depth, and these may consist of multiple arcs. Obviously once the plant has died, the cause of the rock mark may not be apparent. It is then quite possible to misinterpret it as artificial, particularly after modification by weathering.

Dickson (1980) describes another type of kinetic plant mark which he observed on sandstone. It is

> shallow with no definite shape and is a natural phenomenon. It is produced by a low tree branch moving with the wind so as to rub against the sandstone. On examining one of these grooves still being formed the branch was found to be worn half-way through and a month later it had broken away.

He reports that this type of broad and shallow groove can resemble axe grinding grooves, but he cites no examples of known misidentifications (nearly all of the 1967 axe grinding sites reported in eastern Australia are on sandstone; Hiscock and Mitchell 1993: 34). Another type of sandstone marking sometimes produced by plants has been misidentified in this manner on occasion. It occurs usually on the past or present margins of rock exposures. A tree growing in such a location is likely to hug the rock for support with its roots. Every time it sways in the wind, there is a minute movement in its main roots just below the ground, and this, together with soil and fine sand acting as an abrasive, is sufficient to produce quite deep grooves on the rock, which in turn improve the tree's hold on its support. Over the tree's lifetime, such grooves can become up to 10 cm deep. After the tree disappears and the soil erodes, the grooves remain, consisting of sometimes under-cut but usually quite short, meandering and randomly orientated, rounded furrows. At Cape York Peninsula, northern Australia (Amphitheatre petroglyph site near Laura), the pavement edge on which they occur is now more than two metres above the surrounding sediment floor, and in such cases it may be difficult to perceive how these markings could have been made. However, in Ku-ring-gai Chase National Park near Sydney, there are many such grooves, and it was there that a park ranger informed me that he had observed the phenomenon where a tree had been uprooted by the wind.

BP2. *Chemical plant marks*

The second type of marks produced by vegetation are entirely different. Numerous plant species have symbiotic associations between the mycelium of fungi and their roots (conifers, for instance). In endotrophic mycorrhiza, the fungi penetrate deep into the internal cells of the root, while in ectotrophic mycorrhiza they only enter the epidermis. Mycorrhizal associations are complex and remain inadequately understood. In many species of plants they extend to bacteria within the root systems whose presence remains largely unexplained. Presumably they relate to the plant's metabolism, assisting it in dissolving salts (the function of roots, besides providing support, is to supply the plant with water and nutrients, i.e. salts). The respiratory carbon dioxide of these micro-organisms reacts with moisture in the soil to form carbonic acid, which dissolves calcium carbonate locally. The mycorrhizal relationship thus supports the nutrient exchange system and at the same time provides certain plant species with the means of attacking limestone bedrock and utilising it for mechanical support. For instance, in south-western Australian caves, the roots of some eucalypts have penetrated more than 20 m of solid limestone in this fashion (Bednarik 1991a). It is relevant to consider that the CO_2 content of air is in the order of 0.03%, while the CO_2 content of a soil atmosphere (the gaseous component of a soil) can be 300 times as high (Ollier 1969: 40). This carbon dioxide is largely the result of the respiration of soil microbiota (for a detailed discussion of the relevant chemical processes see Hendy 1971).

The resulting markings have been studied in detail more on portable objects of the Pleistocene than on rock, notably on objects of ivory (Russia), bone (China) and ostrich eggshell (India) (Bednarik 1993c, 1993d). These materials consist collectively of organically derived, mineralised calcareous materials dominated by carbonates (or surviving largely as carbonates once fossilised), and they are susceptible to chemical markings by roots in the same way as limestone is. However, the root markings on them are generally smaller, usually 1-2 mm wide. Those I have observed in limestone caves may be as wide as 10 mm, but they are as well rounded in section and of the same morphology (Figure 13).

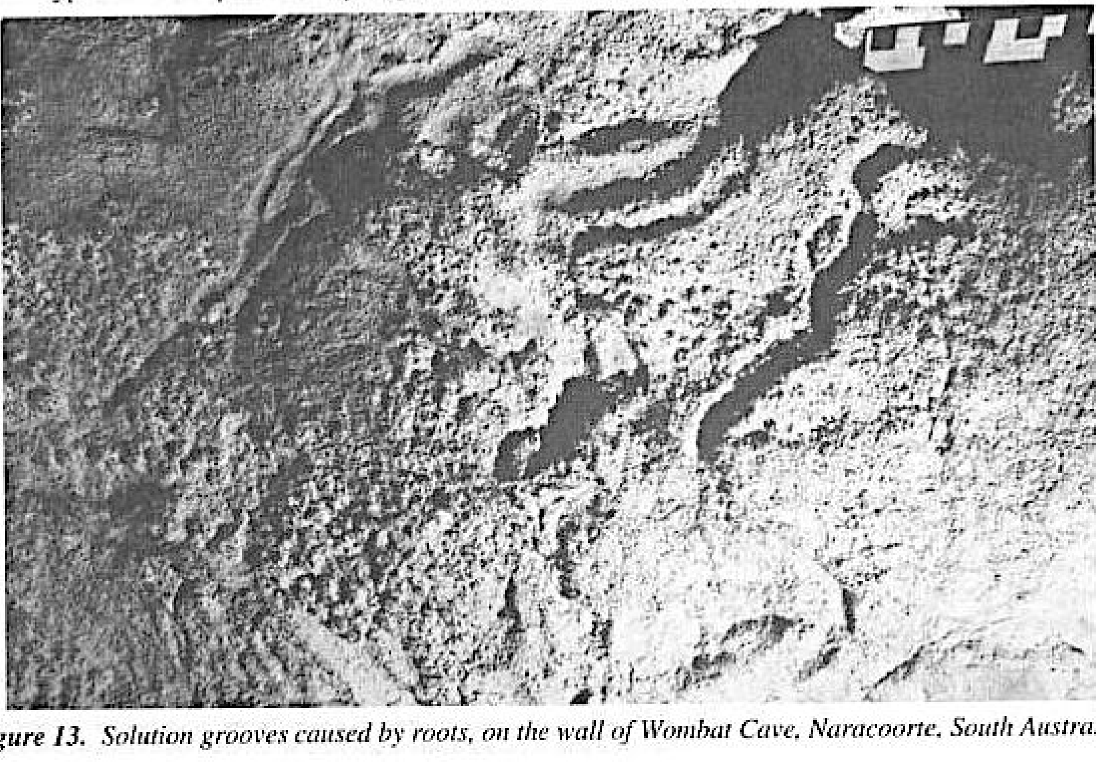

Figure 13. Solution grooves caused by roots, on the wall of Wombat Cave, Naracoorte, South Australia.

Hundreds of markings on sandstone near Remarkable Cave, Tasmania, which had earlier been considered to be rock carvings (Reid 1962), have also been identified as root marks (Both 1963), although it is not clear whether these are chemical or kinetic grooves. At another Tasmanian site, this time on granite, apparent petroglyphs (Sharland 1957) appear to be the result of both plant abrasion (my type BP1) and 'acid leaching' (my type BP2) (cf. Ellis 1958). Nevertheless, I believe that chemical plant markings on rock are most commonly found on carbonate rocks, notably limestone, and on carbonate-cemented sandstone. The roots of at least some plant species are most effective in invading fine cracks and then enlarging their bulk with the help of solution, eventually prising apart rock masses. Where the resulting fracture surfaces become exposed, as on a wall of a cave, the root channels survive as well-rounded grooves which may resemble finger grooves on soft rock, or petroglyphs on harder surfaces. However, the experienced observer can readily discriminate between these markings in probably all cases.

BA. Animal markings

The same does not apply to animal markings on rock surfaces. In particular, animal scratches in caves, which have presented such difficulties to archaeologists in the past (Bednarik 1991a), are not in all cases reliably identifiable, not even by the most experienced observers in the world. Nevertheless, this applies only in exceptional circumstances, and the overwhelming majority of such cave markings can be convincingly attributed. This is a specialist task, however, involving considerable relevant experience. Most importantly, cave markings are subjected to several very common alteration processes, the products of which vary greatly, and an observer needs to be fully conversant with these. For instance, the processes of speleothem growth, maturation and deterioration need to be well understood. Most archaeologists clearly lack these prerequisites, and this has led to numerous misidentifications. In the following chapter I consider the markings of non-human animals, discussing those of human animals last.

BA1. *Animal scratches*

I provide no more than a most rudimentary account of animal scratch markings in the present paper, having offered considerably more detailed analyses previously (especially Bednarik 1981, 1991a, 1993a). It should be stated from the outset that animal markings are not restricted to rock; they occur on many surfaces regularly and in patterns of great consistency. For instance, numerous animal species, ranging from insects to birds and mammals, mark tree trunks. Some examples are the red-necked sap sucker (*Sphyrapicus varius*), a North American bird that constructs ladder-like, geometric arrangements of deeply sculptured squares; or the yellow-bellied glider (*Petaurus australis reginae*) of eastern Australia, which carves trident or V-shaped dendroglyphs (Bednarik 1994b) into its feeding trees; or a variety of large mammalian carnivores (Felidae, Ursidae) which mark tree trunks with their claws to communicate with other members of their species. Elephants 'draw' with their trunks in the dust and can learn to use a paint brush (Diamond 1991). The abilities of non-human primates should not need to be rehearsed here, nor is this the place to discuss concept-mediated behaviour evidence, questions of intentionality and so forth (which are not easily considered outside humanistic anthropocentrism). Here we are merely concerned with the physical externalisations of marking behaviour, irrespective of motivation. Moreover, we are only considering such markings on rock, even though it is useful to perceive rock markings by animals within the greater context of general animal markings and their ethology.

Animal scratch marks are among the most common rock markings in the world, and while they are usually most conspicuous in limestone caves (Bednarik 1991a), they occur also at open air sites. Their common occurrence in caves is a purely taphonomic phenomenon; surfaces are far more often marked outside caves, but they are then exposed to weathering processes and such markings rarely survive for any great length of time. Within deep caves, even faint scratch marks can survive for periods of tens of millennia. The same principle, obviously, applies to rock art: few of the hundreds of thousands of open Pleistocene rock art sites have been found, most have not survived, while many of those in caves probably have. The long survival of animal scratches in caves means that markings of greatly differing ages often occur together, particularly in 'natural animal traps' (caves with vertical entrances) in regions with clawed animals of poor climbing abilities. On the other hand, many claw marks are by species with superb climbing abilities which entered caves habitually. The most numerous animal markings in caves, however, are those of airborne individuals, especially bats. Bats produce rock markings on soft surfaces with their wings as well as with their digital claws, and they are usually of distinctive spatial distribution within a cave's topography. Birds mark such surfaces with their primaries, claws and possibly their mandibles; ungulates do so with horns and antlers on occasion. In Kenya, elephants consuming mineral deposits in caves mark the walls with their tusks. Clawed animals which have marked cave walls include reptiles, but the claw markings of mammalian species are the most common, ranging from those of the tiniest rodents or chiroptera to those of extinct megafaunal species. The most common among the latter are the claw marks of the European cave bear (*Ursus spelaeus*), a powerful animal once ranging from Portugal to the Urals (Bednarik 1993a). Having studied its markings in some fifty caves, I distinguish seven types according to the apparent reasons why they were made (Figure 14).

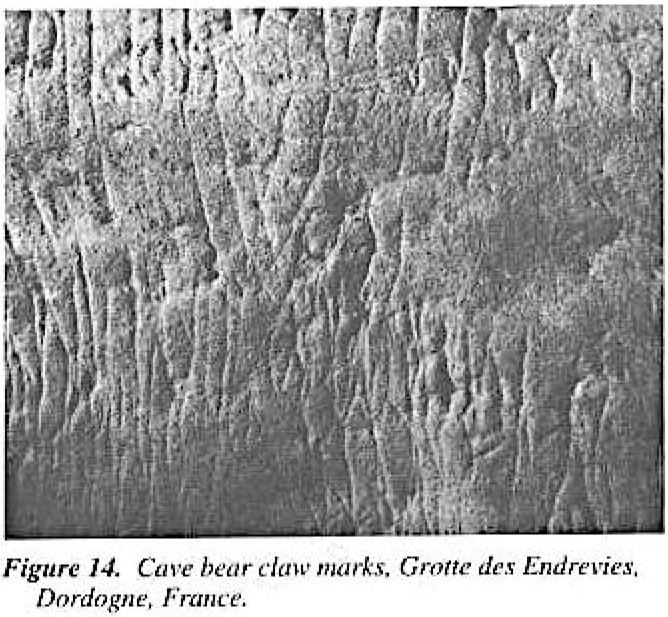

***Figure 14.** Cave bear claw marks, Grotte des Endrevies, Dordogne, France.*

In some European caves, cave bear claw markings cover the walls for kilometres. Megafaunal cave markings are also common in southern Australia, particularly in the Mount Gambier karst region. Some have been tentatively attributed to species on the basis of claw spacing and size, inferred mobility of forelegs, body size, climbing ability, and occurrence of skeletal remains within the cave in question. In many cases, sinkholes and other caves with vertical entrances contain vast deposits of osteal remains, of individuals which fell into the caves and were unable to escape. I have examined hundreds of such sites in several continents, in many cases being the first person to see the bone beds (Bednarik 1992d), and have had ample opportunity to study the behaviour of confined animals from various traces they left (Bednarik 1991a). Australian megafauna species also entered caves voluntarily, and there is some evidence that individuals may have perished in the search for subterranean water. Megafaunal scratch marks in Australia postdate parietal art in some cases, just as they do in Europe. There is no known site of 'cave art' in Australia that does not also contain animal scratches, and the latter are usually far more numerous. Discriminating the two types of marks is the crucial precondition for any informed assessment of the rock art component and, having studied such markings in about one thousand caves, I have developed a healthy respect for the complexity of the subject.

In Australia I define four quite distinctive mammalian scratch marks, apart from bat markings: 'climbing marks' (primarily by possums), 'gouged symmetrical marks' (certain extant species lacking any climbing ability), 'megafaunal marks' and 'exploratory marks' (Figures 15, 16). These distinctive forms do not comprise the entire spectrum of marks present, they are merely frequent, prominent and typical modes of occurrence in one particular geographic region. Obviously the types of animal marks differ in various parts of the world, according to regional animal species, ethology, geomorphological factors and preservation condition, and our knowledge differs according to the research conducted, which is inadequate in a few regions, and practically absent in the rest of the world. In the same way that rock art in caves may have suffered considerable modification through time, animal scratches may have been greatly modified over the millennia, and their visual appearance altered by one or more of several speleo-morphological processes.

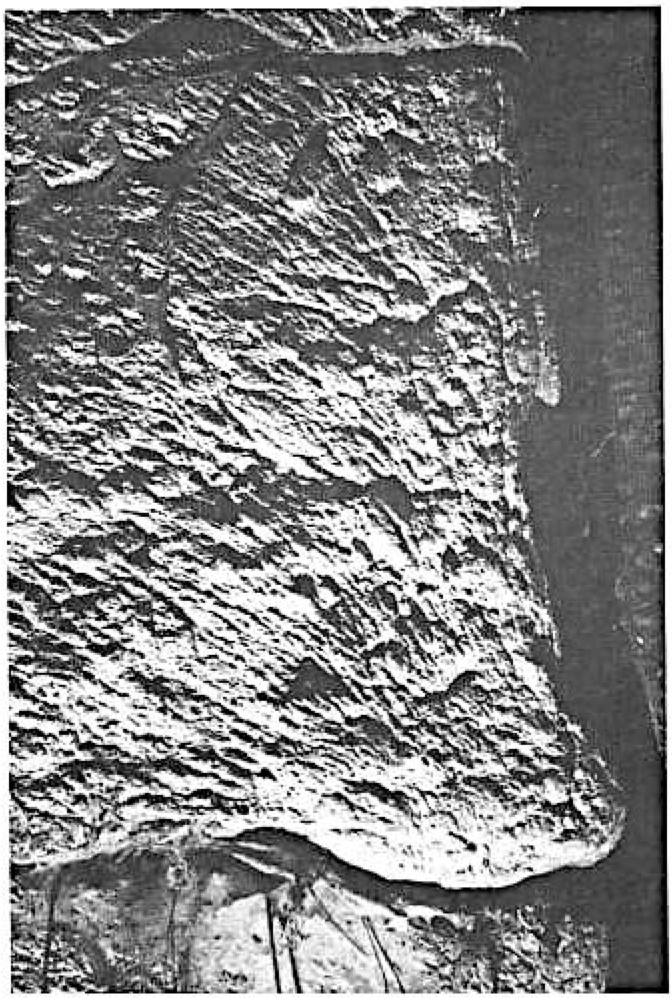

Figure 15. Typical 'gouged symmetrical marks' at base of Gran Gran South Cave, Millicent, South Australia. Identical marks are found around the corner on the right.

Figure 16. *Claw marks by mammals, on vertical wall, several metres above the floor of Robertson Cave, Naracoorte, South Australia.*

In view of this entirely inadequate state of our knowledge it is inappropriate that the status of cave markings be commented upon by non-specialists, notably archaeologists. The subject is far too complex to allow such commentary to be related to management decisions or research findings. We have many examples of misidentifications of cave markings by 'trained' researchers, and I have cited some in the past. Here, I will rehearse just one: the 'human hand' prominently engraved on the upper left hand corner of the rock art panel in the famous Palaeolithic site of Bara Bahau, France (Bednarik 1986b: Fig. 6), has been described as the oldest work of art in the world by various writers, and has been admired by vast numbers of tourists and scholars over four decades. It is almost certainly the work of a cave bear (Bednarik 1981, 1991a: 31, 1993a).

BA2. *Animal polish*

Claw scratches are not the only type of wall markings cave bears produced. The second type is very different, but has also been inadequately studied. The *Bärenschliffe* are panels of polished rock surface, on cave walls as well as on the sides of large floor boulders. They are particularly common in central Europe, and where there has been no subsequent change of floor level they are typically found between 0.4 and 1.4 m above the floor. These polished panels can occur up to a few kilometres into a cave system. They were produced by generations upon generations of cave bears using the same paths in the dark. As their bodies rubbed against the walls, the sand and silt embedded in their shaggy fur acted as an abrasive, gradually smoothing the rock surface (Bednarik 1993a). The reason for the bears' forays deep into caves was to reach hibernation sites, which were typically located in warm air syphons where the air trapped may have been of a considerably higher ambient temperature than that outside the caves, during the harsh winters of stadial peaks. The first Pleistocene rock art found in central Europe (Hahn 1991) has been found on such polished panels, which had later become exfoliated and stratified in the cave floor.

Numerous other species have polished rock surfaces, particularly in caves and rockshelters. They range from those climbing habitually in and out of caves (e.g. possums; Bednarik 1991a), to species using such sites as lairs (cave hyaena, Tasmanian devil etc.), and to those sheltering in cave entrances and rockshelters. Rock art conservators are particularly concerned with the habits of some ungulates, such as feral pigs and water buffaloes in Australia, of rubbing their bodies on rock to rid themselves of parasites. Rock paintings can be rapidly destroyed in this fashion. Not only does this habit result in surface polish, there may also be a deposition of accretionary salts, including perhaps oxalates (Watchman 1990: 48). However, of all the rock markings considered in this paper, animal polish is the least likely to be mistaken for art, although surface polish may have other archaeological significance.

BH. Humanly-made markings

While these are the only types of rock markings that are of interest to the archaeologist, the rock art researcher cannot afford to ignore all the others discussed above. Even though the humanists among hominid ethologists are primarily concerned with 'intentionality' of rock markings, the class of anthropogenic rock markings is best divided into the following two types: those that are the result of some human activity in which there was no conscious desire to leave 'meaningful' marks on the rock; and those in which there was such an intention. We shall adopt this division here and distinguish between utilitarian and non-utilitarian humanly-made marks, rather than just between intentional and unintentional marks. The reason for this is that there are many intentional but still utilitarian marks, as we shall see.

BH1. *Unintentional or utilitarian anthropic marks*

This definition is quite self-explanatory, but it includes a great variety of markings, some of which may even have archaeological significance. Among them may be the marks remaining from mining or quarrying activities, such as the long grooves in Gran Gran Cave, Australia, made by long wooden stakes driven into the limestone to expose a chert seam (Bednarik 1992e). They could easily be mistaken for petroglyphs. Modern mining tools of various types produce a variety of rock markings, as does construction machinery and other heavy equipment: rock drills, core drills, steel tracks of track-mounted vehicles, or gouge marks where a vehicle brushed past a rock face, drag marks on rock pavements, or grooves cut by steel cables being pulled over rock. In short, there is an almost endless variety possible and, particularly if such marks have become weathered, they may easily resemble petroglyphs.

Surprisingly, these marks made by modern machinery have posed significant difficulties for numerous practitioners, and many such marks have been misidentified as pre-Historic rock art by professional prehistorians. It is impossible to devise a set of rules to help avoid such pitfalls, because there will always be 'unusual' specimens which will baffle the archaeologist, and there will always be rock markings of this type which do resemble petroglyph motifs very closely. In my experience, the following two groups of such marks have been misidentified most often:

a. 'Dragmarks': several instances come to mind, including one during a post-congress field trip after the Second AURA Congress, in 1992. A classic example occurred in 1990, while I examined a petroglyph site in Russia with over twenty rock art specialists. The one-metre groove was located on the slope of a granite hill overlooking a lake, on the top of which was a lighthouse. The petroglyphs were all on the lake shore, and this solitary mark lay half way up the hill. Most of the specialists were prepared to accept its authenticity, but it was clear to me that it could not possibly be a petroglyph, despite its weathered appearance. The groove had been incised in one single abrasive motion, uphill rather than downhill. It was aligned with the lighthouse above, so I proposed that some heavy piece of equipment may have been dragged up the hill, perhaps with the help of a tug boat. It could have been a cannon, for instance.

Dragmarks can be very deep, but they are often non-symmetrical in section, very even longitudinally, and they lack the pitted surface of percussion petroglyphs. Often the edges are so steep that the mark can only have been made with metal, and very considerable kinetic force was required to produce them. Obviously they are aligned with the angle of a slope, or the most likely direction of movement. For instance where they are attributable to heavy vehicular construction machinery, they are parallel to the road. Abrasion marks are very rare on hard rock (granite, quartzite, diorite etc.); they are far more common on dolomite, soft sandstone, limestone etc., so where they do occur on plutonic rock they are more likely to be interpreted as petroglyphs. In North America, plough marks have occasionally posed problems for archaeologists, and with some centuries of mechanised agriculture in that continent, such marks may be quite weathered and thus appear more ancient than they actually are.

b. Circular rock marks may resemble petroglyphs, and again several examples have come to my attention. However, their misidentification as petroglyphs by archaeologists is quite unnecessary. Rotating machine tools, such as core drills, can produce perfect circular marks, and will be distorted if the tool slipped laterally when it was applied to the rock surface. Such marks have been found on both horizontal and vertical rock surfaces, and in one case, from Germany, were of about one metre in diameter. Local examples from near my home town of Melbourne are the circular rock marks found at a loose sandstone slab at Sutherland Creek, near Geelong (Bolger 1979). They were examined by archaeologists (including staff archaeologists of the former Victoria Archaeological Survey and the Western Australian Museum) who confirmed their authenticity, and they were thus compared to circular petroglyphs in Tasmania and the 'Cleland Hills Type' of Northern Territory. I find it incredible that professional archaeologists could have come to such a conclusion, considering that no petroglyphs were known from all of Victoria at the time (except the linear engravings and finger marks in New Guinea 2 Cave, Buchan): the markings were quite obviously cut with rotating metal tools of two distinctive (imperial) sizes, and do not remotely resemble circular petroglyphs in Australia or any other continent (circular petroglyphs occur in profusion in all continents other than Antarctica). It would be totally impossible to reproduce the Sutherland Creek marks with stone tools, with their vertical walls in each groove and the narrow groove widths of only a few millimetres (Figure 17).

A very different type of circular mark, also from the Geelong district, was shown to me by R. G. Gunn for evaluation. It consisted of countless narrow, concentric circular marks of varying diameters, forming a deep depression on a boulder of basalt. I judged it to be the result of a rotating metal object, suggesting that it might have served to test an early type of rock drill, or that the block might have been used to hold the axle of some machine in place. Some months later, Gunn informed me that he had indeed located the type of machine that produced such marks: a nineteenth century rock drill.

This great variety of modern utilitarian rock markings, of which the examples cited are only a small sample, obviously needs to be considered before judging any markings on rock surfaces. From the archaeologist's point of view, they may not be very interesting, but there is another group of rock markings which were produced by pre-Historic societies, which were utilitarian and which were also intentional. The first examples springing to mind in Australia are perhaps axe/hatchet-grinding grooves. They are a widespread phenomenon, occurring at thousands of sites (as mentioned above, almost 2000 sites have been registered in the three eastern mainland states alone), almost always on sandstone. But a better example of the type of rock marking I have in mind here are the 'grinding sites drainage grooves'. Caryll Sefton (pers. comm. 1989) reported observing patterns of long grooves on sandstone pavements in the general Sydney region, which she has seen at about twenty sites. They seem to be effective in draining water during rain, and they can occur at petroglyph sites. These long grooves are hammered into the sandstone with stone tools in precisely the same fashion as petroglyphs, they are certainly artificial, and they can form networks of many metres. Their usual archaeological interpretation is that they are uncompleted petroglyphs. When I examined one of the sites during the 1989 AURA field trip, I mooted the hypothesis that some of these lines are drainage systems to keep the grinding areas dry. The managed hydrology of such axe reduction workshop sites would have a significant effect on such a site's effectiveness:

> At one petroglyph pavement we saw a large natural hole in the rock, with adjacent axe grinding grooves. A long groove across the panel is evidently intended to channel water, but instead of leading into the rock hole it channels water around the same and the grinding grooves. Another axe grinding groove, a few metres away, has two long grooves emanating from it which were described as an 'unfinished petroglyph'. ... the pecked lines are designed to drain water out of the axe grinding grooves, and away from the area adjacent to the rock hole, to keep these areas dry, crystalline and hard. It has always been assumed that, in the axe grinding process, water is added to assist it. It seems more logical that the axe was soaked for a few days to soften it, while the grinding area was kept as dry as possible. If this is correct, locations with this type of pattern were in fact self-maintaining workshops (Bednarik 1990: 3).

Figure 17. Circular marks on sandstone, made with metal machine tools. Sutherland Creek, Geelong, Victoria.