LAKE MUNGO

AN ANALYSIS OF THE SURFACE COLLECTION

by

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Except where otherwise
acknowledged the work
reported here is the result
of my own research

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They wept like anything to see
Such quantities of sand:
'If this were only cleared away',
They said, 'it would be grand!'

Lewis Carroll,
'THROUGH THE LOOKING-GLASS'

SUMMARY

Prehistoric artefacts are being eroded from lunettes bordering dry lakes of the Willandra system in western New South Wales. At Lake Mungo the artefacts are found on two principal surfaces which were laid down when the lake was active. These Mungo and Zanci deposits have been radio-carbon dated to about 40,000 years BP and 18,000 BP respectively.

The results of an analysis of the characteristics of the artefacts are presented. Following a summary of the geomorphological and climatic studies relevant to the formation of the lunette, the effect of erosion on the provenance of the artefacts was examined and it was concluded that artefacts up to 2 cm maximum dimension may be moved by surface flow following heavy rain. This was confirmed when the conditions were simulated experimentally but no support was obtained when the displacement of marked artefacts on the lunette surface was recorded.

Problems associated with the detection and recognition of artefacts from a surface of a similar colour were assessed as being unimportant provided it is not intended to recover items smaller than about 1 cm in size. Smaller stones are likely to remain undetected.

An analysis of the surface distribution of the collected implements was inconclusive due to the small sample size and the effect of chance displacement. In particular, an apparently statistically significant result is shown to have little archaeological relevance. The distribution of the more numerous unretouched flakes showed some correspondence with the older Mungo surface but movement of smaller flakes down the surface of the lunette was indicated also.

A detailed comparison of the dimensions and characteristics of the implements was unable to identify major differences between those recovered from the Mungo and Zanci surfaces. However, the mean dimensions of both groups were considerably smaller than those

of three other Australian assemblages of comparable age, including two samples collected previously from the Lake Mungo lunette. In the latter case, however, it is suggested that the first surface collection from a given area may be biassed by erosion which has insufficient time to affect subsequent annual collections.

The thesis concludes by discussing areas for further research which could lead to a more complete interpretation of the surface collection.

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I was fortunate when, many years ago, Dr N.B. Tindale widened my Eurocentric interests to include Australian prehistory. This, with encouragement from my family, eventually led me to undertake the present study.

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CHAPTER 1

INTRODUCTION AND STATEMENT OF THE PROBLEM

The documented prehistory of Australia has relied heavily on evidence gathered from rock shelters and caves. Work on open sites appears less frequently in the literature. The reasons for this disparity are not hard to find; rock shelters protect the successive deposits laid down during years of occupation in a restricted area, the stratification of the organic and other refuse offering the archaeologist a well defined sequence, usually with excellent time control through radio carbon dating.

In contrast, evidence from open sites is often poorly concentrated, the occupation areas being widely separated and often disturbed after deposition, presenting problems in establishing their succession unambiguously. Exceptions are the extensive shell midden sites found on the coast of Australia. These, however, reflect only limited aspects of the inhabitant's coastal economy as indicated by the work of Bowdler (1976) and Lampert (1971). Similarly, the burial sites which have also been examined, for example, at Roonka (Pretty, 1977) could be expected to be limited in the extent of their economic interpretation. It is important, therefore, to take advantage of every opportunity which is offered to broaden our understanding of aboriginal utilization of the resources available to them in other environments.

Such an opportunity apparently presents itself in the record preserved around the shores of dry lakes in western New South Wales and north-west Victoria. Comparable situations may be present in

the south-west of Western Australia where similar lakes occur. In both regions there is ample evidence that at times in the past these lakes were full of deep, fresh water and offered opportunities for extensive exploitation as a rich source of food, including fish, shell fish and probably water fowl, supplemented by other game that was attracted by the assured water supply.

By a fortunate combination of circumstances, the evidence which chronicles such human exploitation has remained sealed in the dunes adjacent to these lakes. Their construction and composition is such that, in contrast to other mobile linear and crescentic dunes found in inland Australia, they have remained static since they were laid down, thereby preserving the original stratigraphy. These dunes or lunettes, which are composed mainly of beach sands and wind-blown material derived from the drying lake bed, follow the eastern and south-eastern shores of the lakes, resulting in their characteristic crescentic plan-form from which the name is derived. They may be of considerable length, those in the lake system which has developed along the Willandra Creek in western New South Wales being up to 40 km long and 140 metres wide.

Recent erosion, which is still continuing, has revealed abundant indications of past human occupation in the form of stone artefacts, small shell middens and possible hearths that are scattered throughout the length of these lunettes. As noted above, the stratigraphy of this material appears to have been preserved until the recent disintegration of the dune surface.

Attempts to select rewarding excavation sites from such an extensive exposure would contain a considerable element of chance, for although apparently localised occupation areas which may be of interest are revealed in the eroding lunette surface from time to time, these areas are of no great vertical extent, are widely separated and are quickly obliterated as the erosion continues. Fragile material including the bones of fish, small animals and egg shell are exposed but this presumed food waste rapidly becomes fragmented and scattered. However, the stone artefacts and the associated lithic waste material are not destroyed but accumulate on the eroding surface to provide evidence of past occupation extending through the dune building period.

Once freed from the dune matrix this surface record becomes blurred and possibly incomplete, since a detailed stratigraphical context is then lacking and that which is present results from capricious Nature's choice in deploying her erosional forces. The distribution is essentially uniform with material scattered widely over the lunette. Concentrations, where they can be identified, are rare, of low density and ill defined. Furthermore, it is possible that a proportion of the blackened areas which occasionally occur may not be hearths but the mark of ancient bushfires,such as burnt tree stumps, for the local water table could well have supported vegetation not unlike that to be found along the banks of the Murray-Darling river system today at those times when the lakes were full.

Despite these limitations, the exposed material extends over a considerable area and thus there is an abundance of data, although lacking in any

great precision. The challenge lies in developing a strategy for interpreting such an extensive, diffuse but potentially unique source of information. The present work represents an attempt to respond to the challenge.

The Nature of the Problem

Previous work, summarised in Chapter 2, has shown that the Willandra Lake System was full or at partial capacity for two long periods of time beginning about 40,000 years ago and separated by an interval of dry conditions, broadly similar to those that have applied for the last few thousand years. The relatively dessicated environment lasted from 22,000 to 18,000 BP and was followed by a brief 2,000 year period when the lakes were again filled.

It is assumed that more intense human activity was encouraged by the favourable lacustrine conditions so that the lunette stratigraphy contains the record of two essentially distinct occupation periods. Casual occupation which continued up to the recent past is thought to have occurred also. Based on this assumption, the present work seeks to determine, from the characteristics and disposition of the stone material exposed on the erosion surface of the lunette, whether differences in technology can be detected between the two principal assemblages.

At first sight the modesty of this aim may be disappointing. It might be expected that some attempt would be made to interpret the recovered material in terms of the behavioural patterns which led to its production. Such an interpretation requires consideration of the three, essentially distinct, phases through which the material passes from the time when it was finally discarded by the user to its eventual recent exposure and recovery.

Practically nothing is known of the first of these phases corresponding to the time when the human component of the deposit was formed. Thompson has described the activities of coastal aboriginies (Thompson, 1939) but the extent to which their behaviour may be transferred to lacustrine environments is uncertain. All that may be assumed is that parties of unknown size and composition camped on the dune presumably gathering and preparing food, and manufacturing and repairing artefacts. Waste products from their activities would have accumulated on the dune surface. A general model describing the use, re-use and eventual abandonment of items in such a system has been proposed (Schiffer, 1972) but has only been tested in a general way (Schiffer, 1973). The size of the groups and the season or period for which they occupied a given locality would have determined the extent and concentration of the debris. Frequently moving groups or groups visiting on a casual basis would have produced a relatively uniform distribution of material while occupation of a more sedentary nature, perhaps within the confines of rudimentary shelters would have resulted in discrete concentrations provided the frequency of occupation or number of groups was not so great that the individual activity areas became superimposed. The mean density of material is so low as to make this unlikely. Furthermore, the frequency of visits either to the lake shores in general or to a given locality on the dune is, as yet, unknown.

The second phase in the life of the Lake Mungo material begins when the items are finally discarded. From that moment they are subjected to taphonomic processes. The latter term, lately borrowed by archaeologists from the geological vocabulary refers to 'the death and decay of organisms, including the process

of preservation as fossils' (Dictionary of Geological Terms, p.425). In the context of the Lake Mungo deposit such processes may conveniently be sub-divided into two periods. The first of these extends up to the time when the items became sealed by subsequent human or wind-borne deposits. Throughout this period opportunities existed for their disturbance during working of the upper levels of the dune by natural forces which could be erosive or faunal origin. The extent to which human activity contributed is again dependant upon the size and frequency of visiting parties and therefore is unknown. Estimates have been made of such surface disturbance within the confines of a rock shelter by Stockton who buried a layer of glass fragments in sand a few centimeters below the surface. After a day's trampling (the intensity of which was not specified) pieces of the glass were found to have come to the surface and to have reached depths of 16 cm resulting in a total separation of 21 cm (Stockton, 1973). However, the relevance of these observations to an open dune surface is questionable.

Once the surface above the deposit has been effectively stabilised, either by the addition of layers which because of their composition are impervious to disturbances occurring at the surface or more simply by deposition of sufficient depth of new material, the second, relatively quiet taphonomical period begins and lasts until the deposits are again exposed by erosion. Throughout this long period the causes of relative displacement of the components of the deposit are confined to such natural agencies as tree roots, worms and burrowing animals. It may be impossible to separate the effects of this period from that preceding it. In a report of excavations of an open site in Belgium, for example, the fitting to the same parent block of flint fragments recovered from levels separated by 30 cm in the vertical plane is described.

The authors conclude that this separation is due to natural processes and the recovered flint is from a single period of occupation (van Noten, et al, 1980). They do not comment, however, on the extent to which trampling contributed to the separation.

If erosion was taking place uniformly across the Lake Mungo dune the exposure of vertically displaced stone fragments from a common core could occur over an interval of many years and thus would appear in quite separate collections. Given that the erosion is variable across the dune surface, pieces of stone from one knapping episode occupying the same stratigraphic level could also appear over a period of several years. Either of these mechanisms could account for the fact that I have never been able to identify two or more fragments from the same origin in a given square. This doubt concerning vertical control was one factor which suggested that a detailed comparison of material within either of the two occupation periods might be premature.

The third and concluding phase in the overall life of the deposit extends from the moment part or all of it that has survived the previous decomposition and dispersal processes is released from the dune matrix by the current erosive action until its recovery as part of the surface collection. This phase may be considered by some to be a continuation of the taphonomical processes. While this may be so, it is certain that the '... process of preservation as fossils' is interrupted in that component items of the deposit may suffer further decomposition and both absolute and relative displacement. These latter aspects are examined in Chapter 3 . To add further to the complexity of the deposit it is possible that, given the lake-side situation, the three-phased sequence outlined above may be too simplistic. Major excursions in water level accompanied by high winds could have led

to erosion and redeposition providing opportunities for items to be cycled at least once and possibly more through all three phases of use, deposition and exposure. On one hand, the sharp margins and rough surfaces of some artifacts have been blunted and smoothed as though they have been subjected to some abrasive activity, perhaps through wave action. On the other hand, there is no suggestion from the dune stratigraphy of gross disturbance of the deposits. Indeed there is evidence from the preserved fine detail that makes it unlikely that there was wholesale mixing of the deposits from the earlier and later periods.

The individual items which make up the exposed surface distribution of the prehistoric material at Lake Mungo are widely separated with generally little suggestion of concentrated work or food preparation sites. This could reflect the distribution in the original deposit or, if this is not the case, it may be because either the taphonomical or the erosive processes during the formation of the dune have resulted in gross mixing and dispersal of any initial concentrations.

It is clear that the potential for disturbance of the material from its deposited location is significant and that correct identification and allocation of qualitative values to each contributing component would be a task of considerable magnitude.

Each of the many uncertainties in the long sequence of events from ancient abandonment to the recent recovery of the surviving components needs to be resolved if one wishes to trace the logical path back

from information derived from the exposed material to the behaviour patterns which led to its deposition. Such resolution would be necessary before detailed hypotheses concerning the behaviour could be formulated and has therefore not been attempted here.

The Problem and Approach

Two aspects which must be established in comparing material from the two levels of the lunette are the confidence that can be placed in the location of the material upon recovery and the adequacy with which the recovered sample represents the exposed material. Neither problem seems to have received much attention previously. One exception is a study published while the present work was in progress which examined the distribution of man-made debris down the slope in front of a cave entrance (Rick, 1976). However, both the slope angle and the concentration of the vegetation were so much greater than that at the Lake Mungo lunette that conditions were not comparable. Given this apparent omission I made some effort to seek confirmation that stone fragments could be subjected to displacement once they had been exposed on the modest dune slope. I considered also the reasons for and extent to which artefacts could be overlooked by collectors resulting in a bias in the collected sample (Chapters 3 and 4).

Given a reliable sample and limited displacement various analytical methods could be employed in the analysis of surface materials at Mungo. Assuming that the artefacts collected consist of several classes or sub-sets, each characterised to a greater or lesser degree by a number of common traits, it is possible to carry out an investigation from three principal viewpoints. These are, firstly, an examination of

the spatial distribution across the surface of the dune of items comprising a given sub-set, secondly an assessment of the degree of correlation between two or more such distributions and finally, a statistical comparison between the members of a particular sub-set in terms of the variation in magnitude of their characteristics as a function of their location.

For a given analysis the most appropriate choice of method is determined by three interdependent constraints: the detail of the hypothesis being examined, the quality of the data and the resources available to carry out the investigation. Complex hypotheses require secure and detailed data for their confirmation and this implies that commensurate manpower or financial support,or both, is available for its collection and analysis. Equally, restrictions on resources carry limitations on the detail to which hypotheses can be tested because all data is necessarily obtained at some cost. The compromises which must be made are inherent in the scientific method as has been recognized, for example, by Waddington in this discussion of the topic. His statement that '... a clear question is no use in itself if there is no available way of answering it' (Waddington, 1977, p.120) sums up the balance which must be struck when designing any programme of research. Binford also, in a discussion of more immediate relevance to the present topic, has noted '... that archaeologists want representative and reliable data within the bounds of their restricted time and resources' (Binford, 1964, p.427).

In the present case the overriding constraints were limitations in the data which was potentially available and the resources at my disposal. These determined the method I selected.

One method commonly used to investigate the distribution of items across an area is to set out a regular grid of points over the surface and examine the distribution of material with reference to the squares of that grid. Examples of the application of this approach include attempts by Redman and Watson to correlate material at the surface with that revealed by subsequent excavation as a means of prospecting for favourable excavation areas (Redman and Watson, 1970); Ammerman and Feldman who have commented on collection uncertainties connected with the method (Ammerman and Feldman, 1978); and Whallon and Dacey each of whom discuss the analysis of data located in gridded areas (Whallon, 1973; Dacey, 1973). In each case, however, the material occurred in considerably greater concentrations than at Lake Mungo. In Dacey's analysis, for example, the average density of scrapers alone over a 63 square metre area was 3.5 per square metre compared with a density of less than 2 retouched artefacts of all types per 100 square metres at Lake Mungo.

The optimum spacing of the grid points required to extract the most information from an area is clearly related amongst other things to the variations in surface density of the items; large differences within a comparatively small area requiring a closer grid spacing than for more uniform distributions in order to reveal the differences more precisely. Indeed,in the extreme the position of each item may be measured exactly,a case of zero grid spacing,but the use of such precision assumes exact knowledge of any prior displacement which may have occurred.

In general,at any site greater variation might be expected as a result of concentrated activity.

However, in the present case, as has been noted, the distribution showed little diversity and there were no groupings which were obviously repetative even in the broadest sense so that there was no strong incentive to consider a closely spaced grid. In the event, a grid had previously been laid out across the dune as a contingency measure when both the rates of erosion there and the extent of feasible research effort were uncertain. The spacing between these grid points was 20 metres. Although I considered other spacings I saw no compelling reason to change that already existing and when, during the course of the work, I reduced selected areas to a 10 metre spacing in order to improve the correspondence between the internal grid divisions and the boundaries of the lunette deposits it proved to be of no significant benefit. Having completed the analysis I am not convinced that,given similar circumstances, there is a case for using squares smaller than, say, half the size used here. However, given a totally different collection strategy to the annual recovery employed here, for example, weekly or monthly collections, with all that implies concerning manpower and equipment resource availability to achieve it, then other grid sizes could well be worth consideration. With a possibly insecure and weakly differentiated sample being made available at a rate controlled by the slow erosion process it was clear that collection was required from a large area in order to provide a good statistical basis for comparisons. Had unlimited resources been available, more frequent collections might have been attempted, reducing the period over which the effects of natural disturbance could act to distort the information revealed by erosion.

More frequent collections could have resulted also in a greater proportion of the material being recovered by reducing the opportunities for reburial. However, in the present case, the number of those assistants who were available for the short periods when work could be conducted and who possessed the desirable combination of knowledge, aptitude and motivation was limited. Such qualities are important, perhaps to an even greater extent than in the case of excavations, as collection from an extensive area does not lend itself to close supervision.

Within a grid having a large spacing there is a choice of collection procedure. In one of these the items are simply collected within each grid quadrat (a general term used to include both square or rectangular areas within the grid) and the analysis consists of a comparison of quadrat contents with that of other quadrats or with some other features of the site. Alternatively, the position of each item within the quadrat is recorded as it is collected; a time consuming procedure but the greater precision permitting a more detailed analysis. Whallon (1973) and Dacey (1973) have published spatial analyses of occupation floors utilising the level of detail provided by the contents of grid quadrats rather than precise locations. Hietala and Stevens (1977) are critical of their attempts on the grounds that their '... simplistic procedures ... are potentially misleading'. (p.557)

In their own analysis of a particularly rich site these authors considered it necessary 'Because of the statistically small artifact class frequencies ...'

to aggregate the contents of several quadrats (p.574). Average densities, across a 36 square metre excavation, of a single type of artefact were as high as 25 per square metre, once again in sharp contrast to an average value of 0.02 retouched artefacts of all types per square metre at Mungo.

Given the low artefact densities at the site, the possibility that items lying on the erosion surface may not have been deposited contemparaneously and the fact that the distribution of material on the surface gave no indication of latent patterns I decided against attempting sophisticated analyses from the start but bore them in mind should their subsequent exploitation prove feasible. Even the comparatively simple correlations attempted in Chapter 5 , however, proved unproductive lending support to the correctness of this decision.

With the constraints of data quality and resource availability outlined above the investigation of the material being eroded from the Lake Mungo dune reported here had a number of facets which, in summary, include the following:

* The method employed in the collection of sample stone material from the lunette. Some inherent limitations of the method are discussed.

* Observations on the location in which the samples are found, including their distribution over the lunette and a comparison with surface features and deposits.

* Consideration of the recent environmental history of the site in order to assess factors which may influence sample location and composition. The effect of slopewash and wind erosion are examined.

* Analysis of the physical characteristics and attributes of the samples including a comparison with material previously collected and with excavated material of comparable age elsewhere in Australia.

* Correlation of sample traits with location and surface deposits.

Aspects which were not considered in detail include alternative methods of collecting from a surface site. Other approaches that were possible included random sampling, collection from grid squares the size of which were in some way optimised, and methods involving the measurement of the co-ordinates of each recovered artefact. Apart from the reduction in the size of some collecting squares in order to increase the correspondence between the internal boundaries of the collection area and the stratified features of the site, none of these was investigated. Against the background of a low average and comparatively uniform density of 0.02 per square metre for all types of artefact, excluding 'waste' flakes, there were no obvious hypotheses to be tested for which a given method seemed best suited. Sampling, for example, attempts to cover more efficiently an area in which variations occur by selecting only some of the squares according to some previously agreed procedure, (see, for example, Schiffer, 1973). The purpose of the present investigation was to compare artefacts from the Mungo and Zanci deposits. With the grid established astride the Mungo-Zanci boundary and the items to be sampled having a low average and comparatively uniform density, sampling strategy would have required the investigation of a much larger area of the dune and seemingly offered no advantages in the Lake Mungo context.

Methods other than straight forward collection were considered in an effort to maximise the information that could be salvaged from the eroding site but all were discarded. Infra-red photography either early or late in the day when temperature differences should exist between the lithic material and the dune surface upon which they were lying was inappropriate. This was because the prehistoric material was often present amongst beach gravels and differentiation between members of each of the artefact sub-sets and the gravel would have been impossible. The camera height required to obtain good photographic cover would also have been difficult to achieve. In the absence of obvious groupings the location of the widely spread items of interest among beach gravel also made sketching approximate positions too time consuming because the position of each one would have needed to be marked to avoid confusion. Time constraints on the collecting period were important. As it was two of the four collections that I supervised suffered as a result of inclement weather when field work was being carried out. One one of these ocassions it was necessary to revisit the grid with a new group of volunteers to complete the work while on the other an accelerated collection was necessary under the threat of a forecast of deteriorating meteorological conditions. On both ocassions a small reduction of unknown extent in the quality of the sample of recovered material may have occurred.

The following chapters begin with an outline description of the Lake Mungo lunette and the circumstances of its formation. Recent geomorphological research in the area is summarised. After the procedures adopted in collecting the material from the surface of the site and their limitations have been discussed, the natural processes which are eroding

the surface of the lunette are examined and the possible effect on the distribution of exposed stone material assessed. Description and analysis of the surface collection follows. Finally, the results are summarised and conclusions and recommendations for further work are suggested.

CHAPTER 2

SITE HISTORY AND PHYSICAL DESCRIPTION

Site History and Geomorphology

Lake Mungo is one of a number of interconnected dry lake beds which make up the Willandra Lake System in western New South Wales. When active in past millenia the lakes were fed by the Willandra Creek, a distributary of the Lachlan River (see Figure 2.1). An unusual feature of these lakes are the extensive stable, crescentic clay dunes or lunettes bordering the depressed lake bed (Figure 2.2).

The prehistoric material now being revealed by the erosion of the dunes was deposited during the formation of the component dune beds rather than on surfaces which had been previously stabilised for long periods of time. The prehistory and geomorphology of the region are therefore intimately linked through the environmental circumstances in which the lunettes were formed. This chapter outlines the development of an environment which, given the abundant evidence of middens, stone tools, and apparent hearths, the aborigines found so attractive and which subsequently preserved the evidence of this activity. The summary is based principally on the work of Bowler (Bowler, 1970, 1972, 1973, 1975, 1976, 1978), to which references the interested reader is enthusiastically referred.

The period of time which is of interest here begins some 45,000 years ago when, following a long period of apparently relatively stable cool, dry conditions probably extending back to the time of the penultimate glaciation some 120,000 years ago, south-eastern Australia entered a wetter, cooler, climatic period.

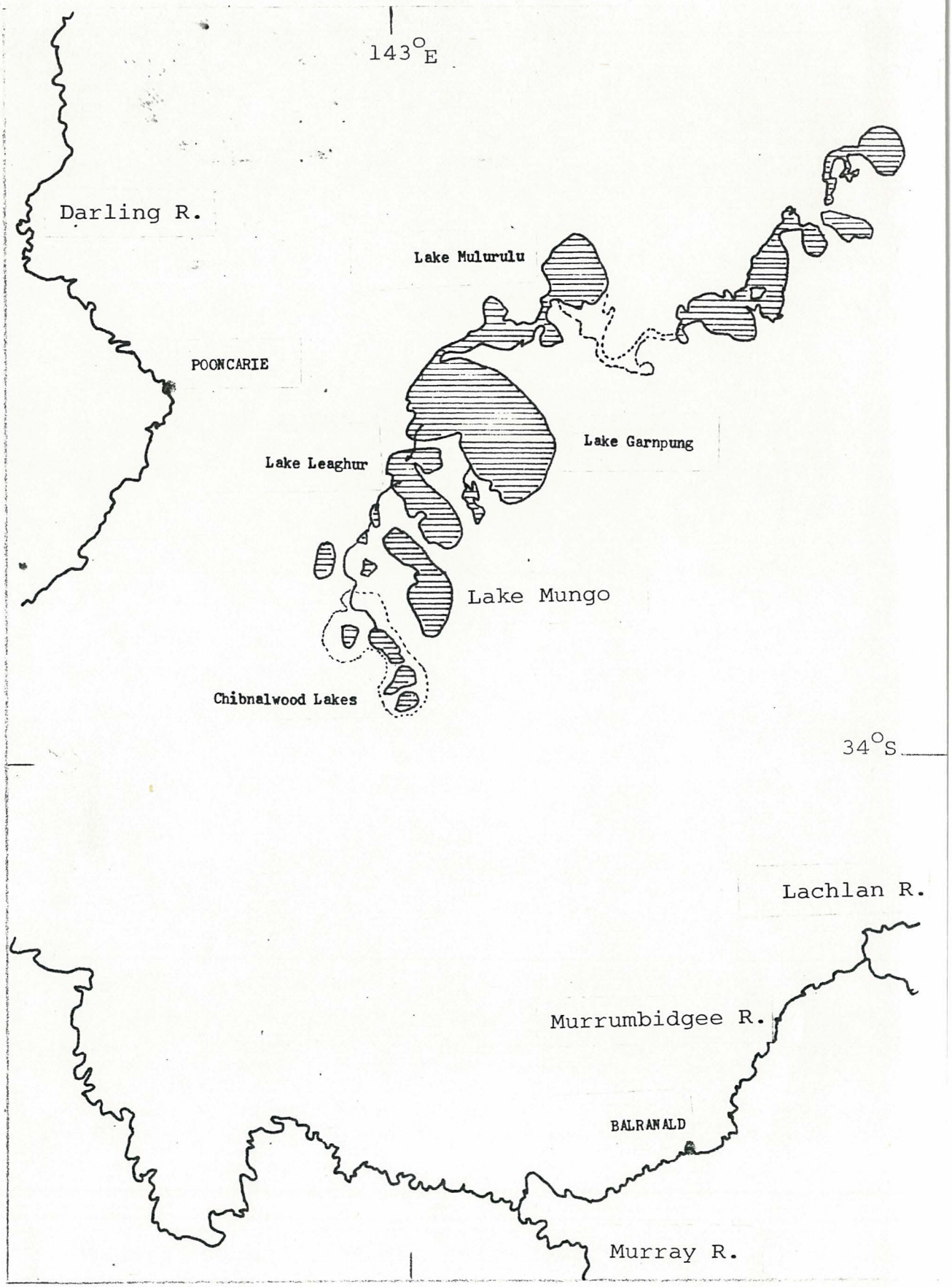

Figure 2.1: The Willandra Lakes

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Approximate position of grid indicated by arrows

(Photo: NATMAP)

Figure 2.2: Aerial Photograph of Lake Mungo

The onset of this change and the subsequent climatic history has been deduced principally from the sedimentary and palynological record in western New South Wales, Wyrie Swamp in South Australia, lake systems in north-west Victoria, Lake George near the headwaters of the Lachlan, the Snowy Mountains and other areas in the south-east of the continent. This evidence has been collated by Bowler and others (Bowler, et al, 1976) and, although some details remain to be clarified, the following broad picture emerges.

The changing conditions which begin about 45,000 years ago and continued until approximately 30,000 BP heralded in the last glacial period. Periglacial slope activity in the Snowy Mountains dated to 31,000 years ago provides positive evidence for this change. Glacial activity developed over the next 5,000 year period of intense cold, the increasingly hostile conditions being indicated by the glacial transgression of trees in Tasmania dated to 26,500 BP, (Bowler, et al, 1976).

The ensuing glacial period was of considerable duration. Some ice retreat is indicated in the Snowy Mountains by 20,000 BP but it is believed that some permanent ice and periglacial activity persisted into the period 20,000 BP to 15,000 BP, (Bowler, et al, 1976). By 15,000 BP, if not earlier, temperatures began increasing and the climate moderated from its arid extreme which coincided with the glacial conditions. Since 10,000 BP, with the exception of minor excursions into a slightly wetter regime, the climatic characteristics apparently have not departed markedly from those being experienced at present.

It was the response of the Willandra lake system to these climatic conditions that resulted in the formation of the dunes at their margins. Their occupation by man for at least the last 35,000 years has provided a rich source of carbon 14 datable material scattered throughout

their depth. The consistency of these dates has ensured that the history of the lake basins and their shores is securely fixed chronologically. Partial listings of the radio carbon dates are to be found in Bowler (1976) and Dare-Edwards (1979). From these dates and geomorphological studies of the lake system, Bowler has identified three principal phases of dune-building activity which he has labelled the Golgol, Mungo and Zanci periods.

A rise in lake levels began at about 45,000 BP. Previously the lakes had been dry for a considerable period, perhaps since 120,000 BP and certainly long enough for a sequence of soil formation to have taken place on the lake bed. Deposits laid down before the rejuvenation of the lakes form the Golgol sequence. The renewal of hydrological activity during the second, Mungo, phase was probably the result of increased runoff caused by the onset of lower temperatures in south-east Australia. Evidence from mollusc and fish remains suggest that, apart from a brief period around 35,000 BP, the lakes remained fresh and probably overflowing until about 27,000 BP. During this time the lake capacity was sufficient for wave action to form beaches providing a source for wind blown quartz sand from which dunes were built behind the shore. Soil development on these dunes has been noted with dates between 36,000 and 26,000 BP (Dare-Edwards, 1979). The first indications of changed conditions occur at 26,000 BP, during the period of glacial advance. At levels in the dune stratigraphy corresponding to this date, clay pellets begin to make up a significant component of the aeolian sediments, marking the start of a process which was to continue, with some interruptions, for the next 10,000 years. Extensive studies of these sediments and comparison with those bordering lakes in Texas and elsewhere, where the transport of pelletal clays to the adjacent dunes is still an active process, have been made by Bowler (Bowler, 1973). The Willandra lakes are typical of many where clay-rich crescentic dunes flank one margin.

Their presence is indicative of a restricted water supply sufficient only to fill the lake partially on a seasonal basis. During the warmer period of the year the brackish contents evaporate exposing mud flats and the saline deposits on the lake bed. The efflourescence of the component salts such as gypsum breaks up the clay crust which is then transported across the lake bed by the prevailing wind to be deposited on the dune. With the return to cooler, more humid conditions as the season advances, the hygroscopic absorption stabilises this annual contribution to the lee dune.

Dare-Edwards (1979), quoting Bowler, believes this period of clay dune formation continued until 22,000 BP and was followed by a period of stability in which soil formation was possible. Concurrently, there appears of have been an influx of red dust from the desert interior resulting in the characteristic rust colour of the Mungo soil. This stable interlude marks the end of Bowler's Mungo phase.

The final geomorphological period, the Zanci phase, which has been studied extensively by Dare-Edwards, began about 18,000 BP, when a return to high water levels is indicated by a thin layer of beach-derived quartz sands deposited on the dune. This episode was of short duration, however, being followed by a renewal of clay dune building corresponding to another, and in the case of Lake Mungo final, drying phase. By 16,000 the ground water level had fallen to such an extent that dessication was complete and no further additions to the dune surfaces were made from the lake floor. Subsequently, soil formation continued until dune building was halted by the erosion which is now taking place.

Research into the geomorphology of the area is continuing. As more evidence accumulates, the fine detail may be subject to slight refinements similar to those reflected in the revision of dates for the changes in

lacustrine conditions in Bowler's own publications (compare, for example Bowler, 1976 and Bowler, et al, 1979). The broad picture remains, however, of an oscillatory hydrological system, the lunette containing two principal depositions of beach sands each overlain by aeolian clays followed by soil horizons.

It was the beach sands bordering an assured supply of fresh water resources that attracted the aboriginal people who left the traces of their occupation sealed beneath the substantial clay deposits. The exposure of these traces dating to 35,000 years ago has focussed archaeological attention on the area. Interest quickened in 1968 when Bowler drew the attention of prehistorians and anthropologists at the Australian National University to an exposure of apparently human bones still *in situ* on a horizon which suggested that they were of an antiquity greater than that previously found in Australia. Subsequent examination confirmed Bowler's supposition. The bones were those of a young woman having a gracile skull of a modern *Homo sapiens* type. Following cremation, the charred bones had been smashed before burial. Analysis of the stratification indicated a date of 26,000 BP (Bowler, et al, 1970). The act of cremation, the earliest yet identified in the world, probably implies a well established philosophical structure concerning life and death comparable with those indicated elsewhere in Neanderthal Europe and the Middle East and exemplified by the flower strewn grave at Shanidar or the child-burial at Teshik-Tash (Roe, 1970).

A sample of the stone tools and debris in the vicinity of the burial was collected and given qualitative description by Jones and Allen (Bowler, et al, 1970). Further work by Allen in the area included a discussion of surface material from Lake Mungo itself, from other lakes in the Willandra system and Lake Tandou some 120 km to the north-west of Lake Mungo as the crow flies, (Allen, 1972). At Lake Mungo artefacts collected from an exposed Mungo surface were classified and their physical characteristics measured

as were those of a second sample recovered from a Zanci surface. Both areas of the dune are within a kilometre or so of that from which the material analysed here originated. From his study, Allen concluded that, despite the great age differences between the 26,000 year old Mungo site and the 15,000 year old Zanci site, " ... the implements ... clearly belong to the same industrial tradition.", (Allen, 1972, p. 274). He expressed doubt, however, about the presence of bias in his collecting procedure on the basis of the low number of unmodified flakes compared to implements. Allen seems also to have accepted, apparently without comment, that some of the classifications that he used for his implement types were not common to both areas. Such distinctions suggest that differences of some sort could exist between the two areas.

Although it was accepted by the Department of Prehistory and Anthropology at the ANU that in any excavation on the lunette the odds are heavily against exposing concentrations of occupation debris, such field work has been conducted at Lake Mungo. Carried out between 1972 and 1976 under the direction of Professor Mulvaney and Mr F.W. Shawcross, a clearer appreciation of the interrelation between the stratigraphy and density of occupation has been gained (Shawcross, pers. comm.).

The most recent contribution to an understanding of the prehistory of the region is that of McIntyre, who has considered that very problem, namely, the prehistory of the <u>area</u>. McIntyre's work has yet to be published.

As a final comment in this brief survey of research on the Willandra lake system, the essential support of the ANU radio carbon dating laboratory must be noted. The long series of carefully obtained dates from the samples of organic material provided has resulted in a secure framework within which the events can be

given their proper spacing. Some thermoluminescence measurements give been made also on hearths in the area providing support to the radio carbon sequence, (Mortlock, 1974).

Site Description

The stone material analysed here was collected from the Lake Mungo lunette in late winter of 1975, 1976 and 1978, sufficient resources not being available to undertake the task in 1977. Additional visits were made to the site by the writer in 1977 and 1979. During 1975-78 surface bone material was separately collected with the artefacts. Stone material was collected in 1979 but neither this nor the bone collection has been analysed.

The area over which the collection is made is at the southern end of the Lake Mungo lunette (Figure 2.3). Approximately 500 metres by 100 metres in extent with the long axis following the length of the dune, it is defined by a series of 5 cm by 5 cm hardwood pegs driven firmly into the compacted sand and clay of the eroding lunette surface. The lengths of the sides of the squares thus formed is 20 metres.

The location, extent and spacing of the grid had been decided some years before I became actively involved. Selection of the location was influenced by its proximity to both the site of the human burials and to the excavations that were being conducted, allowing the possibility of mutually supporting analyses. The extent of the grid was chosen partly on an intuitive assessment of the surface density of the material and partly on the desire to include significant exposed areas of both Mungo and Zanci deposit. The final grid spacing seems to have been fortuitous, some opinions suggesting that a grid of 10 metres squares was intended. There is some support for this in that pegs have been placed at

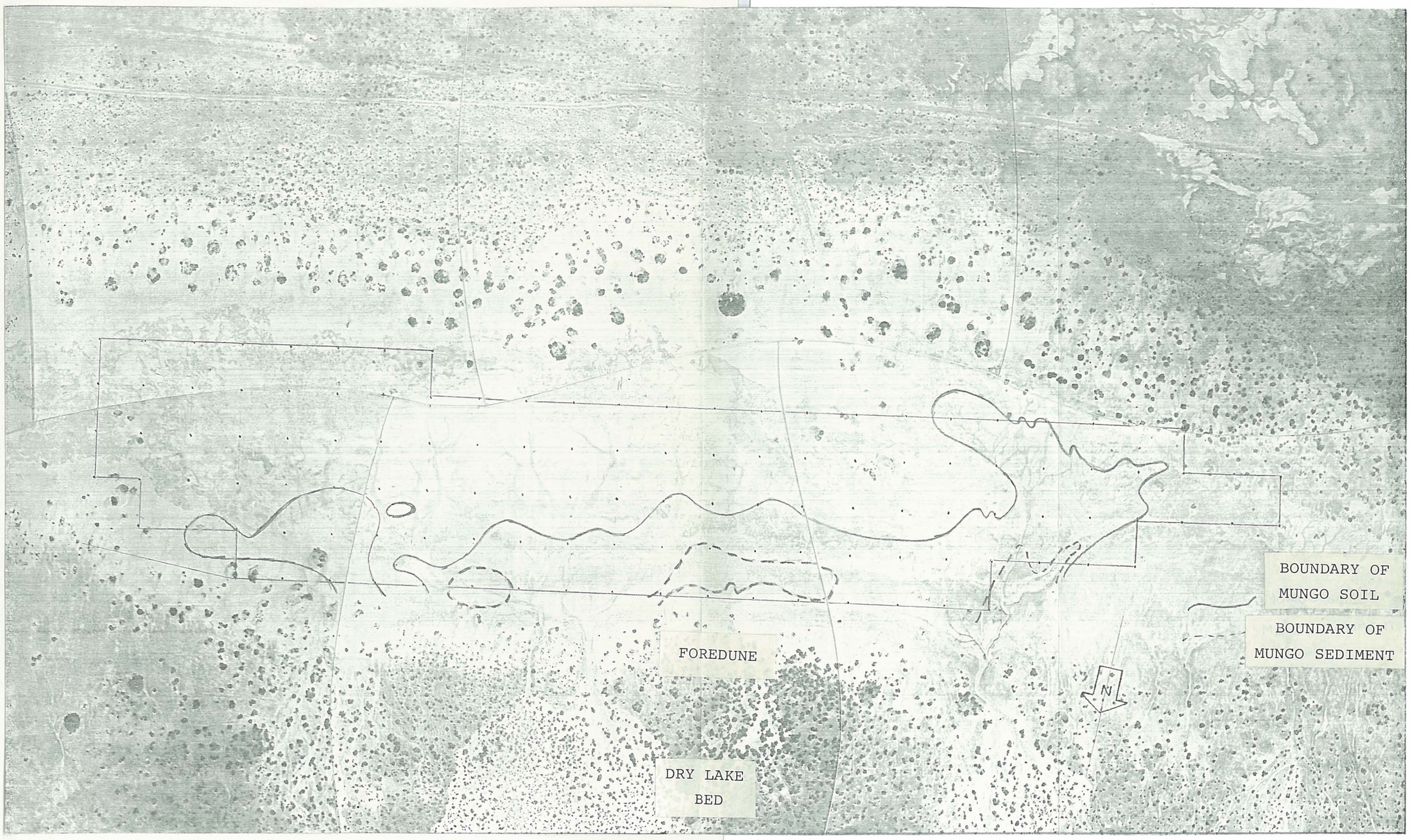


Photo: J. Magee

Figure 2.3 Aerial Photograph of Grid

the closer interval over a small part of the grid. Anticipating later discussion, the closer spacing has some advantages in providing closer control of the data but much tighter management of the collection process is then required.

An outline of the grid area including contours is at Figure 2.4. The method of identifying squares should be noted: rows are labelled by the letters B to F from the higher to the lower parts of the grid, while the numbers 1 to 25, increasing westwards, correspond to the columns of squares. Figure 2.5 is a plan of the grid based on a survey carried out with Mr F.W. Shawcross and Mr P. Clark in 1977. As a comment on the accuracy of the plan, the survey task was divided between the three of us so that each observer was responsible for an adjacent group of columns across the grid. Despite the difficulty in identifying the boundaries between the exposed deposits, which were sometimes overlain with recent blown sand, when the field sketches were married up the maximum discrepancy between them was approximately 1 metre.

The eroded surface of the grid generally slopes towards the dry lake bed with an average fall of 4 metres across the grid. As the contours are based on surveyed heights at the corner of each grid square, they cannot show the small scale variations in the eroded surface. Erosion has reduced the lunette to a rolling surface some 6 or 7 metres below the assumed pre-erosion level with only two steep sided gullies cut into it, the latter having a maximum depth of approximately 2 metres where they leave the grid. Elsewhere the channels generally open onto the flatter areas of the grid nearer the lake bed.

Figure 2.6 (see end paper) is an attempt to obtain a panoramic view of the grid and illustrates far more explicitly than words the surfaces from which the

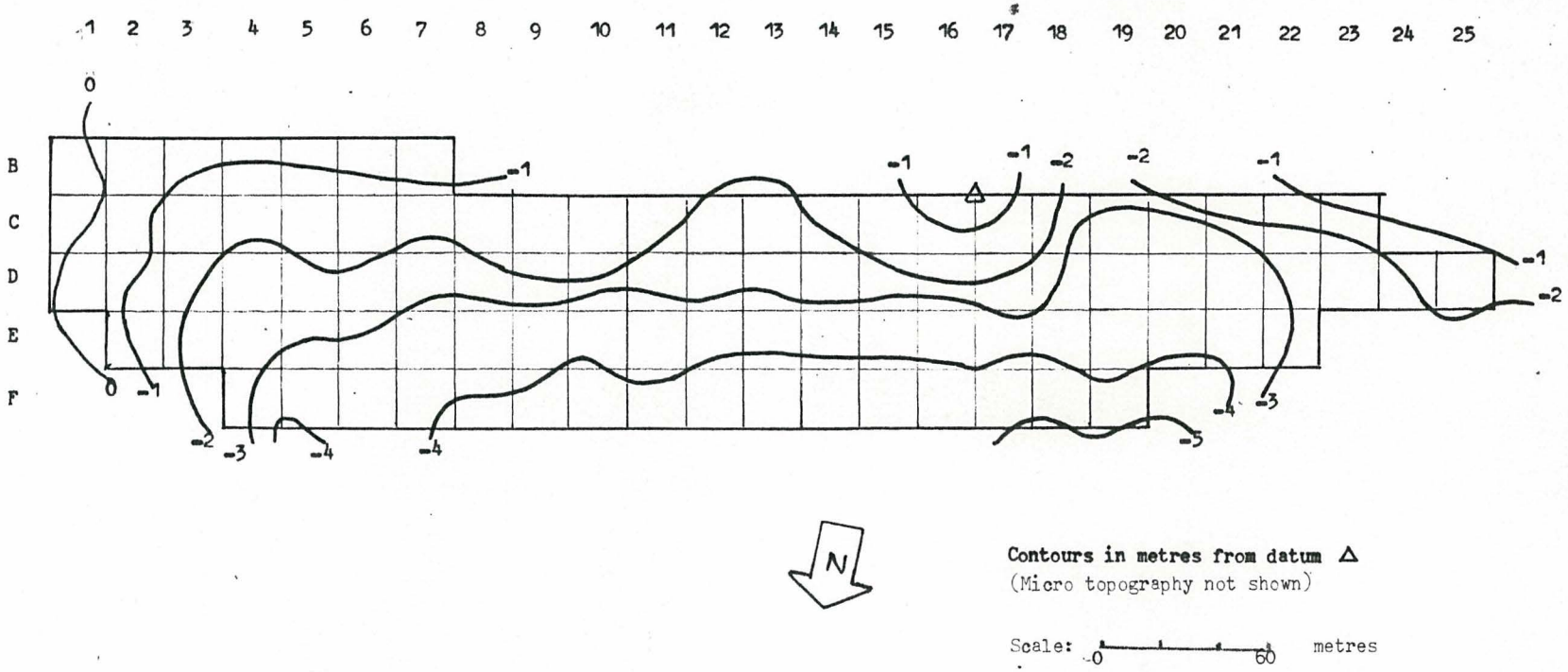
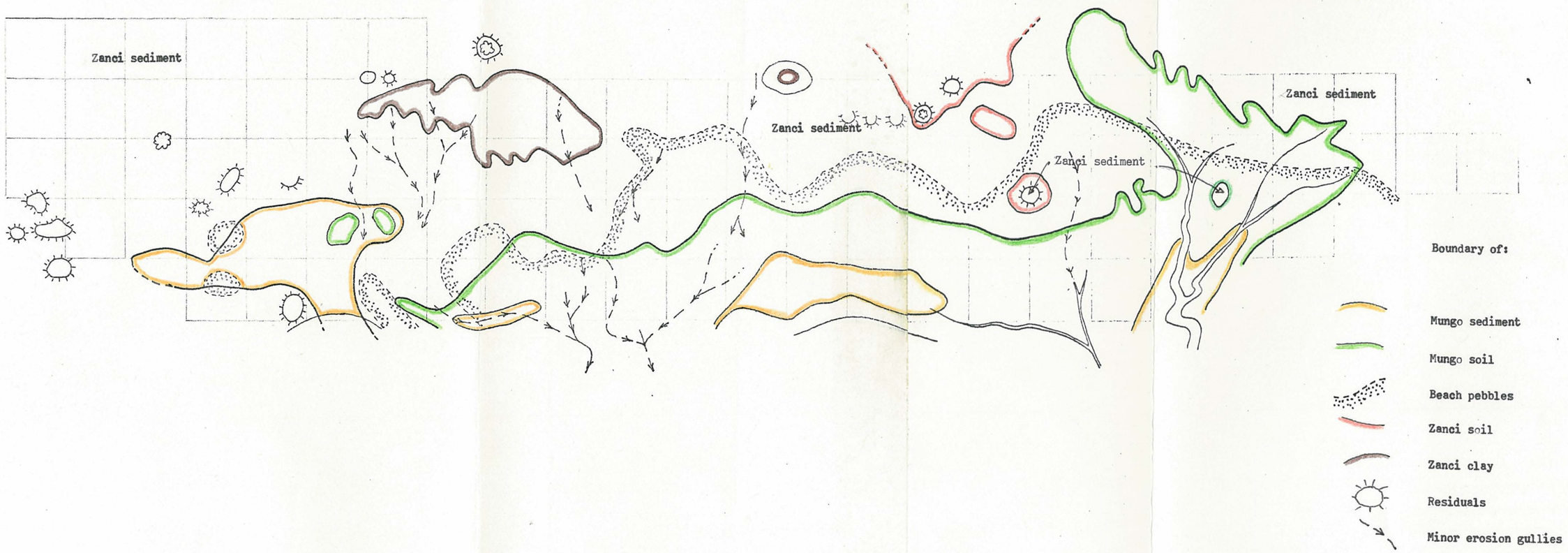


FIG 2.4 Lake Mungo grid - contours



igure 2.5 Plan of Grid Area

artefacts are recovered. Taken from the top of the residual in square F5 with the right edge looking westwards along the grid boundary nearest to the lake bed the photos do not completely encompass the full 180 degrees; the figures on the left are in square D3, leaving some half-dozen squares to the east not illustrated. Some scale of distance is given by the orange four wheel drive vehicle just below the skyline approximately one quarter of the way from the right.

Comparison between Figures 2.5 and 2.6 show the contrast between the white Zanci clay, the Zanci sediments, that is the deposits laid down when the lake was last full some 18,000 years ago, and the red Mungo soil. An impression of the stratification which survives is given by the small remnants centre left. A small area of beach pebbles can be seen between the peg and the collectors. Much more clearly illustrated are those areas where the flow of rainwater is concentrated by the micro-topography to redeposit the products of erosion over fan-like areas on the flatter surfaces of the squares in rows E and F. As there is no significant buildup of sediment in these areas, it must be assumed that the unconsolidated material is subsequently removed by deflation.

Conclusion

In 1976 when my research at Lake Mungo began, the situation was that, while some details remained to be sketched in, the general features of the sequence of dune building were known and securely dated. Radio carbon dates from mollusc shells and from aboriginal occupation debris had yielded a range of dates for every major phase which correlated well with the late Quaternary climatic excursions. Lakeside settlement between 30,000 and 25,000 years ago was incontrovertibly demonstrated by the exposure in the eroding lunette surface of the remains of a young woman, anatomically modern and almost certainly ritually

interred. Both the interest in ritualism and the physical traits of the occupants was confirmed by the later discovery of the ochre-covered remains of a young male.

Examination of the stone tools* lying on the erosion surface prompted Jones to advance the now accepted concept of an 'Australian core tool and scraper tradition', (Bowler, et al, 1970, p. 52) to characterise older Australian stone technologies. Subsequent work by Allen (1972) indicated that, despite the wide timespan indicated, this technology was practised with little or no change for in excess of 20,000 years.

At Lake Mungo itself the erosion process was continuing to expose more artefacts. Were these of any significance or were they merely further samples of a well mixed population of the core tool and scraper tradition? Did they possess any characteristics which correlated with the deposits from which they were eroding? With these questions in mind it was important to show whether surface collection could usefully contribute to their resolution or whether it would merely add to the considerable quantities of material occupying space and gathering dust in the basements of museums and other institutions. I took these considerations as my start point.

*Throughout the following chapters I have followed the Concise Oxford Dictionary definitions of artefact and implement, viz:

artefact: product of prehistoric or aboriginal skill as distinct from similar object naturally produced.

implement: tool.

Thus an unretouched flake struck from a core is an artefact. Its retouched counterpart, having a margin modified to improve its cutting qualities, is an implement.

CHAPTER 3

PROCESSES AT THE SITE SURFACE

Introduction

In this chapter, the processes by which the site is being eroded and the rate of erosion are discussed. The aim, firstly, is to assess the rate at which the lunette surface is removed so that, knowing the quantity of prehistoric material recovered from the site during the annual surface collections, the artefact density within the upper levels of the dune may be estimated. Secondly, since erosion is characterised by the removal of material of particulate and larger size, a comparison of the dimensions and mass of the largest stones that could be disturbed by erosion with items in the surface collection would establish the confidence with which the provenance of the surface material can be accepted.

Such considerations have wider interest. Archaeological surface collecting is a long established practice - indeed, it could be said that archaeology itself grew out of the interest shown in surface finds by the early antiquarians. More recently surface scatters have been used to indicate the probable disposition of the material in the underlying deposits, (Redman, et al, 1970), with the aim of selecting the location of subsequent excavation more effectively. Additionally, interest is increasing in the interpretation of the prehistoric record in terms of site function and ethnographic units. Such uses of the record provided by surface scatters which are now exposed by excavation or erosion rest upon assumptions about the processes involved in the placement and exposure of the component artefacts. The discussion in this chapter may contribute to an understanding of the relevance of some of these assumptions.

Erosional and Post-erosional Disturbance

The product of the erosive forces at work along the lunette were dramatically obvious to Russell Drysdale in 1945 (frontispiece) and remains as evident today. Visits to the more spectacular parts of the Walls of China, as the lunette is popularly known, form a significant component of the local tourist industry at the town of Mildura, some 100 km distant.

At the grid itself erosion is occurring in a less striking fashion. Unlike some other parts of the Walls of China, there are few steep gullies or steep-sided residuals where erosion has been prevented by small trees or shrubs. The undulating denuded surface of the grid area slopes toward the lake bed at angles which on average lie between 1 and 7 degrees with a few widely scattered residuals (Figure 2.6) and generally the difference in height across the grid is 4 metres (see Chapter 2, especially Figure 2.5 for a detailed description).

The exact reasons or timing of the onset of erosion of the lunette is unclear but it has certainly been accelerated by the introduction of exotic species of fauna. The area was settled in 1859 following the passage of the first riverboats up the Darling. The number of sheep in the area had increased to such an extent as to require the construction of the magnificent shearing shed at Mungo Station by 1869.

Given that since their onset the erosional processes have reduced the surface levels sufficiently to expose prehistoric material, there are a number of inter-related processes which influence the further rate of exposure and movement of that material. These are, in probable order of importance:

hydrological processes
aeolean processes
animal, including human, activities.

Each can influence the others. Footprints, for example, may channel the flow of water initiating erosion gullies which deposit areas of silt at the base of slopes. Subsequently, the unconsolidated silt may be blown away during periods of high wind. At present each of the processes is in itself imperfectly understood so that an assessment of the interactions between them would be premature. In the following discussion each aspect is treated separately.

Hydrological Activity. Erosion, in the hydrological context, has been described as '... a work process for which the energy is supplied by the falling raindrops and the slope of the land down which the runoff flows', (Smith and Wischmeier, 1962, p. 114). From an archaeological standpoint the effect of these work processes is twofold:

a. the break-up and removal downslope of the deposit containing the prehistoric artefacts leaving them exposed on the surface; and

b. possible transport of the artefacts downslope from the point where they were exposed originally.

Comprehensive summaries of research carried out on rainfall erosion have been made by Carson and Kirkby (1972) and by Emmett (1978). The following discussion, although leaning on these two sources, examines the physical processes from several viewpoints as an understanding of them may suggest relevant measurements to be made in future work at Lake Mungo and other surface sites.

As noted by Smith & Wischmeier, the mechanical energy required for the process of soil erosion by water is supplied by rainfall. Falling raindrops act as projectiles which, on striking the ground, impart a proportion of their kinetic energy to the surface causing particles of material

on the ground surface to be detached. The resulting debris is then carried upwards and outwards as part of the rainsplash. Should the ground surface be inclined, more debris will return to the surface below rather than above the point of impact, resulting in a net downslope movement of the detached surface material. A fine photograph of the outward dispersal of surface material* by rainsplash is to be found in Ellison's discussion of soil erosion (Ellison, 1952, Pl. 2).

At low rainfall rates following a period of dry weather, the rainwater will infiltrate the pores of the ground surface but at increased intensities the capacity of the ground to absorb more water is exceeded and it remains on the surface. On a sloping surface the water accelerates downhill gaining kinetic energy available for expenditure on further erosion. The flow of surface water is variously referred to as overland flow, sheet wash or Hortonian flow after the first person to explain the phenomenon. (Horton, 1945).

Rainsplash

A knowledge of both the drop size distribution, which is generally characteristic of different types of rainfall such as that from rain depressions, showers or thunderstorms, together with the mathematical expressions describing the increase in terminal velocity of the falling drop with drop size allows the relationships between the rainfall kinetic energy and rainfall intensity in mm per hour, to be derived. Variations exist between the results of different investigators, both in the nature and magnitude of such a relationship. The results of four investigations, summarised by Smith & Wischmeier (1962) indicate agreement on a logarithmic relationship but this has recently been

*In this chapter, in contrast to the remainder of this thesis, the term surface material refers not to prehistoric artefacts but to the fine particles of silt, clay and sand of which the lunette surface is comprised.

challenged by Kinnell, who found that the function was essentially linear (Kinnell, 1973).

Kinnell's relationship is clearly not applicable at rainfall rates less than 5 mm per hour, where it gives negative values of energy being delivered. At rates between 20 and 100 mm/hr, however, Kinnell's values agree closely with those of Smith & Wischmeier.

Despite these minor differences, typically, at a rainfall intensity of 25 mm/hr, energy is delivered at a rate of approximately 20 $J/m^2/sec$ (Joules per square metre per second). This, in more domestic terms, means that a plot of 400 square metres - the size of a single grid square at Mungo - receives energy equivalent to that expended by 7 single bar electric fires. The rainfall energy-intensity relationships assume that the drops have reached their terminal velocity in still air but in driving rain higher velocities are reached which may or may not increase the delivered energy, depending on the geometry of the slope of the ground surface and the instantaneous wind direction.

The contributions by numerous authors leading to an understanding of the relationship between raindrop impact, splash and erosion have been summarised by Smith & Wischmeier (1962, pp. 119 to 122). Briefly, the precedence of raindrop splash as a soil detachment mechanism compared with that of overland run-off has been established experimentally by comparing the soil removal rates from exposed slopes under simulated rainfall with those from comparable slopes protected by a layer of straw or an extremely fine mesh net held a short distance above the soil by wire mesh. Under such conditions raindrop impact and splash are prevented but overland flow is not impeded. Reduction of erosion by up to 90% under identical conditions of surface flow has been reported (Smith & Wischmeier, 1962, p. 123).

The height and distance of the splash depend not only on the raindrop energy but also on the composition and condition of the soil surface. Under continuing rainfall the slope surface may become covered by a water film of sufficient thickness to decelerate the raindrops, reducing splash action. With further increase in water depth, the splash action ceases but raindrop impact nevertheless may impart a turbulence to the overland flow, increasing the effectiveness of the latter as a soil detachment mechanism. Smith & Wischmeier characterise the rainsplash process as having a high capacity for detachment but low capacity for transport, whereas the reverse is true for sheet or overland flow. They note (p. 121) however, in summarising the available literature, that 'The relative importance of splash and run-off erosion have not been established'. This uncertainty is underlined by the statement by Young (1972, p. 65) that 'A high proportion of the kinetic energy of fall is dissipated on impact as heat, very little being transmitted to surface flow.'

Recently work in the laboratory at CSIRO has sought to investigate the process of soil detachment and transport (Walker, et al, 1978). The effect of sheetwash on a tray of sand/soil mixture with and without simulated rainfall was examined. Because the soil was only lightly compacted, extrapolation to naturally occurring cohesive surfaces must be made with caution but Walker and his co-workers found that overland flows impacted by raindrops transported approximately five times that carried by overland flow alone for the same discharge of water. Walker makes no comparison with this result and Smith & Wischmeier's ten-fold increase. By intercepting the material thrown up from the overland flow by rainsplash, it was clear that this aerial component made little contribution to the material transported. Nevertheless, as the magnitude of the overland flows investigated were by themselves insufficient to detach the quantities of material observed, Walker's group concluded that '... the effect of raindrop

impacts within the flow ... provided the main impetus.' in promoting the transport of solids (p. 800). Walker also suggests that raindrop impact frequency is an important aspect of both rainfall intensity and rainfall energy which needs to be considered in erosion studies. This aspect seems not to have been noted previously.

Emmett (1978, p. 157) reports that water depth of the sheetflow also affects the quantity of soil lost. The critical depth for maximum soil removal apparently occurs when the drop diameter is equal to the depth of overland flow.

Overland Flow

Apart from rainsplash, the other generally important mechanism in the rainfall erosion process is overland flow. The term 'overland flow' refers to the naturally occurring flow of water down slopes where the occasional irregularities in the surface may lead to concentrations of the water into rills. Sheetflow describes parts of overland flow where the depth of water is essentially uniform. The characteristics of sheetflow may be described by hydraulic theory and are well summarised by Emmett (1978).

In such analyses it is assumed that sheetflow is an extreme example of flow in a uniformly rough channel of infinite width. An important feature to be established is whether the flow is laminar, that is, with the stream flow lines generally parallel to the channel bed or whether the flow is turbulent. Turbulent flow has a greater capacity to lift material away from the channel bed and for it to be carried away in the body of the water. Nevertheless, Bagnold (1954) has observed that turbulent flow is not essential to the onset of sediment transport. One complication occurring in sheetflow during rainstorms is that the impact of the raindrops results in the flow being turbulent under conditions which otherwise would be laminar. It is considerations such as this, together with the lack

of uniformity of the channel bed in both contour and composition that have led to the adoption of an empirical approach in the investigation of overland flow.

Emmett, summarising his own work at seven sites, gives examples of the flow patterns resulting from the application of artificial rainfall to slopes of different inclination and vegetation cover. He is forced to admit, however, that 'In fact, little is known of the general mechanics of slope erosion by overland flow'. (Emmett, 1978, p. 170).

Other Factors Influencing Erosion by Rainfall

Although the basic mechanisms by which soil particles are detached and transported from a slope surface by rainsplash and overland flow are understood, it is clear that their relative priorities in the total erosion process have by no means been established. This is due to the fact that the efficiency of the total process depends, in part, on other factors which affect the severity of erosion resulting from rainfall of a given quantity, intensity and drop size distribution. Kinnell (1973) notes previous work by Hudson (1961), who suggested that soil loss was determined by the following parameters: physical characteristics of the soil, slope of the area, length of slope, agricultural practice, mechanical protection against erosion and, finally, the power of the rainfall to cause erosion. Smith & Wischmeier (1962), considering a similar set of factors, derived an equation giving the expected annual soil loss which, after further development by the US Department of Agriculture, became known as the Universal Soil Loss Equation. This equation has been criticised by Emmett on the grounds that it includes no term which explicitly takes account of the contribution of overland flow. Because the magnitudes of many of the factors are derived empirically, however, this is not critical. Discussions of the factors other than that due to rainfall in such general soil loss

equations may be found in both Smith & Wischmeier (1962) and Kirkby (1972).

Soil. Smith & Wischmeier note that soil erodibility due to water is influenced by two types of property: those that affect the infiltration rate and permeability, and those that resist dispersion, splashing and transporting forces. The former affect the amount of runoff and if the term soil property is interpreted broadly can include moisture content which is partly determined by antecedent rainfall and evaporative regimes. The second type of property is more closely related to the composition of the soil such as the size of the aggregates and the relative proportions of silt and clay. Erosion ratios or indices usually include factors comparing the percentages of clay and silt in dispersed (i.e. suspended in water) samples with undispersed soil, see for example Kirkby (1972, p. 215). An example of an experimental confirmation of this general relationship may be found in the work of Bruce-Okine and Lal (1975), who examined the energy requirement for disruption of some tropical soils and found that the energy was directly proportional to the amount of clay in the sample and inversely proportional to the sand content. This may provide a partial explanation for the different erosion rates being experienced by the clay and sandy areas at Lake Mungo.

Slope. The severity and distance of the slope from the local crest (i.e., the slope length) determine the velocity and mass of the runoff over its surface and hence the energy available to remove particles. The inclusion of a slope factor in any erosion equation therefore goes part way to meeting Emmett's criticism. The influence of steepness of slope is twofold for, while runoff in general accelerates more rapidly down a steeper slope,

the collecting area of a given length of slope reduces with increased angle to the horizontal.

Smith & Wischmeier and Kirkby give examples of relationships between soil loss and the slope length and gradient.

Soil Management, Human and Animal Activities. The Universal Erosion Equation and other relationships which attempt to assess soil loss include a factor dependent on soil management practices and erosion control measures.

Such practices would include contour ploughing and the encouragement of vegetal cover. No such practices are currently applied to the grid surface at Lake Mungo. Occasionally, events occur which have obvious detrimental effects. In addition to the sheep which are run on the Joulni property, cattle and feral goats graze over the area. Extensive fox and rabbit droppings are present over the whole site as are those of species of kangaroo. Following rain the tracks of other native fauna, including dingo and emu are readily apparent. The effect of this animal traffic, the preferential direction of which seems to be across rather than along the grid, is two-fold. Firstly, as discussed later, fragments of prehistoric material may be displaced and, secondly, the deposit containing them may be disturbed.

Traffic across the site may result in any naturally formed crust being broken and disturbed to the extent that passage by numbers of sheep may pulverise the upper few centimetres. The chances of subsequent detachment and transport of this surface material by water and wind is thus increased.

There is little data on which to base an estimate of the effect of disturbance by animals. Schumm, in

reporting measurements over a three year period made in Colorado (Schumm, 1964) noted a three to one increase in the distance moved between markers in fenced and unfenced areas having a slope of approximately 40%. In the fenced area the mean movement of the markers he put down was 0.11 ft (5 mm) compared with 0.31 ft (15 mm) outside the enclosure. The aim of the work was to determine a relationship between the movement of markers and slope. In a later re-appraisal, data from unrepresentative markers such as wood blocks and metal washers were not included (Schumm, 1967). Furthermore, data corresponding to uncharacteristic movement (not defined) was rejected as being due to disturbance. No reference is made in this later paper to the difference in movement between the fenced and unfenced areas.

Schumm's results cannot be readily translated into the Mungo context. The maximum slope at the Mungo grid is of the order of 12% and this is achieved only locally. The geology differs and the extent and type of vegetational growth within Schumm's fenced area are not recorded. Although the direction of animal movement, mainly sheep in each case, are known, the frequency and numbers are not recorded by Schumm nor are they known at Mungo.

Human activity is evident from the tyre marks of vehicles which cross the area (Figures 3.1 and 3.2). In addition to causing effects similar to those attributed to animals, such continuous depressions may channel surface water producing differential erosion. This result occurs mainly where clay is exposed. On the more sandy areas the weight of the vehicle compacts the surface so that, while the surrounding areas are initially above the tracks, they are more easily eroded, leaving the vehicle tracks as much as two centimetres higher with some indication of the tyre tread remaining, as in Figure 3.2. It could be argued that such differential erosion is indicative of wind erosion (see discussion below) since water would be

Figure 3.1: Vehicle Damage to Lunette

Figure 3.2: Eroded Vehicle Tracks

channelled into the tracks erasing the tread and deepening the ruts. Sometimes man's activities can be directly detrimental to an analysis of the distribution of artefacts. On one occasion the segments of a freshly broken flake were recovered from the edge of a vehicle track where the wheel had passed over only part of the flake.

Direct, but inconclusive, evidence for the possible transport of artefacts across the site is discussed elsewhere (see Chapter 6 and Appendix B). The overall result of animal and human activity is unclear but the net effect is likely to be to introduce unrepresentative data into any quantitative analysis.

Estimates of the Scale of Rainfall Erosion

It is clear from the foregoing discussion that the erosion process at any given site is at best a complex one. Variations in soil composition and surface contour are compounded by the detail of meteorological factors which must be included to obtain any estimates of the denudation process over a period of time. The inter-related factors applicable to this broader picture have been summarised diagrammatically by Morisawia (1968, p. 78). Although mathematical models of overland flow being developed (see, for example, Langford, 1975), in the light of such complexity, theoretical estimates of the amount of soil removed are likely to be of doubtful value.

An empirical approach has been made by Kirkby (1972), whose starting point was the cumulative frequency distribution of distances moved downslope by different sized sand grains and stones in a given storm. The total mean transport was obtained through a knowledge of the grain size distribution across the site and the meteorological data on storm frequency or recurrence interval, intensity and duration. Kirkby notes that processes of surface erosion include factors additional to rainsplash but leaves these quantitatively unexplored. Although he quotes

estimates of the rate of debris transport for two sites in Arizona, Kirkby makes no comparison with observed values.

More recently Pearce (1976) has combined sparse meteorological data with experimental observations on small bare plots to investigate the denudation process in central Canada. He found that the surface was removed at an annual rate of between 1.5 mm and 12 mm. As rainfall observations extended only from May to November, it may be assumed that soil conditioning processes such as frost heave and those occurring under snow cover were active during the remainder of the year. Like Kirkby, Pearce found that, over a period of several years, the greatest amount of erosion resulted from moderate intensity high frequency rainfall rather than from the less frequent spectacular events. Pearce further found a high correlation between the sediment removed from the surface and both the total runoff energy over the slope and the total rainfall intensity during runoff producing storms. This differs from Emmett's doubtful interpretation of the conclusion of Smith & Wischmeier that ' ...the erosive potential of a rainstorm is ... a function of ... drop velocity, rain amount and maximum sustained intensity.' (Smith & Wischmeier, 1962, p. 124) is equivalent to ' ... a few high intensity storms cause a high proportion of total soil erosion', (Emmett, 1970, p. A42).

An extensive series of observations on erosion-related phenomena have been carried out over a period of several years by Leopold and others in New Mexico, (Leopold, et al, 1966). Leopold's illustrations suggest that in some areas the terrain may resemble parts of the Mungo lunette. The work had several aspects including the measurement of soil loss by the exposure of erosion pins, the movement of stones placed in erosion channels and soil creep on the steeper slopes. Unfortunately, detailed rainfall records were not maintained so that analyses of the type carried out by Pearce are not possible. Observed

average annual erosion rates were of the order of 7 mm in an area where average rainfall is approximately 1700 mm annually. Emmett, who took part in this field work, notes that 98% of the erosional sediment from all sources originated from slopes upon which surface rills were absent, indicating the apparent effiency of true sheetflow, (Emmett, 1978). He also wryly observes that attempts to observe overland flow from thunderstorms occurring during periods of his summer fieldwork over a period of ten years were unsuccessful. I can understand his frustration.

It may well have been this failure which led Emmett to conduct the comprehensive series of experiments mentioned earlier in which artificial rainfall was used to investigate overland flow over a series of slopes. Originally published in 1970 by Emmett, the work has been summarised recently, (Emmett, 1978). Primarily concerned with exploring the hydrological processes at work, his artificial rainfall rates of seven to eight inches per hour are substantial. The results include values of sediment loss but no indication of the kinetic energy of the applied rainfall. Sediment loss appears to be low compared with those of Pearce (1976) but the latter, despite using Emmett's hydrological results, makes no comment on this aspect.

Recent field work published in Australia appears to be limited to that of Williams, who compared the effectiveness of creep and slope wash as surface lowering agents in tropical and temperate regions, (Williams, 1973). Williams is critical of the results of others, including Leopold, who have attempted to determine the lowering of the soil surface, claiming that they do not differentiate between soil creep and surface removal. It is difficult to interpret Williams' own results, however, as he is less than specific about the vegetation cover of his temperate zone experimental areas.

Williams provides a tabular summary of similar investigations listing the mean rate of surface lowering on slopes of up to 37 degrees covered by a variety of vegetation in many areas of the world. Values on bare soils range from 0.01 mm per year to over 13 mm per year. The two largest values are considered suspect by Williams but the next value of 4.6 mm per year on bare slopes in Southern France is presented, surprisingly, without comment in view of the author's own observation (Gabert, 1964) as to the severity of the winter:

> 'L'hiver 1962-63, trés rude et neigeux,
> a sérieusement activé l'erosion surtout
> dans les bad-lands en 4 jours 1,49 mm.
> de roches ont été enlevés (soit 45,6%)
> de l'ablation annuelle'

Williams' own values were less than 0.55 mm per year.

Current understanding of rainsplash and runoff erosion summarised in this chapter has shown that the process is complex, depending, as it does, on the many interactions between geological, meteorological and other factors. It is apparent that the surface of sloping land surfaces may be removed at a rate of many millimetres per year. However, in those areas of the world which are subject to aridity an additional and completely different erosion mechanism occurs which results from the action of wind on dry land surfaces.

Wind Erosion

The occurrence of severe dust storms in western New South Wales is a reminder of the potential of strong winds to carry fine material considerable distances. Mobile dunes, where the trajectories of grains of sand from the crest of the dune may be observed in winds of modest speed, are present on the eastern and north-eastern parts of the Walls of China and are further evidence for the

effectiveness of wind forces. This is recognised by Higginson who, in his discussion of soil erosion within the Murray Valley, places Lake Mungo near the margin of the area characterised by wind erosion, (Higginson, 1974). Of more immediate relevance to the Mungo site, it has been necessary to abandon work there on a number of occasions when blown sand makes conditions too unpleasant, (see Figure 3.3). This underlines the fact that surface material there can be removed by wind as well as rain. Pictorial evidence may be found on p. 42 of a Commonwealth and State soil conservation study (Department of Environment, Housing & Community Development, 1978, p. 42) showing mallee roots exposed by wind erosion to a depth of one metre in nearby North West Victoria. Regrettably, the period over which this erosion took place is not recorded.

Descriptions of the modes of transport of dust and sand grains may be found in Mabutt (1977), in Allen (1970) and in Bagnold (1954) where it is noted that, depending on the size of the grains, they may be carried in suspension, or move by saltation or surface creep.

Sand and silt particles of small diameters, less than 0.15 mm, are carried in suspension but are deposited when the wind slackens. Still finer particles remain suspended and may be transported for very large distances as atmospheric dust. In the saltation mechanism grains with dimensions between 0.1 mm and 0.5 mm begin their motion by rolling along the surface. As the wind speed increases, they are lifted up in low, short trajectories and, on striking the ground, may either bounce up and continue their movement or may cause other particles to splash upwards to join the process. Theoretical expressions have been derived describing saltation in terms of the mean height and length of such trajectories (Allen, 1970, p. 98). Finally, those sand grains which are too heavy to be thrown into the air by the impact of saltating particles may still be moved forward by the exchange of momentum to make up the surface creep component of the motion.

Photo: F.W. Shawcross

Figure 3.3: Wind Blown Sand

Estimates of the rate of sand movement have been obtained by Bagnold and more recently by Hsu (1973), in which the quantity of sand moved per unit time is proportional to the cube of the wind velocity, demonstrating the very much greater effect of strong winds. As Mabutt points out (Mabutt, 1977, p. 221), a 50 kph wind of one hour duration is as effective as one of 20 kph blowing for 25 days. Two critical windspeeds are relevant to the description of sand movement. These are the threshold velocity, that is, the velocity at which the particles first move, and the impact velocity, a slightly lower velocity at which movement is sustained. The latter is of a lower velocity reflecting the effect of saltation in lifting particles from the surface. Fluctuations in velocity about these two windspeeds have been investigated by Fan and Disrud (1977), who established that Bagnold's expression and similar relationships derived by others remained essentially valid under unsteady conditions if each perturbation from the mean wind speed was treated as a brief stationary period of the same duration.

Much of the interest in the literature centres on the movement of quartz sand particles in desert environments. In an area such as the Mungo lunette other factors besides wind velocity are important in determining the movement of soil from the surface. Such factors include the shape and density of the particles and the micro-topography and composition of the surface.

The expression for the weight of sand being transported takes account of grain mass and size and introduces a coefficient of proportionality which varies in value from 1.5 for uniform sand to 2.8 for a very wide range of grain size, although the corresponding mass and size values in the latter case are not stated. Mabutt presents a table (pertaining to the Mojave Desert, California) giving examples of threshold velocities, (Mabutt, 1977, p. 220). These vary from a threshold velocity of 17 kph for sand dunes to 53 kph for the movement

from a crusted alluvial fan. A threshold velocity of 21 kph is quoted for coarse sandy wash, which may be relevant to parts of the Mungo site where the products of sheetflow have been deposited. On the other hand, if it is assumed that other areas resemble a 'desert pavement with granule veneer', sand may not be moved until a wind velocity of 32 kph is reached.

The condition of the surface as regards moisture content is also important, as demonstrated experimentally by Bisal & Hsieh (1966). Their results showed the increase in threshold velocity with soil moisture but can also be interpreted as indicating the selective movement of clay, loam and sandy loam components under a given range of conditions of moisture and wind speed.

The theoretical estimates of the quantity of sand moved by the wind made by Bagnold (1954), Allen (1970) and, more recently, by Hsu (1973), each give a somewhat different answer but, as an example, using Bagnold's expression, the quantity of sand moved across a one metre front in one hour by a wind of 20 kph velocity is approximately 1 kg. Under steady state conditions where the grains are being continuously picked up and deposited, this material will have been derived effectively from within a distance less than that of the mean length of the saltation trajectory. An expression for the mean length of trajectory has been derived by Allen (1970, p. 98), which gives a value of some 20 cm for grains of 0.5 mm in diameter. Arbitrarily assuming a density of 2.0 for the surface material (density of quartz 2.5) to take account of the interstices between the grains, Bagnold's estimate means that an amount of sand equivalent to the upper 2.5 mm of the surface is being moved.

This crude estimate is indicative of the importance of wind as an erosive force. It cannot be concluded that the surface is being eroded at a rate of 2.5 mm per hour except perhaps under ideal conditions of steady wind and

uniform, clean, dry sand on an even surface. Nevertheless, Berry (1973), has observed that on the western shore of the Gulf of California within no more than 30 minutes an estimated 30 km per hour wind was effective in eroding away at least the top centimetre of a damp sand beach.

In summary, the movement of sand under the influence of strong winds seems to be well understood and has been studied in relation to dune building in desert conditions and to coastal processes. The problem of quantitative assessment of wind erosion on soils where the material is not well sorted and may be initially partially aggregated seems to have received less attention. Indeed, it is not even clear whether some of the field investigations into sheetflow discussed earlier ignored possible long term contributions from wind erosion or whether such contributions were assessed to be negligible.

Erosion of Mungo Site

The preceding discussion summarising work on erosion has shown that the rate at which the surface at a given site such as the Mungo lunette depends critically on many individual environmental factors including soil type, slope and prevailing weather conditions, and also on the probable interactions between these.

It follows that it would be imprudent to assume that values obtained at other locations are representative of those occurring at Lake Mungo. Theoretical estimates similar to those made by Kirkby (1972), despite their incompleteness, are not possible because rainfall intensity is a crucial parameter in such assessments. Although daily rainfall totals are available in the area, for example at Top Hut and Pooncarie, the nearest continuously recording raingauge is at Mildura, some 100 km to the south west. Even if the rainfall erosion could be accurately assessed, there remains the need to include the component due to wind. Only a minor part of the Mungo grid surface

is mobile sand, with the remainder consisting of a significant proportion of clay or clay binding the sand. Pebbles from ancient beaches are also present. Theoretical estimates of the removal of material are clearly inappropriate under such circumstances.

Faced with this situation, an attempt was made to obtain a crude measure of the rate at which the surface is being eroded at Mungo by measuring the exposed length of the 2 inch by 2 inch wooden pegs defining the corners of the 20 metre squares of the surface grid. Measurements were begun in 1976 but were of an exploratory nature and these did not have the precision which the subsequent analysis showed was necessary. The next opportunity for more exact readings did not arise until September 1978 and it is these measurements together with further records of exposed peg lengths made in May and August 1979 which form the basis of the subsequent discussion. The results in Table 3.1 are based on the average of the lengths of the exposed northern and southern faces of each peg. The upper figures are the differences between these averages obtained in September 1978 and May 1979, giving an estimate of the change in levels over an eight month period. In general, these figures support those for the complete year.

The values obtained (Table 3.1) were necessarily approximate. Firstly, there is the possibility, noted by Williams (1973) but ignored here, that movement may take place relative to the original uneroded surface due to soil creep or as a result of the pegs sinking into the ground under their own weight. Secondly, and probably more importantly in the Mungo context, the area at the base of the pegs is sometimes disturbed by animals or in some parts of the site the shade and added moisture, small though it may be, promotes weed growth, while in other areas the presence of the peg is sufficient to disturb the wind pattern and produce scouring of the surface immediately adjacent to the peg. Finally, in some cases

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	
	4.4	1.0	0.6	-2.5	-7.5	1.0	-0.6																			
	5.7	1.1	0.7	-4.6	-8.2	1.0	-0.9																			
B																										B
	0.3	0.3	1.6	-2.8	4.0	3.8	0.5	3.0	0.3	2.4	2.2	1.3	0.4	1.7	1.5	0.3	-1.7	-0.7	2.4	1.2	1.0	0.2	0.1	-0.7		
	0.9	0.5	1.5	-4.6	4.9	4.2	0.3	3.7	0.9	2.8	3.0	0.9	0.3	1.9	1.6	-0.4	-1.2	1.0	2.5	1.5	1.2	0.4	0.4	-0.4		
C																										C
	0.7	0.5	2.8	1.6	1.2	0.3	2.6	2.7	1.3	1.6	2.5	0.6	0.4	1.9	0.0	0.1	0.6	1.0	0.2	1.8	0.5	0.1	-0.5	0.0	0.1	0.3
	0.6	1.1	3.1	2.4	1.2	0.8	2.9	3.4	1.2	1.4	2.9	0.7	0.5	2.6	0.5	0.5	0.7	0.9	0.5	2.3	0.9	-0.1	-0.3	0.1	0.1	0.1
D																										D
	-1.4	0.1	-0.5	1.7	1.2	2.4	2.1	2.1	2.5	1.7	1.4	0.0	0.5	0.8	0.5	2.2	1.3	2.8	0.5	0.4	0.0	0.6	-0.7	-0.8	-0.1	-0.3
	-2.0	0.4	-0.8	2.1	0.7	2.7	2.5	2.5	3.2	1.9	1.5	1.1	1.1	0.4	-0.4	2.2	0.1	5.2	0.6	0.4	0.4	0.7	-0.7	-0.4	0.1	0.7
E																										E
	-	-	0.2	0.4	2.5	3.0	1.9	1.0	0.5	0.7	0.0	2.0	1.2	0.6	-0.6	0.9	1.0	0.3	0.1	0.6	-1.5	-0.5	-0.6			
	-	-	0.9	0.7	2.5	3.4	2.0	1.9	0.8	0.3	0.2	1.9	1.7	0.7	0.1	-0.8	0.7	0.3	0.3	0.7	-1.4	-0.4	-0.7			
F																										F
	-	-	-	0.2	-3.3	-0.7	0.9	1.9	-	0.6	0.2	0.8	1.0	0.2	-0.1	1.8	0.4	0.9	-0.4	0.1						
	-	-	-	0.1	-2.9	-1.2	1.2	2.6	-	0.9	0.1	1.3	0.3	0.7	0.4	2.4	0.5	-	-0.6	-0.1						

Notes: Units are in cm, negative values indicate accretion

upper row - erosion September 1978 to May 1979
lower row - erosion September 1978 to August 1979

TABLE 3.1 DEPTHS OF EROSION AT MUNGO 1978-79

the tops of the pegs have splintered as a result of the hammer blows needed to drive them into the ground. Such effects increase the difficulty of selecting an accurate datum at many of the pegs. In this respect the undisclosed technique used by Pearce for which he claims an accuracy of ± 0.1 mm (Pearce, 1976, p. 67) is of interest.

In the course of the year in excess of 5 cm of some parts of the surface was removed, while in other areas not 100 metres away loose sand accumulated at a rate of over 8 cm/year. Generally the changes in surface level are of the order of one to two centimetres. Looking at the site as a whole, there is a general decrease in the incremental exposed peg length at the western end. This is an area sparsely covered with grass and the thin soil crust is generally unbroken. Observations at the site suggest that there is no apparent accumulation of loose material here. Two explanations are possible. Firstly, there is no change in peg length at the end of the grid. In this case the differences in the four westernmost readings, corresponding to ± 0.3 cm approximately reflect the measurement errors. Moving eastwards, however, the two sets of readings taken in May and August do show a consistent decrease in peg length leading to the alternative explanation that some of the pegs may be sinking into the ground under their own weight. This seems unlikely, as does soil creep.

Across the site more material is being removed from the area corresponding to the upper rows of Table 3.1, i.e. the higher parts of the dune are eroding faster than the area which is closer to the lake. It is not clear whether this represents a genuine difference in erosion rates between the Mungo and the Zanci deposits for there are many other factors involved, such as the local slope of the dune. It is possible that much of the eroded material is temporarily deposited on the flatter areas in an unconsolidated form until carried away by strong winds. Schumm (1964) observed a similar effect which he explained

in terms of the deposition of eroded material but as the contours at his site were much steeper than at Mungo the two mechanism may not be comparable. Simple application of a 2 x 2 contingency test ignoring the contours of the site showed that the erosion and accumulation patterns of the Mungo and Zanci surfaces are not significantly different at the 5% level.

Based on the figures in Table 3.1, the surface of the grid was lowered on average by 0.85 cm during 1978/79.

Despite the lack of precision of the earlier measurements, support for this result was obtained by comparing the erosion recorded over the 1976-78 period with that during 1978-79 (see Table 3.2). These data are plotted in Figure 3.4. The straight line assumes that the erosion rates of the two periods were the same. It is apparent from the tendency for the points to lie above the line that more of the surface was eroded during 1976-78. A best fit by eye suggests an erosion rate between 1.5 and 2.0 times greater. There are two reasons for the scatter of points. In addition to the measurement errors, a component of the scatter may be due to the non-uniform nature of the site. As discussed above, some areas of the site may respond differentially to the various erosion processes. Thus if the earlier years were wetter or more windy than 1978-79 comparatively more, or less, erosion could be recorded during 1976-78 at two different locations which gave the same value for the final year.

The depths by which the lunette is eroded annually averaged across the site and based on the less precise 1976-78 data is 2.0 cm per year. Bearing in mind the year to year variations in weather conditions, this confirms the value of approximately 1 cm per year obtained in 1978-79.

It is of interest to interpret this deflation rate in terms of the corresponding time span during

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	
	10.5	2.6	3.0	-3.8	0.5	5.4	-1.0																			
	5.7	1.1	0.7	-4.6	-8.2	1.0	-0.9																			
B																										B
	4.5	5.7	4.9	3.8	7.8	10.2	7.8	8.3	4.3	1.0	7.5	8.5	5.6	5.0	2.6	6.5	8.3	10.7	4.4	2.9	5.5	1.0	1.3	0.2		
	0.9	0.5	1.5	-4.6	4.9	4.2	0.3	3.7	0.9	2.8	3.0	0.9	0.3	1.9	1.6	-0.4	-1.2	1.0	2.5	1.5	1.2	0.4	0.4	-0.4		
C																										C
	7.4	6.8	6.8	4.0	6.2	7.4	6.0	4.8	3.5	6.0	5.0	4.8	7.9	4.6	7.4	5.5	2.8	7.5	8.4	1.1	2.0	2.7	1.0	1.0	1.3	4.0
	0.6	1.1	3.1	2.4	1.2	0.8	2.9	3.4	1.2	1.4	2.9	0.7	0.5	2.6	0.5	0.5	0.7	0.9	0.5	2.3	0.9	-0.1	-0.3	0.1	0.1	0.1
D																										D
	-1.3	1.4	-2.9	11.6	6.0	8.0	7.9	6.1	7.5	6.0	6.4	3.1	2.8	9.0	5.0	6.0	4.5	4.5	1.8	2.0	0.2	1.4	1.6	1.3	0.5	-2.5
	-2.0	0.4	-0.8	2.1	0.7	2.7	2.5	2.5	3.2	1.9	1.5	1.1	1.1	0.4	-0.4	2.2	0.1	5.2	0.6	0.4	0.4	0.7	-0.7	-0.4	0.1	0.7
E																										E
	-	-	7.0	4.0	3.9	0.5	2.9	3.5	3.9	3.6	0.5	0.5	2.7	1.5	5.0	4.7	4.8	0.8	1.3	2.2	3.0	1.0	2.6			
	-	-	0.9	0.7	2.5	3.4	2.0	1.9	0.8	0.3	0.2	1.9	1.7	0.7	0.1	-0.8	0.7	0.3	0.3	0.7	-1.4	-0.4	-0.7			
F																										F
	-	-	-	-1.2	6.8	7.4	3.0	8.1	-	2.3	1.0	4.4	3.9	0.7	0.5	8.8	1.7	0.5	1.3	1.0						
	-	-	-	0.1	-2.9	-1.2	1.2	2.6	-	0.9	0.1	1.3	0.3	0.7	0.4	2.4	0.5	-	-0.6	-0.1						

Notes: Units are in cm, negative values indicate accretion

upper row - erosion Sept 1976 to Sept 1978
lower row - erosion Sept 1978 to Aug 1979

TABLE 3.2 DEPTHS OF EROSION AT MUNGO 1976-78 AND 1978-79

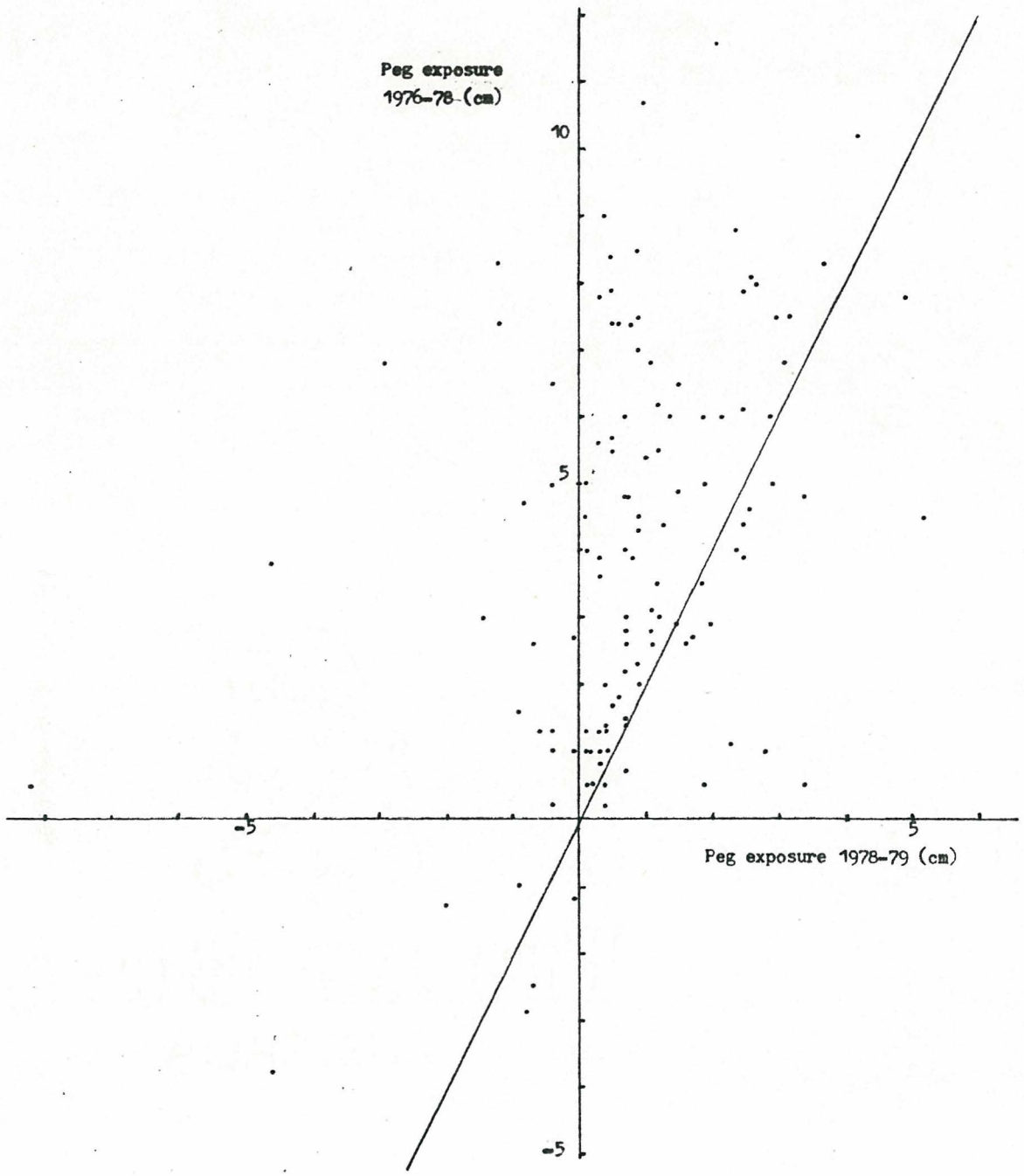


FIG 3.4 Erosion Depths 1976-78 vs 1978-79

the dune-building period. This can only be done very approximately by estimating the total thickness across the bedding of the Zanci deposit from Bowler's diagram (Bowler, 1971, p. 60) to be 44 metres. These deposits were laid down over a period of 1,500 to 2,000 years (Dare-Edwards, 1979) so that a depth of 2.2 to 3.0 cm represents one year's deposit. Thus the Zanci deposits are being eroded at approximately one half the rate at which, allowing for any intervening consolidation, they were laid down.

An estimate of the rate of exposure of the Mungo deposits is possible only for the final saline phase of the Mungo cycle. Dare-Edwards estimates that this extended over a period from 26,000 BP to 22,000 BP with soil formation continuing until 18,000 B.P., (Dare-Edwards, 1979). Bowler's diagram indicates that the present thickness of this deposit is approximately 8 metres so that here erosion of 1 cm removes 10 years of deposition.

Over the whole grid a total volume of approximately 750 cubic metres was lost between 1976 and 1978. As the 1978 surface collection recovered a total of 139 implements exposed since the previous collection in 1976, an approximate estimate of the density of artefacts lying immediately below the erosion surface of the dune is one implement per 5 cubic metres. This figure ignores those artefacts which may become reburied by the eroded material and can only be approximate. By comparison, the upper metre of excavations carried out in 1976 some 0.5 km to the east of the surface site has resulted in artefact densities of between zero and 2.1 artefacts per cubic metre with a mean value of 0.15 artefacts per cubic metre (Shawcross, pers. comm.).

The unretouched flakes recovered from the same excavation gave densities of 2.3 per cubic metre for the Zanci deposits and a maximum of 18.7 per cubic metre in the Mungo levels. The average values obtained from

the Zanci and Mungo surfaces during the 1978 collection were 1.4 and 3.7 unretouched flakes per cubic metre respectively.

Movement of Prehistoric Material

The discussion of the erosion process has focussed, thus far, on the removal of the sand and clay components of the lunette. Embedded in this material are prehistoric artefacts, debitage, other debris, bone, shell fragments as well as the ancient beach pebbles occurring in some areas of the site. It is clearly of vital importance to establish whether the prehistoric material, once exposed, suffers any disturbance and, if so, to assess the probable magnitude and direction of such movement.

The surface prehistoric material is subjected to the same forces which result in the large scale erosion on the dune: wind, rain, and the activities of men and animals. Wind, except under exceptional circumstances, is unlikely to be able to move stone fragments. Such circumstances have been reported in America where boulders have migrated over the moist surface of dried up lake beds under the influence of very strong winds. Whether winds of the appropriate force and direction could induce stones to slide down the steeper surfaces at Mungo when they have been lubricated by rain is a matter for speculation. This author has never observed marks on the surface that would suggest this happening.

Bagnold suggests that, under laboratory conditions and uniform grain size, a wind of only 3.6 km per hour is strong enough to move pebbles of up to 4.6 mm in diameter. Field measurements quoted by Mabutt indicate that a speed of 21 km per hour is required to initiate the creep of granules of 3 mm diameter. Such figures suggest that movement of prehistoric material by wind is unlikely.

Much of the work reported on the movement of stones in water relates to their transport along stream beds (e.g. Leopold, 1966). The flow rates reported in Leopold's work are high, the lowest reported being some 3.6 cubic feet per second per foot of channel cross-section. Some work has been carried out in an archaeological context (Isaac, 1967, Shackley, 1978). Displacement of stones by sheetwash is more difficult to assess as it is dependent upon flow velocity, the depth of flow which may be insufficient to cover the larger items and the type of surface over which the flow is taking place.

Kirkby (1972) has recorded the movement achieved by particles of up to 8 mm in diameter in a single rainstorm in Arizona. In this storm, in which 16 mm of rain fell on bare ground, 10% of particles in the 4-8 mm diameter range moved 5 cm down a 17° slope. Three times that number were moved 2 cm. From observations made over a period of a month in the same area Kirkby found that stones up to 25 mm in diameter moved 5 mm down a slope of 10 degrees. Pearce (1976, p. 67), in an isolated comment. notes that pebbles up to 1 cm in diameter on slopes up to 6.5 degrees did not move even when 65 mm of rainfall was recorded with almost all of it being collected as runoff.

As discussed earlier, Schumm attempted to measure the movement of stone material across a sloping site (Schumm, 1964). In this early report of the work, the results, which are quoted by Kirkby without reservation, are aggregated figures and include the movement of the metal washers and wooden blocks. In his revised report (Schumm, 1967), these unrepresentative items were eliminated from the results as were a further 10% of the marked stones because they had moved either up the slope or an unacceptably large distance. Migratory sheep are suggested as the cause of this disturbance. Schumm concludes that the rate of movement of his stone material which was up to 5 mm thick and 70 mm in maximum dimension may be represented by:

$$V = 100S$$

where V = velocity of movement (mm per year)

S = sine of the angle of the slope.

The immediate relevance of Schumm's work to Mungo is doubtful. As he notes, a significant component of the movement was due to the frost heave in the weathered shale mantle during winter being beaten down by the summer rain. This mechanism is not a factor at Mungo.

Assessment of Movement at Mungo - Experimental

In order to obtain some estimate of the likelihood that artefacts would be moved by runoff, a simple experiment was devised to investigate the water runoff rates, depths and the ground slopes necessary to produce movement. The makeshift apparatus, procedure and results of this experiment are described in Appendix A.

It is clear that this series of experiments could simulate only very approximately conditions occurring on the dune where micro-topography, evenness of flow rates and increased momentum of flow due to eroded material in suspension must be different. Furthermore, every flake has its own values of overall dimension and cross section so that a comprehensive series of experiments would be necessary to establish the effects of these size and shape variables. As it was, it was necessary to examine flake orientation with respect to the flow.

Water velocities occurring under conditions of natural overland flow have been quoted as lying between 0.3 and 15 cm/sec, (Dunne, 1978, p. 240). Corresponding depths are not quoted. Values of the latter were obtained by Emmett (1970) under simulated rainfall conditions but at rainfall intensities of 200 mm/hr which are rarely experienced in nature. Under such severe conditions and accepting the variations between Emmett's sites, depths

generally from 1 mm to 21 mm were observed as the downslope distance increases from 30 centimetres to 30 metres. In the same experiments surface velocities were in the approximate range of 1 to 15 cm/sec. Depths of flow over rough impervious surfaces as a function of rainfall rate and length of flow path have been studied experimentally by Nittim (1977). For the rates and path lengths used by Emmett, he obtained depths between 0.55 mm and 5 mm.

In the experiments carried out here velocities of up to 30 cm/sec were used and depths of about 1-2 mm were obtained. At such depths the flake orientation with respect to the surface becomes particularly important as the flake is only partially covered. When the flake bulb was resting on the unyielding surface of the experimental board it was moved by the flow of water at a much less steep angle than when the bulb was uppermost. Instability was observed when the axis of the flakes were set parallel to the flow. They were rotated by the hydrodynamic forces through 90 degrees in a series of jerking movements as the board slope was increased, finally moving off when the angle approximated that for the transverse position.

The flakes used in the experiments ranged in mass from 0.5 gm to 16.2 gm. Water velocities of 15 cm/sec carried away the flakes smaller than 1.5 gm at slope angles of approximately 12 degrees. Although contours at Lake Mungo based on a theodolite survey at the spacing of the grid pegs gives the maximum slope of 7 degrees, steeper inclinations do occur locally. This consideration, together with the uncertainties of transferring the results of the board experiments to the Mungo context, suggests that it would be unwise to assume that no movement of the lighter flakes occurs on the lunette. The implications of this are considerable. Some natural sorting of the lighter artefacts is probably taking place after exposure.

Efforts were also made to confirm this by measuring the magnitude and direction of the movement of replica artefacts deposited at a number of points across the grid. The results are discussed in Appendix B. Unfortunately, interference with these marked items and several instances of gross movement which was apparently inconsistent with the surface slope in the immediate vicinity prevented firm conclusions from being drawn.

Conclusion

The rate at which prehistoric material is exposed and its possible movement subsequently are determined by the response of the lunette surface to environmental conditions. A study of the literature shows that the processes are the result of compound interactions between many factors of which rainfall and wind are probably the most important. However, the extent to which meteorological conditions are responsible for removal and redistribution of components of the surface material of a given size can only be stated in broad terms. Comparison with erosion rates elsewhere in the world suggest that, while both build up and removal occurs, the surface of the lunette is being lowered by an average of approximately 1 cm annually and this is confirmed by measurements at the grid.

Extrapolation of the behaviour of small flakes under experimental conditions to the situation at the lunette indicates that movement of artefacts of one to two centimetres maximum dimension is plausible. Attempts to estimate such movement directly on the lunette surface at Lake Mungo were inconclusive.

CHAPTER 4

SURFACE COLLECTION

Introduction

The present work comprises a study of the stone material collected from the surface of the Lake Mungo lunette between the years 1975 to 1978. Two broad aspects of the collections are important in establishing the confidence that can be placed in their analysis. These are, firstly, the methods by which the material was recovered and, secondly, the extent to which the collection may be considered representative of the material at the site. It is with these aspects that this chapter is concerned.

Collection Procedure

The efficiency with which the artefacts are recovered, measured in terms of the proportion of exposed artefacts collected, clearly depends upon the ability of those carrying out the collection. Not only in the inherent skill of the individual involved, but also the extent to which the ambient conditions including, for example, weather and the state of the lunette surface encourage the collecting activity. Motivation, experience, and an understanding of the objectives of the task are also contributing factors.

The collections were carried out with the assistance of undergraduate students in the Department of Prehistory and Anthropology, School of General Studies at the Australian National University. In 1975 and 1976 each of the students was 'on loan' for a day from the group taking part in excavations being carried out simultaneously one kilometer to the east. Each student therefore collected from only a part of the grid and

each regarded the task, to varying degrees, as relief or interference with their contribution to the excavating activity. In contrast, the 1978 collection was carried out by a small group of volunteer students dedicated to the task. Although there is no quantitative data to support the impression, it is the author's opinion that the greater understanding of the problems and personal identification with the task led to a collection that was 'better' in terms of fewer artefacts overlooked.

Preparation of the students for the task of collecting began before reaching the site with a discussion of the aims of the research, an outline of the methods and a summary of progress of the analysis. The formation of the lunette and its main features were also described with the help of aerial photographs, maps and sketch maps. Once at the grid familiarisation was reinforced by walking the length of the grid. In the course of this exercise, which also served as a reconnaissance for the author if there had been no opportunity to do this beforehand, the occasion was taken to point out to the collectors the Mungo and Zanci deposits, to identify examples of the less obvious items to be collected, including the various types of rolled and unrolled artefacts, ochre and burnt clay. Other significant aspects of the grid such as the seeming rarity and therefore importance of local concentrations of artefacts, the possibility that artefacts might be washes into and remain in depressions and the occurrence of apparent hearths, were discussed also. However, every attempt was made to express these latter points in an unbiased manner so that the collectors were not discouraged from identifying such features, should they occur. Familiarisation of the site was completed by having each of the pegs defining the grid labelled with its appropriate grid row and column identification as an aid to the subsequent collecting.

The collection itself was carried out by assigning a pair of individuals to each grid square. Within broad limits, the choice of the actual method of collecting was left to the individuals concerned but with the stipulation that the grid square must be covered twice by traversing it back and forth parallel to each of the sides. One reason for this is that the shadow of the collector and the shadow of other stones or of the artefacts sometimes obscure a significant number of the items being collected. The method has been found effective elsewhere (see, for example, Ammerman and Feldman, 1978). Sceptical collectors usually are convinced after their first square by the number of items missed on the first traverse which are to be recovered on the second.

The management of the collecting teams presented no difficulties and I was able to take an active part. However, I suspect that a larger team or an increase in the number of collecting squares might introduce problems. For example, the bags of collected material must be carefully labelled with tags placed internally and tied externally <u>before</u> collection begins in a given square. Despite clear identification of the pegs, some individuals, through lack of familiarity with the site, become confused and others need to be recalled when they continue mechanically collecting beyond the boundaries of the square. Occasionally decisions must be made to abandon work when unfavourable light conditions make further efforts unprofitable. Finally, someone must have clear responsibility for the custody of the collected material. If these factors seem trivial, I can only point to the fact that the 1975 collection, for which, incidentally, I can claim no credit, lacked material from seven squares, as did the 1978 collection for one square. Additionally in 1976, when overnight rain prevented excavation, thereby increasing threefold the number of students available, recording and allocating collecting areas became a full time activity.

Visual Aspects of Surface Collecting

The task of collecting material from the grid involves the detection and recognition of artefacts and manuports lying on the surface. The characteristics of this surface varies across the site, variations occurring in the colour and texture of the surface itself and in the number and size of non-artefact items such as beach gravel, bone and shell fragments amongst which the artefacts are located.

A variety of factors influence the ease and efficiency with which collectors perceive artefacts and it is of interest to consider which of these factors are present at Mungo and what effect they have on the quality of the collection.

The study of visual perception is a branch of psychology and has many aspects ranging from investigating relationships between perceptual ability and personality to military applications of camouflage and target detection. Unfortunately, as recently as 1970, Zusne lamented that there was 'no major work that presents a comprehensive survey of the field'. As noted above, the recovery of artefacts requires both the detection and the recognition of each item. Detection is the discovery of a potential artefact and involves a response to some visual stimulus which the collector has previously identified with artefacts. He may, for example, have as one of these criteria the presence of one or more flake scars. If these are seen on a piece of stone then a detection has been made. Recognition is wider in scope and implies previous learning and the fact that some concept has already been formed requiring an artefact to possess several features simultaneously. Thus, not all detections are confirmed. In the example given above, the supposed artefact may be rejected subsequently if the flake scar is considered to be due to natural fracturing and the item is a piece of beach gravel.

Several factors come to mind as possibly having importance in the detection and recognition process. Among these are intensity of light, size, and shape of the objects and the colour contrast between the artefact and its background. The number of non-artefact items present in the field of view at any one time may be significant as having a potentially confusing influence.

Vernon (1962) states that the important factors in the perception of shape are the intensity of light illuminating the field of view and the brightness differences of the objects and the surfaces in the field. Her discussion of colour suggests that the effect of colour contrast as an aid to visual perception is less well understood, partly due to the semantic problems connected with descriptions of colour by different observers.

Of the experiments which have been carried out to investigate aspects of visual perception, two appear to be immediately pertinent to the processes of surface collecting. Both are limited by the fact that the results were obtained in two dimensions only and both are concerned with the problem of discrimination between relevant and irrevelant shapes.

In the first experimental program observers were asked to identify a regular target shape amongst an irregular array of similar background targets (Boynton, 1957). There were six classes of target figures consisting of irregular rectilinear pentagons, crosses, triangles, quadrangles, re-entrant polygons and Y-shapes, while the other background figures in the array were curvilinear 'blobs' of the same general size and appearance as the target figures. The figures used are illustrated in the original report and in a summary of the work (Graham,1965,p.568). Also shown in each reference is an example field of view which contains one target figure among some 60 background figures. In these experiments the performance of the

observers in correctly detecting and recognising the presence or absence of target figures in a projected display was determined as a function of four factors. These were: target contrast, exposure time, viewing distance and the number of figures in the field of view. Each of these factors has some relevance to the surface collection process.

The percentage of correct detections was comparatively insensitive to target contrast provided the contrast was greater than about 45%. Below that value performance fell off rapidly. Although Boynton does not define the term 'contrast', it is assumed that he uses it in the sense given by Brown and Mueller(1965)p.229 ' ... to describe a relation between neighbouring regions of a visual field which are differently illuminated. The difference may be one of luminance or of wavelength distribution, or of some combination of these'. If so, this experimental result is of some significance. Much of the beach sand on the lunette is derived from the silcrete deposits which also provide almost all of the material from which the artefacts were fashioned so that, apart from textural differences, contrast is generally low and poor recovery rates might be expected. Some improvement could occur in areas where the red Mungo soils are exposed but this is unlikely to be large enough to account for the differences in flake densities discussed in Chapter 5.

The relationship between exposure time and performance of the observers in Boynton's investigation depended upon the number of figures in the field of view. If this was in excess of about 30, then the percentages of correct recognitions increased steeply with viewing time. For smaller numbers correct recognition had been completed within three seconds in over three-quarters of the trials. The relevance of this result to the collecting situation, where the collector's field of view is changing as he moved across the square, is unclear.

Nevertheless, if the number of background objects in his field of view is of the order of 150, Boynton's results suggest that the collector will require about 25 seconds to achieve an 80% chance of ascertaining whether his field of view contains an artefact.

These figures can be interpreted in another way. A collector scanning an area one metre square on the ground some three metres ahead corresponds approximately to the projection geometry used experimentally by Boynton. Experience has shown that pairs of collectors take about 30 to 45 minutes to cover a 20 metre by 20 metre square, depending on the surface density of the material that it contains. Assuming that they do this in a series of examinations of 1 metre square fields of view, they would spend, on average, six seconds in examining each of these fields of view. According to Boynton's results, six seconds is required to obtain in excess of an 80% correct result when the field of view contains 30 objects. The maximum surface density of all objects at the grid has not been estimated as extraneous items such as beach gravels are not counted or recovered but unretouched flake densities reach 80 per grid square or one per 5 square metres. Fragments and waste have about the same density, while the beach gravels probably exceed this by a factor of 20 or more in some areas, resulting in an average of five objects per square metre, well below the 30 of Boynton. Thus, while gross variations in surface density are present, the rate at which collectors move across the site does not appear to be excessive for efficient collection.

The maximum dimensions of Boynton's projected figures was approximately 5 cm, with an average dimension of 3 cm which is comparable with the size of many of the recovered artefacts. The experiments showed that, given good contrast, the percentage of correct recognitions achieved at a distance of 5 metres was between 85% and 90%. A collector of average stature scanning the ground

some two and a half metres ahead has a line of sight of about 3 metres, well short of Boynton's value, suggesting that distance, at least, should not be a significant constraint in identifying the larger artefacts. However, assuming that this result can be scaled with visual angle - and Boynton cautions that this simple equivalence does not always hold - artefacts only 1 cm mean dimension are then being viewed at an experimentally equivalent distance of 15 metres at which distance Boynton's results suggest correct recognition in not more than 40% of cases. On this bases, an appreciable number of the smaller items will not be recovered from the grid.

More recently a second series of experimental results on the search for targets in cluttered visual fields have been published (Williams, 1969). His search field (p. 221) consisted of ' ... 100 forms of a given size (about 2.8, 1.9, 1.3 or 0.8 degrees in visual extent), a given colour (blue, green, yellow, orange or pink) and a given shape (circle, semi-circle, triangle, square or cross).' Each target was projected in a field and carried an identifying number. Subjects were required to locate and specify numerically a particular target given varying amounts of information about its size, shape and colour.

Williams found that subjects located objects much better on the basis of colour than on size or shape. Mean times to find an object specified by colour alone was 7.6 seconds, whereas corresponding times for objects specified by size only was 16.4 seconds and shape only was 20.7 seconds. This latter value may be compared with that obtained by Boynton, whose figures were smaller and apparently black on a white background. In Boynton's case 90% correct identifications were obtained given a 24 second exposure.

Relevance of Experimental Results to Surface Collecting

The similarity between the general colour of the lunette surface and the artefacts has been noted. Furthermore, the size of the majority of artefacts is comparable to that of the beach gravels. Thus the two discriminating factors that Williams found to be most effective are very weakly represented at Mungo, leaving shape as the major basis on which the collectors must operate. It may be noted in passing that Williams' results confirm impressions gained during discussion with the collectors, which suggested that, although they were unaware of the experimental results, colour and shape contrast were important to them in detecting artefacts.

The low contrast at the grid may be improved when collecting is carried out on days of clear sunny weather and the shadows thrown by the objects provide increasing contrast. This may be one reason that collecting seems more difficult in the middle of the day when the increased sun angle minimises shadow. Similarly, collecting on a uniformly overcast day seems less easy.

Textural contrast exists between the consolidated sandy-clay surface and the sand locked in the silcrete matrix of stone fragments. This textural disparity can be a useful stimulus, particularly after light rain or in drizzle conditions when the stone material is more highly reflective. This is often reinforced by a slight darkening of moist soil surface. It is a matter of judgement, therefore, whether sunny or damp overcast conditions are preferable. A dismal and uncomfortable environment may have a counterproductive effect on morale.

The role that surface conditions play in collecting has been noted by Ammerman and Fieldman (1978), when recovering obsidian and other fragments from a surface of sandy clay soil. Their impression was that ' ... an overcast day ... seems to offer better light conditions for seeing

pieces of obsidian on the ground' (p. 736), but they do not elaborate on the departure from normal conditions which are responsible for this.

Surface texture of the artefacts may be particularly important in the case of the 'rolled' artefacts which are believed to have been subjected to wave motion on ancient beaches. Both the texture and shape of these artefacts approach those of the beach gravels amongst which they are found. It is is to be expected therefore that proportionally fewed rolled artefacts are recovered compared with their unrolled counterparts.

Ammerman and Fieldman comment on the ambiguities in statistical data which may be introduced through varying conditions as collectors move across the site. In addition to the ambient light and weather conditions discussed above, the motivation of the collectors as affected by boredom and fatigue introduces yet another factor. This might be overcome to an indeterminate extent by 'salting' the grid with a small number of artefacts, which are later identifiable, the recovery of which would bring that collector significant material or monetary reward. A similar strategy was employed by Boynton (1957) in his perception experiments to maintain interest. The need for such inducement has not seemed necessary at Lake Mungo.

I made one unsuccessful attempt to assess the variability in collecting performance between pairs of observers by recording in code form the squares collected by each pair and assigning squares to them in a chance manner intending to make statistical comparisons between items collected. Unfortunately, the only squares from which statistically significant quantities of material were recovered and which were otherwise comparable in such respects as exposed deposit, presence of beach gravels, and so on were collected by pairs which included

experienced and highly motivated collectors. Not unexpectedly in the light of this there was no significant difference between the material recovered.

I was unable to devise a simple, controlled experiment by which to assess the efficiency of collection under conditions which prevail at Mungo but two relevant experiences can be recalled. In the first, following overnight rain and in incorrect reading of the local raingauge by which the amount of precipitation was overestimated by a factor of ten, I re-collected over a square from which the surface material had been recovered the previous day. I was therefore fully expecting to find many additional implements as the products of erosion and presumably not biased by the knowledge that a collection had been made. I recovered a total of four or five fragments of silcrete only, a quantity fully explicable in terms of the changed contrast due to their surface sheen and the darkened dune surface from the additional moisture.

In the second incident, when searching for a small dummy artefact placed on the surface of the grid among the beach gravels, it has taken me a conservatively estimated minute to relocate it, even knowing its expected position. Acknowledging that elapsed time cannot be estimated accurately, this experience seems to bear out Boynton's result of 25 seconds for an 80% identification accuracy.

Dismissing as unacceptable the conclusion from these events that I am a poor collector on the grounds of my accumulated experience, these casual events suggest that the standard of collection is high but that considerable care is necessary in areas where the background is cluttered by pebbles.

The Effect of Erosion on Sample Content

This discussion has been concerned with the material already exposed at the surface and the extent to which the recovered sample is representative of it. The ultimate interest of the pre-historian, however, lies with the material which is buried within the lunette. It is relevant, therefore, to consider whether differences are possible between the exposed and buried material, ie. between the samples recovered from the surface annually and the one that would be recovered by an excavation.

It is clear that given uniform distribution of artefacts in both cases the range of artefact types that will be recovered is determined by the volume of the dune that is removed, or for a given area, the depth by which the surface is lowered. The rarer items are less likely to be included in a thin slice through the dune while examples of well represented types will always be recovered. Similarly, on those occasions when uncommon material is present the quantities may be disproportionately high in comparison with those in the dune as a whole.

At first sight it might appear that the size of the artefacts could influence their frequency of recovery since items with large dimensions would span several erosion levels. However, as can be demonstrated readily with a pocketful of loose change thrown down on lined paper to represent a vertical section through the lunette, provided the collection strategy is such that no item is recovered unless completely exposed, as was the case with the surface collections at Mungo, the recovered sample is fully representative within the limitations imposed by sample size.

In an excavation the depth of material exposed can be controlled; under erosion it cannot. If erosion is not severe the effect will be such that it may take annual collections extending over several years for a representative sample to be obtained. At Lake Mungo this was overcome by collecting over a large area.

Conclusion

This short discussion has underlined the need for surface collection to be performed by a small team of adequately informed and motivated individuals. Close supervision should not then be necessary beyond ensuring that those squares allocated are in fact those in which collections are made. Studies of visual acuity suggest that some bias may be introduced into the collection by the greater colour contrast between the olive-yellow of much of the silcrete and the redder Mungo soil. Given the much greater density of material recovered from the Mungo areas (see Chapters 5 and 6), this probably is of little consequence. Based on the same studies, it is probable that a proportion of items smaller than about 1 cm maximum dimension are not recovered.

CHAPTER 5

ANALYSIS OF SURFACE MATERIAL BY LOCATION

Introduction

An analysis of surface material requires some discussion of its provenance. It is necessary, in the present case,for example, to assess the confidence with which it can be assumed that the material, once exposed on the dune surface, remains at that location. Once the material has been identified as originating unambiguously from either the Mungo or Zanci deposits, an assessment can be made of the systematic differences, if any, that exist between characteristics of the material from each location.

The data on which to make the distinctions consists of the statistical descriptions of each artefact class. Measurement of characteristics such as length, width, thickness, number of primary and secondary flake scars, length of retouch and so on for each carefully defined class of artefact can be summarised in terms of the resultant frequency distributions with their associated means and standard deviations. Formal statistical tests can then be applied to explore the degree of similarity between these data and thus between the artefact classes from each area. These aspects are considered further in Chapter 6. In contrast, in the following discussion, interest centres mainly on the numerical surface distribution of the artefact classes, rather than on their characteristics.

Differences between the frequency distributions of the same class of artefact in separate areas of the grid could be due to two reasons:

* Inherent differences in the material originally deposited at those locations; and

* Differences resulting from some sorting process in which, for example, lighter or smaller material is carried downslope by heavy rain. The discussion in Chapter 3 shows that this systematic movement is a possibility.

Similarly, an absence of distinguishing characteristics between the statistical description of artefacts of the same class in two regions of the grid could indicate:

* An innate similarity.

* The action of unsystematic 'random' processes thoroughly mixing the material.

There are six situations applicable at the Lake Mungo lunette arising from appropriate combinations of such factors and these are summarised in Table 5.1.

Practical Considerations

The analyst, dependent only on data obtained from the collection is, of course, ignorant of which of these situations pertains. He or she knows only whether the general characteristics and the frequency distributions of the measured attributes of the material collected from the Mungo and Zanci surfaces are the same or not. Further information which may identify systematic movement is available from comparisons between appropriate regions of the surface area. There seems to be no means, however, based on the characteristics of the collection alone, by which to recognise that thorough mixing has occurred. Data reduction in Situations 1 and 6, providing the mixing is sufficiently thorough in the latter case, will show the material characteristics to be uniform across the site and it will not be possible to ascertain whether Mungo and Zanci material differs.

		PAST MOVEMENT OF MATERIAL		
		NOT MOVED	SYSTEMATICALLY MOVED	UNSYSTEMATICALLY MOVED
Characteristics of material found on Mungo and Zanci deposits	Same	Situation 1	Situation 2	Situation 3
	Different	Situation 4	Situation 5	Situation 6

Table 5.1 POSSIBLE SITUATIONS RESULTING FROM DISTURBANCE

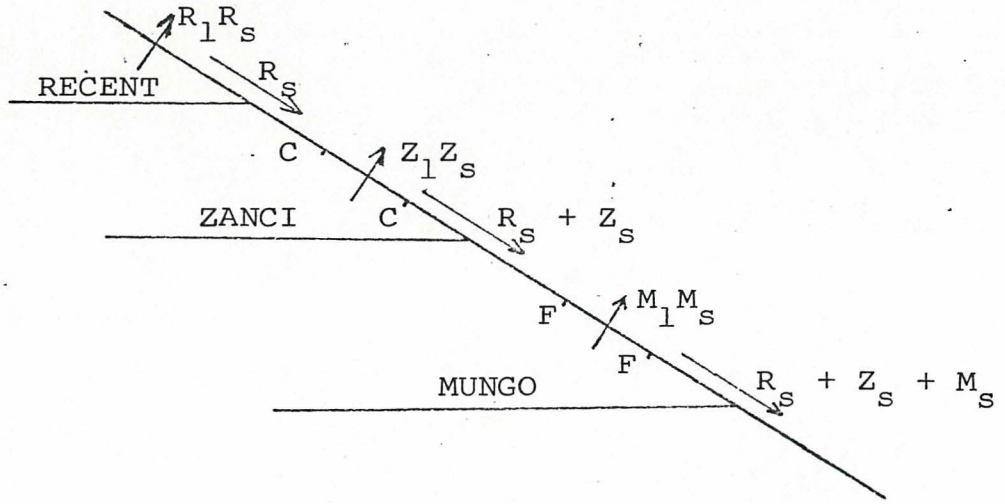
Fortunately, uniform mixing during the formation of the lunette appears to be most unlikely at Lake Mungo. The exposed sections of the dune retain the primary bedding in both the Mungo and Zanci deposits and the deposits themselves are separated by a region of soil development (Bowler, 1971). These factors suggest that any movement which occurred across each temporary surface and its neighbours was limited in scale and rarely, if ever, extended from one type of deposit to the other.

Post erosional mixing is less easily dismissed. Evidence presented later in this chapter shows that some dummy artefacts deposited on the grid area have moved against the direction of the local slope but the discovery of a group of the larger of these replicas suggests that human interference is responsible for some, at least, of this movement. If it can be assumed that significant unsystematic movement is absent from the grid, Situations 3 and 6 of Table 5.1 may be dismissed from further consideration. Situations 2 and 5, where some consistent movement is operating, are then of interest. The most probable mechanism is that of erosion.

Consider, for example, the situation illustrated in Figure 5.1a, where material is being washed down an eroding slope consisting of Zanci and Mungo deposits overlain by surface of recent origin. Consider further two grid squares CC and FF in the Zanci and Mungo deposits.

Assume that material is being eroded from the three surfaces and that in each case the eroded material is made up of two components, one of which may be characterised as 'large' and is not moved down the slope by surface flow, wind erosion of any of the other factors discussed in Chapter 3, while the other 'small' component is subject to such movement.

At any one time the contents of grid square CC will consist of the following (see Figure 5.1b):



Note: See p 85 for nomenclature

Figure 5.1a: Schematic Section of lunette

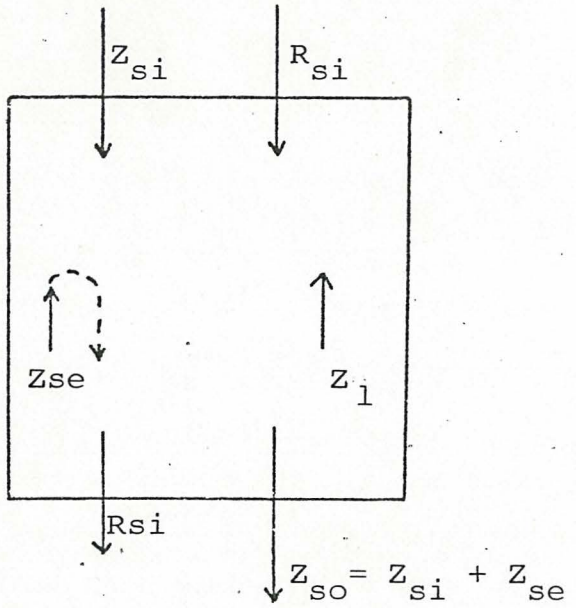
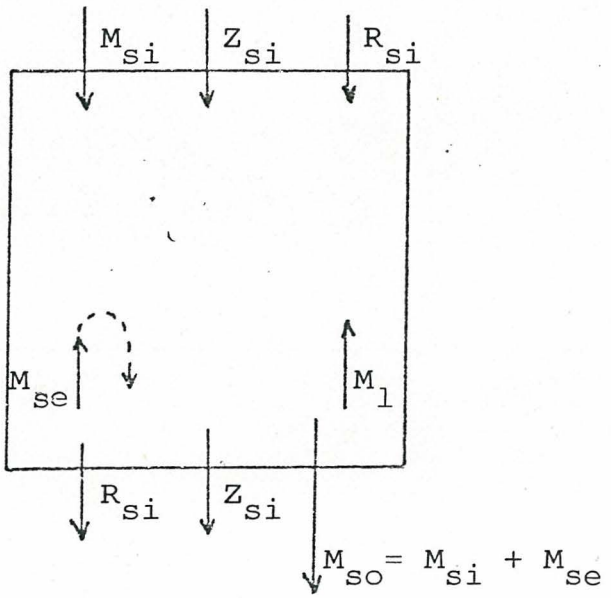


Figure 5.1b: Schematic diagram of Zanci square CC



Note: See p 85 for nomenclature

Figure 5.1c: Schematic diagram of Mungo square FF

Z_1 derived from CC itself by erosion. This component remains in CC.

Z_{se} derived from CC itself by erosion but which will subsequently move out of CC.

Z_{si} derived from Zanci areas above CC.

R_{si} derived from recent areas above CC.

Z_{so} Zanci material leaving CC.

Similar subscripts apply to the material from Mungo and recent deposits.

If Z_1, Z_s, etc. represent the number of artefacts in each class, then Z_1 and Z_{se} are dependent on the rate of erosion and the time which has elapsed since the last collection. The rate of erosion, in turn, is a function of surface slope, weather and catchment area above the slope. The components moving into the square, Z_{si}, R_{si} depend on the slope and the density of material above CC, while the final item Z_{so} also depends on slope and on the density of material of the 'small' class within CC. Assuming a uniform slope across the square and that a steady state has been reached, component R_{si} passes across the square, while

$$Z_{so} = Z_{si} + Z_{se} \qquad \text{.....(1)}$$

This equation merely states the obvious in that, from a region of constant slope from which material is being eroded more or less uniformly, the amount of material being moved increases as one moves down the slope.

The contents of square FF in the Mungo surface (Figure 5.1c) could be discussed in a similar fashion, but note that, in this case, the term Z_{si} is not the same as Z_{si} of Figure 5.1b but is equal to Z_{se} of the lowermost Zanci square above FF.

Let us now relate this ponderous diversion to Table 5.1. In Situation 2 the material derived from the Mungo deposit and the Zanci deposit initially have identical characteristics. The discussion following Equation 1 above indicates that in the lower Zanci squares, or the squares of either deposit since in Situation 2 the Mungo and Zanci material have the same traits, an increase in the amount of material in the 'small' class present is to be expected. Thus, a comparison of the frequency distributions of material derived from the upper and lower levels of the grid will show the mean of the latter to be the smaller of the two.

If the characteristics of material from the two deposits are not the same, as is postulated in Situation 5, then the effect on the statistics of the recovered sample of movement of the Zanci 'small' component onto the Mungo squares is not clear. The differences between the two distributions may be accentuated or masked. However, if material from the <u>same</u> deposit but at different levels down the slope are examined, then any differences, as a first approximation, can be ascribed to movement.

The mechanism postulated above assumes that the eroded surface is uniform and the material moves down it in a more or less direct fashion. There is an alternative process which, although vastly different, would result in a similar difference between the relative quantities of a given class of material in the upper and lower parts of the grid. This alternative still assumes that the smaller items are carried away but that they are quickly channelled into any erosion gullies and ultimately deposited in the lower grid squares onto which some gullies drain. Other flakes could be carried from the grid entirely by the larger gullies which give onto the lake floor. Because the upper rows of the grid in general correspond to the steeper parts of the eroded surface, the result would be a net depletion of material from these rows when compared with those at a lower level. Casual observation at the

site suggests that this process, while plausible, is not a vigorous one since concentrations of artefacts are not found in the gullies after rainfall. It might be of interest, however, by means of a test excavation, to examine the products of erosion where they have been redeposited as fans at the mouths of the gullies that issue onto the lake bed in order to determine what type of material is transported from the grid.

The foregoing discussion on systematic movement assumes that in its absence the recovered samples would be totally representative of the material from each deposit. In other words, the sample of flakes recovered from a Mungo deposit includes the complete range of flakes resulting from all stone working activities during that period of the Mungo era corresponding to the exposed deposit. This assumption is open to question. It may be that the lower Mungo grid squares were the site of water-adjacent activities differing from those pursued further up the dune, in which case the two recovered Mungo samples being used to detect movement, although derived from the same parent population, would differ, leading to a positive, but erroneous, conclusion concerning movement. Although this possibility must be borne in mind, the scale of the present investigation in terms of grid size and the vagaries of the erosion process, which does not necessarily expose simultaneously areas of contrasting activity, precludes its further exploration.

Comparison of Material

In the light of this discussion what useful comparisons can be made between the material on the exposed deposits? The choice is partially constrained by the areas exposed and their relationship to the topography and to the fixed grid pattern. During the 1978 collection an attempt was made to overcome the latter constraint by collecting by quarter squares in those parts of the grid where the Mungo and Zanci surfaces were present in the same grid square.

Resulting from the conditions at the generally inclined surface of the grid, three main comparisons are possible (fig5.2): items from Mungo and Zanci deposits at the same relative distance down the slope (both in row C), and material from Zanci deposits with that from Mungo deposits at the upper and lower levels. Three further comparisons involving Zanci material at the lower level have less import because there are no squares in which Zanci deposits are exposed exclusively in row F. The irregular nature of the deposits in the mixed squares in this row made subdivision into quarter squares during collection in order to increase the sample size unprofitable.

Chapter 6 describes the categories into which the material recovered during the collection was sorted. In each year's collection, apart from irregularly shaped fragments, unretouched flakes comprise the largest group of formalized artefacts. Their comparative simplicity in shape, the lack of ambiguity in defining the attributes required to assign membership of the group and their abundance makes this group an excellent subject for analysis. This has been recognised by Pitts (1978), (Pitts, et al, 1979), who compared flakes from several Mesolithic and Neolithic European sites and by Isaac (1977a) at Olorgesailie. The classification criteria adopted here for an unretouched flake were simple: the presence of a bulb of percussion, a striking platform and a lack of retouch along dorsal or bulbar faces or the flake margins.

For convenience, both the frequency and the surface distribution of unretouched flakes will be considered together and, to this end, the length, width and thickness of all unretouched flakes collected during the 1978 collection were measured. Length was defined as the maximum distance along the perpendicular to the striking platform to a line tangential to the flake margin and parallel to the striking platform. Width was the maximum distance across the flake parallel to the striking platform while thickness was measured along the mutually perpendicular direction.

Statistical Comparisons. The study of statistics and the theory of probability have resulted in a framework of methods being available so that comparisons can be made between samples such as the flakes from different areas in the collection. These are referred to as 'tests' in the sense that a method is chosen to test some hypothesis postulated before the samples are drawn. The samples are shown to be consistent or not consistent with the prior hypothesis. Commonly the null hypothesis is tested against an alternative hypothesis which usually corresponds to a conclusion which could be drawn from the research being undertaken. In the case of two sample means, for example, the null hypothesis states that the means are equal, while the alternative hypothesis could be that a particular sample has the larger mean.

Prior to the 1940s most statistical tests were based on the assumption that the populations from which the samples were drawn had normal distributions. Since then, however, non-parametric statistical tests have been developed which are free from such limiting assumptions. A short history of this development may be found in Bradley (1968).

The advantages to be gained from using non-parametric tests are discussed in non-mathematical terms by Siegel (1956). Primarily, such tests do not require any prior assumptions to be made concerning the shape of the population from which the random sample was drawn. In other words, its parameters need not be known. Other advantages include the availability of some non-parametric tests to deal with data which can only be ranked rather than given numerical values. A further important advantage claimed by Siegel for non-parametric statistical tests is that they ' ... are typically much easier to learn and to apply than are parametric tests.' (1956, p. 33).

Non-parametric statistical tests may be applied to determine whether the distributions of the dimensions of the recovered samples of unretouched flakes were such

that they could be assumed to come from the same population. The test used here is the Kolmogorov-Smirnov two sample test, which is a test of whether two independent samples have been drawn from the same population or, as Siegel carefully notes, from populations with the same distribution, for the two cases are indistinguishable. Except where otherwise stated, the 5% significance level is used. A brief description of the Kolmogorov-Smirnov test is given in Appendix C.

Analysis of the Distribution of Flakes

The results obtained when unretouched flakes collected from the relevant areas were tested are summarised in Table 5.2. The mean, $\bar{x}$ and standard deviation, $S_{\bar{x}}$ of the corresponding samples are given in Tables 5.3 and 5.4.

Comparison of the dimensions of the recovered samples of unretouched flakes showed that only when flakes from row C were compared with those in row F was a difference between the parent populations indicated. In this case in each comparison of length, width and thickness the difference is significant at the 1% level (Table 5.5). In other words, there is a chance of less than one in a hundred that the distributions of the flakes in rows C and F could have been obtained from populations with the same frequency distribution. As neither distribution was weighted by very large or very small flakes, calculation of the means and standard deviations showed that row F contains both more flakes and more small flakes than row C.

Frequency Distributions. What conclusions may be drawn from these results? Comparison of the Mungo and Zanci material in row C, the uppermost extensive row, shows no significant difference in the dimensions of the two samples. This is supported by a similar result in row F. Here, however, the 'Zanci' sample was collected from squares which contained a small proportion of exposed Mungo surfaces so that the sample may have been biased. Additionally, the possibilities that no differences were detected due to the smallness of the supposed Zanci sample or were masked by

SOURCE OF SAMPLES	PARAMETER TESTED		
	Length	Width	Thickness
Row C Mungo deposit vs Zanci deposit	NS	NS	NS
Row F Zanci deposit vs Mungo deposit	NS	NS	NS
Row C vs Row F Zanci + Mungo deposits	S	S	S
Row C Mungo deposit vs Row F Mungo deposit	NS	NS	NS

NS = Not Significant at 5% level
S = Significant at 1% level

Table 5.2 SIGNIFICANCE BETWEEN SAMPLES OF UNRETOUCHED FLAKES

SOURCE OF SAMPLES	Length						Width						Thickness					
	Mungo			Zanci			Mungo			Zanci			Mungo			Zanci		
	$\bar{X}$	S_x	n	$\bar{X}$	S_x	n	$\bar{X}$	S_x	n	$\bar{X}$	S_x	n	$\bar{X}$	S_x	n	$\bar{X}$	S_x	n
Row C Mungo vs Zanci	2.05	1.02	60	2.17	0.86	94	2.07	0.91	54	2.03	0.77	97	0.57	0.36	56	0.63	0.27	104
Row F Zanci vs Mungo	2.05	0.82	60	2.04	0.71	41	2.02	0.79	62	2.04	1.28	41	0.60	0.32	61	0.52	0.28	41

TABLE 5.3 - UNRETOUCHED FLAKES. MEANS AND STANDARD DEVIATIONS OF SAMPLES

SOURCE OF SAMPLES	Length						Width						Thickness					
	Row C			Row F			Row C			Row F			Row C			Row F		
	$\bar{X}$	S_x	n	$\bar{X}$	S_x	n	$\bar{X}$	S_x	n	$\bar{X}$	S_x	n	$\bar{X}$	S_x	n	$\bar{X}$	S_x	n
Row C vs Row F(Zanci & Mungo)	2.15	0.87	171	1.84	0.70	169	2.10	0.88	166	1.77	0.67	172	0.62	0.34	170	0.49	0.27	176
Row C vs Row F(Mungo only)	2.05	1.02	60	2.05	0.82	60	2.07	0.91	54	2.02	0.79	62	0.57	0.36	56	0.60	0.32	61
Square C19 (Zanci & Mungo)	2.12	1.00	79	-			2.06	0.91	79	-			0.63	0.39	79	-		

TABLE 5.4 - UNRETOUCHED FLAKES. MEANS AND STANDARD DEVIATIONS OF SAMPLES

Source of Samples	Length		Width		Thickness	
	D_{max}	$D^{(1)}$	D_{max}	$D^{(1)}$	D_{max}	$D^{(1)}$
Row C Mungo vs Zanci	0.164	0.225	0.106	0.239	0.167	0.240
Row F Zanci vs Mungo	0.143	0.300	0.219	0.300	0.195	0.300
Row C vs Row F Zanci + Mungo(2)	0.181	0.177	0.190	0.177	0.198	0.175
Row C vs Row F Mungo	0.149	0.185	0.168	0.252	0.168	0.283
Row C Zanci vs Square C19	0.154	0.213	0.075	0.213	0.152	0.203

Note: 1. Generally significant at 5% level if $D_{max} > D$.
2. In this row only, significant at 1% level if Dmax > D.

Table 5.5 Critical Values for Kolmogorov-Smirnov test.

an influx of Zanci material that might have been washed down from the upper rows cannot be excluded. The latter possibility may be the reason for the significant difference between the predominantly Zanci row C and the predominantly Mungo row F, and is consistent with the inability of the Kolmogorov-Smirnov test to distinguish between the two deposits at the same level in row C. Unfortunately, the contours and limited extent of the site prevent a direct test of flakes from that part of the Mungo deposit in row F which has only Mungo material in the corresponding squares above it. Thus it is not possible to test the possibility of flakes being moved down an all-Mungo slope. A comparison of the flakes in the Mungo deposit in squares C 19, 20 and 21 with those in F 17, 18 and 19, which are the closest in vertical alignment, revealed no significant difference, suggesting that no additional small flakes were present in squares F 17 to 19. A possible explanation here may be that the Zanci flakes are deflected from these squares by the local contours of the site, yet in contrast, no significant difference exists between squares F 17-19 and F 4-9, indicating that the flakes in the former are not atypical of those found elsewhere in the row.

As an alternative way of investigating the differences between the unretouched flakes, scatter diagrams of flake length versus width were plotted for the flakes from squares 13, 14 and 15 for each row. These diagrams summarise the manner in which the flake outline changes with size. There were no obvious differences between rows and this was confirmed when linear regressions were calculated. The resulting regression coefficients and correlation coefficients are shown in Table 5.6. Application of the t-test to the regression coefficients a_1 (Crow, et al, 1960) showed that there was no statistical difference between the extreme values. There is thus no suggestion that flake shape differs across the grid. This is to be expected in view of the uniformity of the stone unless different flaking techniques were employed.

AREA FROM WHICH FLAKES RECOVERED	n	REGRESSION COEFFICIENTS		CORRELATION COEFFICIENT
		a_0 [1]	a_1 [1,3]	r
C 13 14 15	51	0.908	0.512	0.607
D ditto	20	0.815	0.536	0.699
E [2] ditto	54	0.674	0.560	0.687
F ditto	122	0.701	0.552	0.629

Notes: 1. $w = a_0 + a_1 l$

where w = flake width

l = flake length

2. Excluding Zanci area of E 14

3. No statistical difference between extreme values of a_1 $t = 0.067$, $t_{.025,101} = 1.98$

Table 5.6 UNRETOUCHED FLAKES - Regression of Width vs Length for Squares 13 to 15

Area Distributions. Turning now from the characteristics of the unretouched flakes to their quantity, Figure 5.2 records the average number of flakes recovered in each square per year over the four year period by treating the 1978 collection as a two year accumulation. Data from each collection is shown in figs 5.3 to 5.5.

Comparison with the diagram of the exposed deposits shows that flakes are more numerous in the areas where the Mungo exposures occur. The initial impression is that the correlation is very high, particularly in rows C and D and to a lesser extent in the other two. Row F, being almost entirely on the Mungo surface, has a correspondingly higher average number of flakes per square. Statistical methods, based on very restrictive assumptions of normality, are available which formally test the degree of linear association between one quantitatively measured variable (the number of flakes) and another artificially dichotomised variable (presence or absence of Mungo deposit) through the biserial correlation coefficient (Ostle, 1963).

Because the validity of applying the test to the Lake Mungo data was most questionable, this coefficient was not calculated. However, closer inspection of Figure 5.2 reveals that the correspondence is by no means perfect. For example, in Row C why does Square 20, which, like Square 19, lies on the Mungo surface, not contain a comparable number of flakes? Again, in Row D Squares 19, 20 and 21 are rich in flakes and yet the Mungo exposure is to be found in Squares 20, 21 and 22. Clearly some additional factors are present to account for these and other discrepancies, including an absence of peaks in Row E at Squares 5 and 6, the premature decline in values in Squares E 20 and E 21 and the troughs at Squares 8 and 9 of Rows C and D which do not correlate with the exposed deposits.

It is probable that the micro-topology of the grid surface may, in part, be responsible, giving varying erosion and possibly migration rates. In Rows C and D, for example, flake numbers are better correlated with the

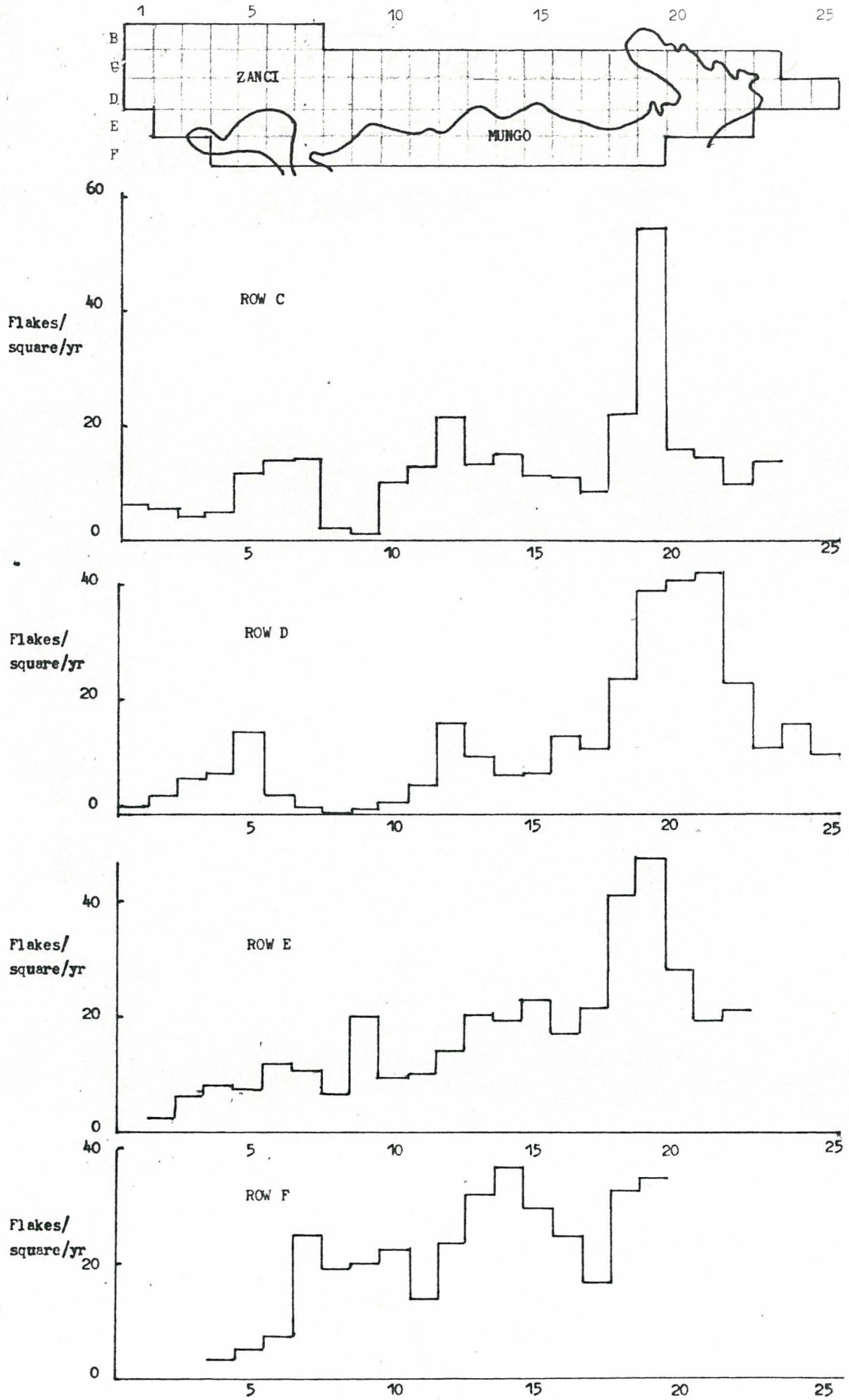


FIG 5.2 Average flake density across grid 1975-78

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
B	26	9		12	20	4	10																		
C	18	9		1	33	29	16	3	4	21	17	32	22	28	16	13	12	35	72	31	22	18	22		
D		2		6	30	1	1	0	3	2	2	19	12	8	18	34	19	47	41	68	85	57	24	17	8
E			20	9	13	15	19	10	15	7	10	27	20	36	42	40	44	49	80	60	17	22			
F					12	8	18	21	20	15	3	22	26	38	26	40	11	84	76						

Fig.5.3 - Spatial Distribution of Unretouched Flakes, 1975

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
B	17	16	7	9	6	8																			
C	3	8	7	13	7	18	26	2	0	11	11	24	9	13	22	22	15	43	64	14	16	8	19		
D	3	5	14	14	15	3	1	1	1	0	7	7	14	12	5	16	18	15	76	53	47	16	12	17	10
E		6	3	14	10	9	13	11	8	6	11	14	24	20	24	20	27	78	58	32	27	16			
F				11	7	5	28	33	20	32	15	30	47	47	39	23	30	26	34						

Fig 5.4 - Spatial Distribution of Unretouched Flakes, 1976

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
B	11	2	3	7	7	6	22																		
C	2	5	4	4	6	9	13	3	1	4	19	30	25	18	8	10	5	16	79	21	19	13	11		
D	1	5	5	8	13	2	3	0	1	0	11	36	12	6	6	4	9	24	36	40	35	16	18	30	19
E		2	3	9	7	18	12	5	28	14		27	34	25	28	8	15	38	58	16	34	46			
F				2	2	16	50	21	48	39	34	41	54	59	52	55	21	20	21						

Fig 5.5 - Spatial Distribution of Unretouched Flakes, 1978

Mungo exposures immediately above the row in question, suggesting some migration down the slope. Again, however, there are some discrepancies as comparison with the contours of Figure 2.4 show. Similarly, comparison with the depth of erosion, as indicated by peg exposure (Table 3.1) did not confirm that flake densities were directly related to the quantity of material removed. Closer study of the grid surface may provide more consistent explanations. Nevertheless, the general impression gained from Figure 5.2 is one of correspondence between Mungo exposures and higher flake densities. The picture was the same each year, ruling out any large scale unsystematic disturbance and suggesting that in any disturbance which does take place horizontal displacement of much of the eroded material is limited.

While the details remain to be determined, the assumption that the Mungo deposit has a higher flake density than the Zanci areas seems valid. Nevertheless, the characteristics of the flakes themselves, in terms of the frequency distributions of length, width and thickness, do not differ in a statistically significant way. This remained so even when, as a final test, the flakes from the 1978 square C 19 only were tested against Row C Zanci material (see Tables 5.4 and 5.5).

Discussion

Three principal results emerge from this study of unretouched flakes:

a. The lowermost row of the grid, row F, contained significantly more small flakes.

b. There was no statistically significant difference between the linear dimensions and the length to width relationships of flakes from the Mungo and Zanci surfaces.

c. There is a strong suggestion of correspondence between the surface density of the flakes and exposed deposit in that increased flake numbers are to be found on the Mungo deposit.

Two additional results must be considered. These are:

d. There was no significant difference between the characteristics of the flakes from the Mungo surface in the uppermost row C and lowermost row F.

e. There was far from perfect correlation between increased flake surface densities and Mungo exposure.

My conclusion is threefold. Firstly, the characteristics of the unretouched flakes from both the Mungo and Zanci deposits do not differ significantly. Secondly, flake densities are higher on the Mungo surfaces than on the Zanci deposits. Finally, some movement, mainly of the smaller flakes, is taking place. Such movement explains their increased frequency in row F and, given the contours within the grid, contributes to the discrepancies between the flake densities and Mungo exposure. Since the movement is down the local slope, it may also account for the similarity between the flake distributions from Mungo deposits in rows C and F because the contours of the Mungo area in row C are such that small flakes could be washed into it from adjacent Zanci squares in the same row.

Assessment of Flake Movement

The conclusion that movement is occurring finds support in the experimental work of Appendix A. Further confirmation was sought by placing dummy artefacts at points across the site and measuring the distances that they had moved one year later. This experiment is described

in Appendix B. The results were inconclusive as some of the markers were grossly interfered with, some apparently moved in a direction opposed to the local slope, while the translation of others was feasible.

Unretouched Rolled Flakes

The most obvious of the sub-categories occurring in the recovered material is that class of artefacts that Bowler refers to as 'rolled', (Bowler, et al, 1970). These have had all sharp edges rounded and are readily distinguished both by eye and by touch, since they possess a surface lustre which gives the artefact what can best be described as an 'oily' feel when handled. Such artefacts are found mainly, but not exclusively, among the beach gravels in the lower squares of the grid (see fig 5.6).

As is the case with the unrolled material, the most frequently occurring of the rolled classes is that for unretouched flakes. These have been excluded from the comparisons of unretouched flakes discussed above for examination now (see Table 5.7 for means and standard deviations).

When the statistical distributions of the rolled and unrolled flakes in row F were compared, there was no significant difference between the two groups in terms of length and width. A significant difference was indicated at the 5% level, however, when thicknesses were compared. A difference in dimensions might be expected if both the rolled and unrolled flakes were originally derived from the same population and one group was subsequently subjected to the abrasion of a beach environment. To explore this hypothesis further, the Kolmogorov-Smirnov test was repeated with an extra 0.5 millimetres added to each of the length, width and thickness dimensions of the measured flakes.

The result was to reduce such differences as there were between the rolled and unrolled distributions

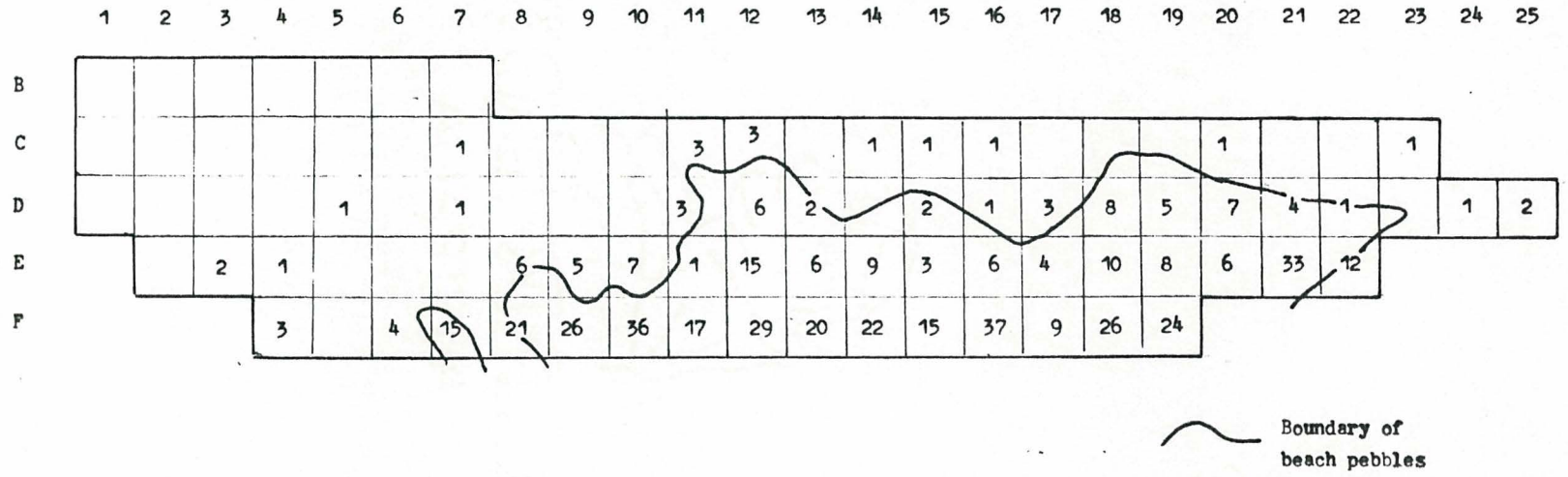


FIG 5.6 Distribution of rolled unretouched flakes 1975-78

SAMPLE	Length			Width			Thickness		
	$\bar{X}$	S_x	n	$\bar{X}$	S_x	n	$\bar{X}$	S_x	n
Unrolled	1.90	0.66	173	1.76	0.66	171	0.49	0.23	173
Rolled	1.72	0.81	173	1.72	0.51	173	0.43	0.17	172

TABLE 5.7 - DIMENSIONS OF UNROLLED AND ROLLED UNRETOUCHED FLAKES

to the extent that, even in the case of flake thickness, the differences were no longer large enough to exceed the arbitrary 5% significance level (see Table 5.8).

Casual observation of the behaviour of flat pebbles subjected to wave action at both sea and inland lake beaches indicates that, while some stones flung up the beach by vigorous wave action may immediately return down the beach slope by rolling with their longitudinal axis horizontal, much of the motion of such pebbles under quieter conditions is a sliding movement with one of the larger faces against the abrasive beach surface.

If these observations are representative, the results of the significance tests are consistent with the hypothesis that the dimensions of the rolled and unrolled flake originally were similar but because the stable position of the flake brings the bulbar or dorsal surface into contact with the beach most often the thickness of the flake suffered a proportionately greater reduction as a result of wave motion.

Even if it is accepted that the rolled and unrolled flakes are derived from populations having the same dimensional characteristics, this provides no useful additional information as to the origin of the rolled flakes. Are they from the Mungo period, Zanci period or a mixture of both?

There were probably several events during both the Mungo and Zanci periods when high water levels and wave action washed away portions of the lunette or left beach gravels high up the beach. Since the pebbles lie also upon Zanci deposits some, at least, of the rolled flakes were probably derived from the Zanci period. It follows that the rolled flakes include both Zanci and Mungo components. Comparison of mixed material with either of its parent populations is unlikely to result in differences.

Dimension	Length		Width		Thickness	
	D_{max}	D	D_{max}	D	D_{max} (1)	D
As measured	0.104	0.145	0.092	0.147	0.155	0.148
Measured + 0.5mm	0.092	0.145	0.033	0.147	0.127	0.148

Note: 1. Significant at 5% level if $D_{max} > D$

Table 5.8 Rolled flakes. Critical values for Kolmogorov-Smirnov test (5% level)

Those isolated rolled flakes that lie outside the area of beach gravels are not without interest in the light of earlier discussion concerning disturbance at the grid. Did their displacement from the beach gravel area occur before or during the time that the lunette was sealed or is it post-erosional? There seems to be no way of deciding.

Surface Distribution of Implements

The surface distribution of the most abundant class of artefact, the unretouched flake, has been shown to have a strong, but not exclusive correspondence to the exposed Mungo deposit. Such was not obviously the case with the other main classes into which the material was sorted: the cores and the scrapers.

Cores. In the 1975 collection most of the 87 retouched and unretouched cores were recovered from the western end of the grid but were not strongly concentrated in the Mungo area. The 1976 and 1978 collections yielded fewer cores. Of the 46 obtained in 1976 some were grouped at the western end but in 1978 the 26 cores were distributed in an apparently random fashion. These distributions are shown in figs 5.7 to 5.9.

Scrapers. These consisted of retouched flakes and pieces (see Chap 6) and were not located in any obvious pattern in any of the three collections. Only in 1976, which yielded the least number, was there a weak tendency for more to be found along the upper row of the grid (see figs 5.10 to 5.12).

One of the striking features of the distribution of the exposed surface material on the Lake Mungo grid is that artefacts rarely, if at all, occur in clear association with each other. With the exception of occasional hearths, there are no areas in which the debris suggests a particular activity. For example, during field work I have unsuccessfully examined supposed hearth areas and the regions surrounding apparent concentrations of artefacts for

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
B		1		1																					
C						1	3	1	1		2		2		1	1		4	4		2		1		
D													2	1	3	1		1				4	1		
E			1				1			1		2		2	5		2		2	2	1				
F							2		1	2				2	2			5	2						

a. Unretouched Cores

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
B		1																							
C															1					3					
D														1							2			1	1
E						1																			
F															2			1							

b. Core Scrapers

Fig 5.7 - Spatial Distribution of Unretouched Cores and Core Scrapers, 1975

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
B	2	1		1																					
C							1									1									
D																	2		2	1				1	
E				1	1			2	2	3					1			2		1					
F									1			1		1			1	1							

a. Unretouched Cores

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
B																									
C			1													1			1						
D				1														1				1			
E								2		1				1						1		1			
F							1	1				1							1						

b. Core Scrapers

Fig 5.8 - Spatial Distribution of Unretouched Cores and Core Scrapers, 1976

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
B							1																		
C										1		1	2					1	1						
D				1																					
E			1																	1					
F							1	1							1			1							

a. Unretouched Cores

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
B																									
C							1												1			1			
D																					1	1			
E				1						1					2			2				1			
F																									

b. Core Scrapers

Fig 5.9 - Spatial Distribution of Unretouched Cores and Core Scrapers, 1978

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
B	2			1	1	2	2																		
C	2	1			1				1		4	2	2			4	1	6			6				
D				1	4						1		1			3					6	5		2	2
E		1			2		1	2	6	2	4			1	4	1	3	5	4		2	2			
F						1	4	3	2	1		1	3	2	6		1	3	3						

a. Retouched Flakes

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
B	2			1	3		1																		
C		1					3			2	2		1	1			1	2		3	2		2		
D																1	1	2			5	5			1
E			1	1		2			2					4	4		3	1	2	3		1			
F					1			1		1			3	5	1		4	4							

b. Retouched Pieces

Fig 5.10- Spatial Distribution of Retouched Flakes and Pieces, 1975

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
B			1																						
C		1			1		2										1		3	2			1		
D			1				1		1		1		1	1	1		1						2	1	2
E						1		1		1			1			1									
F				3		2				1	1	1		1	4		2	1							

a. Retouched Flakes

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
B			1																						
C			1									1			2		1	2	2	1			1		
D																			1		2			1	2
E														1	1				1	1					
F							1					1	1				1	1							

b. Retouched Pieces

Fig 5.11 - Spatial Distribution of Retouched Flakes and Pieces, 1976

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
B	4				1																				
C							3			2	3	1	1	1					2		2	2			
D				2	1		1										1	1			2	1		1	
E					1		1		4	6		1	4		1	1	2		1		1	1			
F						1		1	3	2	4		1	1	3	4	3	2	1						

a. Retouched Flakes

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
B	1				1	2																			
C					1						1	1	1							1	1	2	2		
D						1					1	1			1			2					3		
E							1			3		3		1								1			
F							2								2	1	1	2							

b. Retouched Pieces

Fig 5.12 - Spatial Distribution of Retouched Flakes and Pieces, 1978

evidence of debitage that could be the result of knapping. It was rare to find more than two or three pieces of stone that could have been derived from the same block. Never was the association conclusive.

In the absence of small scale association, is there any correspondence beween the distributions of different artefacts over a wider area? From an inspection of the surface distribution of the sorted material, this seemed unlikely but there was clearly a requirement for a less subjective basis on which to determine the strength of the association between artefact types and between artefacts and stratigraphy.

The problems of spatial analysis are common to many disciplines including ecology, geography and archaeology and surveys from these points of view have been published by Pielou (1969), Berry and Marble (1968) and Hodder and Orton (1976). In general, the data considered by these sources were more definitive than obtained at Mungo.

The comparison of data occurring as a cross-classification is most easily performed through contingency table analysis on which there is an extensive literature, including Goodman (1969) and Kullback (1974) with Everitt (1977) providing perhaps the most readable discussion. Contingency tables, which have been used in an archaeological context by Dacey (1973) and Whallon (1973) are a convenient way of expressing the measure of association between two samples.

An example of the comparison required here and the contingency table summarising it is shown in Table 5.4 There the scraper class has been divided into its component retouched flakes and retouched pieces. The upper left hand entry in the table refers to the number of grid squares in the 1975 collection in which both retouched flakes <u>and</u> retouched pieces are present, the upper right

		Retouched Flakes	
		Present f	Absent $\bar{f}$
Retouched Pieces	Present p	30	11
	Absent $\bar{p}$	22	23

$\chi^2 = 4.32$ for this table

$\chi^2_{0.5,1} = 3.841$ the result is significant at the 5% level

Table 5.9 ASSOCIATION BETWEEN RETOUCHED FLAKES AND RETOUCHED PIECES

to the number in which retouched pieces but not retouched flakes occur and similarly for the remaining two entries.

If the occurrence of retouched flakes is independent of that of retouched pieces, then each of the entries in Table 5.4 should be approximately the same. There should be about as many squares having retouched pieces within their boundaries as there are with flakes within them and so on, but due to the restricted sample size and the sampling method, small deviations from equality would be expected. The significance of these departures, in terms of the probability that they represent some relationship between the two classes of artefact as opposed to a chance event, is estimated by comparing a statistic easily derived from the entries in the contingency table with the values of the χ^2 distribution (Everitt, 1977). In the case considered here, this significance test shows that there is a chance of slightly less than 5% or one in twenty (a commonly used significance level) that the entries in Table 5.4 could have occurred if the collection had been made from an area of randomly distributed retouched flakes and retouched pieces. This result indicates that there is some evidence that the distributions of the two types of artefacts are related but it is far from conclusive. Had the chance been 1% or 0.5%, one might have rejected the null hypothesis that the two are unrelated. Nevertheless, a result near the 5% level should encourage further investigation. Before applying contingency tables indiscriminately in this way, however, it is of interest to examine whether they are appropriate in this context; whether their statistical significance is commensurate with their archaeological significance.

Limitations of Contingency Tables

Cowgill (1977) has discussed the interpretation of significance tests based on contingency tables. He

points out that the same data may be used to estimate the strength of relationships rather than establishing their existence. There is, however, an important aspect which must be considered before effort is expended in further manipulation of the data. This is the necessity of placing any result in its correct archaeological perspective by considering the security of the data upon which it is based.

Reference has been made elsewhere in these pages to possible disturbance of the surface material. Artefacts may be displaced by animal or human traffic across the grid and the possibility has been advanced that slopewash during heavy rain may be sufficient to move some of the artefacts (see Appendix A). Displacement across grid square boundaries also may effectively occur on rare occasions during the course of the collection when collectors accidentally stray into adjacent squares before realising their error. The contingency table discussed above essentially summarises the coincidence of retouched flakes and retouched pieces in each square at the time of collection. What, then, would be the impact of movement of this type on the derived statistical significance?

As an example, consider the case of a retouched flake collected in a given square having actually originated in an adjacent square. How insensitive or robust would the significance level originally obtained be to such an event? Are there frequent opportunities for such an occurrence or can it be dismissed as unlikely?

There are several ways in which the movement of a flake from one grid square to the next can affect the contingency table. To restrict the number of cases, the possibility of a retouched flake being disturbed across more than one grid square boundary will be ignored as will diagonal movement from one grid square to another where they share a common corner. Thus, in an

infinite grid a retouched flake can move from one square into one of only four of its neighbours. As an example of such 'disturbance', consider the effect of a single flake occupying a square empty of retouched pieces being moved into an adjacent flake-less square which contains several retouched pieces. Using the notation f and $\overline{f}$ (f and not f) to represent the presence and absence respectively of a retouched flake in a square and similarly p and $\overline{p}$ for retouched pieces, then the above situation means that the contingency table corresponding to the grid after the disturbance of the flake will have one less square of the types $f\overline{p}$ and $\overline{f}p$ and will increase by one each of the squares of the type fp and $\overline{fp}$. There are a total of eight such transpositions from single-flake squares and a further eight from multiple-flake squares. Of these 16 possibilities, it can be shown that six have no net effect on the entries in the contingency table, while duplication occurs among a further eight, resulting in only six types of change to the table. However, the identification of these six effective changes is based on the assumption of a grid of infinite extent. It is possible that retouched flakes either may be lost to the collection before it was made by being moved over the outer boundary of the grid or added to it from outside the grid limits. Only such movements out of single-flake squares or into flake-less squares will affect the contingency table but as far as introducing new types of change, they do not add to those identified above. For example, the effect on the contingency table of a retouched flake moving out of the grid from a square originally containing only that flake and some retouched pieces is to reduce by one the fp entry and increase the $\overline{f}p$ entries in the table by the same amount. The same change to the table occurs when a flake moves from a single flake and retouched piece square to one containing retouched pieces and one or more flakes.

There is thus a total of six modifications to the contingency table to be considered. These summarise all possible movements of a flake within, out of or into the

grid across not more than the boundary. Each of these movements represents an event which could have occurred before the collection was made so that the situation being analysed is no longer the 'true' one. Using the retouched flake and retouched piece data from the 1975 Mungo surface collection, the effect of such potential movements is summarised in Table 5.10.

As indicated earlier, comparison of the locations of the collected flakes and pieces in Figure 5.9 showed that there was a probability of slightly less than 5% that such a distribution could have occurred by chance. The significance levels corresponding to each of the six types of flake movement are shown in the first row of the table where the values show both increased and decreased significance. For example, the entry in column c shows that, had there been a movement of a retouched flake from an otherwise empty square to an adjacent one containing only retouched pieces before the collection, then the distribution before that event would have had only a 1.2% probability of occurring by chance, a much more significant result than previously.

The question now arises as to the likelihood of disturbances, or number of potential flake movements, which could modify the significance levels. Careful examination of the 1975 grid data produces the figures in the lower two rows of Table 5.10. The entry under column c shows that there are five pairs of adjacent squares between which the movement of a flake would improve the apparent significance from 4.8% to 1.2%. In addition, because some other squares contain more than one flake, there are several possible flake movements between these pairs of squares. In column f there are 57 such movements possible.

The foregoing analysis shows how easily and sometimes dramatically the significance level of the data for retouched flakes and pieces from the 1975 Mungo surface

MODIFICATION TO CONTINGENCY TABLE	ORIGINAL	SINGLE FLAKE SQUARES				MULTIPLE FLAKE SQUARES	
		a	b	c	d	e	f
Significance level of resulting table (%)	4.8	6.4	2.3	1.2	10.0	2.0	5.9
Potential pairs of squares affected	-	10	11	5	4	11	16
Potential number of flake movements	-	10	11	5	4	37	57

Table 5.10 SENSITIVITY OF SIGNIFICANCE LEVEL TO FLAKE MOVEMENT

collection would be changed by the movement of a single flake within the grid. Possible changes due to movement into or out of the grid which have not been enumerated here provide further opportunities for modifying the significance level. The necessary distances to be moved cannot be estimated precisely since the co-ordinates of the flakes were not recorded as they are recovered but the displacements could lie between a matter of centimetres (just over boundaries of squares) and some 28 metres (assuming a flake is moved almost diagonally across the square from the corner of one square to the corner of the next).

Blackened Rock

Material like blackened 'rock' is recovered from the Lake Mungo lunette. This material is of two types. The first consists of porous, sandy and to some extent brittle, slabs where the density of blackening gradually decreased to nothing with 1 cm of the surface. The second type is represented by much harder fragments of apparently rounded calcrete having a shiny black surface. Postulating that the porous material might be remnants of hearth beds and the rounded fragments were related to the .. "rounded pebbles of calcrete ... and their probable function was as hearth stones or as anvils ...", (Bowler, et al, 1970, p. 52) the distributions of both types that were recovered in 1975 were plotted. There was little correspondence between the two and only a tendency for examples of blackened calcrete to be more frequent at the western end of the grid.

It is unfortunate that the few fragments of blackened material obtained in the whole of the 1976 and 1978 collections was insignificantly low, preventing any further investigation along these lines.

Discussion

Clearly the application of 2 x 2 contingency tables to the Lake Mungo surface collection is inappropriate. It must be accepted that this conclusion is no more than just reward for the apparent blind employment of a statistical test where there was scant reason for advancing the hypothesis being tested. However, the exercise illustrates the need, as advocated by Cowgill (1977) to consider carefully the archaeological implications of the statistical result. In the present case by postulating the disturbance, by accidental or natural means, of one of the retouched flakes the statistical conclusion is invalidated. The same is true of the retouched pieces so that, unless the possibility of movement can be confidently excluded, any expression of statistical significance is valueless in the archaeological context. Decrease in sensitivity of contingency tables may be obtained if the number of entries in each cell is increased without changing their relative proportions. Attempts to achieve this by using the results of two collections in the one contingency table, however, were unsuccessful as the difference between the relative frequencies was reduced. The validity of such a step is in any case open to question as increasing the timespan of the data, given the current rates of erosion, means that occupation levels extending over several years are being aggregated. Under these circumstances, only if the occupation density of the groups inhabiting the dune is insufficient to cause overlap of occupation debris, will discrimination within the contingency table be improved.

Heitala and Stevens (1977) have considered spatial analysis in the context of the distribution of excavated material, arguing that pattern detection such as that considered here using contingency tables alone, is too simplistic. If further efforts are contemplated to worry some conclusions out of the surface distribution of the Lake Mungo material, then the methods that they suggest

must be considered. Attention must be given to the size of the squares of the grid. At present, in the absence of any indications of significant concentrations of prehistoric material, the only factor suggesting any change is the need to modify the internal grid boundaries to minimise the number of square containing both Mungo and Zanci deposits. Given the current implement densities, any decrease in size will increase the number of unoccupied squares and, although the methods outlined by Heitala and Stevens make allowance statistically for this, the question of implement movement into these squares remains. The sensitivity of any method to surface disturbance must be shown to be acceptable since absence of movement cannot be guaranteed. Indeed, given the low surface density of surface material, it is suggested that such methods are unlikely to have much relevance to the investigations at Lake Mungo.

Conclusion

This exploratory analysis of the surface distribution of the material collected at Lake Mungo has resulted in little in the way of conclusive results. There is some indication that the frequency distributions of the unretouched flakes differ between the upper and lower levels of the grid and this seems to be independent of the exposed deposit upon which the flakes were located. Nevertheless, there is some correlation between the surface density of the flakes and these deposits but there are also departures from agreement which suggest the influence of other factors. It is probable that some smaller flakes are washed down the site, resulting in lower mean values for the dimensions of the flakes recovered from the lower levels. This migration of flakes, together with the micro-topography of the grid surface and the differential rates of erosion, may combine in varying degrees across the grid to blur the correlation between flake density and deposit.

Attempts to determine the correspondence between the surface distributions of the implements recovered from the grid using contingency tables failed. Although the number of artefacts was sufficient to produce a statistically significant result, the fact that disturbance of the material could not be dismissed meant that this was archaeologically meaningless.

CHAPTER 6

ANALYSIS OF THE SURFACE MATERIAL BY CHARACTERISTICS

Introduction

The surface collection for the three years 1975, 1976 and 1978 included 600 items exhibiting retouch. In addition approximately 100 unretouched cores and almost 1700 unretouched flakes were recovered as well as an estimated similar quantity of lumps and fragments of the same materials from which the artefacts had been fashioned. I have applied the term artefact to all stone pieces that have been brought to the site and subject to modification by man. Implements are those artefacts that have been, in my judgement, purposely shaped to form a tool. The material in the collections was almost exclusively silcrete, only occasional pieces of chert and other types of stone occurring, amounting to no more than 14 retouched pieces of chert and one piece of quartz and a similar quantity of unretouched flakes and fragments in total. In character the silcrete varied over a wide range from very coarse to very fine grained material, its colour varying, with few exceptions, from a sandy yellow through olive to grey.

Classification of Collection

The procedures adopted to sort, classify and measure the artefacts in each year's collection were the same. Initial inspection of the material collected from each square, during which the items were broadly classified according to type, was followed by more detailed examination, including reclassification if necessary, and measurement of the principal features of each retouched artefact. Finally the dimensions of unretouched flakes and cores were measured.

It was quickly apparent that the generally undifferentiated characteristics of the recovered artefacts did not lend themselves to a division of more than a few main

categories.

The following were chosen:

a. scrapers, which were further divided into:

(1) retouched flakes

(2) retouched pieces

b. retouched cores

c. unretouched cores

d. unretouched flakes

e. waste material

f. interesting pieces

The few 'classical' pieces, for example thumbnail scrapers, backed blades and burren slugs, were identified separately when they occurred. Some examples of this material are illustrated in Figures 6.1 and 6.2 and the recovered quantities are given in Table 6.1.

The first and last items in the list call for some explanation. Jones, in introducing the discussion of the analysis of his Rocky Cape material, identifies a breakthrough as having occurred in archaeology when worked edges rather than total implements were isolated and analysed. (Jones, 1971, p. 318). This approach has been followed to varying extents by White (1967), Lampert (1971), Allen (1972) and by Jones himself, and finds support in the ethnographic work of Gould (Gould, Koster and Sontz, 1971) and O'Connell (1977). Nevertheless, some acknowledgement of the form an implement remains when, at the outset of most analyses, broad subdivisions into cores, flakes and scrapers are made. In deciding on the classifications listed above I was influenced by Jones' unbiased statistical approach, although I could not allow myself the luxury of his depth of analysis, and by Lampert's reluctance to have his scrapers '... tortured into unrealistic categories'. (Lampert, 1971, p. 23). Additionally, in the mood of Isaac, I hoped to squeeze blood not so much from the stones themselves as from the data on the stones. (Isaac, 1977.b).

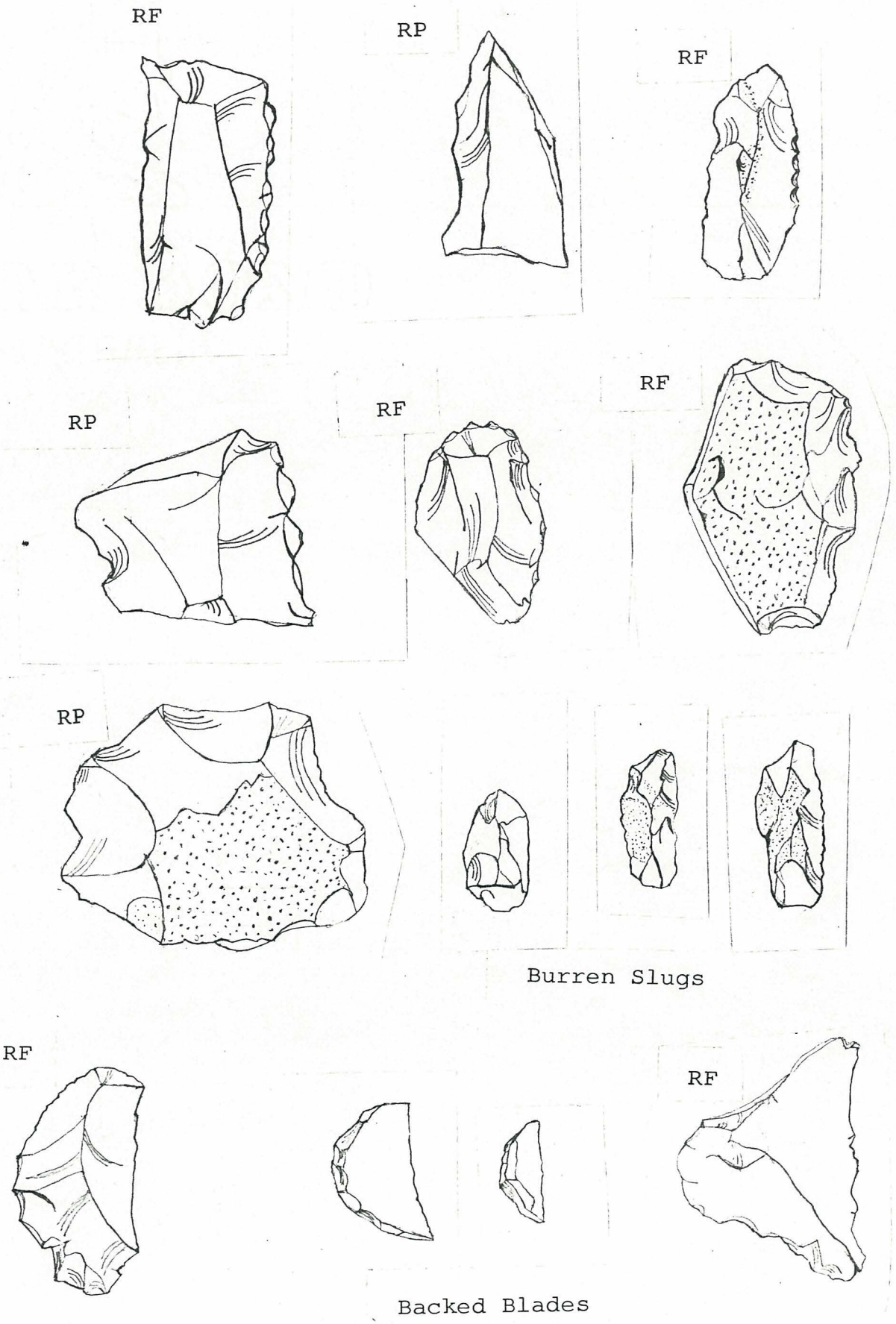


Figure 6.1: Retouched Flakes (RF), Retouched Pieces (RP) and other implements

(Actual Size)

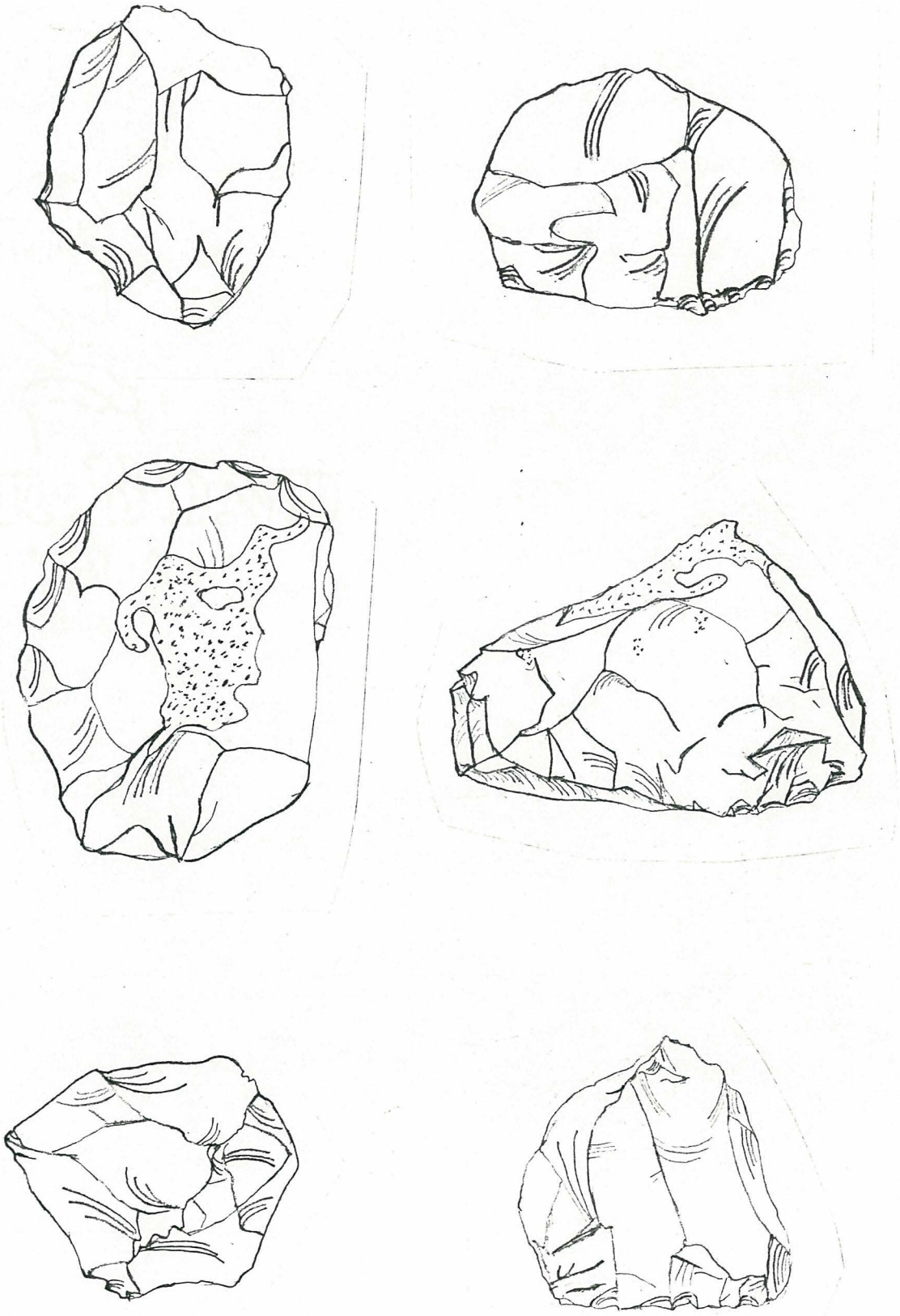


Figure 6.2: Cores. (top and side view)
(Actual Size)

ARTEFACT CATEGORY	YEAR		
	1975	1976	1978
Scrapers:			
Retouched Flakes	133	46	82
Retouched Pieces	86	28	40
Retouched Cores	14	16	12
Unretouched Flakes	1697	1678	1684
Unretouched Cores	74	30	14
Waste Pieces	Not Counted		

TABLE 6.1 - SUMMARY OF ARTEFACTS COLLECTED, BY YEAR

Such sadistic metaphors aside, I could not fully appreciate and thus accept the subjective classification of others such as that outlined by McCarthy (1976) about which Jones has expressed reservations (Jones, 1971, p.315). Furthermore, I wished to confirm independently, and as fully as time allowed, some aspects of the typology used by Allen in his analysis of Lake Mungo surface material (Allen, 1972). I have followed Lampert in his definition of scrapers, ie. '... as a piece of stone with all or part of its margin unifacially and systematically retouched to form a working edge that could have been used for scraping' (Lampert, 1971, p.16) accepting, as he does, that the implements in this category may not have been used for scraping. Unlike Lampert, however, I have excluded core-scrapers from the outset and allocated them to a separate category (see b. above). Neither the term core-scraper nor the alternative of retouched core that I have used here are completely satisfactory since they both presume that the basis of the retouched piece is a core. Flood's designation 'thick steep edged scraper' (Flood, 1974) may be more appropriate for the Mungo collection but because inspection by eye suggested that, apart from secondary working, the retouched and unretouched cores were very similar I have used the terminology at (b) above.

My justification for separately identifying the retouched pieces was that the striking platform and bulb of percussion of the former provide potential reference points for consistent orientation and measurement. Furthermore, I wished to explore the possibility that tools made on flakes might be, in some way, more purposeful. Given that there must have been occasions when stone suitable for minor modification was not to hand, a flake of the appropriate dimensions would have been detached and prepared. If such was the case and if these implements separated out into a discrete category, they would be more representative of an ideal, of a conceptualisation in the manner of the mental templates of Deetz (1967). It is unlikely, in view of the large ratio of retouched flakes to retouched cores, that the production of the latter would have formed the purposeful element about which the collection was centred. The results

show that the small extra effort was not entirely wasted and the distinction has been retained through much of the following discussion.

The final category of the classification, that of 'interesting pieces' includes items that were thought to be worthy of special treatment and comprised fragments of edge ground material, ochre and pieces of stone of a strikingly atypical colour or composition, for which it might be possible to determine the source quarry as evidence of barter or exchange routes. Alternatively, the location of fragments of identical material found elsewhere in the same or another year's collection might be indicative of the scale of disturbance and mixing at the grid. Unfortunately, apart from several unsuccessful attempts to match distinctively coloured artefacts, time has not yet permitted further investigation along these lines.

Scrapers - General Description

The criteria used here to distinguish between retouched flakes and retouched pieces is the possession by the former of a bulb of percussion and the indication, sometimes only through the surface contours formed by the shock-wave, of a point of percussion. A striking platform frequently can be identified.

Both classes of scraper were generally low profiled and irregular in shape giving no grounds for supposing that further sub-division could be identified except in the sense used by McCarthy (1976) of side, end, side and end scrapers and so on. But the very irregularity in overall shape of the items suggested that this would be an unprofitable course. In the 1978 collection, for example, an attempt to assign the retouched flakes and pieces to such categories is summarised in Table 6.2.

The principal difficulty experienced, and the one most often leading to the assignment of the implement to the 'Not Determined' category, was the lack of a significantly longer axis to give relevance, even allowing a generous interpretation, to terms such as 'end' or 'side'. Such interpretive generosity may account for the fact that some 58% of the scrapers could be categorised (Table 6.2).

Classification	Possible Scraper Type				
	End	Side	Side and End	Double Sided	Not Determined
Retouched Flakes	8	25	6	8	34
Retouched Pieces	4	11	4	5	14

Table 6.2 ATTEMPTED CLASSIFICATION OF SCRAPERS - 1978 COLLECTION

More generally, over the three collections the figure was 40% which may be compared with the value of 35% obtained, for example, by Mulvaney (Mulvaney, et al, 1965,p.175).

On both retouched flakes and pieces well developed retouch is uncommon. Such retouch, consisting of edges with distinct percussion scars separated by spurs, when present, was of limited extent from a few blows only. Dentated edges are almost absent from the collections. The remainder of the retouched edges consist of macroscopic step flaking upon which finer (in the sense of smaller but not more regular) retouch is superimposed. The scale of this latter retouch may be judged from the fact that it was found of assistance to view it through a lens giving a two to three-times magnification in order to resolve the individual scars comfortably. The irregularity of the retouch suggests that it may be the result of use wear. Secondary retouch of the surface suggestive of any desire to improve the aesthetic appearance of the scrapers was rare with the only exceptions being the thumbnail scrapers and backed blades.

Measurement of Scrapers

In order to more succinctly summarise the character of the scraper component of the collections the following dimensions and attributes of each scraper were recorded.

Scraper Dimensions. The length, width and thickness of each implement were obtained using a measuring board. In the case of retouched flakes the implement was placed bulb downward on the board and the length determined as the maximum distance of the margin perpendicular to the plane of the striking platform. Width was the maximum distance across the flake perpendicular to the length and parallel to the board's surface. Thickness was the remaining dimension perpendicular to length and width.

The dimensions of the retouched pieces were defined in a broadly similar fashion. Each item was placed on the board with the predominantly smooth surface downward. This

surface was overwhelmingly, but not exclusively, that at which the blows had been directed to produce the retouch, so leaving scars on the reverse face. In the absence of any reference point, the determination of length and other dimensions required the specification of an arbitrary rule. In an attempt to maintain relevance to the retouched flakes, rather than measure the maximum dimension, length and width were defined as the larger and smaller sides of the smallest rectangle which would contain the retouched piece. Thus the length of an artefact approximating to a right angled triangle in plan is the height of the triangle rather than its hypotenuse, whereas the length of a flake similar in shape to an equilateral triangle would equal that of the side rather than the altitude. Further discussion of the relationship of the convention used here to that employing the maximum length as reference appears below.

Scraper Attributes. Other features of the scrapers were selected for examination. These included the length of retouch, its radius of curvature, the number of primary and secondary flake scars and the presence of cortex on the implement. In addition an attempt was made to measure the steepness of retouch.

Scraper Retouch. Jones' method was used to obtain the length of retouch. A sharp, soft pencil was used to draw around the perimeter of the scraper and the length of both the margin and that part of the margin exhibiting retouch obtained from the outline using a map measure. The tracing was also used to obtain an estimation of the radius of curvature of the retouched margin by matching the outline with the circumferences of a series of circles engraved on clear plastic. The radius of that circle which best fitted the mean curve about which the detailed profile of the worked edge fluctuated was recorded. This procedure was not without difficulty, however, due to the large proportion of implements having worked edges that were irregular in outline or which had outlines over the length of which the radius varied. However, it was not possible to further classify such irregular implements into groups possessing common features. If more than one radius was obviously present on a single continuously

retouched margin no measurement was taken since it was not clear whether the toolmaker regarded either curve or the region of inflexion as being important. The rejection rate was high. Even including those radii from implements that had more than one unambiguous, separate retouched segments only some 220 measurable radii were obtained from approximately 420 scrapers.

A comparable problem was experienced in attempting to quantify the secondary retouch on the margins. Steepness of retouch appeared to be one suitable parameter but again the wide variation in angle perpendicular to the margin at different points along the length of any one working edge cast doubt on the usefulness of these data.

The number of retouch scars was assessed also for most artefacts but with little confidence on my part in the majority of cases. As noted earlier, bold, regular retouch was rare. Step flaking was the type most frequently exhibited with the secondary flaking confused in magnitude and direction so that differentiation from other possible forms such as blunting retouch or edge wear was often impossible.

Discussion

As the principal interest in the analysis of the Lake Mungo surface collection centres on the identification of the differences, if any, between the material derived from the Mungo and Zanci deposits, I attempted to make comparisons on this basis as often as the data allowed. This is facilitated by the layout of the grid. Mungo deposits only are exposed at the surface of 14 of the squares, Zanci deposits only in a further 48 squares, while the surfaces of the remaining 30 squares include both Mungo and Zanci deposits. Despite the disparity in size, the surface density of artefacts was such that comparable numbers were recovered from each type of area.

In any analysis it would be prudent to accept that, given the conclusions of Chapter 3 and without

specifying the mechanism in detail, the material originally fashioned and discarded during the two periods when the Mungo and Zanci deposits were being laid down could have suffered significant disturbance before, during or after its exposure. Indeed, Dare-Edwards, in discussing valley formation on the dune bordering the neighbouring Lake Chibnalwood, states that 'The (regular) pattern of valleys is interpreted as the result of fluvial erosion of the dune contemporaneously with the addition of aeolian material' (Dare-Edwards, 1979, p.142). Similar processes, perhaps on a smaller scale, may have operated at Lake Mungo.

If it is assumed that differences did exist between the characteristics of the two assemblages, two extreme cases requiring analysis may be considered. Intermediate cases may occur and need to be assessed as appropriate. In the first, where the material is essentially undisturbed, the differences should be revealed in a direct comparison of the implements recovered from the Mungo and Zanci areas. When the stone material has been thoroughly disturbed, however, the characteristics of the collection will be similar everywhere within the grid area but, providing the maxima in the original undisturbed Mungo and Zanci deposits are separated sufficiently, the assumed differences could appear as similar multi-modalities in the frequency distributions from the Zanci, Mungo and mixed areas. The presence of such multimodal distributions, however, does not provide proof of differences between the deposits. It may be that one or other of the distributions is itself multimodal. Nevertheless, the existence of more than one mode suggests that further investigation, at least, is desirable. Examples include surface collection at shorter intervals throughout the year to reduce the effects of disturbance, collection in clearly defined areas of Mungo and Zanci deposits elsewhere on the dune from essentially horizontal surfaces where mixing is less likely or the conduct of a detailed study of the erosion process at the site so that allowance can be made for its disturbing influence.

In analysing the data I carried out the following steps. Separate histograms of the parameter being examined were first plotted for the implements recovered from the Mungo and Zanci deposits and from the complete grid. The remaining area, made up of squares containing the final deposits of the Mungo dune building era and the earliest record of occupation in the Zanci period, could contain material of some interest. I considered, however, that being mixed it would have little diagnostic value but for completeness I carried out the analysis for this area also.

The histograms gave me a 'feel' for the data, in some way analogous to the manner in which an experienced archeologist obtains an assessment of the contents of a collection by handling the material it contains.

Having obtained the sample frequency distributions for the Mungo and Zanci areas, I then carried out a formal comparison using the Kolmogorov-Smirnov two sample test (Seigel, 1956) in an attempt to establish whether statistically significant differences existed. Unfortunately, even in cases where visual inspection suggested that the plotted distributions were dissimilar, these could be given no statistical weight probably because the sample size was insufficient. I estimate that if the sample size were doubled and the frequency distributions were to remain identical in the larger sample to those found here, then it might be possible to demonstrate statistically significant differences between the Mungo and Zanci deposits.

The Kolmogorov-Smirnov test, by making a comparison between two cumulative frequency distributions, compares all parameters of the original distributions including the mean and the spread of values around it. Less stringent tests, including, for example, the median test (Seigel, 1956) are more restricted in their comparison. Despite this relaxation, I was unable to detect any difference in central tendencies between the Mungo and Zanci deposits when I applied the median test. A brief description of the Kolmogorov-Smirnov tests is given in Appendix C.

The analysis was carried out without recourse to a large computer installation. Far from being an over-reaction to criticisms against the practice, scornfully summarised in abbreviations such as GIGO - Guesses In Gospel Out - this was done deliberately. Much of the investigation was exploratory and as the quantity of data involved was not excessive, by the time I had made my initial assessments as to its quality and identified those aspects warranting more detailed analysis, I had completed much of the ground work. Furthermore, given the relatively small amount of data involved, the calculations could be readily computed using one of the many programmable electronic calculators now available. The calculator used here was a Hewlett-Packard HP65, together with some of the programs contained in the HP65 STAT PAC 1 package.

Results

The results of the analysis of the measurements of the implements of the Lake Mungo surface collection may be summarised with a rapidity which belies the effort in obtaining them. No statistically significant difference was found between the samples of each of the broad implement type recovered from the different areas of the eroding lunette surface. A more detailed statement of the results follows.

Analysis of Scrapers

Dimensions. The principal dimensions and retouch characteristics were analysed separately for the two groups into which I had divided the scrapers, i.e. retouched flakes and retouched pieces. They were then combined and the characteristics of scrapers as a single group examined. Results were obtained for both the component and combined groups for material recovered from the three types of exposed surfaces Mungo, Zanci and mixed Mungo and Zanci. Finally, the results for all three grid areas were combined. As a summary the means and standard deviations for each of these

combinations of classes of implement and erosion areas are presented in Table 6.3 noting that as the mean and standard deviation are but two parameters that characterise distributions, it is possible for two such distributions which differ in shape to share the same values. Such dramatic differences in shape were not the case here, however, for the application of the Kolmogorov-Smirnov and median tests were unable to detect statistically significant differences between comparable samples. Frequency histograms of the data on which Table 6.3 is based are given in Figures 6.3 to 6.5.and values of the Kolmogorov-Smirnov statistic in Table 6.4.

Despite its statistical insignificance, Table 6.3 has two aspects which may be of interest. Firstly, for each of the dimensions of length, width and thickness, the mean values for the scrapers as a combined group increase as the samples originate from the Mungo, Zanci and mixed areas. This result reflects the numerical weight over the retouched pieces of the retouched flakes where the same ranking appears. While the differences are small in comparison with the standard deviations, nowhere exceeding five millimeters and more usually less than two, the regularity is noteworthy.

There seems to be no ready explanation in terms of erosion. A transport of smaller, lighter material onto the lower, Mungo surfaces, thereby decreasing the mean values for that area, would require that the mixed areas, intermediate in terms of their position on the erosion surface, be intermediate also in mean dimensional values, but this is not the case.

The implements in the collection, almost without exception, are fashioned from local silcrete so that the increase in average dimension corresponds to an increase in the mean mass of items recovered from the grid squares containing both Zanci and Mungo deposits. Is it possible that the larger values in the mixed areas are the result of a differential migration of heavier material through the body

DIMENSIONS (cm)		FLAKES			PIECES			ALL SCRAPERS		
		μ	σ	N	μ	σ	N	μ	σ	N
LENGTH	MUNGO	3.34	1.27	65	3.74	1.43	45	3.41	1.11	110
	ZANCI	3.59	1.08	82	3.70	1.27	60	3.57	1.06	142
	MIXED	3.80	1.35	114	3.53	1.02	50	3.63	1.15	164
	ALL	3.57	1.19	261	3.61	1.18	155	3.54	1.11	416
WIDTH	MUNGO	2.77	1.04	61	2.76	1.22	50	2.66	0.96	111
	ZANCI	2.67	0.86	82	2.62	0.85	59	2.68	0.83	141
	MIXED	2.78	1.07	116	2.57	1.04	52	2.72	1.08	168
	ALL	2.74	1.00	259	2.69	1.06	161	2.71	1.01	420
THICKNESS	MUNGO	0.92	0.40	69	1.33	0.65	49	1.08	0.57	118
	ZANCI	0.96	0.32	81	1.34	0.62	58	1.11	0.50	139
	MIXED	1.13	0.60	112	1.46	0.72	52	1.21	0.65	164
	ALL	1.03	0.49	262	1.35	0.69	159	1.14	0.58	421

Table 6.3 LAKE MUNGO SCRAPER DIMENSIONS

ARTEFACT CATEGORY	KOLMOGOROV-SMIRNOV STATISTIC $D^{(1)}$			
	D_{max}			CRITICAL VALUE $D_{.05}$
	LENGTH	WIDTH	THICKNESS	
SCRAPERS	8.6×10^{-2}	9.6×10^{-2}	9.5×10^{-2}	1.7×10^{-1}
RETOUCHED FLAKES	1.2×10^{-1}	9.4×10^{-2}	1.1×10^{-1}	2.2×10^{-1}
RETOUCHED PIECES	8.4×10^{-2}	6.9×10^{-2}	8.1×10^{-2}	2.6×10^{-1}

Note (1) $D_{max} > D_{.05}$ for statistical significance at the 5% level

TABLE 6.4 - COMPARISON OF ARTEFACT DIMENSIONS OF MUNGO AND ZANCI ARTEFACTS - VALUES OF KOLMOGOROV-SMIRNOV STATISTIC

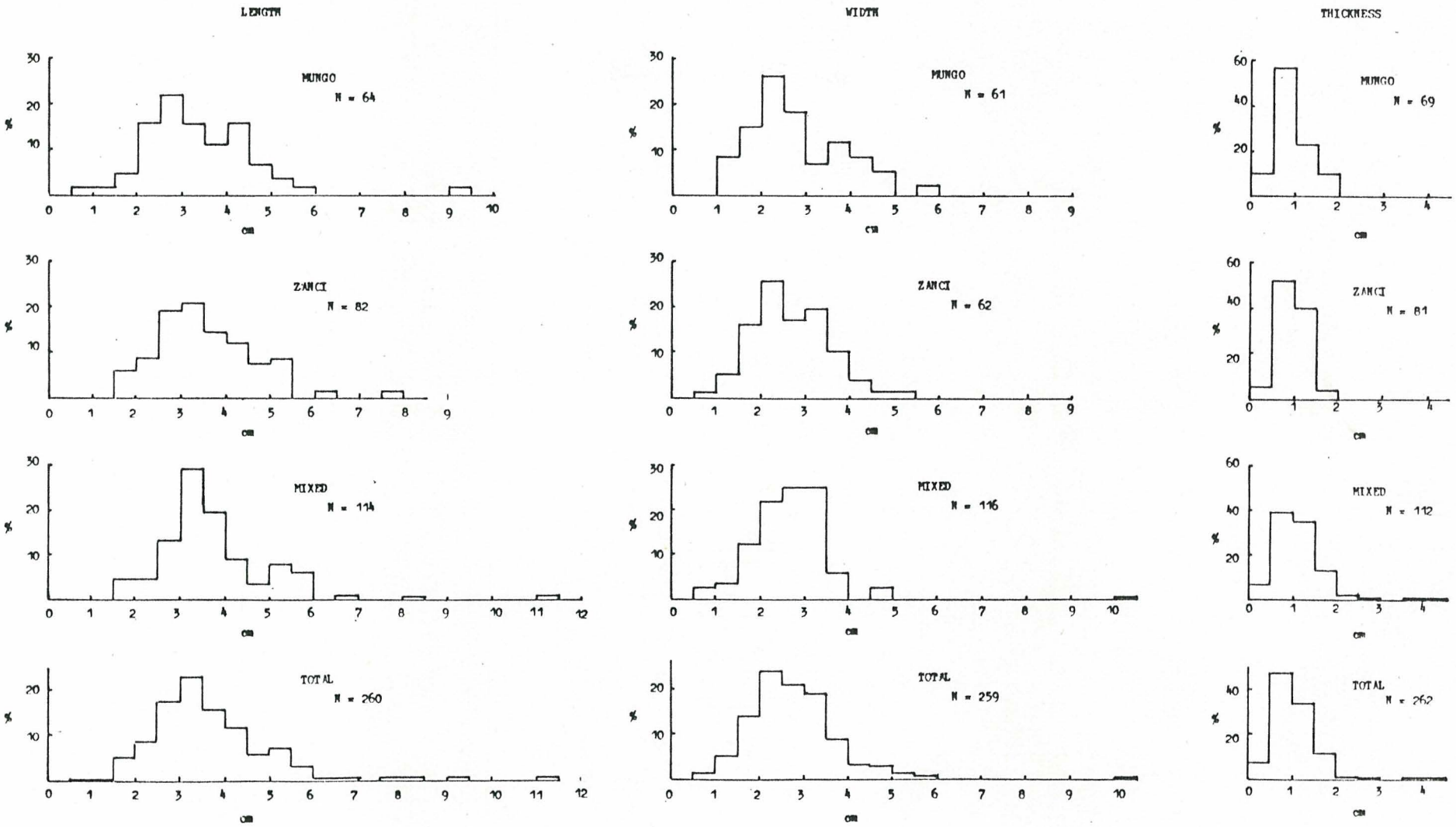


FIGURE 6.3 - RETOUCHED FLAKES - DIMENSIONS

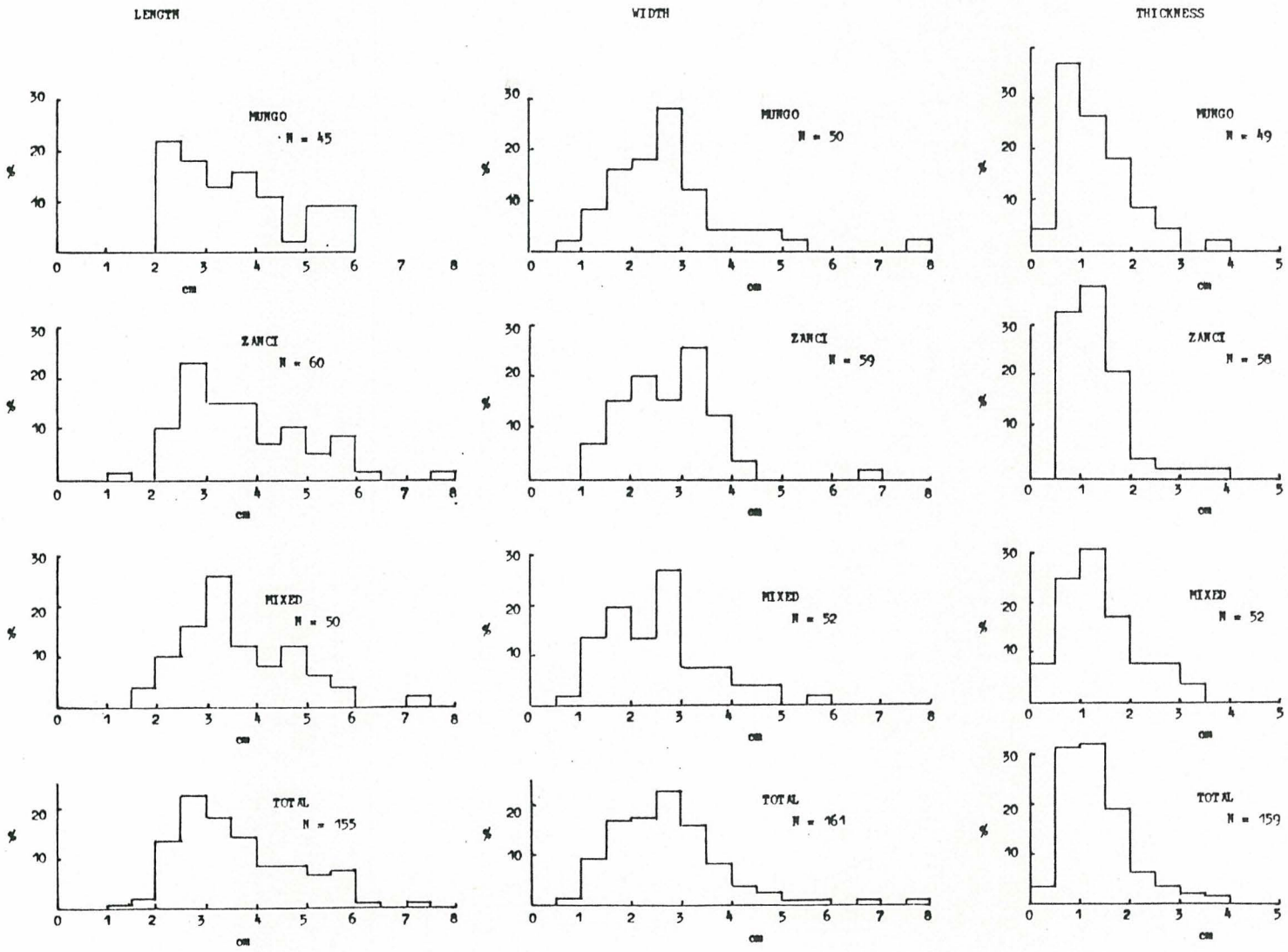


FIGURE 6.4 - RETOUCHED PIECES - DIMENSIONS

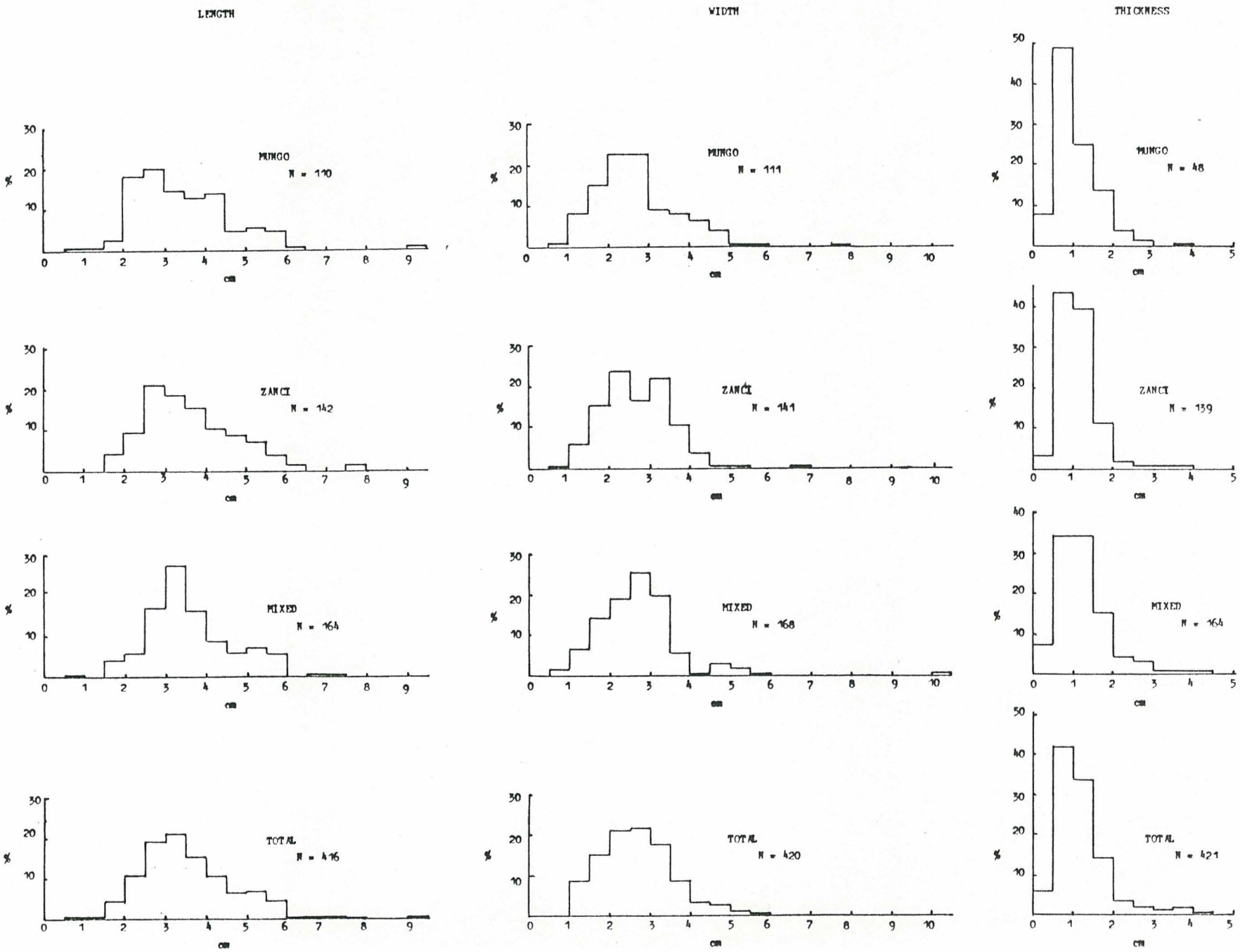


FIGURE 6.5 - SCRAPERS - DIMENSIONS

of the lunette? During the thousands of years of general dune stability the hiatus in the dune characteristics corresponding to the 4000 year period of soil formation following the end of the Mungo dune building phase (Dare-Edwards, 1979) may have been sufficient to arrest, partially at least, movement across the Zanci-Mungo boundary. This would result in the remaining lower Zanci levels being richer in heavier items while the larger items would have migrated from the upper Mungo levels which lie immediately below the Mungo-Zanci interlude.

The evidence from the retouched pieces, for which the results for length and width have a ranking which is exactly the reverse of the retouched flakes, does not support this hypothesis. On the other hand, a comparison of the dimensions of the retouched flakes in the Zanci area from grid row C and grid row D, adjacent to but down-slope from row C, confirmed the trend of larger mean values at the lower levels. However, the samples in neither row exceeded 30 implements with the difference in means and standard deviations being comparable with those in Table 6.3. The tentative hypothesis of differential migration therefore receives little support but may merit consideration if work on the surface collection continues.

The second aspect in Table 6.3 that is worthy of comment concerns the comparison between retouched flakes and retouched pieces. In length and width the mean values, taken over the total grid area, are similar and, as might be expected, the average thickness of the retouched pieces exceeds that of the flakes. The thickness histograms showed (Figures 6.3 and 6.4), however, that while some of the difference could be attributed to the pieces being generally thicker, that is, there was a shift of the histogram for pieces to the right of that for flakes, there was also a significantly greater number of retouched pieces of between two to four centimetres in thickness. I was able to verify that this was not due to any confusion in distinguishing between the thicker scrapers

and low backed cores, but following examination of this group of implements, I am not convinced that these thicker retouched pieces have in common anything more than thickness with which to warrant separate classification.

A general comparison of the histograms corresponding to the entries in Table 6.3 produces little that merits comment. Only the scrapers recovered from the Zanci areas exhibited bimodality, all others being essentially unimodal. Bimodality of the Zanci scrapers was limited to the width dimension and was weakly present in both retouched pieces and retouched flakes. Histograms for all scrapers from the Mungo and Zanci areas and for all scrapers regardless of area are given in Figure 6.5.

Retouch. Table 6.5 summarises the measurements of scraper retouch. In most cases the retouched margin was limited to a length of between one and five centimetres, only a few implements having retouch greater than six centimetres. There were no apparent differences between the Mungo and Zanci material, either when the retouch was expressed as a linear measure or as a percentage of the total margin (see Figures 6.6 to 6.11).

I also endeavoured to make measurements of the radius of curvature of the retouched margin, the angle of the retouched perpendicular to the working edge and the length of the implement perpendicular to the retouched margin. Where the margin was curved, this latter distance was taken along the radius bisecting the arc along the margin. My aim in attempting to assess tool length perpendicular to the cutting edge was to explore the possibility that, just as some modern knives and chisels have similar dimensions and bear a superficial resemblance to each other, they differ greatly in the position of the cutting edge relative to the long axis. This or a similar parameter might be useful when the hafting of stone implements is being considered and, while I had no such expectations here, this measure promised

RETOUCH		FLAKES			PIECES			ALL SCRAPERS		
		μ	σ	N	μ	σ	N	μ	σ	N
LENGTH (cm)	MUNGO	2.86	1.65	73	3.23	1.66	52	2.99	1.69	125
	ZANCI	3.16	1.51	91	3.32	1.96	64	3.20	1.71	155
	MIXED	3.19	1.91	107	3.36	2.24	50	3.14	1.83	157
	ALL	3.05	1.71	271	3.34	2.00	166	3.16	1.78	437
PERCENTAGE	MUNGO	28.0	14.4	75	36.1	22.3	61	31.1	18.3	136
	ZANCI	31.7	15.8	93	27.3	17.0	51	29.3	17.3	144
	MIXED	28.4	16.6	97	30.6	18.0	45	29.1	17.0	142
	ALL	30.1	15.7	265	33.2	19.7	157	29.8	17.5	422
RADIUS (cm)	MUNGO	3.21	4.94	60	-0.33	7.99	14	2.42	5.45	74
	ZANCI	3.39	6.41	71	4.46	4.30	27	3.68	5.90	98
	MIXED	3.44	5.01	31	4.57	5.31	17	3.67	5.07	48
	ALL	3.33	5.61	162	3.65	5.41	58	3.38	5.55	220

Table 6.5 LAKE MUNGO SCRAPER RETOUCH CHARACTERISTICS

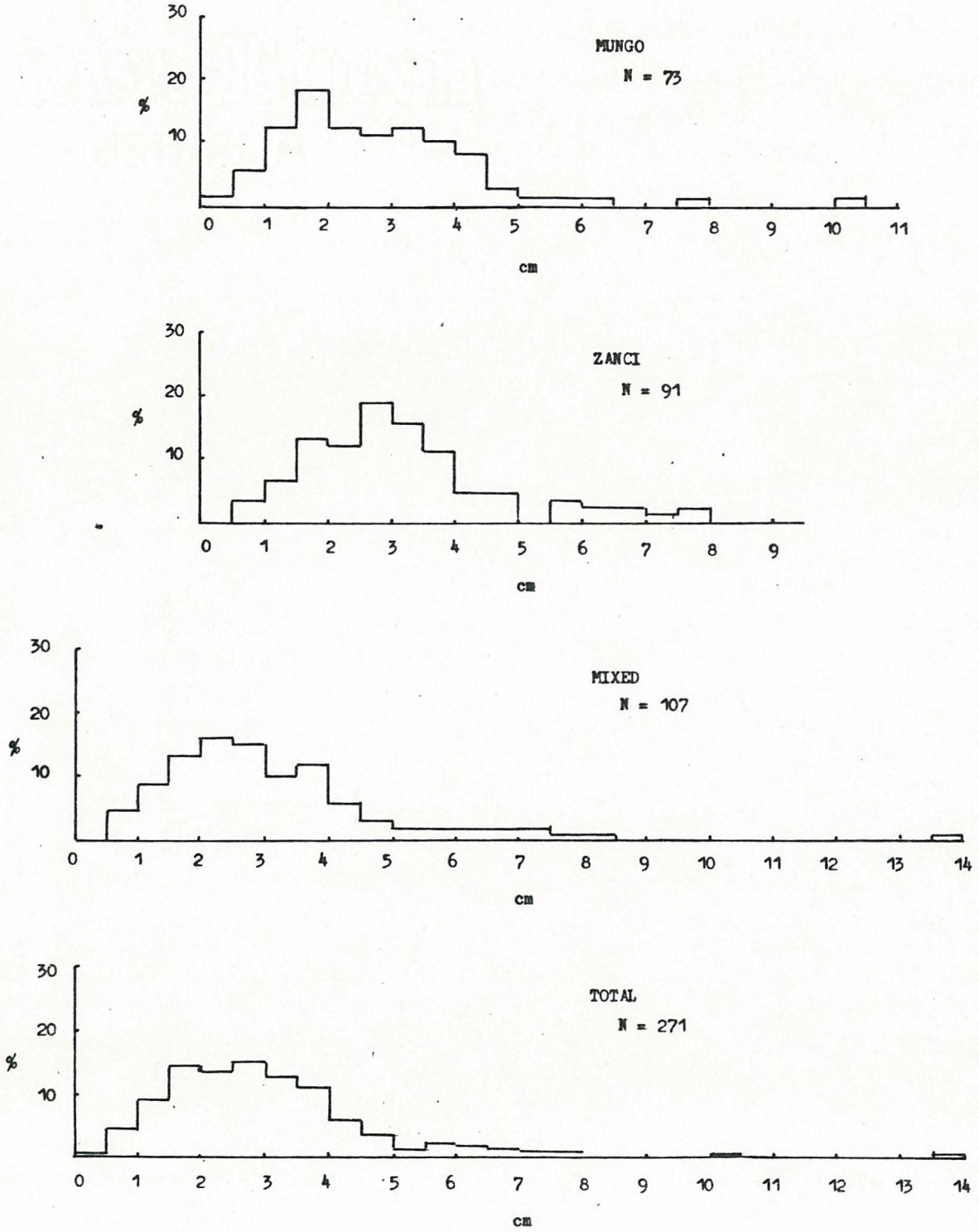


FIG 6.6 Retouched Flakes - Length of Retouch

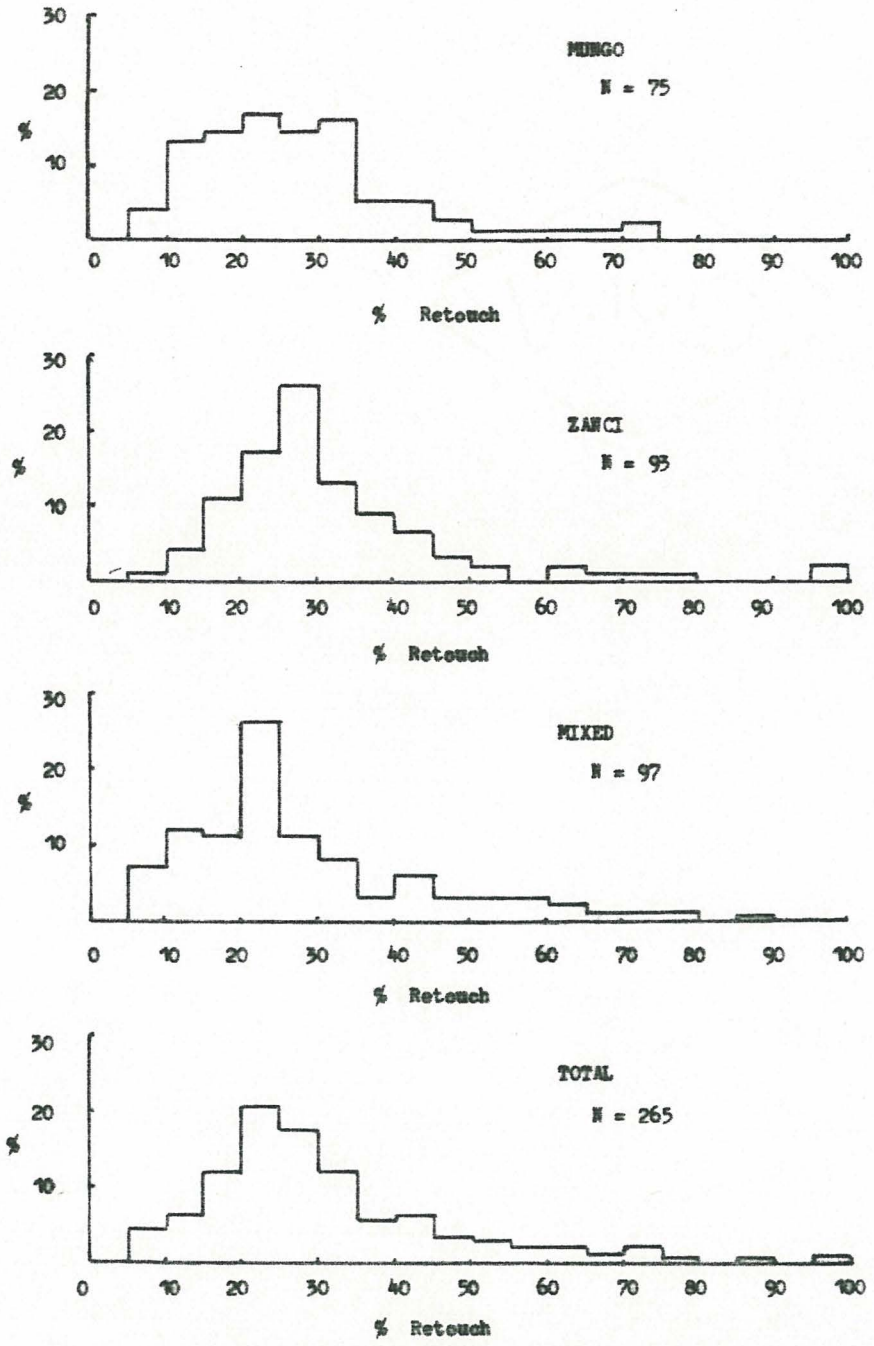


FIG 6.7 Retouched Flakes - Percentage Retouch

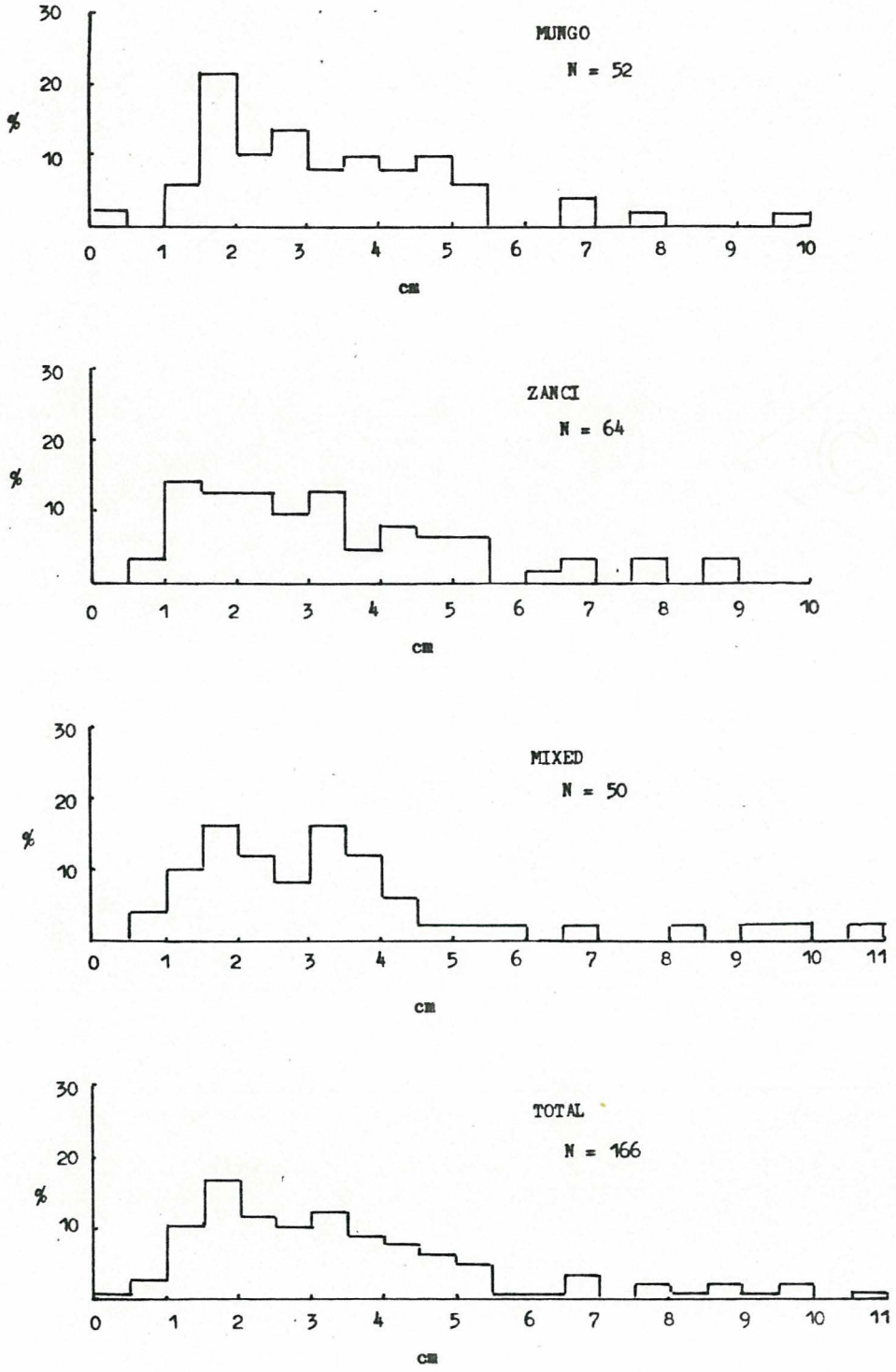


FIG 6.8 Retouched Pieces - Length of Retouch

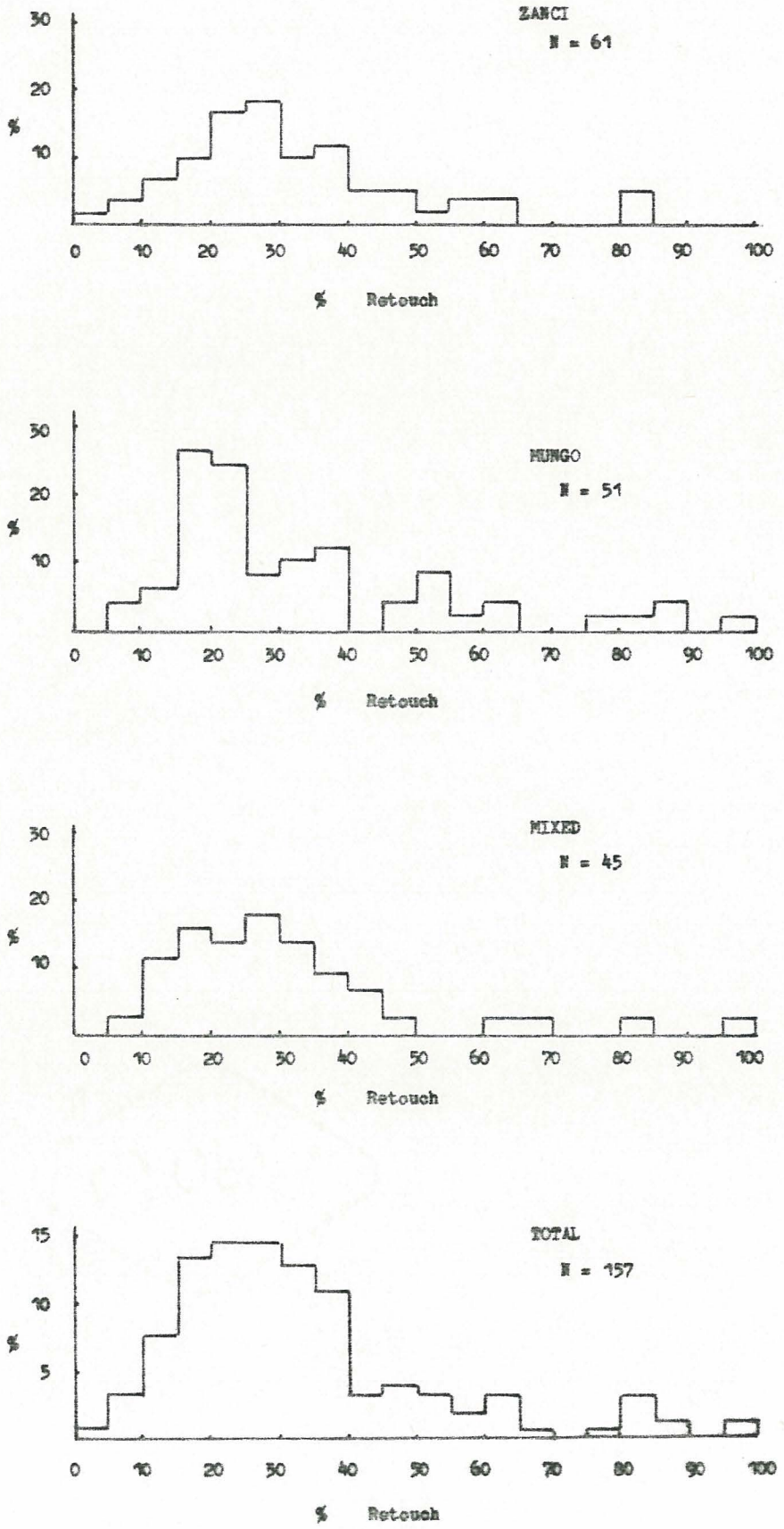


FIG 6.9 Retouched Pieces - Percentage Retouch

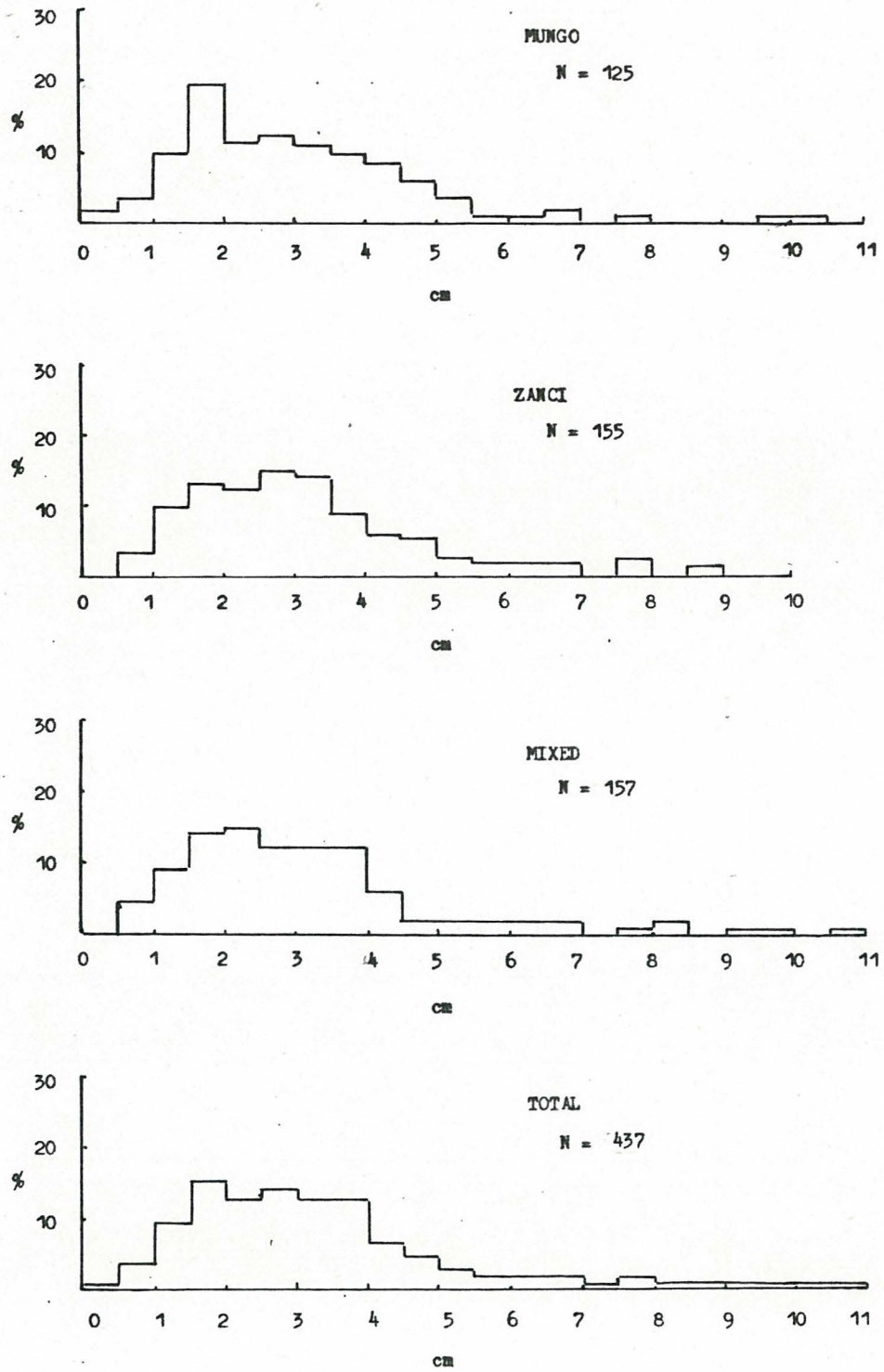


FIG 6.10 Scrapers - Length of Retouch

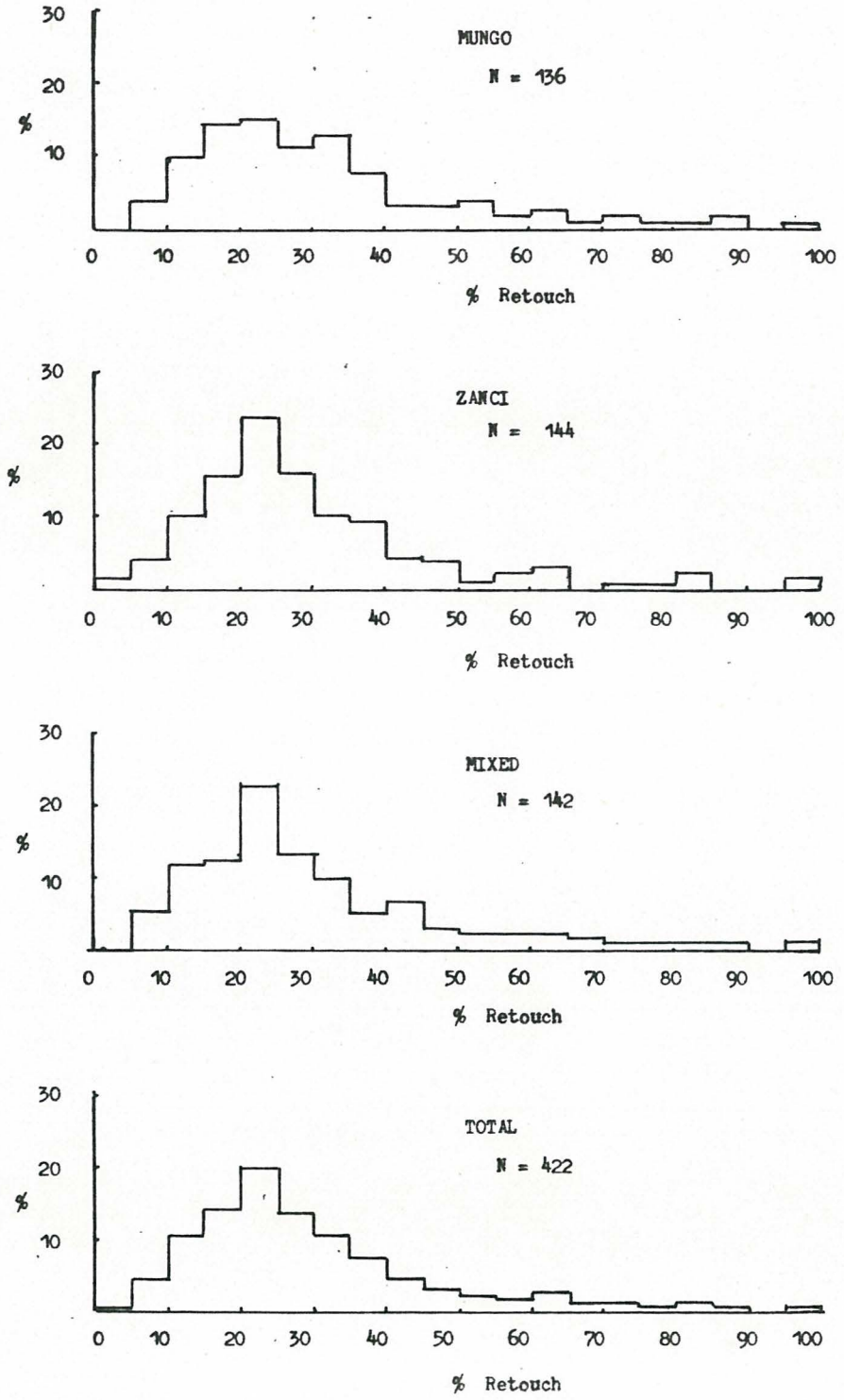


FIG 6.11 Scrapers - Percentage Retouch

to provide a more objective method of separating side and end scrapers. The measurements turned out to be so inconsistent, however, that I abandoned the attempt, this defeat presumably bearing out my scepticism, arrived at subjectively, that the application of McCarthy's classification to the Lake Mungo collection is inappropriate.

Statistically significant differences between the retouch characteristics of the Mungo and the Zanci material were sought by comparing the retouched pieces and retouched flakes separately and then combined together as a scraper group. Radius of curvature and length of retouch, both as a linear measure and as a percentage of the total margin were tested. Only the radius of curvature of the retouched pieces produced a significant result (see Table 6.6). In this case it was inappropriate, because of the small number of measurements available from the Mungo and the Zanci areas, to use the Kolmogorov-Smirnov test. Application of the Mann-Whitney test (Siegel, 1956, p.116) produced a significant difference at the 5% level ($p < 0.04$) between the retouched pieces recovered from the two surfaces with the Zanci pieces generally having a more convex margins. In view of the arbitrary way in which some margins with irregular profiles were excluded from measurement (see p.136) the weight that can be attached to this result cannot be great since the comparison was made between only approximately 20% and 40% of the Mungo and Zanci material respectively.

The proportion of irregular margins itself, however, is not without interest. Approximately 75% of the retouched flakes from both the Mungo and the Zanci surfaces had 'measurable' radii, ie. the retouched margins were sensibly regular. In contrast, as noted above, the ratio was lower at about 30% for the retouched pieces. It is tempting to speculate that this resulted from the more purposeful formation of a flake with the smooth margin in the mind of the knapper from the outset whereas the use of pieces was more opportunistic with sufficient reshaping undertaken only for the immediate task. Unfortunately this hypothesis finds no support

from the flakes and pieces recovered from the mixed areas where the percentage of 'measureable' or regular margins is the same for both types at approximately 30%.

I was dissatisfied with my measurements of angle of retouch. Initial inspection of the Lake Mungo material left an impression that the retouch was of an ad hoc nature, in many cases varying in angle and type along the margin. Jones, faced with a similar problem, made a number of measurements around the worked perimeter (Jones, 1971, p.333). My efforts were limited to estimates of what I considered to be the average, maximum and minimum angles, made by comparing the sloping retouched face with a protractor. I persisted with these gross measures on the scrapers in the 1976 collection and found that the majority of angles fell between 45 and 85 degrees with some preference for the interval between 65 and 85 degrees. There was no suggestion that retouch could be classified as 'steep' in preference to other types. As examples of the observed variability, single scrapers exhibited retouch where the maximum and minimum angles were separated by as much as 60 degrees.

Core Scrapers and Unretouched Cores

With a total of only 45 core scrapers, comparison of these implements according to their location was not attempted. Figure 6.12 summarises the dimensions of all retouched cores. The average thickness of both the retouched and unretouched cores is less than the average length of the retouched flakes. While the larger flakes could have been derived from these cores before additional preparation reduced their size, the absence of large cores at the grid suggests that many of the larger flakes were not prepared on the dune itself. The length of retouch of the majority

ARTEFACT CATEGORY	KOLMOGOROV-SMIRNOV STATISTIC D (1)				
	Dmax		$D_{.05}$	Dmax	$D_{.05}$
	LENGTH OF RETOUCH	% RETOUCH	-	RADIUS OF CURVATURE	-
SCRAPER	8.4×10^{-2}	6.6×10^{-2}	1.6×10^{-1}	2.0×10^{-1}	2.1×10^{-1}
RETOUCHED FLAKES	1.4×10^{-1}	1.0×10^{-1}	2.1×10^{-1}	4.9×10^{-2}	2.4×10^{-1}
RETOUCHED PIECES	9.5×10^{-2}	1.0×10^{-1}	2.5×10^{-1}	Mann-Whitney Test $p < 0.038$	

TABLE 6.6 - COMPARISON OF RETOUCH CHARACTERISTICS OF MUNGO AND ZANCI MATERIAL - VALUES OF KOLMOGOROV-SMIRNOV STATISTIC

NOTE (1) - For Kolmogorov-Smirnov test $Dmax \geqslant D_{.05}$ for statistical significance at 5% level

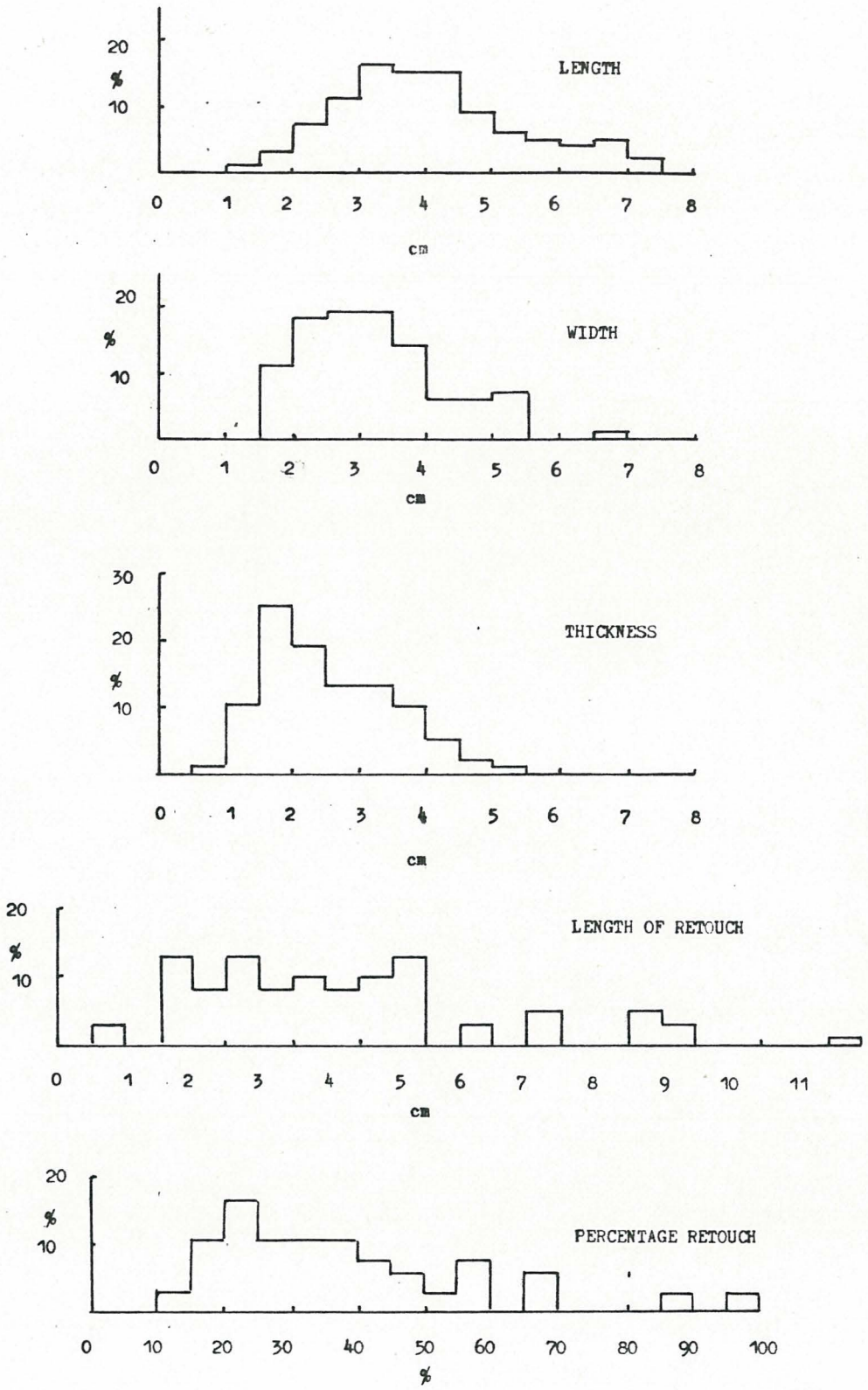


FIG 6.12 Core and Core-Scraper Characteristics

of cores was between 1.5 and 5.5 centimetres with no apparent preferred intermediate value. Similarly, when expressed as a percentage of the total margin values were spread evenly between 15% and 60% with only a few implements falling beyond these limits. The mean and standard deviations of the dimensions and length of retouch of the cores are given in Table 6.12,which includes also data on the dimensions of the unretouched cores. These do not differ in size significantly from their retouched counterparts.

Other Implements

Thumbnail Scrapers. Six thumbnail scrapers were recovered in the course of the 1976 collection with one additional example in 1978. The seven implements were located, apparently at random, in all rows of the grid, four being found on the Zanci surface, two on mixed Mungo/Zanci exposed areas and one on a Mungo surface. As the numbers are small, the characteristics of the thumbnail scrapers are presented in full in Table 6.7a.

Backed Blades. The material collected during 1976 and 1978 included a single microlith and six backed blades. Again, their location appeared to be unrelated to the exposed surface on which they were found and, again, 1976 was a good year for backed blades, half of them being recovered then. Dimensions and the extent of blunting retouch are included in Table 6.7b.

Burren and Tula Slugs. A total of three adze slugs were identified, one from the Zanci and two from the Mungo surface. The latter were made of an unusual honey coloured chert, were geometrically similar and were recovered from the same grid square in 1978.

The evident scatter of 'recent' material across all surfaces when an assessment of possible differences between two older assemblages is being attempted demands further discussion.

SQUARE RECOVERED	DEPOSIT	DIMENSIONS (cm)			RETOUCH	
		LENGTH	WIDTH	THICKNESS	LENGTH (cm)	%
F13	Mungo	1.3	1.2	0.7	2.1	51
B1	Zanci	2.0	1.6	1.0	5.1	100
C8	Zanci	1.8	1.5	0.6	1.4	27
C12	Zanci	1.5	1.3	0.6	2.7	47
D4	Zanci	1.2	0.9	0.4	3.0	73
D20	Mixed	1.8	1.6	0.6	4.9	93
E7	Mixed	1.7	1.6	0.5	3.4	52

Table 6.7a THUMBNAIL SCRAPER CHARACTERISTICS

SQUARE RECOVERED	DEPOSIT	DIMENSIONS (cm)			RETOUCH (blunting)	
		LENGTH	WIDTH	THICKNESS	LENGTH (cm)	%
F13	Mungo	1.6	0.7	0.3	2.2	54
F13	Mungo	2.3	1.4	0.6	4.1	62
B1	Zanci	2.3	1.1	0.6	Backing broken	
C5	Zanci	1.8	1.2	0.5	2.1	42
C14	Zanci	2.1	1.1	0.6	2.5	42
E21	Mixed	2.5	1.5	0.5	4.0	58

Table 6.7b BACKED BLADE CHARACTERISTICS

Recent material was presumably deposited on the dune surface prior to the onset of erosion and processes can be proposed to account for the presence of such material on the present deflation surfaces. Firstly, slopewash could transport the lighter material in the interval between annual collections from the recent deposits above the grid to the grid squares where they are found. This finds little support in the experimental work presented in Annex B where none of the dummy artefacts that had not suffered gross interference had moved more than a few metres.

The second process is a less dramatic version of the first. It is assumed that movement is again effected by slopewash but that temporary reburial in the erosion silt takes place so that the translation of artefacts across the site can occur more slowly by avoiding recovery in the collections made in the intervening years. The feasibility of this composite mechanism is difficult to assess. Two of the small replica artefacts deposited on essentially flat areas could not be located and have presumably been buried.

Finally, displacement may have taken place in a generally vertical rather than horizontal direction. Bowler has published stratigraphic sections through the southern end of the Lake Mungo lunette, (Bowler, et al, 1970, Bowler, 1971) in which he has included the pre-deflation surfaces in outline. Accepting the indicative nature of this aspect of his diagrams, an estimate can be obtained of the vertical movement necessary for recent material to reach the present deflation levels from the pre-erosion surface. While neither of Bowler's diagrams corresponds exactly to the location of the grid area on the lunette they are within 2 km and are broadly representative of it. Distances between one and ten metres from the pre-deflation surface are obtained for the depth of the present Mungo surface and between four and six metres for the Zanci areas. However, the approximate nature of these values may be judged from the fact that at one point Bowler's notional pre-deflation surface is shown some three metres

above the Zanci soil to which it corresponds. A vertical displacement of the order of one to two metres therefore may be sufficient to account for the presence of recent amongst the ancient material. Both the rat kangaroo *(Bettongia Leseuer)* and the hairy nosed wombat *(Lasiorhinus gillespiei)* were known to have been present in the region in 1850 (Bowler et al, 1970, p. 53). Both are burrowing animals and evidence of their activity is apparent when one's foot breaks through one of the fossilised burrows that lie beneath the grid or when erosion exposes the skeletons of one of the animals that has apparently died in its burrow. No estimate has been made of the age of these remains and many may be contemporaneous with the period of dune building. If some date from the last few thousand years, however, and this is possible as the burrows of the wombat are usually 3-5 metres long (The Australian Encyclopaedia, Vol. 6, p. 349), the burrows provide evidence that there was access from the surface to the ancient deposits in recent times.

This discussion has done no more than present feasible explanations for the presence of recent material among considerably older examples. No assessment of the corresponding probabilities seems possible. The quantity of implements involved is small, as is their size. Transport by slopewash requires the recent material to be derived from an area a few metres wide along the upper edge of the grid where the recent deposits are being eroded. An average of two thumbnail scrapers per year from a 500 metre strip of this width does not seem excessive. Additionally, only small implements of comparatively recent origin have been found. There seems to be no reason why larger items should not find their way down burrows but sorting would take place under the action of erosive forces moving material across the surface. Furthermore, erosion presumably varies annually and it may be significant that 70% of the group made up of thumbnail scrapers and backed blades were recovered in the one year. Unfortunately, time has not yet permitted a detailed examination of the local meterological records to see whether conditions in 1976 could have accounted for this.

Summary

In summary, the analysis of the surface material collected at Lake Mungo in 1975, 76 and 78 is unable to demonstrate statistically significant differences in the characteristics of artefacts recovered from the Mungo and Zanci deposits. The present data suggest, however, that differences that are acceptable statistically might be revealed if the sample size were doubled. Additionally, multimodal frequency distributions appearing in different areas, suggesting a mixture of populations with markedly different characteristics, are absent. The width of scrapers found on the Zanci surface provide a weak exception to unimodality but this is not repeated in material recovered from the Mungo or mixed areas.

Types of implements generally accepted to be representative of more recent traditions such as backed blades and thumbnail scrapers are found as isolated examples throughout the site. It has not been possible to demonstrate whether their presence is due to horizontal transport by slopewash from recent deposits or it has been brought about by the action of burrowing animals.

Comparison and Discussion

It is of interest to compare the results presented in Tables 6.3 and 6.5 with the characteristics of material of a comparable age obtained elsewhere in Australia. Such comparison requires to be made on a common basis of measurement.

When deciding not to make the maximum length the reference measurement for the implements in the Lake Mungo collections I recognised that comparison would be necessary with the results of others who had chosen to employ that parameter. I therefore recorded both measures together with the corresponding widths for a sample of implements in order

to obtain the necessary conversion factors. These are shown in Figure 6.13. As an example of the use of this diagram, I obtained mean values of 34.1 mm and 26.6 mm for the length and width respectively of retouched flakes recovered from the Mungo surfaces. Had I used maximum length as my reference measurement instead of measuring it perpendicular to the striking platform, my values would then have been 37.3 mm and 23.6 mm, obtained by entering Figure 6.11 on the horizontal axis at 34.1 mm and reading off from line (a) for length and similarly at 26.6 mm and line (b) for width.

It is interesting to note from Figure 6.13 that practically no correction is required for the width measurement of retouched pieces or, in other words, on average the method of measurement used here gives the same width value as that obtained by taking the maximum length of the piece as the reference measurement. Some caution is required in using other parts of the diagram however. Clearly, the maximum length of very small flakes is overestimated by the linear equation used here but a greater sophistication is probably not called for if interest is restricted to the central parts of the diagram.

With the necessary relationships established, it is possible to compare results from other relevant Australian sites. Examples with assemblages dated to 12,000 years BP or earlier include those of Keniff Cave (Mulvaney and Joyce, 1965), Burrill Lake (Lampert, 1971) and Lake Mungo itself (Allen, 1972).

Mulvaney saw the Kenniff cave material as comprising two components, the first consisting of non-hafted implements only followed by a second technology which included hafting. This hypothesis was later adapted and broadened by Jones and Allen following an initial examination of surface material at Lake Mungo when they proposed the term 'the Australian core tool and scraper tradition' for the earlier cultural tradition, thus avoiding the need for subjective

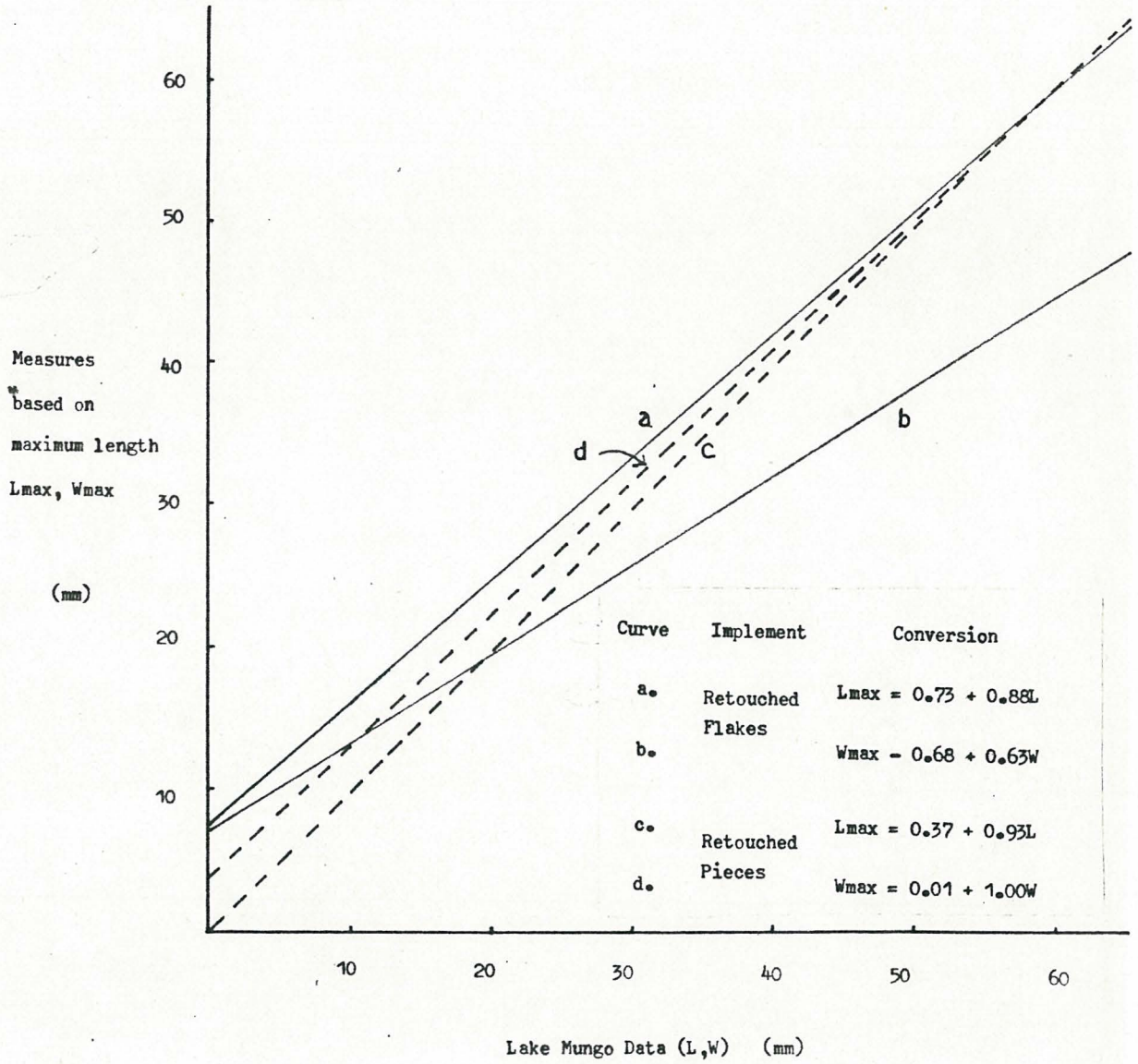


FIG 6.13 Implement Measurement - Conversion Diagram

assessments concerning the mounting of the stone implements (Bowler et al, 1970, p. 52).

The results of Mulvaney's analysis of the dimensions of the non-hafted implements are presented in the form of histograms for length, width and thickness. These data are further subdivided according to depth at intervals of approximately two feet (60 centimetres). The retouch on implements from all levels is summarised as the percentage of the margin that had received secondary working. I recovered the mean and standard deviation of each parameter from the grouped data in these diagrams and they are listed in Table 6.5 where both the values for material from the entire excavation and those for the 8 to 10.5 feet level (2.5 to 3.5 metres, approximately) are given. Carbon 14 dates from this level gave values of 9 to 13,000 years BP, although earlier dates were indicated for samples obtained above this level.

The method of measurement of the implements adopted by Mulvaney had some similarity to mine in that 'when the striking platform was evident, the implement was orientated with the platform as base ...'. (Mulvaney,et al, 1965, p. 177). When the platform was missing, however, the long axis was oriented vertically. In the latter case, and when the implement bore little resemblance to a flake, I reverted to the dimensions of the smallest external rectangle for length and width (see p.135). Our method of measuring width and thickness as the two perpendicular measurements to length was identical.

Despite this similarity in method,the mean values I obtained for the dimensions of scrapers at Lake Mungo are less than Mulvaney's (see Table 6.8). The difference is significant at the .001% level in length. A comparable difference in thickness is not unexpected since, in contrast to Mulvaney, I have subjected core implements to a separate analysis.

SCRAPER CHARACTERISTICS		KENNIFF CAVE						LAKE MUNGO					
		8-10.5 feet			All Levels			Mungo			Zanci		
		μ	σ	N	μ	σ	N	μ	σ	N	μ	σ	N
Length	mm	41 ±	12	32	46 ±	17	249	34 ±	11	110	36 ±	11	142
Width	mm	40 ±	12	32	41 ±	14	249	27 ±	10	111	27 ±	8	141
Thickness	mm	16 ±	6	33	27 ±	7	191	11 ±	6	118	11 ±	5	139
Retouch	%		-		43	20	247	31	18	136	29.3	17	144

Table 6.8 COMPARISON OF LAKE MUNGO AND KENNIFF CAVE DATA

Comprehensive results from his excavation at Burrill Lake, on the South Coast of New South Wales, have been presented by Lampert who identified five cultural divisions, the earliest dated to approximately 21,000 years. (Lampert, 1971). Given the probable intense occupation periods at Lake Mungo separated by a period of dessication between 22,000 years BP and 18,000 years BP (Dare-Edwards, 1979), two sets of the Burrill Lake results are of interest: those from Level III dated to about 12,500 years BP and those from the lower two levels for which dates of approximately 20,800 years BP were obtained and which are combined by Lampert.

Lampert measured length and breadth as '... the longest and shortest axis in the horizontal plane, irrespective of the position of striking platform on flake and blade tools'. Thickness is the maximum possible measurement perpendicular to the horizontal plane. (Lampert, 1971, p. 16).

In his summary of scraper characteristics core tools are included but by using data on cores which Lampert analysed separately I have attempted to allow for this for the scrapers located in Levels IV-V where three core implements were found. In view of the rather small resultant effect, this was not repeated for Level III where only one core was recovered. Comparison with the Burrill Lake data requires my data to be transformed as discussed above. This has been done in Table 6.9. Once again, the values of the characteristics of the Lake Mungo material fall below those from Lampert's material. I have not tested for statistical difference in this case because the histogram for scraper length reconstructed from Lampert's data lies further to the right than Mulvaney's which has already been shown to be significantly different to the Lake Mungo material analysed here.

In his discussion, Lampert examines the correlation

SCRAPER CHARACTERISTICS	BURRILL LAKE (1)						LAKE MUNGO (2)					
	Level III			Levels IV-V			Mungo			Zanci		
	μ	σ	N	μ	σ	N	μ	σ	N	μ	σ	N
Length mm	42	± 19	65	47	± 18	59	37	± 18	110	39	± 16	142
Width mm	33	± 12	65	36	± 12	59	26	± 13	111	25	± 11	141
Thickness mm	18	± 11	65	19	± 11	59	11	± 6	118	11	± 5	139
Retouch: length	49	± 22	65	45	± 25	59	30	± 17	125	32	± 17	155
%	42	± 20	65	33	± 16	59	31	± 18	136	29	± 17	144

Notes: 1. Cores excluded from Level V.

2. Measured dimensions converted to maximum length equivalence.

Table 6.9 COMPARISON OF LAKE MUNGO AND BURRILL LAKE SCRAPERS

coefficients between selected pairs of scraper characteristics. I chose to compare my results with two of these: scraper thickness and length of retouch. Between the first two, like Lampert, I found a significant positive correlation but in contrast there was no correlation ($r < 0.02$) between thickness and length of retouch.

Lampert also provides data on the ratios of width to length and of thickness to width. While acknowledging the direct application of such ratios in discriminating between more stylised assemblages, as in the work of Pitts (1978), I investigated the relationship between width and length using a linear regression. I wished to see whether there were differences in the length-width characteristics of the Mungo, Zanci and Mixed deposit areas.

The relevant scatter diagrams showed that there was no clustering of points suggestive of any division of the scrapers into groups of short-wide, long-thin or any other grouping. The regressions obtained from all three areas were very similar; all showed good correlation between the two dimensions ($r = 0.8$ for the Mungo and Zanci areas, 0.69 for the Mixed area), and the regression slopes for all three areas were about 0.6, the values obtained being summarised in Table 6.10. The slope is an alternative, but not equivalent, average relationship between width and length representing the average increase on width per unit increase in length. Note also, from Table 6.10 that the regression lines do not pass through the origin.

The final comparison to be made here is between my results and those of Allen (1972), who analysed surface material from two areas of the Lake Mungo lunette. The first area - Mungo I - was adjacent to the location where the human remains were discovered in 1968 (Bowler, 1970) and is assumed to correspond to a Mungo surface. Allen's second collection area was approximately 500 metres to the west on Zanci sediments. This latter area which Allen refers

DEPOSIT	REGRESSION COEFFICIENTS		CORRELATION COEFFICIENT	NUMBER
	a_o	a_1	r	N
Mungo	0.43	0.60	0.80	68
Zanci	0.34	0.64	0.81	100
Mixed	0.53	0.57	0.69	105

Regression $w = a_o + a_1 l$

where w = scraper width

l = scraper length

Table 6.10 SCRAPER WIDTH-LENGTH REGRESSION

to as the Walls of China site is immediately adjacent to the grid.

Allen concludes that 'The Mungo site is 26,000 years old; the Walls of China site is younger than 15,000 years. Despite the great age differences ... the implements ... clearly belong to the same industrial tradition'. (Allen, 1972, p. 279). Nevertheless, his classification of the Mungo implements consists of six categories compared with eight in the Zanci material. Only three of these, including the 'miscellaneous' category are common. I have therefore been selective in comparing my results with his.

In the Zanci comparison I have combined the data he presents for five categories, omitting the flat adze slugs, horse-hoof cores and steep edge scrapers. The first two of these I have classified separately from scrapers and should not therefore appear in any comparison but the steep edge scrapers cannot be so easily rejected. Allen's definition was that they are 'manufactured on thick flakes or cores'. If the former, I would have included them among the retouched flakes, while in the latter case I would have classed them as cores, but it may be that Allen's steep edge scrapers would correspond to some of the implements that contribute to the 'tail' of the distribution of my retouched pieces (see Page 147). I finally excluded them in a completely arbitrary fashion with the result that the data here attributed to Allen may underestimate the average dimensional characteristics of his material.

Despite such underestimation, the average dimensions of Allen's Zanci collection are still in excess of those of the implements recovered from the grid (see Table 6.11)but it is not obvious from his summary to assess the reason. In the discussion, Allen expresses a reservation that ' ... the low number of unmodified flakes compared to implements suggests that the collection may have been biased

SCRAPER CHARACTERISTICS	ALLEN (1972)[1]						ROBINSON (1975-78)[2]					
	MUNGO			ZANCI			MUNGO			ZANCI		
	μ	σ	N	μ	σ	N	μ	σ	N	μ	σ	N
Length mm	53	± 11	81	41	± 18	66	37	± 18	110	39	± 16	142
Width mm	39	± 8	81	30	± 8	66	26	± 13	111	25	± 11	141
Thickness mm	20	± 4	81	13	± 5	66	11	± 6	118	11	± 5	139
Retouch: length	45	± 21	82	35	± 12	68	30	± 17	125	32	± 17	155
%	37	± 16	82	41	± 10	68	31	± 18	136	29	± 17	144

Notes: 1. Based on selected classes of scraper (see text).

2. Measured dimensions converted to maximum length equivalence.

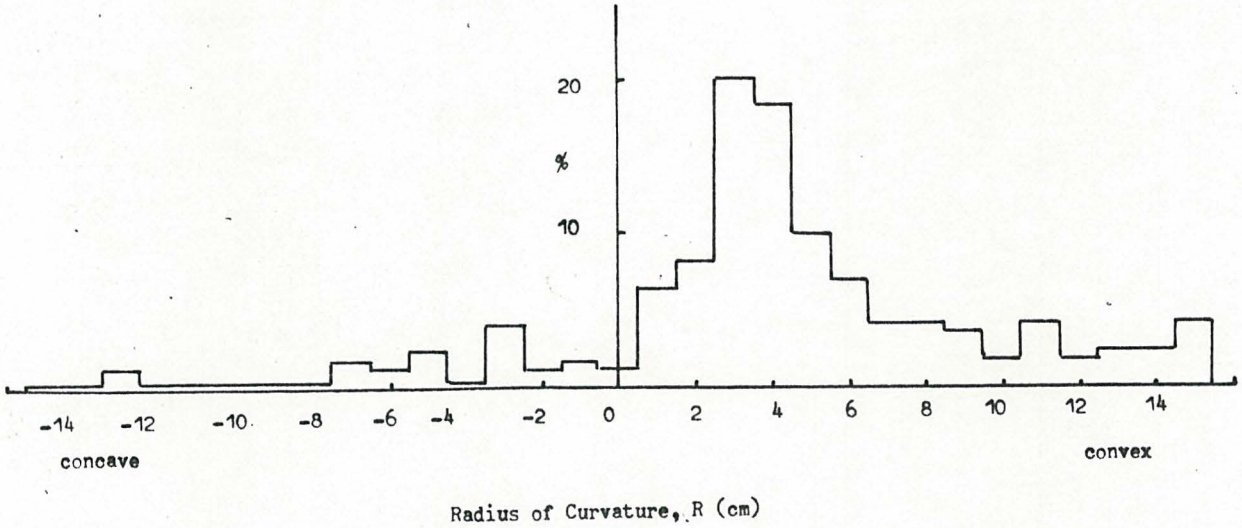
Table 6.11 COMPARISON OF LAKE MUNGO SCRAPER CHARACTERISTICS

towards larger stones.' (Allen, 1972, p.263). If this is so, my results are similarly biased for I obtained an average of 11 flakes per implement compared with Allen's ratio of 10:1.

The eight fold classification of his Zanci material employed by Allen includes round edged scrapers and straight edge scrapers. Apart from minor differences in the retouch characteristics both are flat with round edged scrapers '... made on flakes possessing a relatively straight edge'. My measurements of the radius of curvature (Figure 6.14), imprecise as they are, tend not to support such a dichotomy although I felt confident of measuring the radius of curvature of only 168 or approximately 40% of the total of 416 scrapers, including core scrapers, the remainder being irregular, S-shaped or having variations in the retouch characteristics margin. The problem lies in the quantitative definition of 'straight'. If 'straight-edged' requires the radius to be arbitrarily greater than 10 centimetres there were 53 or 32% within this category compared with 108 or 64% with a radius less than 5 centimetres. If, however, the radius of curvature of a margin must exceed 15 centimetres for it to be classed as 'straight', then less than 10% of the scrapers measured fall into this category. I can only add that, in handling the material, I was not conscious of straight-edged or any other geometrically shaped scrapers forming well defined groups.

The characteristics of the combined horse hoof cores and steep-edge scraper categories from Allen's Walls of China site are shown in Table 6.12, together with the values for cores from Burrill Lake and from the recent Lake Mungo surface collections. Although not repeated here, it may be of interest to note that the values of the parameters of the steep scrapers from the Pleistocene levels at Cloggs Cave in East Gippsland, Victoria (Flood, 1974) are intermediate between those of Allen and myself for each of the characteristics in Table 6.12.

In summary, the measurements of the working edges of the implements do not support the sub-division of scrapers in terms of their plan-form that was used by Allen. The analysis of the implements collected from the grid shows that, although



Note: Scrapers with R $> \pm 15$ not plotted

FIG 6.14 Scrapers - Radius of Curvature

CORE CHARACTERISTICS	RETOUCHED									UNRETOUCHED		
	BURRILL LAKE			LAKE MUNGO (1972)[1] (Walls of China)			LAKE MUNGO[2] (1975-78)			LAKE MUNGO (1975-78)		
	μ	σ	N	μ	σ	N	μ	σ	N	μ	σ	N
Length mm	56	± 34	7	62	± 18	44	39	± 17	43	41	± 14	123
Width mm	41	± 20	7	45	± 14	44	32	± 10	43	31	± 10	118
Thickness mm	47	± 23	7	30	± 10	44	25	± 8	45	25	± 10	115
Retouch: length	117	± 52	7	60	± 23	61	43	± 24	39			
%	82	± 18	7	36	± 13	61	39	± 20	36			

Notes: 1. Includes cores and steep edge scrapers.

2. Measured dimensions converted to maximum length equivalence.

Table 6.12 COMPARISON OF LAKE MUNGO AND BURRILL LAKE CORES

exact comparison is not possible, as a group their mean dimensions are smaller in all respects than those of the material obtained by Allen from the same lunette.

Consistent differences of such magnitude between collections made at essentially the same location were unexpected. As they are present even in measurements of thickness for which there can be no ambiguity due to orientation on the measuring board, explanations other than those based on differences in methods of measurement must be sought. Several come to mind. Firstly, there may have been differences in the composition of the collections. While it was beyond the scope of this exercise to examine Allen's collection some general comparisons may be made on the basis of his published data.

At Mungo I, Allen's collection was made from 13 separate small areas where surface material was concentrated. He obtained 440 artefacts from a total area, estimated from his published diagrams, of 325 m^2. During the 1978 collection 606 cores, scrapers and unretouched flakes plus an approximately equal quantity of fragments were recovered from an area of 6400m^2 of exposed Mungo surface. Allen's surface densities from his selected areas are thus some seven times greater than the average at the grid. In further contrast at least 25% of his collection was selected for analysis as implements. By comparison the fraction of the recovered grid material classed as implements was only 3%, the majority being waste and unretouched flakes. These figures indicate a dissimilarity between the two collections arising, possibly, from the different collection strategies. with Allen's being more selective than the purposely all-encompassing grid collection.

Allen was further selective when choosing his Mungo scrapers for analysis. In each collection a proportion of artefacts recovered from the lunette exhibit some encrustation of a white carbonate or calcrete. At the time that Allen carried out his analysis it was considered that the presence of calcrete adhering to the surface of an item ensured that it had its origins in the Mungo, as opposed to Zanci, deposits. Allen therefore used this as his criterion together with the fact that they were found on a Mungo surface for the selection of Mungo artefacts. A close correlation between the occurrance of calcrete and artefact origin is no longer believed to hold and a similar criterion was not used in analysing the material recovered from the Mungo surface in 1975 to 1978 collections when only a few implements showed any traces of calcrete. If, however, the mean dimensions of these implements are calculated it is found that the values obtained correspond to those obtained by Allen (see Table 6.13). Although the sample is small the figures suggest that calcrete encrusted implements may, on average, be larger than those with no calcrete.

One can only speculate why this might be so. At the simplest level,if the calcrete, when in solution, percolates through the body of the lunette more or less uniformly,larger items stand more chance of intercepting the flow and, if the surface is suitable, deposits may build up. The process may be more complex, with the solution following preferred paths. The presence of large items of dramatically different material such as silcrete in the otherwise largely uniform body of the dune may serve as points of origin for such paths analagous to the way the formation of stalactites is determined by the cracks in the roof of a cave. If this were so it might be expected that cores being, in general,

	ALLEN		SURFACE COLLECTION	
	Scrapers	Core Scrapers	Scrapers	Retouched and Unretouched Cores
Length (mm)	48 ± 14	62 ± 18	44 ± 20	56 ± 16
Width (mm)	35 ± 8	45 ± 14	36 ± 16	50 ± 5
Thickness (mm)	17 ± 4	30 ± 12	14 ± 9	29 ± 7

TABLE 6.13 - COMPARISON OF CALCRETE ENCRUSTED IMPLEMENTS

larger would be more likely to have calcrete deposited on their surfaces. There is little support for this in the material recovered from the grid. 2.6% of the cores were encrusted while the figure for scrapers was 4.5%. Comparison of the data in Table 6.13 shows, however, that the difference in dimensions of scrapers and cores is small.

Another, more plausible explanation is that in Allen's results we are seeing the results of years of erosion, where, in the absence of previous collections, the larger, heavier material is left more or less in place after the gradual removal downslope of some of the lighter component. The first collection from the grid area was made in 1973 and another in 1974 before the 1975 to 1978 collections analysed here. Allen's material was obtained from an area adjacent to but not overlapping the grid area. If weighting of the initial collection due to erosional effects was occurring then the material in the first of the collections from the grid area would be expected to show larger mean dimensions than those from subsequent field work. It is possible to test this hypothesis numerically using data provided by Dr Isobel McBryde (1973 values from McBryde, in press, and 1974 figures by personal communication) under whose direction the 1974 and 1975 collections were made [1] and who supervised the classification, measurement and analysis of the 1973 and 1975 scrapers by her students. Her results are, therefore, quite independent of those obtained by Allen and myself.

The mean dimensions of the scrapers from the years 1969 to 1978 are summarised in Figure 6.15 where it is apparent that the values fall in the manner predicted. In explanation of Figure 6.15 it should be noted that the scraper dimensions differ slightly from those given in Table 6.12. This is because McBryde's

(1) The 1973 collection was made under the direction of Mr P. Bellwood

scrapers were analysed without particular reference to their provenance and could thus have originated from all three grid surfaces: Mungo, Zanci and mixed. To be consistent, the results for the years 1975, 1976 and 1978, therefore, similarly include scrapers from the mixed areas, in contrast to the data given in Table 6.12, which is confined to the Mungo and Zanci surfaces. Inclusion of these additional scrapers did not change the resulting values of the mean dimensions significantly, except in length where the mean values were reduced. The 1969 values are the result of combining Allen's Mungo and Zanci figures in Table 6.12.

In Figure 6.15 there is striking agreement between Allen's 1969 and McBryde's 1973 values, which correspond to material obtained from previously uncollected areas. There is similar broad agreement, but with smaller mean dimensions, among the values for the subsequent 1974 to 1978 collections from the grid. If it is assumed that the data represent two independent samples from an uncollected area and four from a collected area the data may be combined to obtain mean values for the previously uncollected and collected areas respectively (Table 6.14). As Allen's raw data was not available, it is necessary, in order to test statistically the difference between the two sets of mean values, to assume further that both parent populations are normally distributed. On this basis it is found that the differences are highly significant at better than the 0.1% level for each dimension.

A further hypothesis which might account for the differences in collection characteristics over time is that they reflect a trend in technology. This can be supported by an alternative interpretation of Figure 6.15. Previously the data from 1969 and

Year	N	Dimension					
		Length		Width		Thickness	
		$\bar{X}$	S_x	$\bar{X}$	S_x	$\bar{X}$	S_x
1969	147	47.6	14.6	34.9	9.2	16.9	5.7
1973	47	48.5	14.6	36.9	8.7	19.4	8.8
1974	39	39.5	10.7	30.5	10.3	11.7	5.3
1975	215	38.0	11.7	27.3	9.5	12.0	5.4
1976	73	35.8	10.9	26.3	8.4	11.3	5.0
1978	122	33.6	11.7	27.4	9.9	11.0	5.5
1969 and 1973	194	47.8	14.6	35.4	9.1	17.4	6.8
1974 to 1978	449	37.6	16.4	28.4	9.5	11.6	5.4

Table 6.14. Mean Dimension of Lake Mungo Samples 1969 to 1978

1973 were regarded as being obtained under comparable conditions. If, however, it is assumed that the 1973 data are for some reason uncharacteristic, and noting the hiatus in the horizontal axis then Allen's 1969 results and those from 1974 onwards exhibit a trend toward smaller mean dimensions with time.

A statistical test is available for such trends (Crow, et al 1960) but is subject to assumptions of normality of the parent populations and equality of population standard deviations. If these are made and the test applied, cook-book fashion, only in the case of the thickness dimension is the trend not significant at the 5% level.

The change in mean values over this period is the result of fewer large scrapers being recovered in successive years. This is consistent with a similar trend from 1975 to 1978 in the relative quantities of unretouched flakes and cores which form two other classes of small to medium and large items respectively (see Table 6.1).

The rapidity of the change in mean dimension of the scrapers, which probably corresponds to a lowering of the lunette surface of not more than at most 20 cm is unexpected but other features of the eroded surface have been observed to change. For example, in 1973 when I paid my first visit to the site, there were several apparent hearths emerging from the Zanci erosion surface. These contained thin pieces of red burnt clay not unlike crude pottery in form which, it was suggested, could have been packed round small animals before they were cooked. Despite the specific requests that were made to the collectors in 1976, 1978 and 1979, neither they nor I recovered more than one or two pieces not more than one or two

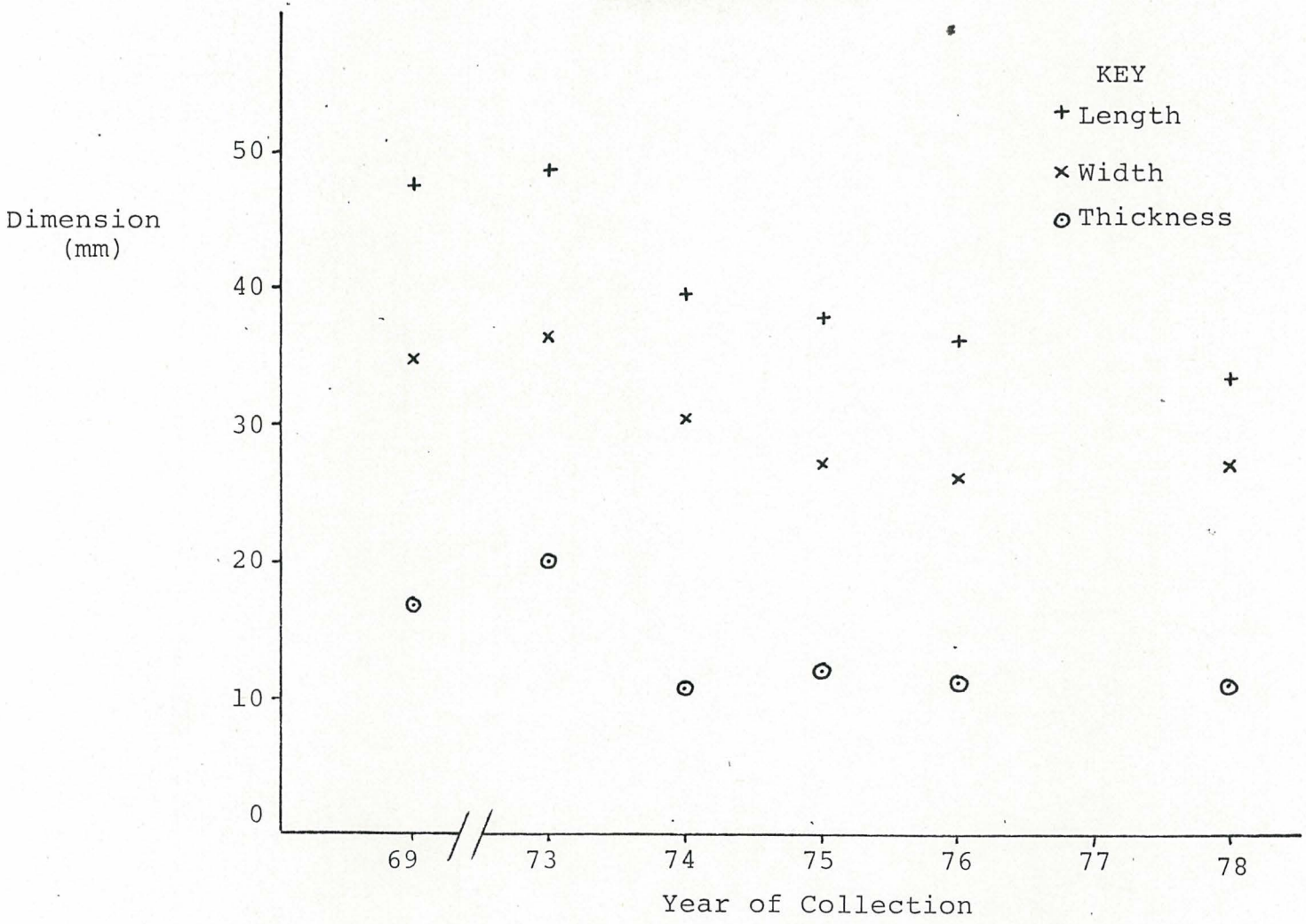


Fig. 6.15 Scraper Mean Dimensions vs Year of Collection

centimetres in area. It is not clear why further examples have not appeared. My impression at the time was that the hearths were eroding in situ and the small surface scatter made it unlikely that they were derived from an earlier surface and had been lowered by erosion. It may be that the clay was the debris at the bottom of fire pits dug from an earlier surface but further investigation must await the appearance of additional examples.

Despite some change in one aspect of the lunette surface and any interpretation of the data in Figure 6.15, it is unlikely that the decreasing mean dimensions are due to changing technology. In Table 6.11 both Allen's results and my own are presented for material from the Mungo and the Zanci surfaces. A decrease in mean dimensions is apparent for each. Comparable technological changes towards smaller dimensions in both deposits at levels separated by millenia is most improbable.

Another, less plausible, explanation for the change in scraper size with time is that the area is being impoverished by the unauthorised removal of implements. It is evident from the relocation of some of the dummy artefacts that the grid area has visitors who are attracted by stones of an atypical appearance at least (see Chapter 5), but examples of the core and scraper tradition can hardly be said to possess the aesthetic appeal of pirri or Kimberley points that would warrant their wholesale removal. Some novelty may lie in their supposed age, however.

Estimates of the rate required depend on assumptions about the size of the items taken but, as an example, each year some 60 scrapers 6 centimetres in length would need to be removed if my mean length measurements are to agree with Allen's and the 1973 collection.

Continuing to set aside the 1973 results, for the moment, Allen's collections were restricted to areas very much smaller than that covered by the grid. In addition it is not clear to what extent his collecting activity was confined to the recovery of fully eroded items lying on the surface or if partially embedded material also was withdrawn from the lunette deposits.

Baker has considered some aspects of the 'size effect' in surface collections using a very simple model of the cycle of deposition, sedimentation, erosion and re-utilisation. His definition of the size effect is that 'if items of several kinds are distributed in a site, the probability that any item will be visible on the surface is directly proportional to its gross size.' (Baker, 1978, p.288). Supporting arguments and data are advanced which suggest that scavenging and re-use as an archaeological deposit is built up leads to a preponderance of large artefacts in the upper and surface levels. His conclusion largely ignores unknown factors such as the increase in the number of small items at the expense of the larger ones due to re-shaping or the rate at which new material is introduced to the site.

Accepting his broad conclusion, however, it is possible that Allen's collection from the hearths on the Mungo surface was affected by contemporary surface scavenging concentrating the larger items that were exposed at the time of occupation. It is not clear whether the same can be said of the Zanci material collected over a larger area. Unfortunately, Baker's arguments applied to the Kenniff Cave and Burrill Lake excavations would mean that the lower levels, with which the Mungo material has been compared, would have suffered some depletion of larger items, thereby

reducing the true difference between their mean dimensions and those from the recent surface collection. Furthermore, the 1973 collection, which also had above average dimensions, was not restricted to the vicinity of hearth areas but extended across the entire grid.

If the Kenniff Cave, Burrill Lake and previous Mungo material is representative, perhaps it is the recent surface collection which is atypical. Mean values are reduced either by the exclusion of large items or by the inclusion of small implements.

It is unfortunate that Allen does not illustrate his results graphically, but comparison with Mulvaney's histograms (Mulvaney, et al, 1965) showed that both effects were present; there were proportionately more small scrapers and fewer very large scrapers in the recent Mungo surface collection.

There seems to be no reason why large items, if present, should not be recognised and recovered during surface collecting or omitted during sorting and analysis. The inclusion of an excess of small scrapers could be the result of mis-classification during sorting. I may have included among the scraper category items which would have been rejected by others as having trivial or unintentional retouch although it is not clear why this error, if it occurred, should be limited to the small scrapers; not all large scrapers were characterised by extensive retouch.

Summarising, the most likely explanation for the difference between the mean dimensions of the scrapers collected in 1969 and 1973 and those recovered during later collections seems to be that the former were found in areas from which material had not been gathered previously. It is possible that erosion

working over a period of many years had removed a proportion of smaller items from the dune surface, increasing the mean dimensions of the remaining samples of material. The interval of one or two years between subsequent collections was insufficient for these same erosion processes to have a significant impact.

Conclusion

The contents of this chapter covers two themes: a comparison of artefacts collected during the years 1969 to 1978 from the Mungo and Zanci surfaces and a further comparison of these Lake Mungo implements with material elsewhere in Australia.

Mungo and Zanci Surfaces. There is nothing to suggest that there are differences in the characteristics of the implements found on the Mungo and Zanci surfaces. This conclusion is supported by formal statistical tests on the data available but it is possible that a data base of approximately twice the size could give differences which do have statistical significance. In addition, there is a consistent ranking in size with type of deposit which, although based on extremely small differences, is not explicable in terms of movement of artefacts by erosive forces. Further work might confirm this ranking and enlarge the statistical data base. The presence of isolated examples of recent industrial traditions, including thumbnail scrapers and backed blades, on the exposed ancient Mungo and Zanci deposits may be indicative of mixing by erosion. It is possible, however, that activity by burrowing animals could have contributed to this spread.

Comparison with Other Work. Despite differences in classification and method of measurement, it appears that, in comparison with approximately contemporary material

from Kenniff Cave, Burrill Lake and two earlier collections at Lake Mungo itself the mean dimensions of the recently recovered artefacts from the grid at Lake Mungo are significantly smaller in average dimension and quantity of retouch. It is suggested that the differences between the Lake Mungo collections may be explained by the removal by erosion over a period of many years of some of the smaller items from the sloping dune surface. Both the sites at Kenniff Cave and Burrill Lake were shelters, however, and such a mechanism would have been absent there. Without additional evidence about the factors which could have influenced such geographically and environmentally disparate sites there would be little value in speculating upon the reasons for such differences.

While no quantitative comparison between the surface material and that recovered from the two adjacent excavations has been carried out, superficial examination revealed no differences between the two samples. Indeed there were some striking similarities including the presence of a rolled artefact among the items excavated (Shawcross and Kaye, 1980, p122).

CHAPTER 7

SUMMARY AND CONCLUSION

The aim of this chapter is to review the research reported here and to consider the extent to which the aims outlined in Chapter 1 have been met. There the major objective was described as an assessment of any differences in technology in the material recovered from the Mungo and Zanci surfaces at the Lake Mungo grid. In order to achieve this goal with any confidence it was necessary to examine the question within a broader context and consider not only those aspects of the processes, both past and present, which have been and still are active in the development and subsequent decay of the site but also the method by which the samples of artefacts were obtained.

Taking as the point of departure the earlier geomorphological and archaeological analyses summarised in Chapter 2, I developed my investigation through a study of the effects of natural erosion and other potential sources of disturbance on the security of provenance of the exposed material. I next considered the factors influencing the completeness of the collection itself before analysing the surface distribution of the artefact classes identified within the recovered material. Finally, measurements of the physical characteristics of these component classes were made and correlated with the deposits exposed on the surface of the eroding lunette. The broad conclusions from each of these aspects of the work are now summarised.

Erosion and Surface Disturbance. A survey of the literature on slopewash and wind erosion showed that these forces had the potential to move the smaller artefacts.

This was confirmed by a simple experiment in which the behaviour of flakes positioned in shallow water flowing down an approximate replication of the sloping lunette surface was examined. Nevertheless, despite the success of this simulation with small flakes, photographic records at the grid indicate that flat stones of about 5 cm dimension and an estimated 2 cm thickness are not moved appreciably despite lying on a surface which was subsequently lowered to become a rainfall erosion channel of 2 or 3 cm depth. These records suggest that a carefully positioned series of stereophotographs of small areas of the grid over a period of many months could provide useful data on the movement of surface material. Absolute accuracy in repositioning the camera, while desirable, would not be essential if relative movement only between artefacts is of interest.

It is clear that the replica artefacts left on the surface of the grid are suffering some interference but, because of their unexpected degeneration into an atypical appearance,the extent to which this evidence may be transferred to the prehistoric material is uncertain. Confirmation will only be attained by depositing more exact and durable replicas for later recovery. Such action may contain the seeds of a method of site protection against unauthorised collectors similar to that employed at American Civil War sites where the ravages of metal detector-toting souvenir hunters were halted by salting the areas with modern metal discs buried below the surface.

Estimates of the rates at which the surfaces of the lunette are eroding were obtained from the increasing exposure of the pegs which define the grid squares. The concentrations of artefacts per unit volume of deposit which would be required to yield the quantity collected from the surface following a year's erosion were estimated and found to be comparable with those from a nearby excavation.

The question of the scale of erosion applying at times during the dune building and occupational phases was not addressed despite its obvious importance to the study of artefact distributions. It has been reported by Dare-Edwards that heavy rainfall produced significant changes in the surface contours of the Lake Chibnalwood lunette in the past. The conditions responsible for these changes during an otherwise generally aeolian depositional period might be expected to have had some impact on the Lake Mungo environment which lies within 15 km of Lake Chibnalwood but no assessment of the magnitude of the disturbance has been attempted. Surprisingly, the impact on the area of the dune where the grid is located is apparently small, for, as noted by Bowler, the fine bedding is sufficiently preserved to suggest the seasonal nature of deposition (Bowler, 1971, p.61).

The principal conclusion to be drawn from the consideration of erosion at the site is that it has some effect on the distribution of the material but is a major factor only over a period of many years. This is supported by a comparison of the characteristics of the surface material collected at different times. A disappointing discovery was that the surface material is subject to human interference. Surface sites, and therefore the work based on them, are particularly vulnerable to such activities and, in contrast to an excavated record of occupation, there may be no evidence of such intervention.

Collection processes. Studies of visual perception have shown that contrast between the item for which a search is being made and its background in terms of colour, shape and size is important. Comparison between the range of circumstances for which this research is valid and the ambient conditions at Lake Mungo lead to the conclusion that artefacts less than 1 cm in maximum dimension may not be

detected and recovered. In one respect this is unimportant for there are no indications from the finished implements of any major change in technology throughout the deposit. Thus the characteristics of the products of the implement shaping processes which probably make up the bulk of the smaller artefacts would not be expected to change and their absence from the collection is not critical for comparison purposes. However, the importance of recovering a complete sample of waste material also lies in assessing whether the implements were fashioned at the lunette or elsewhere, for example, at the source of the stone. Absence of a major proportion of large unretouched flakes suggests that these were subsequently utilised or that roughed out implement blanks were brought to the site.

'Salting' the surface with small replica artefacts prior to future collections may be a way of both increasing the motivation of collectors through rewards and simultaneously allowing an estimate to be made of the efficiency of the recovery process, particularly at the lower end of the size range.

Surface Distribution. The distribution of material may be considered at two levels: small scale where the dimensions are similar to those of the grid squares and large scale with areas comparable to those of the features of the lunette.

At the small scale, although blackened areas with a few large unshaped stones in the immediate vicinity have been noted, concentrated surface scatters of occupation debris have not been observed during visits to the grid extending over a four year period. This is in contrast to earlier admittedly superficial personal impressions concerning the lunette. It may be an indication of the infrequency with which true hearths are eroded from a specific area in that once the initial surface accumulation has

been cleared there may be an interval of many years before a further example is exposed. Alternatively, this section of the lunette near to its southern limit may have been unattractive for domestic activity. What were the conditions on the adjacent lake shore beyond the end of the lunette during periods of occupation? If they consisted of marsh and swamp, for example, those exploiting the resources of the lake shore would have weighed the advantages to be gained from proximity to a water fowl refuge and to a source of edible water plants against the increased tolerance demanded by the presence of mosquitos and other insects.

Formal analysis of the large scale mutual distribution patterns of the different types of implements was frustrated by the critical response of the method to the possibility that natural processes could lead to the disturbance of the implements subsequent to their exposure. Although results of theoretically statistical significance were obtained for correlation between some artefact classes, such mathematical assessments could not be allowed to take precedence over the physical processes at the lunette. The opportunities for the displacement of implements by natural means were shown to be sufficient to call into question any conclusion having a solely numerical basis. If this avenue of comparison is to be followed, and as yet its value remains unproven at Lake Mungo, more robust analytical methods must be sought in conjunction with more precise information concerning artefact movement.

Unretouched flakes proved an exception to the generally irregular surface distribution of artefacts, showing a much increased density in areas where the Mungo deposits were exposed. The correspondence was not exact, however, leaving the question to be resolved by additional research.

This is one case where the application of smaller grid squares would assist by allowing a closer comparison between flake surface density, deposit boundaries and surface contours.

The presence of a small number of backed blades and thumbnail scrapers, which post-date the core tool and scraper tradition, on both Zanci and Mungo exposures could indicate thorough mixing of the surface material. It is difficult to reconcile their postulated movement right across the grid from the recent deposits at the crest of the lunette with the evidently static concentrations of unretouched flakes. Other plausible explanations, including faunal activity, can be advanced for their apparently anomalous appearance.

Attributes of the Surface Collection. Comparisons between the implements recovered from the Mungo and Zanci surfaces showed no significant differences between any of their characteristics. This is in general agreement with Allen's conclusion (Allen, 1972, p 279). The most striking feature was the contrast between their average dimensions and those of other material of the same period at Kenniff Cave and Burrill Lake and artefacts previously recovered at Lake Mungo itself. The mean values of length, width and thickness of the recent Lake Mungo surface collections were smaller.

The significantly larger dimensions of the implements recovered by Allen in 1969 can be explained if it is assumed that the erosive agencies acting on material at the lunette surface cause the sample recovered by the very first collection in an area to be biased as a result of the removal of a proportion of the smaller items during the preceding years. Successive, more frequent collections give no opportunity for this mechanism to have an appreciable impact. This interpretation of the

apparent discrepancy at Mungo receives support from a comparison of the first and subsequent collections from the grid itself. The Kenniff Cave and Burrill Lake material was excavated from shelters, however, and as similar processes would have been absent the differences between their average implement characteristics and those at Mungo must apparently be accepted.

Discussion

The conduct of any research inevitably leads to further questions which require resolution. This is especially so in the present case where the results are less conclusive than one might hope. It is therefore necessary to consider whether it is feasible to resolve these questions through continued application of the same methods or whether new strategies must be adopted.

Recalling that the primary aim was to determine whether significant differences were present in the stone technologies of the Mungo and Zanci periods consider, first, the constraints encountered in attempting to achieve that aim.

Questions concerning the differences between implements of the Mungo and Zanci periods imply that material fashioned at those times can be unambiguously identified. In contrast to a large proportion of excavated material, such is not the case with items from a surface collection potentially subject to disturbance. At Lake Mungo collectors retrieve only items which have been completely released from the dune matrix and are discouraged from 'excavating' in situ artefacts on the grounds that they lack the necessary skills to recognise and develop important deposits of buried material should they occur. Furthermore, the total number of in situ items

would make up only a small proportion of the total collection and so have a negligible effect on its statistical parameters.

The provenance of the remainder of the material lying freely on the surface cannot be guaranteed. Wilful disturbance of replica items has been detected but the extent to which it applies to the prehistoric artefacts is unknown. This problem aside, experimental and statistical comparisons show that the forces of erosion probably have a differential effect by moving the lighter pieces of stone once they have been exposed. The upper limits in size and the extent of the movement and its significance in given annual collections, although small, cannot be specified precisely.

Even if it were possible to be confident of the pre-exposure spatial distribution of the collection, questions concerning the history of the artefacts between the time of their deposition and their re-exposure require resolution. The presence of beach pebbles on Zanci deposits and the evidence from nearby Lake Chibnalwood are indicative of vigorous weather patterns contrasting strongly with the apparently orderly sequence of deposits exposed on the residuals on the grid. It would be remarkable if the lunette has remained completely untouched by disruptive forces throughout its 40,000 year life. Occasional examples of re-used artefacts from an earlier period were identified in the mass of observations recorded during the sorting of the collections. These include the presence of retouch on a previously rolled artefact and the partial reshaping of an otherwise patinated surface and indicate a long period of exposure to the elements between the two periods of modification.

As has been noted, attempts to correlate the surface distribution of the artefacts with the exposed Mungo and Zanci deposits were unsuccessful, as were efforts to separate the collection on the basis of dimensions and attributes. Only the distribution of the unretouched flakes showed some correspondence with the exposed Mungo surface but even here agreement was far from perfect. It may be significant that apart from waste fragments and stone chips these flakes had the largest samples of any of the artefact classes. Positive results in other categories may have been denied by inadequate sample sizes.

As far as differences between the artefacts deposited during the two principal periods are concerned, it must be concluded that Allen's deduction of continuity throughout the dune building period cannot be challenged. However, at this stage it is again doubtful whether the sample size is sufficient to allow a more unequivocal statement to be made.

Further Research. The results presented here concerning the apparent lack of distinction between the stone technologies of the Mungo and Zanci periods have been generally inconclusive. Assuming that resource limitations force the continuation of the method of annual total surface collection, one may attempt to avoid the limitations on the validity of the conclusions which may be drawn in the presence of constraints such as those outlined above in one or two ways. The constraints may be either overcome or removed. If neither is possible then the expenditure of resources on further research on the Lake Mungo surface collection must be questioned.

Taking the second of the alternatives, removal, or at least easing,of the constraints may be possible, by transferring the investigation to other carefully selected, essentially horizontal areas of the dune, to avoid some of the uncertainties caused by that component of movement of

material due to erosion. Additionally, if there is less ready access to this area also then the likelihood of disturbance by human intruders may be reduced but the risk cannot be eliminated entirely. It may not be possible, however, to meet the specification of a horizontal area of sufficient expanse to yield an adequate sample within an acceptable time frame for it is unlikely that a horizontal surface would be conducive to rapid erosion. Furthermore, it would be most desirable for both Zanci and Mungo deposits to be exposed in the same area. If this is not the case and differences are detected between the Mungo and Zanci implements it is less easy to conclude that these are due to a change in basic technology but may follow from a different economic response to seasonal or environmental conditions at the various regions of the lake shore.

It is not clear to what extent less accessible areas of the lunettes of any of the lakes of the Willandra system meet these conditions and even if they do exist, they are not entirely free of additional problems. For example, there remains the need to assemble an adequate sample of each type of artefact requiring many years work unless an area particularly rich in lithic material can be found.

Since it is not apparent that a new area would present outstanding advantages the extended use of the present grid area needs to be considered. A clear advantage is that classification and measurement of material from previous collections and adjacent excavations provide a data base on which to build. This information may reduce the additional work required to reach firm conclusions about the site and in the case of the results from the excavations may increase confidence in those conclusions by providing independent corroberation. Nevertheless, the disadvantages common to all surface sites still need to be overcome.

If valid estimates are to be made of the effect of such extraneous factors as the movement of items across the lunette surface, from whatever causes, or their removal or reburial the introduction of well designed, unobtrusive, yet readily locateable replicas as control items is considered to be essential. These factors may bias the recovered samples and, given the low concentrations of artefacts, additional collection over a number of years will be necessary in order to accumulate samples of acceptable size. A common basis for the sample components is vital.

Replica artefacts made entirely of a mixture of sand and epoxy resin, rather than as a surface coating attempted here may be more durable in that the differential expansion of the stone and the epoxy will be avoided. Relocation of each replica each year could be achieved by embedding a small slug of ferrous metal within it when it is made to produce a response when sweeping the area with a metal detector. Extraneous items of metal in a lunette primarily composed of sand and clay should be negligible. The numbers, dimensions and initial locations of the replicas across the grid clearly should match those of the prehistoric material. Before each collection begins, the position of each replica should be marked and recorded so as to avoid inadvertant recovery and to enable its displacement since the previous collection to be calculated. Supplementary data on the movement of surface material could be sought through the stereophotography of representative small areas.

Additional constraints are imposed by limitations in time and space. The need for an adequate sample size has been mentioned. On the basis of the frequency distributions of the recovered scrapers, the inclusion of data from a further three years' collection could yield a difference that has statistical significance. Data from the collection made in 1979 could be included in further

analyses so that it is estimated that two further collections are required. Allowing a margin of safety, collection for three additional seasons is indicated. In planning this field work there is no evidence that any change in grid spacing is necessary except in those areas where both Mungo and Zanci deposits occur in the same grid square. A reduction from 20 metres to 10 metres in dimensions of the square is sufficient to isolate one or other of the deposits. The alternative of defining and collecting either side of the boundary between them is an unnecessary complication at this stage.

In conclusion, it is clear that there are several areas requiring investigation before the surface collection can begin to be interpreted in terms of the activities of the former occupants of the lunette. For example, despite the excellent geomorphological studies, there is as yet a gap in our knowledge of the short term conditions to which the surface material on the lunette has been exposed throughout its life. Is the present erosion the very first episode of natural large scale disturbance that the dune has experienced? Are there processes which result in significant vertical migration of material within the dune or can it be assumed that such movement would be absent given the finely preserved bedding in the dune? A further aspect of the analysis that warrants more consideration is the near correspondence between the Mungo deposits and the increased unretouched flake concentrations. An examination of the numbers of flakes encountered during Shawcross' excavations shows that flake abundance decreased rapidly with depth below the Mungo soil horizon. Collections confined to this component of the Mungo deposit alone with due regard to the local contours, since the greatest concentration of flakes broadly correspond to the steeper slopes, could be of interest. More frequent collections also may be appropriate.

If additional resources were to become available entirely different research strategies are possible. In the present work effort has been essentially limited to annual visits to the site. Such frequency could well be the case in any study of surface material in more remote parts of Australia. With more frequent inspections possible closer surveillance of the area could be maintained to the extent that transient features such as the distribution of artefacts around the supposed hearth areas could be recorded. The development of such strategies is, however, beyond the scope of this discussion but no-one who has stood on the freshly eroded surfaces and tried to visualise the circumstances when the lake was full can doubt the value of further research.

The moon lights a thousand candles upon the water,
But none for the carver of stone; and nobody comes
Of his own long-scattered tribe to remember him
With dance and song and firelight under the gums;
But he walks again for me at the water's rim
And works at his rock, and a light begins to glow
Clear for his sake among the dark of my mind
Where the branches reach and the silent waters flow.

Douglas Stewart,
ROCK CARVING.

APPENDIX A

EXPERIMENTS ON THE MOVEMENT OF FLAKES IN SHALLOW WATER FLOW

Introduction

This appendix describes the simple experiments conducted to explore the possibility that prehistoric material on the sloping surfaces of the Lake Mungo grid could suffer some displacement during overland flow.

Evidence from the literature was presented in Chapter 3 that water flow of a few millimetres depth could result from the passage of rainstorms across the grid. The work of Emmett (1978), Pearce (1976) and Kirkby (1978) in particular included discussions of water flow rates and depths occurring during rain. Several estimates of the rates of removal of soil and sand from the surface under such conditions have been made (see Chapter 3) and data have been obtained on the movement of sub-angular stones of 6 cm diameter in streams of two to three times this depth (Kelling, et al, 1967), following earlier work on particle movement in stream beds by Rubey (1938). Little information is available, however, on the intermediate flow regime where the depth of flow is less than the thickness of the stone and less than the horizontal dimensions by an order of magnitude and more.

Aim

As stated above, the aim of the experiments were to explore the possibility of prehistoric material on the grid being moved in the overland flow following rainfall. This objective is purposely cautious. In particular, the experiments did not seek to simulate conditions occurring at the lunette by setting up an exact analogue of a small area of the grid. Many of the gross differences will be identified during following description.

Experimental Procedure

The surface of the grid at Lake Mungo is more or less even in that there are few discontinuities in the slope of the sandy clay crust. The slope of the surface generally lies between 3 degrees and 12 degrees. This surface was represented experimentally by sheets of wet-and-dry cloth glued to a piece of marine seven-plywood. A water channel was formed over this surface by attaching two wooden battens along the board. Variations in slope were achieved by raising one end of the board by means of a motor car screw jack (see Figure A.1). A flow of water was introduced near the upper end of the water channel through an elongated spray directed at right angles to the board. The flow rate was controlled by tightening or loosening the clamps holding wooden blocks either side of the garden hose feeding the spray.

The behaviour of several flakes in shallow water was investigated by setting the board at a series of angles, restricting the water flow and placing the flake at a point near the lower end of the channel at the required orientation. By releasing the clamps slowly, the flow rate was gradually increased until the flake moved and was eventually carried away by the water flow. This flow rate was recorded by uncoupling the hose from the spray and recording the time required to fill a known capacity container.

There are many obvious differences between this crude set up and the natural rain soaked surface at the grid. Among the conditions occurring at Lake Mungo, but not experimentally, are:

* there is a small component of the flow into the surface;

* the surface is softened by rainfall and may itself be mobile;

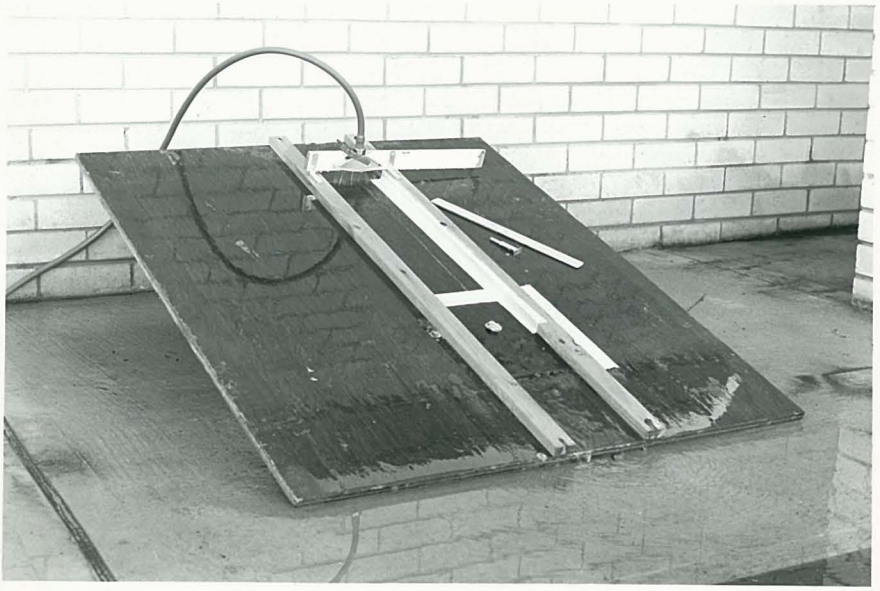


Photo: I.R. Ridgway

Figure A.1: Apparatus for Water-flow Experiments

* the surface roughness, both at sand grain size and over dimensions comparable with the channel length, is not uniform;

* raindrops will generally be falling on water flow, increasing turbulence; and

* there are no sharp channel walls to introduce edge effects, although, under more carefully controlled conditions, corrections can be applied to allow for this effect (Nittim, 1977, p. 52).

The flakes used were drawn from those collected from a single square. There may have been some value in selecting flakes which were in some way 'average' but, to emphasise the point yet again, the thrust of this investigation was to test the likelihood of any movement of artefacts by overland flow at Mungo. Flake characteristics were less important than establishing that movement was possible. Under the conditions of the experiment, all the selected flakes moved at some stage. Figure A.2 illustrates the four flakes used; the corresponding dimensions are given in Table A.1.

As a final comment on the exploratory nature of the experiment, it should be noted that the overall results are based on one observation at each combination of flake, flake orientation, slope angle and flow rate. Further comment on this aspect appears below.

Results

Flake Axis Parallel to the Flow

The conditions under which the flakes moved are summarised in Figure A.3, where the angle at which the flake began to slide down the board is plotted against the flow rate per unit width of channel. Despite the scatter,

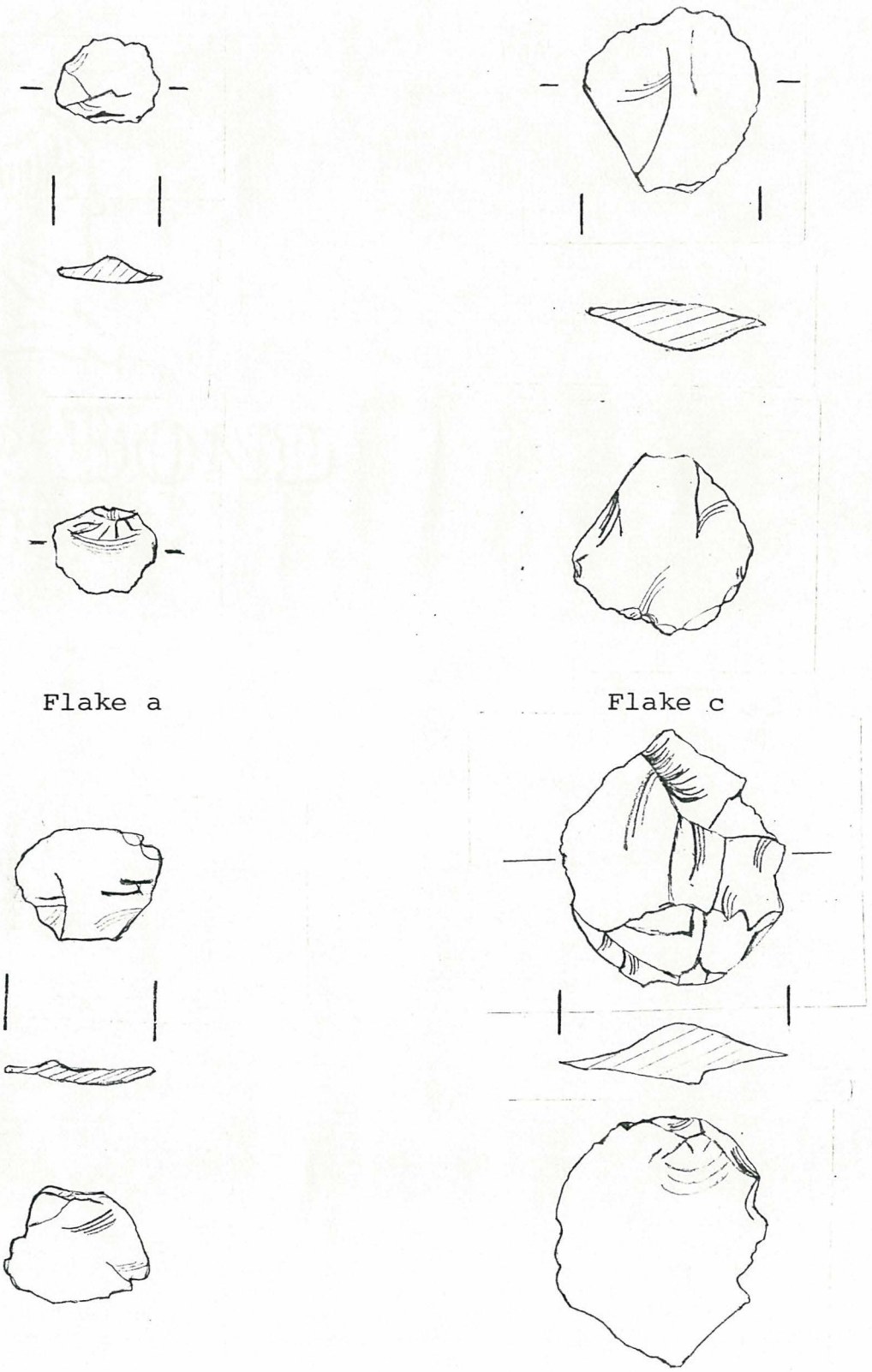
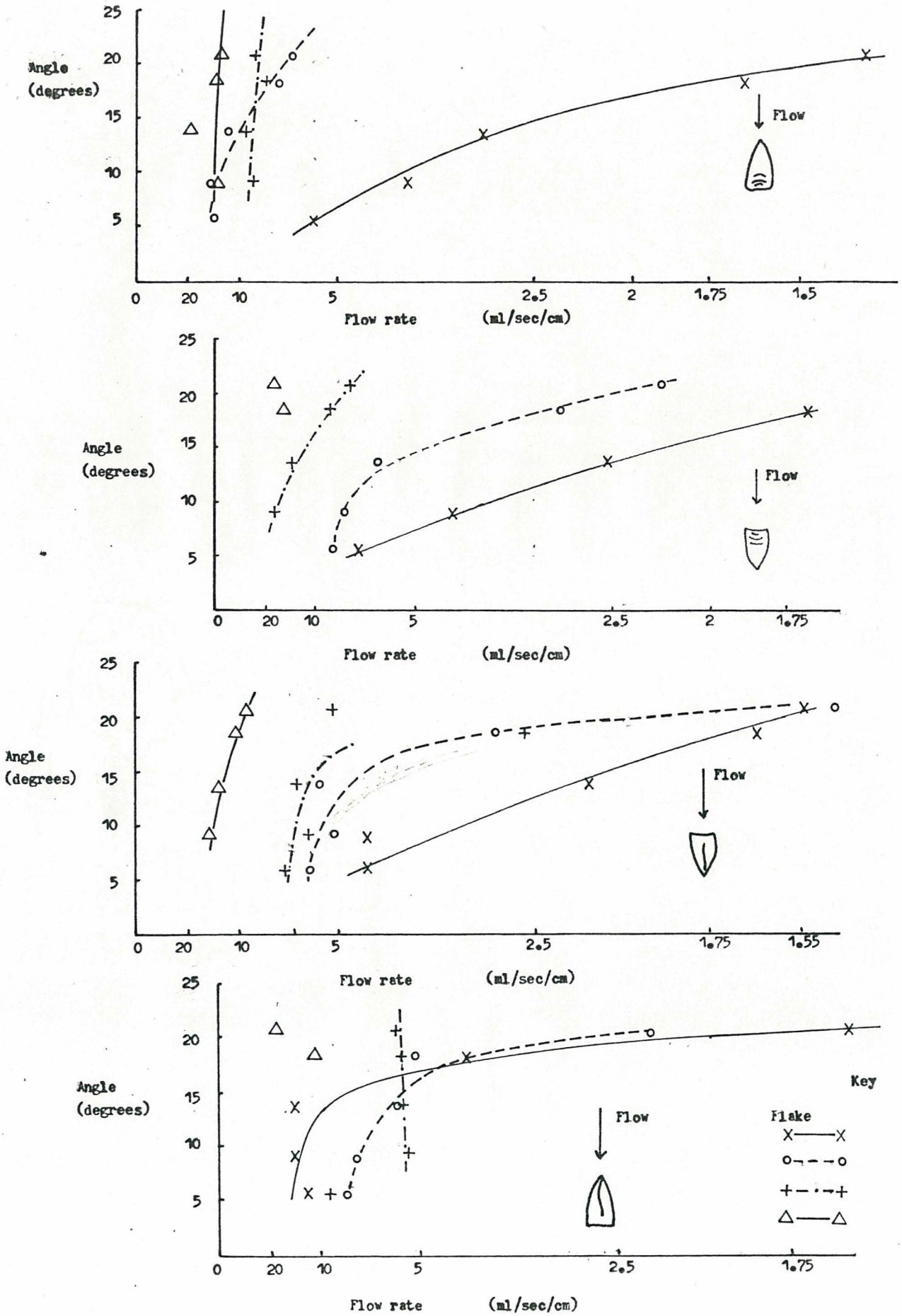


Figure A.2: Flakes Used in Experiments
(Actual Size)

FLAKE	Length (cm)	Width (cm)	Thickness (cm)	Weight (cm)
A	1.15	1.40	0.10	0.4
B	1.60	2.05	0.40	1.2
C	2.65	2.50	0.25	2.5
D	3.70	3.20	0.80	9.5

Table A1: Dimensions and Weights of Experimental Flakes



Note: Flake orientation shown diagramatically

FIG A.3 Results - Flake Axis Parallel To Flow

the behaviour generally conforms to what might be expected: the smaller, lighter flakes are moved at slower flow rates and smaller slopes than their larger, heavier counterparts. Nevertheless, there are some deviations from the expected pattern which are very probably due to differences in shape between flakes. In the upper three diagrams of Figure A.3 the flow rates at which flake B moves off are generally lower than those for flake A, while there is a reversal of this tendency in the lower diagram. In the bulb down, striking platform down orientation the distal margin of flake B curved upward away from the surface of the board, allowing water to flow under the flake and lift it off to surface. The reverse was true for flake A, where the flow tended to force it down onto the surface. The differences in behaviour of flake C in the bulb down positions (Figure A.4) is due to a similar asymmetry between the striking platform and the distal end. As noted above, the points plotted correspond to a single observation. On those occasions when readings were repeated, the values obtained for flow rates were within about ten percent of the original value. In view of the limited basis of the observations, the curves are intended merely to assist in identifying points common to the same flake. Similarly, as the diagrams are not intended to be employed predictively, no apology is offered for the inverse horizontal scale.

Other asymmetries gave rise to anomalous behaviour. At a 20 degree slope, flake C in the bulb down, striking platform up position was unstable and rotated at a low flow rate but then found a stable position from which it finally moved at a much higher flow rate.

Flake Axis Perpendicular to the Flow

The effect of flake asymmetry was far more marked when the flakes were positioned with their long axis across the flow (Figure A.5). Flake A moved more readily. In fact, at the larger angles it was not possible to reduce the flow sufficiently without introducing surges into it. Flake D

Photo: I.R. Ridgway

Figure A.4: Flow Round Flake C

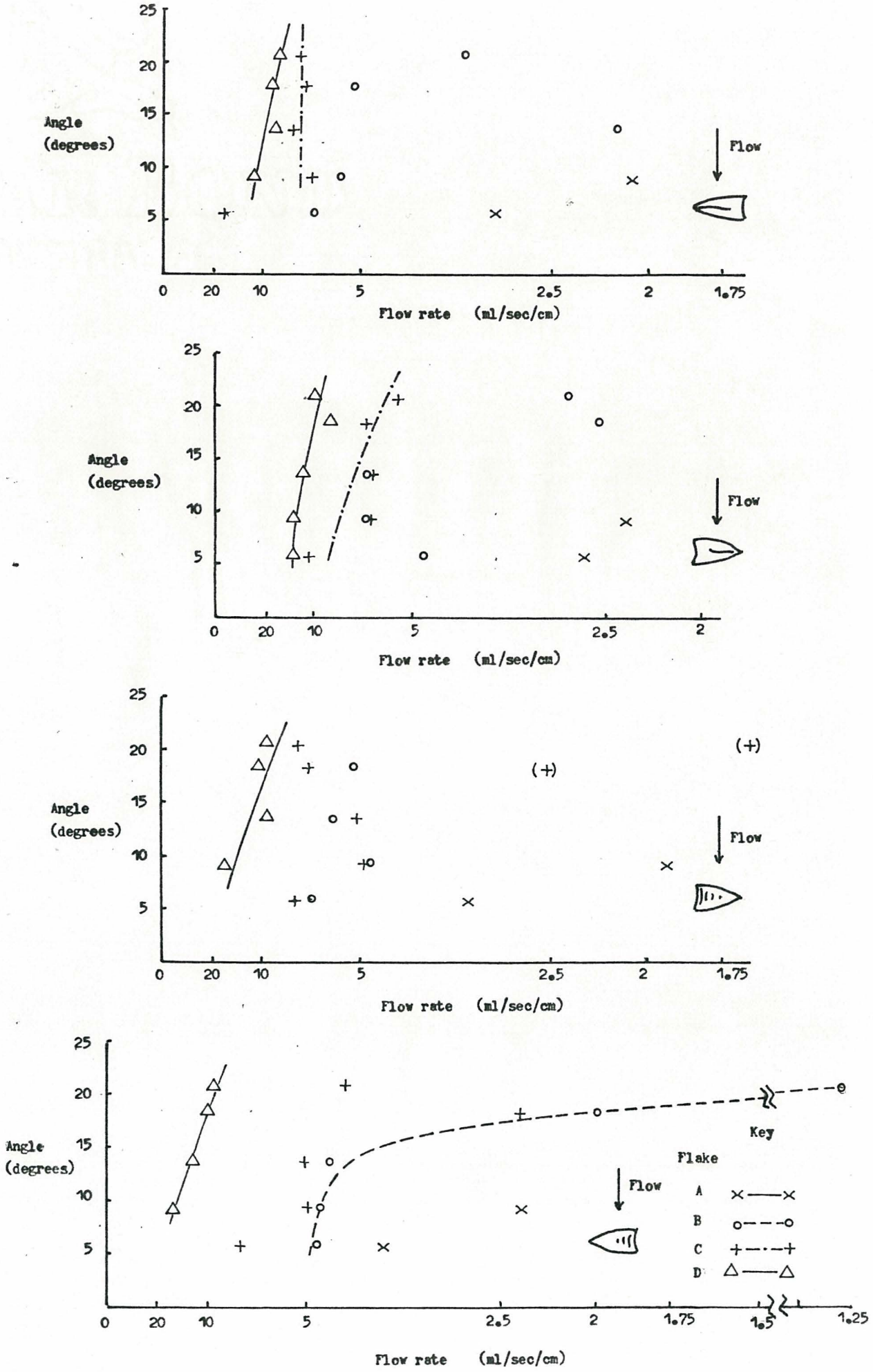


FIG A.4 Results - Flake Axis Perpendicular to Flow

behaved in a regular manner, as did flake C in the bulb down position. In the bulb up, striking platform left position, however, flake C at an angle of 18 degrees or more readily rotated to a more stable position, finally moving off at a flow rate comparable to that required when the axis was parallel to the flow. The points at which this flake first rotated are shown in parenthesis and are well to the right of those at which translation took place. Other combinations of flake and flake orientation resulted in an initial movement to a more stable position often by what can best be described as a flapping motion before the flake was carried away after an increase in flow rate.

Discussion

The velocity of flow in these experiments could not be determined with any accuracy. Although attempts were made to measure the depth of flow using a depth gauge, no precision can be claimed beyond stating that the values fell between 1 and 2 mm for the distance between the water surface and the tops of the grains on the emery cloth. Those measurements were taken when the flow rates down the board were between 2 and 5 ml/sec/cm. The relationship between water velocity, depth of flow and slope is given by the Manning formula (Young, 1972, p. 64):

$$\upsilon_x = \frac{1}{n} \cdot d_x^{0.67} \, S^{0.5}$$

where υ_x = mean velocity x ft from the watershed

d_x = flow depth

S = slope gradient

n = Manning resistance coefficient.

Making the gross assumption that this expression is approximately true under the conditions of the experiment

and assuming further that the resistance coefficient takes a value of 0.012 equal to that of 'smooth concrete' (Chow, 1964, pp. 7-25), velocities in the region of 30 cm/sec are indicated.

Measured values of the depth of natural overland flow are rare. Green, without quoting his sources, summarises the range as follows: 'Measurement of sheet runoff at rates of 1.25 to 3.68 in. per hour on bare plots of up to 20% slope with a slope length of 116.7 ft show depths of flow ranging from 0.06 to 0.15 in', (Green, 1970, p. 187). Again using the Manning equation, together with Chow's values for the resistance coefficient for earth channels of between 0.017 and 0.020, these conditions correspond to a velocity of 35 cm/sec. This may be compared with Emmett's measures values on a natural slope under a simulated rainfall of 8 m/hr (200 mm/hr). None of Emmett's field plots were free of vegetation but compromising on slope and vegetation cover in selecting from his data, he observed a depth of flow of .04 ft (1.2 cm) and a velocity of 0.78 ft/sec (24 cm/sec) 100 ft from the watershed on a 10% slope having 10% vegetal cover.

The estimated speeds and depths obtained for the flow past the flakes, at least up to experimentally observed flow rates of 5 ml/sec/cm, therefore seem representative of those likely to occur at Mungo. Within this range flakes A and B were moved for both of the flake axis orientations tested. Flake C moved under some conditions when its axis was perpendicular to the flow. This suggests that flakes having similar shape and mass characteristics may move across the grid at Mungo under conditions of heavy rainfall.

At Mungo water seepage through the ground surface immediately beneath the flake may reduce friction. Additionally, particles may be in suspension in the surface flow effectively increasing its momentum. Thus

flake movement at the grid may be initiated at a lower flow velocity than that observed experimentally, but it is not clear whether material of the size of flake D would be set in motion.

Conclusion

These experiments show no more than that small flakes can be moved at angles less than 10 degrees, a slope slightly higher than the average at Mungo, by flow rates which have been observed in nature. Larger flakes may be set in motion only on steeper slopes presumably to continue across less steep slopes once the initial friction has been overcome.

APPENDIX B

OBSERVATIONS OF THE MOVEMENT OF DUMMY ARTEFACTS ON THE DUNE SURFACE

Introduction

In October 1978, in order to confirm whether stone material on the site is subject to movement, some 20 'dummy artefacts' were placed at a number of recorded points across the dune surface.

Results

The dummy artefacts were knapped from a distinctive brown ribbon obsidian which originated in America, thereby removing any possibility of confusion with the local material. These artefacts were deposited in pairs with a small flake some 20 centimetres away from a much heavier core, the larger ones being 7 centimetres in maximum dimension. The smaller flakes were derived from these cores. In order to reduce the contrast between the colour of the obsidian and that of the silcrete generally occurring at Mungo, each dummy artefact was coated with an epoxy resin and then covered with sand. Excess sand was removed after the resin had dried and an identification number painted on each item. It was unfortunate that under the extremes of temperature to which these artefacts were subsequently subjected when exposed at Mungo the epoxy resin lifted from the surface revealing the original obsidian. Seven months after their deposition, two of the larger artefacts were found at one point having been collected by an unknown, observant, but unwelcome visitor to the site.

Not all artefacts suffered such obvious visitor interference, however, and remained in the area in which they were originally placed. Table B.1 records the original and subsequent positions of the dummy artefacts,

Artefact Number	Grid Square	Local[1] Slope (degrees)		DISTANCE FROM SW CORNER OF GRID SQUARE					
				Deposited 1978		Measured 1979		Distance Moved (cm)	
		E	N	E	N	E	N	E	N
2	E22	2.9	2.4	1140	1140	1150	1110	+10	-30
17				1140	1140	1145	1105	+5	-35
7	C20	2.9	4.3	580	160	Removed		-	-
25				580	160	1365	1545	+785	+1385
11	E19	1.0	1.4	1150	610	575	410	-575	-200
26				1150	610	1185	660	+35	+50
3	D18	-7.1	0	1270	1580	Removed		-	-
27				1270	1580	1760	1940	490	360
18	F16	0	0	650	390	715	400	65	10
28				650	390	650	420	0	30
16	F12	0	0	740	320	Not Located		-	-
20				740	320	Not Located		-	-
1	B7	1.0	3.8	960	370	1000	385	40	15
29				960	410	490	1080	-470	670
4	C5	1.4	1.9	830	730	840	795	10	65
10				830	730	800	785	-30	55
6	D3	-2.4	1.0	20	10	720	120	700	110
32				20	10	30	15	10	5

Note: 1. 'Local' is that within a 1 metre radius. Slope is positive when falling towards east and north respectively.

Table B.1 MOVEMENT OF DUMMY ARTEFACTS, 1977-78

together with comments as appropriate. No clear picture emerges. Three pairs of artefacts suffered no significant movement (Nos. 2, 17; 18, 28 and 4, 10). In the case of two other pairs (11, 26; 6, 32), the larger core was found several metres from the point at which it was deposited, while the very much lighter flake had not moved. This does not suggest natural disturbance, particularly as core 6 had apparently crossed a slight ridge in the dune surface, but possibly that the core had been kicked by an animal or picked up and discarded almost immediately by a casual visitor. In one case the reverse pattern of movement was observed with the lighter flake having moved (Nos. 1, 29). As noted above, two of the larger artefacts had been removed (Nos. 7, 3). Movement of the corresponding flakes differed. In one case it was found several metres away at a level some 80 cm above the point where it was deposited. The companion flake to the other collected core was found in a small erosion gully, having moved some 16 metres. Such movement is possible as the pair were placed on a steep bare slope above the gully. Movement probably occurred before the core was picked up, otherwise the flake might also have been retrieved. The final pair of dummy artefacts (Nos. 16, 20) put down among the beach gravel on the flatter, lower part of the site have never been located, despite intensive searches. It is possible but unlikely that they and the beach gravel were washed away or buried, to be replaced by newly exposed gravel. Neither the core nor the flake were large enough to attract attention from a distance of more than a few metres but in view of the fate of other items collection by visitors cannot be ruled out entirely.

Discussion and Conclusion

The picture that emerges is so confused that no firm conclusions are possible. Three pairs of artefacts have not moved appreciably. The distance and direction of movement recorded by two further flakes is feasible. In the case of the remainder of the artefacts, it is clear

either that they have been moved or doubt can be cast on the translation that they have sustained being entirely due to natural causes.

What are the implications that these results have for the interpretation of the surface collection? It is obvious that the site is being visited by collectors who are unaware of the nature of the work being carried out there. This is disturbing, particularly as it is impossible to assess the effect that such activities might have on the surface collection. On the one hand, the dummy artefacts which were moved were comparatively large, being approximately 5 cm or greater along their maximum dimension. Other large prehistoric artefacts may be collected also. On the other hand, the ribbon obsidian specimens, when the resin coating has weathered and flaked, are very striking items and may therefore have been selected for that reason alone. Other than these general statements, it is not possible to define the boundaries of interest of such collectors nor to assess the effect that they may be having on the surface collection being analysed.

Movement is unrelated to the direction and steepness of the local slope and does not follow any readily apparent pattern. It is not even possible to determine whether the translations are typical of the prehistoric material but if they are, it is difficult to postulate natural mechanism which could be responsible for the direction and magnitude of all of them. Clearly, to be useful, the experiment of putting down dummy artefacts as markers needs to be repeated with more numerous and less distinctive artefacts. An epoxy resin and sand mixture cast in core and flake moulds should match the local materials in shape and colour. The difficulties that this would present in subsequently locating each item could be overcome by including an iron rod in the casting in order to produce a response in a metal detector.

a

b

c

Figure B.1: Dispersal of Hearth Stones

An illustration of changes at the surface of the site is shown in the three photographs in Figure B.1. These show the same scatter of large stones, probably the remnants of a hearth in front of a small and decaying remnant. It lies just outside the grid beyond the boundary of square C10. Photograph a. was taken in 1977, b. in May 1979 and c. in August 1979. The scale in each photograph is provided by the 15 inch wooden ruler. While the yellow colour of the upper photograph is partly due to poor exposure in the late afternoon, that of the lower two is representative of the surface on a dull and sunny day respectively, providing an interesting sidelight on the contrast problem discussed in Chapter 4.

There has been some re-arrangement of the larger stones between photos a. and b. with the one beyond the right end of the ruler moving down to left. The stone which is some 30 cm to the left of and in line with the ruler in photo a. has fallen on its side in b. The paths of the rills have also been obliterated, presumably by deflation.

In photo c., taken 14 weeks after photo b., erosion channels up to 5 cm deep have been cut into the surface and the build up of sand behind the group of large stones has been removed. However, even though they lie within the nearer erosion channel, the two stones beyond the larger grey block have not moved appreciably - a few centimetres at most. Some other small stones appear to have moved but identification is less certain.

APPENDIX C

THE KOLMOGOROV-SMIRNOV TEST

The Kolmogorov-Smirnov test is used to test whether two independent samples have been drawn from the same population or populations with the same distribution. Any difference between the samples, eg. in central tendency, skewness or dispersion is disclosed by the test which compares their cumulative distributions. Clearly, if the samples come from the same population their cumulative distributions should show only small, random, distributions. On the other hand the cumulative distributions of samples from different distributions should show rather larger differences.

The statistic used in the Kolmogorov-Smirnov test is the difference between the step functions, using a common interval, of the two cumulative frequency distributions.

If n_1, n_2 are the number of observations in each sample and K_1, K_2 are the number of scores equal to or less than X then the respective observed cumulative step functions are $S_1(X)$ and $S_2(X)$ where:

$$S_1(X) = \frac{K_1}{n_1} \text{ and } S_2(X) = \frac{K_2}{n_2}$$

The difference between the step functions at a given interval is thus:

$$D = S_1(X) - S_2(X)$$

The two-tailed Kolmogorov-Smirnov test is used, as in the present case, to determine whether there is a difference between the two distributions. In such cases the maximum absolute value of D, D_{max} is compared with published values of the probability of obtaining values as large as the observed D under the null hypothesis that the two samples come from the same distribution.

At the 5% level of significance, when the size of each sample is greater than 40, the critical value is given by:

$$D_{.05} = 1.36 \sqrt{\frac{n_1 + n_2}{n_1 n_2}}$$

while at the 1% level:

$$D_{.01} = 1.63 \sqrt{\frac{n_1 + n_2}{n_1 n_2}}$$

As an illustrative example, it may be of interest to note that $D_{.05} = 0.2$ approximately when $n_1 = n_2 = 92$.

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