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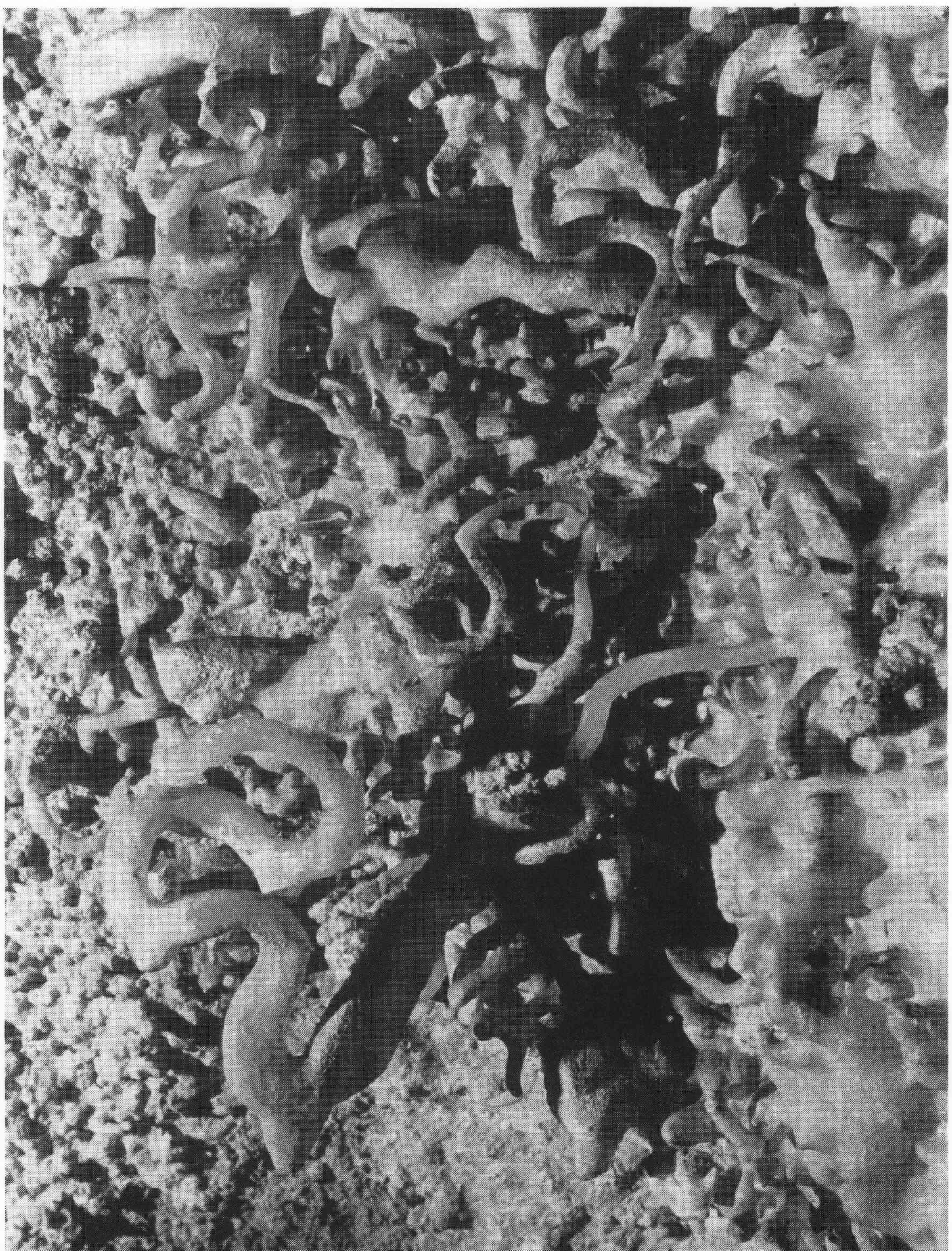

H. Coleman Helictites, Shawl Cave

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ON NATURAL CAVE MARKINGS

Robert G. Bednarik

Abstract

This paper attempts to bring some light into the question of distinguishing petroglyphs from natural markings in caves, by exploring the range of the latter. Some types of natural markings resemble simple linear rock incisions and other forms of petroglyphs. A variety of natural processes causing cave markings are considered. An evaluation of their characteristics shows that it should be possible to confidently identify the cause of parietal markings in the vast majority of cases.

INTRODUCTION

A perusal of literature on markings in limestone caves soon reveals the difficulties archaeologists have in dealing with these phenomena. It is astounding to observe how some of the more precarious archaeological propositions, for example in Australia, have quickly and quite without opposition advanced to accepted archaeological dogma. The introduction as engraved plaques, of the limestone plates bearing an assortment of crisscrossing lines found in the Devil's Lair Cave (W.A.[1]) provides an example (Dortch, 1976). Alternative explanations for the lines are not discussed, their identification as artefacts remains uncontested, and Australia is attributed with a Pleistocene tradition externalised on portable objects with linear, non-iconic incisions which are thought to relate to the finger lines in Koonalda Cave. Indeed, the marked limestone slab Gallus excavated there (Gallus, 1971:Pl.IX), from just above Floor 6 in Trench III, renders this neat hypothesis somewhat plausible. It, too, has linear markings, and its time of deposition is presumed to be of an order of magnitude similar to the older of the Devil's Lair specimens.

The 'engraved plaques' from Trench 9 of Devil's Lair are of greatly differing ages, about 12,000 and 20,400 years, they consist of 'extremely friable' aeolian calcarenite (Dortch, 1976:33) and bear a network of striations on one of the flat faces of each plate. These lines are far from uniform in their depths or widths, varying from pronounced incisions to 'many extremely fine striations', too numerous to illustrate. The material is in fact so friable that the 'very large number of minute striations' includes many that were made with a fine nylon brush when a specimen was cleaned after excavation! Nevertheless, Dortch discounts natural agencies in the formation of these lines, mainly on the basis that some lines join others without intersecting them (i.e., they change direction).

I have examined striations such as those described by Dortch at numerous archaeological sites in most continents. For instance, I have recovered striated objects from Acheulian and Mousterian layers, and striations can even occur on hard materials such as obsidian (Vértes, 1959:166). The perhaps best examples I have ever seen occur on large numbers of stone slabs in the sandstone shelter Toca do Sítio do Meio, Brazil, but here the excavating archaeologist was careful enough to consult a specialist before making hasty pronouncements in print.

Such markings can be caused by a great variety of mechanical agencies, such as cryoturbation, solifluction, tectonic movement of clastics, simple gravity movement of detritus, animal burrowing, or displacement by humans or animals when, for example, treading on the objects (taphonomy). It seems reasonable to suggest that if a slab of 'extremely friable' aeolian calcarenite is in contact with a hard surface, and if there is an amount of sand or grit, particularly quartz grains of varying sizes (Dortch's plaques contain quartz grains), present between the two contact planes, markings would result if the slab is moved whilst pressure is applied perpendicularly, as would be the case if someone stepped on it, or sat on it. It is self-evident that sand grains caught between two uneven surfaces will produce totally erratic patterns, including sudden changes of direction. Numerous factors would combine to determine the configurations so produced, as well as the depths of incisions: the amount of pressure; the topography of both surfaces; evenness of applied pressure; sizes, shapes and relative hardness of grains; their position relative to the surface relief; direction of movement and so on.

The incised fragment from Koonalda Cave should not be cited in support of a cultural interpretation of the plaques, because anthropic involvement is even more remote in that example. This small limestone slab bears at least three sets of sub-parallel incisions which resemble animal marks, both in configuration and groove detail (e.g., cuneiform commencement). Since animal claw marks are very common in Koonalda Cave I see no compelling reason to ignore the possibility that this slab bears such scratch marks. Moreover, if we wish to remain objective we will also have to concede that a link between the deposition date of this slab and the finger flutings in the Northwest Passage is precarious. We have not even demonstrated that the humanly made tool incisions - which certainly do exist in addition to the actual finger flutings, particularly near the entry to the Squeeze Area - are contemporary with the finger marks at this site. The evidence in numerous other Australian caves would seriously question this (Bednarik, 1990). Conversely, (and contrary to popular belief), the rock art of Koonalda is not securely dated: all published ^{14}C dates are incompatible at one standard deviation, they are not stratigraphically consistent, but the art seems to pre-date the

[1] ASF code numbers of sites are not given in this paper because in many cases the sites contain fragile cave art, the only protection of which is in the confidentiality of the cave locations or because they are not listed in the records of the ASF. Also, Aboriginal names were introduced for most of these sites (Bednarik 1990). Many sites mentioned are not in Australia. Many of the less sensitive Australian sites are so well known to speleologists that they need not be identified further.

inundation of the lower part of the passage around 20,000 BP (Bednarik, 1986).

These introductory comments indicate a need of establishing criteria for distinguishing humanly made from natural markings. It is surprisingly common for archaeological investigators to describe natural phenomena, including rock markings, as artefacts, and I have published corrections for such claims from the Americas, Europe, the U.S.S.R. and India (for a recent summary, see Bednarik, 1991). In Australia, some researchers have described Australian cave markings resembling animal scratches as petroglyphs (e.g. Hamilton-Smith et al., 1980; Pretty et al., 1983:21; NPWS, 1983:21-22; Sharpe and Sharpe, 1976; Sharpe, 1982) and one has described finger flutings as having been executed with hand-held animal claws (Hallam, 1971; see correction in Bednarik, 1987/88), which has led to a controversy that awaits clarification. These claims must not be put aside simply because they are in disagreement with the dominant paradigm. All too often, scientific consensus has been wrong in the past, and the claims made in respect to Koonalda, Tantanoola, Cutta Cutta and Kintore Caves need to be examined objectively. Whilst we cannot afford to reject them without a qualified assessment of the entire subject, we equally cannot afford to develop any form of concept regarding the cultural meaning or purport of markings which have not been satisfactorily demonstrated to be cultural. There are far too many such attempts which have been published (e.g., in Australia: Bolger, 1979; Pretty et al., 1983; Reid, 1962; Sharland, 1957; some spectacular overseas examples are Rogers, 1981, corrected by Sieveking, 1982; or Loendorf, 1986, corrected by Bednarik, 1987).

The question of distinguishing humanly made from natural markings is of fundamental importance to the research of early rock art, if the same is to have any scientific relevance. To meet this need I commenced a study of natural cave markings in 1975, which has so far covered hundreds of caves (about 340 in Australia alone), in dozens of countries. The Parietal Markings Project has resulted in several developments, such as the discovery of the densest concentration of cave art in the world (Aslin et al., Bednarik and Bednarik, 1985; Bednarik, 1990); the first direct radiometric dating of rock art in the world (Bednarik, 1984); the evolution of new methods, epistemic frameworks, cultural models and modes of enquiry; and the acquisition of experience in discriminating between natural and artificial markings. It should be said from the outset that there is no short-cut, no golden formula, for recognising either cave petroglyphs, or non-cultural markings. But the present controversy can certainly be resolved. Misinterpretations are usually the result of a lack of familiarity with both types of markings, and with the alteration processes they can be subjected to. Most misapprehensions were by authors who, at the time of presenting their accounts, had only seen one such site, or a few similar sites in a small area. But there is no cave in the world even remotely representative of all phenomena one would need to be familiar with.

My strategy has always been to systematically discount natural agencies before considering human agency, a practice reflected here in my concern with the various natural markings found in limestone caves. Primarily, we are of course concerned with animal claw marks. I will examine specific prominent varieties of them, and the behaviour of animals inside caves. Once we have considered the reasons why animals may mark cave walls we will find it considerably easier to recognise the ensuing marks; many of the distinguishing criteria will become self-evident.

MARKINGS OF NON-VERTEBRATE ORIGIN

Essentially, all secondary markings on rock surfaces are a type of response of lithospheric materials to conditions determined by atmosphere, hydrosphere or biosphere. Thus from a geological point of view, even petroglyphs are a form of weathering, as they are caused by biospheric factors. However, from the cognitive archaeologist's perspective it would seem most expedient to divide rock markings into those of geomorphological significance (including those caused by the biosphere, i.e., by plants, animals and - unintentionally - by humans); and those consciously fashioned by humans. Until we master this distinction, a task for which archaeologists are certainly not qualified, it seems futile to muse about the artistic merits of the markings, their purport or whatever other 'cultural' significance archaeologists may be eager to attribute to such markings.

'Non-cultural' rock markings can be broadly divided into those caused by inorganic geological processes, by plant, animal or by human action. Both (1963) reports hundreds of figures at Remarkable Cave, Tasmania, which had earlier been described as petroglyphs, but were attributed by him to roots. Similarly, at Blue Tier, also Tasmania, marks first described as being of Aboriginal origin were found to have been formed, 'and are still being formed, by a combined action of plant abrasion and acid leaching' (Sims, 1977:432). Such marks are fairly common outside caves, and students of rock art would be well advised to familiarise themselves with these phenomena. Many of the deep grooves found in the sandstone regions of Sydney and Cape York peninsula are caused by tree roots and have been described as axe grinding grooves or petroglyphs by archaeologists. They occur especially at the edge of rock exposures, where a tree once hugged the rock for support. As it swayed in the wind, minute movement combined with sand and soil acting as abrasive produced grooves of up to 10 cm depth over the tree's life time.

Such marks are unlikely to occur in caves, but a second type is very likely to be found there. I have described the effects of symbiotic mycorrhyza on archaeological objects consisting of calcium carbonate (refuting once again archaeological claims of early art: in India I rejected the markings on 44 ostrich egg shell fragments of the Late Pleistocene as being man-made, finding the same patterns on numerous Siberian Palaeolithic statuettes [Bednarik, 1991]), and it is obvious that similar markings are likely to be found on limestone. In many Australian caves, tree roots can be found 20 m and more below the surface (e.g., in Lake Cave, W.A.) and the ability of roots to produce grooves in limestone has been established (Wall and Wilford 1966). In contrast to the first type of root markings, which is essentially the result of mechanical action, the root marks likely to occur in limestone caves were not produced by the roots themselves, but by the chemical reaction between the respiratory carbon dioxide (and possibly organic acids) of the symbiotic micro-organisms present in root systems. The resultant linear marks are often well rounded in section, and if they are of the appropriate size they may well resemble finger lines. However, they are easy to recognise by the experienced observer.

Geomorphological action appears to result only rarely in marks within caves that are likely to be mistaken for petroglyphs. Besides the striations caused by some form of sediment transport, which I have touched upon in my introduction, and the abrasions or incisions talus material often produces on cave walls (a good example is depicted in Maynard and Edwards, 1971:Pl.32), there are two processes in particular that need to be mentioned. The first is *Karren* formation, which affects sloping surfaces of carbonate rock (limestone, dolomite). Where these are exposed to non-vadose atmospheric water flowing over rock, enriched with biological CO_2 from soil micro-organisms, *Rillenkarren* may form. These linear, parallel flutings can be of very regular spacing. As they deepen, they mature to become *Rinnenkarren* which can develop to depths exceeding 1 m. These karst phenomena are quite rare in Australia, and apparently lacking in the Nullarbor region (Jennings, 1963:60), where *Kamenitsa* and smaller pitting can nevertheless be observed (poorly developed *Karren* are widespread, however). I have found *Rillenkarren* elsewhere in Australia, including in Orchestra Shell Cave (W.A.), a site with finger flutings. In the western part of the cave as known prior to 1984 (Bednarik, 1987/88), rainwater has access to the cave wall and has shaped parallel grooves of 3-5 mm depth, as well as other solution phenomena. A prominent panel of *Karren* occurs 25 m west of the entrance to Piccaninny Cave (S.A.), which looks deceptively like a set of about 40 pecked and abraded, parallel lines.

Karren formation in caves is usually limited to locations that are accessible to water other than seepage through overlying rock. Water that has percolated through the closed system of the rock strata conveys bicarbonate up to equilibrium solubility, which is of course a function not only of CO_2 availability or pH, but also of pressure. This means that, even when such a solution is not saturated, its ability to mobilise any further cations upon emergence in the cave space is determined by deducting those already present from the solvent potential in the atmospheric conditions. In practice the result is normally negative, that is, there is a surplus of solute, and the vadose water is therefore unable to effect any surface solution. Erosion within caves is largely phreatic, involving substantial bodies of water and often turbulence and flow which increase solvent potential dramatically. Thus the admissibility of *Karren* formation as a possible interpretation of wall markings can be assessed by speleo-genetic study.

Another geomorphological process producing petroglyph-like markings is a form of selective mass exfoliation (Thornbury, 1954:40). Most types of rock experience near-surface leaching which often results in the formation of a cutaneous weathering zone. It may be protected against mechanical erosion by case hardening (Bednarik, 1979:24). Other factors may contribute to establishing a subcutaneous zone that is less mechanically resistant than the surface layer: varying expansion coefficients and absorption characteristics of diurnal oscillations, anisotropic properties of component minerals, prolonged retention of moisture and associated increased incidence of chemical reactions, deposition of migratory salts and others. Once exfoliation is introduced, i.e., once the case hardening has been punctured, weathering of both surface layers proceeds comparatively unimpeded. If it occurs in selective patterns, the visual result may closely resemble pecked glyphs. Groups of pits are very common, and intricate designs, lines and curvilinear forms may occur. In a sufficiently large sample, apparently figurative motifs may even be discerned. However, by surveying the results of weathering processes active in the area, the natural character of such marks can usually be established. In particular, weathering is not active in deep caves, and can at best affect entrance areas, or rock shelters.

Sandstones are frequently subjected to the described processes, and in addition the laminations often inherent to these rocks also give rise to selective erosion resulting in quite regular surface marks. A classical example is provided by a set of concentric arcs I found in a shelter near Signal Peak, Grampians, which not only appears anthropic, but also resembles closely the 'style' of the archaic petroglyphs common especially in south-eastern Australia. Yet I attribute it to natural processes.

The difficulties experienced in determining the origin of such marks are well illustrated by Sims' (1977) summary of the known petroglyph sites in Tasmania: of 20 locations claimed to have art, Sims could only confirm 12, the authenticity of the others being doubtful as unconfirmed, or from natural phenomena.

'Geological' rock markings can also be produced by linear solution along very thin lamellae of intruded mineral, bedding planes or along minute joints, forming grooves that often appear artificial, particularly if they cross each other as it is common in Buchan limestone (Vic.). Rare instances of this process also occur, for example, in the south-east of South Australia (see Plate 1) and at Koonalda Cave. Normally they

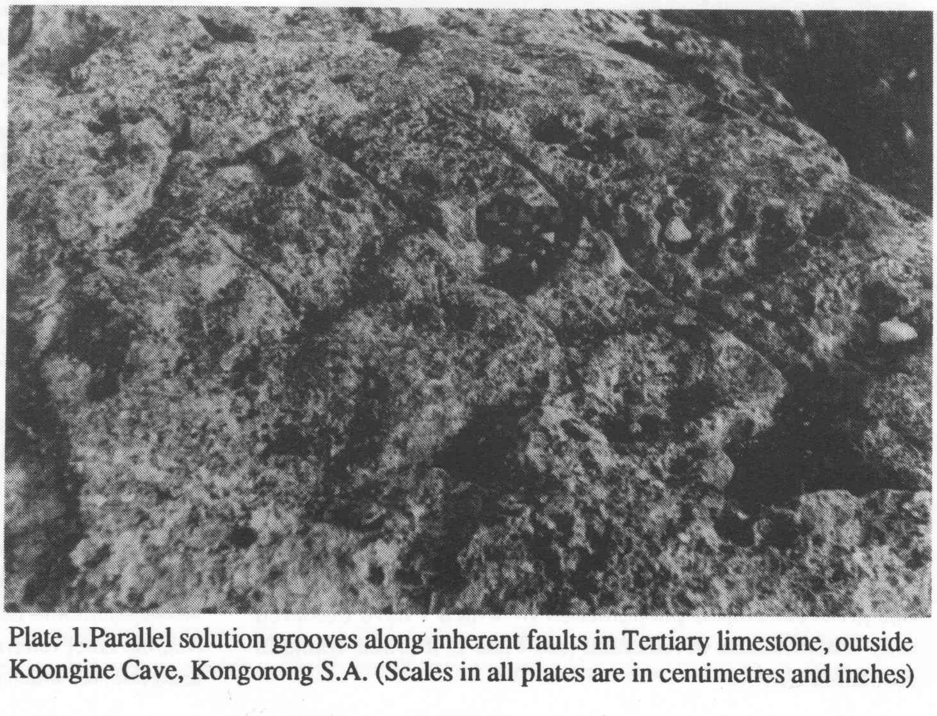

Plate 1. Parallel solution grooves along inherent faults in Tertiary limestone, outside Koongine Cave, Kongorong S.A. (Scales in all plates are in centimetres and inches)

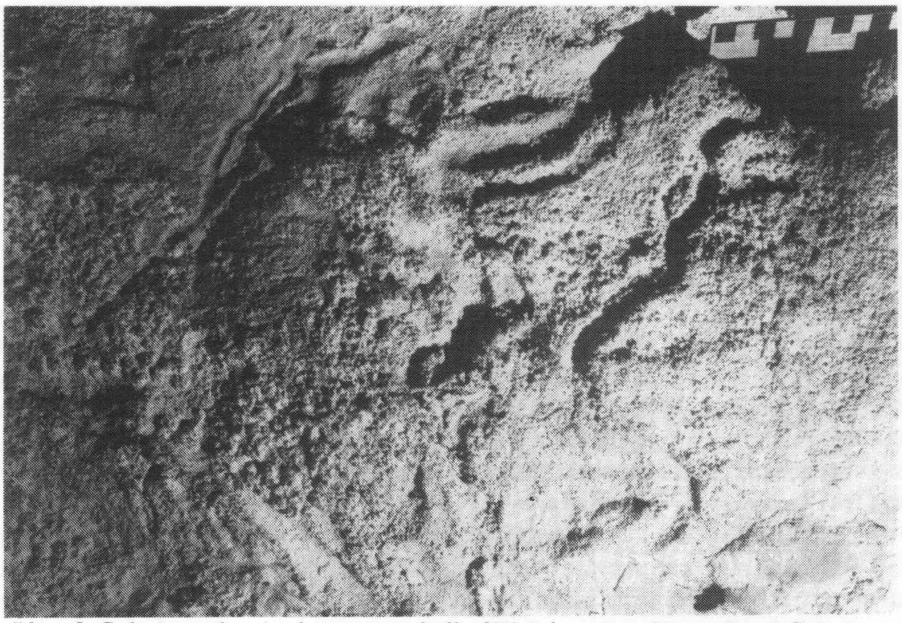

Plate 2. Solution tubes in the western hall of Wombat cave, Naracoorte, S.A.

Plate 3. Bat markings on Montmilch, *Malangine Cave, Kongorong, S.A.*

can easily be recognised as being natural markings, but there have been instances of controversies here too (e.g., Rogers, 1981; cf. Sieveking, 1982).

Finally, rock within caves may fracture along small solution tubes of about 20-30 mm diameter, causing conspicuous grooves. This is phenomenon of which I have observed only few instances in Australia (see Plate 2; it is also found in Koonalda Cave).

In summary, rock markings of geological significance can be identified, in the great majority of cases, by an assiduous investigation of the processes that may conceivably have caused them, or that are potential contributing factors; and by an objective evaluation of their products. Archaeologists must restrain their desire to assign archaeological purport of any form to markings that may be fortuitous or 'geological' in nature.

ANIMAL MARKINGS IN CAVES

In contrast, to distinguish animal marks from parietal petroglyphs is often a more difficult task. In view of the widespread difficulties with this subject I shall discuss it in some depth. Animal marks are not the result of a conscious activity, although they can be purposeful and intentional (much to the surprise of naive archaeologists who conduct debates about 'symbolism' and marking behaviour). Like geological markings, they can thus be deemed to conform to some principles permitting statistical assessment with an adequate degree of objectivity. The difficulties of which to be conscious resemble those surrounding other archaeological controversies, such as the ones dealing with the perennial 'naturefacts' vs artefacts debates in stone tool typology, and the taphonomy vs worked bone debates.

In my view the most numerous parietal animal marks are those made by bats (Plate 3). Two varieties can be distinguished: scratches by the airborne mammals, caused by wings and perhaps by the digital claws; and the marks caused by roosting or landing specimens. Both forms necessitate soft surfaces, usually cutaneous travertine or the autochthonous mode of *Montmilch*[2].

King-Webster and Kenny (1958) have suggested 'bat erosion' to be responsible for dome or bell-shaped ceiling pockets (probably *Kolke*) in a cave in Trinidad. Their view was quickly challenged by Hooper (1958) who correctly identified the phreatic origin of such typical cave phenomena, and who also observed claw marks of bats on soft ceiling deposits in Devonian caves. I have studied numerous Caribbean caves and found no evidence for the continuing claims of local researchers supporting the view of King-Webster and Kenny.

The filigree lattices of innumerable lines produced by airborne bats are common throughout the world. The fine scratches can be straight or curved, and run in any direction. The characteristics of these marks are:

- They are practically absent in all but large recesses of a cave wall. Even slight saliences, such as the ridges in *Montmilch* finger flutings, are sufficient to attract numerous fine and

[2] I use the scientific term Montmilch (Schmid, 1958) here to refer to what is colloquially known as moonmilk, a translation of the German *Mondmilch*. Other central European names are *Bergmilch*, *Galmei* and *Nix*, the latter referring to the use of the speleothem as ophthalmic analgesic, for which it was mined in Europe during the Middle Ages.

shallow incisions, whereas the depressions in the finger lines remain unmarked. Where this marking process is intensive the ridges may be all but worn away, and in such instances the finger lines become gradually indistinguishable.

- The markings caused by airborne bats are concentrated in well defined spatial zones, determined perhaps by the general configuration of the convacuational space (this is the accessible air space, which is part of the evacuational space - the total cavity volume, including solid and liquid cave deposits contained in it), and perhaps by the preferred traffic routes therein. While pronounced in southern France, this may not be as distinctive in all regions as it is obviously related to variables such as the behaviour of diverse species and the morphologies of caves.

The second type of bat marking is often most inconspicuous. For smaller species, a maze of very fine, short incisions may be detected on low ceiling portions, as well as within small avens and *Kolke*. This may be caused by the claws of bats frequenting favoured roosting sites. I have observed undercutting around minor projections of hardened speleothem that may indicate a considerable duration for the process. In Cutta Cutta Cave (N.T.), many of the sub-parallel sets of incisions reported by Walsh (1964) were produced by large bats. Walsh refrains from attributing the markings (at this site and at nearby Kintore Cave, which I have not visited) to any cause, but archaeologists were quick to relate these marks to those of Orchestra Shell Cave (W.A.), apparently because they occur on ceilings in both instances (Mulvaney, 1975:279).

Other flying species enter caves and produce markings on soft deposits. Australian caves are commonly inhabited by the welcome swallow (*Hirundo neoxena*) and fairy martin (*Cecropis ariel*), both of which construct nests of mud pellets on the walls and ceilings. Nests of the former species in fact occur at several of the Australian sites of *Montmilch* finger flutings: at Orchestra Shell, Mandurah, Koorine, Kriton, Kra, Malangine and Koongine Caves, among others. Small wall areas adjacent to swallow nests are densely covered with vertical grooves (Plate 4), produced by the primaries, claws and perhaps mandibles of the airborne cave dwellers. Such lines are generally faint, straight, shallow and short, and they lack a cuneiform element which is often the hall mark of mammalian claw marks.

Owls preying on bats penetrate deeply into cave systems (Bachofen-Echt, 1931:711) in pursuit of their quarry, and could conceivably cause sporadic similar marks. *Mustelidae* also forage many hundreds of metres into caves in their hunt for *Chiroptera*. Both the tracks and claw marks of martens occur abundantly in the Drachenhöhle, Austria, up to 500 m from the entrance.

Numerous other species enter caves, for a variety of reasons, and most are capable of marking walls. Markings are not limited to those shaped with claws or wings; walls and ceilings may be marked very effectively by the bodies (the most impressive evidence being the *Bärenschliffe* in European caves), even by horns tusks (elephants in Africa) or antlers, of animals. In Australia, erratic deep lines on ceilings have been suggested to have been caused by bovine horns, and hair of domesticated species was found embedded in the soft surface deposit. In Eurasia, with its large megafaunal Pleistocene animal population, animal marks of various types are very common.

The best-studied type of animal markings in caves are of course those of the cave bear (*Ursus spelaeus*), and they can often be found in direct association with Upper Palaeolithic art in western Europe. On occasion, claw marks of cave bears have been interpreted as petroglyphs. For instance, the famous engraving of a human hand on the upper left hand end of the art panel in Bara-Bahau (Dordogne, France), which has been called the oldest work of art (Glory, 1955:Pl.2), is almost certainly a cave bear mark. Vértes (1965) reports a small panel of deep scratch marks from the Hillebrand Jen Cave (NE-Bükk Mountains, Hungary) that resemble cave bear claw marks. He identifies them as humanly made on the basis of their oblique inclination, since the bear scratches he has seen on photographs are of a different orientation (presumably perpendicular). The site contains cave bear remains (Vértes, 1959), and the claw marks of the cave bear can in fact be orientated at any angle, including horizontal, and they can also be found on cave ceilings (Bednarik in prep.).

An Australian archaeologist observed that many individual and grouped scratches occur among Upper Palaeolithic art, and can be seen in many of the published illustrations, 'where their occurrence passes without comment' (Hallam, 1971:101). She speculates what the apparent 1+3+1 spacing could mean, which she sees as resembling that of a few Australian sites where she considers an animal claw fastened to the end of a stick may have been used by humans. Yet the answer is simple: it did not occur to the French rock art specialists to make special mention of the many cave bear marks under and over French cave art, because their nature is well known to them. For instance, they extend virtually for kilometres along the walls of Rouffignac, and they are common in many major caves, from the Pyrenees to the Urals.

My detailed study of cave bear scratches in over 50 European caves resulted in some surprising proposals: the large and no doubt fierce bears appear to have been snared in their hibernation haunts by Palaeolithic hunters; and among the 11 different types of claw marks I distinguish, one appears to be intentional and 'semantic' - even though it could not be seen in the dark (Bednarik, in prep.). Cave bear claw marks can be found well over a kilometre into a mountain, they are frequent around hibernation pits, and during the cryocratic periods (the stadial peaks) of the Pleistocene, the animals sought refuge in the warmer air trapped in rising passages.

Whilst the cave bear marks of Europe have been the subject of some previous research (notably Bachofen-Echt, 1931), other parietal animal markings have attracted almost no attention. I have been able to consider the opinions and findings of earlier workers in attempting to explain the significance of the bear marks, but in the case of other scratches we would benefit from initially posing the question: why should animals have scratched cave walls at all?

BEHAVIOUR OF NON-HUMAN ANIMALS IN CAVES

I suggest that we need to investigate aspects of animal behaviour within caves. Two basic types of caves are to be considered: those permitting ready access and egress (predominantly horizontal), and those acting as natural traps (including at least one shaft that is difficult or impossible to negotiate). One would expect the animal markings found in the two cave types to differ significantly in arrangement, location, direction, species representation, depth, density, distribution and so forth. This is the case to a point, but the distinction is not quite so clear-cut. The ability of any one species to leave a cave is not only a function of accessibility, but also of the species' mobility, notably its climbing ability: whilst one species may find it impossible to escape from a shaft, another might enter and leave the same shaft habitually. Moreover, accessibility of a cave is by no means unchanging through time - in fact it rarely is. It may be altered quite dramatically, and as it is modified, the population characteristics of the accumulating wall markings change. These concepts are well exemplified in South Australian caves, which possess some of the greatest concentrations of cave claw markings in the world.

If the objective is to recognise the animal origin of ambiguous parietal markings, that is, to quantify the characteristics of animal marks for the purpose of distinguishing marks probably made by humans, it is inevitable that we should ask: do animals have 'motives' to produce such marks? Do they behave in such a way only whilst in caves? Do different species have different reasons for incising rock surfaces?

The paucity of publications on this subject could be the result of various factors: speleologists probably felt little inclination to concern themselves in any detail with the markings they often encountered on their subterranean forays; animal behaviourists may have had little dialogue with the former; and prehistorians or students of parietal art may not have considered themselves competent enough for a qualified view on this subject. Most people examining animal marks in caves would be deterred by the apparent scarcity of known sites of such phenomena, and they would probably realise that they are dealing with a very small, unrepresentative sample.

A basic tenet of behaviourism stresses the role of the environment as a determinant of both human and animal behaviour. It goes without saying that for a species not accustomed to a cave environment there can hardly exist more aberrant surroundings than those it will encounter within a cave. Yet it is quite certain that non-troglophiles can adjust to a cave environment, and I believe that they may tolerate very high danger levels in situations of stress.

To facilitate the present discussion we must distinguish three categories of animals: troglobites, trogloxenes and accidental trogloxenes. The first group consists almost entirely of non-vertebrates, sometimes lacks pigmentation and vision, and has adapted to a life without light and diurnal cycles, in conditions of constantly high air humidity. Owing to their small sizes, they are unable to produce any significant parietal markings, especially claw marks (Richards, 1962).

The distinction between the latter two groups is really a matter of degree and it should be noted that more than three groups can be distinguished, depending on the criteria: biospeleologists would identify five groups for instance. The trogloxenes enter caves habitually, or remain in them for long periods, but still rely for their nutrient supply on outside sources. They are able to negotiate cave passages totally devoid of light, and may penetrate kilometres into a cave system. Obviously they must possess a sensory system capable of guiding them: ultrasonic echo-location, a particularly acute sense of smell, a keen topographic memory, or a system of spatial orientation we cannot know about. Accidental trogloxenes, however, lack these, and like vegetation, they will only proceed into a subterranean environment as far as daylight penetrates. But if pursued by a predator, if desperate for water, or if blinded they might enter the dark zone.

How would a non-trogloxene react if it has escaped major injury, but finds itself trapped in a cave? Such behaviour has not been observed effectively, but some evidence can be secured by studying the remains of perished animals. Throughout the world there are numerous such animal traps - prime targets of palaeontological research. Often the victims remained mobile after their plunge, and died eventually of thirst or starvation. In the huge shaft cave Buraco do Sansao, Brazil, upon reaching the floor following several aborted attempts by others, I discovered a surface deposit of megafaunal bones covered entirely with a thick glistening calcite skin - an incredible sight (Bednarik, 1989). Thou-

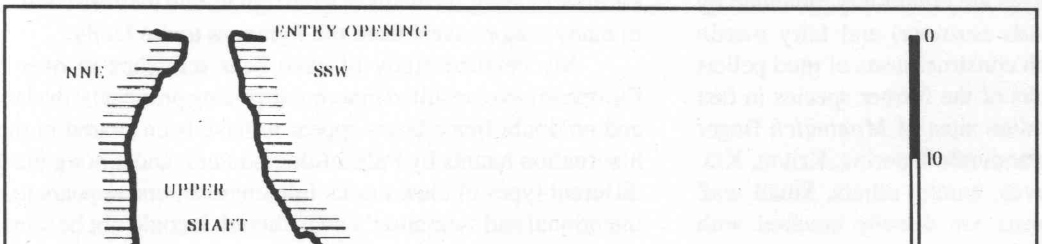

Figure 1. Gläserkogelschacht

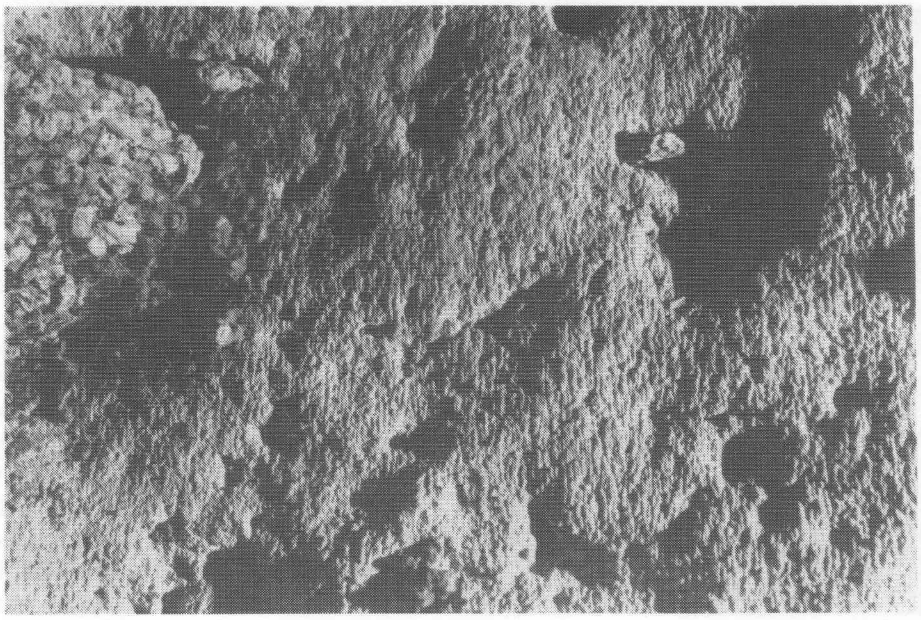

Plate 4. Vertical marking adjacent to a swallow nest (seen on left), Koongine Cave.

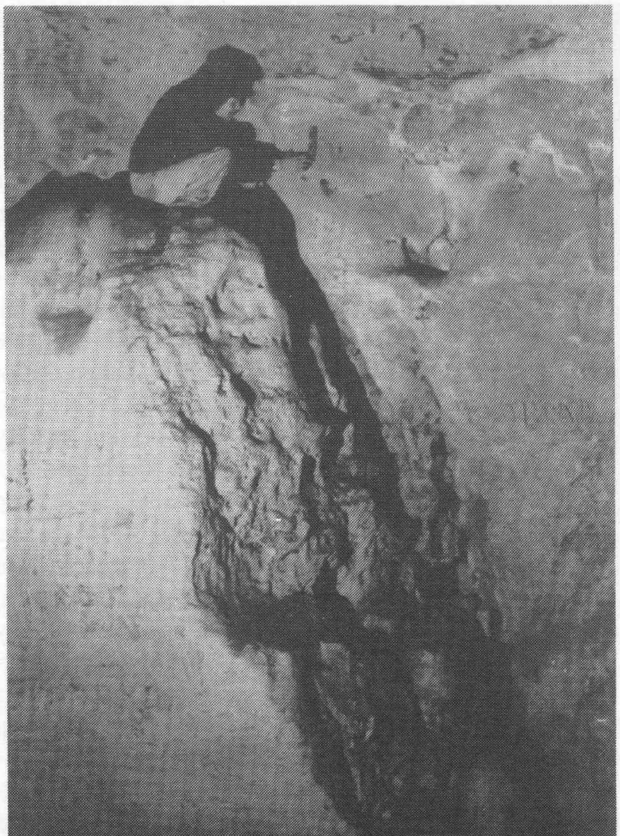

Plate 5. Surveying animal climbing marks, about 10 m above the floor of Robertson Cave, Naracoorte, S.A.

sands of Australian caves have acted as similar traps, and most still contain remains of their victims, at some sites amounting to vast numbers of individuals. Many of their claw marks tell a grim story of the desperate struggle of many of these doomed animals.

The limestone plateau of the Schneealpe, Austria, contains several such traps. The Gläserkogelschacht is among a number I have investigated. Most of the animals that fell into it seem to have survived a 24 metre fall because they landed on a cone of firn (frozen snow). The large hall they found themselves in has only one other exit: a narrow squeeze, just wide enough to allow an adult person to pass. It leads abruptly to a lower shaft (Figure 1).

In 1962 the Vienna Museum of Natural Sciences commissioned an expedition to recover a large sample of osteal material from the shaft. With a group of speleologists I salvaged about 350 kg of bone remains of a Late Pleistocene megafauna. I also reached the pond at the base of the lower shaft, and found, embedded in the fine clay surface around it, a number of small articulated skeletons, as well as the tracks of these animals. Not only had they reached this lowest level and remained mobile, their tracks and long bones indicated no impairment from broken limbs.

The remains of the large mammals in the upper chamber had been transported by the downward movement of the talus slope, and possessed many 'dry' fractures. The absence of small species is conspicuous here, the remains being largely those of *Bos primigenius*, *Bison priscus*, *Alces alces* and *Cervus elaphus*. In the lower hall, only two specimens were examined, *Lepus sp.* and *Mustela erminea*.

Obviously the configuration of the cavities (see Figure 1) has effected a sorting of the animal remains according to the size of species.

This scenario leaves us with two potential explanations: the second fall of the small individuals was again purely accidental; or the hapless creatures slid into the total darkness in an act of final desperation. The first possibility requires that all these individuals slipped accidentally, despite the nasty experience they had gone through some days earlier, thus the second - voluntary entry into the lower shaft - is the most likely explanation.

The observations at the Gläserkogelschacht suggest that an animal faced with the prospect of indefinite confinement in a cave, subjected to starvation and thirst, does not necessarily resign itself to an inevitable fate. Behavioural patterns permit at least some non-trogloxenes to seek the uncertain prospects offered by a totally dark abyss: instant death, or access to water, or perhaps even a very slim hope of reaching passages leading back to the surface.

CAUSES AND TYPES OF ANIMAL SCRATCH MARKS IN CAVES

Traces of desperate escape attempts can be found in most caves with vertical entrances where the walls are soft enough to render claw marks discernible. The natural trap sites of Australia contain the remains of many millions of animals which have perished in them (consider for example the caves at Naracoorte, e.g., Wombat Cave; McEachern's Cave [Wakefield, 1967]; Amphitheatre Cave [Bednarik, 1968]; Robertson Cave). I have observed evidence of almost unbelievable climbing feats in numerous caves. At Princess Margaret Rose Cave, one of many marked caves which were inaccessible to prehistoric

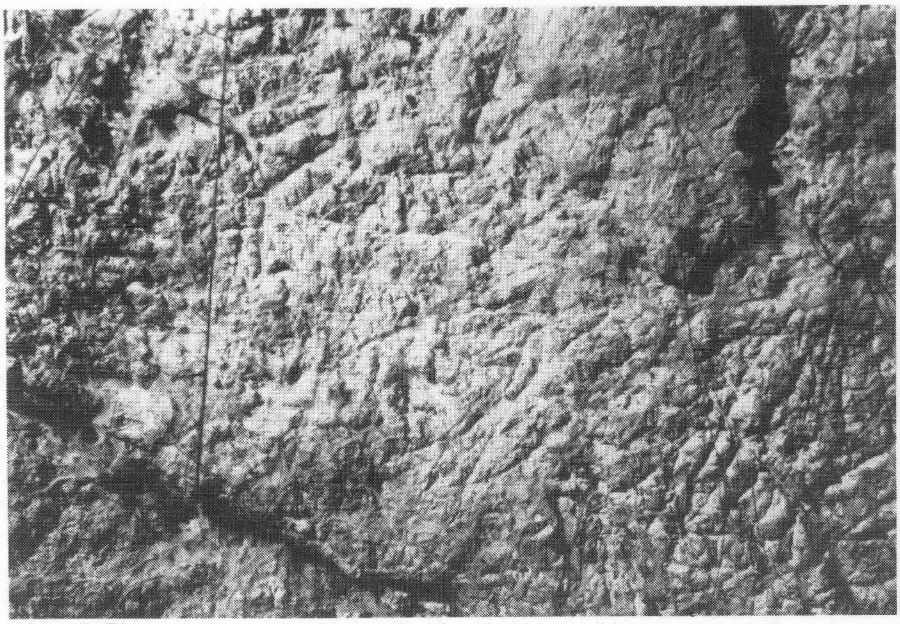

Plate 6. Claw marks on the underside of a chockstone blocking upward progress, 9 m above the floor of Gran Gran South cave, Millicent, S.A.

Plate 7. Small set of claw marks and another larger spacing. near the floor of Robertson Cave.

people, claw scratches occur on vertical walls at up to 5.5 m from the present floor. Naturally, this circumstance could be due to a floor subsidence or sediment removal by water action, but similar markings occur in literally hundreds of other caves. They are present at even greater heights in Robertson Cave (Plate 5), and they are found in many narrow and often deep shafts that were quite inaccessible to human beings lacking sophisticated equipment. For example, Gran Gran South Cave consists of an 18 m-deep shaft. Animal claw marks can be found at most levels, but they are particularly dense wherever upward progress was impeded - especially in an aven about 10 m from the floor. The numerous distinct claw scratches on the perfectly flat, horizontal underside of a block measuring about 1 m across, located some 9 m above the floor, bear witness to an incredible climbing ability (Plate 6). They contrast starkly with the pronouncement by some Australian writers on an animal's inability to mark flat ceilings it cannot reach from a floor (Walsh, 1964; Mulvaney, 1975:279).

Just below the mouth of Mount Graham Cave, a possum has made its home in the vertical cave wall, watching warily as we explored the shaft. To enter and leave its burrow it has each time to jump over the sheer chasm exceeding 25 m in depth, and in doing so can ill-afford to miss its precarious mark. The shaft flares out towards the bottom, and markings occur up the overhanging walls.

The three entry shafts into Grave Site Gran Gran Cave have been densely marked by animal claws. Locally the rock has been rubbed so many times by the bodies of climbing individuals that it is distinctly polished. These vertical walls appear to be scaled quite routinely, and the climbing ability evidenced in considerably less accessible caves suggests that certain species should not have experienced difficulties in entering and leaving this cave at will, possibly just to obtain drinking water. Other creatures were not as fortunate, as the tens of thousands of often deeply furrowed grooves near the floor level suggest.

Cave shaft openings are not the only animal traps, solution tubes can also open to the surface, and small animals sliding into them would find themselves in a gallery developed horizontally. Sink holes may act as traps if the walls are sufficiently hard to climb. When part of a cave system collapses, a cave that had served as a trap may become readily accessible. It is then difficult to determine whether the claw marks are related to its 'closed' phase, or to the period since the present entrance was formed (e.g., Hereford's Stream). Then again, some caverns were once entered by megafaunal species that could not possibly fit through the present entry openings (e.g., Wombat, Fowl Yard, Grave Site Gran Gran and Yaranda Caves). Obviously, large entrances existed during earlier periods but were at some stage blocked, usually by tectonic adjustment (using the term in its correct sense: tectonic and seismic are not synonymous).

Both trogloxenes and non-trogloxenes can find themselves in the predicament of having fallen into a cave, or of being confined by such events as inundation, rockfalls, earthslides, or - especially in Pleistocene Europe - avalanches or snowdrifts. Some of the claw marks illustrate the extremes some individuals went to in their quest for self-preservation. At the base of the more than 30 m-high, 20 m overhanging, imposing walls of the lower hall in Robertson Cave occur puny marks of small rodents or marsupials (Plate 7), some measuring only a few millimetres over four digits: a vivid demonstration of the overwhelming futility of most such attempts, yet at the same time a telling testimony of the compelling urge to survive.

Despite the relative futility of these endeavours they were

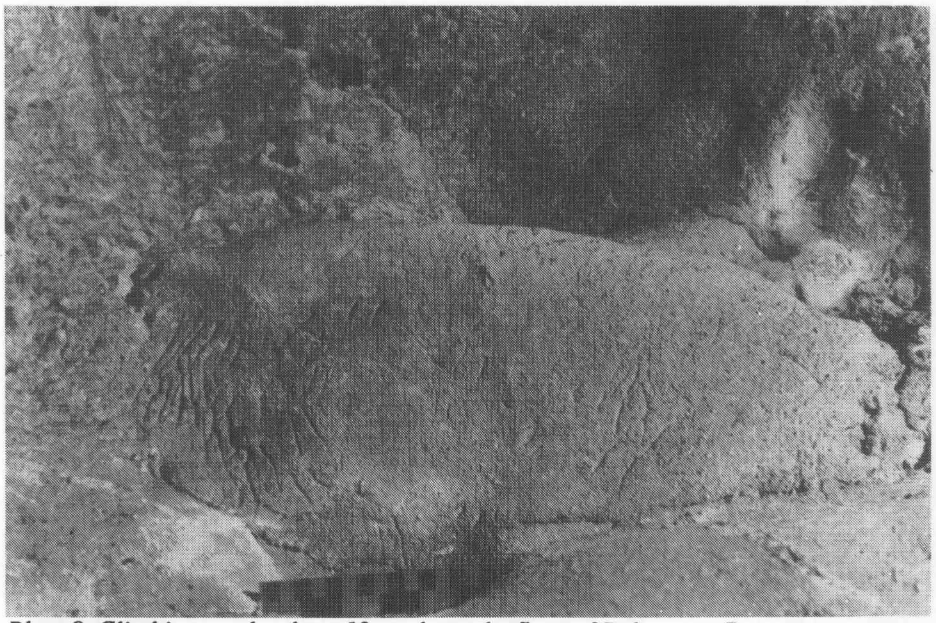
Plate 8. Climbing marks about 12 m above the floor of Robertson Cave.


Plate 9. Typical animal climbing marks at a point where further upward progress seems impossible, 14 m above the floor, Robertson Cave.

still the most rational course of action available to the trapped victims. Any upward advance involved a faint glimmer of hope that some rising passage or solution tube might be reached.

The claw marks in Australian caves are mostly those of mammals, as the recovered animal remains seem to confirm. Species differentiation is often possible between markings, partly because they permit inferences concerning the substantially varying climbing abilities. In Australia I distinguish four broad categories of the scratches:

- **Climbing marks** are most common above ledges, along cracks, edges of blocks and chockstones, and generally at locations that either provide some hold or that obstruct upward progress (Plates 8-10). The maximum reach of individuals involved can often be determined with accuracy, especially where dense concentrations radiate from a position where the animals reaching out were clearly perched. If an arc of such marks is centred on a small ledge measuring only a few centimetres, the distance of the marks from that ledge delimit the range of the animal concerned. I have found these to be quite consistent in many instances. At the same time, claw spacing in individual sets also gives a fair idea of the size of a specimen. Both indices frequently identify possums as the most likely makers of this class of scratches. As these incredibly agile marsupials are able to scale vertical brick and concrete walls seemingly effortlessly with their outsized claws (own observation), most cave walls would not present serious impediments to them. Factors to be taken into consideration when examining such markings are climbing techniques, and degree of confidence in moving about in total darkness, both of which are attributes differing considerably in the various species identified among the remains studied in caves across southern Australia. For instance, I have compared the climbing technique of *Phascolarctos cinereus* and *Trichosurus vulpecula*. If trapped subterraneanly, the former would conceivably produce mostly short, oblique marks at salient features such as columns and projections, sloping down near the apex of these; whilst the latter would leave long, predominantly vertical sets where it slipped, and shorter, variously oriented sets where the rock surface was surveyed. Conversely, nocturnal species are more likely to tumble into a cave shaft, particularly if their mode of movement on the ground is rather awkward - as is the case with the two species just mentioned. A perfectly preserved skeleton of a Brushtail possum lies embedded in the flowstone floor of Augusta Jewel Cave (W.A.), a cave from which escape does not seem possible, and there are similarly fossilised remains of a kangaroo rat in the floor of the Shades of Death Cave (Vic.).

- **Gouged symmetrical marks** appear to relate to species unable to scale the walls. Typically, they occur on two surfaces forming a vertical salience, such as a ridge or a corner. Dense concentrations of deeply furrowed grooves cannot be separated into individual sets. The lines are arranged almost horizontally near the floor but their angle of inclination increases with height until, at the animal's maximum reach of up to 1.5-1.8 m, they are nearly vertical. The symmetrical manner in which the grooves converge towards the salience (Plates 11, 12) appears to indicate that the front legs were both used simultaneously by the animals, standing upright as they helplessly clawed the wall. Macropods and especially wombats are the most likely cause of these deeply grooved patterns.

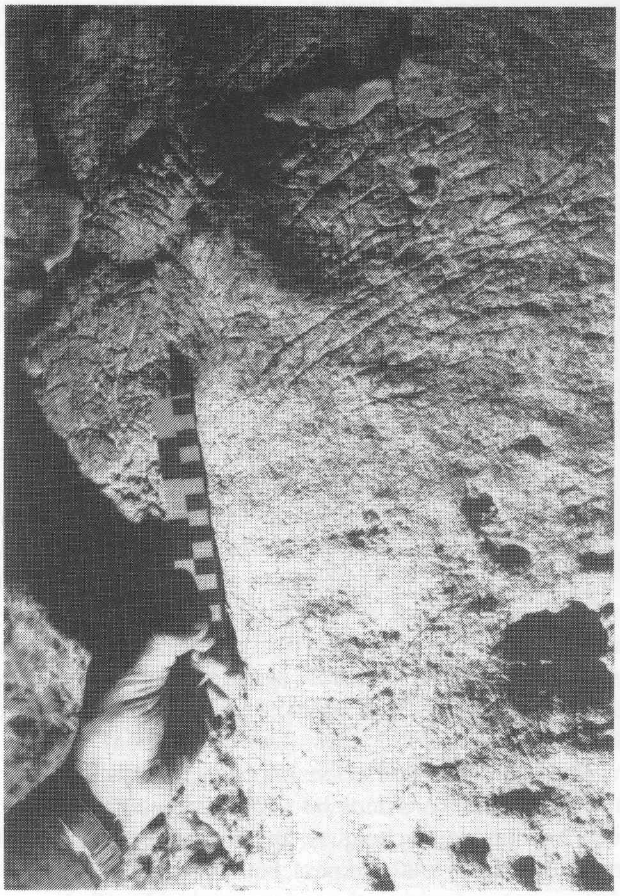

Plate 10. Typical climbing marks, Grave Site Gran Gran Cave, Millicent, S.A.

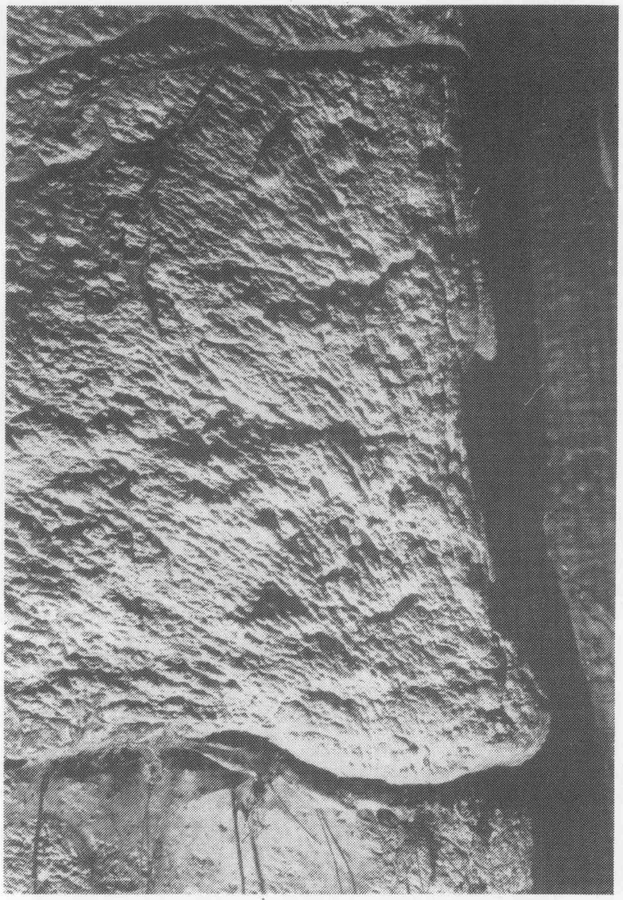

Plate 12. Gouged symmetrical marks, left part, Gran Gran South Cave.

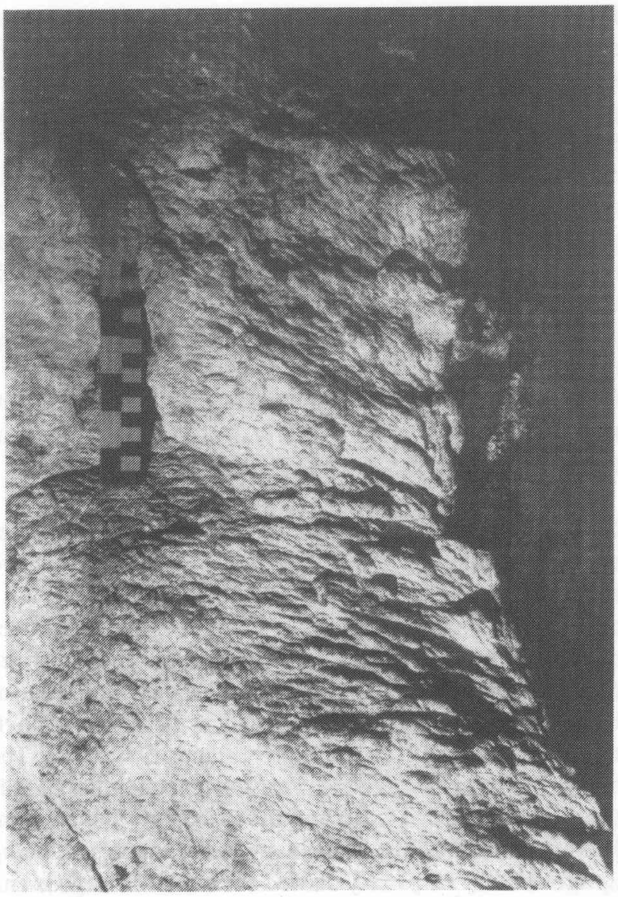

Plate 11. Gouged symmetrical marks (left half only), Grave Site Gran Gran Cave.

● **Megafaunal marks**. Owing to their size, spacing, and in some cases location, a number of often particularly deep scratch marks appear to have been produced by now extinct, large species. We know very little about the habitat and behaviour of *Macropus titan*, the *Protemnodon* species, or *Diprotodontidae*, all of which had a reach exceeding that of a human. The largest of the *Macropodidae*, *Procoptodon*, is attributed with extremely long arms capable of pulling down tree branches. It is in my view the most probable cause of several groups of marks in Mt Gambier caves. Because of corrosion, megafaunal marks always appear very ancient. Their spacings between claws, of 35 mm and more, contrast with a range of 11-23 mm for adjacent, much more recent and lower sets (where related to stable rock floors) that might be of modern species. *Thylacoleo carnifex* had very large claws, and its postulated myelophagous (bone crushing) diet is suggestive of Europe's *Crocuta crocuta spelaea*, a well-known trogloxene. A few scratches on a ceiling in Robertson Cave have an average claw spacing of about 50 mm (Plate 13). This exceeds the mean spacing of cave bear marks (about 34 mm). As far as I am aware, of the known Australian Upper Pleistocene species, only the marsupial lion could have caused these marks. Extensive megafaunal markings occur at many other Mt Gambier sites, such as Grave Site Gran Gran Cave (at lowest level, just above water table), Wombat Cave (only in eastern portion), Nung-kol Cave, Yaranda Cave etc. They are often partly covered by floor deposits (Plate 14).

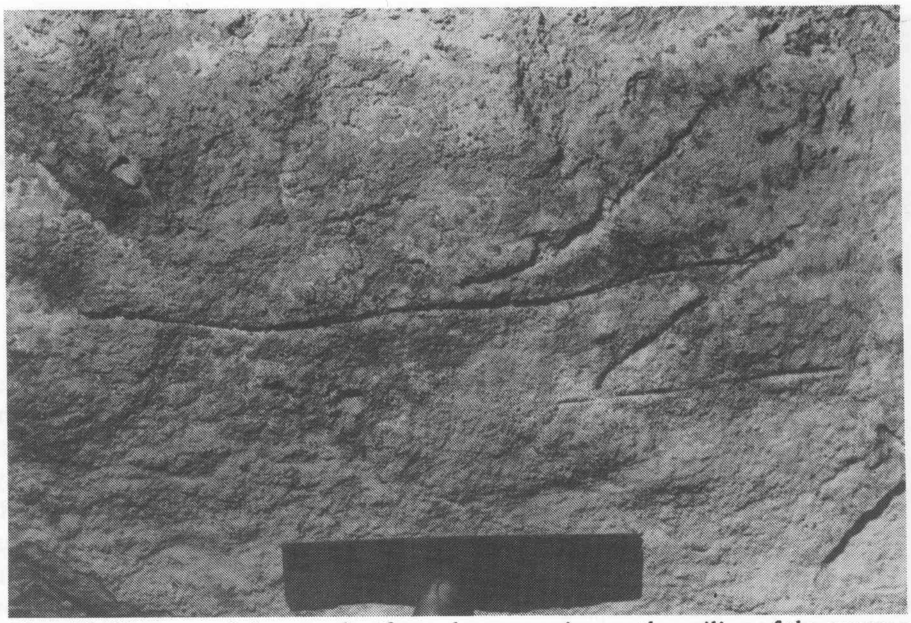

Plate 13. Two sets of claw marks of very large spacing on the ceiling of the entrance hall of Robertson Cave.

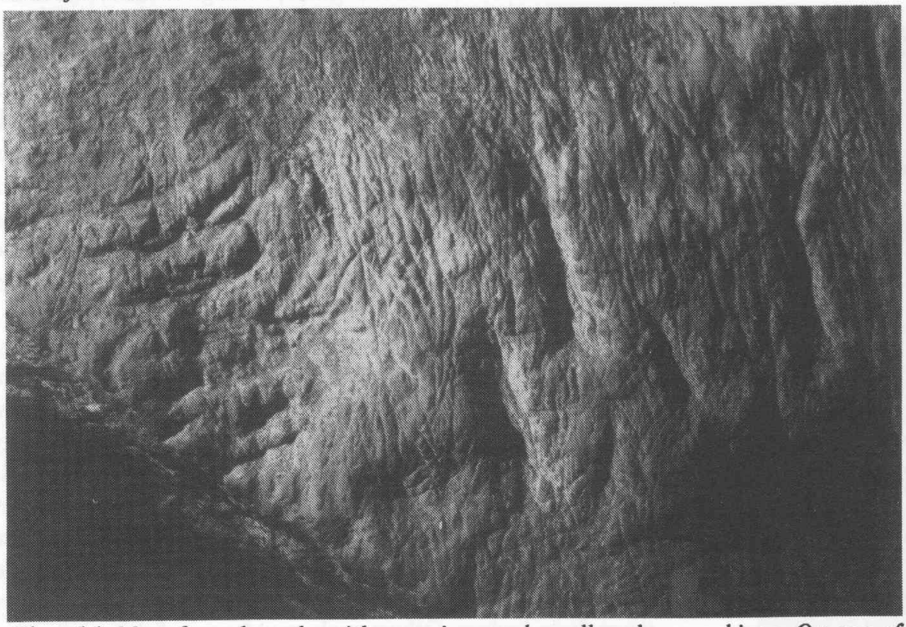

Plate 14. Megafaunal marks with superimposed smaller claw markings. On one of the many incised large floor boulders in the eastern hall of Wombat Cave.

- **Exploratory and 'incidental' marks** are found not only among the more accessible wall portions, but also on boulders resting on the floor, and they occur mostly in the lightless parts of caves (or rather, the parts that were lightless at the time the marks were produced). They are perhaps attributable primarily to non-trogloxenes feeling their way through the dark, marking obstacles as they grope about. It would seem difficult, however, to distinguish them from other types of 'accidental' markings, such as those effected by trogloxenes whilst inhabiting the cave. Generally, exploratory scratches are not restricted to caves acting as animal traps, but often occur in horizontally structured caves, at least some of which have clearly not experienced significant changes to their accessibility. It is important to consider the probable behaviour of animals forced to relinquish the use of their visual sense on entering the zone of total darkness. Typically, a sudden increase in the frequency of wall markings occurs at the threshold of natural light, in caves permitting otherwise unimpeded movement, for instance in Dickson's Cave (Buchan, Vic.) and Koonalda Cave. In my view they are mostly of non-trogloxenes which are unable to cope with an environment they are driven into by circumstances, such as the promise of water as indicated by increasing air humidity (Plates 15-17).

The Tantanoola Cave markings are among those suggested to be humanly made (Plate 18). None of the line arrangements differ appreciably from those studied at about 200 sites of the general region. Complexity of the 'designs' is in fact quite moderate in comparison to that at some other sites where a human involvement is precluded, but claw spacing is above the averages of other sites: a sample of 17 identifiable sets provided a mean line spacing of 18.8 mm. It is to be noted that, no limestone cave of more than 10-15 m length is free of animal markings, anywhere in the world, with the probable exception of a few Antarctic caves.

The scratch markings in Koonalda Cave commence as soon as the threshold of discernible light is passed. On the walls they generally reach to about 1.5 m height, which indicates that those visible are more recent than the huge roof falls that have taken place here. Many of the floor boulders are also marked by sets of incisions (Sharpe and Sharpe, 1976), and it should be noted that they, and the wall scratches, refer to the most recent level of the talus. Since the finger flutings in the same passage (Gallus, 1968) precede the most recent rockfalls, the marked clastics cannot be chronologically compatible with them. If the boulder scratches were the result of human activity, it would have to be attributed to a different occupation than that which resulted in the rock art. However, the boulder markings include no configurations or groove characteristics demanding a human origin. They closely resemble marks I identify as mammalian elsewhere, and I would in fact find it remarkable if, of all the suitably endowed caves, Koonalda Cave would be the only one lacking animal scratch marks - particularly as it is such an outstanding animal trap, with its enormous sinkhole entrance. I believe that a human origin should only be postulated if an animal origin can be ruled out with confidence. In my view, this has not been proven here, nor has it been attempted to refute an attribution of the marks to animals. No researcher who is familiar with cave wall markings as a general phenomenon (i.e., who has studied them thoroughly in more than 100 caves!) would support the proposal. Moreover, the concept implicit in describing the

Plate 15. Elaborate arrangement of 'exploratory marks', lower hall of Robertson Cave.

Plate 16. Sub-parallel groove arrangement concealed by speleothem. Various details suggest that the marks were made by animals. Note both ends of set nearest scale. Karake Cave also contains rock art, including finger flutings. Karake Cave, Mt. Gambier, S.A.

Koonalda Art Passage as a 'sanctuary', which relates to an inappropriate and Eurocentric ideology.

The former presence of *Sarcophilus* in the cave is attested not only by its remains, but probably also by fragmented long bones of consumed prey (Thorne, 1971:46). Thorne also lists four genera of *Dasyuridae* from R.V.S. Wright's excavation, *Peramelidae*, and two *Macropodidae*, including possibly *Macropus rufus*. Gallus (1977:379, Pls 10-12) reports a variety of further kangaroo remains from among the talus boulders, including a row of vertebrae, apparently articulated.

CONCLUSION

Two more, very common types of cave markings need to be mentioned: the marks left by speleologists, and those of human visitors of recent times generally. Speleologist's marks are particularly evident in narrow or low passages, commonly occurring on ceilings, in the form of long single grooves, abrasions, finger marks and so forth. They are easy to recognise, through location, direction and freshness. Marks left intentionally by recent visitors are collectively known as graffiti. They are of significance to the rock art student for several reasons. Since they are frequently dated, carved inscriptions or those made with soot or pencil have provided invaluable information about weathering and patination rates, formation rates of *Montmilch* and other speleothems, recent changes in accessibility and more. They also provide potential data for sociocultural analysis and various other approaches (e.g. Morwood and Kaiser-Glass, 1991).

It is clear from this paper that the natural cave markings most likely to be mistaken for 'prehistoric' petroglyphs are animal scratches. To assist in assessing them, a tentative taxonomic model describing them in a systematic manner may be useful. I submit that the status of an animal-made mark is determined by three co-ordinates: species, vehicle (i.e., the part of the body presumed to have caused the mark), and purpose ('motives' or reasons for making the mark). The essential characteristics of each animal mark are determined only by these three factors. Others such as softness of the medium or subsequent speleothem growth, may influence the appearance of a mark greatly, but not its essential characteristics.

Presumably, there are many reasons why animals have marked parietal surfaces. Their 'motives' could include the following:

- Attempts to escape from the cave, either because the entrance has been blocked, or because it cannot be reached.
- Territorial marking behaviour; obviously only relevant to trogloxenes.
- Fighting among individuals could conceivably result in damage to the walls of a confined space.
- Struggles of animals caught in snares or under rock falls has been suggested to explain certain unusual marks, especially deep horizontal scratches.
- Mating excitement or behaviour seems a plausible explanation for some marks.
- An animal pursued by a predator, including a human, may withdraw into deeper parts of a cave and, acting under stress, claw at the wall to find a way to escape.

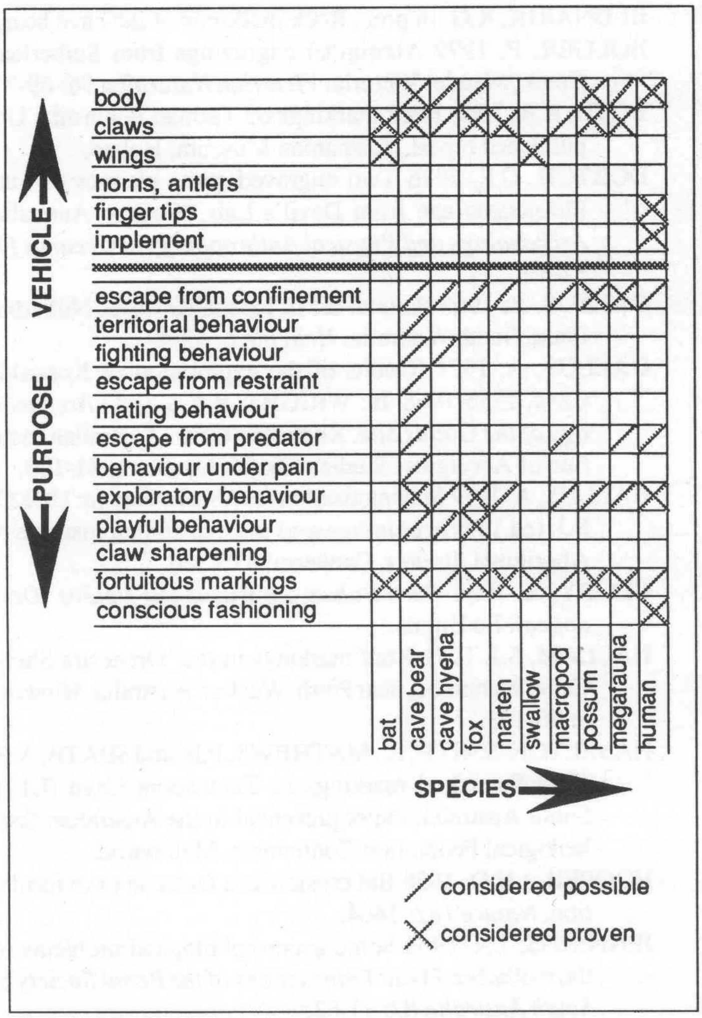

Figure 2. A taxonomy of parietal markings using their three principal characteristics as the coordinates of a three-dimensional model.

- Perhaps great pain of ill or injured animals, which may seek refuge in caves or have fallen into a shaft, induces some species to claw nearby rocks.
- Certain trogloxene species may seek to penetrate deeper into a cave, in an exploratory fashion. They also clear narrow passages, and in the process are likely to mark rock surfaces.
- Some trogloxenes may scratch cave walls in a more or less playful manner. Adolescent animal behaviour could be considered here.
- Conceivably, some of the claw markings could be interpreted as claw sharpening marks, but for the great majority of such marks this explanation is not plausible.
- Finally, several types of animal markings are simply incidental to 'normal', everyday behaviour, and these can be extremely common: the marks of flying species, the polishing of rock by countless bodies rubbing against them, the scratches of the horns of ungulates in cave entrances, or the marks caused when constructing burrows all fall into this category.

Tentative species identification from claw marks is often possible, and occasionally definite identification, by a detailed assessment of factors such as: line spacing in individual sets; configuration of claws at point of commencement; height (where the former floor level can be reliably inferred); inferences regarding mobility of fore leg and shoulder; indications of body size (by spatial restrictions); and impressions of paws on soft or soot-covered surfaces.

The identification of animal scratch marks would be simplified if the three-dimensional model offered here for discussion and further development (Figure 2) were improved from further input as the range of identifiable markings grows. If the model were perfect and complete (which it is of course not even remotely) it would be possible to determine with it one of the factors (or the range eligible for consideration) by ascertaining the two other factors. Unfortunately, this is often not practicable, but since only a limited number of interpretations are usually tenable for the co-ordinates 'Species' and 'Purpose' (limited by aspects of size, relative location, geographic location etc.), and since 'Vehicle' can often be established reliably in any case, one would hope that by checking all possible combinations of the potentially acceptable individual co-ordinates, only a small number of these combinations would remain plausible.

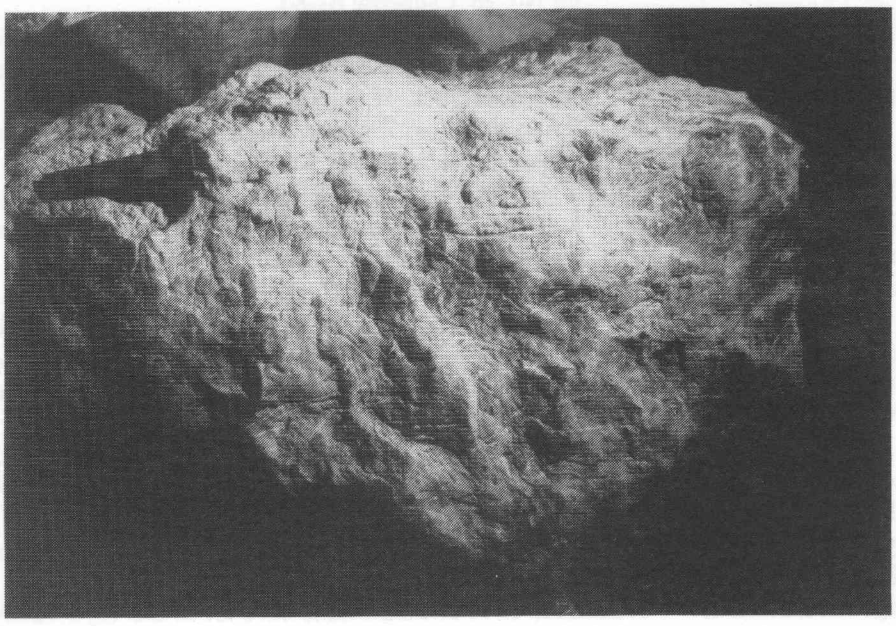

Plate 17. Boulder completely covered by animal scratches, Grave Site Gran Gran Cave.

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Plate 18. Animal scratches in Tantanoola Cave, S.A.

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CAVES OF EASTERN FIJI

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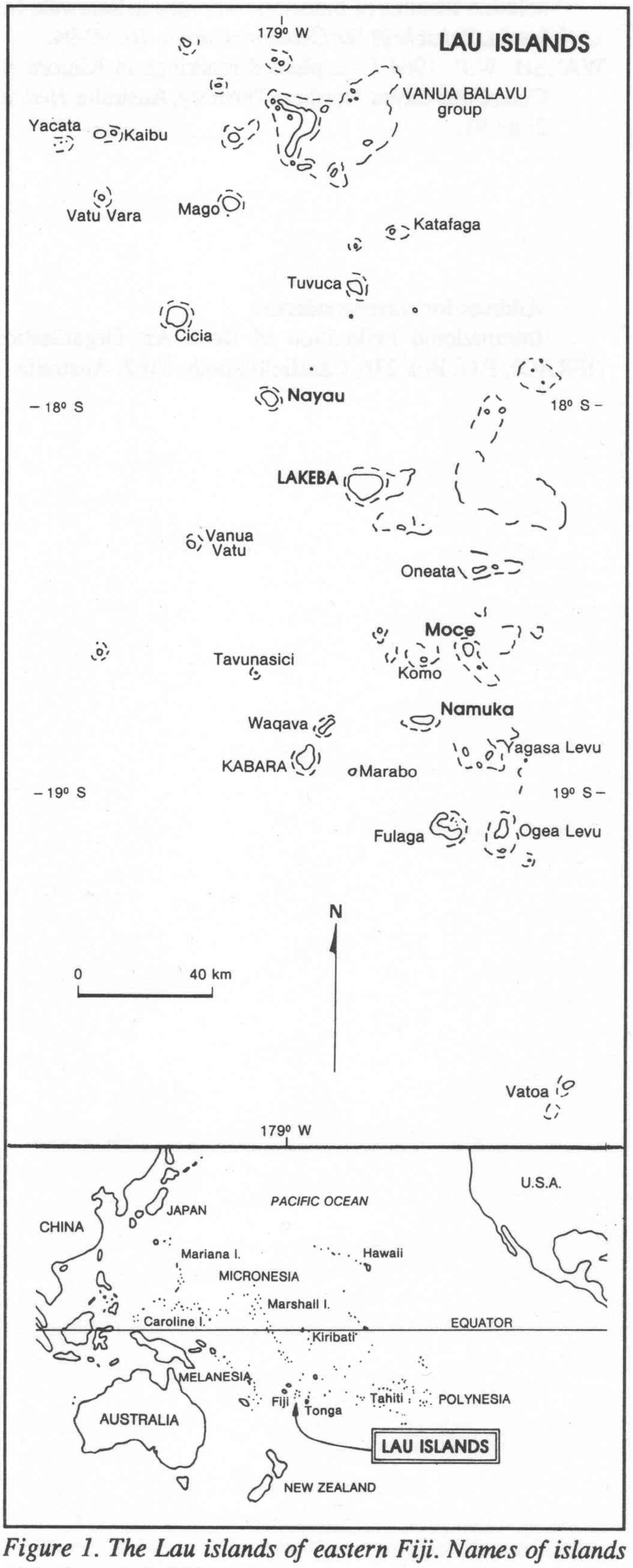

Figure 1. The Lau islands of eastern Fiji. Names of islands visited are in bold letters

Abstract

A number of caves from the islands of Lakeba, Nayau, Namuka and Moce in the Lau Islands Group, Fiji, are described and mapped for the first time. Limestone caves appear to be typical of those of coral islands. Geomorphically they reveal that a first phase of cave development was phreatic, followed by an extended period of vadose development, and some caves are still active water courses. All the islands indicate uplift relative to sea level. Minor volcanic caves are found on Moce Island. Social requirements for cave exploration in Fiji are outlined.

INTRODUCTION

In the course of geomorphological field studies on several of the Lau Islands in eastern Fiji we investigated many caves, most of which had not been reported in print before, although they were well known to local people. These caves are described here, with a discussion of their geological significance and human associations.

THE LAU ISLANDS

The Lau Islands rise from the north-south trending Lau Ridge around longitude 179° W and between latitudes 16°46' S and 21° S (Figure 1). Tertiary volcanoes form the cores of most Lau islands although these are commonly entirely blanketed by limestone. Occasionally the limestone only fringes the old volcano giving rise to islands similar in form and structure to the *makatea* islands in the Cook Islands and French Polynesia to the east. *Makatea* is a rubbly limestone.

The Lau limestones contain few corals and are not considered to be the products of shallow-water deposition (Ladd and Hoffmeister, 1946). The Lau Islands are a type locality for the hypothesis that Pacific raised limestone islands with lowland centres are not uplifted atolls, as supposed by Darwin, but are caused by karstic solution. The emergence of these limestones is believed to have taken place within the last 3 million years or so. In the long term, emergence was intermittent, as indicated by erosional terraces on most islands (Nunn, 1987; 1988). In the shorter term, as indicated by the successions of emerged notches found in the modern cliffs of many islands, there has been repeated uplift.

The best maps of the Lau Islands are the 1:25,000 geological map series (4 sheets) published by the Fiji Mineral Resources Department. The outlines of the geology and physiography of the islands visited (Figs. 2, 4, 5 and 9) are based on these maps.

CAVES OF LAU

On most limestone coasts in Lau, caves are forming at the junction between sea level and the water table. Such caves are best developed where an offshore reef is absent or distant.

Two broad types of emerged caves are recognised. There are lines of shallow sea caves which often appear as a continuous notch above the modern coastal notch. Then there are the much larger caves, the seaward entrances to which are at considerable distances from the shore and which generally reach much greater elevations than the other type. Although we investigated both types, this discussion is confined to the latter, which are of greatest spelaeological interest.

Descriptions of some Lau Island caves were included in the accounts of Gardiner (1898), Agassiz (1989), Sawyer and Andrews (1901), Thompson (1940) and Gilbert (1984). Our survey was carried out in central and southern Lau and included the dominantly limestone islands of Lakeba (pronounced and sometimes written as Lakemba), Nayau and Namuka (Namuka-i-Lau) and the volcanic island of Moce (sometimes written as Mothe: pronounced Mo-they). Each of these islands and the caves we examined are discussed below.

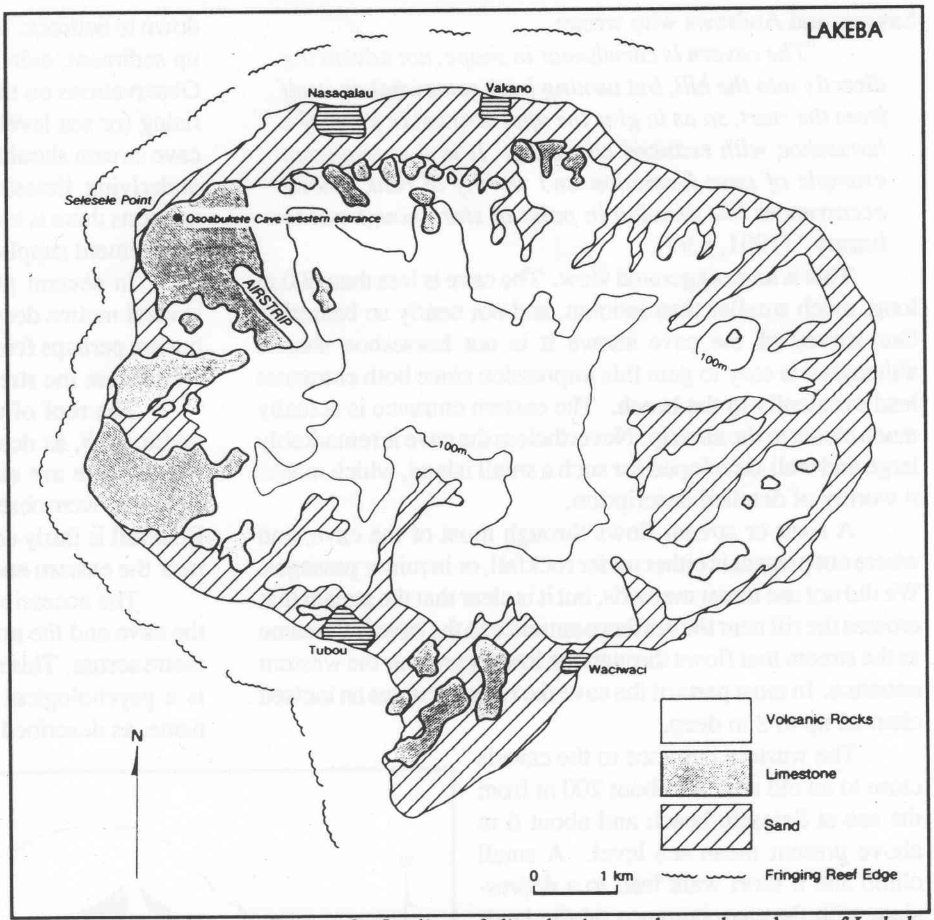

Figure 2. Outline of the physiography and geology of Lakeba

Lakeba

Lakeba is the largest island of the Lau group (55.9 km²) with an exposed core of volcanic rocks and a discontinuous fringe of *makatea* limestone. The largest mass of limestone is in the northwest of the island reaching the coast at Selesele. Its highest point, named Vagandra, was an early settlement site. Details of the early settlement history and the results of archaeological excavations, mainly in shallow caves, were given by Best (1984).

A high island such as Lakeba has a basically radial drainage pattern developed on the original volcanic cone. The drainage pattern is extended over the limestone when emergence brings the limestone above sea level. However, on porous limestone there is a universal trend for the drainage to go underground, aided by solution. This resulted in the formation of caves.

The geological map of Lakeba (Figure 2) shows a barrier of limestone between a large alluviated valley and the sea. The airport on Lakeba is located on a large strip of alluvium in a blind valley just landwards of Vagadra. The stream that once flowed this way disappears into the limestone and follows a subterranean route to the sea.

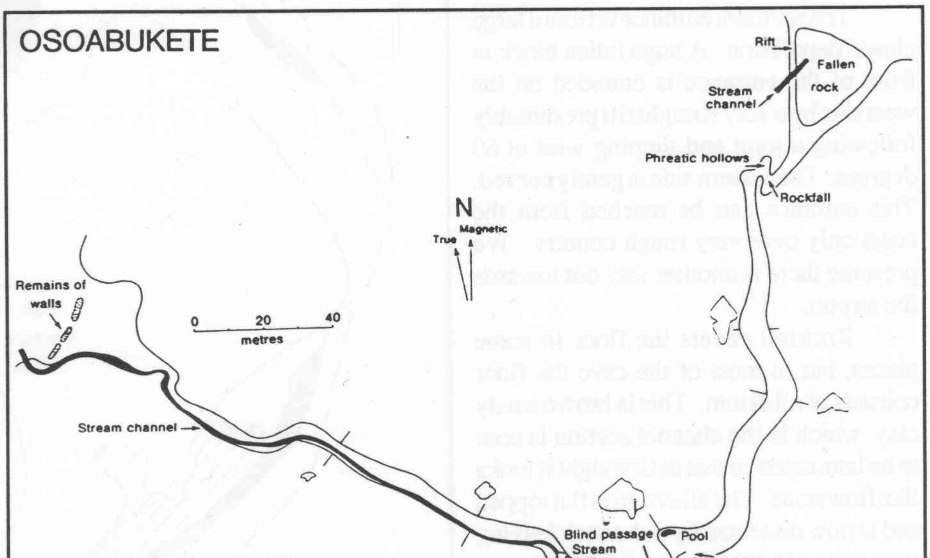

Figure 3. Plan of Osoabukete Cave, northwest Lakeba

Osoabukete Cave

A plan of the cave is shown in Figure 3. This cave was surveyed by us in March, 1990, using compass and tape. A few rough sketch sections are also shown.

Osoabukete Cave is also known as Nasaqalau Cave, Nasaqalau being the name of the closest settlement. Although passing reference to Osoabukete has been made by several writers (Smythe, 1864; Best, 1984), the only description was by

Sawyer and Andrews who wrote:

"The cavern is curvilinear in shape, not advancing directly into the hill, but turning back somewhat on itself from the start, so as to give the appearance, in plan, of a horseshoe with reduced convexity. It is a magnificent example of cave formation and worthy of rank among occurrences like Jenolan in point of size, though not in beauty" (1901, p.97).

This is an exaggerated view. The cave is less than 600 m long, much smaller than Jenolan, and not nearly so beautiful. Our survey of the cave shows it is not horseshoe shaped although it is easy to gain this impression since both entrances lead eventually to the beach. The eastern entrance is actually much closer to the airstrip. Nevertheless the cave is remarkably large and well-developed for such a small island, which makes it worthy of detailed description.

A river or stream flows through most of the cave, and where not present is either under rockfall, or in minor passages. We did not use tracer methods, but it is clear that the stream that crosses the rift near the northern entrance to the cave is the same as the stream that flows through the lower part near the western entrance. In most parts of the cave the river occupies an incised channel up to 3 m deep.

The western entrance to the cave is close to an old sea cliff about 200 m from the sea at Selesele beach and about 6 m above present mean sea level. A small climb and a short walk lead to a depression, with the cave entrance on the landward side.

The northern entrance is from a large closed depression. A huge fallen block in front of the entrance is bounded on the west side by a very straight rift presumably following a joint and dipping west at 60 degrees. The eastern side is gently curved. This entrance can be reached from the coast only over very rough country. We presume there is another way out towards the airport.

Rockfall covers the floor in some places, but in most of the cave the floor consists of alluvium. This is brown sandy clay, which in the channel section is seen to be laminated so that at first sight it looks like flowstone. The alluvium is flat topped and is now dissected by a channel, leaving terraces just like river terraces of the ground surface. In a few places the alluvium has been almost entirely removed, with just small shelves marking the old floor level. Near the western entrance the channel is about a metre wide at the bottom, three metres wide near the top, and is incised about two metres.

The actual channel was dry at the time of our visit. The floor was a typical alluvial channel, with large ripples in the alluvium suggesting high flow rates at times of flood. It is interesting that nowhere does the channel seem to have cut down to bedrock. It may be that the cave stream is still building up sediment, aided perhaps by soil erosion in the catchment. Observations on the coast of Lakeba suggest that the island is rising (or sea level falling), from which one might expect the cave stream should cut right through the alluvium and into the underlying limestone. The fact that this is not happening suggests there is indeed a compensating increase in the amount of sediment supplied to the cave.

In several places there are pits in the alluvial terrace several metres deep. They have not been examined in detail, but are perhaps formed by sapping by underground streams, in which case the stream course must sometimes change.

The roof of the cave in many places has the shape of a gothic arch, as described by Sawyer and Andrews. In many places there are stalactites, shawls and less frequent pillars. Helictites were observed in a chamber near the northern entrance. Rockfall is fairly common, especially near both entrances and near the eastern end of the southern passage.

The accessible connection between the southern part of the cave and the northern part is through a small hole about a metre across. This narrowing, although by no means a squeeze, is a psychological barrier which possibly gave the cave its name, as described later.

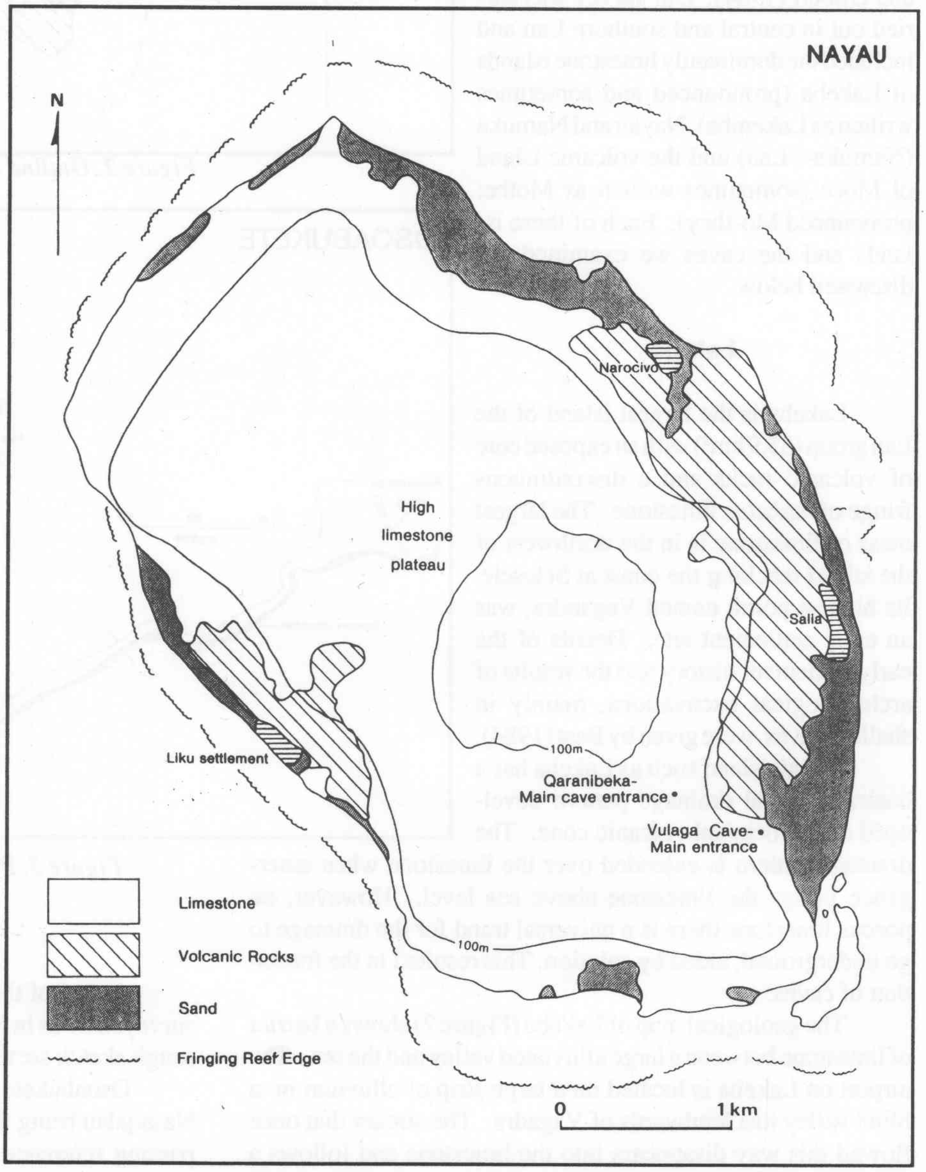

Figure 4. Outline of the physiography and geology of Nayau

Although the cave is a typical river-passage cave, essentially vadose (formed above the water table) there are a few phreatic scallops, bell-holes and a blind passage indicating an earlier phreatic phase (formed below the water table).

The name Osoabukete, meaning "pregnant woman cannot pass", is a reference to the narrow passage connecting the two main parts of the cave. In the past, we were told, women who were suspected of being pregnant were led through the cave. If they were unable to slide through the passage connecting the two main parts of the cave they were declared pregnant. The word was then passed around the village and the pregnancy could be openly acknowledged.

The remains of stone walls at the western entrance to the cave testify to its importance as a defensive site and a refuge in the early history of Lakeba. The walls were originally built to heights of 4-6 m with narrow passages through them. Attackers would be forced to go through these passages allowing the defenders to concentrate their efforts in a few places, apparently an effective procedure. Best (1984) made a small excavation at the front of this cave (his site 166) and reported the presence of material diagnostic of human habitation.

According to Jese Rawaico of Tubou village on Lakeba, this cave was one of the two places settled first by migrants from the largest Fiji island of Viti Levu to the west, the other place being between the modern settlements of Tubou and Waciwaci.

Local people on Lakeba relate how another branch of the cave was sealed off by member of the landowning unit (*matagali*) in Nasagalau, at some time in the distant past, for reasons that are not known. No sign of a sealed passage was found during our survey.

Nayau

The island of Nayau (18.4 km²), 30 km northwest of Lakeba, is quite different from Lakeba. The volcano was once wholly covered by limestone. Since emergence, erosion has exposed the flanks of the old volcano but not its upper part. The highest area of Nayau is therefore a limestone plateau beneath which the summit of the old volcano is assumed to be buried. The three settlements are located on the volcanic rocks exposed by erosion along the island's coast (Figure 4).

Recent emergence of the island has caused the caves at the foot of the high cliffs bordering the plateau to rise above the water-table/sea-level interface. We investigated one such large cave at Vulaga (Fulaga) in southeast Nayau and found it was very similar to Osoabukete on Lakeba described above. Many people living on Nayau told us stories about underground passages connecting cliff-foot caves with those entered from the plateau but our stay was unfortunately too brief to allow to investigate these claims.

We did, however, examine a fissure cave (Qaranibeka - "cave infested with bats") on the edge of the plateau southwest of Salia village, the entrance to which is within a doline reached after a hair-raising climb across the cliff edge. A few small chambers with a variety of dripstone and flowstone features had developed along the southeastern side of the fissure cave which was elongated northeast-southwest. The northwest side of the cave was much straighter than the other, mostly forming a wall dipping northwest at 80 degrees to the horizontal. Although we did not penetrate far into this cave, it was seen to descend vertically for at least 40-60 m.

Namuka

The island of Namuka (12.8 km2), 64 km south-southeast of Lakeba, is composed wholly of limestone (Figure 5). The inlet, almost wholly enclosed, on the central south coast of Namuka may follow the lines of a buried volcanic caldera but nowhere are volcanic rocks exposed to confirm this.

All the caves we examined in the centre of Namuka are collapse features which do not penetrate far through the bedrock limestone. The largest of these caves, Qarananubu (Nubu/Numbu Cave), has an entrance 35 m high and contains a large pool from which water is pumped to supply the settlements.

Much larger are the caves cut in the cliffs of the island's north coast. These caves have entrances at three broad levels;

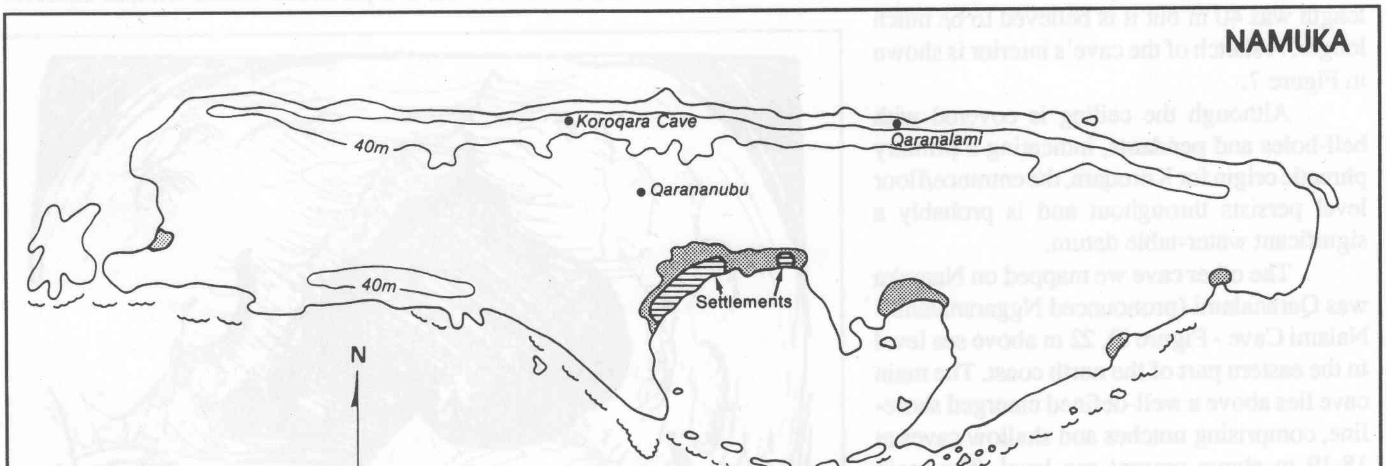

Figure 5. Outline of the physiography and geology of Namuka

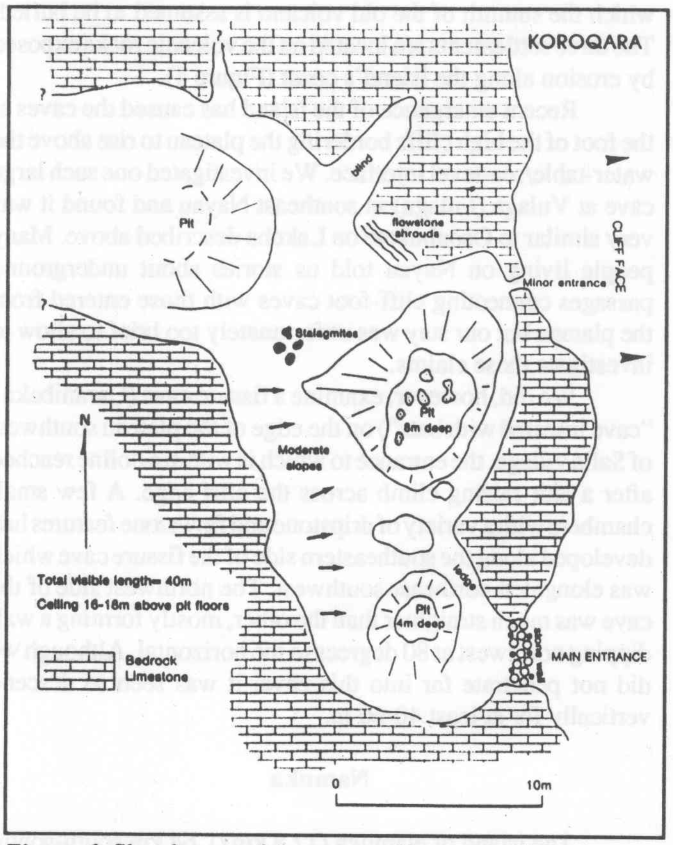

Figure 6. Sketch map of the cave at Koroqara, Namuka

30 m, 22 m and within 3 m of present mean sea level. Owing to difficulty of access, only two caves were investigated in detail.

Koroqara (pronounced Koronggara - Figure 6) is one of a line of large caves at 30 m above sea level on the western part of Namuka's north coast. The entrance is comparatively narrow and has the remains of a stone wall crossing it. This was built when the cave was used as a defensive retreat at the time people were inhabiting an inland settlement nearby.

The distance between the ceiling and floor of the cave is 16-18 m. Owing to large pits in the floor, some of which were 8 m deep, we could not penetrate far into this cave: total visible length was 40 m but it is believed to be much longer. A sketch of the cave's interior is shown in Figure 7.

Although the ceiling is covered with bell-holes and pendants, indicating a primary phreatic origin for Koroqara, the entrance/floor level persists throughout and is probably a significant water-table datum.

The other cave we mapped on Namuka was Qaranalami (pronounced Nggaranalami - Nalami Cave - Figure 8), 22 m above sea level in the eastern part of the north coast. The main cave lies above a well-defined emerged shoreline, comprising notches and shallow caves at 18-19 m above present sea level. The main entrance to the cave is 14 m wide and has no evidence of human construction, which confirms the unsuitability of this cave as a defensive position. Some small walls, probably in great disrepair, were found in the western-most chamber. Numerous stalactites and stalagmites were found along the centre of the southern passage.

Although most of this cave is of collapse origin, there is at least one crawl passage which may lead to a primary cave. A few parts of the ceiling in the western-most chamber of this cave displayed bell-holes and pendants indicating, as for Koroqara, a phreatic origin for this cave although an extended period of vadose development predating collapse also seems probable.

Moce

In contrast to the other Lau islands described, Moce (10.8 km² in area), 51 km southeast of Lakeba, is wholly volcanic in composition (Figure 9). Most caves on Moce are shallow and follow fissures or easily eroded bedding planes between adjacent lava flows or between a lava flow and an agglomerate. The deepest cave we saw on Moce is one of the latter variety and is found at Qelekuro (pronounced Nggelekuro) on the southeast coast. The passage can only be crawled along and extends at least 15 m upwards at an angle of about 30 degrees to the horizontal. No indisputable lava-tube caves were found on Moce.

ACCESS AND PROTOCOL

It is necessary to follow certain procedures in order to travel and visit caves within the Lau islands. In the first instance, permission must be sought from the paramount chief of the islands, the *Tui Lau*. Once this is granted, a visit should be planned in association with the *Roko Tui Lau*, the islands' principal administrator, through the offices of the Fijian Affairs Board in Suva. Since no hotel accommodation is available in Lau, arrangements to stay in villages should be made.

There are regular flights by Fiji Air to Vanua Balavu, Cicia and Lakeba islands in Lau. Other islands can be reached only by boat. Inter-island shipping services are infrequent and irregular; boats may be hired locally.

It is not possible for visitors to move freely within the islands or even within a particular island without observing

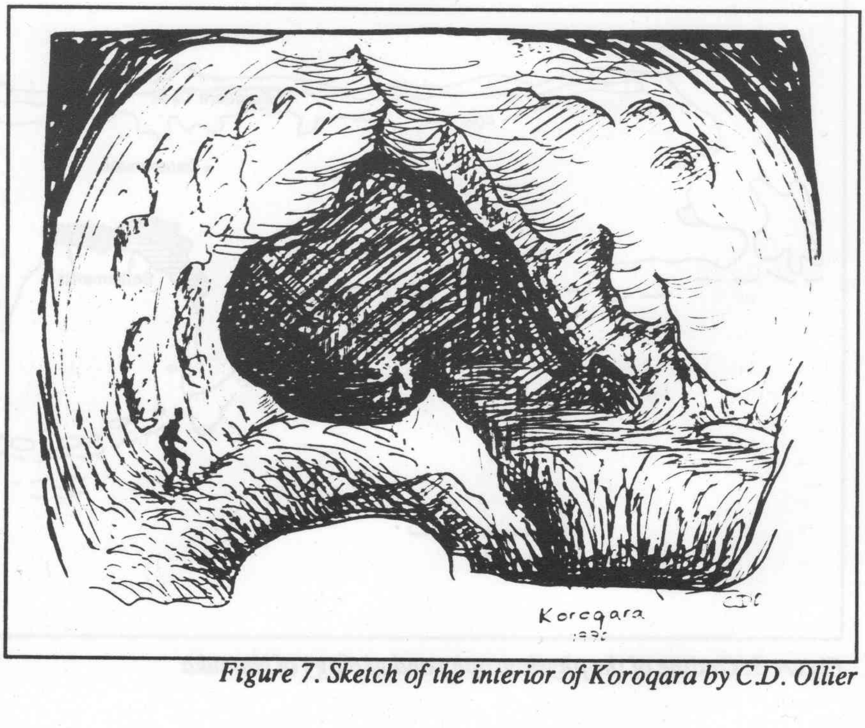

Figure 7. Sketch of the interior of Koroqara by C.D. Ollier

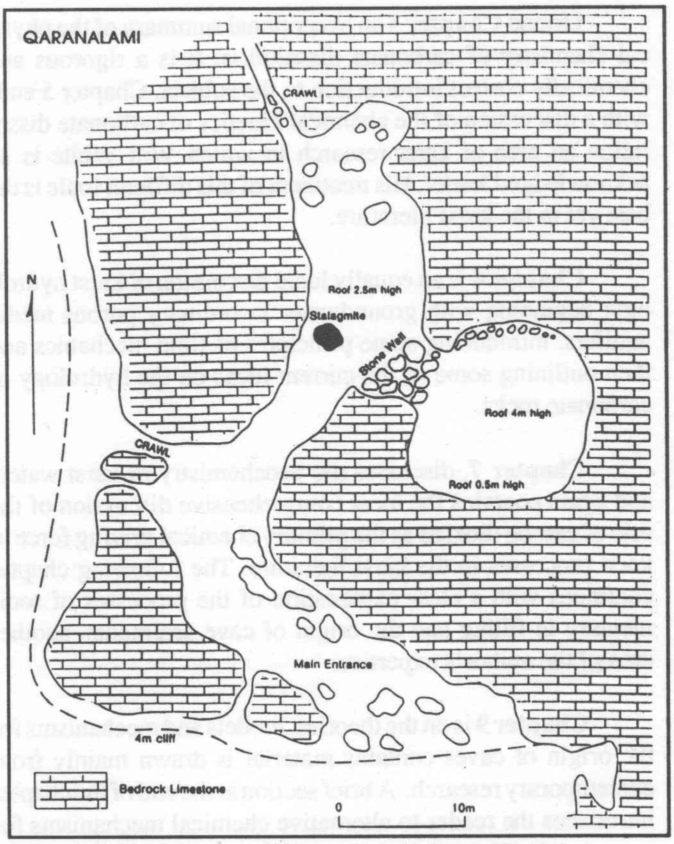

Figure 8. Sketch map of the cave at Nalami, Namuka

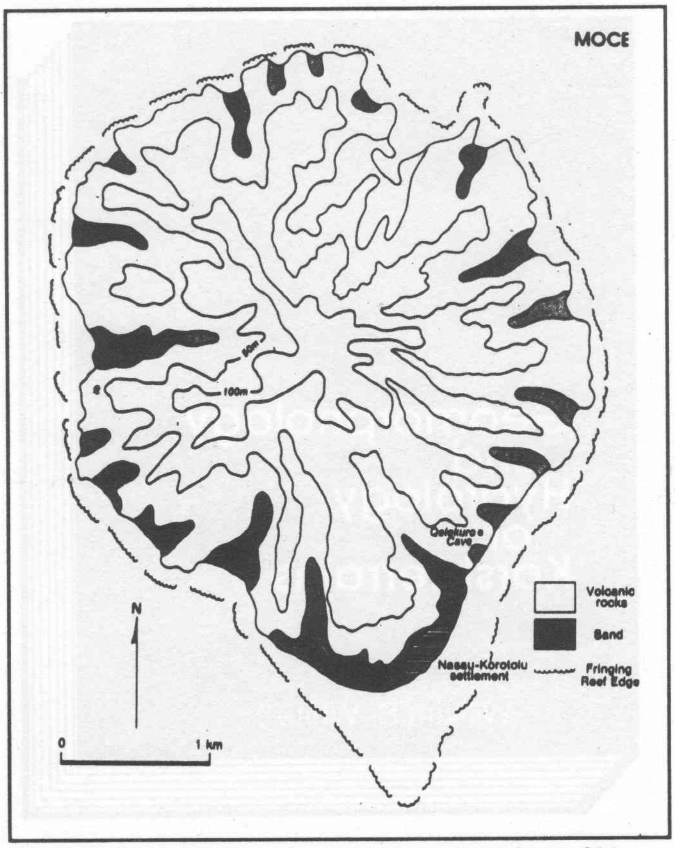

Figure 9. Outline of the physiography and geology of Moce

certain protocol. Before visiting a particular cave, for example, the leader of the landowning unit (the *mataqali*) should be sought, and his/her permission requested in the traditional manner by the presentation of dried roots of *yaqona* (*Piper methysticum*). An excellent reference to this and other aspects of the Fijian way of life is Ravuvu (1983).

CONCLUSION

The caves described are of considerable scientific interest. They hold clues not only to cave genesis but also to the evolution of coral islands in general, to the nature of emergence, and environmental changes in the South Pacific. There is great potential for more detailed surveys in eastern Fiji.

ACKNOWLEDGEMENTS

We are grateful to the *Tui Nayau* and *Tui Lau*, the Right Honourable Ratu Sir Kamisese Mara for permission to carry out research in Lau. We thank Ramasi (Isikeli Ralovo) of Nasaqalau for allowing us access to Osoabukete, and the *mataqali ko Taqalevu (Cokenikoro)* for their considerable help on Lakeba. We acknowledge the help of Jale and Nainasa Kacimaiwai on Nayau, Eroni Bavono and Atelaite Se on Namuka, and Semiti Cama and Kesaia Balewai on Moce. Some field expenses were met by University of the South Pacific grant 0703-8910.

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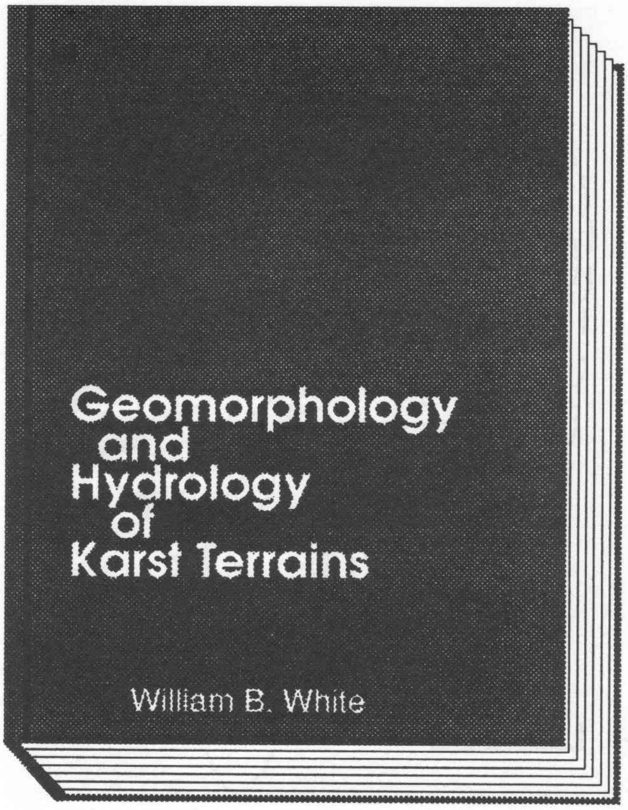

BOOK REVIEW

William B. White, .Geomorphology and Hydrology of Karst Terrains, Oxford University Press, 1988, 464 pp , 192 Figures and Plates, 33 Tables. ISBN 0-19-504444-4. Hardback. Available from The NSS, Bookstore, National Speleological Society, Cave Avenue, Huntsville, AL35810, USA. Cost $US 43.00.

Professor William B White is an eminent worker in karst research with a long career in karst studies. In the book "Geomorphology and Hydrology of Karst Terrains" the author demonstrates much of his own innovative approach to cave science, The author is also an experienced caver and in the introduction to his book Will White recognises the support he has received from the sporting cavers and the importance their contribution to his cave research and speleology is acknowledged in a number of places. Many of his examples and illustrations are first hand from the karst areas in which he has carried out research with the result that his descriptions of karst phenomena are detailed and accurate.

The first four chapters are mainly descriptive and dealing with surface and underground landforms in karst regions. The illustrations are largely drawn from the Americas as is the terminology which is that of Tennessee phosphate miners and engineers rather than Yorkshire shepherds and European karst geomorphologists.

I found **Chapter 5** an exceptional summary of the physical chemistry of carbonate dissolution. It is a rigorous and chemically correct introduction to the subject. Chapter 5 ends with a discussion of the chemical kinetics of carbonate dissolution an area of karst research in which Will White is an acknowledged leader. His treatment of this difficult topic is the best yet in the karst literature.

Chapter 6 is an equally lucid discussion of karst hydrology; beginning with groundwater in ordinary porous media aquifers, introducing some principles of fluid mechanics and then outlining some of the current ideas on the hydrology of carbonate rocks.

Chapter 7, discusses the geochemistry of karst waters and again contains the most comprehensive discussion of the role of carbon dioxide as the primary chemical driving force in karst processes in the karst literature. The following chapter continues with a clear explanation of the processes of sedimentary in-filling and the origin of cave sediments, another area of the author's expertise.

Chapter 9 is on the theories, models and mechanisms for the origin of caves contains material is drawn mainly from contemporary research. A brief section at the end of the chapter introduces the reader to alternative chemical mechanisms for cave development. It is followed by a concise review of the methods of establishing the evolution of karst systems through geologic time in Chapter 10.

Chapters 11 and 12 briefly introduce karst in evaporite rocks, which are more soluble than the alkaline earth carbonates and karst in such rocks as granites and quartzites, which are generally regarded as insoluble. Karst processes in these rocks are becoming increasingly important as more examples of the problems they can cause in construction of major civil engineering projects came to light.

The author describes the last two chapters "as what it is all about". Both are devoted to environmental problems that result from urbanisation and major construction on karst. They are loosely separated into land-use problems and water resources problems. I found the chapter on water resource problems the more satisfying as once again it reflects the authors and my interests and research.

In general, the book is a pleasure to read, its production is excellent with clear figures and photographs mostly taken by the author, many of which have been reproduced with exceptional clarity. Will White is both strong on concepts and the necessity for these to be reinforced by experiment which makes "Geomorphology and Hydrology of Karst Terrains" an ideal text for an undergraduate course in karst geomorphology and hydrology. In addition, it is a must for any researcher who requires an introduction to the chemistry of karst processes.

Julia M. James
School of Chemistry
The University of Sydney
NSW 2006
Australia

INFORMATION FOR CONTRIBUTORS

SCOPE

Contributors from all fields of study related to speleology will be considered for publication. Suitable field include Earth Sciences, Speleochemistry, Hydrology, Meteorology, Conservation, Biospeleology, History, Major Exploration (Expedition) Reports, Equipment and Techniques, Surveying and Cartography, Photography and Documentation. Comprehensive descriptive accounts of the exploration and morphology of individual caves will be welcomed, but simple trip reports and brief cave descriptions are not adequate. Papers overall should not exceed 20 printed pages in length. Contributors intending to write at greater length or requiring any advice on details of preparation are invited to correspond with the Editors. All manuscripts will be read by referees. Short "Letters to the Editor", expressing a personal view or giving a preliminary report of interesting findings, are welcomed, and will be given preference for speedy publication.

MANUSCRIPTS

Submitted manuscripts should be in final form ready for publication. As proofs are not normally sent to authors particular care should be taken to check for typing errors. Manuscripts should be typed, double spaced, on one side of the paper. The title should be upper case bold and the author's names should follow. A brief and explicit summary of the notable aspects of the paper, headed abstract, should precede the main text.

Throughout the main text headings should be in upper case, centred and bold, while subheadings should use lower case bold aligned with the left margin. Acknowledgements should be placed at the end of the text before the references, and the author's addresses for correspondence should follow the references.

Authors are requested to submit a copy of their manuscript on floppy disk as well as "hard copy" in the first instance. Disks may be 3 1/2" or 5 1/4" in either IBM or Macintosh format. If sending text as a word processing document (Microsoft Word etc.), please send a copy as "text" on the same disk.

REFERENCES

References should be listed alphabetically at the end of the manuscript and cited in the text by the author's name and the year of publication (e.g. "(Grey, 1988)"). Where there is more than one reference to the same author in one year the letters a, b, c, etc. should be added. If there are more than two authors, they should all be named at the first citation and in the reference list, but the first name followed by "et al." should be used in subsequent citations. References should be checked particularly carefully for accuracy. Journal titles should be abbreviated following the "World List of Scientific Periodicals", which is available in most large libraries.

The following examples illustrate the style:

GREY, M.R., 1973 Cavernicolous spiders from the Nullarbor Plain and south-west Australia. *J. Aust. ent. Soc. 12:* 207-221.

VANDEL, A., 1965 *Biospeleology. The Biology of the Cavernicolous Animals.* Pergamon, London. Pp. xxiv, 524.

WIGLEY, T.M.L. and WOOD, I.D., 1967 Meteorology of the Nullarbor Plain Caves. In: J.R. DUNKLEY and T.M.L. WIGLEY (eds), *Caves of the Nullarbor. A Review of Speleological Investigations in the Nullarbor Plain. Southern Austalia:* 32-34. Speleological Research Council, Sydney.

ILLUSTRATIONS

Figures and photographs should not duplicate information in tables or other material. Photographs should be clear black and white prints with sharp focus. The number of pages with photographs will be kept to a minimum. Where several photographs are to form one plate they should be mounted together on white card. Any lettering required on photographs should be applies with "Letraset". Figures should be drawn in Indian ink on white card, heavy paper or tracing material and lettered using stencils or "Letraset" or supplied as Laser prints. Most computer drawn documents can also be handled if they are in Macintosh format.

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