be cited, however, from many other countries, e.g. Azerbaijan (Anati 2001: Fig. 10) or Greece (Papanikolaou 2005).

On the other hand, an illiterate Quechua man of Karakara, Bolivia, has insisted that these phenomena were not created by human hand. He has explained that they are perhaps the result of lightning strikes, presumably because the specific examples he referred to where located on exposed rock outcrops so high above the current riverbed that he could not conceptually relate them to the river. While his explanation is not correct, it does demonstrate, as I have observed on numerous occasions, that the explanations of ethnoscientists (sensu Mark P. Leone) are sometimes closer to those of science itself than to those of archaeologists. Non-archaeologists frequently outperform archaeologists in the identification of supposedly archaeological phenomena (Bednarik 1994a), and this also applies to potholes.

*Lithological cupmarks*

Only two types are briefly mentioned here. In the first, thousands of pit markings on tesselated sandstone pavements in the Sydney region, Australia, are the subject of an ongoing controversy (Cairns and Branagan 1992). Extensive lattices of deeply eroded natural grooves divide some twenty-five known pavements into mosaics of geometric shapes, most often hexagons. The tesselation has not been explained satisfactorily by geologists, but it is evident that the vertical disconformities causing it extend well into the substrate (at least 20 cm, but probably much deeper). In my view, the tesselation (Fig. 6) has been caused by cumulative stresses of a susceptible facies, and the reason for the geometric shapes is much the same as the laws causing the way a drying mud cover in a floodplain breaks up into hexagonal or other

*Figure 6. Typical tesselation polygons, Elvina Track site, Ku-ring-gai Chase National Park, near Sydney, Australia.*

*Figure 7. Natural cup-shaped marks, resembling cupules, on a tesselation polygon at Elvina Track site.*

geometric features: in both cases the layer consists of a sediment of entirely randomly oriented grains. These inherent tessellation characteristics of Sydney sandstones have given rise to selective weathering which formed the grooves, whose natural character is generally accepted. The largest of these pavements, the Elvina Track site, measures about 6500 square metres. Many of its thousands of polygonal panels bear a number of pits of 20–50 mm diameter. These pits closely resemble small cupules, and it is possible that some have been modified by humans, because a number of genuine petroglyphs occur also at the site, located in a region rich in rock art. However, the pits are essentially natural phenomena (Bednarik 1990a). Each polygon has similar run-off characteristics: near the borders, the profile curves gently towards the surrounding groove, into which rainwater drains readily (Fig. 7). Drainage is slower in the more central parts of the polygon, and water will remain in even the slightest depressions there. Differential granular exfoliation is the result, leading to drainage towards the gradually deepening depression. This process favours regular spacings as watersheds are established in the micro-topography of each polygon. Once under way, it leads inevitably to foci of erosional activity, and ever-accelerating rates of erosion in just one location — the pit forming in the middle of each 'local drainage zone' (Fig. 8). The result is a natural pattern of regularity, which the uncritical observer is likely to interpret as intentional.

While the process responsible for this example can be observed frequently in nature, my second example, also from Australia, refers to circumstances that are more unusual. Several vertical panels of hard but very weathered siliceous sandstone south of Horsham, Victoria, are densely covered by cup-shaped marks of typical cupule appearance. There are several hundred such marks at the site, all measuring between 5 and 10 cm in diameter, and a few centimetres deep (Fig. 9). Superficially the exposures seem indistinguishable from anthropic cupule panels, and yet they are entirely natural products of geological antiquity. I consider them to be the result of a complex lithological process at the time the rock formed, in which a layer of highly water-sorted, evenly sized near-spherical cobbles was deposited on quartz sand. The sand bed was metamorphosed to a slightly quartzitic sandstone. Erosive processes then removed the pebble conglomerate completely, presumably because it was less weathering resistant than the silica cement of the sandstone. This facies was replaced by a highly ferruginous conglomerate of maximal very coarse sand/small pebble fraction, fluvial detritus, filling in the hollows left by the cobbles. Most of this second conglomerate eroded subsequently, and the remaining negative impressions of the cobbles were exposed

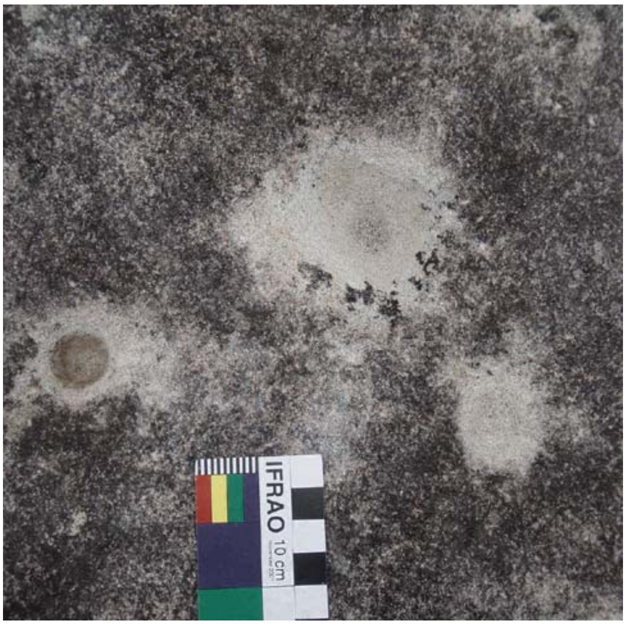


*Figure 8. Three small cup-shaped natural solution marks, almost 20 mm deep; the specimen on the left has vertical walls. Elvina Track site.*

*Figure 9. Cupule-like erosion pits south of Horsham, Victoria, Australia.*

*Figure 10. Close-up view of some of the lithological sandstone pits near Horsham, with remains of the ferruginous conglomerate still present in them.*

to weathering action. Once weathered, the dense groups of hemispherical depressions became almost indistinguishable from cupules. However, significant remains of the ferruginous facies still adhere to many areas of the panels (Fig. 10).

*Solution phenomena*

A variety of rock types, most especially sedimentary facies, can be susceptible to pitting by localised granular or mass erosion. This can take many forms (Bednarik 2007a: 20–23), but one distinctive example is found on carbonate rocks, especially limestone, the *Kamenitza*. Numerous examples, often occurring together with cupules, are illustrated by Papanikolaou from Greece (2005: 87, 91–94, 98, 105, 109, 110, 120–125, 134–146). Less pronounced forms of smaller sizes occur, and where such phenomena are well developed they can resemble cupules. A specific weathering phenomenon, the tafone, is defined as a 'roughly hemispherical hollow weathered in rock at the surface' (Jennings 1985). It has been documented in sandstone, dolerite, limestone, rhyolite tuff, metamorphosed conglomerate, and particularly in granitic rocks (Dragovich 1969; Martini 1978; Smith 1978). Tafoni can occur in many climates, from the Antarctic to hot arid regions, and are also found on Mars (Cooke et al. 1993). Their development tends to commence from zones of differential weathering on a rock surface, attributable to variations in lithology, structure, composition, texture or biota (Dragovich 1969). Once a tafone has begun to form, the interior of its concavity tends to erode faster than the visor. There are two schools of thought on the formation process: one holds that there are inherent differences in the rock hardness and moisture content between the interior and exterior parts (the 'core softening' theory, e.g. Conca and Rossman 1985; cf. Matsukura and Tanaka 2000), while the other attributes the process to microclimatic differences between the interior and the exterior, specifically of humidity and salinity (e.g. Dragovich 1969).

Both are perhaps partially right: the core softening (particularly pronounced on some sandstones) is probably the result of how rock surface geometry affects moisture retention, especially in arid regions (Bednarik 2001a [2007a]: 22). More prominent rock aspects dry faster than those sheltered from wind and insolation, and they weather slower (through case hardening). The process leads logically to cavernous, deeply alveolar features that could not be mistaken for anthropic phenomena. However, in the early stages, small tafoni may well resemble eroded cupules or similar anthropic features. Although large specimens measure several metres, the smallest tafoni do fall within the size range of cupules.

Another solution phenomenon found particularly on granite is the gnamma, a rock-hole on a horizontal rock exposure that is of particular importance in Australia, where it commonly served as a water source (Bayly 1999: 18–20, Fig. 2). Forming from initially cup-sized depressions, gnammas can measure several metres across, after gradual enlargement by chemical weathering. Found especially on the top of domed inselbergs (Twidale and Corbin 1963), the name of this geomorphological feature derives from Western Desert Aboriginal languages and means 'rock-hole' (Bayly 1999: 20). Gnammas were of great importance to the Aborigines (and European explorers; Giles 1889: Vol.1: 211, 217; Lindsay 1893; Calvert 1897; Carnegie 1898), who protected them against evaporation and fouling by animals (Helms 1896), and who sometimes diverted water into them from nearby rock surfaces by pounding channelling grooves (Tindale and Lindsay 1963: 65; such hydraulic grooves have also been reported from axe grinding panels, see Bednarik 1990a). In practice, most gnammas are too large to be

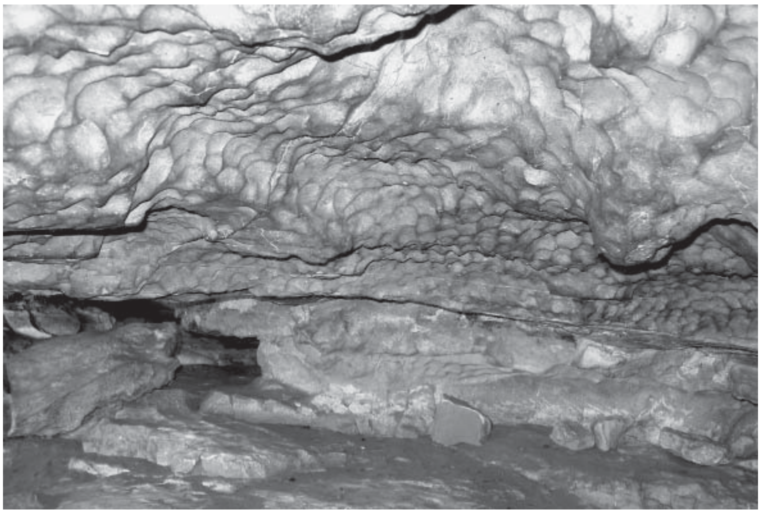

***Figure 11.*** *Natural cup-shaped markings on the walls and ceiling of Mawanga Cave, Mfangano Island, Kenya (photograph courtesy of Jean Clottes).*

***Figure 12.*** Verwitterungswannen *(solution pans) on Uluru (formerly Ayers Rock), central Australia.*

mistaken for cupules or other anthropic markings, but it is thought that, in Australia at least, humans contributed to the enlargement of some specimens by removing loose and weakened rock (Jutson 1934). Gnammas are closely related to *Kamenitza*, the main difference being in the role of the rock's impermeability in the case of the former.

Another solution phenomenon closely resembling cupules has been reported only recently. Campbell et al. (2007) illustrate dense concentrations of natural cupules from the ceiling, walls and to some extent even the floor of a limestone cave (J. Clottes, pers. comm. Dec. 2007) on Mfangano Island in Lake Victoria (Kenya). The cup formations in Mawanga Cave vaguely resemble limestone solution often seen in the tropics, except that here they are arranged as dense patterning (Fig. 11). Since this is a newly discovered, and perhaps unusual phenomenon, no explanation has been offered for it so far, but it may relate to endemic conditions at the site or constitute a local form of tafoni.

*Clegg's 'snames'*

Clegg (2007) has recently described a phenomenon he calls 'snames'. He defines these as 'shallow, approximately circular, flat-bottomed depressions, a metre or so in diameter', which he has found on Sydney sandstone. His illustrations depict them as being several centimetres to perhaps 10 cm deep, and clearly unrelated to the site's tesselation. He is baffled by them and reports that several geologists could not explain them and had never encountered such features before. But the phenomena he describes are well known (e.g. Cremeens et al. 2005), including in Australia (Fig. 12). They have been described as '*Opferkessel*' (another severely misleading archaeologist's term) and their correct geomorphological name is *Verwitterungswanne* or solution pan (cf. pan hole, *tinajita*, *Kamenitza*, *kamenica*, *kamenitsa*, *lakouva*, *ythrolakkos*, *bljudce*, *cuenco*, *tinajita*, *erime tavasi*, *skalne kotlice*, *scalba*, *skalnica*; see Bednarik 2001a [2007a]: 21). This biochemical phenomenon occurs on flattish horizontal rock surfaces lacking drainage and it can be found on many lithologies. It occurs most commonly on sedimentary rocks, but similar forms occur also on granitic facies (see gnamma) and other rock types. Recently, Rowe and Chance (2007) have described a few examples on limestone in Qatar (Fig. 13), which are *Kamenitza*. Nevertheless, care must be

***Figure 13.*** *Large Kamenitza on limestone in northern Qatar, Arabian Peninsula (photograph courtesy of Marvin Rowe).*

***Figure 14.*** *Shallow* Verwitterungswanne *at Elvina Track site, north of Sydney.*

*Figure 15. Deeply eroded solution pan, truncating several tesselation columns, about 10 cm deep and just over one metre wide; one of Clegg's 'snames' (see colour image on back cover).*

taken in its identification, because similar phenomena may conceivably be caused by other processes, such as fire. Nevertheless, *Verwitterungswannen* have distinctive features by which they can be identified, and their formation processes are understood. It is not appropriate to invent a new name for them, there already are far too many names because other commentators have done so without realising that the phenomenon has a name and has been defined and explained scientifically.

I have examined many of Clegg's 'snames' at the Elvina Track site and other, nearby locations in Ku-ring-gai Chase National Park, Sydney (Figs 14 to 16). Some of them are roughly circular, but irregular shapes also occur. They range in size up to 4 m and are without exception horizontal, because it is the retention of rainwater that causes their formation. However, it is wrong to separate them taxonomically from other solution phenomena at the site, on the basis of size or shape. In reality, there is a continuum ranging in size from 20 mm to 4 m, and in shape from circular to any random shape, the most common sizes being between 5 cm and 20 cm (Fig. 17). While the smaller fraction has been falsely defined as cupules (see above), the larger examples, which can extend across several tesselation columns, constitute Clegg's 'snames'. All of these phenomena are natural features, as shown by field microscopy (Fig. 18).

The difficulties in discriminating between natural and artificial features have spawned countless confrontations between archaeologists and other researchers, in many areas of archaeology (beginning, perhaps, with Boucher de Perthes' 'worthless pebbles'

*Figure 16. Elvina Track tesselation with several cupule-like natural cup marks and one of Clegg's 'snames' in the background, here partly filled with rainwater.*

*Figure 17. Section of the Elvina Track sandstone pavement, looking north, showing the density and great diversity of the countless solution phenomena.*

of well over a hundred years ago). An early example involving rock depressions featured Leiden professor K. Martin who ridiculed C. A. van Sypesteyn (a later Governor of Suriname) over this issue (Martin 1887; see also Bubberman 1977: 566) — who turned out to be right. It is hoped that the above brief comments can prompt archaeologists to consult specialists of rock markings (rather than general geologists) when facing such issues.

**Anthropic features resembling cupules**

In addition to the many *natural* features that have been misunderstood or misidentified as cupules or cupule-like phenomena (the above list is not complete) there are also various anthropic rock markings they have been confused with. In particular, rock mortars and metates can resemble large cupules. A metate typically consists of a stone slab with a ground depression, which may be elongate or circular, depending on the direction of movement of the grinding stone (called *mano*), used generally in grinding materials such as foodstuffs (e.g. Lange 1996). In Mesoamerica, especially Costa Rica, decorated ceremonial metates made of volcanic rock have been described. In North America, the term 'grinding slab' has been used to define large rocks bearing a number of anthropic hollows that were used, for instance, to grind acorns, and these features can resemble cupule boulders rather closely (Alvarez and Peri 1987: 12). The term metate is an American variation of the more widely found quern stones, which occur among the remains of agricultural societies. The term mortar also is more general, describing essentially a rock hollow, portable or non-portable, that was used in conjunction with a pestle to crush, grind and mix substances (grain, meat, ochre, medicines or numerous others). It is obvious that distinctions between these various terms are fairly arbitrary, depending mostly on assumed economic activities, and that in reality the surviving traces of these features tend to grade into other types. The only major technological distinction might be that metates are most often the result of to-and-fro abrasion, while mortars or querns relate more to rotating or crushing motions.

Similarly, there is no obvious or self-evident separation between some of these economic features and non-utilitarian cupules; rather, the discrimination can only be made after exhaustive study of the features in question, and after detailed consideration of various aspects. This is usually beyond archaeological taxonomisation endeavours and involves a whole host of considerations, concerning lithology, macroscopic and microscopic traces, orientation, inclination, spatial context and so forth. These are discussed below. Similarly, many cupules occur on lithophones, and it is then questionable whether they could reasonably be described as non-utilitarian, as cupules are generally

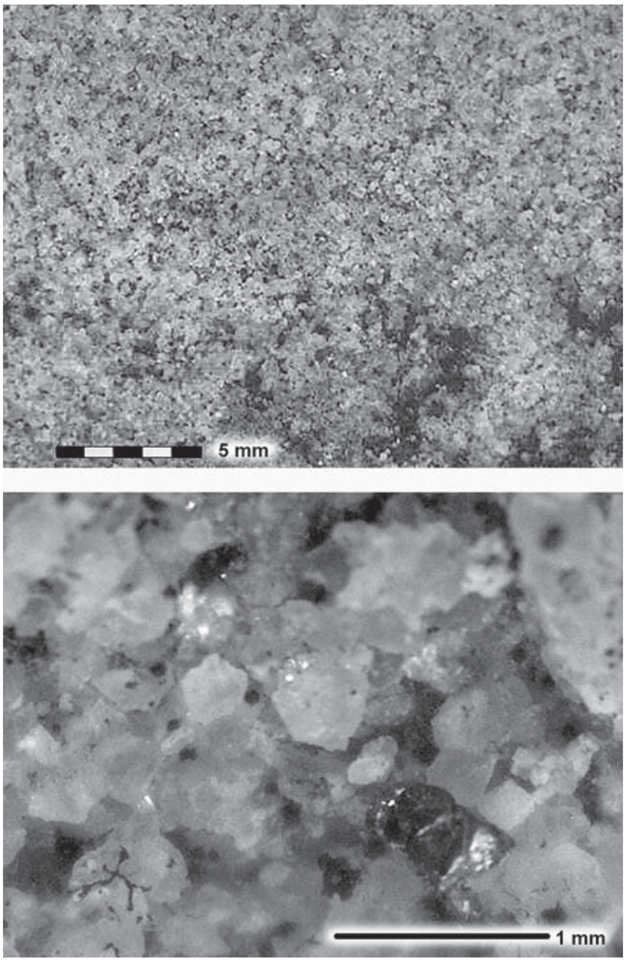


***Figure 18.*** *Microphotographs of the heavily corroded surface of one of Clegg's 'snames'.*

presumed to be. The proper recognition of lithophone cupules is in itself a complex subject that will need to be considered in any identification of cupules (see below). Indeed, an absolute separation between utilitarian and non-utilitarian cupule-like features is in the final analysis impossible, even if we had reliable ethnographic information — as we will see below. A cupule could only be entirely non-utilitarian (symbolic) if no practical consideration were involved in its production. We cannot determine this with finite precision in the extremely sparse ethnographic instances of interpretation available to us, so it would be correspondingly much more difficult to make such distinction in the countless cases we have that lack any form of ethnography. Clearly, science cannot involve itself in such issues, on the basis of the sound data currently available to it.

Other types of anthropic and utilitarian rock markings vaguely resembling cupules of various types occur. One example are large and deep rock depressions in soft rock that have been suggested to have served as storage pits (Fig. 19). Modern tool marks have sometimes been mistaken for petroglyphs by archaeologists (Bednarik 1994a), including markings by rock drills, core drills and other modern

***Figure 19.*** *Deep and large utilitarian pits on tufa, near La Paz, Bolivia.*

equipment. Some of these traces can resemble cupules and similar phenomena, especially when they have been subjected to rapid weathering. An example are the several dozen rock holes at Blue Tier in Tasmania, arranged in an alignment that is 19.5 metres long (Sharland 1957; see Bednarik et al. 2007: Fig. 2).

**Defining cupules**

In order to function as a discipline, archaeology is obliged to create taxonomies (Adams and Adams 1991). This is attempted by grouping together perceived phenomena on the basis of apparently shared properties or common denominators of phenomenon categories. The endeavour in this is to determine those common denominators that are 'crucial' for valid classification, such as those applying to the Periodic System of Elements. However, in reality even disciplines like geology and biology have considerable difficulties in the formulation of objectively valid taxonomies, as is evident, for instance, from the controversies over what constitutes a species. This is difficult enough in living species, and much more so in palaeontology. It has given rise to incredible confusion in the case of the taxonomy and cladistics of hominin species, but it is even more pronounced in archaeology, where all phenomenon categories are essentially invented and where no ready test exists to determine which is the *common* crucial denominator (CCD) of any 'objective' phenomenon category (Bednarik 1994b: 149). The strength of any taxonomy in archaeology is determined essentially by authority and consensus — or, rather, by an equilibrium between these two competing forces. Both, obviously, are determinants of very questionably value: authority is not about veracity, and consensus delivers only democracy, an ideal that is worthless in science.

To develop working hypotheses it is essential that some semblance of definition of what constitutes a cupule be established. The standard definition is 'a hemispherical percussion petroglyph, which may occur on a horizontal or vertical surface' (Bednarik et al. 2003). This implies three basic definitional criteria:

1. Being a petroglyph, it must have been made by human hand. This can be determined by eliminating all potentially available natural explanations.
2. It must have been made by numerous blows of percussion. Where its surface is not too much altered by weathering, grains or crystals of the rock should show signs of percussion, i.e. fractured or crushed particles, recognisable microscopically by conchoidal fractures with impact points, internal cracking of crystals and signs of surface bruising. On very soft rock types, production traces may include detailed macroscopic tool marks.
3. As a petroglyph, it has been made intentionally, and it is expected to possess some non-utilitarian or symbolic function, even though its production may also have involved utilitarian dimensions.

In the vast majority of cases the third criterion can be expected to be beyond the ability of the researcher to define reliably, so its discriminatory worth is in practice limited. Nevertheless, it needs to be borne in mind as it is the most crucial of the defining characteristics, and there are cases where it can be applied successfully. The second criterion is significantly more useful, because it can often be applied and is reliable, testable and replicable. But it is the first criterion that is of universal application, and that is most readily at the disposal of the field researcher. That is why I began this paper by listing the phenomena with which cupules have most commonly been confused. Documented difficulties in discriminating between cupules and other rock markings permit several observations. For instance, two of those cited (Cairns and Branagan 1992; Clegg 2007) imply that the matter cannot be resolved by 'experts', such as senior academic geologists. As Clegg observes, he has sought the advice of several specialists on his 'snames', none of whom had ever seen or heard of *Kamenitza* or *Verwitterungswannen*, even though such phenomena are very well explained in the geomorphological literature. In fact Clegg explicitly discounts the capacity of 'experts' to solve such matters, stating that '[t]hese respondent experts clearly knew much less than I remembered from physical geography courses in the 1950s'. I concur, and I would add that much the same applies throughout archaeology. I have noted before that 'archaeologically untutored observers with a good understanding of natural processes, such as foresters, naturalists, indigenes leading traditional lives and peasants in remote regions' are often much better qualified than formally educated archaeologists in discriminating between rock art and natural rock markings, or between stone artefacts and similar geofacts. It is well known that many graduate archaeologists are incapable of recognising stone tools effectively (and most archaeologists cannot fully master this in their entire lives), yet I have observed a four-year-old girl who made this distinction without hesitation, recognising stone

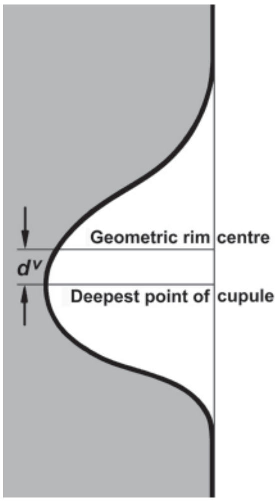


***Figure 20.*** *Typical section of the majority of cupules on vertical panels, showing the vertical displacement* d$^v$*: the deepest point of a vertical cupule is typically below its geometrical centre.*

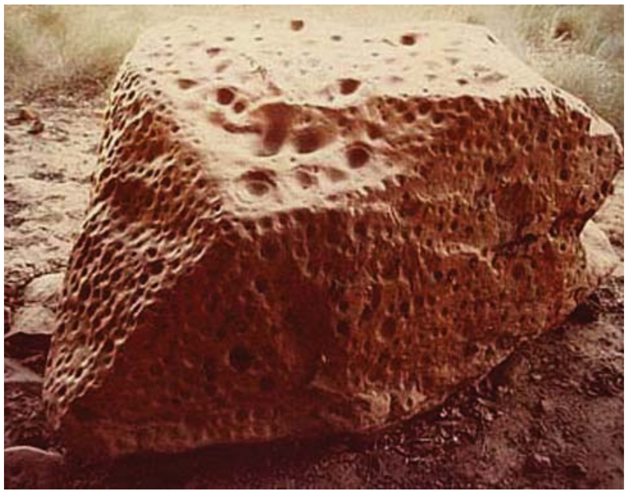

***Figure 21.*** *Large floor boulder in rockshelter, Victoria River District, northern Australia, covered by numerous cupules.*

tools on the ground up to several metres away with unfailing accuracy. I have made many such observations and have come to the conclusion that it is paradoxically a formal archaeological training that inhibits such abilities, and it is also this training that predisposes practitioners to searching for patterns and, having found them, interpreting them as signs of intentionality (Bednarik 1994a). Long-time collectors of stone tools, who typically lack formal archaeological training, are often much better judges of stone artefacts than are university-trained lithics experts and I have observed incredible discriminatory abilities in illiterate autodidacts.

The importance of this point is that it also applies to cupule identification, and many of the comments I made concerning the discrimination of human and other animal markings on cave walls (Bednarik 2004a) are highly relevant to cupules studies. In particular, I reiterate the comparison with the incredible abilities of perception and discrimination shown by an Aboriginal tracker to detect the near-invisible, and sometimes apparently the invisible. Just as that ability cannot be deconstructed into its components and then re-assembled without considerable loss in resolution or integrity, the ability to decide whether a hemispherical marking on rock is a cupule can involve the marshalling of almost subliminal information. It cannot, therefore, be conveyed in its entirety in writing, but I shall attempt to define the underlying parameters.

Cupules occur almost always in groups, and frequently in very large accumulations, numbering hundreds at single sites, even thousands on occasion. Single occurrences are very rare and need to be carefully scrutinised. Nearly all cupules are of diameters of between 1.5 cm and 10 cm, but on rare occasions larger examples do occur. They may be found on horizontal, sloping or vertical surfaces, but almost never on overhead panels (which other rock art occurs on frequently; cupules do occur overhead in the Kimberley of Australia, but very rarely; another example is Grotte Boussaingault in France; Nelh 1986). Very broadly speaking, those on surfaces inclined <45° seem to constitute more than one half of the world's total repertoire. There are notable differences between horizontal and vertical cupules. On vertical panels, their rims tend to be slightly more ovoid, with the larger width orientated vertically. Moreover, there is also a strong tendency for the deepest point to be located below the geometrical centre of the cupule rim (Fig. 20). Replication has confirmed that this characteristic is related to the biomechanics of cupule making. Vertical cupules tend to be on average smaller than horizontal ones, and exceptionally large specimens seem to be limited entirely to horizontal or slightly sloping panels. This is very probably related to the fact that the production of a horizontal cupule tends to be physically less demanding than that of a cupule on a vertical panel. A large proportion of cupules were not executed on bedrock pavements or walls, but on large boulders, and this applies not only to recent traditions, but also to those of the Lower and Middle Palaeolithic (e.g. Sai Island, Sudan; La Ferrassie, France; Auditorium Cave and Daraki-Chattan, India). Various traditions seem to have had a preference for large boulders on the floor of rockshelters, on which virtually every accessible surface area may have been covered by cupules (Fig. 21). The facility of distinguishing between cupules presumably made on vertical surfaces and those on horizontal surfaces can allow the identification of subsequently moved boulders whose surfaces are no longer orientated as they were at the time the cupules were made.

The identification of cupules can be considered fully secure when there are traces discernible of the tools used in making them, as is often the case, or where the pits are spatially orientated in such patterns that intentionality is clearly evident (e.g. where they are arranged in linear rows, multiple rows or other discernible geometric formations that could hardly be random). Furthermore, dense concentrations of pits on vertical walls of caves or shelters can safely be regarded as cupules without further scepticism in most cases. Utilitarian rock hollows occur primarily on near horizontal surfaces, or at best on sloping panels, and there appears to be no practical reason why features such as mortars, querns or metates could possibly occur on vertical bedrock walls. Similarly, there are very few known natural processes that may mimic cupules on vertical walls. In rare instances where boulders have been displaced, such features may now occur in vertical positions, but in general the secure identification of cupules is greatly facilitated by their occurrence on walls.

With this simple elimination procedure we have secured the recognition of perhaps up to three quarters of the world's cupules, but there remain those that show no work traces, are not 'intentionally' arranged, occur on more or less horizontal panels, yet cannot be determined to belong to any of the known natural or anthropic rock markings resembling cupules. Mindful of their inconclusive status, much closer attention is then required. How does the specialist form an opinion about their nature? This process is partly empirical, partly subliminal. The specialist has seen tens of thousands of cupules and has formed a mental template of their range of morphology relative to lithological properties, weathering and panel topography, even site morphology. Cupules are not randomly placed in the panel's or the site's topography, and specific spatial aspects are evident in their location. For instance, the required biokinetic activity of creating these petroglyphs is such an aspect. The specialist will look also for telltale characteristics, such as the 'sagging' vertical section when the hollows occur on steeply inclined panels, or for the robusticity of separating walls (on hard rock types it is impossible to maintain thin separation walls between cupules), the precise contour along the rim of each cupule (cupules lack distinctly acute rims except in certain unusual preservation conditions which are understood), the relief of the walls, and particularly the cupule morphology relative to lithological contingents (each type and hardness of rock favours specific cupule morphologies). Cupules featuring 'erratic' shapes need to be examined closely, and where they comprise faults or inclusions in the rock fabric, special attention must be given to these aspects. In situations with specific spatial restrictions (narrow cavity, or above thin ledges to stand on), the placement of the cupules relative to site morphology will be important and can even provide information on the makers' body sizes. On particularly hard lithologies, it needs to be remembered that only direct percussion with a stone can be effective, therefore the shape of a cupule must be consistent with the highly skilled application of such a tool. This kind of experience results from replication work (see below), not from any academic learning.

Nevertheless, it must be said clearly that even if all natural and utilitarian anthropic possibilities have been exhausted, and the phenomenon we examine does indeed rightly and squarely fall into the morphological category 'cupule', we still need to remember that this is an arbitrary pigeonhole class. It is highly unlikely that all the cupules of the world, of all the periods from the Lower Palaeolithic to the 20th century, do indeed form a single definable phenomenon that should be considered as a singular class. All we can say is that what we define as cupules are in most (but not all) cases hemispherical depressions or holes in natural rock surfaces, in most (but not all) cases under 10 cm in diameter, and that were mostly made by direct percussion (but not always), but were probably never made by abrasive motion. They can occur in any orientation, and less than half of the world's cupules are found on more or less vertical panels. This is a reasonable *working definition* at this stage, but whether we are dealing with what should be defined as a single phenomenon must remain an open issue.

**A brief ethnography of cupules**

Having thus hopefully created some doubts concerning certainties about cupules, let us next turn to their interpretation. Here we find a mother lode of archaeological humbug still awaiting detailed mining. Let us be quite blunt on this point: archaeology has not presented a scientifically based, or even plausible, explanation or interpretation of the rather strange behaviour pattern manifested in cupules. I am only aware of a few ethnographic explanations of cupules in the world literature, of which one or two are probably 'derived' interpretations, and others are of little help in formulating anything approaching a generic explanation. Only Mountford's (1976) observation of 1940 and perhaps a few American examples meet the strict requirements of a scientific interpretation, and it is limited to a very small number of cupule locations. The first case concerns the story of the death of Tukalili, the cockatoo-woman, a creation myth collected in the Northern Territory of Australia (Fig. 22). Her totemic body, a large boulder near Nantaguna springs, bears in a recess around sixteen horizontal cupules. They are the result of *pulkarin* rituals conducted to cause the pink cockatoo (*Cacatua leadbeateri*) to lay more eggs. This is accomplished through the mineral powder rising into the air as the cupules are pounded. The dust represents the *kuranita* of the rock and, as it is thus released, it fertilises the female cockatoos. *Kuranita* (life essence) can rise like a mist into the air from any 'increase site', impregnating a specific plant, animal or natural force the site is associated with, through its release by an appropriate ceremony. It then increases the supply or strength of that entity, which can range from a plague of head lice to bring down on one's enemies to the supply of an edible tree gum. It has also been suggested (Taçon et al. 1997: 947) that some cupule sites near the Mann River in eastern Arnhem Land are related to Green Plum Dreaming ceremonies but there is no evidence that this was their original use.

In Mountford's example the cupules are clearly not the intended result of the exercise; the fertilising dust or essence is the crucial element. The cupules are an incidental but the only surviving consequence of the ritual activity in question, and what we need to be most aware of is that this authentic interpretation of cupules could never be determined archaeologically. This example is not just one of the very few scientific explanations of any cupules in the world, it also shows the general impotence of archaeology in explaining archaeological phenomena. Without the recorded ethnographic observation, an archaeologist could never expect to formulate the authentic explanation. All correct interpretations of the residue that archaeologists chose to call archaeological remains are just as remote and unfathomable as is the interpretation of the cupules at Tukalili's site.

A second ethnographic explanation of cupules on a limited number of specific rocks comes from California and was recorded early in the 20th century by Barrett (1908: 164–165, 1952: 385–387; see also Loeb 1926: 247; Gifford and Kroeber 1937: 186; Heizer 1953; Grant 1967: 106; Hedges 1983a, 1983b). Specific boulders bearing collections of cupules were visited by Pomo women to conduct fertility ceremonies. These rituals, intended to lead to conception, involved the collection of the 'fertilising' dust created in pounding the cupules. The rock is either steatite or chlorite schist, the powder was made into a paste which was usually applied to the woman's skin, or, in one case recorded, was inserted into her vagina to achieve pregnancy through the rock's magical essence. However, the cupules at these sites tend to be outnumbered by incised grooves, and Hedges (1983b) emphasises that the ethnographic explanation of the Pomo 'baby rocks', as they are called, should not be extended to other cupule sites (McGowan 1982). Nevertheless, one cupule site used in fertility rituals has also been reported from New Mexico, Mother Rock on To'wa yäl'länne (Corn Mountain) near Zuni Pueblo (Stevenson 1887: 539–540; also Fewkes 1891: 9–10). There, the pregnant woman would collect the mineral powder 'into a tiny vase made for the purpose' and deposit it in a wall cavity, if she desired a daughter (Stevenson 1904: 295).

The parallel development of the concept of a fertilising effect of the mineral powder resulting from pounding cupules is certainly an interesting observation, but it can easily elicit unwarranted extrapolation to other sites. Other ethnographic indications in the western United States provide very different explanations. The Klamath of southern Oregon are said to have renewed cupules in order to summon the wind to change the weather (Spier 1930: 21). Similarly, the Shasta of California sought to influence the weather: they incised straight parallel grooves into selected 'rain rocks' to increase or decrease snowfall, and they pounded cupules to induce rainfall and wind (Heizer 1953). This also brings to mind the northern Australian custom of cutting sub-parallel grooves into bedrock to 'make Old Man Rain bleed' (Arndt 1962: 171). Again, it is evident how similar cultural practices can be developed independently, without any contact. Parkman (1992: 367) speculates that the percussion sound of pounding cupules could have been intended to 'attract or replace thunder'. He notes, in support of this contention, that 'among the Kashaya Pomo, women grinding acorns in their mortars took special precautions to prevent unwanted rain'. Apparently they prepared shelters to muffle the sound, so as not to summon rain unintentionally (Alvarez and Peri 1987: 12). Similarly, the Shasta covered their rain rocks in order to prevent rain (Heizer 1953). Parkman (1988a) offers one further explanation for cupules, in describing rock slabs at Takimitlding and Medilding, California, as Hupa 'calendar stones'. It appears from his description that contemporary Hupa believe the stones to have had some astronomical role, but the consultants were unable to explain the actual function of these features and the interpretation cannot be regarded as secure.

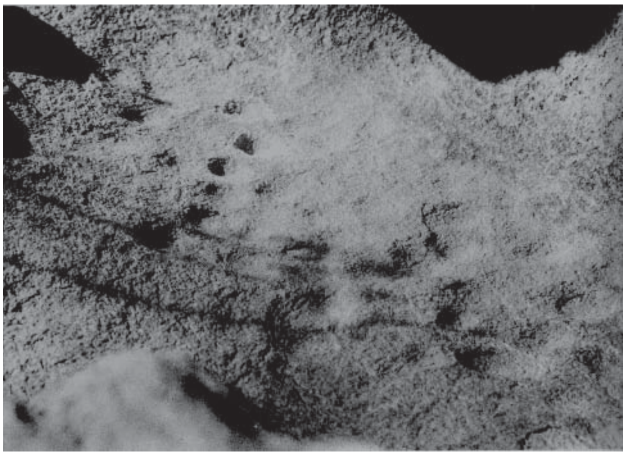

***Figure 22.*** *The Tukalili increase site near Nantaguna springs, Northern Territory, Australia. The precise emic significance of the cupules has been recorded (1940 photograph by Charles P. Mountford).*

Another correct ethnographic interpretation of cupules I can offer is illustrated in Figure 23. Here, a properly knowledgeable person demonstrates the use of a cupule, one of several dozen at the site that were still being renewed in 2004. The elongate quartzite rock he squats on is a lithophone, the use and purpose of which were explained and demonstrated to me.

*Figure 23.* *Renewal/reuse of a cupule on a lithophone or rock gong, Pola Bhata, Madhya Pradesh, India, in 2004 (see also colour image on back cover).*

In this instance, the cupule is again incidental, and — as was the case in the previous examples — its relative position to other cupules is irrelevant; it does not represent astronomical observations or whatever else ethnocentric observers like to invent. On the other hand, there is anecdotic information suggesting that along the Ganges, especially in Punjab, Indian women desiring to become pregnant pour sacred water into cupules, once again linking the rock art to fertility. In Hawaii, umbilical stumps of babies were reportedly placed in cupules for 'long life' (Callahan 2004).

A further ethnographic interpretation concerns the Kebaroti site complex and the Lanet site in southern Kenya. Here, Odak (1992) reported a number of cupule pavements which the local Kuria people have interpreted to him as *boa* game boards. It appears, however, that the cupules predate these people and that their interpretation is not that of the makers, but is one imposed on pre-existing rock art. There is scientific evidence from other sites that cupules were re-used after they were first created (Steinbring and Lanteigne 1991; Huber 1995), sometimes many millennia later. One specific cupule at Moda Bhata, India, pounded about 9000 years ago, was briefly reworked about 7200 years later (Bednarik et al. 2005: 182). Pre-existing cupules were often incorporated in the beliefs or practices of later people. This raises yet another warning: it would be premature to equate the perceived 'age' of a cupule with its full antiquity: many cupules were no doubt initially created long before their most recent retouch event, and if the latter is extensive enough, no traces of earlier surfaces are likely to remain within the cupule. It is therefore best to regard as the cupule's 'age' its time of the most recent use evidence, i.e. as being a minimum age. Many cupules, especially the oldest known in the world, occur on particularly erosion-resistant rock types, such as quartzite, gneissic granite and even crystalline quartz (Bednarik et al. 2005). Finally, one more ethnographic interpretation of cupules is mentioned in the next section, from Zimbabwe.

**Cupules and lithophones**

Phenomena that certainly do fall within the definition of cupules often occur on lithophones, in many parts of the world. As a generic term, 'lithophone' defines a musical instrument consisting of a number of rock pieces (discs or slabs) that produce musical notes when struck. Their use appears to have considerable antiquity. One of the most suitable natural features are stalactites in limestone caves, and impact traces on series of such speleothems in caves of the Franco-Cantabrian region containing also other Upper Palaeolithic activity traces have been interpreted as evidence that these were used as lithophones, e.g. at Nerja, Les Fieux and Pech-Merle (Dams 1984, 1985). Each stalactite yields a particular tone, its acoustic properties being determined by its dimensions and material properties.

However, such assemblages of a number of stones yielding different sounds are not readily available in nature, except in some limestone caves. The far more common kind of lithophone occurs in the form of individual rocks found to have good acoustic properties, i.e. yielding a high-pitched metallic sound when struck. Such lithophones or rock gongs (Montage 1965) have been used widely around the world, but have been reported most often from Africa, Asia and North America. They can be of many different rock types, but there does appear to be a preference for granitic stones. It is important to note that the crucial characteristics are not those of the material, but those of shape and contact with the supporting mass. Irrespective of rock type, the best lithophonic sound results are always obtained from rocks that are thin, discoid or elongate, and only supported at very limited contact surfaces. Ideally, they are long and slender, and supported only at one end, which is why stalactites are excellent candidates. To function best, the stone must be as free as possible to resonate unhindered when struck, which allows it to increase the intensity and prolongation of sound by sympathetic vibration. This is achieved through minimal contact with other rocks, often less than 5% of the boulder's total surface area, and the best sound effects seem to be generated by free-standing stone spires attached to bedrock at one end. However, these are susceptible to breakage, precisely because of their resonant characteristics: if the build-up of the

***Figure 24.*** *Another view of some of the several lithophones at Pola Bhata. Note the second lithophone, lower right, which has been broken in relatively recent time.*

***Figure 25.*** *Lithophone in the Serengeti Plain, near Banagi, northern Tanzania. Note the recently renewed and fully patinated cupules.*

sympathetic vibration exceeds the stone's mechanical strength, it can snap, a fate manifested in many broken stalactites. Figure 24 shows two lithophones side by side, one still in use, and the other, to the right of it, broken off relatively recently (as evident from the fresh fracture surface), almost certainly because it was overtaxed. This site, located on the eastern shore of the Ghandi Sagar Reservoir in India, features several lithophones, some consisting of long, finger-like rock spires measuring almost 2 m. The rock type is in this instance a well-metamorphosed quartzite, and the site features substantial deposits of Acheulian and Mesolithic artefacts. Lithophones at the Kinderdam site, near Vryburg in South Africa, illustrated by Coulson (2007a), appear to be of the same morphology and bear similar large cupules.

Numerous stones formerly used as lithophones may be difficult to detect, the only traces of their use being faint impact markings that may have weathered away or may go unnoticed. For instance, clusters of random percussion marks are found in many parts of southern Africa, thought to be the residue of 'rituals at which the production of percussive sound such as hammering or drumming was required' (Ouzman 1998: 38). Those of interest in the present context are specimens that bear cupules. They occur frequently in sub-Saharan Africa (Singer 1961), for instance in Nigeria (Conant 1960), Uganda (Jackson et al. 1965) or Tanzania (Fig. 25). Several granite lithophones from Zimbabwe are described by Huwiler (1998: 148), who reports that they are locally called *mujejeje*. These occur near burial places and were still used recently to communicate with ancestors interred in the vicinity. Other rock gongs in Zimbabwe are mentioned by Robinson (1958) and Cooke (1964). A superb slab lithopone with distinctive rows of deep cupules from Lewa Downs, Kenya, graces the front page of the *TARA Newsletter* No. 6, March 2005. It is quite probable that the considerable cupule concentrations of Twyfelfontein in Namibia and Spitskop in South Africa (Viereck and Rudner 1957; van Hoek 2004) are the result of the use of boulders as lithophones. There can be little doubt that the gneissic rock disc at Morajhari near Ajmer, India (Kumar et al. 2003: Fig. 2; Bednarik et al. 2005: Fig. 42), is a rock gong, and there are many other instances known in India. An excellent example is the large rock flake at Jhiri Nala, located about a kilometre from the ancient cupule site Bajanibhat, east of Kotputli, also in Rajasthan. Bajanibhat in fact means 'rock that gives sound'. The lithophone of Jhiri Nala is a thin flake measuring several metres length that split from a huge granite boulder by natural agency (probably impact, as there is no discernible evidence of lightning; see Bednarik 2007a: 62), remaining in vertical position but standing almost free. It is therefore an excellent candidate for use as a lithophone, and even though it is in a most inaccessible location, it bears two very large cupules attesting to its use (Fig. 26). Numerous 'ringing rocks' have been reported from the United States, and some limited ethnographic evidence is available. In southern California, DuBois relates them to girls' puberty rites of the Luiseño (1908: 115) as well as to the boys' ant ordeal ritual (DuBois 1908: 92, 95, 121). Roberts (1917: 110–117) provides a narrative relating the use of a Kumeyaay ringing stone in an apparent supplication ritual, although in this case, Hedges (1993) reports no cupules from the site. In another case, in Tulare county, California, Hedges did locate cupules on a Yokut lithophone site reported earlier (Latta 1977:

*Figure 26. The tip of the Jhiri Nala lithophone, Rajasthan, bearing two huge cupules and extensive evidence of flaking along the margin.*

196). Bell Rock, a 7-tonne granite boulder moved to the Bowers Museum in Santa Ana, bears numerous cupules (Knight 1979), and Hedges (1990) has also reported cupule sites from Menifee valley, some on lithophones.

The significance of sound to pre-Historic societies, and in particular the possible connection between some rock art and the acoustic qualities of rock art sites has been extensively investigated by several scholars, especially by Waller (1993). In the case of lithophonic cupules, the connection is indisputable. But to produce the required harmonics frequency in the stone, it merely has to be struck, there is no need to produce cupules. Replication has shown conclusively that the striking precision required to achieve sharply demarcated cupules involves very deliberate targeting. It therefore needs to be explained why the users of rock gongs did in certain cases not just strike the rock indiscriminately, or even restrict their blows to specific areas, but instead very deliberately produced cupules that may be several centimetres deep. One utilitarian explanation is that once a location on a lithophone was determined to yield the best possible sound, subsequent use focused on that particular spot, which eventually, after generations of use, resulted in a cupule. This appears most plausible where only one cupule occurs on a large lithophone, appearing to occupy its optimal position (as in Fig. 23). However, this is not usually the case, and where numerous cupules appear to be randomly arranged over a boulder it is more likely that the convention of making cupules is not purely utilitarian. This question is certainly in need of further and much more detailed empirical investigation. The subjective impression I have formed from my observations is that distinctively delineated cupules are made very deliberately: the impact blows have to be aimed at a very small area. This would suggest a conscious connection between the production of sound and the act of creating the cupule.

Judging from the few recorded instances it seems the utilitarian role of lithophones or rock gongs relates primarily to the communicating ability of the produced sound, and the metallic sound of effective lithophones can carry over distances of several kilometres. As mentioned above, in one report it serves to communicate with ancestors. The local villager shown in Figure 23, who offered spontaneously to demonstrate the traditional use of the large and very deep cupule, has provided a detailed explanation. The purpose of sounding this rock gong is to prompt all local villagers to assemble at a predetermined location. The man explained that several cupules at the site are still in regular use today for this purpose, he demonstrated the use of two of them, and his information was confirmed by the very recent use traces observed in others.

The remaining question is, how does one distinguish between cupules on a rock gong and 'general cupules', or how does one recognise a rock gong from its cupules? To be effective as a gong or lithophone, a rock must have quite distinctive physical characteristics as described above. However, it is highly possible that there is no hard and fast discrimination, because one class effectively grades into the other. Perhaps the audible aspects of cupule making were of significance even when the boulder being worked upon had very poor lithophonic qualities, at least in specific traditions. We do know, however, that there were at least some circumstances where the acoustic side effects of cupule production were apparently of no consequence, from the other recorded ethnographic productions of cupules mentioned above.

**Cupules in time**

Having thus hopefully established some semblance of an initial working definition of cupules, but at the same time qualified this by adequately conveying that there are ample ambiguities to banish any notion of finite or universal rules, we are ready to tackle the issues of spatial and temporal distribution. Cupules occur commonly in most parts of the world, and they can be found in astronomical numbers in many regions. Moreover, they first begin to appear in the Lower Palaeolithic period, and in some cultures, such as in India and Australia, they were still made or used in the most recent past. Their ubiquity, and especially their appearance so early in hominin history, renders it extremely unlikely that we are dealing with a culturally homogeneous phenomenon persisting through the ages. Rather, this class of artefact is probably only defined by its morphological homogeneity, and its apparently universal occurrence and characteristics are partly artefacts of our data-collecting strategies. This question will be discussed below.

Cupules are unequivocally among the most perdurable of all non-utilitarian anthropic rock markings. It is of considerable significance that nearly all of the petroglyphs currently known of the Lower Palaeolithic are cupules (only four exceptions are known at present). Taphonomic logic (Bednarik 1994c) decrees how very improbable it is that this was the first rock art produced, and it is highly likely that other forms of rock art were in use then, but have apparently not survived (see below). This is confirmed by the occasional discovery of haematite crayons of the Lower Palaeolithic that were used to mark rock surfaces (Bednarik 1990b), and by the finds from numerous sites of portable engravings and other palaeoart discoveries (Bednarik 2003).

The earliest object ever suggested to bear cupules is the pecked phonolite cobble from Olduvai FLK North 1 in Bed 1, Tanzania, about 1.74 Ma old (Leakey 1971: 269; cf. Bednarik 2003: Fig. 21). The rounded stone bears a deep cup-shaped, anthropic mark on one side, and a shallower such mark on the other. It does bring to mind a few very similar Middle to Upper Magdalenian quartzite and granite cobbles from France, from Laugerie-Basse and La Garenne (Lartet and Christy 1875; Tarel 1912, 1919; Peyrony 1918, 1920; de Beaune 1987, 1989). However, the Oldowan specimen may be the product of a utilitarian process. Vaguely cupule-like features on rock have on occasion been reported to be produced by chimps, and in South America even by monkeys, resulting from such activities as cracking nuts (McGrew 1992: 205, 1993). Joulian (1995: Fig. 5) presents a chimpanzee *percuteur* from Monogaga, Ivory Coast, that looks rather similar to Leakey's Olduvai specimen.

The first cupule demonstrated to be of the Lower Palaeolithic is one of two petroglyphs found on a quartzite boulder in one of two excavated trenches in Auditorium Cave, Bhimbetka site complex, central India, covered by the top of the upper Acheulian horizon (Bednarik 1992, 1993a, 1993b, 2001b, 2004b) but probably belonging to the lower chopping tool horizon. After detailed study of the site I proposed that nine further cupules nearby, but occurring above ground, were probably of similar antiquity (Bednarik 1996), but this was on the basis of largely circumstantial evidence. However, in the same year, Kumar (1996) reported the discovery of an assemblage of about 500 cupules in Daraki-Chattan, another Indian quartzite cave, which he suspected might also be of extremely great age. This was followed by further reports of Indian cupule sites of apparent Pleistocene antiquity, those of the Hathikheda sites (a series of outcrops of massive white quartz near Ajmer, including Moda Bhata; see back cover), the large Morajhari cupule site (also in the vicinity of Ajmer), and the sites Bajanibhat and Jhiri Nala (near Kotputli). But microerosion analyses at two of these sites has provided only Holocene ages so far (Bednarik and Kumar 2002; Bednarik et al. 2005), although the oldest phase of the complex Bajanibhat site does remain a viable candidate for Lower or Middle Palaeolithic antiquity. However, the substantial corpus at Daraki-Chattan


***Figure 27.*** *Excavated cupules from the entrance floor deposit in Daraki-Chattan Cave, central India, dating from the site's occupation by hominins with a chopping tool tradition predating the site's Acheulian.*

has been clearly demonstrated to be made by people with a chopping tool industry similar to the Oldowan, which underlies substantial Acheulian and Micoquian-like occupation layers. In the sediments at the entrance of this cave, some thirty exfoliated cupules (Fig. 27) were excavated in and below the Acheulian deposit, extending all the way to the chopping tool layer, while numerous hammerstones used in the production of the approximately 540 cupules of the cave were concentrated in this lowest occupation deposit (Bednarik et al. 2005). This sound stratigraphical evidence suggests that the cupules in Auditorium Cave, too, are perhaps not of the Acheulian as previously suggested by me, but also belong to the chopping tool tradition found under the site's two Acheulian horizons, and separated from them by a sterile layer. Peter Beaumont has recently reported finding extremely early cupule sites in the Korannaberg region, southern Kalahari (Beaumont in press). Like those in India, they occur on heavily metamorphosed and thus particularly weathering-resistant quartzite, and they appear to be either of the MSA or earlier.

In addition to the two sites of confirmed Lower Palaeolithic cupules in India, a sandstone slab with seven small cupules and one very large cupule has recently been reported from Sai Island, Sudan, believed to be in the order of 200 000 years old (van Peer et al. 2003). This find from the Lower Sangoan immediately brings to mind the very similar limestone block excavated in La Ferrassie, France, which had been placed over the grave of a 'Neanderthal' child, with the cupules on the underside, i.e. facing the interment (burial No. 6; Capitan and Peyrony 1926; Peyrony 1934: 33–36, Fig. 33; cf. Levy 1948: 66). It has always been assumed to be of the Mousterian, but bearing in mind that the other blocks with cupules at this and some other sites in close vicinity are Aurignacian, I would like to ask, what is the evidence for this specimen to be of the Mousterian? The fact that

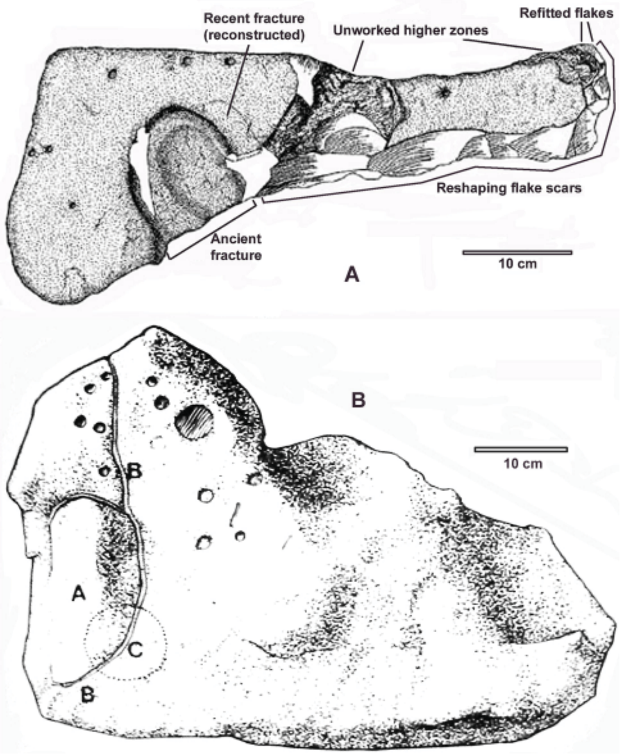


***Figure 28.*** *Comparison of the Lower Palaeolithic (Sangoan) slab with cupules from Sai Island, Sudan, with the Middle Palaeolithic (Mousterian?) cupule slab from La Ferrassie, France (after van Peer at al. 2003 and Peyrony 1934).*

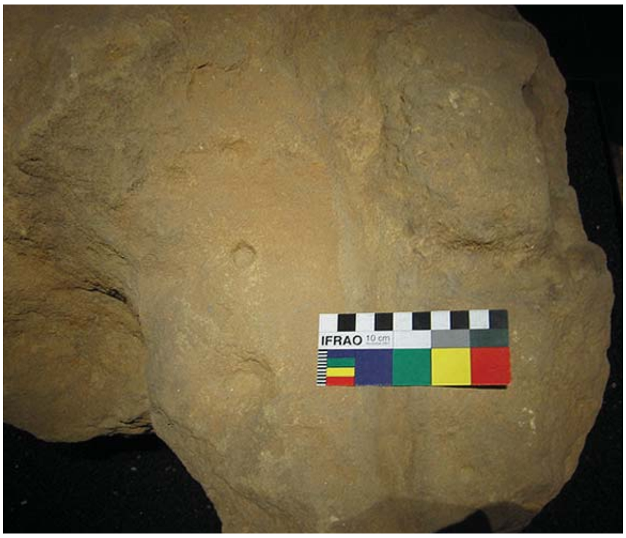


***Figure 29.*** *Partial view of the sepulchral Neanderthal stone block, showing some of the cupules and, in the centre of the image, an area of anthropic abrasion.*

it is part of a 'Neanderthal' grave does not necessarily make it Mousterian, if the Aurignacian is also a 'Neanderthal' tradition, as I have argued it may well be (Bednarik 2007b). Perhaps burial 6 in La Ferrassie reinforces that point.

This sepulchral slab, which I have studied microscopically (Bednarik in prep.), bears one large cupule plus up to seventeen small ones (Figs 28, 29). Some of the marks are very faint and questionable (I reject some of those Lorblanchet mentions, as have others who examined the specimen), and most of them seem arranged in pairs. Another specimen (La Ferrassie 16) from the same site bears a similar number of small cupules, as well as many even smaller impact marks, besides a supposed vulvar motif and the legs and belly line of an animal (Fig. 30). It is thought to be of the Aurignacian, however, suggesting either cultural continuity between the Mousterian and the later tradition, or that both are of the Aurignacian: cupules are used in much the same way on both, being mostly very small, and made on sizeable limestone blocks.

By the time of the Middle Palaeolithic, cupules had globally become very common indeed. Tens of thousands occur just in Australia, where all Pleistocene and early Holocene rock art is necessarily associated with Mode 3 lithic industries (Foley and Lahr 1997), as is literally all rock art of Tasmania. One might be tempted to see cupules as a '*Leitmotif*' of Middle Palaeolithic/MSA traditions, so dominant do they appear to be at that time, but they are found in even greater numbers in some of the Holocene periods. They also occur in the European Upper Palaeolithic, where they tend to be described as 'pitted blocks' because they are most often found on cave clasts or boulders. They are, however, more abundant in the earliest Upper Palaeolithic, and they are thought to be less common in the Upper Périgordian (i.e. the western Gravettian) than in the Aurignacian (de Beaune 1992). In all probability they were more closely associated with robust humans of the Final Pleistocene (Bednarik 2007b). Many examples occur at Le Cellier, Castanet and Blanchard and have been attributed to the Aurignacian I to IV (Delluc and Delluc 1978), often associated with incised lines and sometimes with 'vulva motifs'. Some of these specimens suggest cognitively very complex uses of cupules in the Aurignacian (Fig. 31), presumably by Robusts. Less

***Figure 30.*** *The engraved clast No. 16 from La Ferrassie, Middle Aurignacian, with the main cupules and the presumed vulva symbol emphasised*

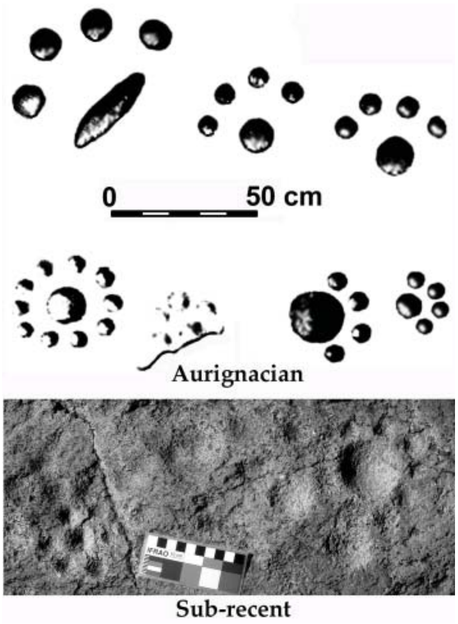


***Figure 31.*** *A selection of Aurignacian cupule arrangements on three limestone clasts from Abri Blanchard, France (top), compared with others of recent age on schist at Llave Chico, Bolivia (below). The age difference between the two groups is at least 30 000 years.*

commonly, cupules have also been reported from sites of the Gravettian (Laussel), Sulutrean (Badegoule) and the Magdalenian, such as Abri Reverdit (de Beaune 2000: 71). With the latter tradition, they even occur on small, round and very hard cobbles, such as the specimens from Laugerie-Basse and Abri de La Garenne (op. cit.: 101). Particularly noteworthy are two pieces, mid or upper Magdalenian, one of brown quartzite, one of granite, each bearing a cupule centred in a perfectly formed, deeply hammered ring. These well-rounded stones, under 10.5 cm, resemble the typical cup-and-ring features of much more recent times closely, and are thus unlikely to be utilitarian. At Limeuil cupules appear together with engraved lines (Capitan and Bouyssonie 1924: Pl. X), at La Ferrassie Peyrony (1934: 67–69, 75–78) reported them from the Middle Aurignacian levels, while in Cosquer Cave they occur on bedrock rather than clasts (Clottes et al. 2005: Figs 194, 195) and are probably of the mid-Upper Palaeolithic.

Cupules are much more common from apparent Holocene contexts, being most frequently described as Neolithic or Metal Ages features, for instance in western Europe (e.g. d'Arragon 1994; Steinbring and Lanteigne 1991). There they are frequently found with megalithic evidence (Fig. 32). In some of these mid to late Holocene traditions it appears cupules were used with specific semiotic or syntactic meanings; for instance it is assumed that cupules placed between the legs of anthropomorphous petroglyphs denoted female sex. However, cupules are not restricted to pre-Historic times, they continue to be produced or

***Figure 32.*** *Cupules on the truncation surface of one of the more than 100 menhirs of the cromlech of Almendres, near Evora, southern Portugal.*

re-used in Europe until well into the Historical periods (Mandl 1995; Rizzi 1995; Schwegler 1995: 112–113; Costas Goberna et al. 1999: 166). The most recently made cupules that have been convincingly dated in Europe are of the Middle Ages, at an age of only about E1030 years BP (at the Rupe Magna, Grosio, Italy, see Fig. 33; Bednarik 2001c), and even more recent, up to the early 18th century C.E. (Rizzi 1995: 81). In parts of Europe, cupules occur commonly on the exterior walls of churches.

In other continents, too, Holocene cupules are

***Figure 33.*** *Cupules and other petroglyphs on Rupe Magna, Grosio, Italy, some of the Middle Ages. Note glacial striae and white quartz veins in the schist.*

***Figure 34.*** *Pleistocene cupules at Sandy Creek 1 site, Cape York Peninsula, north-eastern Australia, on sandstone.*

ubiquitous features of numerous rock art traditions. But before we consider these, it is appropriate to briefly return to the issue of 'Middle Palaeolithic' cupules. In accordance with Foley and Lahr's typological taxonomy, all of Australia's Pleistocene and early Holocene technological traditions are of 'Middle Palaeolithic' nature. The continent was initially settled by Middle Palaeolithic seafarers from Wallacea (Bednarik 1999a), and the descendants of these colonisers retained their 'core and scraper' lithics until the mid-Holocene. Moreover, in Tasmania the human population became separated from that of the mainland about 12 400 years BP, i.e. when the sea-level passed about –56 m, and they retained this mode 3 technology right up to the time of British colonisation around 200 years ago. One may consider this tradition as the only 'Middle Palaeolithic culture' witnessed and described (however inadequately) in Historical times. More relevantly, in the present context, the petroglyph traditions of Tasmania seem to be dominated by mostly small cupules, among which occur rare large cupules (Bednarik et al. 2007), i.e. their pattern of occurrence resembles that found elsewhere with 'Lower' and 'Middle Palaeolithic' traditions. In some of the major petroglyph regions of mainland Australia, such as the Pilbara on the west coast, cupules are often very numerous, occurring in large numbers on individual boulders, and there is frequent evidence that they precede most or all other petroglyphs in those areas (e.g. McNickle 1991; Bednarik 1993a). On the other hand, the Jinmium controversy (Fullagar et al. 1996) demonstrated that it is impossible to generalise. Nevertheless, there can be no reasonable doubt that Pleistocene cupules occur in the tens of thousands in Australia, if not hundreds of thousands, from the Pilbara in the far west (especially the eastern Pilbara) via Carpenter Gap (Tangalma) in the Kimberley to the Cape York Peninsula in the east, where the cupule panel of Sandy Creek 1 (Fig. 34) refers to an important Pleistocene site (Morwood 2002).

In Africa, one vertical cupule panel has been minimum-dated by excavation. Clark (1958: 21–22) has obtained a carbon isotope age of 6310 ± 250 years BP from the sediment of Chifubwa Stream Rockshelter in northern Zimbabwe.

**Cupules of the world**

In North America it has long been observed that the apparently earliest rock art tradition consists of the 'pit-and-groove' (Heizer and Baumhoff 1962; Grant 1967: 26, 106, 131, 140, 152) or 'pitted boulder' genres (Parkman 1992). Parkman proposed that this tradition dates from 'pre-Hokan' or Palaeo-Indian times, i.e. from between 12 000 and 9000 years BP. However, North American cupules also occur in clearly very much more recent contexts; for instance they have been reported from Canadian limestone sites (Steinbring 1991), on which they are unlikely to survive for more than a very few thousand years. Nevertheless, several cupule sites occur in Canada, the most impressive being the Monolith No. 1 at the Herschel Petroglyph site in south-western Saskatchewan (Steinbring 1999). Similarly, the large numbers of cupules I have observed in Mexico, at such sites as Cerro Calera, near Caborca, which often form geometric arrangements or alignments, are certainly of the Holocene, and most probably of the late Holocene (see also Mountjoy 1974). In the United States, the most comprehensive information on cupule occurrences is available from California (e.g. Payen 1968; Heizer and Clewlow 1973; Fleshman 1975; Minor 1975; True and Baumhoff 1981; Smith and Lerch 1984; Hotz-Steenhoven 1986; Nissen and Ritter 1986; Newman and Mark 1986; Parkman 1986, 1988b, 1988c; Grant 1987: 26; Ritter and Parkman 1992; Sonin 1995), elsewhere in the Southwest (e. g. Schaafsma 1980; Labadie 1992; Malotki and Weaver 2002: 152; Malotki 2007: 8, 23, 26, 38, 41, 182), the Columbian plateau (Loring and Loring 1982; Keyser 1992) and North Dakota (Steinbring 1999).

The important corpus of cupules in the American West continues into Mexico (Mountjoy 1974, 1987; Grove 1987; Bednarik 1993a), whereas reports from Mesoamerica and the Caribbean are rare. At some Olmec sites, cupules are considered to have been used to 'deface' or re-use earlier features (Clewlow et al. 1967; Gay 1973; Grove 1981; Grieder 1982). Boulders with cupules have also been reported from limestone caves on Yucatan (Mercer 1895: 28; Valentine 1965; Strecker 1983). Further south, Kennedy (1973) reports cupules from Costa Rica, and Stone (1972) has recorded a cupule boulder with incised grooves at Barriles in Panama, which he thinks dates from the Agua Buenas period, c. 2000 years ago. The cupules at the Chiriqui site in Panama were mentioned already by Rau (1882: 60).

In South America, cupules have been most thoroughly studied in Bolivia (Querejazu Lewis 1991, 2001: 89–108), and in recent years at such sites as Inca Huasi, Lakatambo, Toro Muerto, Uyuchama 2 (all in the Mizque valley), at the two Karakara sites near Tarata, and the Roca Fortunato (Fig. 35) and Kalatrancani complexes near Cochabamba. Although credible dating of any one South American cupule remains elusive, reliable indirect age estimates of petroglyph features are available from Toro Muerto,

***Figure 35.*** *Some of the many hundreds of cupules at the newly discovered Roca Fortunato, Cochabamba, Bolivia, on schist.*

Lakatambo and Inca Huasi (Bednarik 2000, 2001d) and I am confident that meaningful results will shortly become available from the two site complexes near Cochabamba (Bednarik and Querejazu Lewis in prep.). Preliminary results from Kalatrancani 3 suggest very recent ages for the cupules, in the order of 1400 C.E. Several of these sites resemble the pit-and-groove sites of the western United States closely, and the possibility of securing ethnographic information concerning their cultural role is currently under investigation. Cupule sites occur also elsewhere in Bolivia, but their mode of occurrence differs somewhat from region to region. For instance at Achocalla, just south of La Paz (Heredia and Rivera 1991; Strecker 1991), they occur on a volcanic tuff, are relatively large, and form linear alignments in several cases (Fig. 36). Such arrangements are also found, for example, in the younger tradition at Inca Huasi (Bednarik 2000, 2001d). Another Bolivian cupule site is depicted by Giedion (1962: 185, Figs 114, 115).

In neighbouring Peru, cupules occur at many rock art sites, such as the Toro Muerto complex — which I regard as South America's largest petroglyph assemblage (Linares Málaga 1960, 1988; van Hoek 2003). At this and many other localities, however, the cupules are usually incorporated into figurative or complex geometric compositions. Pure cupule sites, or cupules with abraded grooves sites, do occur, however, such as those of Pantiacolla (Thiermann 1977) and Lungamari Puntilla (Parkman 1994). Cupule sites with abraded grooves have also been recorded in Colombia, for instance at Roca de Los Afiladores or Roca de Las Cúpulas (Muñoz 2006: 68, 81, 104, 110, 111), or cupules occur together with other petroglyphs, as they do at Roca de Las Espirales, Roca La Familia and Roca Del Mangón (Muñoz 2006: 95, 114, 123, 138). Rodríguez (1998: Fig. 2) illustrates a typical cupule rock at Mesitas de El Colegio on which a water trough has been constructed, one of several outcrops at the site bearing cupules and abraded grooves. Hornell (1925), Jackson (1982), Dubelaar

***Figure 36.*** *Matthias Strecker with rows of aligned cupules at Site 3, Rock B, Achocalla, near La Paz, Bolivia, on tufa.*

(1998: Figs 3, 4) and Gelemur de Rendón and Rendón García (1998: 125, 227) mention further Colombian cupule sites.

Venezuelan cupules were first introduced by Marcano (1890: 199), and much more recently by Cruxent (1971), Pollak-Eltz (1976) and Straka Bull (1980). They can be found in various parts of this country, as well as in neighbouring regions. There are several reports of cupule sites from the Antillean island Martinique, including those by Delawarde (1937: 8), Revert (1949: 202) and Mattioni (1971: 25). Cupules have also been mentioned elsewhere in the Lesser Antilles, for instance by Williams (1978), who reported them from Guyana as well. Oliver (1964) notes the occurrence of cupules in Puerto Rico, Kirby (1976) on St Vincent. Poonai (1967), Grieder (1982: 41, Fig. 17), Schaedel (1951: Fig. 9) and Dubelaar (1986a: 189) have mentioned further cupule sites from Guyana. Turtle Rock (Dubelaar 1986a: 189–191) bears in the order of five hundred cupules with a surrounding groove. Williams (1983) notes that *punctates* in Guyana cannot be interpreted. In neighbouring Suriname, cupule sites have been depicted by Dubelaar (1986a: 41–60, 128), whose otherwise comprehensive overview of South American petroglyphs unfortunately excludes pure cupule sites entirely (see Dubelaar 1986b: 4).

There are numerous reports of cupules from Brazil, beginning with Mallery (1893: Fig. 124) who illustrates a corpus of over 300 cupules and geometric petroglyphs from Pedra Lavrada. Some of the Brazilian sites are pure cupule sites, but in the majority of cases the cupules are incorporated in either iconic or non-iconic arrangements. Particularly noteworthy are the very precisely made cupule patterns at such sites as Lajedo de Soledade, Pedra de Ingá, Lajinha, Serra da Careta and Jatuarana (Jorge et al. 2006: 54, 60, 62, 63, 84, 138, 165, 192–194, 224, 225). In Amazonia, cupules appear to be limited in occurrence to compositions with other geometric elements (e.g. Pereira 2003: 113, 206, 207). Grieder (1982: 39, 41) reports cupules from the Abrigo du Sol, Mato Grosso.

By contrast, there is rather less information available on Argentine cupules, but the country's founding father of archaeology, Oswald Menghin (1958), does mention them, as do Podestá et al. (1991). Of particular interest in any study of the chronological distribution of cupules is their occurrence in Epullán Grande Cave, northern Patagonia, because this site contains the earliest securely 'dated' rock art so far reported from the Americas. Crivelli Montero and Fernández (1996) report a carbon isotope result of 9970 ± 100 years BP (LP-213) from a basal layer hearth, which in part covered a series of petroglyphs on the bedrock floor and is thus a minimum age for the rock art. Menghin (1957) reports cupules also from Chile. Other Chilean reports of cupules are by Breton (1910), Strube (1928: 93), Gajardo-Tovar (1958–59) and Ortiz-Troncoso (1977), but note the complications with the *tacitas* in Chile, and the several publications on this cited above.

In perusing the literature on petroglyphs in India it is hard to detect much evidence that this country is as rich in cupules as determined by the EIP Project (Bednarik et al. 2005). An early description is by Rivett-Carnac (1883), of more than 200 cupules, mostly arranged in alignments, at Chandeshwar. Indian cupules are often found associated with dolmen or cromlechs, for instance at those of Pattadakal or Vengupattu, and they occur in huge numbers in early to mid-Holocene contexts, but are poorly represented in the literature. They are common throughout Hindustan, along the Indus, on the foot of the Himalayas, in Kashmir and Jammu. In central India, they were generally not recognised until 1990, and first identified at Raisen and Auditorium Cave (Bednarik et al. 1991; Bednarik 1992, 1993a, 1993b, 1996, 2000/01), but since then, numerous finds have been reported (Kumar and Sharma 1995; Kumar 1996, 1998, 2000/01a, 2000/01b; Bednarik and Kumar 2002; Kumar et al. 2006). These in turn have prompted detailed descriptions in other parts of the country, such as that by Pradhan et al. (2007) of cupule sites in Orissa. Unquestionably, one of the most significant aspects of Indian cupule occurrences is the presence of a few sites of Lower Palaeolithic antiquity (Bednarik et al. 2005), which is so far unmatched in the rest of the world. This finding has greatly contributed to a resurgence in the interest in cupules elsewhere.

However, other than that, the Indian situation seems to be reflected in much of Asia: cupules occur in most countries of that continent, they seem to be absent or rare only in the north, in Siberia, yet they are rarely mentioned in the specialist literature. For instance, cupules feature at Chinese petroglyph sites, but their occurrence needs to be teased out of published reports by examining photographs, they receive scant mention by researchers (Shanlin 1989; Fu 1989: 202, 1992: 369; Zhenming 1991: 65, 70). They appear to be most common from Inner Mongolia to Chinese Turkestan, especially in Wulanchabu, but occur also in Jiangsu Province (Fu 1989). Tao (1999) describes two pure cupule sites at Hua'an, Fujian Province. Cupules occur even in Macao and Hong Kong. Very comprehensive information is available from Japan, in particular through the newsletter of the Japan Petrograph Society, *The Petrograph News*. Literally dozens of brief reports suggest that cupules are a significant component of Japanese rock art, and probably the dominant form of motif in that country. Indeed, the Japanese corpus is probably the most comprehensively published national body of cupules in the world, with the possible exception of Estonia. From the rest of Asia, information is very patchy indeed. From the north we have a small stone slab with four cupules from the Neolithic site Boysmana II of eastern Siberia, dated between 6500 and 5000 years BP (Brodyansky 2001). Cupules certainly occur in the central regions, e.g. in Azerbaijan (at Buyukdash, Gobustan; Anati 2001: Fig. 11) and on the Tibetan Plateau (e.g. Ryser 1999: 33). Pohle's substantial volume is a rich source on cupules in the Tibetan Himalayas, showing their extensive occurrence also in northern Nepal (Pohle 2000: 373) while no information from Pakistan is available (Bemmann and König 1994, the only comprehensive source I have for that country, show no cupules). Limited data are available from the Middle East (Wreschner 1976; Ahlstroem 1978), with best resolution from the Arabian Peninsula (Bednarik and Khan 2005: 55, 58, 76–78).

In Europe, cupules occur widely and in almost all countries. In fact in one country, Estonia, they seem to make up all known rock art, which is represented by about 1500 stones or boulders bearing cupules (Poikalainen 1995). By contrast, the petroglyphs of nearby Karelia seem to be entirely free of them (Poikalainen and Ernits 1998), except possibly to the far north (Shumkin 1991). In Ireland, cupules constitute about 55% of all petroglyphs, and they also dominate the rock art of the Former Yugoslav Republic of Macedonia. Although a significant proportion of that country's 'rock art' consists in fact of natural markings of several types, it is still clear from the limited published information that cupules dominate numerically among these petroglyphs (Aleksovski 2000: 62, 64, 70, 72, 75–80, 83, 90–101). In neighbouring Greece, Papanikolaou's (2005) comprehensive review of the rock art of the Prefecture of Larissa presents a substantial corpus consisting almost entirely of cupules.

While their percentages of other national inventories are perhaps mostly lower, it seems again that this may sometimes be attributable to their neglect in recordings. In many cases they find no mention at all, but do appear in photographs of petroglyph sites. For instance there is limited reference to cupules in the major Alpine site complexes, yet they are so prominent, for instance, at Roccio Clapier, Valle di Susa, Valtellina (Bednarik 1999b), Valcamonica (e.g. Pià d'Ort, Ossimi, Bedolina), Spronserjoch at Vellau and Elvas at Brixen in Italy; or in France at Table de l'Arcelle Neuve and Pierre des Saints, Mont Cenis; in Switzerland at Evolène, Zermatt and Carschenna (Diethelm and Diethelm 2000). Even Germany, with its rather limited repertoire of rock art, still has a few pure cupule sites, such as Mankmoss, Albersdorf and Bunsoher (Schleswig-Holstein), the largest occurrence being in the Berma Wald near Lothe. However, they are more common in Denmark (e.g. Glob 1969): at Møn, Vasagard Dysse and Arnagar on Bornholm, Kirke Stillinge and Hyllingebjerg. Several reports of cupules are available from Norway (Sognnes 1995; Walderhaug 1995, Mandt 1995) and Sweden (Henschen-Nyman 1982; Larson 1989; Milstreu 1999: 56), with sites such as Tanum, Vitlycke and Stenbacken mentioned frequently.

Cupules as a specific phenomenon have been afforded particular attention in Switzerland (e.g. Knowles 1981; Schwegler 1992, 1995), Austria (Mandl 1995) and parts of northern Italy. There are numerous reports from many parts of Austria, including the Mühlviertel region, Styria, Carinthia and Tyrol, but many specimens are probably natural features, especially Kamenitza. Schwegler attempted a comprehensive chronology of Swiss cupules and those of some adjacent regions that covers the last 7000 years, i.e. commencing with the Neolithic (1995: 121), and Rossi (1999) also provides a very useful geoarchaeological perspective of petroglyphs, including cupules, in this case at sites in northern Italy. Rizzi (1995) presents most impressive regional dating evidence for cupules, from Trentino-Alto in the Italian Alps. This was made possible by the discovery of cupule stones in the structures of several stone structure remains, ranging in age from the Eneolithic through to the late Iron Age. The Roman period, interestingly, seems free of cupules, but they reappear in great numbers with the high Middle Ages.

Numerous reports of cupules are also available from France (Guirand 1964; Germond 1980; Nelh 1980, 1986; Senee 1981; Quinet 1984; Knowles 1984; Agnel 1988; Bretaudeau 1992a, 1992b, 1993). In western Europe (Portugal, north-western Spain, France, Ireland and United Kingdom), as in India, cupules or cup-and-ring motifs are again frequently associated with megalithic structures (Shee-Twohig 1981; van Hoek 1997). In Galicia they occur also commonly on bedrock (Costas Goberna and Novoa Alvarez 1993; Costas Goberna et al. 1993/94; Costas Goberna and Hidalgo Cuñarro 1998: 77, 126, 127, 171; Costas Goberna et al. 1999: 33, 34, 36, 39, 62). Their distribution in the United Kingdom (Hemp 1926, 1938; Lynch 1969; Morris 1970; Walker 1970, 1977; Piggott 1973; Powell 1973; Beckensall 1983; Marshall 1985; Steinbring and Lanteigne 1991; Bradley 1991, 1995; Barker 1992; Jackson 1995; Children and Nash 1997; van Hoek 1997; Sharkey 2004; Nash 2006a, 2006b) as well as in Ireland (Johnson 1991; Jackson 1995; van Hoek 1988, 1997) is well documented. As early as 140 years ago, Simpson (1867) designed a taxonomy of cupules and other British petroglyphs he considered related to them. Essentially, his system of seven elementary classes encompasses various ring and spiral motifs, mostly including cupules, but his types 6 and 7 lack them. Indeed, the only one of his types we are concerned with in the present context is his type 1. Rau (1882: 60) already noticed the great similarity between cup and ring petroglyphs from the British Isles and other parts of the world, referring specifically to the site Chiriqui in Panama.

Cupules certainly occur in the Sahara (Le Quellec 1998: 378–380, 390, 394, 459, 461; Le Quellec et al. 2005: 187; Lutz and Lutz 1997: Pl. R), but are almost universally neglected in favour of the more photogenic rock art forms, most especially the rich iconography of all Saharan rock art regions. Francaviglia (2005) is the only paper in the authoritative journal *Sahara* dealing specifically with Saharan cupules, citing examples from Umm Singid and Jebel as-Suqur (both Sudan), Tadrart Acacus (Libya). Moroccan cupules are mentioned by Grebenart and Pierret (1966). Much the same pattern of sporadic mention applies to the rest of the African continent, but it improves towards the south. Odak (1992) has reviewed cupule sites in southern Kenya, and Coulson (2007b) reports a recently discovered major cupule site south of Mt Nyiro, on the edge of the Rift Valley, also in Kenya. There are several reports of cupule sites or occurrences from Zimbabwe (Dart 1953; Clark 1958; Chaplin 1963; Cooke 1964; Walker 1987; Swan 1996). Botswana possesses the impressive Tsodilo site complex, the sites of which are comprised either largely or purely of cupules (Rudner 1965; Campbell et al. 1995). A number of further cupule sites from sub-Saharan Africa have already been mentioned in the above chapters on ethnography and lithophones. Further sites from South Africa have been reported from time to time (e.g. Schoonraad 1960; Geldmacher 1967; Tobias 1967; Fock 1969).

Oceania, too, has contributed myriad cupule sites, in Australia as well as in the islands. Beginning with the Hawai'ian Islands (Cox and Stasack 1970; Steinbring and Steinbring 1983) and Rapa Nui (Lee 1992), cupules are found on many Pacific islands. At the Puuloa site on Hawai'i (main island), more than 30 000 have been recorded. Lee provides a comprehensive count of petroglyphs for Rapa Nui, but due to their massive numbers has not quantified cupules. She reports that they sometimes occur on the *moai*, the famous monumental statues of that island (Lee 1992: Pl. 6). Cupule occurrences have also been reported from Papua New Guinea (Williams 1931; Leask 1943), New Ireland (Gunn 1986), the Solomon Islands (Roe 1992), from Vanuatu (MacDonald 1899; Hébert 1965; Garanger 1972; Spriggs and Mumford 1992), New Caledonia (Frimigacci and Monnin 1980; Monnin 1986) and Fiji (at Beranayaho, Vana Levu; Wanke 2001/2: 42). Interestingly, the most comprehensive survey of New Zealand's rock art (Kreuzer and Dunn 1982) features no cupules.

A vast number of cupules occurs in Australia, including those of many hundreds of pure or almost pure cupule sites. They are most common across the north of the continent (Edwards 1979; Flood 1987, 1997; McNickle 1991, 1993; Chaloupka 1993: 234–236; Welch 1993; Walsh 1994: 90–93; Graham and Mulvaney 1995; Taçon et al. 1997; Donaldson 2007: 9) and it is often pointed out that cupules are apparently the earliest surviving form of rock art in these regions. Apart from the Pilbara, Kimberley, Victoria River district, Tanami Desert, Arnhem Land and Cape York Peninsula, cupule sites also occur in smaller concentrations in the Chillagoe limestone area, and extend south into the Hervey (Bednarik 1993a) and Expedition Ranges of central Queensland. Cupules appear in most other parts of Australia where rock art is found in major concentrations, such as for example on the lower Murray River (Anati 1991: 96), and in Tasmania they are the dominant rock art motif (Sims 1977; Bednarik et al. 2007).

Overall, cupules can be found in most of the world's petroglyph regions, but there are consistent indications that they have been systematically ignored in many cases, the notable exceptions being where figurative art is absent or relatively rare. In most petroglyph-rich regions they have found relatively little attention, and published information may be limited to their incidental occurrence in photographs together with other motifs, typically without comment. It is therefore to be expected that, at a global scale, cupules are significantly under-represented in the published record and have been widely ignored in the recording of rock art. Despite this limitation it can be said that cupules are the most common petroglyph motif in the world (probably followed by linear abraded grooves). Their study as a specific phenomenon, particularly in a scientific format, is significantly hampered by this widespread bias. Nevertheless, an attempt will be made here to consider scientific approaches.

**The scientific study of cupules**

If we exclude what has been written about the distribution of cupules (which is limited and biased), their purported meanings (which are almost universally pure conjecture) 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 a century, 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; 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 over a century, 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.

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.

*The technology of cupules*

In reviewing the technology of petroglyphs I have briefly considered the replication of cupules and suggested parameters for its standardisation (Bednarik 1998: 30, Fig. 5). Since then, Kumar has conducted more detailed replicative research 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 pain and often had to interrupt their work to rest. Their cupules tend to be slightly larger than those in nearby Daraki-Chattan Cave, illustrating a lack of skill (striking precision) relative to the Palaeolithic cupule makers who, we may safely assume, were also of much greater physical strength (consider their skeletal muscle attachments) and endurance.

Kumar's precise observations show dramatically that an incredible physical effort was required to create the Daraki-Chattan assemblage of about 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 so clearly 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 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 perhaps hard to appreciate fully.

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) making observed ethnographically involved direct percussion, or pounding, and not pecking (sensu Maynard 1977); and that those who have conducted petroglyph replication work (Crawford 1964: 44; McCarthy 1967: 19; Sierts 1968; Savvateyev 1977; Bednarik 1991, 1998; Kumar 2007) universally regard indirect percussion as impracticable.

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 (Moda Bhata; cf. back cover), occurring on pure white quartz, is about 100 mm deep (Bednarik et al. 2005: 181). 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 in several continents, it takes only about two minutes to create such a cupule (Bednarik 1998: 30). Quartzite is chemically and morphologically rather similar, except that this sedimentary rock has been metamorphosed (i.e. recrystallised). 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 will

***Figure 37**. Cupules on wall of McNickle's Shelter, Western Australia, on mudstone.*

be discussed below.

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) in Walsh's portmanteau word is so also. There is, as noted, no evidence that cupules were made by pecking (Keyser 2007 re other petroglyphs notwithstanding). Moreover, Walsh's assumption that the rock had not been fully metamorphosed at the time of cupule production is geologically naive. The metamorphosis of these rocks to quartzite takes many millions of years and occurs at great depths. The earliest cupules of Australia can, according to present knowledge, be no more than a few tens of thousands of years old. In fact Walsh's pronouncement comes close to the view of Aborigines that petroglyphs were made 'when the rocks were soft' (Flood 2006). It is far more likely that his 'pebraded cupules' are relatively unweathered specimens still showing the sheen of the crushing, whereas his 'pecked cupules' are weathered examples that experienced some degree of granular exfoliation.

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. 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, the greater the chance of detecting such traces, increasing the potential of securing valuable technological data. The softest rock on which I have recorded cupules is moisture-containing Miocene limestone in caves, which is soft enough to be easily marked by a fingernail (hardness 1 or 1½). At one Australian site I have observed hundreds of cupules on mudstone (hardness 3) with extensive, perfectly preserved work traces. Such instances show that indirect percussion has often been used on soft types of rock, but 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.

*The role of the lithology in the science of cupules*

These considerations lead directly to the influence the lithology has on cupules, on their dimensions, their morphology, on distribution and taphonomy. To create a scientific base from which to validly speculate about the cultural roles of cupules, it is essential that these topics are explored first and the relevant variables are understood. I begin this by considering a cupule site I named after the late Howard McNickle, who drew my attention to it in the 1980s. McNickle's Shelter is located near Wittenoom, a ghost town in the Pilbara of Western Australia. This very large shelter, formed along horizontally bedded rock strata of various types, contains one of the very few painting panels of the entire Pilbara, on the underside of one of the eroding laminae. Between 0.5 m and 1 m above the floor runs a layer of mudstone for the full 50 m length of the shelter's wall. It is significantly softer than the many facies above and below it, and it was apparently this quality that attracted the production of hundreds of pit-shaped markings (Fig. 37, and back cover). Many of these bear distinctive tool marks, which are perfectly preserved, suggesting that these cupules may be of relatively recent ages. The tool marks, both within the cupules and in their vicinity, are readily visible at the macroscopic level, but their microscopic study reveals even more detail about the production of these features. The site is superbly suited for forensic reconstruction of the gestures involved, and if there is a scientific way to determine the physical circumstances of creation, such work has to be at its core. The most obvious characteristics are the following two. In addition to the randomly arranged cupules along the narrow horizontal band of soft rock, there are also thousands of impact marks, scrape marks, incisions, and some broad abrasion marks, apparently of ages similar to

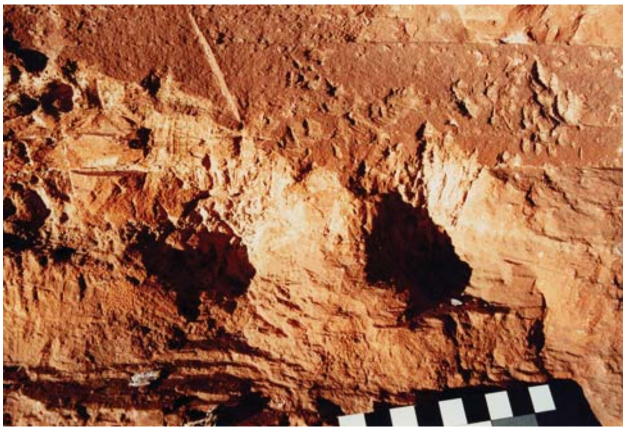

***Figure 38**. Close-up view of cupules with surrounding percussion and scraping traces, McNickle's Shelter.*

***Figure 39.** Deep cupules on very soft limestone wall in Ngrang Cave, Victoria.*

those of the cupules (Fig. 38). This suggests that the making of the cupules was perhaps only one aspect of behaviour manifested at the site, and that those traces would not have survived on much harder rock, or at sites that suffered extensive subsequent weathering. Secondly, the cupules are on average deeper relative to their rim diameter than they are on harder rock. There is a distinctive endeavour evident of keeping the diameter small, because on such a relatively soft medium, it would be easy to gouge deeper by allowing the hole to be larger. Therefore one of the most distinctive characteristics of these cupules is that the makers deliberately kept the diameters small, but tried to dig as deeply as possible into the rock.

We have already noted much the same above, in reference to very hard rock types, and when we test the underlying proposition by turning to examples on even softer rock, we find the same principle manifested. In the entrance part of Ngrang Cave, a limestone site in Victoria (Bednarik 1990c), there are forty-five 'extraction pits' on a single wall, many of them bearing corroded but still recognisable tool marks. This rock is so workable that the holes have been gouged up to 19.5 cm deep, and they are mostly deeper than wide (Fig. 39). Naturally this was not possible to achieve by direct percussion, but Montelle and I have by replication established the types of tools most likely used. What I wish to emphasise here is that these pits certainly do not look like typical sandstone or granite cupules, and some observers would probably reject their inclusion under the rubric of cupules. In my view, they were created by the very same behaviour patterns as the more 'conventional' cupules, and I return here to my proposition that this definition merely refers to *our convention* of taxonomy, and not necessarily to objective classes. It is easy to become trapped in our own nomenclatures, and in this case, the CCD of the phenomenon category may well not be apparent from our preconceived idea of the concept 'cupule' (e.g. a specific diameter/depth ratio or shape or size). Instead of focusing on what we are inclined to formulate as 'the type' — which we can only base on a taphonomically distorted sample under the best possible circumstances — we need to ask: which forms of the phenomenon would be expected to be under-represented in the total available sample (see below, under taphonomy)? We also need to ask: if we had the 'total living sample' (i.e. all cupules ever made), how would it affect our conjectures about the CCD?

Since it had become apparent to me that there might be a causal relationship between cupule depth and lithology, and since the ratio of cupule depth to rim diameter seemed to matter greatly to most cupule makers, I decided to test that relationship. Cupules are found on rocks of up to hardness 7, so I secured random samples of cupule depths from rocks ranging in hardness from very soft limestone through to fully metamorphosed quartzite and massive crystalline quartz. The result (Fig. 40) seems to indicate a strong correlation: the softer the rock, the deeper the cupule, on average. While my samples may be judged small, and greater refinement of the method is certainly desirable, the trend is far too distinctive to ignore. Nevertheless, I believe that future work of this type should employ different criteria. In particular, we might use the ratio of diameter : depth against hardness of rock, instead of simply plotting cupule depth against hardness. With that alternative method we are likely to find the trend even more pronounced.

The implications of these observations are of considerable consequences to the interpretation of cupules, even to their identification. If I had had no data on cupules of the softest rock type, hardness 1, I could have predicted their dimensions and ratio on the basis of the quantified trend. As the sample from Ngrang and some other caves in the Mt Gambier region shows, I would have been correct had I extrapolated the curve in Figure 40. Therefore the inclusion of these particularly large pits in the category 'cupules' is fully justified, and

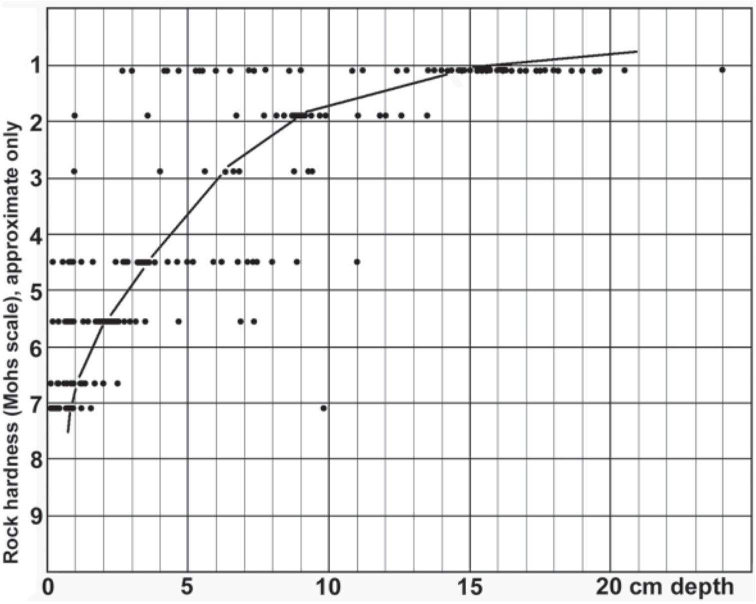


***Figure 40.*** *The depths of cupules as a function of rock hardness, compiled from random but reasonably representative samples.*

we are beginning to formulate what appears to be a more realistic definition of 'cupule'. We are also beginning to realise that what we describe as cupules is essentially the result of specific behaviour patterns, and that these can, in fact, be examined scientifically. That does not mean that all things we currently call cupules were made for the same reasons, or with the same cultural behaviour or motivation, but when it comes to biokinetic behaviour, the empirical evidence narrows the possible range down quite considerably. Again, the Mt Gambier caves provide important and germane information. There are many cases of vertical panels in these caves that are completely covered by deep gashes, pits and grooves, and they may be as much as 5 m long. The advanced corrosion state of these enigmatic features suggests great antiquity (Aslin and Bednarik 1984: 40, and see Pl. 3). They certainly lack resemblance with customary cupule panels, even though cupule-like pits do occur on them. But what deserves detailed investigation is not visual resemblance, it is the degree of similarity in the behaviour patterns evident. What I detect in these panels of apparently frenzied percussion activity is simply a lack of focused impact, but as noted above, some cupule panels on soft rock types also show, between the actual cupules, a good deal of unfocused work marks (see Fig. 38).


***Figure 41.*** *Non-accretionary laminar surface feature in a cupule on eroding quartzite, Indragarh Hill, near Bhanpura, India.*

A phenomenon sometimes observed in cupules requires special attention under the heading of 'lithology'. It was first commented upon in relation to a small cupule site located on the plateau above Daraki-Chattan Cave in central India, a few hundred metres north of the cave (Bednarik et al. 2005: 186). A geometric arrangement of cupules, thought to be of the Holocene, bears a remarkable laminar surface feature within each cupule. This resembles an accretionary deposit of some kind (Fig. 41), yet microscopic examination excludes that possibility. The lamina consists of the original floor of the cupule, rather than a deposited mineral crust, and is exfoliating. The rock surface surrounding the cupules has been subjected to granular exfoliation, whereas in the cupules much of the original surface at the time of their execution has been preserved. It appears as if the sustained application of kinetic energy during cupule production has somehow created a cutaneous zone that was more resistant to weathering than the unmodified surface. In a nearby palaeo-riverbed, boulders that were heavily polished by fluvial action show precisely the same phenomenon: a surface lamina that is slightly more resistant to erosion than the very dense quartzite. Moreover, Francaviglia's (2005) photographs of cupules from Umm Singid and particularly from Jebel as-Suqur (Sudan) seem to illustrate the very same phenomenon (Francaviglia 2005: Figs 2, 7, and especially the close-up in Fig. 5). I have observed a similar instance of cupule surface consolidation in northern Saudi Arabia, at Shuwaymas, on much less metamorphosed sandstone (Bednarik and Khan 2005: Fig. 14). Closer examination of these features is warranted and their origins need to be established. They seem to differ from case hardening in that the resistant skin is very thin, and the phenomenon may be relevant to issues of dating. One possible explanation would be that the great kinetic energy brought to bear on a cupule has somehow converted (slightly metamorphosed?) the colloid silica cement. I cannot cite a process by which this could have

***Figure 42**. Heavily weathered cupules outside Escoural Cave, southern Portugal, on marble, thought to be of the Bronze Age.*

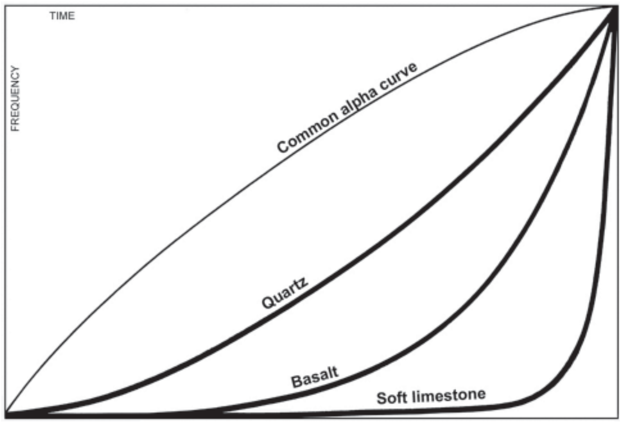


***Figure 43.** Experimental prediction of β-curves for cupules on hard (quartz), medium (basalt) and soft rock (limestone) according to taphonomic logic.*

occurred, but as it seems the most reasonable explanation I place the possibility before the reader and perhaps someone may care to comment.

*The taphonomy of cupules*

Reference has already been made to the importance of taphonomic considerations. The first demand in any pursuit that professes to be a scientific study of palaeoart is always the *coherent identification of that part of the extant characteristics of the evidence that is not the result of taphonomic processes* (Bednarik 1993c). Taphonomic logic (Bednarik 1994c) requires that we expect a significant part of the empirical evidence about cupules to be greatly distorted, most especially the variables related to degradation. In much the same way that it takes perhaps a thousand times longer to create a cupule on quartzite than to make an identical one on chemically very similar siliceous sandstone (several days vs two minutes, as noted), it may take a thousand times longer to wear away the quartzite cupule by natural processes of erosion. To understand the scale of the effects of taphonomy, the great magnitude of these ratios must be appreciated. The probability that a cupule of a specific depth would survive for a given period of time might be a thousand times greater if it occurred on a very hard rock rather than a much softer rock. But rock hardness is certainly not the only variable determining longevity; others are location, climate (e.g. precipitation pH, which is variable through time), rock chemistry, site morphology or hydrology, biological factors and so forth.

It is certainly no coincidence that the oldest cupules so far discovered occur on extremely weathering-resistant rock and are located in caves, safe from atmospheric water. At Daraki-Chattan, very faint traces of probable cupules occur on one boulder outside the cave, but they were only found in the course of careful examination of the site and would not be noticed *or* accepted elsewhere. They suggest that the site's cupules only survived in good condition because they were not exposed to rain. Similarly, cupules in a sandstone shelter should not be expected to have survived for such a great time span (i.e. since the Lower Palaeolithic), even though they were not exposed to rain (consider the Jinmium dating fiasco). At the other end of the scale it would be absurd to expect cupules on, say, schist exposed to rainfall to survive for more than a few millennia — notwithstanding the belief of many European archaeologists that even very shallow, perfectly preserved rock engravings in the Côa valley of Portugal survived practically unweathered on schist for more than twenty millennia. And it would probably be futile to expect finding cupules of more than 2000 years age on exposed, un-metamorphosed limestone (Mandl 1995; Bednarik 2007a: 164), although they can survive reasonably well from the mid-Holocene on marble (Fig. 42). It is thus very apparent that the interdependence of lithology and taphonomy is a great deal more important to the scientific study of cupules than anything archaeology can provide, and that the potential effects of these variables tend to be significantly greater than their cursory consideration might imply. Another important taphonomic conclusion is that cupules, despite being the oldest rock art found, cannot be the earliest rock art made (Bednarik 1997a). If the earliest examples of a phenomenon category in archaeology are the most deterioration resistant possible, it is illogical to assume that they are the earliest produced.

It also follows, however, that cupules on soft rock are greatly under-represented on the surviving record, and that their frequent occurrence on basaltic, granitic or harder rocks is a taphonomic phenomenon.

The more typical cupules should be those found on, say, limestone or mudstone, and as expected these tend to be relatively recent, unless occurring in well-sheltered locations. Clearly, then, we need to apply taphonomic logic to the surviving corpus of cupules. Without rehearsing here its principles, or explaining the concepts of taphonomic lag and threshold, I refer readers to the relevant literature (e.g. Bednarik 1994c) and discuss only the predicted β-curves for the relevant variables. If we compare my experimental shape predictions of β for quartz, basalt and limestone cupules (Fig. 43), ignoring here other taphonomic variables, we see that it is difficult to avoid the conclusions that increasing over-representation is a function of (a) rock erosion resistance and (b) antiquity. For the sake of simplicity I assume here that the cumulative population of each of the three groups is identical. That taphonomy selects in favour of any properties facilitating longevity is obvious, but how effective is this selection quantitatively? If we focus mainly on the right part of the graph we see that the logic clearly demands that, for the duration of the time with appreciable surviving limestone specimens, nearly all quartzite ones and most of the basalt ones would have survived. Naturally we do not know the total population numbers, nor how production varied through time, but this model demonstrates that we must expect the over-representation factor to be far more effective than a common sense prediction might suggest. Taphonomy eliminates nearly all populations on some rock types during a time period that registers very little impact on certain other types.

This may sound overly theoretical, but it provides a timely warning that, when we consider the world's surviving cupule repertoire, we see a sample that must be assumed to be greatly distorted, and the phenomenon it is intended to represent would need to have appeared very differently if we only had access to the entire population. Therefore, once again, I return to the several above warnings: our construct of 'cupule' is not set in stone, it is a tentative working hypothesis that remains very much in need of testing of the type I have implied here. I have teased out a whole list of reasons for this scepticism, which stands in stark contrast to the brash but unfounded interpretation attempts we have seen for much more than a century.

The perhaps most obvious factor preventing a development of such a scientific approach to cupules is the distinctive lack of systematic empirical information about the subject. No standardised forms of comprehensive data are available, which means that we even lack proper description of what has presently survived. In surprisingly many cases we lack the most basic descriptions of petrography, metrics and statistics, therefore no attempt has been made to even rudimentarily describe the sites, apart from their locations and some possibly inconsequential archaeological pronouncements about them (e.g. presence of other signs of human activity, which may date from a different period). This is not a criticism of those who have collected field data, but of those who created the conditions that determined what field data ought to be collected. While the field researcher needs to know what types of data are required, a rudderless discipline, relying on archaeology's bootstrapping epistemology, has not determined this and left the site surveyor to his or her own devices. This has been a monumentally wasteful exercise, in the sense that enormous efforts have been invested in securing data that are not adequate for scientific purposes.

*A standard method to define cupules empirically*

For that reason it is timely to propose a standard method for descriptive work at cupule sites. Limitations of time, resources and competence may impair the comprehensiveness of the recording work possible, therefore I first list the absolute minimum requirements, and then those I would hope to see met in studies professing to be comprehensive:

*Level 1*: 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 level 2 recording.

*Level 2*:
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 20.
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.

**Towards a scientific interpretation of cupules**

The most commonly mentioned archaeological interpretations of cupules could be grouped into a number of classes, based on purported uses in:

1. The preparation of paints;
2. Unspecified or specified cultic or magic rituals;
3. The pounding of medicines (mineral or plant), pigments or spices;
4. The placement of offerings ('*Opferschalen*'), including human blood and semen.
5. The depiction of star constellations.
6. The map-like depiction of topographic elements of nearby landscapes.
7. Geophagy (ingestion of mineral dust).
8. Board games.
9. A symbolism that is no longer recoverable.

Four of these explanations could at best only account for horizontal cupules and can therefore be excluded for all others, or at least vertical ones. Moreover, they are proposed without the facility of falsification, i.e. no evidence for them is presented, they are simply guesses. The explanation as patterns of heavenly bodies is particularly popular in China and parts of Europe, and is also offered (even for Pleistocene specimens) without any tangible evidence. Star constellations, we can reasonably assume, are random features, and it is then not surprising that they resemble other random or fortuitous arrangements (indeed, I have witnessed an advocate of this belief surveying a group of potholes for the purpose of determining their astronomical meaning, unaware that they are natural features). However, large groupings of cupules tend to be cumulative, i.e. the marks constituting them were made singly and at greatly different times. That renders this explanation highly unlikely, if not impossible. In all cases I am aware of, including the sepulchral La Ferrassie block, the resemblance with star constellations is only vague. For the vast majority of cupule constellations, no corresponding star charts have been proposed, and this notion appears to be without empirical basis as well as being unfalsifiable. Moreover, the greater the number of cupules on a single panel, the lesser the resemblance to any star pattern, so when there are several hundred the weakness of the notion becomes clear. But most importantly, it cannot be tested, it is therefore not a scientific proposition.

The explanation of random cupule groups as maps, popular in the Alpine regions of Europe, falls into the same category. It is untestable, has no ethnographic support, and is a priori unlikely unless all cupules were made at the same time. It is also reminiscent of other endeavours of seeking rock art explanations, in which various patterns are thought to be pre-Historic maps, apparently without justification. There is very limited evidence for the ingestion of mineral dust but it is mentioned as a possibility (E. Malotki, pers. comm.; cf. Callahan 2004).

The notion of the use of cupules in board games is somewhat more promising. Odak (1992) considers the possibility that cupule patterns at two sites in southern Kenya represent *boa* game boards. Pohle (2000: 199–202) discusses the conceivability of geometrically arranged cupules having been used in the *uluk* and *rama rildok* games of Nepal and accepts that many of the cupule arrangements relate to the latter game (Pohle 2000: Tafeln 1.1, 14–16, 18.1, 28.2). *Rama rildok* is a mancala game, which Bandini-König (1999) also cites for cupules at Hodar, in the uppermost Indus valley, and Fu (1989: 179) for Chinese sites. Cupules proposed to have been used in board games occur typically in closely packed geometric alignments, i.e. in multiple rows, and on horizontal rock panels. Obviously the ethnographic foundation of this interpretation requires further investigation, but it can be regarded as a possible explanation in certain cases. Mancala (or mankala) games occur widely in Africa and Asia (Murray 1952: 162) and seem to have an ancient history (e.g. Robinson 1959: Pl. 27), apparently extending back to the Neolithic in the Middle East (Rollefson 1992).

Better based appears Flood's suggestion that, in central Australia, 'a strong case can be made that cupules are the by-product of increase ceremonies, but the usual caveats must of course be added' (Flood 1997: 149). We have limited ethnographic information that in some of the tens of thousands of cultural traditions that can be said to have existed since the first known cupules were made, they served for purposes related to fertility and to increase rituals, and we know that many cupules designate lithophones. However, faced by the immensity of numbers of cupules ever made (very probably many times their surviving number) and of the enormous time span accounting for them, it is obvious that these glimpses are of very limited value in explaining the general phenomenon. For instance, I might consider the sepulchral block with cupules from La Ferrassie, note the 'fissure' on it which several commentators have pointed out, and suggest that it resembles a vulva, flanked on both sides by several cupules. That gels well with the ethnographic observation that some cupules are fertility-related, and even receives

***Figure 44.*** *Plan view of lithophone slab, showing the random distribution of cupules; gneissic granite, Morajhari, Rajasthan, India.*

good support from the occurrence of cupules in 'vulvar triangles' (cf. Fig. 30). But does it justify the application of this interpretation to a specimen that is over 30 000 years old? Perhaps that explanation is right (it is certainly more likely so than the various alternative ones we have seen), but scientifically it remains unsatisfactory. It may be more circumspect to regard the snippets of sound explanations we do have as being incidental to some other, less obvious but generic principle. In particular, they raise unanswered questions that imply some unknown cultural dimension in these extremely limited cases we have reasonable explanations for. In all the secure ethnographic interpretations, there is no obvious need for the marks to assume precisely the very specific form of cupules. There is some merit in the assumption that, for lithophonic cupules, impact was focused on a very specific point because it yielded the best sound. However, even this is limited to some specimens, whereas on most lithophones there are numerous markings (Fig. 44), all consisting of perfectly formed cupules, i.e. percussion was not just focused in their production, but was highly focused and quite deliberately so.

This, I have noted, is perhaps the most distinguishing characteristic of all cupules: most appear to be as small as technically possible, but made very deeply, relative to rock hardness. Which brings us back to the notion that those on the softest rocks are perhaps those most likely to provide the basis of explanatory hypotheses. The harder the rock, the greater the technological limitation imposed on a cupule. It is simply impossible to create a cupule that is deeper than wide on quartzite (i.e. that has a diameter : depth ratio of <1), using the means available in pre-History. But it is possible to do so on very soft rock. To me, the most stunning aspect of cupules is that already the earliest examples we have, at such sites as Daraki-Chattan, clearly externalise the principle of smallest diameter and greatest depth achievable. They already seem to be statements of perfection, deliberately made to formalised qualities — an observation I made previously concerning disc beads of the Lower Palaeolithic (Bednarik 1997b). I found that ostrich eggshell beads of the Acheulian had been made as small as possible, and that the precise central placement of their perforations could only be achieved by a very deliberate process of production. Much the same can be said about the earliest cupules available to us. Having explored the implications of such observations on our concepts of hominin cognition elsewhere, I draw here attention to the idea that the inherent 'mental template' perhaps expressed in cupules appears not to have changed over hundreds of millennia, nor does it seem to vary across the globe. I find it difficult to see this as an artefact of our taxonomy. Therefore, if we are to approach the topic of meaning or purpose of non-utilitarian cupules, we need to consider them as the surviving traces of specific behaviour patterns. In some form or fashion, they represent an endeavour of penetrating into rock in a very specific way. This is most evident where they occur on the softest rock types, and where the work traces most clearly express the principle of 'penetrating the rock'. At this stage more should not be said; it is not my purpose here to interpret, and our data base is quite clearly inadequate.

Nevertheless, we can observe profitably that, when we consider that cupules are one of the simplest possible forms of 'rock art', and our profound inability to understand them — even to effectively quantify the surviving corpus so far, or to in any way deal with them comprehensively in the ways of science — we begin to faintly comprehend our academic impotence in dealing with the many far more complex forms of rock art or other palaeoart we have. We fleetingly glimpse proof that, when I emphasise that the *scientific* study of rock art is infinitely more complex than we had imagined, I am quite probably right.

But as usual, it should not be a matter of asking what science can do for us, but what we can do for science.

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