HIGHLAND NEW GUINEA HUNTER-GATHERERS: THE EVIDENCE OF NOMBE ROCKSHELTER, SIMBU WITH EMPHASIS ON THE PLEISTOCENE

by

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Declaration

Unless otherwise indicated, this
thesis represents the original work of the author.

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ABSTRACT

HIGHLAND NEW GUINEA HUNTER-GATHERERS: THE EVIDENCE OF NOMBE ROCKSHELTER, SIMBU WITH EMPHASIS ON THE PLEISTOCENE

Nombe rockshelter was excavated by M-J. Mountain between 1971 and 1980. Human activity is first documented at the site at about 25,000 bp and continues through to the present. Four extinct Pleistocene herbivores, *Protemnodon nombe*, *Protemnodon tumbuna*, *Dendrolagus noibano* and a diprotodontid, occur in late Pleistocene strata together with human artefacts. Large quantities of animal bone were recovered and the analysis of these supplies the major data for the research.

Three main issues are addressed:

1. The nature of the relationship between the early humans and their environment through the period that covers the late glacial maximum at about 18,000 bp.
2. The relationship between humans and the extinct species, including the thylacine, *Thylacinus cynocephalus*, which was a major predator at the site, contributing bone to the deposits during the Pleistocene.
3. The use of faunal evidence as an indicator of economic and subsistence activities as well as local environmental changes.

The data show that the human activity during the late Pleistocene at Nombe was sporadic over the period from about 25,000 bp to about 15,000 bp. Hunters were probably targeting the large herbivores living in high altitude forest and other species adapted to high altitude cold environments. Humans and large herbivores coexisted for about 10,000 years before the animals disappeared from the record. This coexistence does not suggest a rapid demise through human overkill.

Palynological evidence suggests that people were deliberately firing small patches of highland forest as early as 30,000 bp. Such clearing could have been used to promote forest-edge plants especially *Pandanus*, which has rich oily nuts. These small clearings could also have been used as an aid to hunting.

By the end of the Pleistocene, human hunting had switched to emphasise medium and smaller forest animals, especially fruit bats, macropodids, phalangers and possums. Bat hunting was especially important at Nombe, which is in a limestone area with many caves.

In the early Holocene the temperatures rose and sub-alpine grasslands were greatly reduced as forest spread to higher altitudes. The archaeological evidence shows that more sites were occupied by 10,000 bp than before and the faunal

data at Nombe indicate a steep rise in the grassland wallaby, *Thylogale brunii.* This species adapts easily to forest disturbance and may indicate that forest clearance was increasing in the locality. The early Holocene was the period of intense human settlement of the site.

The faunal analysis employed in this study is designed to test the broad questions about human-environment relationships rather than to supply detailed information about the size and sex representation in the species present. Species are often dealt with as a group and no individual bone measurements have been taken. The computer database has been designed to produce a flexible data set that can easily be adapted to taxonomic change. The success of the approach suggests that faunal evidence can be a sensitive indicator of environmental change and can be used to examine human predation strategies and changes in economic subsistence.

NOTES

This thesis is in two volumes:

Volume 1 contains the text of the thesis and all supporting material.

Volume 2 comprises the site profiles.

References in the text to the site profiles such as:

" ... Dasyurid bones occur ^{P2,P4}... "

refer the reader to site profiles 2 ***(P2)*** and 4 ***(P4)*** in Volume 2.

Unless otherwise stated, all data in this thesis relate to excavated material from the site of Nombe, Simbu Province, Papua New Guinea. Unless tables and figures specify otherwise, they refer to the site of Nombe or data from that site.

Figures 2.1, 2.2, 2.3, 2.4, 2.6, 3.2, 3.3, 3.4 and 3.5 were drawn by Winifred Mumford from site drawings prepared by the author. Figures 2.5 and 3.1 were prepared by Barry Shaw from original drawings by David Gillieson. Uncited photographs were taken by Barry Shaw.

"New Guinea" is used to refer to the island of New Guinea which today includes "mainland" Papua New Guinea and the Indonesian Province of Irian Jaya. "Papua New Guinea" refers to the country of Papua New Guinea. The "highlands" refers to the highland region (over about 1300 m above sea level) of the island of New Guinea and includes Irian Jaya.

Totals in the data were originally added to one more significant place than is shown in the text or tables. However the nature of the samples and the accuracy of excavation does not justify such detail so the data and totals were then reduced by one significant place to avoid spurious accuracy. This may result in totals differing slightly in the final digit. In addition, some data is presented as <1, meaning "present", but less than one. Where <1 appears several times in a sum, the resultant total may differ even more. Nevertheless, data totals are correct.

All excavated materials from Nombe and other sites, which are at present housed in the Department of Archaeology and Anthropology at the Australian National University, are the property of the National Museum of Papua New Guinea and will be returned there on completion of analyses together with the site documentation.

All radiocarbon dating results are expressed in conventional radiocarbon ages (BP) with the statistical error range (±) supplied with the date (Stuiver and Polach 1977)

Abbreviations:

asl	Above sea level
ANU	Australian National University
ESR	Electron spin resonance
MNI	Minimum number of individual animals
PNG	Papua New Guinea
NISP	Number of identified specimens

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This thesis is the product of twenty years of research and there are many people, both in Papua New Guinea and Australia, to whom I am most grateful.

I received an Australian National University scholarship which enabled me to leave the University of Papua New Guinea to pursue this research full time; earlier field work was financed by the University of Papua New Guinea. I thank both institutions for their support.

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Other staff, both past and present, at the Australian National University have encouraged me, especially in the last six months of almost full time analysis and writing. Several people were extremely helpful with advice and encouragement, especially Professor Isabel McBryde, Wilfred Shawcross, Ian Farrington and Nancy Sharp, while at an earlier stage of research I received assistance from Dr Jenny Hope, Dr Phil Hughes, Dr Bryant Allen, Dr Robin Hide, Professor Jim Allen and Dragi Markovic. I am most grateful to all of them.

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Dave Gillieson also contributed a great deal to this thesis in the early 1980s with his enthusiastic analysis of the sediments. Win Mumford produced superb drawings to guide the reader through the intricacy of Nombe stratigraphy and I am more than grateful for the time and care she has spent in her productions.

Several people assisted me in the lengthy tasks of washing, sorting and cleaning the materials and later identification and weighing of bone. I am grateful to Prue Gaffey, Richard Mulvaney, Alan Lance and others.

Several others assisted in faunal identifications, among whom I especially thank Dr Tim Flannery, Dr Ken Aplin, Dr Colin Pardoe, Dr Jerry Van Tets and Mrs Diane Foley.

While I was in Papua New Guinea, both at the Department of Anthropology and Sociology at the University of Papua New Guinea and in the villages and settlements of the Simbu Province, I received a great deal of practical assistance, personal kindness and help in various ways. I would particularly like to thank Mark Rosen, Headmaster of Chuave High School for the friendship that he generously extended to Barry, Emma and myself. It was always a pleasure to see students from the school at the site and the school was most helpful to the project. There were other highland residents such as Mr and Mrs Brown, Mr and Mrs Lapthorne, Mr and Mrs Bourke and others who most generously extended hospitality and assistance over the several visits made from 1971 to 1980.

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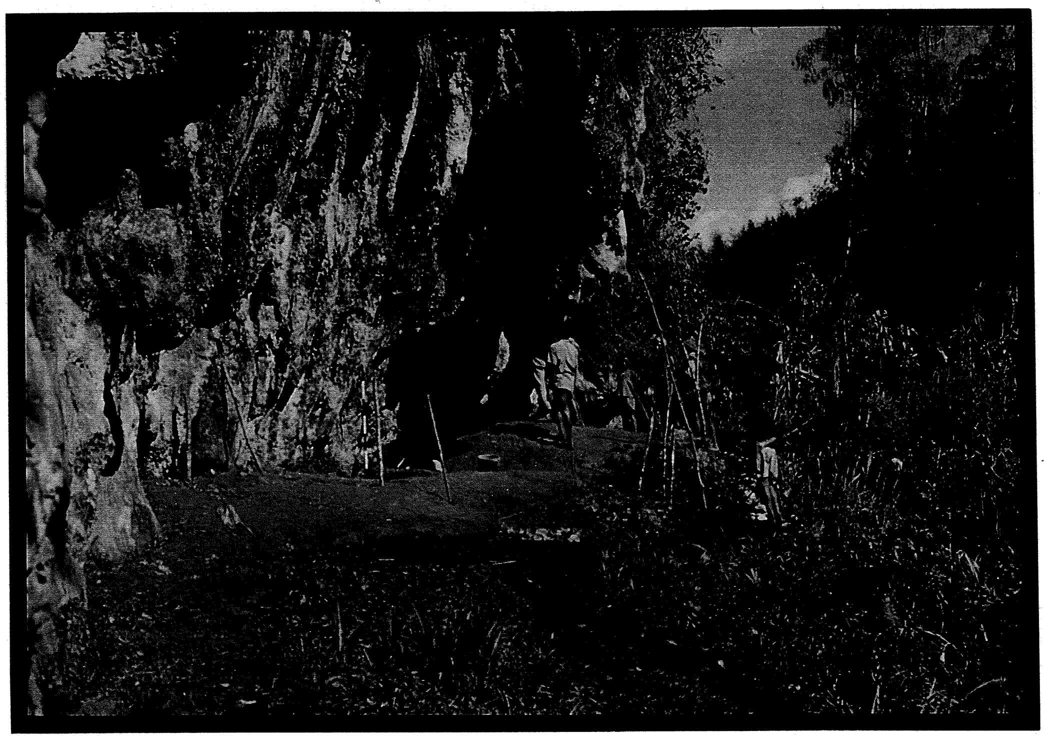

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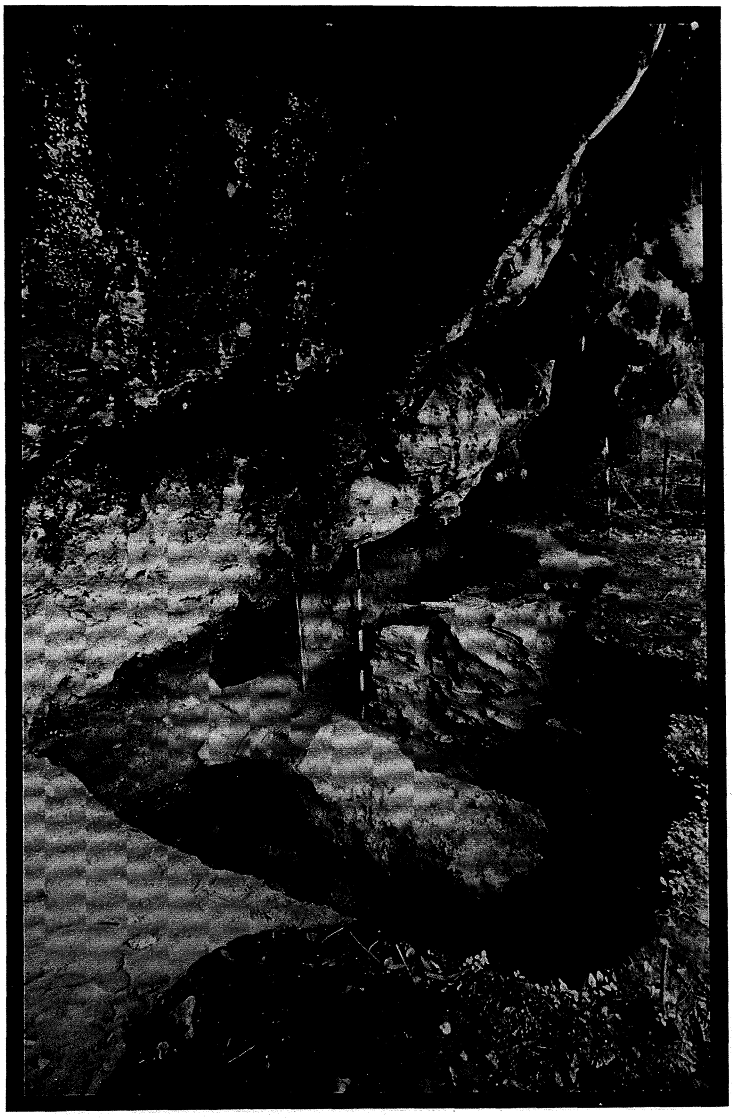

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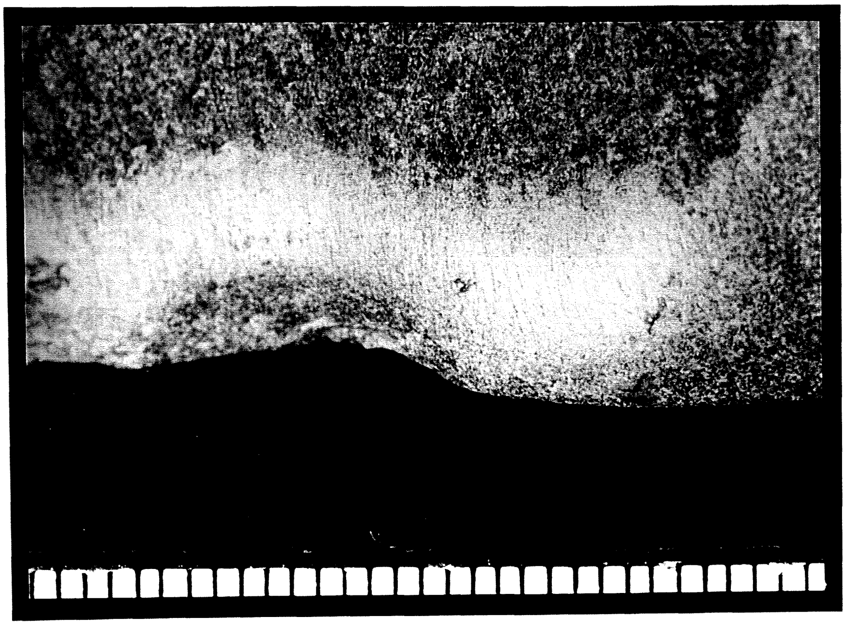

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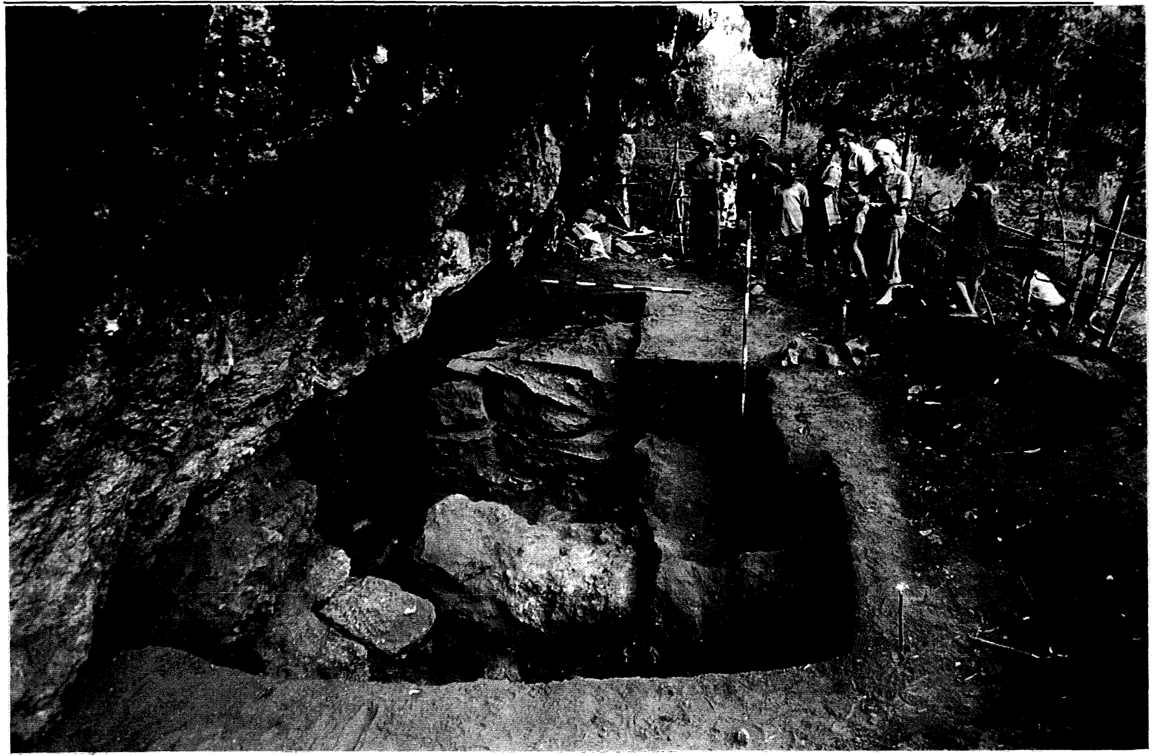

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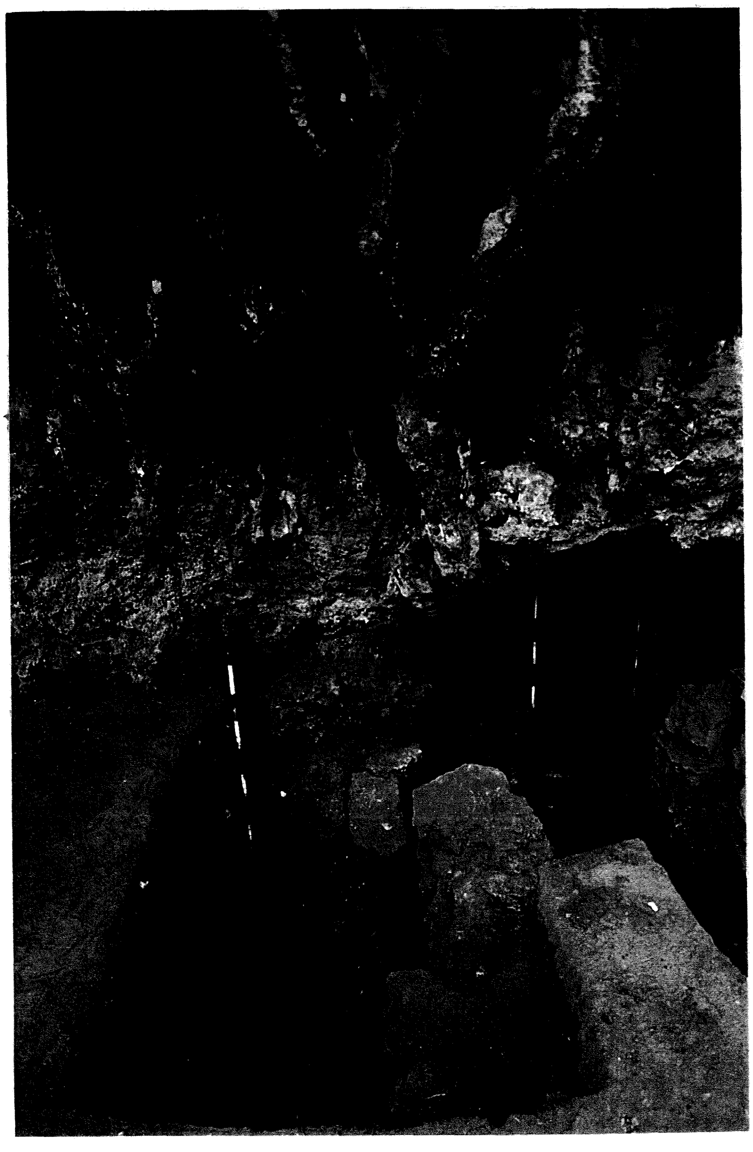

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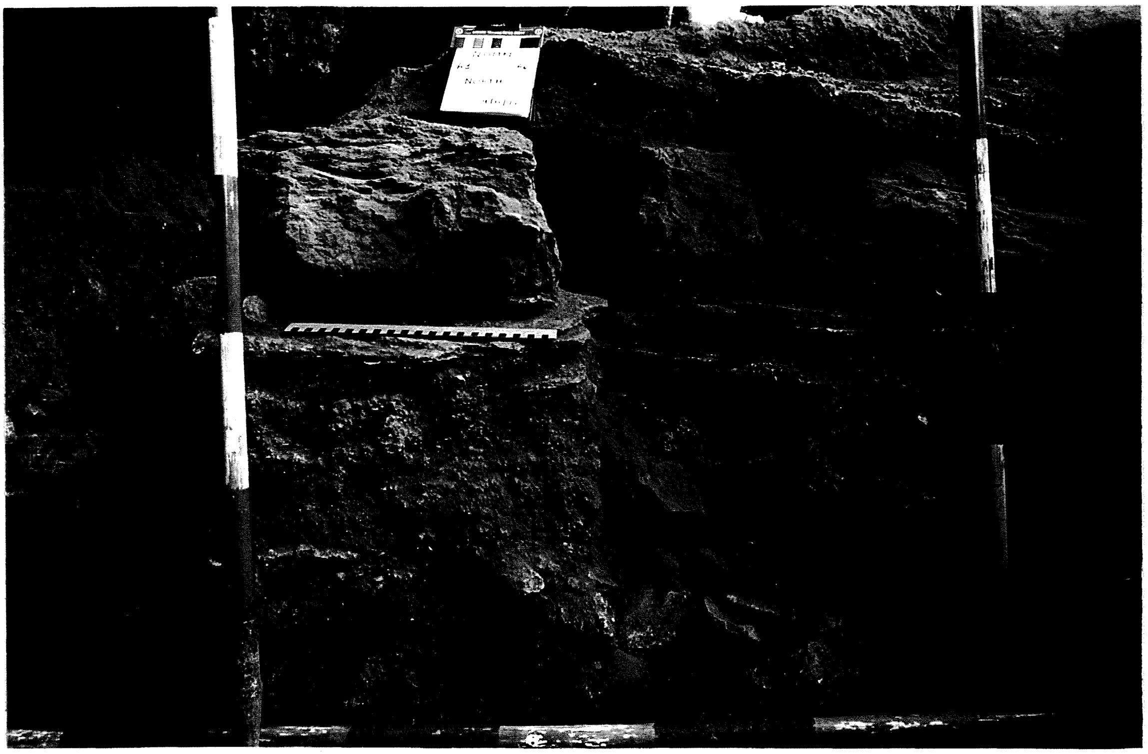

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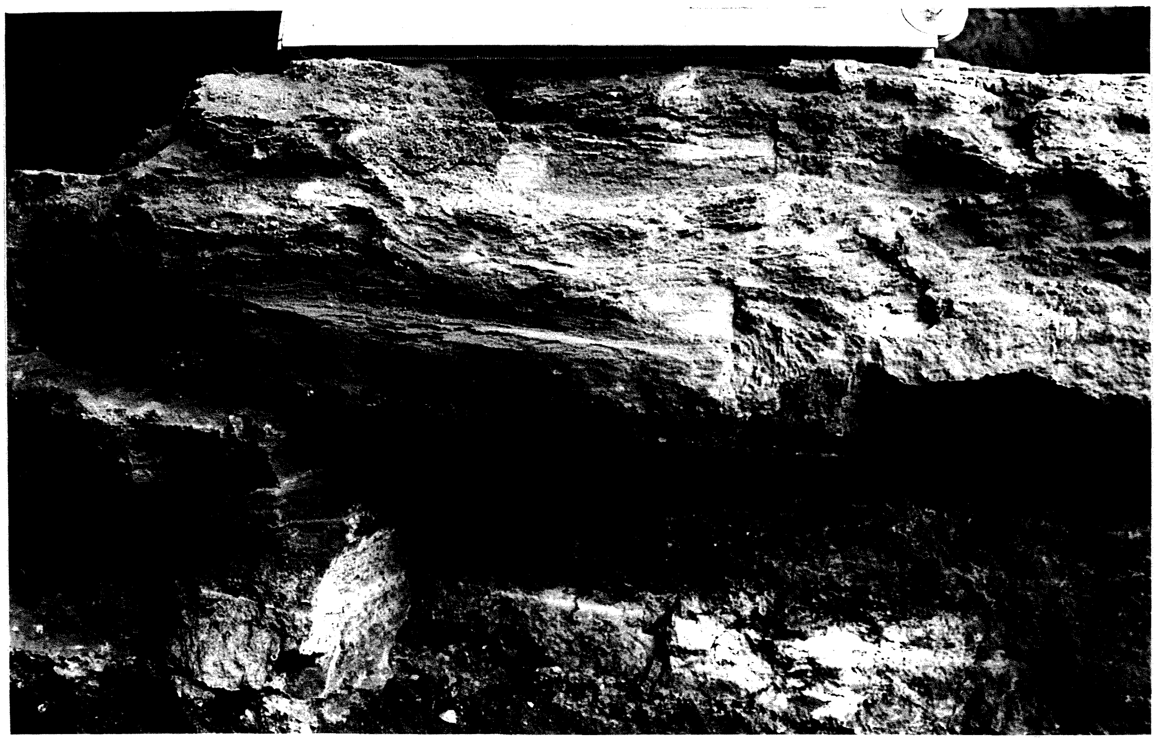

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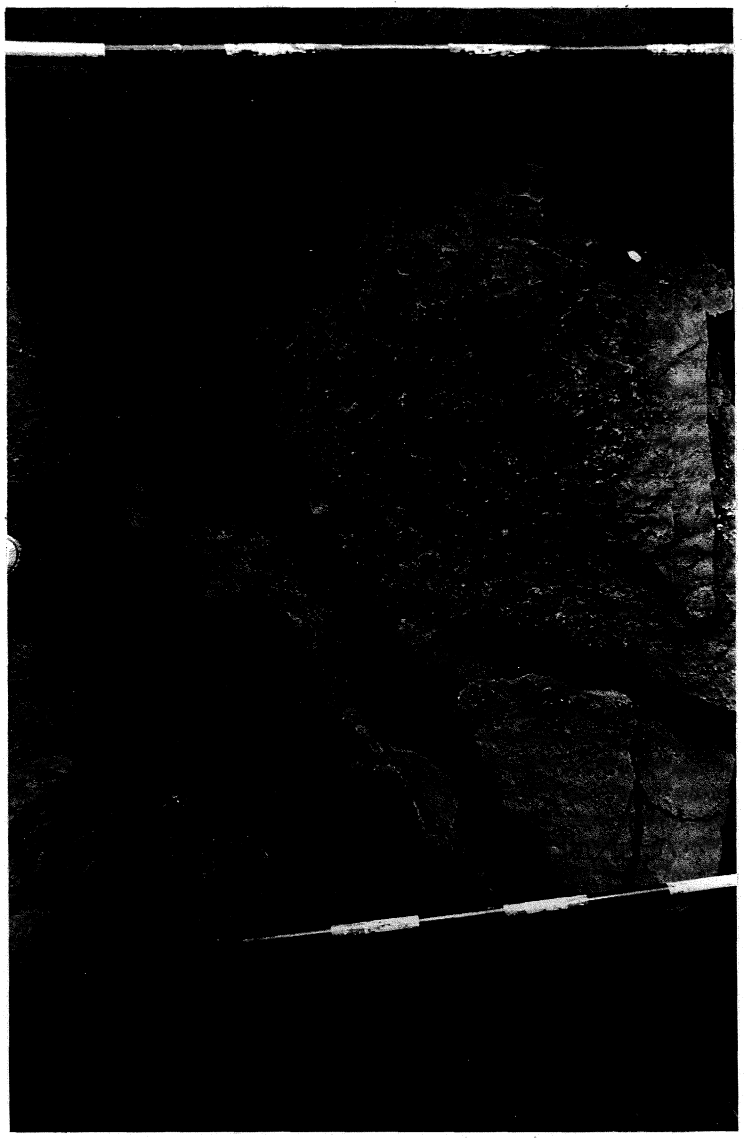

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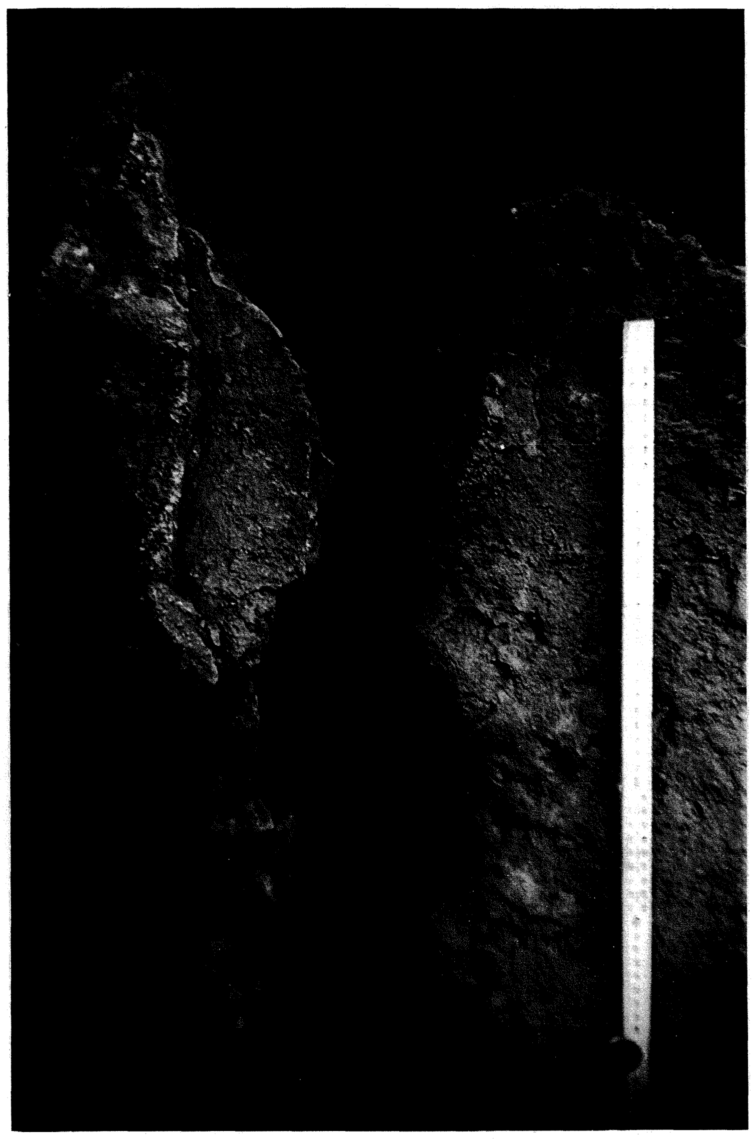

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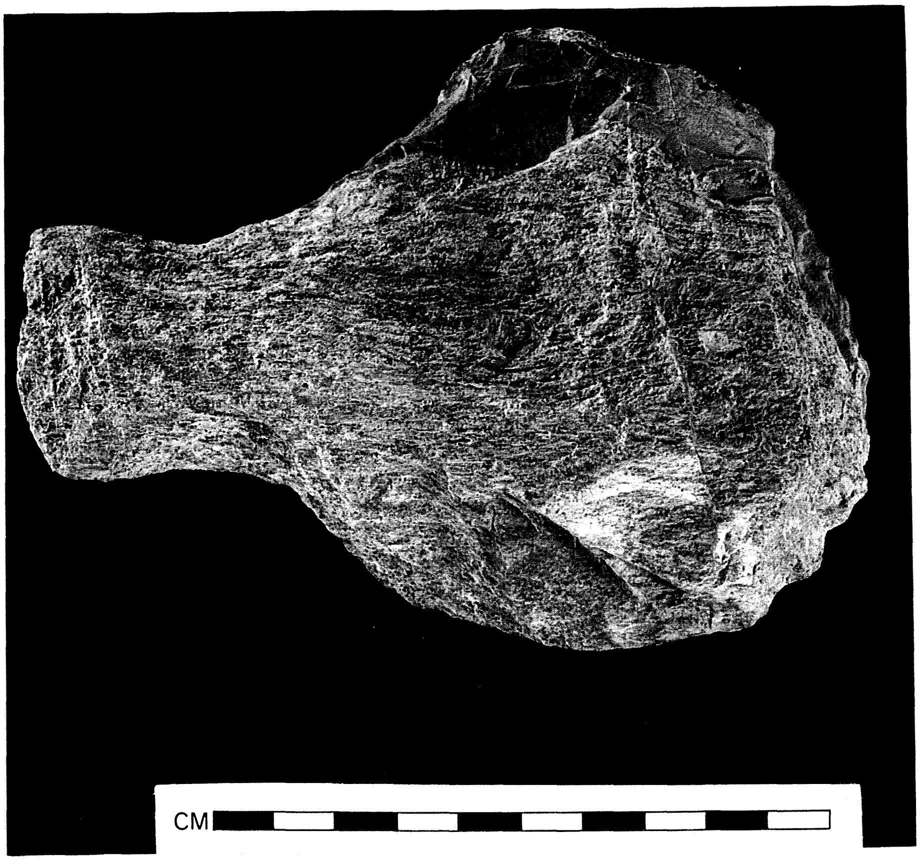

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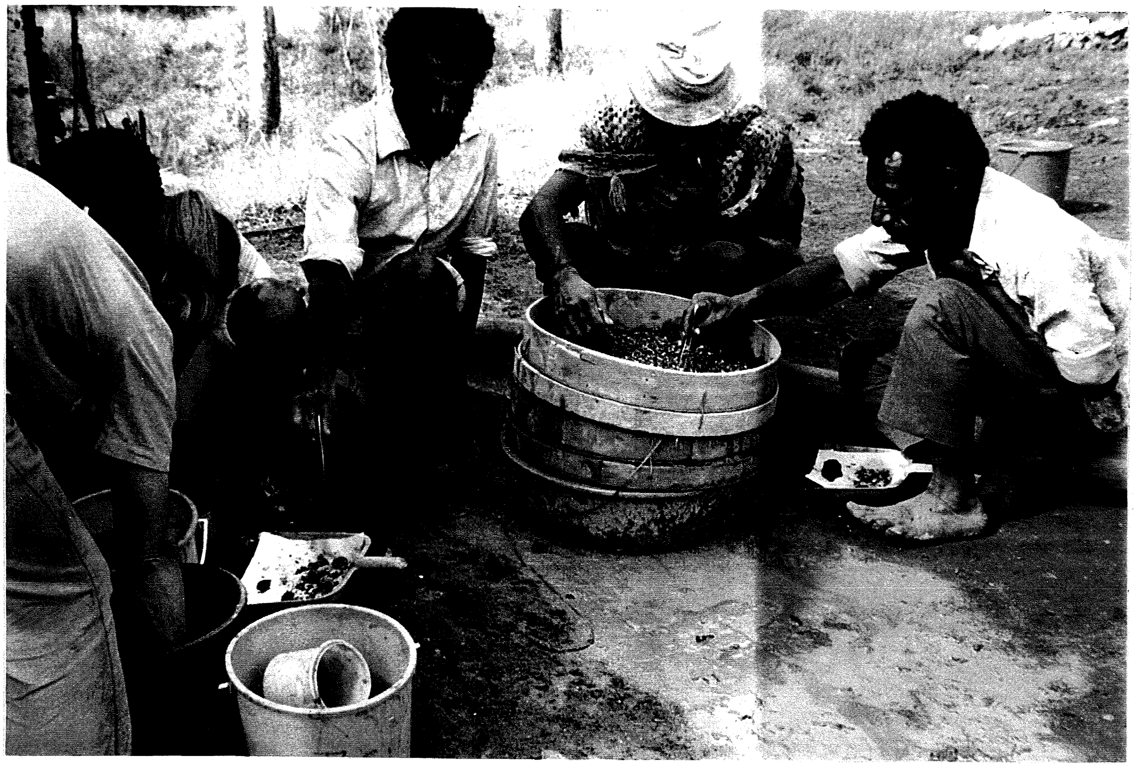

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Chapter 1

Introduction

1.1 RATIONALE

> A study of bones is however, not sufficient to clarify our ancient past. We must know how to use information and organise research, and we must increase the reliability with which we construct the past. Binford (1981:1)

This thesis is basically about bones and the ways in which archaeologists use them to provide information through which to construct a version of the past. Binford showed that such data and the associated research methods were far from satisfactory in the period before 1981. His work, of which *Bones: Ancient Men and Modern Myths* published in 1981 is one of the most important, has been a prime example of how accepted traditional methods have been examined and found to be inadequate. Binford has shown several ways in which the archaeologist can evaluate bones as a major source of archaeological data and has provided examples of new ideas. Brain's seminal book *The Hunters or the Hunted*? is another example of a reassessment of old theories, leading to re-analysis of data and the production of a 'new prehistory'.

Research in this tradition on Pleistocene sites and data from many parts of the world has identified many incorrect assumptions that caused errors in earlier interpretations (e.g. Turner 1981a, 1981b; Gamble 1979, 1983, 1986, 1987). Turner has been concerned with the lack of appreciation of the role played by the large carnivores in bone accumulations at sites long accepted as the domain of Palaeolithic hunters. Gamble (1979) re-analysed the remains from several Pleistocene sites in central Germany, concluding that human activity was only marginally concerned, if at all, in the accumulation of bones in a number of Middle Palaeolithic sites which had previously been interpreted as part of a cult of the European cave bear. In his masterly survey of the Palaeolithic settlement of Europe, Gamble (1987) provided a new perspective in Palaeolithic interpretation, moving away from the rigid typology of stone artefacts towards an assessment of how people had adapted to the exigencies of late Pleistocene environmental change through social and cultural strategies.

It is not only new research that changes ideas and the pattern of research. A week before this thesis was completed, I finally obtained a copy of Weigelt (1989). It is the book I wished I had written, it being one of the most thoroughly researched taphonomic analyses of bones. The collection of data, through a program of fieldwork, is comprehensive and scrupulous. The analysis concludes with a series of conclusions or laws, which can be tested by those of us with a fascination for the process of decay and the translation of a rather bloody and pathetic carcass into a pattern of archaeological bone. Yet this book was written in 1927 by Johannes Weigelt, a German scientist who studied death on the Texas coastal plains, and which only became available in English 65 years later as *Recent Vertebrate Carcasses and their Paleobiological Implications* (Weigelt 1989). As one reviewer has said, 'It is perhaps the most significant volume concerning taphonomy to be published in the 1980s'. Taphonomy is a vital element of the research presented in this thesis.

1.2 THE RESEARCH PROJECT

This thesis grew out of fieldwork, excavation and the data recovered. I was an archaeologist investigating a site with a problem common to archaeologists, that of complex stratigraphy: stratigraphy that was indeed so complex that the previous excavator (White 1967), unable to spend further time at the site, had decided not to have any radiocarbon samples analysed since he thought the results would have been of little assistance in understanding the abundant data recovered from the site.

Only two professional archaeologists had worked in the highlands of Papua New Guinea before the beginning of this project in 1971. S. E. Bulmer had carried out an extensive survey of archaeological sites from the Baiyer River valley in the Western Highlands to the Chuave area of what was, in 1959/60, the Eastern Highlands. Her MA thesis (Bulmer 1966/1976) includes information on two excavations which she carried out at Yuku rockshelter, Western Highlands and Kiowa rockshelter, Simbu Province. Following this, White undertook further surveys and more extensive excavations in 1964, in Simbu and further east, for his doctoral thesis (White 1967, 1972). White subsequently also excavated at the open site of Kosipe, Central Province (White, Crook and Buxton 1970), dating some of the recovered stone artefacts (including several waisted artefacts) to a period before the glacial maximum of c.18,000 bp. This occupation, at c. 26,000 bp was the earliest evidence for human occupation of the highlands.

My field work commenced in October 1971. I was joined by Ian Saem Majnep (at that time of the Department of Anthropology and Sociology, University of Papua New Guinea) as archaeological assistant and interpreter. The project involved a re-investigation of two Simbu rockshelters that had already been examined by White, both of which had produced interesting and plentiful data but had major stratigraphical or chronological problems. During this re-investigation, data were collected from one site, Nombe, that suggested early human occupation. A waisted artefact similar to the Kosipe examples and an edge-ground axe of the type shown by Carmel White (Schrire 1982) to go back into the late Pleistocene in northern Australia, were recovered from levels below the base of White's excavations. Even more interesting was the discovery of bone from extinct Pleistocene species (first recognised by J. Hope and later identified by Flannery (Flannery, Mountain and Aplin 1983) in the same sediments as the artefacts as well as in the very basal sediments of the excavation.

This was not the first time that an archaeological site in highland New Guinea had produced such bone. White had recovered a tooth of an extinct macropodid in the lowest levels of Kafiavana (White 1972; Plane 1972) but since this was below the level of the first human occupation, it was presumed that there was no connection with human activity. Bulmer had recovered thylacine (*Thylacinus cynocephalus*) in levels with clear evidence of human presence at Kiowa (Bulmer 1966/76; Van Deusen 1963). But the evidence recovered during the 1971 excavation season at Nombe was far more extensive than at either of those sites. Several different species were present in the clays at the bottom of the site. Higher in the site the suite of animals clearly altered. In Stratum B, which contained evidence for intensive human occupation, (White had ceased to excavate at the bottom of this level), the fauna appeared superficially to be similar to the range of animals expected in highland regions today. The relationship between the fauna, the natural environment and human activity interested me because of the intensifying debate on this relationship evident, for example, in the work of Binford (1981), Gamble (1979), Clarke (1976) and Isaac (1981). If the site's stratigraphical and chronological complexities could be solved, it was clear that the Nombe faunal data had the potential to make a substantial contribution to the debates on the complex relationship over time between humans, animals and the environment.

The project developed in the early 1970s as a personal research project funded by the University of Papua New Guinea. A group of prehistory students and staff from the Department of Anthropology and Sociology worked with me at the site in 1974 and 1975. Although a great deal of progress was made in understanding the stratigraphical problems, it was clear that further research on the sediments and their chronology would be required for a real understanding of site development. Faunal analysis could only be successful if a great deal of time was devoted to identification; no adequate faunal collections were available in Papua New Guinea. The research project was accepted as a doctoral thesis topic by the Australian National University in 1978.

1.3 AIMS

There are two main areas of research interest that can be pursued through an analysis of the Nombe data, and can be phased in the form of questions.

- ☐ How have the human populations of the highlands increasingly imposed their way of life on the landscape during the last 10,000 years? The documented modern ethnographic variations have their roots in prehistoric human activity and Nombe could contribute to the debate about the history of hunting/collecting in the Holocene in the context of the effects of agricultural activity on the progress of forest clearance and the development of grasslands. A detailed analysis of the data from the Holocene strata (A and B) at the site would provide evidence relevant to these areas of debate, including the question of the introduction of the exotic animals, namely the pig and the dog.

- ☐ What was the nature of the prior relationship between human beings and their natural environment within one region of the highlands of New Guinea? Relevant to this debate would be the analysis of the data recovered from the Pleistocene strata at Nombe (D and C). What was the environment like before humans arrived in the highlands and could the first modifications of that environment for human benefit be documented?

Given the complexities of each of these broad topics, it was not going to be possible to cover both in the thesis research. Since Nombe was apparently unique as a site of Pleistocene occupation, I judged the second question more important. I also found it more challenging. It required deducing evidence about the earliest stages of the relationship between human populations and their environment. Unlike many other parts of the world where various species of hominid existed at earlier times, New Guinea provides an example of the immediate and direct exploitation by *Homo sapiens* of a previously untouched environment.

Human hunting and collecting had their effects on that environment from the first arrival of the species, but the nature of the changes effected is far more subtle and their interpretation more controversial than in later periods of prehistory. Hunter-gatherer activities are often seen by members of our ecologically destructive generation as representing an ideal balance between environmental supply and human dependence. But wherever the human race has been successful, it has inevitably expanded, developed new technologies, spread into neighbouring territory and, over thousands of years, changed the environments into which it has moved. Documenting the early stages in this relationship in the New Guinea highlands would not be straightforward and the interpretations would be open to challenge. Nevertheless, the pursuit of the question was important and the necessary techniques and choice of appropriate analyses were challenging.

The research was therefore structured to study three broad but related issues.

- ☐ **The nature of the relationship between the early human occupants of the highlands and the environment in which they became participants.** When people first entered the highlands of New Guinea, about 30,000 years ago or more, they entered a landscape affected by the lower temperatures of the late Pleistocene. Hope and Hope (1976) had suggested that human hunters were attracted to the alpine grasslands and shrub-rich forest edge which constituted a resource zone particularly for hunting that virtually disappeared with the warmer temperatures of the Holocene. Could data from Nombe be used to test this theory?

- ☐ **The contentious issue of Pleistocene extinctions and the role of human beings in that process** (Martin 1967; Martin and Klein 1984). The recovery of bones of extinct species in levels containing evidence for human presence at Nombe offer an opportunity to look at this issue at a new site.
- ☐ **The nature of the transition from hunting and gathering to horticultural subsistence.** All highland societies today are horticultural and derive little of their basic subsistence from the activities of hunting and gathering in their heavily impacted environments. In their rockshelter excavations neither Bulmer nor White had identified any specific change in stone technology that reflected a change in the subsistence economy, although Bulmer (Bulmer and Bulmer 1964) certainly identified the arrival of the ground stone axe-adze as heralding the beginning of agriculture. White (1972:147) could see no major artefactual change after the initial settlement of the region 'for some considerable time, until at least 4000 bp'. He concluded that his overall impression from the archaeological evidence available to 1972

  > ... is one of sameness and continuity. This perhaps indicates only that some basic aspects of life in the Highlands continued unaltered by other economic and technological changes. However it may point to a stability or continuity not often found in post-Pleistocene prehistory. (White 1972:148)

  Subsequent archaeological and palynological work in the upper Wahgi valley west of Nombe, provided the basis for claims that horticulture made its appearance in the highlands early in the Holocene and that it had effected marked changes on the vegetation by the mid-Holocene as a result of repeated clearance under a forest fallow regime (Golson 1977; Golson and Hughes 1980). Was it possible in the light of this environmental consideration, that the faunal evidence would be more sensitive than the artefactual evidence to the change in economy?

1.4 METHODS

With the decision to focus on these issues it was necessary to identify the **techniques** that would be necessary to produce appropriate data.

Sediment analysis: The complexities of the Nombe stratigraphy, involving many different sedimentary processes, required the cooperation of a geomorphologist. David Gillieson was then beginning his thesis work on limestone caves in the highlands and was interested in working at Nombe. He visited the field area at the end of 1979 during the last season of Nombe excavations and this cooperation provided both of us with an opportunity to further our own research projects. His extensive and thorough analyses provided the data that was then interwoven with the stratigraphic record to construct a scenario for the depositional history of the site (Gillieson and Mountain 1983).

Dating: In order to fit the depositional record into a chronological framework, Henry Polach and John Head of the Radiocarbon Laboratory at the Australian National University spent much effort working on the problems of dating a variety of materials from Nombe, including snail shell, bone and flowstones.

Faunal analysis: The analysis of the extensive faunal collections from the excavations forms the backbone of the research. Taphonomic considerations were crucial to this. Clearly there were major variations in the bone material from the Holocene and Pleistocene strata; these variations had to be examined and accounted for before any interpretation could be offered.

There was a great deal of bone to be identified, but there were problems in the employment of conventional 'bone by bone' techniques. Methods of analysis had to be devised that would provide data to allow the examination of the main issues but which could be carried out within the time constraints imposed by the thesis.

Computer analysis: The use of a computer database was essential, but complex decisions had to be made on the classification of the data for computer entry, the programs to be used and the flexibility necessary to enable the testing of the subsidiary hypotheses which would emerge during the research. It is necessary to note that, at the time this data was computerised, the mainframe computers of the Australian National University did not have a suitable database program and the use of computers in archaeology was still in its tentative beginnings.

1.5 LIMITATIONS

There were also a number of **problems** with the site data. Since the fieldwork had commenced in 1971 as a short term project to re-examine stratigraphical and chronological problems, there had been no planning for long term goals. The aims and objectives altered as the project developed and this had repercussions in the recovery and recording of evidence.

- ☐ The scale of the excavations became less extensive with each field season and the techniques employed more refined in a bid to achieve a more detailed recovery of archaeological material. This has led to a situation where it has been necessary to amalgamate several sets of data, each on a different level of refinement, in order to present a unified database.

- ☐ Techniques were not specifically designed for the maximum recovery of bone evidence during the early seasons and this had to be rectified during the thesis fieldwork.
- ☐ Certain information was not collected at the beginning of the project; for example, snail shell was not retained in 1971.
- ☐ At the beginning of my first excavations in 1971, there was little stratigraphic differentiation in the top levels and therefore the units of excavation at the time were fairly coarse. However, greater control was required for the thesis work.
- ☐ The re-excavation and backfilling of the site had altered the ground levels on the site, causing recording problems.
- ☐ The location of the site, about 45 minutes walk from the nearest road, caused logistical problems in the removal of evidence (especially heavy blocks of materials consolidated by calcium carbonate) and the cost of transporting material back to Canberra meant that some interesting evidence contained in those blocks had to be left at the site.

In short, a more coherent pattern of research would have been instituted had the continuation of the investigation been foreseen in 1971.

1.6 POSITIVES

A factor that has had a major and beneficial influence on the progress of the research have been the advances made in our understanding of the regional prehistory and knowledge of the highland fauna since the thesis was started in 1978. The ideas and information from these studies have suggested new ways of using the Nombe data and provided a rich background against which to develop the interpretations presented in later chapters.

As Hope and Swadling (1992) have recently said,

> the more we discover, the more complex the picture of human-environmental interaction in this remarkable island.

This thesis aims to allow the site of Nombe to make its contribution.

Chapter 2

Locality and Archaeological Excavation

2.1 BRIEF DESCRIPTION OF LOCALITY AND SITE

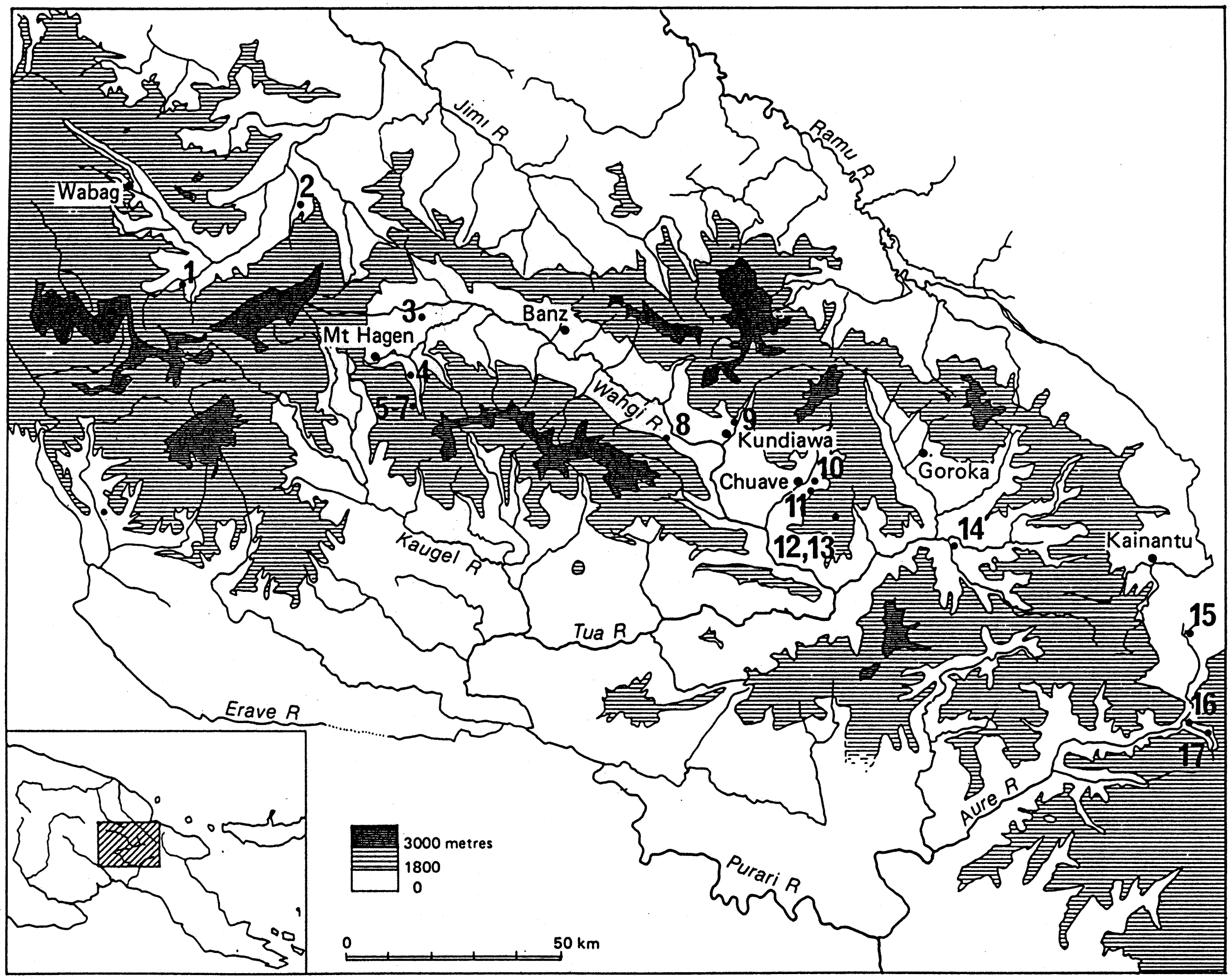
2.1.1 Topography and altitude

The cave and rockshelter of Nombe is in the Elimbari-Porol Range limestone escarpment (PNG 1:100,000 Topographic series sheet 7985 Goroka). Figure 2.1 shows the location of Nombe within the New Guinea highlands together with other major highland sites. A more detailed local map is included as Figure 2.2.

Nombe is on the eastern edge of a block of limestone bounded to the north by the river Mai and to the east and south by the Movi Beds and the drainage of the River Futoga. To the west the steep scarp slope is dominated by the triangular peak of Mount Elimbari (2850 m). The dip slope is generally fairly gentle. There is little land in the vicinity under 1500 m, apart from the area immediately adjacent to the river at Chuave. Most of the area is between 1600 m and 2200 m in altitude with higher slopes to the east and some limited higher areas on the upper zones of Mount Elimbari itself. The site is at 1720 m on the western edge of the dipslope at 6°10'S, 145°10'E.

2.1.2 Local geology

The Elimbari limestone escarpment is formed from the Chimbu limestone belt of Eocene to Oligocene age, overlaid on the north and east by the Movi Beds which consist of volcanolithic and calcareous sandstones, siltstones, shales and conglomeratic minor cherts (Figure 2.3). The junction between these two formations has become an area for cliffed doline development, and the karst scenery has allowed drainage patterns to develop partial underground systems. The dip slope of the escarpment is crossed by a number of high angle faults, running from the scarp ridge down the slope in a generally north-eastern direction. In areas where the vegetation has been cleared for gardens these strike-controlled ridges are extremely clear.



Archaeological Sites

1. Tsak Pumakos
2. Yuku
3. Kuk
4. Manim
5. Kamapuk
6. Etpiti
7. Tugeri
8. Anbannigl
9. Omkombogo
10. Kiowa
11. Nombe
12. Lemouru
13. Uweka
14. Kafiavana
15. Aibura
16. Batari
17. NFX

Figure 2.1 Locality map of Papua New Guinea highlands, showing Nombe and other highlands archaeological sites

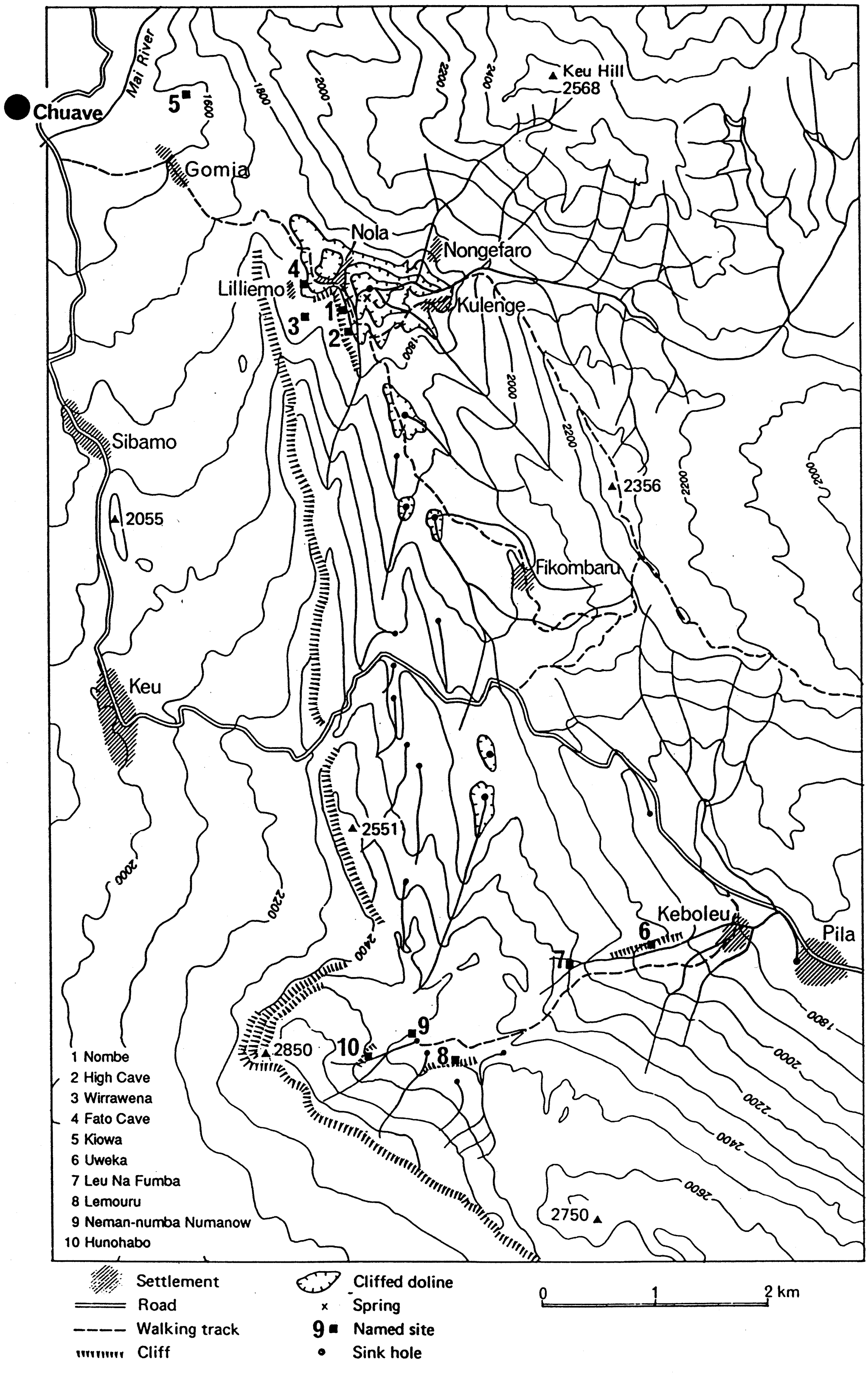


Figure 2.2 **Detailed locality map of Nombe**

At the time of major uplift of the Elimbari massif, the Movi Beds would have largely overlain the Chimbu limestone but subsequent erosion has stripped away much of the Movi Beds (Bain, Mackenzie and Ryburn 1975). Relict conglomeratic sediments from the mouth of Fato Cave (Figure 2.2), 300 m north of Nombe and on flat saddles between the cliffed dolines near Nola village (found and reported by Gillieson (1982:345)), suggest that the Movi Beds have existed over this area before erosion took place and the streams began to drop underground.

2.1.3 Local drainage

In the immediate area of Nombe, drainage patterns show a general northward flow to the River Mai (also called Mairi and Marifutiga), which flows out of the Bismarck Mountains to join the River Wahgi. The local drainage pattern is shown in Figure 2.4. Over the watershed in the valley east of Mount Elimbari the drainage flows south, to the smaller River Futoga which flows directly into the Tua River. All these rivers eventually join into the Purari River and reach the sea in the Gulf of Papua. Local drainage is irregular due to the karst topography; many streams are seasonal and run only during periods of continuous heavy rain and streams frequently disappear underground and re-emerge further down the slope. The archaeological site of Kiowa is close to a resurgence of a substantial stream and the Lombila doline below Nombe swallows a stream at its base (presumably the same waterway).

Gillieson (1982:345) postulates that an integrated drainage surface must have existed at one time from the east side of Mount Elimbari along the valley in a northerly direction past Nombe and Kiowa down to the River Mai. The subsequent erosion and formation of karst features have caused much of the drainage to go underground leaving an interrupted line of surface drainage. On the karst slopes there are many dolines, for example Wirrawena on the grassland slope above Nombe, and some larger cliffed dolines are found along the drainage routes. There are also caves and rockshelters in the limestone, some, like Fato Cave, of considerable size. While some karst caves still have water flowing through them most are dry for most of the year becoming damp with active water drips during continuous rain, sometimes even with minor streams issuing after extremely heavy rain.

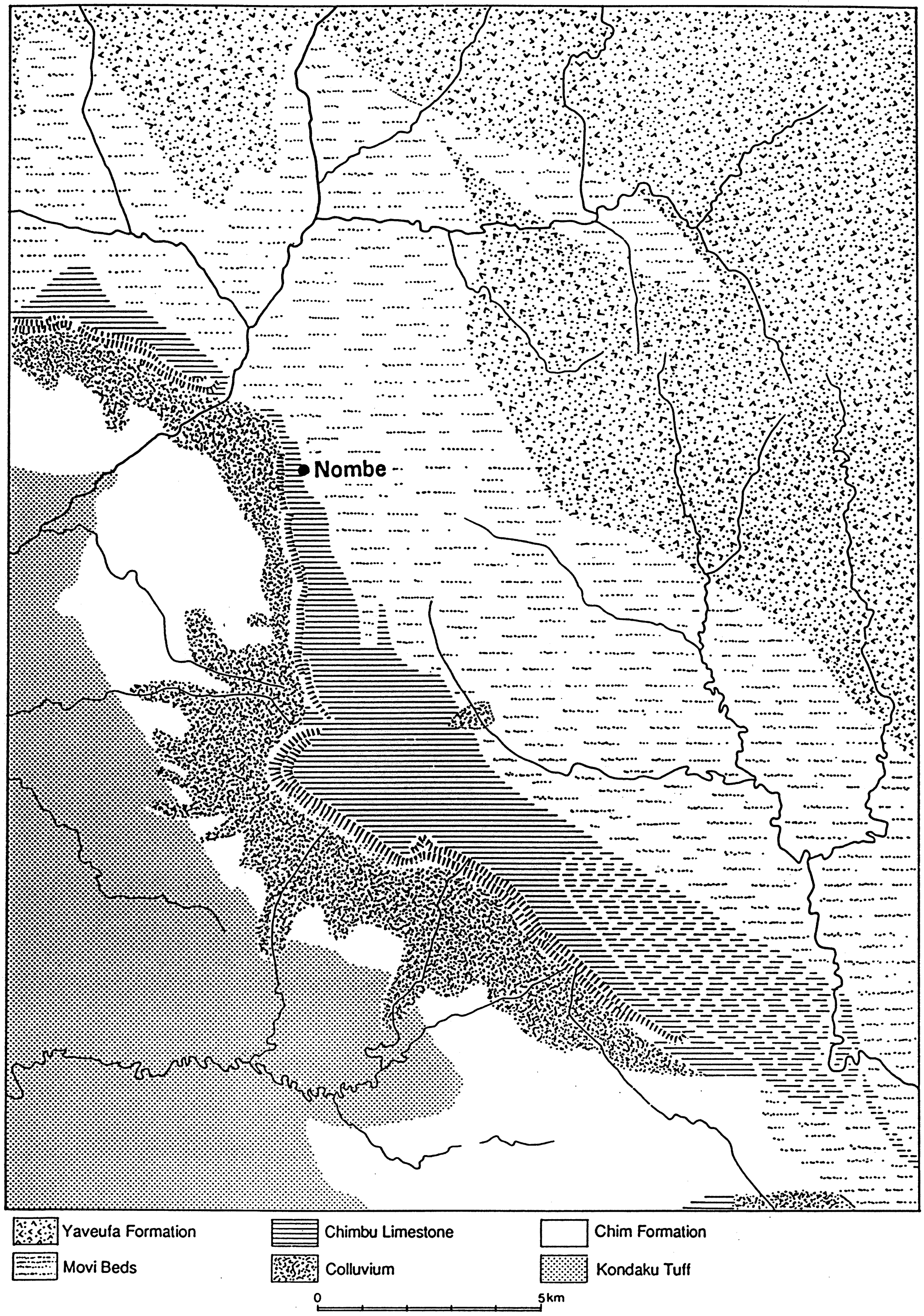
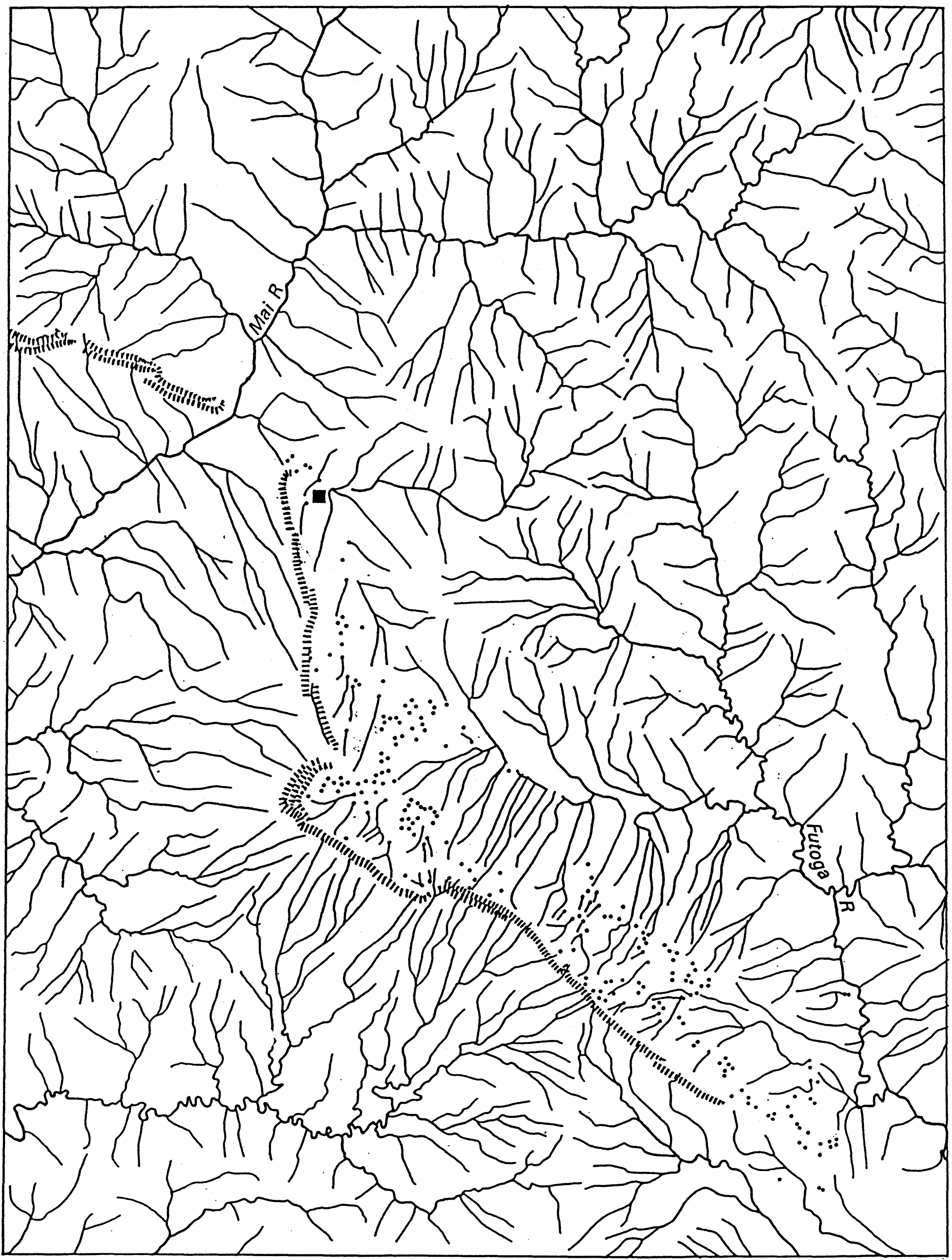


Figure 2.3 **Geology of Nombe region**



● Sinkhole ■ Nombe

Figure 2.4 Drainage map of Nombe region

About 10 m south of Nombe rockshelter is a cave, High Cave (Figure 2.5), with an entrance about 3 m above the level of the path running along the foot of the cliff. This cave can be entered and there is a passage leading towards the north:

> ...the northern end of the passage terminated in a steep drop (10 m) cut in clay sediments, with a stream channel visible at its base. This channel is at the same level as Nombe rockshelter, and its continuation is suggested by buried stalactites and wall pockets at the rear of Nombe rockshelter (Gillieson 1982:347)

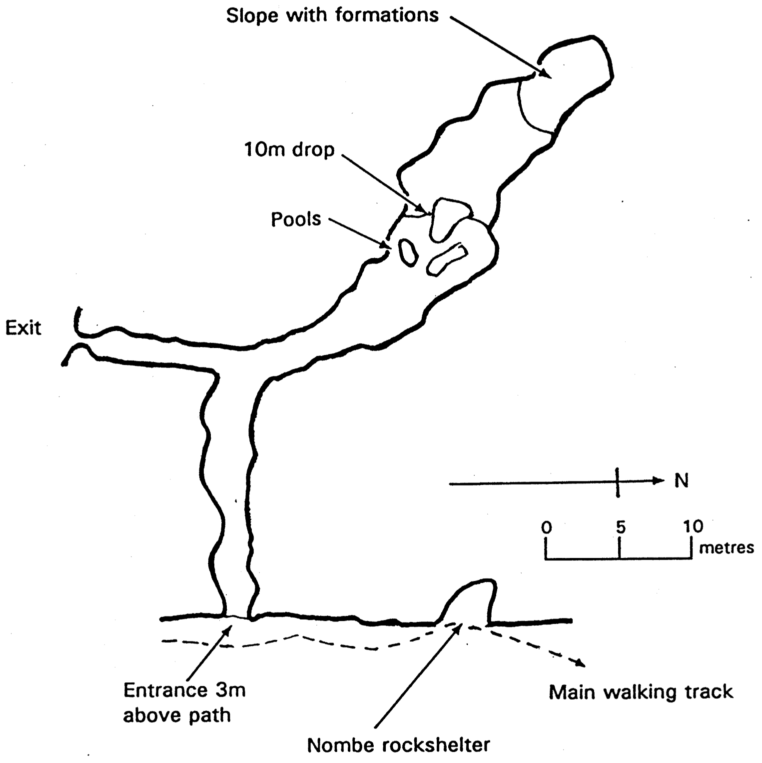


Figure 2.5 **Plan of High Cave**

2.1.4 Local soils

The soils of the Goroka-Mount Hagen region are classified generally as tropohumults and humitropepts (Bleeker 1983). The humitropepts are found mainly in the highlands between 1500 m and 3000 m under wet climates, on moderate to steeply sloping terrains away from volcanoes. A specific example taken from the eastern slopes of Mount Elimbari at 1980 m has been classified as a tropohumult (order: ultisols; suborder: humults; great group: tropohumults). This was previously classified as a mixture of humic brown clay and red latasols (Bleeker and Healey 1980:860). These are subgroups recently divided off from more general categories that were previously described as predominantly humic brown clays with a high humus content in the topsoil, occurring on a widespread variety of parent rocks, including igneous, metamorphic and sedimentary groups (Haantjens *et al.* 1970). The work of Pain and Blong (1979) pointed out the importance of volcanic ash in the formation of the soils of the area, with ash coming from eruptions of Mount Karimui, Mount Au and Crater Mountain (Howlett, Hide and Young 1976:84).

2.1.5 Site of Nombe (1720 m)

The site of Nombe lies at the foot of a cliff that occurs in the karst limestone formation on the western edge of the Elimbari dip slope. The base of the cliff is now used as a pathway along the top of the cleared slope descending into the doline. This slope is at present alternately used for fenced gardens or regenerating fallow bush with secondary vegetation. Nombe lies below the eastern end of a strike-controlled ridge, running from the cliff top to the top of the Elimbari scarp ridge.

Nombe was among a group of local caves/rockshelters identified and explored by speleological enthusiasts based in Goroka in the 1950s. When Bulmer came to survey the region she identified 'Nombi' (Bulmer 1960:27) as a 'long rock shelter just west of the cave (High Cave). A number of modern type axes and axe roughouts were found on the surface, which is badly disturbed soil. Smoke stains at several points along overhang'. There is now a very small cave at the back of the site, the back of which is blocked by sediments, behind which a larger cave probably opens into the extensive local karst system. There is a reasonable area of rock shelter, frequently used now as a temporary shelter and resting place for people moving between local villages and gardens (Plate 2 and Figure 2.2). People stop at the site and frequently light a small fire, dug into the dusty top levels, to cook corn or sweet potato. The cliff in the vicinity of the site has been painted with a number of designs, using red, white and black colours. These are often in positions well above the path, difficult to reach without some form of scaffolding. There is extensive blackening of the cliff, both from smoke and also from natural staining.

2.2 METHODS EMPLOYED DURING ARCHAEOLOGICAL WORK AT SITE

The research during the 1960s at the site was outlined in Chapter 1; some detail of the methods used in these excavations, and the aims and methods of the 1979/80 fieldwork, is now necessary. Figure 2.6 presents plans of the series of excavations at Nombe while the remainder of this section discusses the techniques and methods used for each field season.

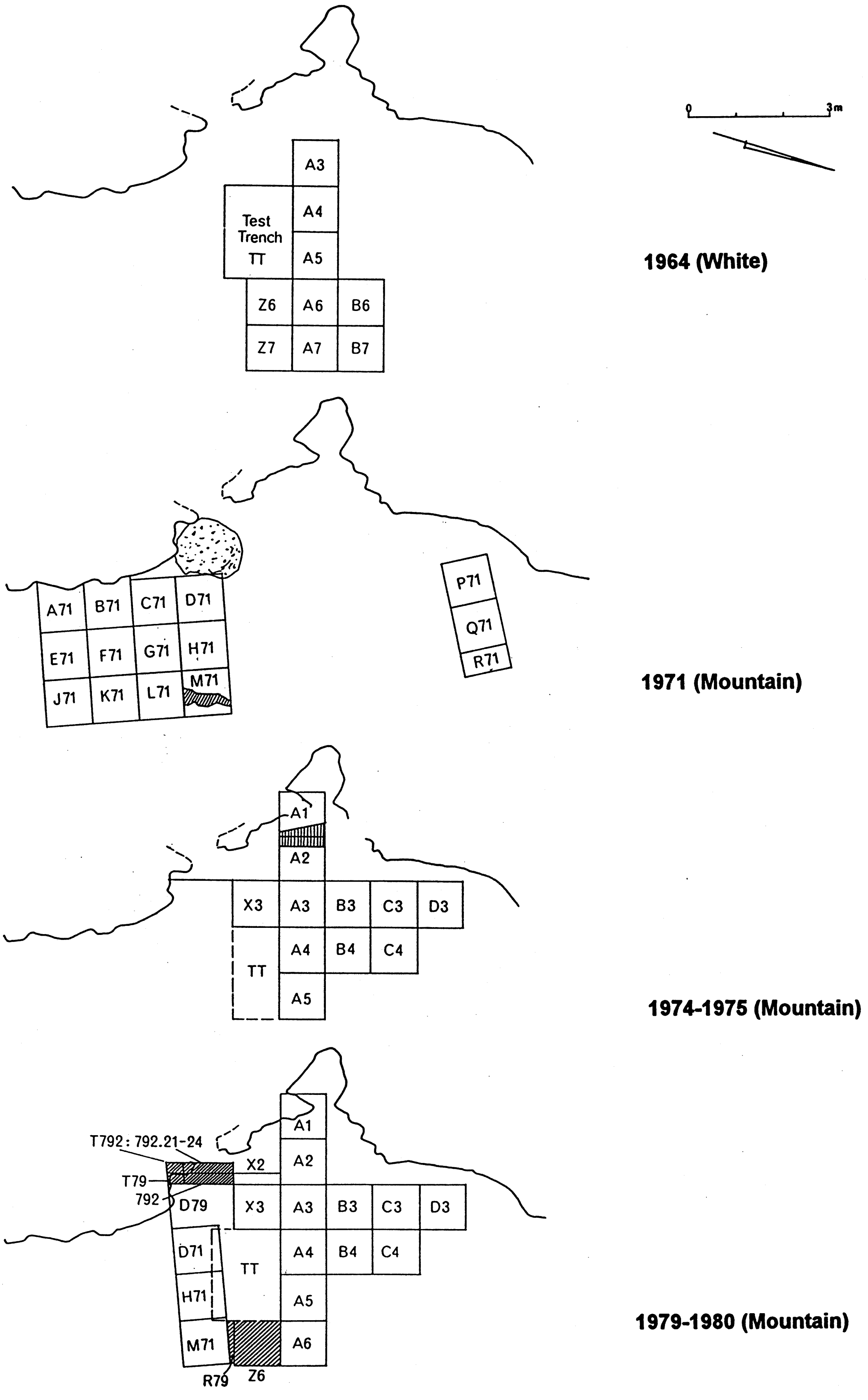


Figure 2.6 **Plans of the excavations at Nombe**

2.2.1 Areas excavated and techniques used from 1964 to 1975

1964 season

The area opened by White in September 1964 (White 1967) is shown in Figure 2.6. His Test Trench was large (2 m x 1.5 m) and 4.5 m^3 of deposit was removed in two days. Further excavations were carried out in October 1964 immediately to the north and east of the Test Trench in metre squares designated as A3, A4, A5, A6, A7, Z6 and Z7.

All deposits were sieved through a 6.4 mm (¼") screen. Most of the squares contained a series of ashy and loamy sediments on top of a redbrown clay that appeared at varying depths below the 1964 ground surface. Squares A3-5 ***P4*** contained complex stratigraphy that included cracked flowstones and associated slipped deposits that led White to suspect that tectonic movements might have caused considerable disturbance on the site (White 1972:127). He decided to group the finds into only two categories: materials from above and in front (to the south) of the flowstones and those from below the flowstone sheets. In retrospect it was unfortunate that he encountered one of the most complex areas of the site.

1971 season

On my initial visit to the site I was concerned with an investigation into the stratigraphic problems encountered by White. A 12 m^2 area was chosen for excavation to the south of White's 1964 excavations (Figure 2.6). Spits of 10-20 cm were removed using local labour under the direction of myself and Ian Saem Majnep, technical assistant in the Department of Anthropology and Sociology at the University of Papua New Guinea. One metre of ashy soils and brown loams was removed from the grid ***P10*** producing very large quantities of artefactual debris, all sieved through 6.4 mm sieves without difficulty due to the dry dusty nature of the sediment. There was no sign of flowstone or other sediments. It was then decided to concentrate on the three squares (D71, H71, M71) at the north of the grid, bordering the Test Trench of White. Below the levels of the brown loams, redbrown clay deposits were located ***P9***. These were below the bottom level of White's excavations but contained occasional artefacts and well preserved, often very large bone later identified as belonging to a series of extinct species of megafauna. Excavations were carried out by 10 cm or 20 cm spits within recognisable sedimentary units and all deposits were sieved through 6.4mm mesh, and all bone and artefactual stone were retained. However, snail and egg shell were not consistently collected during this field season. The redbrown clay was thick and very difficult to work. It had to be broken up by hand and archaeological materials were extracted in the sieve.

A further area was excavated to the north of the site (P71, Q71, R71,[P3]) and showed little similarity with White's A3-7 profile or with the stratigraphy from the grid to the south (A71-M71). Although redbrown clay was present, often close to the surface in this area, it appeared to contain no extinct fauna except thylacine while the artefacts included chips from polished stone axes. These factors indicate that this clay is of more recent origin than the redbrown clays found in the west and south of the site, which were found at a much lower depth below the surface. Charcoal was only found in very small quantities in the upper levels of the excavation (too little for the requirements of conventional radiocarbon dating) and none at all from the redbrown clays. However, the quantity and variety of archaeological materials recovered in 1971, including extinct fauna, continued to prove the value of further investigation. In particular the nature of the association between extinct fauna and human artefacts required further evaluation.

1974 and 1975 seasons

Work continued as the project became incorporated into the fieldwork training for students taking courses in prehistory at the University of Papua New Guinea. It became necessary to reopen White's area of excavation to examine the remaining stratigraphy at first-hand, since it was so difficult to match the stratigraphies of 1964 and 1971. In 1974 a short field season was made to Nombe and the backfilling from White's Test Trench and squares A3-5 was removed. Excavation was continued in the redbrown clays underlying the base of White's excavations in these squares which were contiguous with the redbrown clay in the bottom of the squares D71, H71 and M71. New squares were opened (A1, A2 and X3). The following year these squares were completed and further squares (B3, C3 and D3) were added. Also in 1975, squares B4 and C4 were excavated to expose the top of the uppermost flowstone sheets (Figure 3.4).

As in 1971, excavation was carried out in 10-20 cm spits within recognisable sedimentary units, all deposits were sieved through 6.4 mm mesh and all materials found were kept, including snail shell. Charcoal was still very rare even in the top levels and no radiocarbon samples were submitted.

2.3 DESIGNATION OF AREAS AND EXCAVATION UNITS AT NOMBE

Had the research work at Nombe been planned and excavated as one integrated research project, the designation of all areas and excavation units would have been undertaken in accordance with the aims of the overall project. However, since the research aims and excavation requirements changed as the project evolved, these designations were added to and altered as techniques changed, resulting in a complex and often cumbersome system that requires careful explanation.

2.3.1 Designation of squares

White named the 'Test Trench' and his grid of nine squares of one metre square with an alphanumeric system (White 1967) (Figure 3.2). The 14½ squares (of one metre square) dug in 1971 were provided with separate names since, due to changes in level at the site it was difficult to be sure of the exact location of previous trenches not uncovered. Each metre square was labelled with 71 prefixed by an alphabetic character. Later squares were either incorporated into White's system (once his trenches were relocated) where suitable, or were named with the last two numbers of the year of excavation and an alphabetic character. There is one exception here as part of the Wet-sieved Strip was named 792.

In some squares where archaeological material was extremely abundant, an internal division was made in the square, usually a subdivision north to south into two areas each 1 m x 0.5 m, designated 1 (towards the west) and 2 (towards the east), so for example H71(1) and M71(2).

2.3.2 Designation of spits

The 1971 squares were dug by spits and these are designated by numbers following the square (for example, PQR71:3, H71(1):5 or M71:9). Bags of material from the same spit were designated only by date. In 1974 and 1975 squares were also dug by 10 cm or 20 cm spits but here each bag of material was given a catalogue registration number in order to record all finds with greater accuracy. These numbers can be of one, two or three digits following the spit number, so that C3:1 14 and 17 are two bags of material from the same spit of one square while within the square A2 in the second spit there are six bags of material, involving finds from a later disturbance and other individually bagged finds. Due to the complexities of the stratigraphy within the site and the fact that some squares were dug from the base of White's previous excavations and not from ground level, there is no correlation implied between spit numbers in different squares in the way of sediment matrix, depth below surface levels or datums or chronological period. Such correlations (involving stratum designations) were made at a later stage of analysis with the results of radiocarbon dating and other analytical tests to hand.

2.3.3 Designation of small wet-sieved units in 1979/80

In 1979/80 wet-sieving was employed and the designated unit of excavation involved here was a bucket or less. Spit numbering was irrelevant since far more flexible control was possible in later analysis. A strip of only 25 cm breadth was excavated by subdividing it into nine columns, four (named .11, .12, .13 and .14) within each of the squares 792 and X2 and one filling the remaining space to the south, T79. Within each column the material was removed according to changes in sediment matrix and each bucket was given a catalogue registration number of three digits. The units therefore have the square designation, the column numbering and the registration number. An example would be 792.14 238 or X2.11 126. One hundred and thirty-six units were excavated within the Wet-sieved Strip. Some excavation units from R79 and Z6 were also wet-sieved in 1979/80 and these were designated in a similar system. R79 was subdivided into eastern, central and western areas and Z6 was divided into four strips (11-14) running from east to west. A catalogue registration number of two or three digits was added to each bag of finds recovered.

2.4 TECHNIQUES OF 1979-80 EXCAVATIONS AT NOMBE

By 1979 the project had become part of a doctoral thesis and the aims of the excavation had altered. There existed a substantial quantity of excavated materials and stratigraphic information that had to be taken into account from previous excavation during interpretation. There were still considerable problems with the stratigraphy, especially in the necessity to test whether deposits that appeared visually similar from separate areas of the site were, in fact, of similar origin and if so, whether they were deposited at the same period of time. There were also problems in that previous excavation had been by fairly gross units, of at least 10 cm depth over a metre square and in many cases greater in depth. It was necessary, in order to be able to analyse some rather elusive stratigraphic units in further detail, to proceed by smaller archaeological units that could be amalgamated in a more flexible fashion. Wet-sieving was desirable to recover very small bone, charcoal and plant remains. There was also an urgent need for chronological pointers to the development of the site and, since charcoal had proved so rare on the site, the dating of other materials had to be considered.

It was in response to these specific requirements that further investigation of Nombe was carried out from November 1979 to February 1980. In order to test the validity of the stratigraphy as it was perceived in 1979 (Section 3.1.1), David Gillieson, was invited to visit the site for two weeks in mid-November 1979 to undertake sampling for sediment analysis of the deposits at Nombe. In order that Gillieson and I could examine and sample from as much of the previously excavated areas as possible, the backfilling of the squares in central areas of the site was removed.

Following Gillieson's visit to the site, work on the excavation of the Wet-sieved Strip began. This site was chosen since it was the only area of the site that contained all the major stratigraphical deposits without deposits that had proved either archaeologically sterile (such as the tephras) or extremely difficult to excavate (such as the flowstones and consolidated deposits). Since the chosen area lay behind the Consolidated Block D79/X3 ***P1***, it was necessary to remove this prior to the wet-sieving. Due to its hardness and in view of limited time, rather crude methods had to be used (mainly hammer and chisel) to break it down. Where feasible, archaeological material was removed from the consolidated matrix but this was not always possible. Some very large pieces were taken back to Canberra intact but others had to be left due to the expense of transport.

Once the Consolidated Block of D79 and the underlying redbrown clays had been removed, excavation began on the narrow strip immediately behind it, subsequently referred to as the Wet-sieved Strip (Figure 3.2). This was divided into nine columns as described in Section 2.3.3 and was excavated by numbered units of one sediment matrix (no more deposit than would fit into one bucket). The sediment in each excavation unit was fully described and its dimensions noted. One hundred and thirty-six units were processed, each bucketful was weighed and the weight of the natural stone occurring within that bucket was recorded before being discarded. By this means it was possible to calculate the bulk density of each unit; but, since the weighing was done at the site immediately after removal from the ground, the results vary from those obtained from laboratory air-dried samples.

The contents of each bucket were wet-sieved by adding water from the local stream with 5 ml of detergent and passing through a series of sieves, the last of which had a mesh of 1 mm. The top deposits dissolved well and materials could be easily removed, but the process was much more difficult in the clay deposits and in some cases hand-sorting from the sieves had to be used to aid the lengthy process of washing the clay through the mesh. It was not possible to retain every minute chip of eggshell or bone, especially in the levels where they were very abundant since this would have involved the retention of the entire volume of sediment for all Stratum B units. However, one sample was retained containing the entire complement of tiny shell and bone fragments from the Stratum B deposits, where the highest density of artefacts with eggshell was recorded. It was possible to excavate and process up to 10 buckets per day, using two full time local assistants and many part-time helpers. The final deposits left in the 1 mm sieve were emptied on to absorbent paper, wrapped, carefully labelled and left hanging to dry in the air. Deposits remaining on the surface of the liquid were scooped up and dried out in the same way.

In order to provide a set of comparative data from an area of the site further to the east, near the drip line, it was decided to wet-sieve the deposits of a small strip labelled R79 that theoretically still remained between M71 and Z6 (Figure 3.2). However, when excavation began here, it was found that due to the erosion of the edges of previous trenches, there were no original deposits left in the strip for the first 20 cm - 30 cm below the existing ground level. Basal deposits in square Z6, below the depth at which White had ceased excavation in 1964, were also excavated. Wet-sieving was only applied to about half the deposits excavated from Z6 and R79 during 1979-1980 due to lack of time. Apart from some small excavations to determine the limits of a heavy brown clay within the basal levels of squares D71, X3 and A5 and the removal of four surface units by wet-sieving from the next 25 cm strip within square 792, no further excavations were carried out.

All finds from each bucket excavated were amalgamated in one labelled bag for storage and later flown to Canberra for analysis.

Chapter 3

Stratigraphy and a Model of Sediment Deposition at Nombe

3.1 STRATIGRAPHY AT NOMBE

Crucial to the Nombe research was the interpretation and dating of every area of the site. It is impossible to analyse the contents of any sediment with any confidence without understanding that sediment's precise stratigraphic and chronological position in the site.

The lack of charcoal in most deposits was, by 1979, a major impediment to the production of a satisfactory chronological framework. A new program of dating was therefore initiated following discussions with the Australian National University Radiocarbon Laboratory staff. This program was to include the dating of samples from materials known to exist in the site in order to produce a set of coherent dates. These materials were:

Charcoal. At this stage charcoal had only been documented in small amounts from surface sediments. It was planned to obtain larger charcoal samples through wet-sieving of lower deposits.

Bone. Bone is readily available throughout the site. However, the declining collagen content with increasing age would reduce the ability to date by ^{14}C methods.

Snail shell. Snail shells are a major component of the older redbrown clays which include few other suitable dating materials.

Flowstone and calcite-capped cemented clay. Flowstones occur in the middle stratigraphic level and offered an opportunity for dating. A series of cemented clay blocks capped with thin calcite layers occur at the base of the site and are also suitable for radiocarbon dating.

The results of this complex program of dating had to be integrated with an interpretation of all sediments present. The site's central areas revealed four distinct main strata (Plate 5) but the peripheral areas were much more difficult to analyse. This chapter begins with a summary of the perceived strata in 1979 and then discusses all sediments in more detail. The manner in which different analyses were integrated into the emerging understanding of the site is discussed and a finally detailed model of site development over 30,000 years is presented.

3.1.1 Perceived stratigraphy (Profiles 1-11)

Stratum A - Top sediments, usually loose dusty soils resolving to firmer darker loams.

Stratum B - Dark brown loam, similar to Stratum A but with a noticeable increase in the quantity of human artefacts and especially in animal bone, a high proportion of which is burnt and broken.

Stratum C - This stratum includes several sediments including flowstones, tephras and a reddish brown sediment with a higher proportion of clay than in higher sediments.

Stratum D - Various types of clay: mainly redbrown heavy clay but below which is textured ginger clay and a basal brown, even stickier, heavier clay.

However, there were areas of the site where this basic stratigraphy was not apparent. The analysis of these areas therefore depended on:

- ☐ the radiocarbon dating of sediments;
- ☐ archaeological data from the sediments; and
- ☐ sediment analysis undertaken by Gillieson.

An example of such an area occurs at the base of C3 and D3 ***P2*** where several different sediments underlie conventional Stratum A and B type sediments. It was not clear whether they should be Stratum B, C or even D sediments. Some deposits of comparable sedimentary type and origin have been laid down at different times and therefore may contain quite different archaeological materials. Such deposits are of course classified according to the time of deposition not the sedimentary similarities of the deposit. For example, redbrown clays normally belong to Stratum D but in some areas of the site deposits of redbrown clay have been classified (after deliberation) as belonging to Stratum B (as in Profiles 2 and 10).

3.1.2 Mixing of deposits

During analysis it was realised that some of the sediments had been mixed and that in specific areas stratigraphy was inverted, probably due to human activity towards the end of the Pleistocene. All sedimentary units were carefully examined for evidence of such disturbance and, if any hint of such mixing was detected, an "X" was included after the unit designation and such units were removed from further analysis.

3.2 DETAILED DESCRIPTION OF SEDIMENTS IN EACH STRATUM

The following sections describe the perceived stratigraphy; each stratum consists of a number of sediment types, each with an individual numerical designation. Colour references are from the Munsell Standard Soil Color Charts, 1975.

3.2.1 Stratum A: the top deposits

These generally consist of fine dusty or ashy soils, varying from cream (10YR 6/2), through grey brown (5YR 3/3, 10YR 4/4) to dark brown (5YR 2/2) or almost black (5YR 1/7).

Stratum A contains three subgroups:

A1: grey brown dusty soil;

A2: similar but with an greatly increased ash content; and

A3: darker, more humic and often wetter surface deposits.

Profiles 5, 8 and 10 show the variations within Stratum A. Stratum A sediments are all extremely light and are very easily disturbed by human, pig and dog activity. This has created a great deal of change in the ground level in relation to the limestone cliff face. Between the first surface - level recording in October 1964 and the end of the final field season in February 1980 there was a drop of as much as 50 cm in some areas [*P11*]. This was due to the normal, frequent human movement on the site as well as the archaeological excavation and settling of the back-filled trenches. The depth of Stratum A varies from under 10 cm [*P5,7,8*] to over 100 cm in the eastern (front) part of the site [*P9,10*]. In one area, in the south of D79 [*P1*], the brown sediments of Stratum A (which are here very deep and lie within the D79 Channel), are overlain by blacker, wetter, surface deposits in the Drainage Crack that also belong to Stratum A, but are of a more recent date.

Stratum A deposits contain artefacts, a little scattered charcoal in protected places, a few large blocks of limestone and occasional cooking stones.

3.2.2 Stratum B: the bone stratum

The interface between Stratum A and Stratum B is extremely marked near the western area (back) of the site and three types of B strata are evident:

B4: the sediment matrix, is normally brown loam (5YR 3/2) and is similar to that at the base of Stratum A. There is a visible increase in the density of archaeological material, especially in the quantity of bone. Profile 5 shows this clearly, where the quantity of burnt and fragmented bone increases suddenly to produce a noticeable stratigraphic change.

B2: in the area of A3/B3 ***P4*** where the brown loam changes to yellow grey ashy sediment (2.5Y 5/2) this is designated as B2, similar to the matrix of the overlying Stratum A deposits in the same area and again differentiated by a noticeable increase in artefact density.

B5X: in squares A1 and A2 at the base of the brown loam where there is a red or brownish gritty layer it is labelled Stratum B5X· Profile 4 shows that this layer appears connected with the local disturbance caused by the digging of the A1/2 Trench.

However, in squares C3 and D3, Stratum B cannot readily be differentiated from Stratum A because of the similar density of bone fragments in both strata. Three types of B strata have been designated in this area:

B9: is a brown loam flecked with red particles, containing artefacts, lying underneath the top grey brown dusty soil of Stratum A ***P1,2***.

B6: is a redbrown clayey sediment (also flecked with red) lying under B9, in D3 and the northern area of C3. This melds at the base of those squares into another redbrown clay, also designated B6. This continues into PQR71 where it thickens considerably and rises to within 50 cm of the present ground surface in R71 ***P3***. These are much younger than the redbrown clays to the south and west of the site.

B8: is a basal dark red clay (2.5YR 2/4) found in C3. This appears to be older than the redbrown clay at the base of D3.

In the 1979/80 excavations of the basal levels of squares Z6 and R79 it was found that the top redbrown clays immediately under White's 1964 excavation base overlay a band of very dark, rather wet loamy deposits (B7) at the eastern side of Z6. Both this loam and the overlying clay contained high proportions of artefacts and bone and show no evidence of Pleistocene fauna. Both deposits have been designated as Stratum B and are presumed to be Holocene in date. It is likely that the redbrown clay that White found at the base of his excavations in the eastern squares (A7-8, B7-8 and Z7-8) belongs to the same recent redbrown clay rather than to the Stratum D Pleistocene redbrown clay that occurs farther west.

B7: is a dark wet loam lying directly on redbrown clays which, from their archaeological content, are designated as Stratum D Pleistocene clays.

B3: is a redbrown clay lying over B7 and under stratum B4 deposits.

There is an area of stratigraphic complexity in Stratum B in the southern face of squares D79 and D71 ***P9***. At this point Stratum B appears to represent three distinct periods of deposition, each overlaid on the other, sloping downwards from west to east.

In the eastern areas of the site ***P4***, erosion (presumably caused by the drip line and the natural eastward fall of deposits towards the Lombila Doline slopes) has truncated the Stratum B4 sediments along with the underlying Stratum C deposits which have been replaced with more recent Stratum A deposits. However, in Profile 9 (only three metres to the south) the Stratum B4 sediments continue beyond the drip line in M71, although the underlying redbrown clay drops in level, which may indicate earlier dripline erosion.

Artefacts are especially prominent in Stratum B in both H71 and M71 where the matrix is brown loamy sediment (5YR 3/2).

Pieces of tephra-like material are common in this stratum, both in the D79-M71 trench[P9,10], and also within the Consolidated Block in D79/X3[P6].

3.2.3 Stratum C: various deposits

These deposits occur beneath the Stratum B deposits and above the underlying clays of Stratum D. Their sedimentary origin is mixed and not all elements always occur together. Although they therefore form a rather unsatisfactory stratum, it is necessary to isolate them as an independent stratum between D and B, since together they represent an important period of the site's sedimentary history.

There are three elements present in Stratum C: flowstone sheets, tephra-like blocks and redbrown sediments[P1,4] (Plate 4). It is the flowstones and tephra-like blocks that are so prominent in the stratigraphy as uncovered by White in squares A5-8 in 1964. Nevertheless, both these elements occur within other strata and are not exclusive to Stratum C; flowstone is found attached to the roof[P7], high in the Consolidated Block D79/X3[P9] and in the paper-thin traces occurring towards the top of the redbrown clays in A4/A5[P4]. There are pieces of this tephra-like deposit in the basal clays[P6,7], as well as within Stratum B[P6,9,10] and at the base of Stratum B levels in the Wet-sieved Strip[P8], where a band of distinct blue/grey (5PB 5/1) sandy pellets lies at the top of Stratum C, immediately under the bottom of the thick bone levels of Stratum B. No tephra-like materials occur in the northern squares (C3-PQR71) or in the squares south of Profile 9 (A71-C71, E71-G71 and J71-L71).

The thickness of these Stratum C flowstone sheets varies from under 1 cm to over 10 cm. The sheets are commonly brilliant white and crystalline, but some are creamier (2.5Y 8/2). Like the flowstone in the centre of X3[P6], they sometimes have mixed deposits adhering to their underside containing loam, charcoal flecks and artefacts. They can occur lying almost horizontally[P4] but more commonly with a pronounced south-eastwards slope, presumably resulting from the ground surface slope on which they were formed. It is established that flowstones can form on considerable slopes. The cracks (Plate 9) that are now evident in the flowstone sheets and tephra-like blocks which caused White to exercise such caution in artefact analysis (White

1967:127), could have developed as the result of purely local factors, such as increased solutional enlargement of underlying bedrock joints (Gillieson 1982:347).

The tephra-like blocks that are sandwiched between flowstone sheets 2 and 3 in A3, A4, and A5 [P1,4] are generally greenish-grey in colour (10Y 3/2, 10Y 5/1). The basal part of these blocks is clearly laminated with a gritty sandy texture. The upper part shows a more vesicular structure with less clear laminations (Plate 10). Under the bottom of the consolidated blocks in the D79/X3 area, there are pieces of similar tephra-like, greenish-grey, sandy materials [P1,11] lying directly on top of the basal redbrown clays, although they are not continuous throughout those squares [P6].

The sediment matrix in which the Stratum C flowstones and large tephra-like blocks occur comprises redbrown sediments (5YR 4/4 and 4/6), designated C8, with a high apparent clay content, but drier and much less plastic than the underlying redbrown clays. They are described by Gillieson (1982:352) as cemented redbrown clay with a coarse granular texture. They often contain small chunks or larger blocks of limestone, as well as occasional artefacts and bones. These redbrown sediments occur as a thin capping to the redbrown clays above the line of Flowstone 3 in A3 [P4] and to the south of the major flowstone and tephra-like block area in A3 and X3 [P1]. They do not occur to the west of the A1/2 Trench [P4,5] or in the D71-M71 squares [P9].

In the centre and west of the Consolidated Block D79/X3 [P6], there is a thin level of redbrown sediment running over the basal redbrown clays and containing tephra-like pieces. Further west again in the Wet-sieved Strip [P7,8] there are thicker deposits of redbrown sediment overlying the redbrown clays, containing artefacts and snails. These sediments lie between the base of Stratum B and the top of the Stratum D redbrown clays and have been designated as Stratum C deposits. In Profile 8 (only 25 cm to the west), these redbrown sediments lie between a thick level of large snails and a thin but easily visible scattering of lumps of blue-grey tephra-like material which underlies the thick Stratum B deposits.

3.2.4 Stratum D: redbrown clays

The redbrown clays occur throughout the basal levels of the site. They are clearly identifiable but are present in six distinct subgroups:

D4: thick, heavy, brown, plastic clay designated D4 (5YR 3/6). This occurs at the base of the excavated profiles towards the west (back) of the shelter [P4,5,6,7,8]. This clay always slopes strongly to the south-east. In the eastern areas of the site this brown, plastic clay cannot be recognised as an independent unit.

D3: basal redbrown clays (5YR 4/8) designated as D3 in D71-M71, R79 and Z6 and A6 [P9,10,11]. They are equally as heavy and plastic in texture as the D4 clays but occur very rarely within the excavations.

D2: lighter textured, drier, ginger-coloured redbrown clay (7.5YR 5/6) designated as D2. This south-easterly sloping band lies above the heavy, plastic, brown clay. In the west of the site, there is another area of D2 clay [P1,4,6,7&8].

D1/D5: bright redbrown clay (5YR 4/6) which accounts for most of the remaining clay. This is designated as D1 when free of limestone fragments and D5 when it contains considerable amounts of limestone pieces. D1/D5 is found overlying all previous D clay groups and in some areas is found alone. It is frequently of considerable thickness and in H71 reaches 70 cm in depth over the basal 'floor' of cemented clay blocks [P9].

The Munsell Soil Color Charts are extremely inadequate on the redbrown range of colours found in Strata C and D at Nombe. Gillieson classifies Stratum D as yellowish brown, following the notation of colours such as 10YR 5/6 and 5/8, but I found the tones more correctly described as redbrown and cover varieties including 7.5YR 5/8 and 5YR 4/6.

3.2.5 Other components of the stratigraphy and site

In the lower strata, C and D, there are many large land snails, often found in clusters. These also occur immediately under Stratum B in some places at the west of the site (for example in squares A1, A2, B3 and the Wet-sieved Strip).

There are also a number of very large, presumably fallen, limestone blocks in the shelter, usually resting on and in the basal redbrown clays (Plate 8). Some were too large to be removed or continued under the baulks; these included those shown in White's Test Trench [P11], A6[P4], C3/D3 and PQR71 [P1,2,3] and Z6 [P10]. Others, of a smaller overall size and in more convenient areas, were removed during excavation. In some cases, the top of these blocks has been altered by continuing accretion of calcium carbonate and other materials, so that there are now artefacts and snails attached [P2,11] (Plate 13). In other places the limestone has altered in appearance and composition, so that patches of soft yellow limestone sit over a base of hard grey limestone [P1,2].

In areas of active roof drips, existing deposits have been cemented together into blocks by calcium carbonate accretion [P1,7,9]. These blocks are referred to as consolidated or brecciated blocks and, in the case of one extreme example of this process, as the Consolidated Block D79/X3P1. Here, blocks of consolidated deposits have gradually built up over the redbrown clays and tephra-like sediments until a solid block of deposits has actually become cemented to the limestone roof. When this was removed, several active roof drips continued to emerge from the remaining roof boss in the 1979/80 wet season.

In the base of the site in squares D71-M71 there is a 'floor' of flat blocks which appear to be made of cemented clay, capped frequently by a thin layer of calcite (Gillieson 1982:360) ***P9,10,11***.

The importance of water flow in the site formation can be seen in the number of roof pendants and of large and still active water drips that occur during the wet season ***P4***.

In squares A1 and A2 there is a very distinct man-made trench dug across the cave, increasing in size and depth towards the north ***P4,5***. This was only located within Pleistocene sediments in the archaeological squares A1 and A2 and is referred to as the A1/2 Trench.

3.3 PROGRAM OF SEDIMENT ANALYSIS

Although many elements of this stratigraphy appeared well defined, sediment analysis was essential to determine whether the four strata had originated from similar sedimentary processes. Without this there could be little meaningful analysis of the archaeological materials.

3.3.1 Sediment analysis

During his Nombe visit, Gillieson took samples from the exposed profiles following discussions on the perceived stratigraphy as set out in the previous sections. He analysed the 41 samples including some supplied from excavations before and after his departure; their positions are shown in Profiles 1-11. His results (Gillieson 1982: 373-423) largely verified the perceived stratigraphic groups (strata A-D) and provided information on the sedimentary processes that formed the deposits. His analysis produced four groupings of samples which he named A-D. In order to prevent confusion with the already existing Strata designations A-D, I have altered his group names as follows: Group A becomes Group W, Group B becomes Group X, Group C becomes Group Y and Group D becomes Group Z.

Group W. All six samples taken from Stratum A (sample numbers 44, 50, 54, 55, 75/68 and 75/69) and three taken from Stratum B (sample numbers 33, 34 and 21) group together in the sediment analysis to form Group W. The stratigraphic position of these samples is shown on Profiles 1, 3, 4 and 6. They represent many of the variations occurring within the strata as described in Section 3.2. They contain an extremely poorly sorted group of particles that spread over the sands, silts and clays, with a low content of fine clay particles. Since the perceived differences between Stratum A and B lie in the increase in archaeological matter within similar sedimentary matrices, this result is as expected. The sedimentary matrix is drawn from a large number of sources, including wind-blown soils from gardens, fire ash, slopewash from heavy rains, cliff run-off and human rubbish from occupation and activity at the site.

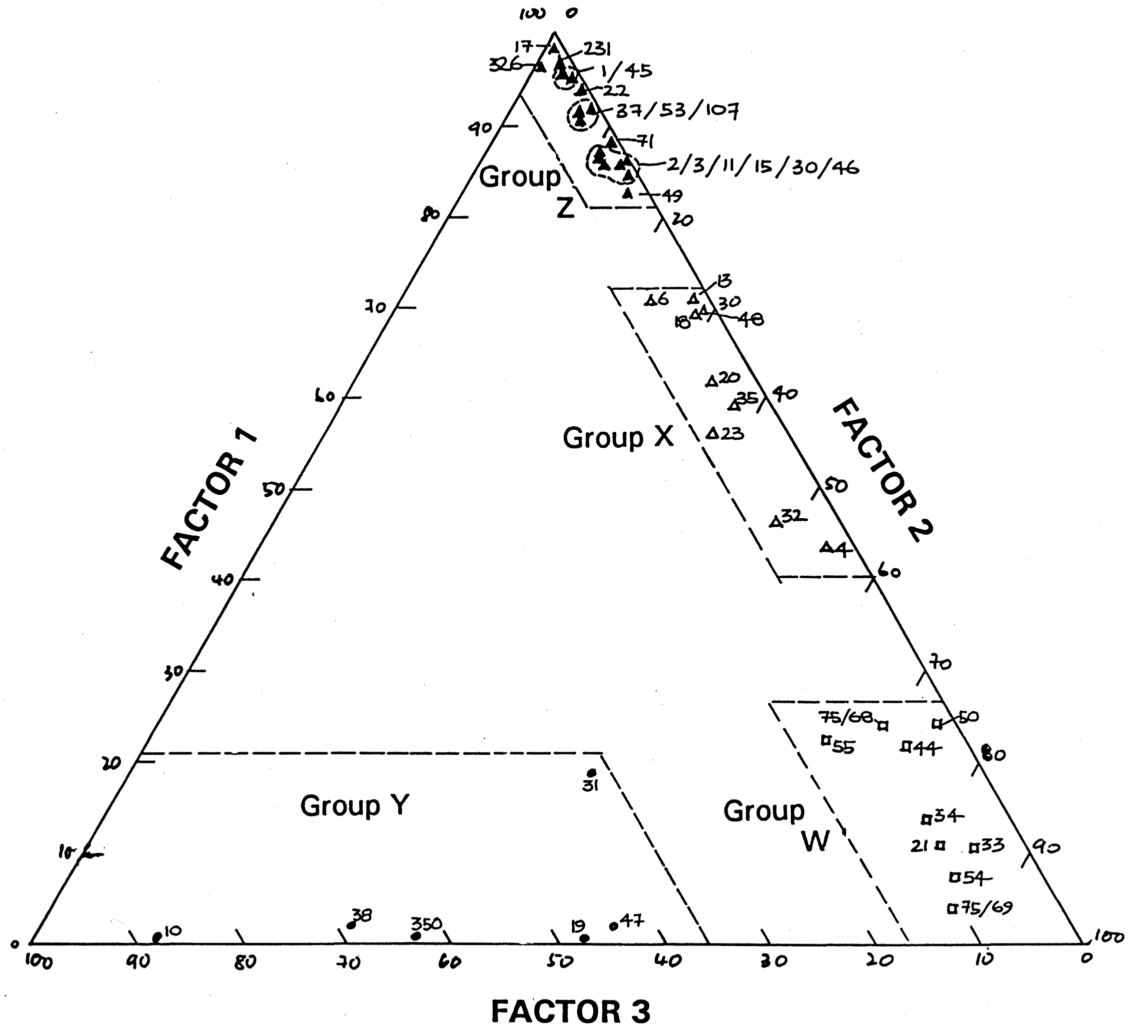


Figure 3.1 Plot of normalised varimax factor scores for Nombe sediments
Source: Modified from Gillieson (1982:Figure 113)

Group Z. One major objective was to test the sedimentary similarity within the varying types and occurrences of the redbrown clay of Stratum D. Accordingly, a large number of samples was taken from this stratum throughout the site and covering all varieties of texture and colour. Seventeen of these samples formed one sedimentary group, Group Z. The sample numbers are 53, 1, 2, 3, 11, 15, 22, 107, 37, 17, 75/71, 45, 46, 49, 30, 231 and 326 in Stratum D ^{P1,2,4,5,6,7,9,11}. Figure 3.1 shows the close final grouping of the samples as determined by particle analysis. Although there are minor variations within the particle size patterns of the 17 samples, they are extremely closely correlated which suggests that the variations within the redbrown clays were due to minor differences of source material or later weathering. Gillieson (1982:390) notes that the textures of this group all fall within the envelope of the slopewash deposits from another cave site, Selminum Tem, in the Western Province of Papua New Guinea, where there is still a stream flowing through the site, and therefore suggests that the samples in Group Z originated from deposition of fine clays by an active spring and stream at Nombe.

Group Y. Six further samples (sample numbers 10, 31, 38, 350, 47 and 19) all contain a considerable proportion of fine sand and form a separate sedimentary group, Group Y, whose sediments were generally poorly sorted. Although these samples come from different stratigraphic positions within Strata B and C $^{\boldsymbol{P1,2,4,6,9}}$, they are all from areas where tephra-like materials were located. The fairly wide variation in the particle size patterns of these samples (Gillieson 1982:387) indicates not only differences within the composition of the samples (for example, there is a wide variation in colour present) but also the presence of other sediments within some samples. I suggest that this group represents a number of separate tephra occurrences, laid down at different periods of time and in most cases mixed with components from their surrounding matrices.

Group X. The remaining samples are the least satisfactory in terms of verifying the perceived stratigraphy and do not correlate well with any group of stratigraphic features. There are nine samples: three from Stratum B (4, 32 and 48), two from the redbrown sediments of Stratum C (6, 20), one (35) from a block of consolidated materials under a flowstone sheet in X3, one from the top of the redbrown clays (13), one from the dry, ginger variety of redbrown clay (18) and the last from the basal filling of the A1/2 Trench (23). Their stratigraphic positions can be seen on Profiles 1, 2, 4, 6 and 9. Figure 3.1 shows how this group (Group X) sits between the ranges of Group W (with little fine clay) and Group Z (with a predominance of fine clays). However, many of these samples come from unique stratigraphic positions and may well represent examples of mixing of materials from various situations, for example samples 4, 48, 35, 20, 23. I suspect that if further samples were collected and analysed from other unique situations where mixing could have occurred, results might spread even farther along the range from Group W to Group Z, rather than produce a tighter grouping of Group X.

3.3.2 Summary of sediment groups in relation to perceived strata

Sediment group W shows high correlation with Strata A and B. These are archaeologically distinct but geomorphologically uniform.

Sediment group Z shows high correlation with Stratum D.

Sediment group Y shows high correlation with tephras from the site.

Sediment group X contains a subgroup of samples from Stratum C redbrown sediments, together with some samples from the top of the redbrown clays, as well as a number of samples that are the result of physical mixing of deposits from Strata B, C and D.

Gillieson (1982b) used scanning electron microscopy to test some hypotheses as to the origin of some deposits at Nombe. His work confirmed that the redbrown clays were fluviatile in origin, the quartz crystals displaying the typical rolled rounded features caused during water movement. It was obvious that firing had played an important role in the formation of deposits in Stratum A and B and this was again confirmed by the shape and cracking of the quartz particles in those strata.

3.4 DATING

Detailed scrutiny of the sediments, backed by a program of sediment analysis, provided a comprehensive understanding of the processes which, over a long period, formed the sediments now existing at Nombe. But without evidence of the chronology of these processes it is not possible to produce a meaningful model of site development.

The ambitious dating program, which included many controversial materials not systematically used at that time for archaeological dating, produced the evidence necessary for the chronological framework.

Through wet-sieving techniques it was planned to recover sufficient charcoal for ^{14}C dating during the 1979/80 fieldwork season. However, adequate samples were only found in Stratum A. Small quantities occurred in other strata, but never in large enough amounts for conventional ^{14}C dating techniques.

On return from the field, samples of several other datable materials were therefore prepared, including bone, snail shell and calcite speleothems. This last category was also suitable for uranium/thorium dating and Gillieson submitted three Nombe samples to Professor D. Forde, McMaster University, Canada.

All dates used in this thesis are presented as a range of one standard deviation on each side of the mean since this provides a more accurate representation of the age of each sample than quoting the date as presented by the laboratory. The ^{14}C results are reported in Appendix B as "Conventional Ages" (Stuiver and Polach 1977), and any environmental correction factors can be considered separately, since these values are laboratory measurements and are not subject to any change. Table 3.1 presents all dates from the site.

Table 3.1 **^{14}C dates from Nombe sediments and incorporated materials as originally laid down (see note)**

Stratum	Range Age BP	ANU No.	Correction
Stratum D2	33 050 – 31 150	ANU 2566	
	30 100 – 29 100	ANU 2565	
Stratum D1/5	25 200 – 24 400	ANU 2578	Corrected
Stratum C	14 800 – 14 500	ANU 2580	Corrected
	13 650 – 12 650	ANU 3683	
	12 000 – 11 700	ANU 2581	Corrected
	11 810 – 11 490	ANU 3681	
	11 590 – 11 210	ANU 2569	
	10 150 – 10 350	ANU 2579	
	10 150 – 10 350	ANU 2576	
Stratum B	9 930 – 9 370	ANU 3686	
	9 160 – 7 480	ANU 3687	
	6 860 – 6 620	ANU 3688	
	6 470 – 6 290	ANU 3075	
	5 990 – 5 630	ANU 3074	
	5 980 – 5 760	ANU 3076	
	5 450 – 5 230	ANU 3684	
	5 310 – 4 870	ANU 3689	
Stratum A	3 730 – 3 110	ANU 2570	
	980 – 820	ANU 3685	Charcoal insoluble
	100.4 ± 09%M	ANU 3073	

***Note*:** This list only includes dates from materials within sediments interpreted as 'in situ'. It does not include dates from samples interpreted as coming from material thrown up by human trenching in the Pleistocene clays or from samples using snail from several squares.

3.4.1 Interpretation of laboratory dates

The use of varied materials in the dating process required not only great care and difficulty in dating each sample but extreme caution in the interpretation of the laboratory dates. The δ^{13}C results for the ^{14}C samples (Table 3.1) provide information on:

☐ mode of deposition (flowstones and calcite samples),
☐ living environment (snail shells), and
☐ possible contamination and diet (bones).

This information can provide clues as to whether the samples are contaminated and whether the same or different correction factors can be used for samples of the same type. In the case of the bone and snail samples these figures conform to the range expected (Stuiver and Polach 1977:358), so that little correction should be necessary.

Bone samples

The $\delta^{13}C$ figures from the bone samples (Table 3.2) suggest that the bone has not been subjected to long periods of saturation by water, but rather the process has been one of frequent soaking and drying. This accords with the interpretation of the post-Pleistocene sedimentary history of the site from which all but one of the bone samples derives. Some contamination is present from acid insoluble soil; for example, in the case of ANU 3076 it was not possible to date a collagen fraction due to the presence of acid insoluble residue. Where bone dates are quoted, the oldest result of each pair has been used, after consultation with John Head of the Australian National University Radiocarbon Laboratory. The results obtained for ANU 3685 (charcoal) indicate the possible presence of younger humic acids in the site. Hence, if the collagen is contaminated by humic material, it would provide a falsely young age. Similarly there is no evidence of mobility of old carbonate through the site. Because of this, any carbonate contamination of the bone apatite would produce a falsely young age. There is every indication that the apatite is contaminated in some cases and the collagen is contaminated in others. In every case, even the oldest result should be considered as a minimum age (i.e. both fractions may be contaminated). The table below shows that the $\delta^{13}C$ figures for the bone samples are furthest apart in cases where the collagen fraction is younger and therefore the apatite result is likely to be more reliable. In cases where the difference between the $\delta^{13}C$ results is smaller, the collagen fraction is older and therefore has been used. In the case of ANU 3687, where the $\delta^{13}C$ results differ greatly, the date ranges overlap and the widest range has been chosen.

Table 3.2 **$\delta^{13}C$ values for ^{14}C bone samples**

ANU number	$\delta^{13}C$ Apatite $^{0}/_{00}$	$\delta^{13}C$ Collagen $^{0}/_{00}$	Difference	Apatite range	Collagen range
3074	-11.1*	-23.2	12.1	5 630 – 5 990	4 920 – 5 140
3075	-11.1	-21.8*	10.7	5 790 – 6 010	6 290 – 6 470
3076	-11.4	na	-	5 760 – 5 980	na
3683	-10.3*	-24.0	13.7	12 650 – 13 650	5 470 – 6 950
3684	-14.2	-23.4*	9.2	2 940 – 3 500	5 230 – 5 450
3686	-14.9	-23.8*	9.8	8 800 – 9 200	9 370 – 9 930
3687	-9.9*	-23.5*	13.6	7 720 – 8 420	7 480 – 9 160
3688	-14.8	-23.4*	8.6	5 670 – 6 090	6 620 – 6 860
3689	-12.5	-23.5*	11.0	3 040 – 3 480	4 870 – 5 310

Notes: na Not available for reasons stated in text.
* = most reliable date

Snail samples

Verification of the reliability of the results is particularly necessary in the case of the snail samples since, in three cases (ANU 2564 and 3076, ANU 3682 and 3683 and ANU 3681 and 3687), samples of snail shell and bone from the same archaeological unit have widely differing results, raising doubt as to the reliability of some of the snail shell dates. However, the $\delta^{13}C$ results (Table 3.3) are of the expected order and there seems no likelihood of major correction factors having to be applied to the results. The $\delta^{13}C$ results from the snail samples show two groupings: ANU 2562 and 3329 were apparently formed in equilibrium with the atmosphere, but the rest of the samples show a higher organic composition. ANU 2562 and 3329 are both from samples known to contain snail shell that may be of very recent date, found on or immediately below the modern surface, whereas the rest are from sealed archaeological deposits. This result is thus not unexpected.

Table 3.3 Radiocarbon dating from snail samples at Nombe

Lab No	Position	Date Age BP	Range Age BP	$\delta^{13}C$ $^0/_{00}$
ANU 2562	Mixed	6 360 ± 210	6 150 – 6 570	-7.9 ± 0.4
ANU 2563	Mixed	16 500 ± 280	16 220 – 16 780	-12.9 ± 0.4
ANU 2564	A1:4 21,24	26 000 ± 1 050	24 950 – 27 050	-8.6 ± 0.4
ANU 2565	X3:6 1	29 600 ± 500	29 100 – 30 100	-11.1 ± 0.4
ANU 2566	A4:3 3	32 100 ± 590	30 050 – 31 150	-12.3 ± 0.4
ANU 3681	C3:4 40,46	11 650 ± 160	11 490 – 11 810	-11.3 ± 0.4
ANU 3682	T79 174,175	27 600 ± 900	26 700 – 28 500	-11.2 ± 0.4
ANU 3329	Simbu limestone	100.4 ± 0.9		-7.1 ± 0.4

Anomalous dates

ANU 2562 was an attempt to date the top deposits of Stratum A at a time (1979) when the full complexities of the stratigraphy were not yet understood. Because of the scarcity of easily dated materials, snail shells, often fragments only, were amalgamated from a number of different squares; A1:1, B3:0, C3:1, D3:1, PQR71:1, X3:1 and A1:2. It is now realised that the snail shells from A1:2 come from the top of the Stratum B deposits and even the A1:1 shells may belong to Stratum B since the extremely thin nature of the top Stratum A deposits in the western areas of the site was not appreciated in 1979. The resulting range of 6150-6570 bp must reflect a contamination by older material. Recalculation using Table 2 from Polach, Golson and Head (1983:151) on the basis of presumed contamination by both samples from A1, using the weights of snails to estimate the proportions, produced a revised date of within the last 1000 years which is satisfactory.

There remains one anomalous date of 16,220-16,780 bp produced from a number of snail shells from various squares (ANU 2563) in an attempt to provide a date in 1979 for the deposits lying from 20 cm to 40 cm below the present ground surface.

Due to the scarcity of suitable dating materials, snail shells from four different locations were amalgamated for the sample, these being A2:2, X3:2, B4:1 and A3:2. The snails from this last location, it is now realised, belong to Stratum C redbrown sediments mixed with tephra-like pieces that lie under Stratum B. It is presumed that these Late Pleistocene snails caused the date to be considerably older than was expected. However, from the table provided in Polach, Golson and Head (1983:151), the resulting correction (using the weights of the snails to estimate the proportions) still produces an unsatisfactory result of about 14,500 bp. The remaining snail dates presentc no collection or technical difficulties and the discrepancies between bone and snail samples from one area required stratigraphic interpretation (see 3.5.5).

Flowstone and calcite samples

The $\delta^{13}C$ figures from the flowstones and calcite samples (Table 3.4) suggest that further correction is necessary on some of these, especially on the results from Flowstones 2 and 3 (ANU 2580 and 2581) and to a smaller extent on the calcite capping sample (ANU 2578).

Table 3.4 Radiocarbon dating from flowstone and calcite samples at Nombe

Lab. No.	Position	Date Age BP	Range Age BP	$\delta^{13}C$ $^0/_{00}$
ANU 2576	X3 Flowstone 1	10 250 ± 100	9 250 – 11 250	-8.9 ± 0.4
ANU 2579	A4 Flowstone 1	10 250 ± 100	10 150 – 10 350	-8.0 ± 0.4
ANU 2581	A4 Flowstone 2	13 900 ± 130	13 770 – 14 030	+1.3 ± 0.4
ANU 2580	A4 Flowstone 3	16 700 ± 180	16 520 – 16 880	+0.1 ± 0.4
ANU 2578	D71 Calcite capping	27 000 ± 550	26 450 – 27 550	-3.1 ± 0.4

Gillieson (1982:368-370) discusses the possible necessary corrections to the results from the calcite speleothems. He concludes that ANU 2576 and 2579 from Flowstones 1 ^{P1,4} were formed in isotopic equilibrium with the atmosphere but that the positive $\delta^{13}C$ results from ANU 2580 and 2581 from Flowstones 2 and 3 ^{P4} show that these flowstones were laid down under a different regime in isolation from atmospheric carbon dioxide. Gillieson and I agree that these sheets were likely, from the stratigraphic evidence, to have been formed as floe calcite within a gour pool (Section 4.6.3). J. Head (pers. comm.) believes that a correction factor of less than 2000 years should be applied to these results and to the result of ANU 2578 (calcite capping in D71 ^{P9}). This would mean that the revised dates become as follows:

ANU 2581 changes from 13,770-14,030 bp to c. 11,700-12,000 bp.

ANU 2580 changes from 16,520-16,880 bp to c. 14,500-14,800 bp.

ANU 2578 changes from 26,450-27,550 bp to c. 24,400-25,500 bp.

Uranium/thorium samples

Only two of the three samples submitted for uranium/thorium dating produced results and only one of those (McMaster 80055-1) was satisfactory in the stratigraphic interpretation of the site (see Section 4.5.4). The other sample (McMaster 80054-1) of thin calcite capping from a cemented clay block to the west of the Waisted Blade Crack in M71 [P9] gave the apparent result of 6800±900 bp which does not conform with the Pleistocene dates from other materials in the same stratum. Gillieson (1982:370) discusses the possibility that the sample suffered thorium depletion through bonding with phosphates in adjacent bone, thus producing a date that is much younger than the actual age of the sample.

3.5. MODEL OF SEDIMENT DEPOSITION AT NOMBE ROCKSHELTER

3.5.1 Introduction

The reconstruction of the development of the deposits at Nombe is based on the interpretation of the interlocking sets of evidence presented in previous sections:

- ☐ the **perceived stratigraphy** (Section 3.1.1);
- ☐ the **sediment analysis** carried out by Gillieson (Section 3.3);
- ☐ the laboratory **radiocarbon results** (Appendix B) and their subsequent interpretation (Section 3.4); and
- ☐ the analysis of **archaeological and faunal material** recovered from the deposits.

The stratigraphical sequence provided by this reconstruction forms the basis for the analysis and interpretation of the archaeology. Table 3.5 provides all the ^{14}C results used in this reconstruction of the stratigraphic sequence.

Table 3.5 **^{14}C results from Nombe in stratigraphic sequence**

Stratum	Square	Spit	Catalogue number	Date range BP	Material	ANU Lab No.	
D2	A4	3	3	31 150 – 33050	Snail shell	2566	
D2	X3	6	1	29 100 – 30100	Snail shell	2565	
D1	D71	9	-	24 400 – 25500	Calcite	2578	Corrected
C8	A4	-	-	14 500 – 14 800	Flowstone	2580	Corrected
C8x	T79	174/175		12 650 – 13 650	Bone	3683	
C8	A4	-		11 700 – 12 000	Flowstone	2581	Corrected
C8	D79	-	46	11 210 – 11 590	Charcoal	2569	
C8	X3	-	-	10 150 – 10 350	Flowstone	2576	
C8	A4	-	-	10 150 – 10 350	Flowstone	2579	
B8	C3	4	40/46	11 490 – 11 810	Snail shell	3681	
B4	H71	7	-	9 370 – 9 930	Bone	3686	
B8	C3	4	40/46	7 480 – 9 160	Bone	3687	
B4	X3	3	55	6 620 – 6 860	Bone	3688	
B4	A1	4	17/21/24	5 760 – 5 989	Bone	3076	
B4	A1	3	14/19	6 290 – 6 470	Bone	3075	
B2	A1	2	13/16	5 630 – 5 990	Bone	3074	
B4	J71	5	-	5 230 – 5 450	Bone	3684	
B6	PQR71	5	-	4 870 – 5 310	Bone	3689	
A3	D79	-	99	3 110 – 3 730	Charcoal	2570	
A3	T79	-	120/121/122	820 – 980	Charcoal	3685	
A1	J71	3	-	100.4±09%M	Charcoal	3073	
C8x	B3	3	9	30 050 – 31 150	Snail shell	2568	
C8x	T79	-	174/175	26 700 – 28 500	Snail shell	3682	
B4x	A1	4	21/24	24 950 – 27 050	Snail shell	2564	

A preliminary reconstruction of the sedimentary history of Nombe was published in Gillieson and Mountain (1983). Subsequently, Gillieson (1982) put forward a detailed interpretation of the geomorphological evidence before the stratigraphic and chronological model was complete. Consequently, although much of Gillieson's analysis has been used as the basis of this reconstruction, there are some differences between the sedimentary histories of the site as presented in Gillieson (1982: Section 5.5) and the version presented here.

The site development model is presented in six stages representing the major processal events at the Nombe site from about 33,000 bp to the present. These stages do not necessarily represent the major stratigraphic divisions of the site and are not used in later analysis. A table summarising the deposition model is presented at the end of this chapter (Table 3.6). Figure 3.2 sets out a plan of the excavation.

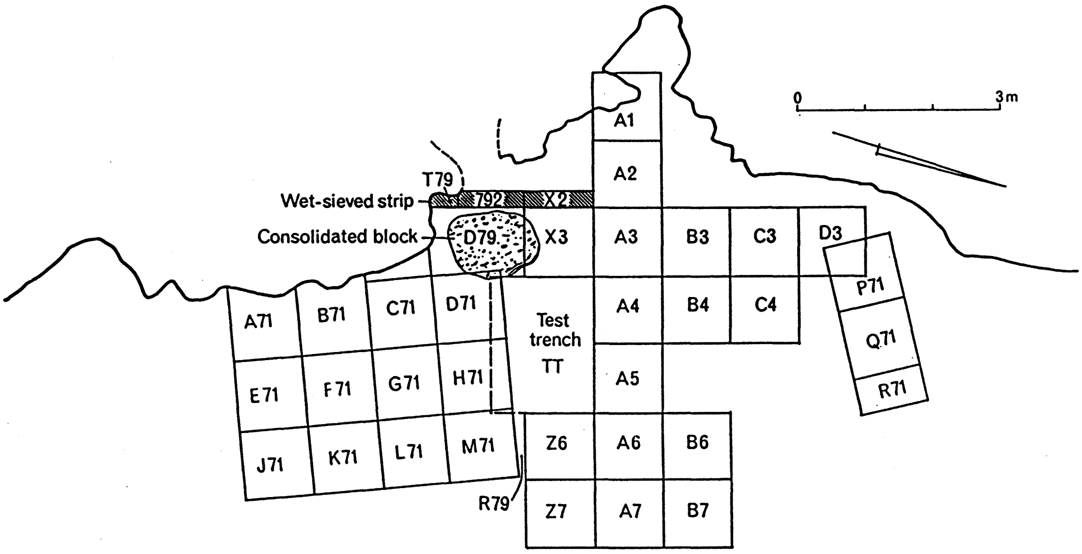


Figure 3.2 **Nombe: plan of excavation squares**

3.5.2 Stage 1

The deposits involved in this first stage are the basal, heavy, plastic, brown (D4) and redbrown (D3) clays and the ginger-coloured redbrown (D2) clays that lie over them. Both the D4 and D2 types are found in the central and western areas of the site *P1,2,4,5,6,7,8*. In the narrow cracks between the cemented clay blocks in eastern section of this site *P9* there is a very plastic redbrown clay (D3) that is similar in sediment composition to the heavy plastic brown clay, but of a redbrown colour, not easily distinguishable from the clays above. Only extremely small quantities of this clay were excavated due to its restricted position between cemented clay blocks that were not removed.

The heavy plastic clays at the base of the site are practically stone-free and contain little other material. These deposits contain a very high proportion of fine clay and occupy one extreme in Gillieson's Group Z (Figure 3.1). The overlying ginger-coloured redbrown clays appear drier and less plastic and contain many land snails and frequent pieces of limestone. The sediment analysis of two samples (18 and 107) shows that these deposits are more variable and mixed in origin than most of the other redbrown clays. Sample 107 falls into Group Z but sample 18 is part of a small subgroup of Group X with samples from the redbrown sediments all containing less fine clays and more silts than the underlying redbrown clays. This may suggest that the slopewash material came from mixed origins and also that subsequent weathering and new deposition has altered the nature of the sediments.

Gillieson suggests (1982:347) that at this stage Nombe must have been rather damp and inhospitable, with an active stream emerging at the base of the cliff inside a small shelter or cave, running a winding course through banks of redbrown clays. This type of situation occurs today in some sites within the highlands of Papua New Guinea, for example at Selminum Tem, Southern Highlands (Gillieson 1982:182). The load of the stream would vary according to the rainfall. In times of heavy rain, large amounts of slopewash sediment would be deposited in the stream channel and between blocks of cemented clay or on the existing banks of the stream. The deposits would vary according to their original source and later weathering may also have caused variations in colour or texture, resulting in bands of recognisably different types of redbrown clay. Much of the material would be reworked with fresh deposition in times of flooding.

The evidence for such stream banks can be seen in the sloping nature of the basal redbrown clays in the central regions of the site [***P1,2,4,5,6,7,8***]. They slope strongly to the south-east, not merely from west to east as might be expected from the normal slope of deposits outwards from shelter to hill slope. The channel of the stream appears to have run to the south of this northern bank through squares T79 and 792, D79, D71-M71, R79 and possibly also Z6.

There is some evidence in the higher deposits for a slope on the southern side of this channel also; two pieces of cassowary bone were found to join which came from the basal levels of the thick bone stratum in H71:7 and the neighbouring K71:4 about 30 cm higher in level, indicating a considerable slope from south to north in the area where the southern bank of redbrown clays would be expected in underlying and unexcavated deposits. In Profiles 7 and 8 there is evidence of the rise of the redbrown clays at the south of the Wet-sieved Strip, which probably represents the southern side of the stream channel.

There are no radiocarbon dates from the heavy plastic brown clay but it must date earlier than the earliest date from the band of ginger redbrown clay that lies above it. There are two dates from this ginger redbrown clay, both on snail shell (ANU 2565 and 2566); ANU 2566, the earlier of the two, with a range of 31,150-33,050 bp, comes from the ginger band at the base of square A4 [***P4***] and ANU 2565, with a range of 29,100-30,100 bp, was collected from a slightly higher area of that formation in square X3 [***P6***]. This suggests that Stage began some time before 33,000 bp and continued at least to 29,100 bp. However, ANU 2578 from the calcite capping on a cemented block of clay at the base of the stream channel in D71, gave a corrected range of 24,400-25,500 bp and may provide a later *terminus ante quem* for the end of Stage 1.

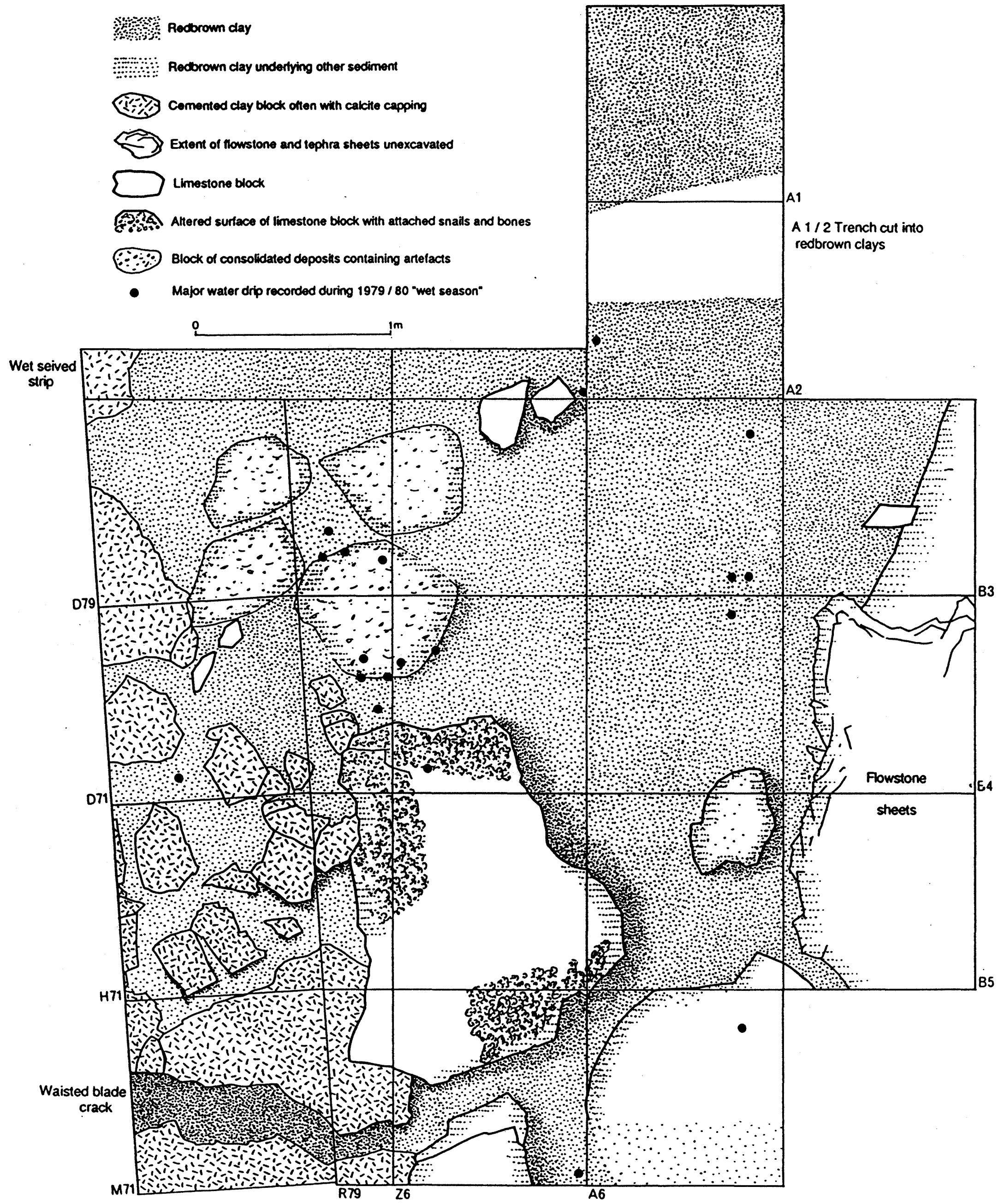


Figure 3.3 **Detailed plan of central area of the site at completion of excavation and after removal of flowstones**

3.5.3 Stage 2

During Stage 2 the remaining redbrown clays of Stratum D were deposited. Figure 3.3 is a detailed plan of the central areas of the site at the completion of excavation.

At the base of the stream channel as described in Stage 1, there is a 'floor' of cemented clay blocks running from M71, R79 and Z6 through the base of squares H71, D71 and into the eastern part of D79, often capped with a thin layer of calcite ***P1,9,10,11***. The calcite has apparently been deposited from active roof drips thus cementing the clay underneath to form resistant blocks (Gillieson and Mountain 1983:56). This suggests that the clay at the base of the stream channel was exposed for sufficient time for the formation of such a 'floor' to take place and that the stream was not active during this process.

The remaining redbrown clays that do not occur in perceptible layers must have been laid down as fine clay deposits from the spring which filled in the original stream channel over the 'floor' of blocks and the banks of earlier redbrown clays of Stage 1 (Gillieson 1982:390). Sedimentary analysis shows the close similarity between nine samples taken from this type of deposit (sediment samples 46 and 49 ***P9***, 37 ***P6***, 30 ***P5*** and samples 22, 1, 2, 3 and 15 ***P4*** together forming much of Group Z (Figure 3.1). By the time the redbrown clays ceased to be deposited, their total depth in the central and western parts of the site was as much as 70 cm ***P9***. The uniformity of the sediment, and the lack of periodic layering, gives the impression that these sediments were laid down relatively quickly. However, the earliest and latest dates of Stage 2 show that it lasted about 9500 years. It would be surprising if during that length of time there were no visible variations in the deposits. This suggests that there may be a time gap in the sequence of deposits between the top of the redbrown clays and sediments and the base of the overlying flowstone formation - in fact a disconformity. No visible disconformity appears in the stratigraphy of the redbrown clays but it is possible that periods of erosion have removed some deposits either at one or possibly at several periods of time during Stage 2. It is more likely there was a disconformity in the deposits between the top of the redbrown clays and Flowstone 2.

Gillieson (1982:347, 427) suggests that during this period of deposition the process of solutional enlargement in the underlying joints of the limestone must have been increasingly active. Gradually the water flow and its associated load of slopewash deposits would have been taken further down into the karst limestone system, eventually replacing the spring outlet and stream at Nombe with a spring that emerged farther down the slope of the Lombila doline. Such a spring exists today. Deposition of the redbrown clays would have become more sporadic and the balance between depositional and erosional factors must have become critical, until no further redbrown clay was deposited in the Pleistocene period.

Several large limestone blocks must have fallen from the roof and become lodged in the build-up of the redbrown clays. The large block in White's Test Trench[P11] probably assisted in the formation of the northern bank of the stream and other smaller blocks in A6[P4], Z6[P10], B3[P1,2] (Figure 3.3) and in the northern area of the Test Trench probably fell on this northern bank. Further to the north again, a large block was deposited on top of the clays[P1,2] bringing the ground level in the area of squares B3, C3, D3, B4, C4 and PQR71 well above that of the more southern regions of the site.

A sample from the calcite capping of a cemented clay block at the base of D71[P9] (ANU 2578) gave a range of 24,400-25,500 bp (corrected from 26,450-27,550 bp) indicating that the channel was still open at that time and that Stage 1 had not yet ended. There must have been lengthy periods when water flow was minimal, while the calcite cappings formed on the clay blocks that were cementing in the base of that channel.

There are no radiocarbon determinations from undisturbed areas of redbrown clay from Stage 2, but ANU 2580 from Flowstone 3, overlying the redbrown clays in A3/4P4, shows that they had ceased to be deposited by 14,500-14,800 bp (corrected from 16,520-16,880 bp).

Three radiocarbon dates on snail shells that chronologically appear to belong to Stages 1 or 2 (ANU 2564, 2568 and 3682) are from material that was redeposited at a later stage of the history of the site.

3.5.4 Stage 3

Stage 3 is a complex period that involves the deposition of the sediments of Stratum C. Figure 3.4 is a detailed plan of central area of the excavation before the removal of flowsheets.

The sediment composition of the deposits at the top of the redbrown clay of Stratum D and into the redbrown sediments of Stratum C reflects the decline in slopewash components as seen in the decrease in clay content in Group X of the sediment analysis (Section 3.3.1). These samples in fact contain higher proportions of sands, gravels and silts than does Group Z from Stratum D deposits. Rates of deposition and constant water flow must have declined and allowed for the build-up of other forms of deposit. The increased sands, gravels and silts were possibly deposited by occasional periods of flooding when water carrying coarse materials escaped through the old stream outlet at Nombe.

Increasing quantities of calcium carbonate were being laid down in thin flowstone sheets in the top levels of the redbrown clay in A4/A5[P4]. These are visible when cut in section but too fragile to survive excavation. The first sheet that was thick enough to be removed and dated (Flowstone 3) lies on top of redbrown clays, immediately under redbrown sediments. The corrected date of that flowstone (ANU 2580) at 14,500-14,800 bp provides a *terminus ante quem* for those redbrown clays, as already noted in Section 3.5.2.

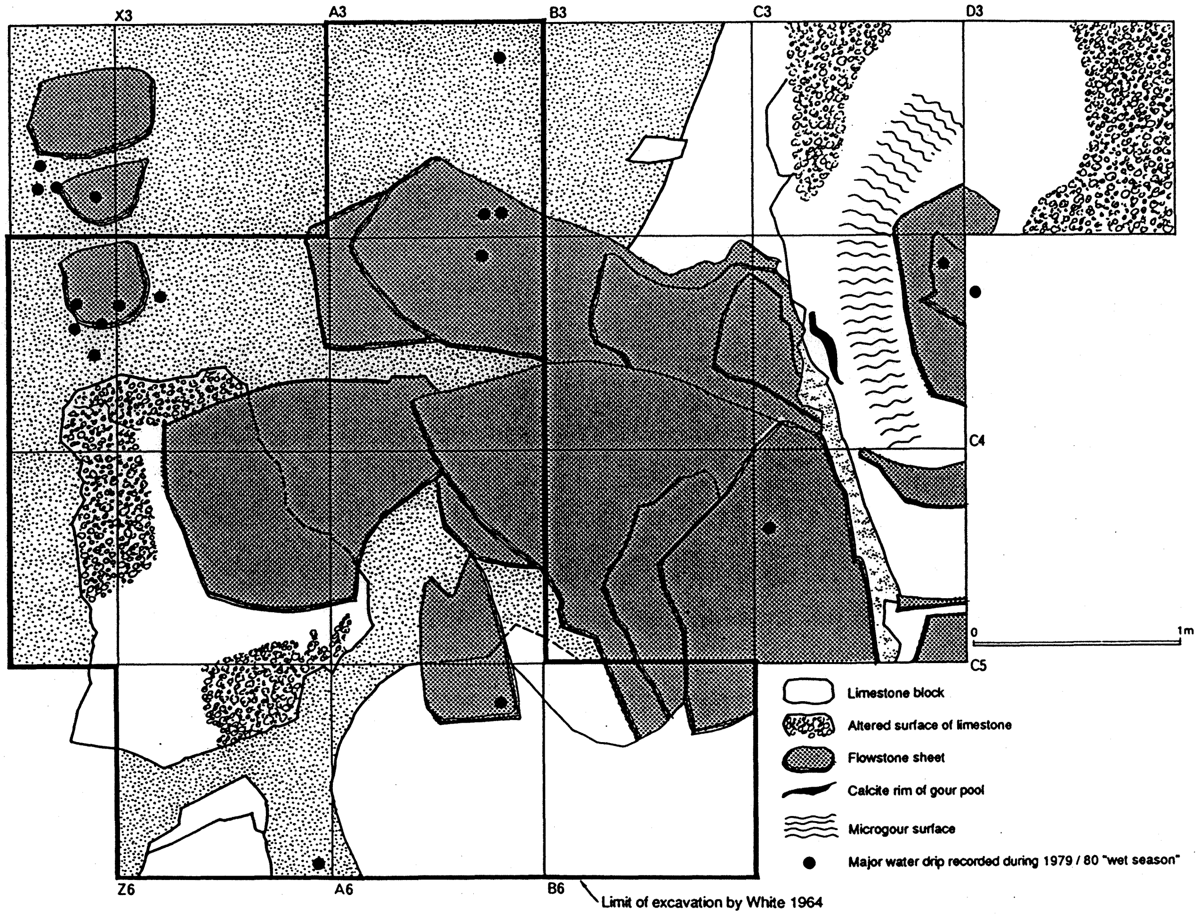


Figure 3.4 **Detailed plan of excavation (central area before removal of flowstones)**

The build-up of increasingly thick flowstone sheets (for example Flowstone 2 *P4*) in the top of the redbrown clays and redbrown sediments seems to indicate a change in the nature of the depositional processes on the site that is not merely accountable by the decrease in deposition rates. Gillieson (1982:428-430) puts forward the theory that thinning of the vegetation on the limestone slopes above the site led to an increase in the amount of available carbon dioxide, which in turn would be reflected in cave drip hardness:

> Degassing of water films in the cave with a higher carbonate content would result in a higher rate of flowstone formation. The dense root mat under *Nothofagus* forest may produce higher soil CO_2 levels. Although no work has been carried out on this in Papua New Guinea, vegetation change during the last glacial maximum may have resulted in increased rates of flowstone formation at Nombe. To test this hypothesis it would be necessary to monitor levels of soil and cave CO_2 and cave drip hardness in Papua New Guinean karsts under different vegetation types. (Gillieson 1982:430)

Vegetation changes are known to have occurred as a consequence of the changes in climate involving a decrease in temperature and changes in precipitation in the last phase of the Pleistocene (Bowler *et al.* 1976:389). As a result, the vegetational zones were at lower levels than today. G. Hope (1983b:40) posits that the upper limit of the montane forest, now about 3900-4000 m, was about 2000-2400 m during the period from 20,000 bp to 15,000 bp. He suggests that above that level trees were sparse and shrubs and tree ferns were scattered in open grasslands. The top of the ridge above Nombe is just over 2000 m, rising to the nearby peak of Mount Elimbari at 2850 m. The montane forest assumed to have been growing on the exposed slope above Nombe during most of the Pleistocene could have suffered from this gradual altitudinal decline, possibly resulting in thin *Nothofagus* forest covering much of the slope with very few trees existing at or near the ridge top. Gillieson's theory also allows some sort of clearance (natural or artificial) of the vegetation above Nombe (Gillieson 1982:430), but without supporting evidence this is only speculation.

As the rate of water flow decreased and the remaining clays acted as impervious barriers with the fallen rocks, ground water must have accumulated in pools, allowing the build up of a large pool in the northern (higher) part of the site. Evidence supporting this reconstruction comes from the large blocks of sediment that occur between Flowstones 2 and 3 in squares A3-5. These probably represent tephra that fell into standing water and settled in thick laminations. Any excess water from this pool would overflow down the face of the fallen limestone block in C3/D3 and its accumulated accretions *P1,2*. Eventually, a gour pool (a pool bounded by a rib or ridge of calcite, formed by precipitation from water flowing over the rim) developed above Flowstone 2. The gour pool rim can best be seen in Figure 3.4 and Plates 11 & 12 which clearly show the fragment of curved calcite rib that remains on the top of the south tip of the limestone block in C3/C4. There is also evidence of microgours (miniature gours with associated tiny pools of the order of 1 cm wide and deep) that formed as the water trickled over the limestone block to the north ***P1***. This also implies that Flowstone 2 and maybe also Flowstone 3 were laid down as floe calcite sheets within a water pool, accounting for the differences between the $\delta^{13}C$ figures for radiocarbon samples from these flowstones (ANU 2580 and 2581) and the more normal $\delta^{13}C$ values for flowstones dated by ANU 2576 and 2579 (Table 3.4). That water pool may have been formed on older clay deposits that were re-exposed through eroding forces removing subsequent clays.

The considerable amount of volcanic ash that found its way into this pool and built up above Flowstone 3 seems to be mixed with fire ash towards the top, producing a vesicular deposit which is less clearly laminated (Plate 10). Finally, when the tephra-like blocks almost completely filled the pool, it was capped by another flowstone, Flowstone 2. A final flowstone, Flowstone 1, is stratified above Flowstone 2 in A4/5 with some redbrown sediments separating the two ***P4***.

The consolidation of the tephra-like blocks in the pool must have caused standing water to drain away. Continued enlargement of the underlying solutional joints and subsequent slipping of the underlying clays probably accounted for the subsequent break-up of the soft tephra-like blocks and rigid crystalline flowstone sheets. This allowed, at a later date, more recent sediments to penetrate into those cracks. Further accumulation of some redbrown sediments continued but deposition in the period following the formation of Flowstone 1 seems to have been extremely slow until the build-up of Stratum B deposits began in the next stage of development.

A number of dates have been produced from this series of well stratified flowstones (Plate 4). The date of Flowstone 3 (ANU 2580) has already been discussed since it provides a boundary for the division between Stages 2 and 3 at a date of 14,500-14,800 bp (corrected from the apparent date of 16,520-16,880 bp, see Section 4.4). Flowstone 2 (ANU 2581) dates to 11,700-12,000 bp (corrected from 13,770-14,030 bp). The tephra blocks that lie between Flowstones 2 and 3 ***P4*** must date to the period between ANU 2581 and ANU 2579. There is some probability that the volcanic event that caused these tephras is the same as that which resulted in the tephra known as Ep Ash found in Kuk Swamp, Mount Hagen (Gillieson 1982:387; Gillieson and Mountain 1983:56). Flowstone 1 has been dated (ANU 2579) with a range of 10,150-10,350 bp. This correlates well with two dates, ANU 2576 with a range of 10,150-10,350 bp and a uranium/thorium date (McMaster 80055-1) with a range of 9,100-15,300 bp, both of which come from a thick flowstone that occurs in D79/X3 ***P1,6*** suggesting that this also is Flowstone 1. If so, this must have been formed as a steeply dipping deposit, sloping south and east, lying over redbrown sediments that had built up partly on the tephra-like deposits in the pool and the overlying Flowstone 2 and partly over the area of A3 to the south of that pool [P1,4].

This hypothesis is compatible with the date of 11,210-11,590 bp (ANU 2569) on charcoal extracted from a block of consolidated deposit lying underneath the flowstone in D79/X3, as well as with the presence of tephra-like pieces that are present in the redbrown sediments on which that consolidated block lies [P6]. Sediment sample 38 comes from these tephra-like pieces and, like sample 10 from the tephra-like block in A4, belongs to sediment Group Y. However, the two samples show considerable differences, which should be expected as sample 10 came from the top of the A4 block and may have other materials such as fire ash mixed in with the tephra. The tephra-like blocks lying over the redbrown clays in D79 [P1] were not included in the sediment analysis, but their stratigraphic position and similarity in physical appearance to the tephra-like blocks in A4/5 suggest that they originate from the same volcanic event as caused the thick deposits there. There is a possibility of a disconformity in the sediment build-up between these redbrown clays and the tephra-like blocks lying on top.

The top of the Stratum C redbrown deposits is dated to 12,650-13,650 bp by ANU 3683, a bone sample from T79 [P7-9]. However, since there has been disturbance above this (caused by human activity during Stage 4, see Section 3.5.5), it is possible that the top of Stratum C was truncated in this area of the site and that the date of 10,150-10,350 bp (ANU 2576 and 2579) from Flowstone 1 in A4/5 and D79/X3 is a more reliable date for the end of this stage.

A date which appears to be chronologically related to Stage 3 is ANU 3681, 11,490-11,810 bp, from the basal red clays over the fallen limestone block in C3 [P2]. Gillieson (1982:354) found that the red clay at the base of C3 (sediment sample 75/71 [P2]), consisting of clays and organic silts, is a member of Group Z along with most of the other redbrown clays. Since there is an associated bone date of 7480-9160 bp (ANU 3687) from precisely the same location without any apparent reason for the difference in age, this area is difficult to interpret stratigraphically. Further analysis of the archaeological materials within this deposit may clarify the position. There could have been very spasmodic accumulations of red clay in the basal pockets of the limestone block as slopewash sediments from the late Pleistocene into the early Holocene.

3.5.5 Stage 4

At this stage in the sedimentary and chronological history of Nombe there occurs a feature that causes disturbance of the earlier redbrown clays in the western part of the site. A trench was found deliberately cut into the basal clays in A1/2, running north-south across the squares (Figure 3.3 [P4,5]). The excavated material seems to have been subsequently dumped to either side of the feature over Stratum C deposits to the east ***P2*** and Stratum D deposits to the west ***P4,5***, where the brown gritty loam and red gritty sediments are thought to be upcast from the digging of Trench A1/2. The basal filling of this trench contains archaeological material that is very similar to that from the redbrown clays (Section 3.3.1) but sediment sample 23 falls into the mixed group of sedimentary deposits, Group X, (section 4.3.1). Above this mixed filling lie pieces of tephra-like material similar to that found between Flowstone 2 and 3 in Profile 4 (sediment sample 19 falls into group Y, Section 3.3.1). The filling is sealed by the thick layer of brown loam and ash deposits containing large amounts of bone designated as Stratum B. Human action was certainly responsible for the excavation of this A1/2 Trench and evidence for this statement and the possible reasons for the activity will be discussed in Chapter 4.

Two puzzling phenomena occurred in the area of the A1/2 Trench:

- ☐ pieces of extinct and often heavily burnt bone had been found in several archaeological units rather high in the stratigraphy where they had originally been interpreted as in situ; and
- ☐ several radiocarbon dates on snail shell from similar archaeological units of similar stratigraphic height and close to the A1/2 squares, gave results that were more in keeping with stratigraphical positions low in Stratum D. In two cases such dates were accompanied by much later dates on bone recovered from the same archaeological unit (ANU 2564 and 3076, ANU 3682 and 3683).

An 'upcast' theory satisfactorily explains these dates. A red gritty deposit containing Pleistocene snail shell (ANU 2564 at 24,950-27,050 bp) from the A1/2 Trench has been thrown up from the digging of the A1/2 Trench and later become incorporated with the base of the succeeding Stratum B deposit (ANU 3076 at 5760-5980 bp) in A1:4 ***P4*** and, in the case of the samples from T79 174 and 175, Pleistocene snail (ANU 3682 at 26,700-28,500 bp) was thrown on to the existing material at the top of Stratum C (ANU 3683 at 12,650-13,650 bp) ***P7,8***.

Another snail date of 30,050-31,150 bp (ANU 2568) came from shells recovered from a very mixed deposit in which redbrown sediments, very large pieces of limestone, many large snail shells and blocks of tephra-like material occurred together immediately over the top of the redbrown clays in B3 (Profile 2). Sediment sample 20 from the same archaeological unit proved to be fairly mixed in origin and belongs to the intermediate Group X (see Section 3.3). Whether this situation can be explained by the 'upcast' theory is uncertain.

Close scrutiny of the original field profile drawings does not always clearly indicate the limits of the dumping or disturbance. Wherever there is any doubt as to the stratigraphic integrity of any archaeological unit, it has been designated with an X after the stratum letter and not included in any analysis of stratum content. Since the event of trenching and upcast occurred, the dumped materials have merged into the sediments on to which they were thrown. In some cases (for example in the Wet-sieved Strip ***P7,8***) the weathering processes appear to have broken down the original composition of the clays, resulting in a mixture of materials at the top of the redbrown area that originate from Stratum D, in a matrix too similar to the underlying Stratum C deposits to be now recognisable. The extent of the disturbance might be clarified by further sediment analyses from samples near the 792/X2 boundary where it appears from the profile that the possible areas of disturbance are at their limit. There is no sign of dumping in X3 either from the profile or from ^{14}C results.

The A1/2 Trench must have been dug after the redbrown clay had ceased to be deposited but before the accumulation of the thick Stratum B deposits that run undisturbed over the A1/2 Trench filling. This brackets the period of time to between the date of Flowstone 3 (ANU 2580) at 14,500-14,800 bp and the oldest known date of Stratum B, which for the entire site is in H71 ***P9*** at 9370-9930 bp (ANU 3686), although the basal date for the Stratum B deposits immediately above the trench infillings are younger, at 5760-5980 bp (ANU 3076 ***P4***). There are no other helpful dates for pinpointing this stage. A substantial piece of the tephra-like material, containing both laminations and vesicular structure, such as occurs in the blocks found in the adjoining squares A3-5, has tipped into the filling of the A1/2 Trench ***P4***. It may have been in position on the edge of that trench when it was dug, but due to gradual erosion of the sides, it could have been dislodged and tipped into the half-full trench. A possible alternative theory is that the tephra post-dates the trench and the block was deliberately put or accidentally fell into the trench whilst infilling was proceeding. The disturbed nature of the redbrown sediments and ^{14}C dates from areas on the edge of the A1/2 Trench ***P4*** seem to suggest the later theory with the tephra-like block forming over upcast from the Trench. If this theory is correct, the A1/2 Trench must have been dug before the formation of that tephra-like material which, because of its strong similarities with the A3/5 tephra-like blocks, may date to between 14,800 and 11,700 bp, the bracketing dates for Flowstones 3 and 2. There is an apparent minimum age of between 10,000 and 12,000 bp for Ep tephra (J. Golson pers. comm.), which has strong similarities to the Nombe material.

3.5.6 Stage 5

The next stage of deposition at Nombe involved the accumulation of Stratum B. This stage shows an increase in human activity at the site, with the deposition of large amounts of burnt fragmented bone and artefacts. The very thick bone level Stratum B is clearly visible in the western parts of the site ***P4,5,6,7,8***.

In some areas Stratum B is very thin, having suffered from erosion; for example, under a prominent overhanging rock pendant in the roof over A4/B4, above the jagged edge of the underlying tephras and flowstone sheets ^{P4} and towards the eastern margins of the sheltered ground in square M71 ^{P9,10}.

A bone sample from H71 (ANU 3686) from the base of Stratum B, close to the top of the redbrown clays ^{P9} provides the oldest date for this accumulation at 9370-9930 bp. On this evidence a date of 7480-9160 bp (ANU 3687) from a bone sample at the base of C3 ^{P2} would belong chronologically to Stratum B. However, in fact it lies about 20 cm below the base of a brown loam with red flecks that continues the line of the more normal thick bone layer of Stratum B from the adjoining square B3. It is hard to be sure of the chronology of the upper strata in squares C3 and D3 but it may be an indication that Stratum B deposits were accumulating differentially in various parts of the site. It suggests that for the first 3000 years of the Holocene, thick Stratum B deposits accumulated at first in the hollow over the top of the in-filled Pleistocene stream channel in squares D71-M71, while there were scattered deposits in other areas such as C3.

There is also an older date from a snail sample (ANU 3681) from the C3 basal clay (11,490-11,810 bp). This may indicate that eroding agents (including humans) were extremely active and there was frequent removal of many sediments during the last part of the Pleistocene and early Holocene thus allowing bone and snail in close proximity to differ in age by some 2000 years.

The thick bone stratum in the west of the site has been well dated by three stratified samples from the top (ANU 3074 with a range of 5630-5990 bp), middle (ANU 3075 with a range of 6290-6470 bp) and base (ANU 3076 with a range of 5760-5980 bp which due to contamination by acid insoluble soil failed to give a collagen result).

These results come from nearly 50 cm of Stratum B in A1 ^{P4} and the extremely small range of only 5630-6470 bp suggests that the deposit was built up very rapidly. ANU 3688 from the base of Stratum B in X3 ^{P6,11} with a range of 6620-6860 bp may provide a more likely date for the beginning of the build up of the bone level at the west and centre of the site than ANU 3076.

The date at which the period of intense human activity producing Stratum B declined is bracketed by ANU 3074 from the top of Stratum B in A1 ^{P4} with a range of 5630-5990 bp and the oldest dates for the overlying Stratum A deposits (ANU 2570, 3110-3730 bp). There is a bone sample (ANU 3684) from the Stratum B deposits at the bottom of the excavation in an outlying part of the site - J71 ^{P10}. This gives a range of 5230-5450 bp. which correlates well with the other dates produced.

ANU 3689, at 4870-5310 bp, is a little younger than other Stratum B results elsewhere on the site but actually dates the redbrown clay in PQR71. These clays obviously represent a different episode of deposition from the Pleistocene redbrown clays in the south and central areas of the site. Clays were deposited by fluviatile action at different periods of the development of the site. Gillieson (1982:356) hypothesises that this wedge of redbrown clay in the northern squares, which was not included in the sediment analysis, was due to flooding from north of the site, causing slopewash deposits to be brought down and deposited over the fallen limestone block that lay on top of Pleistocene redbrown clay. Other redbrown clays found towards the drip line also appear by their archaeological contents to be Holocene in date and must have been laid down during the period of the formation of Stratum B over the top of the eroded Pleistocene redbrown clays, for example in Z6 (see discussion of Stratum B in Section 3.2.2). Severe flooding, such as is suggested by Gillieson, may also account for the formation of Channel D79, described below (Section 3.5.7).

Other dates from higher levels in Stratum A are all considerably later and do not assist in dating the change from Stratum B to Stratum A. It seems probable therefore that Stratum B in the western areas of the site (squares A1/2) ends about 5600-6000 bp when the deposits reached within 20 cm of the roof level at the back of square A1 [P5] and possibly when the area was used for a burial [P4]. In areas where the deposits were still within comfortable distance of the roof, it is possible that the top of Stratum B deposits are a little later in date. Elsewhere the change from Stratum B to Stratum A seems to have occurred sometime after the dates that give the ranges of 4870-5310 bp from PQR71:5 (ANU 3689) and 5230-5450 bp from J71:5 (ANU 3684).

3.5.7 Stage 6

At some stage after the period between about 5450 bp and 4900 bp the human activity on the site altered. The change from Stratum B to Stratum A deposits involves a purely archaeological phenomena, namely a decrease in the rate of accumulation of deposits and in the density of artefact deposition. However, the site was still frequently used, either on a more periodic basis or by people concerned with different activities than those which produced the bone-rich levels of Stratum B.

There is a date of 3110-3730 bp (ANU 2570) from Stratum A deposits lying 1.10 m below Datum A on the south side of the Consolidated Block of deposits in D79/X3 at a level where Strata B or C deposits might be expected. Profile 6 shows that this charcoal sample was collected from a block of deposit only a few centimetres above the level of ANU 2569 which was charcoal from another block of deposit stratified under Flowstone 1 and dating to 11,210-11,590 bp. The explanation lies in the build-up of the large Consolidated Block of cemented deposits in D79/X3 and its effect on drainage.

Profile 1 shows how the deposits lying over the layer of tephra-like blocks became cemented together with calcium carbonate from the overhanging roof boss, eventually sealing on to the roof itself. This may have effectively created a permanent blockage to the temporary drainage necessary after heavy rain. Local inhabitants say that in periods of extremely heavy and prolonged rain they can remember a small stream emerging from the site, presumably fed from the internal karst system within the limestone, probably through solution tunnels. At the very end of the 1979-80 field season, after excavation of the Wet-sieved Strip had been completed, some surface deposits were removed from the next strip to the west (T792, 792.21 and 792.22). These deposits had effectively sealed the eastern entrance to another chamber. In the ceiling of this chamber were many small roof pendants and at least one chimney. It is quite possible that such drainage chimneys connect directly to the end of the passage that exists inside High Cave, the cave that is situated in the cliff face to the south of Nombe rock shelter (see Section 2.1.3 and Figure 2.5). Through such channels, it is likely that excess flood water can still drain out through the newly discovered chamber and to the south of the Consolidated Block D79/X3 through squares C71/D71, H71 and M71, following the line of the Pleistocene stream channel. Indeed, it had been noted during the first excavations in 1971 that there was a change in the deposits at the back of C71, where there were very dark humic, damp sediments in a crack (the Drainage Crack, Figure 3.5) between the overhanging rock boss at the top of the Consolidated Block D79/X3 and the cliff face to the west of squares A71, B71 and C71.

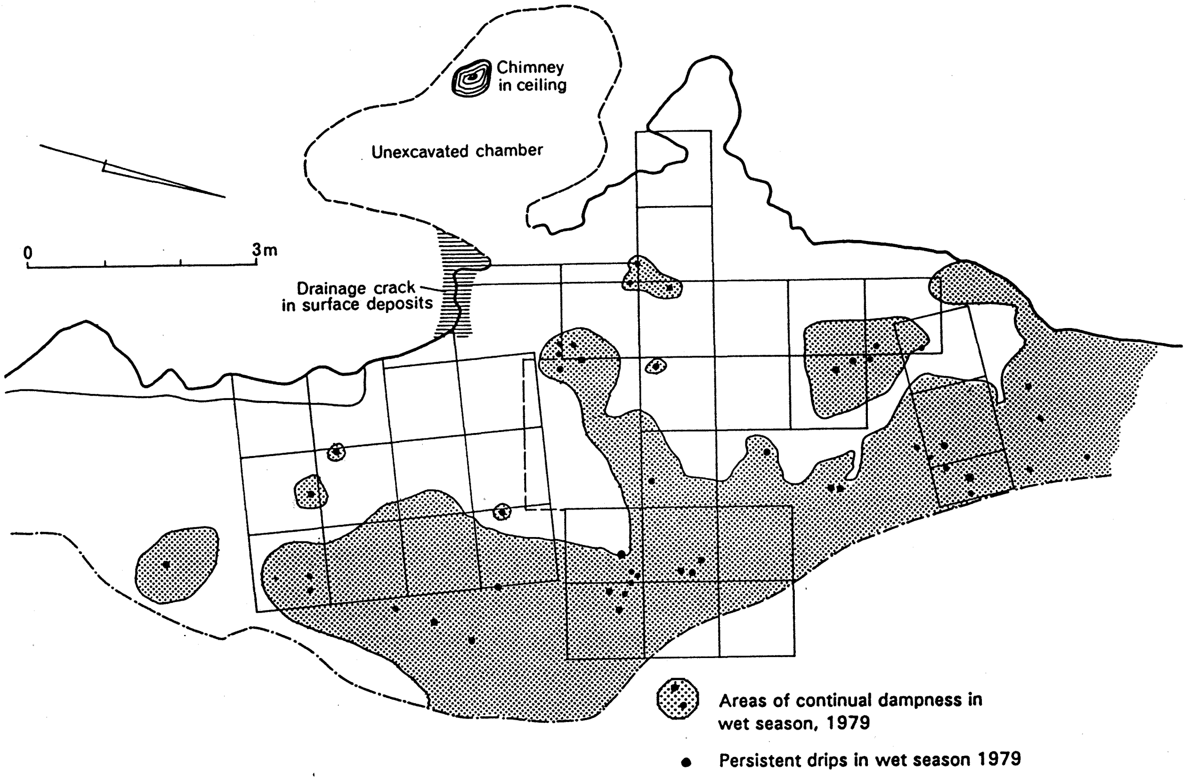


Figure 3.5 **Nombe rockshelter wet/damp areas as recorded in 1979**

It would seem that the area of D79/D71 had acted as the outlet of the Pleistocene stream for many years and that even after that old channel was filled with redbrown clays, the area had still served as a sump for deposition and drainage. After the final sealing of the Consolidated Block in D79/X3 excess drainage had to be channelled to the south of the area gouging out another channel in the Holocene deposits. This has led to a severe disconformity within the archaeological deposits within a small zone of D79, so that Strata C and B materials from within the body of the Consolidated Block D79/X3 are now higher than Stratum A deposits lying in Channel D79 immediately to the south of them.

The date of 3110-3730 bp from ANU 2570 ^{P6} shows that the Consolidated Block D79/X3 was already blocking the passage of flood drainage by then and that the Channel D79 had already formed.

A bone date from J71:5 in Stratum B (ANU 3684 ^{P10}) gives the range 5230-5450 bp, suggesting that the overlying 50 cm of undifferentiated brown sediment throughout the 1971 grid has accumulated over the last 5-5500 years (cf. Profile 9) whereas charcoal from J71:3 dates to within the last hundred years (ANU 3073). This charcoal was probably collected from a cooking pit that was dug from much nearer the present surface but, due to the powdery soft nature of the sediments in Stratum A, no trace of the outline of the pit excavation remains. However, an electro-spin resonance estimation on a piece of bone from the same level as the charcoal suggests that it is certainly much older than the charcoal.

Stratum A deposits vary greatly in depth. White found four joining pieces and a chip of a polished stone axe (White 1972:127) in a number of squares at different depths below the existing surface *P4*. Those pieces from the more western squares were close to the surface but those from the squares further to the east are up to 0.8 m below Datum A indicating that the build-up of Stratum A deposits in the front of the shelter was considerable. A charcoal sample from the very top black, humic deposits of Stratum A in the Wet-sieved Strip (ANU 3685 *P7,8,9,11*) with a range of 810-970 bp, shows that the depositsaccumulation has tended in very recent time to be towards the eastern, more protected areas near the sides and back of the present cave.

Table 3.6 Depositional model: summary of stages of sediment deposition at Nombe

Stage	Bracketing Dates (BP)	Sediment description	Sediment units	Reconstructed site Environment
6	Present to (4870-5310)	● Light dusty sediment ● Darker sediment	A1 A2	This stage continues the pattern of stage 5 with a decrease in the quantity of artefacts and bone.
5	(4870-5310) to (9370-9930)	● Brown loams with many artefacts and bones ● Mixed loams and clays ● Redbrown clays	B2, B4 B6,B7,B9 B3, B8	During this stage there was a build up of thick dark brown loam with many artefacts and heavily burnt bones in the main body of the cave while in other parts of the site there were clays, probably deposited by flooding or water seepage.
4	Some period between (9370-9930) & (14 500-14 800)	● Probable upcast from excavation of trench A1/2	C8X, B5X	This appeared to be a brief stage when humans dug a short trench into earlier sediments, depositing the upcast onto the current surface of the cave
3	(10 150-10 350) to (14 500-14 800)	● Flowstones ● Redbrown sediments ● Tephra blocks	C8 C8 C8	There was a great deal of sedimentary activity during this stage
2	(14 500-14 800) to (24 400-25 500)	● Redbrown clays	D1, D5	These clays were deposited in a stream channel. There is a possible disconformity between the top of these clays and the overlying tephras and flowstone layers.
1	(24 400-25 500) to (33 050-31 150) and older	● Ginger coloured redbrown clay ● Basal redbrown clay ● Basal brown clay (Some of these clay blocks are capped with calcite layers)	D2 D3 D4	These sediments are in the slopes of an active stream channel running through the cave and on the floor of this channel.

Chapter 4

Human Activity at Nombe: the Evidence

4.1 INTRODUCTION

Nombe has a complex and varied stratigraphy. The six stage model of depositional history derived from the stratigraphic evidence together with the results of sediment analysis and dating was presented in Chapter 3. This now lays the temporal and geomorphological framework within which the evidence for human activity can be examined to produce a broad survey of human activity at the site and its extent over time. The human evidence includes many different and complementary indicators.

It is also necessary to identify and discuss the taphonomic factors and their impact on the site materials. This follows in Chapter 6.

The changing impact of human settlement on the natural depositional history of the site itself must also be estimated. In a site with such a long history of human activity there is an obvious, but complex, interaction between people, their activities and natural processes which all combine to determine its depositional history. It is therefore necessary here to incorporate the human evidence in so far as it has impacted on the geomorphological history of the site.

This is not a site where stratigraphy and chronology allow subdivision into short periods. Therefore the major stratigraphical divisions of the site provide the most appropriate units of archaeological analysis.

Intra-site comparisons are made through the use of density or concentration levels of a range of recovered materials in many instances confirmed by sediment chemistry.

4.1.1 Indicators of human activity

Human activity within a cave or rockshelter can leave many indicators:

☐ artefacts;
☐ food wastes;
☐ fire ash and burnt stones; and
☐ changes to the sediment chemistry (as discussed in Section 4.7).

While data on any one indicator may provide valuable information, such data are not sufficient in themselves to estimate the intensity of human activity. It is therefore essential to monitor as many indicators as possible and utilise these in the analysis to ensure convergence in the overall data and to overcome any anomalous results. Therefore this chapter traces a wide range of archaeological components through the stratigraphic sequence of the site. The materials specifically documented are:

- artefactual stone,
- bone (both the total quantity and the proportion that is burnt),
- ochre,
- eggshell,
- snail shell,
- other shell (marine or fresh water molluscs), and
- charcoal and vegetable matter.

The four chemical elements monitored from sediment samples were carbon, nitrogen, phosphorus and potassium.

The overall picture that emerges from this convergent data is one of sporadic human activity during the Pleistocene increasing in intensity at the beginning of the Holocene period.

4.2 SAMPLING PROCEDURES FOR ANALYSIS

Since extremely large quantities of archaeological data were recovered from the excavations over the period 1971 - 1980, it was clearly not possible to analyse the entire set of data for this study. Consistent guidelines were developed for the sampling of data based on knowledge of the site. It was clearly necessary to retain all areas of the site which were important for the understanding of the stratigraphy, especially the central areas of the excavation. However, it was also important to include a representative sample of squares from the excavation.

4.2.1 Choice of squares for analysis

The decision to exclude squares from the analysis was made soon after return from the field in March 1980. The following decisions were made:

- The five central squares (C71-G71 and L71) in the 12 m grid excavated in the south of the site in 1971 were excluded. Only the six peripheral squares of A71, B71, J71, K71, H71 and M71) were retained. Nine squares (A71, B71, C71, E71, F71, G71, J71, K71, L71) were not excavated below the top levels of Stratum B and above that there was no sign of major stratigraphical change present and only two samples were submitted for radiocarbon dating.
- The entire stratigraphic sequence has been excavated from the three squares in the northernmost part of the 1971 grid (D71, H71, M71). Square D71 was excluded from this analysis because of extreme stratigraphic complexity. H71 and M71 provide sufficient evidence from the coarser techniques used in 1971.

- ☐ The neighbouring complex square of D79 was excluded due to the partial nature of the recovered material; the deposits of the Consolidated Block could not be sieved, physically separated or even transported away from the site (due to transport costs).
- ☐ Square X3 was also rejected since the more detailed data from the Wet-sieved Strip immediately to the west would provide similar but preferable data.

The analysed squares of the site are grouped together into a number of larger areas sharing a similar stratigraphic sequence. The most common grouping is of two neighbouring squares. Wet-sieving occurs only in the Wet-sieved Strip and in some units in R79Z6.

Dating samples were taken from several excluded squares in order to provide an overall picture of the chronological development of the site. All materials recovered from the chosen areas during excavations from 1971-80 have been included except data designated as "mixed". These are discussed in the next section.

4.2.2 Choice of archaeological units

The term "archaeological unit" is frequently used in the analysis which follows. This is defined as an undivided quantity of sediment excavated at one time and everything included in that sediment. In other words, a "unit" is the defined space to which any material can be allocated. Due to the very large quantities of archaeological material it was not possible to three-dimensional plots of individual finds. Since excavation techniques varied from coarse techniques through to wet sieving, the relevant unit can vary from over 200 litres to about 5 litres.

All material from the squares selected for analysis was catalogued, sorted and weighed on return from the field and all faunal material identified. However, during the stratigraphic and chronological analysis of the site sequences, it became clear that certain archaeological units had been subjected to stratigraphic disturbance and contained material from more than one stage of sedimentation (see Section 3.5.5). All such units were designated as "mixed" and although they are included in the computer database were withdrawn from further analysis (Section 6.5.2.).

Table 4.1 sets out the quantities of materials recovered, presented, from only those units which were classified as unmixed and which therefore form the basis of later analysis.

Table 4.1 Quantities of material recovered from squares included in analysis.

		Data initially analysed			Data included in analysis *excluding* "mixed" units		
	Units	**Wet-sieved**	**Not wet-sieved**	**Total**	**Wet-sieved**	**Not wet-sieved**	**Total**
Volume	Litres	907.3	15 561.4	16 468.7	731.7	14 688.1	15 419.8
Bone	g	13 146.7	38 318.5	51 465.2	11 309.9	34 847.4	46 157.3
Artefactual stone	g	4 281.6	47 448.7	51 730.3	4 141.6	46 435.3	50 576.9
Ochre	g	327.5	581.7	909.2	319.2	557.8	877.0
Snail shell	g	3 857.4	1 753.6	5 611.0	2 123.1	888.4	3 011.5
Egg shell	g	64.3	69.9	134.2	60.3	68.3	128.6
Other shell	g	5.9	88.8	94.7	5.9	83.2	89.1
Obsidian	g	1.5	2.8	4.3	1.5	2.8	4.3
Charcoal	g	42.1	10.5	52.6	40.6	10.5	51.1
Vegetable matter	g	2.4	8.1	10.5	2.3	8.1	10.4
Glass	g	1.7	1.0	2.7	1.7	1.0	2.7
Number of units		164	193	357	130	177	307

4.3 COMPARISON BETWEEN NON WET-SIEVED UNITS AND WET-SIEVED UNITS

There are problems in the presentation of a site-wide analysis of archaeological materials from each stratum. Alterations in research aims and field methods from 1971-80 (see Sections 2.2 and 2.4) had a dramatic impact on archaeological data recovery rates. In 1971 neither snail shell nor eggshell was retained and the coarse sieving of 1971-75 lost most smaller fragments of all materials. In 1979/80 wet-sieving techniques were employed in limited excavations (Section 2.4) and the recovery rate for archaeological data increased accordingly.

Table 4.2 shows the complexity in the analysis arising not only from sampling procedures but also from the change in sieving and recovery techniques.

Table 4.2 Breakdown of units within chosen squares by sieving technique and stratum

	Units initially used in analysis (number)	Mixed units (number)		Unmixed units (number)	
Wet-sieved units	164	34		130	
Non wet-sieved units	193	16		177	
Totals	357	50		307	
Stratum A	63	2	(0 w-s)	61	(18 w-s)
Stratum B	109	9	(1 w-s)	100	(31 w-s)
Stratum C	44	27	(22 w-s)	17	(10 w-s)
Stratum D1/5	109	12	(11 w-s)	97	(55 w-s)
Stratum D2	21	0	(0 w-s)	21	(13 w-s)
Stratum D3/4	11	0	(0 w-s)	11	(3 w-s)
Total Units Present	357	50	(34 w-s)	307	(130 w-s)

Note: w-s: Wet-sieved

Table 4.3 compares the recovery rate of material from a number of comparable wet-sieved and non wet-sieved units. Recovery rates of bone and artefactual stone are two to seven times higher for wet-sieved units. A2 and the Wet-sieved Strip are both inside the small cave area. They are adjacent areas from which similar amounts of each material would be expected.

Table 4.3 Comparison between recovery rates from wet-sieved and non wet-sieved units

Position	Strata	Units	Volume litres	Bone g/litre	Artefactual stone g/litre	Ochre g/litre	Snail shell g/litre	Egg shell g/litre
Wet-sieved Strip	B4	24	139.9	45.7	19.5	1.7	1.3	0.4
A2 (nw-s)	B2/4/5	12	950.0	6.5	3.3	0.1	<0.1	<0.1
Ratio wet-sieved:non wet-sieved recovery rates				**7**	**6**			
R79Z6 (w-s units)	B3	6	34.1	20.1	25.3	1.1	0.8	0.1
R79Z6 (nw-s units)	B3	7	165.0	7.3	11.1	0.5	0.2	<0.1
Ratio wet-sieved:non wet-sieved recovery rates				**3**	**2**			

Notes:
w-s: wet-sieved nw-s: Non wet-sieved
B2/4/5 sediments are loams/ashes, B3 is a redbrown clay

Table 4.3 highlights a problem in presenting results from such varied techniques since the substantial difference in recovery rate could easily obscure other differences which might show variation in site usage or function. The evidence produced by the two techniques is therefore presented separately; the reader must always be aware of variations possibly caused by the method of recovery.

4.4 APPROPRIATE ANALYTICAL STRATIGRAPHICAL DIVISIONS

Stratigraphical subdivision within Stratum A is not justified. The deposits are light, highly mobile sediments and there is evidence that finds have moved irregularly within its limits (for example, the varied depths below the 1964 surface of the four joining pieces of one polished axe found by White [P4]). In square J71 an ESR result from bone found at the same level as charcoal submitted for ^{14}C dating (ANU 3073) proved to be much later in date. This apparent anomaly can be explained by the way in which hearths are often dug several centimetres into the ground surface, but the resulting charcoal and ash soon become amalgamated into the surrounding ash and dust so that no distinct pit edge is recognised on excavation. Consequently, I believe that Stratum A has to be dealt with as one entire stratigraphical unit covering approximately the last 5000 years. Although it may be tempting to see whether there are significant variations between the material recovered from the top and the bottom of the stratum, such subdivision is not valid and has not been attempted.

However, Stratum B is a different case. There is a substantial sequence of chronological markers available from increasing depths within the stratum and the sediments are more cohesive and stable. There are two very different sediment types involved that appear to be chronologically consecutive. Three subdivisions have been made purely on depth of deposit, the top division (T), the central (C) and the bottom (B) divisions. The depth of deposits within Stratum B vary within the site and so each area was divided into three. These divisions have no sedimentary justification, they are purely a device to test whether the large quantities of data from different levels of Stratum B excavation do present different patterns. Many archaeologists work on the assumption that material from lower spits is automatically earlier than material from spits above them. I believe that such assumptions need justification and that without clear stratigraphic divisions (not present in Stratum B at Nombe) or good chronological controls (which are present at Nombe in Stratum B) there can be no justification for analysing each spit separately. These three subdivisions each appear to contain suites of material finds that are slightly different and may represent developmental changes from bottom to top.

Stratum D1/D5 consists of the undifferentiated redbrown clay that accumulated in the Pleistocene prior to the formation of the flowstones. However, although it is up to 85 cm thick in some parts of the site, there is no evidence of any internal layering within the deposit. The only sediment subdivision that was made was between redbrown clay (D1) and redbrown clay with considerable quantities of limestone fragments (D5 from the base of the Wet-sieved Strip). The absence of any internal chronological markers confirms that sediment and classification of the material contained therein cannot be subdivided by position within the stratum.

Some tentative electron-spin resonance results suggest that all the D1 redbrown clays lie within the range 25,000-29,000 bp. This implies a major disconformity between the top of the redbrown clays and the laying down of the flowstones that are now situated immediately over them. I feel strongly that it is not justified to subdivide a stratum (as some excavators do) solely on the grounds that finds from the base levels will be consistently older than those higher up within the identical sediment matrix.

Strata C, D2 and D3/D4 are all small in volume and contain fewer finds than the other strata. They cannot be subdivided on stratigraphical grounds but are representative of three important time periods in the site development and utilisation. I therefore present the data in this chapter in eight stratigraphical units. These are detailed in Table 4.4.

Table 4.4 Stratigraphical units chosen for analysis of indicators of human activity

	Approximate age range		**Units [a]**	
Strata	**bp**	**kyr**	**No**	**Volume (litres)**
Stratum A	Present – 5 000	5.0	61	5 391.4
Stratum B: top	5 000 – 6 000	1.0	37	2 954.2
Stratum B: centre	6 000 – 7 500	1.5	35	1 660.2
Stratum B: base	7 500 – 10 000	2.5	28	1 177.1
Stratum C	10 000 – 15 000	5.0	17	743.1
Stratum D1 & D5	15 000 – 25 000	10.0	97	2 758.1
Stratum D2	25 000 – 33 000	8.0	21	398.6
Stratum D3 & D4	33 000 – ?	?	11	337.1
Totals:			**307**	**15 419.8**

Note: a: Excludes "mixed" units

4.5 DENSITY LEVELS

The analysis of intra-site variation in the occurrence of any type of recovered material is inherently complex. A number of workers have used various measures of density (or concentration indices) tailored to specific sites, materials or research requirements, although the basic concept of density is very similar.

A density measure based on weight per volume of matrix was clearly appropriate for the Nombe analysis since this would provide a means of comparing evidence from different volumes of sediment.

Volumes are expressed in litres rather than in cubic metres (there are 100 litres in one cubic metre) thereby avoiding the use of very small decimal numbers. Density figures are presented as grams per litre. In the case of sparse components this does have a disadvantage since the resultant density figures may be less than 0.1 gram/litre. Figures of this type should therefore be interpreted with caution since they appear to imply a greater degree of accuracy than is the case.

Density levels (or concentration indices) have been used in recent years in several ways. For example, Egloff (1979:32) shows inter- and intra-site variation by individual density graphs of six major components recovered, and Schrire (1982:34) uses density analysis to provide a measure of the relative importance of various materials from a number of middens. Bowdler (1979:Ch.3) employs density levels of bone to assist in differentiating between the products of animal and of human predation. All these researchers show density as weight (mass) per volumetric unit and this method is used here.

Vanderwal and Horton (1984:40) discuss some further examples of the use of the 'concentration index' and themselves use a concentration figure based on minimum number and weight. Balme, Merrilees and Porter (1978:45) use a density figure, which they call 'incidence per m^3', to provide an effective comparison between all vertebrate species throughout a site. In work at the two rockshelters of Kastritsa and Asprokaliko in Greece, two measures of density, termed 'geometric density' and 'time density', are employed by Bailey *et al.* (1983). In the first they present the quantity of material by a straight count of objects, i.e. the number of artefacts per volumetric unit. This may have been necessary for those sites given the preservation of materials and earlier recording techniques but certainly at Nombe any attempt to enumerate artefacts or fragments of bone or shell as a measure of variability would lead to extreme definitional problems. Wet-sieving produces a mass of minute fragments of both bone and shell that would be meaningless to count but which can be weighed, so that density figures based on mass offers a comparison across a number of specific areas of the site.

4.6 INTRA-SITE DENSITY COMPARISONS

In examining the density patterns of materials throughout the site, the six largest categories present in Table 4.1 are normally used:

- ☐ **bone** includes all faunal evidence recovered from animal bodies (bones, teeth, carapace, claws, beak) but not shell;
- ☐ **artefactual stone** refers to humanly modified stone but does not differentiate between stylised recognisable types (such as polished stone axes or decorated stone pestles) or primary unused flakes;
- ☐ **ochre** refers to pieces of iron oxide (of varying shades of red or yellow) probably used as colouring matter;
- ☐ **snail shell** is assumed to come from snails as natural inhabitants of the site and therefore independent of human activity;
- ☐ **egg shell** comes from megapode or cassowary eggs, presumably after the consumption of the contents by people; and
- ☐ **other shell** comes from freshwater or marine molluscs which were either food remains or trade items from other areas.

The small quantities of obsidian, charcoal, vegetable matter and glass will be discussed separately.

4.6.1 Stratum A

Materials from Stratum A covering approximately the last 5000 years were analysed from nine areas, only one of which was excavated by wet-sieving methods. Table 4.5 includes density patterns for the five major components (together with the figures for shell other than snail or egg and the percentage of the bone that was burnt) within those areas. The Stratum A deposits in the central squares of the site (i.e. Test Trench, A4, A5) were removed by White in 1964 and since there are no ^{14}C dates from that material it is impossible to be precise as to the stratigraphic divisions within that material.

Table 4.5 Density of major components of Stratum A units

Position	Number of units	Volume	Bone	Artefactual stone	Ochre	Snail shell	Egg shell	Other shell	Burnt Bone
		litres	g/litre	g/litre	g/litre	g/litre	g/litre	g/litre	%
Wet-sieved Strip	18	118.9	6.2	1.2	<0.1	0.1	<0.1	<0.1	70
Non wet-sieved:									
A1/A2	2	300.0	0.9	0.5	<0.1	<0.1	<0.1	<0.1	53
A3/B3	2	300.0	0.6	0.7	<0.1	<0.1	0.0	<0.1	73
B4/C4	4	300.0	1.0	0.7	0.0	<0.1	<0.1	<0.1	69
C3/D3	5	475.0	3.7	1.7	<0.1	<0.1	<0.1	<0.1	32
PQR71	5	737.5	0.9	0.7	0.0	na	na	<0.1	31
H71/M71	9	1 080.0	1.6	2.7	<0.1	na	na	0.0	90
J71/K71	8	1 040.0	0.7	0.8	0.0	na	na	<0.1	74
A71/B71	8	1 040.0	1.1	0.5	<0.1	na	na	0.0	47
Totals	61	5 391.4							
Total recovered	**(grams)**		**7 471**	**6 333**	**114**	**27**	**20**	**50**	

Note: na: not appropriate since material not collected

There is little doubt from Table 4.5 that Stratum A deposits are closely associated with human activity. Artefactual stone is present in significant amounts in all areas excavated and small amounts of yellow and red ochre occur in two-thirds of the areas. Bone is present throughout and usually a high proportion is burnt. Eggshell was not collected consistently in 1971 but it was found in small quantities in the areas for which it is entered in the table. None occurs in B3 where the surface deposits were thin and may have been eroded in 1964 by activities connected with White's excavations. Snail shell occurs only in very small quantities.

A superficial interpretation of Table 4.5 could be that the Wet-sieved Strip shows the highest density of use or disposal during the years that Stratum A was accumulating. But if the increased recovery rates from wet-sieved units (Table 4.3) are taken into consideration (Section 4.3), then it is clear that it is the non wet-sieved area of C3/D3 which produced the highest quantity of materials during the last 5000 years. This area seems to have been a narrow gully lying between the higher flowstone sheets in squares B4 and C4 that were formed about 10,000 bp or later and the face of the limestone shelter immediately west of C3 and D3. Stratum B deposits, consisting of a brown loam with red flecks and a Holocene redbrown clay, accumulated over the fallen limestone block. These are not very thick and subsequently a gully formed over them that may have been used deliberately as, or naturally became, a refuse catchment zone during the period of Stratum A accumulation. The bone there is remarkably well preserved with a higher proportion of fragile bones, such as skulls, than in other Stratum A locations. It also shows a low percentage of burning, which suggests that far from being human waste this is possibly bone refuse from a bird of prey roosting on the cliff above the site (Section 6.6.2.3). There is also a low burning ratio in the neighbouring squares of PQR71 although the overall quantity of bone there is far lower, as would be expected since the gully only exists under the shelter wall and does not extend into Q71 or R71 where the sediments are mainly Holocene redbrown clays.

Elsewhere in Stratum A the range of the proportion of bone that is burnt is higher, varying from 47 to 90%.

Another area where the quantity of bone is low is the peripheral area of J71/K71. The remaining areas do not vary very much in the density figures for Stratum A bone, except for a marked increase in H71/M71. This overlies the original site of the Pleistocene stream (Section 3.5.2) which continued as an occasional drainage route during the Holocene for water which issued from the cave after very high rainfall (Section 3.5.7). Density figures for stone artefacts may be biased by earlier surface collecting by archaeologists and speleologists, who are likely to have removed obvious stone artefacts, such as polished axes, lying in surface deposits of light dusty ash and soil. Charcoal was present in a sample collected from a hearth in J71:3 (submitted for ^{14}C dating, ANU 3073). In the Wet-sieved Strip, 15 g of charcoal was collected and submitted for ^{14}C dating (ANU 3685).

The range of 'other shell' present includes small cowrie shells (*Cypraea annulus*), frequently used in recent times as personal decoration on head bands or belts, and fragments of pearl shell (*Pinctada maxima*) also well known as a valuable trade commodity in Simbu as discussed by Hughes (1977). Several fresh water mussels (probably from the family Hyriidae) were present in the C3 area but do not occur anywhere else at the site. These are common in highland streams (White 1972:19, 94).

A few (presumably modern) pandanus drupes were found within the top centimetres of Stratum A in J71, K71, C4 and WSS and some fragments of green and brown glass (probably from beer bottles which are now commonly found on the ground surface of the site).

4.6.2 Stratum B

Seven separate types of deposit occur in Stratum B as discussed in Chapter 3.

All these deposits, whether wet-sieved or not, show high density levels of bone, artefactual stone and ochre combined with the constant presence of eggshell and a low density of snail shell.

Stratum B shows evidence of the most consistent and concentrated use of the shelter by human beings, having the highest densities of artefacts recorded on the site. This phase of activity can be dated to 5000-10,000 years bp. In some of the areas excavated, only the top few centimetres of Stratum B were removed, whereas in other areas the entire Stratum was completely excavated. It has already been argued that Stratum B can be subdivided into three components (section 3.4) and accordingly the density patterns of the top, centre and base levels of Stratum B are presented separately in Tables 4.6, 4.7 and 4.8.

Table 4.6 Density of major components of Stratum B units (top level)

Position	Stratum	Number of units	Volume litres	Bone g/litre	Artefactual stone g/litre	Ochre g/litre	Snail shell g/litre	Egg shell g/litre	Other shell g/litre	Burnt bone %
Wet-sieved Strip	B4	9	54.2	34.9	18.2	1.8	2.5	0.3	0.0	90
Non wet-sieved:										
A1/A2	B2	8	600.0	5.2	3.0	0.1	<0.1	<0.1	<0.1	6
C3/D3	B2/6/9	5	475.0	1.4	1.4	<0.1	<0.1	0.0	<0.1	39
PQR71	B6	4	1 200.0	0.4	0.4	0.0	na	na	<0.1	8
H71/M71	B4	5	225.0	8.9	34.1	<0.1	na	na	0.0	85
J71/K71	B4	3	200.0	1.2	6.7	<0.1	na	na	0.0	95
A71/B71	B4	3	200.0	7.0	10.2	<0.1	na	na	0.0	86
Totals		37	2 954.2							
Total recovered	(grams)			9 824	15 004	218	151	32	33	

Note: na = not appropriate since material not collected

Table 4.7 Density of major components of Stratum B units (centre level)

Position	Stratum	Number of units	Volume litres	Bone g/litre	Artefactual stone g/litre	Ochre g/litre	Snail shell g/litre	Egg shell g/litre	Other shell g/litre	Burnt bone %
Wet-sieved Strip	B4	5	85.7	52.6	20.3	1.7	0.6	0.4	<0.1	93
Non wet-sieved:										
A1/A2	B4/5		674.5	7.0	3.4	<0.1	0.1	<0.1	0.0	92
A3/B3	B2	2	175.0	4.1	2.4	0.0	<0.1	<0.1	0.0	91
C3/D3	B6/9	5	350.0	1.9	2.4	<0.1	0.1	0.0	0.0	15
H71/M71	B4	4	375.0	3.1	10.9	<0.1	na	na	0.0	99
Totals		35	1 660.2							
Total recovered	(grams)			11 782	9 389	254	200	48	0	

Note: na = not appropriate since material not collected

Table 4.8 Density of major components of Stratum B units (base level)

Position	Stratum	Number of units	Volume litres	Bone g/litre	Artefactual stone g/litre	Ochre g/litre	Snail shell g/litre	Egg shell g/litre	Other shell g/litre	Burnt bone %
Wet-sieved Strip										
R79/Z6	B3/7	7	41.9	19.4	24.0	1.2	0.6	0.1	0.0	41
Non wet-sieved:										
C3	B8	2	37.5	4.1	2.6	0.0	1.4	0.0	0.0	<1
H71/M71	B4	8	777.0	5.8	13.8	<0.1	na	na	<0.1	82
R79/Z6	B4/3/7	11	320.7	7.4	15.3	0.5	0.2	<0.1	<0.1	73
Totals		28	1 177.1							
Total recovered	(grams)			7 859	16 706	262	158	27	6	

Note: na = not appropriate since material not collected

Bone densities are highest in the centre level while stone artefact densities are highest in the base level. Overall the levels of bone and stone artefact are very high, especially in the top and central levels and, with one exception, show a remarkable rise over the figures for Stratum A. The exception is C3 and D3. The gully in squares H71 and M71 shows extremely high levels of artefactual stone, which may have been washed in from neighbouring areas by later flooding in Stages 5 and 6 (see Section 3.5.6 and 3.5.7). This area is not necessarily subject to higher levels of activity and deposition but the presence of even occasional stream activity from the internal karst system may have swept accumulated debris into a temporary gully, which would then fill up again during the succeeding dry periods of occupation.

The peripheral squares of the area excavated always show lower densities than the central areas. The level of burning on the bone is generally extremely high except in the northern squares of C3/D3 and PQR71. Other indicators of human activity such as the presence of ochre and eggshell are present everywhere except again in C3/D3, PQR71 and the thin top levels of A3/B3. There are small quantities of snail shell throughout Stratum B.

Tables 4.6-4.8 indicate three areas of very high density (all in brown loam sediment).

- ☐ Toward the western region of the shelter in the Wet-sieved Strip and the neighbouring squares of A1 and A2 there is a high density area which is at present the entrance to the small cave. In the past this would have been a larger cave and a significant area of human activity when ground levels were much lower.
- ☐ In the eastern area there is another high density area. This is located over the top of the original Pleistocene stream channel which by 10,000 bp would have been filled with redbrown clay but would still be forming a gully through squares D71, H71, M71 and R79 as the path for occasional drainage across the site. Thus the greater density may be due to erosion.
- ☐ Another area showing high density occurs in squares A71 and B71 under the wall of the shelter during the last years of occupation of Stratum B.

The area of square C3 and D3 appears to have had lower discard during the period of Stratum B accumulation than in the following Stratum A in contrast to the rest of the site, and the PQR71 squares show the lowest densities of bone and artefactual stone for the stratum. However, the deposits in this area have a high clay content and the densities may reflect a high decay factor for burnt bone in anaerobic clay sediments as much as indicating peripheral areas of human activity during Stratum B accumulation. It is noticeable that the only Stratum B units to show less than 69% burnt bone are those with clayey loam or clay sediments. Factors that could be involved in such regions include the brittleness and loss in weight of burnt bone combined with local flooding (which is instrumental in producing the clay, see Section 3.5.6) that may have carried away small, light fragments leaving behind the larger, heavier less burnt bone covered by clay).

Stratum B is the only stratum from which obsidian flakes were recovered; two from the Wet-sieved Strip and one from the top of Stratum B in A2 and another in H71. Occasional small pieces of pearl shell (*Pinctada maxima*) and one fragment of a freshwater mussel shell (*? Pinctada sp.*) occur within Stratum B and a very small amount of charcoal (insufficient for dating purposes by conventional means) was recovered from wet-sieved units. No vegetable remains were found or any recent artefacts such as glass or metal.

Table 4.9 Summary of density of major components of Stratum B units

Position	Number of units	Volume litres	Bone g/litre	Artefactual stone g/litre	Ochre g/litre	Snail shell g/litre	Egg shell g/litre	Other shell g/litre	Burnt bone %
Wet-sieved Units	31	181.8	39.8	20.5	1.6	1.2	0.3	<0.1	8
Non wet-sieved Units	69	5 609.7	4.0	6.6	<0.1	<0.1	<0.1	<0.1	6
Totals	100	5 791.5							
Total recovered	**(grams)**		**11 782**	**9 389**	**254**	**200**	**48**	**0**	

4.6.3 Stratum C

An immediate question raised by the data in Table 4.10 below is why there are so few Stratum C units. There are no excavated Stratum C deposits in the southern parts of the site since excavation there ceased in 1971 before Stratum B deposits had been completely removed. In the northern area of the site, the presence of a large fallen block of limestone that underlies the Stratum B deposits in squares C3 and D3 dictated the cessation of excavation there in 1974-5. Therefore, the only remaining squares in which Stratum C deposits were found are A1, A2, A3, the Wet-sieved Strip, the southern half of B3 and C4 and B4. Within many of the remaining units there are signs of disturbance, normally connected with possible dumping of earlier material on to Stratum C deposits after the digging of Trench A1/2.

Table 4.10 Density of material from Stratum C units

Position	Stratum	Number of units	Volume litres	Bone g/litre	Artefactual stone g/litre	Ochre g/litre	Snail shell g/litre	Egg shell g/litre	Other shell g/litre	Burnt bone %
Wet-sieved Strip	C8	10	43.1	7.1	0.2	<0.1	2.3	<0.1	<0.1	29
A3/B3	C8	3	200.0	0.6	0.0	0.0	0.2	0.0	0.0	74
C4	C8	1	100.0	1.1	0.2	<0.1	<0.1	0.0	0.0	51
A5	C8	3	400.0	0.2	<0.1	<0.1	0.2	0.0	0.0	12
Totals		17	743.1							
Total recovered	**(grams)**			**609**	**28**	**12**	**235**	**1**	**1**	

Sections 3.5.3 and 3.5.4 discuss the decline in deposition rates towards the top of the redbrown clays and sediments of the late Pleistocene period. Once the constant stream flow sank below the level of the Nombe outlet, deposition rates must have slowed a great deal. No artefactual material was contained in the flowstone sheets or tephra-like blocks that constitute much of the Stratum C sediments and there was major disturbance caused by the digging of Trench A1/2 when earlier deposits were dumped as upcast on existing Stratum C deposits (Section 3.5.4). Dumping is especially evident in the southern part of the Wet-sieved Strip where bone from large extinct fauna originally from Stratum D deposits appears within Stratum C redbrown sediments. All such mixed Stratum C units have had to be removed from analysis as there is no way of telling which elements originally came from which stratum. Over half the designated Stratum C units have had to be excluded from the analysis, whereas in Stratum B less than 10% of the originally designated units were found to

be mixed and therefore removed from the analysis. However, even the total volume of Stratum C units (including mixed units) falls far below that of any other strata except for the basal levels of Stratum D, which were only excavated in small amounts, since they contained very few artefacts. Table 4.10 emphasises the small quantities of Stratum C deposits.

It is clear that the sedimentation rates for Stratum C deposits were exceptionally variable. For example, very high rates are evident during the deposition of the tephra-like deposits yet in other areas rates are very low. Nevertheless, it is unlikely from the low density of human artefacts that there was anything more than transitory and short term human activity at the site during those 5000 years. It is also probable that erosion rates were often high during that time and reduced the original volume of deposit (for example in C3, Section 3.5.6), and in places possibly removed it altogether. The absence of 'lag' deposits of archaeological or natural stone over Stratum D clays seems to confirm the low level of human activity during the period covered by Stratum C. If there is a disconformity between the top of Stratum D and the basal levels of Stratum C at a time of human settlement, some evidence would be expected to remain. The flowstone sheets and tephra-like blocks were laid down mainly under water (Section 3.5.4) and water flow may have been responsible for considerable erosion of redbrown sediment and clays to the south of the gour pool in squares such as H71, M71, R79 and Z6, where Stratum C deposits are absent from the present stratigraphy.

Another question raised by Table 4.10 concerns the degree to which human activity was responsible for the components found within Stratum C. It is clear that the densities for all components are low, although the bone density in the Wet-sieved Strip is slightly higher than for Stratum A. The densities for stone artefacts are very low with only 28g in total. But there are positive signs of human activity such as small quantities of charcoal, eggshell and other shell found in the Wet-sieved Strip and a mean of 46% burnt bone, which suggest that human activity was present although more sporadically and less intensively than in the younger strata. Moderate quantities of snail shell are present in the Wet-sieved Strip but, as will be discussed later, these are thought to be a natural addition to the deposits, not a result of direct human activity.

4.6.4 Strata D1 and D5

These deposits accumulated between about 24,500 and 15,000 bp. While the evidence for human activity appears thin there are sufficient indications that people were present at certain times on the site during the 10,000 years when redbrown clay was being deposited. These sediments are found in the central and western areas of the site. Although digging the A1/2 Trench removed some of the Stratum D redbrown clay, the 1974-5 excavations in A1 did not continue below the base of Stratum C because of lack of time.

Table 4.11 Density of material from Stratum D1 and D5 units

Position	Stratum	Number of units	Volume litres	Bone g/litre	Artefactual stone g/litre	Ochre g/litre	Snail shell g/litre	Egg shell g/litre	Other shell g/litre	Burnt bone %
A: Areas of the Pleistocene stream channel:										
Wet-sieved										
W-sieved strip	D1/5	38	189.9	4.2	<0.1	<0.1	8.1	0.0	0.0	9
R79Z6	D1	17	108.5	18.1	2.2	<0.1	1.1	<0.1	0.0	17
Non wet-sieved:										
R79Z6	D1	13	321.1	2.4	2.5	<0.1	0.4	0.0	0.0	7
H71/M71	D1	10	643.7	4.2	3.2	0.0	na	na	0.0	17
B: Other areas of Stratum D1 sediments:										
A2	D1	1	150.0	0.2	0.0	0.0	<0.1	0.0	0.0	8
A3/B3	D1	4	400.0	0.4	0.0	0.0	0.2	0.0	0.0	11
TTA45	D1	14	944.9	1.3	<0.1	0.0	0.1	0.0	0.0	8
Totals		98	2 818.1							
Total recovered	**(grams)**			**7 965**	**3 107**	**17**	**1 972**	**<1**	**0**	

Note: na: not appropriate since material not collected

It is apparent from Table 4.11 that there is a great deal of variation in the artefact densities within Stratum D1, especially between those squares that constitute the infilling of the Pleistocene stream channel (Section 3.5.3) i.e. the Wet-sieved Strip, H71, M71, R79 and Z6, and those squares in other areas of D1 deposits i.e. A2, A3, A4, B3 and A5. The density levels of both bone and artefactual stone are substantially higher within the stream channel areas suggesting that more artefacts were directly dropped in the channel area or that it became a natural final repository for artefacts dropped nearby, sometimes becoming lodged amongst the cemented clay blocks on the floor of that channel. The next flood of redbrown slopewash deposits covered and retained the artefactual remains.

Small amounts of charcoal were recovered from basal areas of R79 where there is a distinct concentration of burnt bone, charcoal fragments, artefactual stone and ochre pieces that suggest an area of direct human occupation. Some 2.5 g of charcoal has been submitted for accelerator ^{14}C dating by the Radio Carbon Laboratory, Australian National University but cannot yet be processed since the accelerator facility is not yet operational. The distribution of the density patterns in D1 suggests that not only did bones and stone artefacts get washed into the old stream channel running through the site but that there are identifiable locations of human activity within the deposit although, as will be argued later, much bone within Stratum D1 may well result from animal predation. Large pockets of land snail shells occur throughout these sediments.

4.6.5 Strata D2, D3 and D4

These three deposits are individual components of the lowest part of Stratum D (Section 3.5.2). Although substantial volumes of D2 were excavated, very little of the lowest two sediments was removed since they clearly contained little to connect them with human activity and, in the eastern areas of the site, access to the heavy clays was very restricted due to the blocks of cemented clay on the floor of the Pleistocene stream channel, which would have been extremely difficult to remove. D2 deposits can be dated to the period between approximately 24,400 and 33,000 bp and, since there are no dates from either D3 or D4, the period of time covered by their deposition is not known.

Table 4.12 Density of material from Strata D2, D3 and D4 units.

Position	Number of units	Volume litres	Bone g/litre	Artefactual stone g/litre	Ochre g/litre	Snail shell g/litre	Egg shell g/litre	Other shell g/litre	Burnt bone %
Stratum D2:									
W-sieved Strip	13	73.6	3.7	0.0	0.0	2.0	0.0	0.0	3
A3/B3 nw-s	6	275.0	0.4	0.0	0.0	0.1	0.0	0.0	24
A4 nw-s	2	50.0	2.7	0.2	0.0	1.3	0.0	0.0	2
Totals	21	398.6							
Total recovered (gms)			***526***	***9***	***0***	***248***	***0***	***0***	
Stratum D3									
R79Z6 w-s	3	15.9	1.2	0.0	0.0	0.1	0.0	0.0	0
R79Z6 nw-s	1	16.2	1.7	0.0	0.0	0.3	0.0	0.0	5
HM71 nw-s	1	60.0	5.2	0.0	0.0	0.0	0.0	0.0	3
Totals	5	92.1							
Total recovered (gms)			***354***	***0***	***0***	***6***	***0***	***0***	
Stratum D4									
A2 nw-s	1	150.0	<0.1	0.0	0.0	<0.1	0.0	0.0	0
B3 nw-s	2	62.5	0.1	0.0	0.0	0.2	0.0	0.0	0
A4/5 nw-s	3	32.5	0.4	0.0	0.0	0.0	0.0	0.0	0
Totals	6	245.0							
Total recovered (gms)			***76***	***0***	***0***	***16***	***0***	***0***	
Total recovered from D2/D3/D4 (grams)		***980.7***	***959***	***9***	***0***	***270***	***0***	***0***	

***Note*:** w-s: wet-sieved
nw-s: not wet-sieved

It can be seen from Table 4.12 that with sediments of increasing depth in Stratum D the evidence for human association becomes much thinner. Only two small stone artefacts were recovered from the top surface of a sloping bank of ginger clay (D2) and in that position they could belong to the overlying Stratum D1. There was no charcoal or eggshell at all. The overall percentage of burnt bone was a very low 7%, certainly not a strong enough claim in itself for the presence of human activity. There are great problems in identifying 'burning' at these low levels (see discussion in Section 6.5.) and mineral staining might account for discolouration of such a small quantity of bone. No ochre, charcoal or eggshell was recorded from either Strata D3 or D4 and there the percentage of burning is below 3%. Therefore there is no irrefutable indication of human activity. Land snails are not uncommon in Stratum D2 but few occur in the basal clays of D3 or D4. The bone material in this stratum could well have been deposited by animals before human activity began on the site but there must remain a slight possibility that humans were present during the formation of these basal clays.

4.6.6 Summary of densities

The summary table shows the consistent rise, from strata D1 upwards, in evidence that indicates human presence with an impressive increase in materials indicating human activity at the changeover from the Pleistocene to the Holocene periods followed by a decline during the last period on the site from about 5,000 bp to the present.

Table 4.13 Summary table of density of materials recovered

	Wet-sieved units							Non wet-sieved units						
Strata	Bone	Arte-factual stone	Ochre	Snail shell	Egg shell	Other shell	Burnt Bone	Bone	Arte-factual stone	Ochre	Snail shell	Egg shell	Other shell	Burnt bone
	g/L	g/L	g/L	g/L	g/L	g/L	%	g/L	g/L	g/L	g/L	g/L	g/L	%
A	6.2	1.2	<0.1	0.1	<0.1	<0.1	67	1.3	1.2	<0.1	<0.1[n13]	<0.1[n13]	<0.1	61
B(T)	34.9	18.2	1.8	2.5	0.3	0.0	90	2.7	4.8	<0.1	<0.1[n13]	<0.1[n13]	<0.1	58
B(C)	52.6	20.3	1.7	0.6	0.4	<0.1	92	4.6	4.9	<0.1	0.1[n16]	<0.1[n16]	0.0	73
B(B)	19.4	24.0	1.2	0.6	0.1	0.0	40	6.2	13.8	0.2	0.3[n13]	<0.1[n13]	<0.1	60
C	7.1	0.2	<0.1	2.3	<0.1	<0.1	29	0.4	<0.1	<0.1	0.2	0.0	0.0	35
D1/5	9.2	0.9	<0.1	5.5	<0.1	0.0	15	2.0	1.1	<0.1	0.1	0.0	0.0	14
D2	3.7	0.0	0.0	1.4	0.0	0.0	2	0.8	<0.1	0.0	0.3	0.0	0.0	12
D3/4	1.2	0.0	0.0	0.1	0.0	0.0	0	1.3	0.0	0.0	<0.1	0.0	0.0	3

Note:

[n13]: Number of units used (remainder were not used since materials were not collected consistently).

4.7 CHEMICAL ANALYSES ON SEDIMENT SAMPLES

The conclusions on the changing intensity of human activity at the site during the five major periods of stratum building are confirmed by sediment chemistry data produced by Gillieson from his 41 sediment samples.

The relationship between human settlement and high levels of certain chemicals has been an underutilised tool for archaeological analysis. While its use as sole evidence is limited, it is of considerable value in the confirmation of archaeological evidence. Chemical analysis of sediments has been employed to confirm human presence on a number of archaeological sites (Gillieson 1982a:392). In 1983, chemical analysis was applied to archaeological deposits from a wide range of sites on the Indian subcontinent (Joshi and Deotare 1983). The authors emphasise that the carbon, nitrogen and phosphorus content of sediments all increase with human settlement through food waste, human and domestic animal excreta and urine, and vegetable materials used for bedding, burning or the production of artefacts. However, on the surface, the high levels of these elements can decrease rapidly through leaching, bio-oxidation and chemical activity. The levels of carbon and nitrogen should decline proportionally during these processes. The level of phosphorus, on the other hand, is more stable and less liable to decrease with time, since it is not greatly affected by leaching and chemical change often converts phosphorus to an extremely stable form.

Some researchers, including Gillieson (1982a:393), believe that phosphorus can be added to sediments by leaching from buried bone. On the other hand, Joshi and Deotare (1983:98) state that 'bones do not substantially increase the phosphorus of archaeological sites' and they have done experiments on human burial pits to justify their claim. Gillieson believes that leaching from bone may account for some high phosphorus figures in Stratum D1. Another explanation may be that such readings indicate occasional periods of high levels of human activity during the Pleistocene. Potassium is produced largely from wood ash so that a high level of potassium can indicate an area in which fires had been lit by humans. Density levels of artefactual stone and burnt bone in Stratum D1/D5 confirm that there were occasional visits to the site by human hunters. There are, of course, many other factors which may affect the levels of certain chemicals in sediments such as the pH level, water flow and the nature of the parent rock.

I have discussed in Section 3.3 the way in which Gillieson (1982a: 392-401) allocated his 41 Nombe sediment samples to four groups and the interpretation of those results. He allocated each of these samples to a specific stratum. After my further work on the Nombe sequence I now disagree with his strata allocation in one or two cases. His groups (which I have renamed W, X, Y and Z) contain samples of similar sedimentological origin and nature but which can be widely separated chronologically and stratigraphically. I therefore present Gillieson's data according to my assessment of the stratigraphic and chronological position of each individual sample. Much of the information on which I base this was not available to Gillieson at the time he was writing. Table 4.4 therefore differs in some degree from his Table 54.

Table 4.14 Chemical analyses from Nombe sediments by Stratum group

Stratum	Position		C%	N%	K%	P%
A1	Top	Mean	5.93	0.10	0.28	0.64
		Std dev	2.25	0.05	0.22	0.22
		Range	2.9 – 8.46	0.05 – 0.16	0.13 – 0.59	0.39 – 0.93
3 Samples from Group W						
A1	Base	Mean	3.80	0.11	0.24	1.34
		Std dev	0.61	0.05	0.04	0.16
		Range	3.19 – 4.40	0.06 – 0.16	0.20 – 0.27	1.18 – 1.49
2 samples from Group W						
B4	Top	Mean	4.45	0.11	0.15	0.91
		Std dev	1.42	0.02	0.02	0.01
		Range	3.04 – 6.39	0.08 – 0.14	0.13 – 0.17	0.90 – 0.93
3 samples, 2 from Group X and 1 from Group W						
B4	Base	Mean	4.78	0.13	0.19	1.27
		Std dev	1.75	0.04	0.07	0.63
		Range	3.40 – 7.79	0.08 – 0.18	0.09 – 0.25	0.20 – 1.84
4 samples, 2 from Group Y,1 from Group X and 1 from Group W						
C	(Without Tephra)	Mean	1.31	0.09	0.11	0.25
		Std dev	0.28	0.01	0.02	0.16
		Range	1.06 – 1.74	0.08 – 0.11	0.08 – 0.14	0.12 – 0.51
4 samples, 3 from Group X, 1 from Group Z						
C	(Mainly Tephra)	Mean	0.62	0.04	0.11	0.14
		Std dev	0.37	0.02	0.07	0.07
		Range	0.06 – 1.19	0.01 – 0.06	0.06 – 0.26	0.04 – 0.23
3 samples from Group Y						
D1	Top	Mean	0.65	0.10	0.08	0.69
		Std dev	0.44	0.06	0.04	0.68
		Range	0.13 – 1.39	0.04 – 0.20	0.03 – 0.12	0.08 – 1.97
5 samples, 4 from Group Z, 1 from group X						
D1	Centre	Mean	1.12	0.08	0.13	0.53
		Std dev	0.88	0.01	0.02	0.29
		Range	0.40 – 2.36	0.07 – 0.09	0.07 – 0.18	0.16 – 0.88
3 samples from Group Z						
D1	Base	Mean	0.46	0.08	0.07	0.51
		Std dev	0.24	0.01	0.02	0.05
		Range	0.33 – 0.79	0.07 – 0.11	0.06 – 0.10	0.45 – 0.59
4 Samples from Group Z						
D2		Mean	2.32	0.09	0.08	0.41
		Std dev	1.93	0.02	0.02	0.05
		Range	0.39 – 4.24	0.07 – 0.10	0.06 – 0.10	0.36 – 0.46
2 Samples, 1 from Group X, 1 from Group Z						
D3 & 4		Mean	1.21	0.07	0.12	0.35
		Std dev	1.41	0.03	0.05	0.11
		Range	0.20 – 3.63	0.02 – 0.08	0.07 – 0.19	0.26 – 0.54
3 Samples from Group Z						

Gillieson gives comparable figures from natural limestone as: C 0.08%, N 0.05%, P 0.02% and K 0.03%. Bleeker and Healey (1980:860) give one example of a sediment sequence from Mount Elimbari at 1980m asl. It is a tropohumult sediment on limestone and its chemical constituents are:

Horizon	**Depth (cm)**	**N%**	**C%**	**K%**
A1	0-30	0.21	-	0.12
B2	30-180	-	0.4	0.06

Horizon A1 is a dark greyish brown (10YR 3/2) with dry dark brown clay (7.5YR 3/2) and Horizon B2 is a yellowish red (5YR 4/8 & 4/6) heavy clay. From its position and altitude it is probable that Horizon A1 is an old garden soil which would account for the high nitrogen and potassium readings.

Table 4.4 shows a number of clear trends, especially the high levels of all four elements in the Stratum B levels and the rapid drop in values below the base of that stratum. Low values for all four elements are present in the Stratum C samples with tephra-like deposits, as would be expected, and there are sufficient occasional high readings in Stratum D at all levels to suggest that some human activity took place throughout that period but was sporadic and never of sustained duration.

Individually the carbon readings show a wide range of high values throughout Strata A and B declining with Strata C and D but with a scatter of values well above 2.00% throughout the history of the site. Nitrogen shows similar trends, but there are no values of over 0.10% below the base of Stratum B. Phosphorus is very variable but generally declines with age under Stratum B, showing particularly low readings in the oldest strata, while potassium shows a steady decline below Stratum B.

There is no doubt that Nombe was most intensively utilised during the period from the end of the Pleistocene, about 10,000 bp to about 5000 bp, especially during the final 2000 years of that time. However, there is plenty of evidence to show that humans were active at the site during the late Pleistocene and had been making sporadic visits to Nombe from at least 33,000 bp onwards. Both density figures and chemical analysis confirm these trends.

4.8 SUMMARY OF EVIDENCE FOR HUMAN ACTIVITY AT NOMBE

The evidence from the density levels of materials indicating human presence further confirmed by chemical data and the index of burnt bone, all show the growing dominance of people at the rock shelter and cave of Nombe throughout the late Pleistocene period into the Holocene.

During the last 5000 years people have been very active at the site while probably living in settlements in the locality. There is strong evidence for frequent fire lighting and food preparation and consumption. The site was almost certainly used as a hunting base and more recently as a resting place on the frequently used walking track through the valley.

There is no doubt that the site was most intensively utilised by humans during the period from the end of the Pleistocene, about 10,000 to about 5000 years ago. The large quantities of artefactual stone, heavily burnt and broken bone, high proportions of egg shell and decorative shell as well as the confirming chemical evidence for human presence, all indicate the site was a base camp over this period.

Previous to that period there is evidence to show that humans were active at the site during the late Pleistocene (Stratum C). In particular the digging of Trench A1/2 ***P4,5*** must be examined as evidence for human activity at a time when other indicators such as the density levels and the chemical evidence from sediments point to only rare human visits. Only a small area of this trench was revealed in the excavations. The western side of the trench is extremely straight and appears to have been cut through the underlying clays with a sharp-edged artefact (such as a sharpened wooden spade of the type used within living memory by ditch cutters in the Baliem area of Irian Jaya and also recovered from swampy deposits at Kuk Tea station, Western Highlands (Steensberg 1980)). The angles between the side of the trench and the top of the redbrown clay on the western top edge and at the base of the trench are also still fairly sharp, especially at the southern end. This suggests that the trench had not been left open for very long. The filling in the basal 30-40 cm was a mixed clay, found to belong to Group X by Gillieson. Bones of extinct fauna were present in that filling alongside other bone. Higher filling included redbrown sediment typical of Stratum C with large fragments of tephra-like blocks tipped into the filling. It is only possible to guess the total shape and size of Trench A1/2. The decreasing dimensions at the southern end of the excavated section suggest that it may end a little further south, possibly opening on to the northern bank of the Stratum D1/5 stream channel crossing the site. The trench expands towards the northern end apparently heading for the unexcavated zone between the rock face and squares B3, C3 and D3. There is no trace of the feature in any other part of the excavation.

One possible function for the trench was as a drainage channel for water that had built up during the formation of Stratum C deposits in the northern areas of the site in which the tephra-like material had settled. During a periodic visit more space may have been required and it could have been decided to drain the gour-pool. The presence of the pool, the flowstone and tephra-like sediments may have given the site special significance. The trench, once the water had drained off, may have been backfilled quickly with some of the original filling mixed with whatever deposits were on the surface at the time. All indications, such as the straight sides, its positioning across the natural disposition of underlying sediments, the rapid refilling with sediment similar to the redbrown clay into which the trench is dug, demonstrate the trench's human origin. It does not seem possible to interpret it as a natural feature of the site.

The trench remained evident as a surface depression for a considerable period of time since Stratum B brown loams with high proportions of burnt bone fill the upper part of the trench. It was only during the later Holocene that human debris filled and obliterated the traces of Trench A1/2.

The presence of stone artefacts and a reasonable proportion of burnt bone indicates human activity at the site during the deposition of Stratum D1/5. It does not seem unreasonable to suggest that people came to the site for unknown lengths of time while hunting in the surrounding environment. The lack of charcoal, egg shell, and decreasing quantities of carbon and nitrogen in the sediments indicate that such visits may have been only occasional through the 10,000 year period. There are also indications that during this time the site was also subject to erosional factors such as periodic flooding, which could have removed archaeological material.

The lowest levels of the site (Strata D2/3/4) show no completely incontrovertible signs of human activity although a weak argument for the presence of humans can also be made. The bone from there will be treated at the present as the result of pre-human animal activity until further analyses of these specimens is examined later in Chapters 8 and 9.

Chapter 5

Comparisons with other Archaeological Data from the New Guinea Highlands

5.1 DISCUSSION

This chapter examines the evidence for human activity from other archaeological sites within the highlands of New Guinea during the last 26,000 years.

There are a number of sites that have been excavated within the highland zone of Papua New Guinea, beginning with Bulmer's excavations at Kiowa and Yuku (Bulmer 1966/76). There is a fundamental problem when comparing the published data from these sites with the Nombe material as presented in Chapter 4. White (1972) found comparison between his Eastern Highlands sites and those of Bulmer difficult, especially since his classification system for stone artefactual evidence was irreconcilable with that of Bulmer. There are similar difficulties comparing Nombe data with other data since no other researcher has published comprehensive information on the densities of all classes of data recovered in relation to the volume of deposit from which they came. Aplin (1981) does provide data from which the bone densities at Kamapuk can be produced. Where there are radiocarbon dates from other sites they are often difficult to reconcile with the stratigraphical subdivisions of the sites. Nevertheless, some useful comparisons can be made with excavators' published data including Christensen's posthumous data from two of his four excavations analysed and published by other researchers.

White's Eastern Highlands site data (1967, 1972) are the most valuable and comparisons can be made between Kafiavana, Batari and Nombe. All three produced evidence of human occupation during the Holocene period and for varying periods during the end of the Pleistocene. Two other sites that also appear to have been used over a comparable time period are Yuku and Kiowa, both excavated by Bulmer from 1959 to 1960. However, the data in Bulmer 1966/76 are not sufficiently quantified to make direct comparisons possible and I have only been able to make more generalised and hence less satisfactory comparisons. Christensen excavated an interesting set of sites at differing altitudes in the Wurup Valley in the early 1970s which had been actively used by people from the end of the Pleistocene and through much of the Holocene. The complete data are not available due to his death in 1974 before completion of the research. However, Aplin worked on the fauna from the site of

Kamapuk (Aplin 1981) and Mangi (1984) on the artefactual stone material from Manim. Table 5.1 sets out the available numerical data for the sites of Kafiavana and Batari.

Table 5.1 Quantities of archaeological material excavated from Kafiavana and Batari cave sites, Eastern Highlands Province, Papua New Guinea

KAFIAVANA		Range of ^{14}C dates	Stone artefacts no/m^3	Ochre g/m^3	Animals MNI no/m^3	Marine shells number
Horizon	I		95	54.1	5.2	5
	II	4 520 – 4 860	118	60.0	2.6	3
	III		100	126.7	4.0	3
	IV		100	111.0	2.8	1
	V		71	70.6	5.0	0
	VI	9 150 – 9 430	49	90.1	3.3	0
	VII	>9 500	47	10.1	0.3	4
	VIII	10 360 – 11 100	52	23.0	2.9	0
	IX		11	9.5	2.6	?1
Clay with extinct Pleistocene fauna			0	0.0	Present	0

BATARI		Range of ^{14}C dates	Stone artefacts no/m^3	Ochre g/m^3	Animals MNI no/m^3	Marine shells number	Casso-wary egg shell
Horizon	I	797 – 903	76	17.8	26.1	4	3.5
	II		133	45.6	23.6	0	6.0
	III		188	6.7	31.0	0	16.5
	IV Upper	8 040 – 8 420	80	14.7	45.6	0	1.3
	IV Lower	16 150 – 17 550					

Note
MNI: minimum number of individuals present
Source: Adapted from White (1972)

These density patterns echo the general patterns of change in the upper levels of Nombe. The quantities of artefactual stone increase below the top levels and are at their highest between about 4500 and 8000 bp, but remain in significant numbers into the Pleistocene. Although the faunal evidence is presented only in the form of minimum numbers of wild animals, this can provide some measure of change in quantity over more than 11,000 years. Kafiavana has low and rather erratic bone figures but Batari shows higher figures with a consistent rise in the quantities of animals from the present back through the Holocene. Like Nombe both sites have bone present in Pleistocene levels while other indicators of human presence (such as ochre, marine shell and artefactual stone) are slight or altogether absent.

Christensen (1975) recorded 88 sites within the Wurup Valley, in the Western Highlands, and excavated four in some detail to provide material for a comparison of the altitudinal, economic and environmental factors in land-human relationships within the area during the Holocene period. His analysis was incomplete at his death in December 1974 but two later workers have presented much of the evidence from two of these sites: Manim (2) and Kamapuk. Mangi (1984) has analysed many of the stone artefacts from Manim (2). No bones were recovered from this site and there is no quantification of shell or other materials.

Table 5.2 Quantities of archaeological material recovered from Manim (2) rockshelter, Western Highlands Province, Papua New Guinea.

Layer	Position	ANU No	Range	Artefactual Stone no/m^3	Ochre Present	Grindstones Present
I				3		
II	Top	1368	340 – 480	161		
III				24		
	Base	1370	2 270 – 2 490			
IV	Top	1371	2 210 – 2 390	59	Present	Present
	Base	1372	3 450 – 3 710			
Va				6 032	Present	Present
	?	1373	4 730 – 5 990			
Vb				18 442	Present	Present
Vc				3 333	Present	Present
	Base	1375	9 450 – 9 890			
VI				64		
	Base	1467	9 260 – 10 480			
	Base	1463	9 260+?			

Note: Stone artefacts include waste flakes as well as worked implements
Source: Adapted from Mangi (1984)

These figures indicate that the major period of human utilisation at Manim (2) was also from about 4000-c.9000 bp. Aplin (1981) carried out a most interesting analysis on the fauna from the small shelter higher up the valley than Manim. Here, although the bone was extensive, the other cultural evidence is extremely thin.

Table 5.3 Quantities Of archaeological evidence recovered from Kamapuk rockshelter, Western Highlands Province, Papua New Guinea

Stratigraphic units	ANU No	^{14}C dates range bp	Bone g/m^3	Axe flakes	Stone art.	Shell art	Bone art
I			347.50	7	-	-	1
I/II			396.06	6	3	-	-
II			681.45	2	4	2	1
Base	1326	2 470 – 2 610					
II/III			1 736.19	2	3	2	-
III			1 629.68	6	5	8	-
Base	1325	4 240 – 4 400					

Note:
Stone art: Stone artefacts
Shell art: Shell artefacts
Bone art: Bone artefacts
Source: Adapted from Aplin (1981)

The original table (Aplin 1981 Table 3.2) is confusing and I may have misinterpreted the totals of stone, shell and bone artefacts in each stratigraphic unit. However, minor variations will not change the fact that the number of artefacts throughout the entire occupation of the site is extremely low. It shows that the initial human use of the site in the first quarter of the fifth millennium bp produced large quantities of burnt and broken bone but these declined after a period of a little over 2000 years. It is not possible to compare this period of site use directly with the Nombe data since no subdivisions of cultural material are possible at Nombe over the last 5000 years.

Nevertheless, the bone density figures from Kamapuk provide the only directly comparative published data from any highland excavation. Bone density data were calculated from the data presented in Aplin (1981: Table 3.1 and Appendix Table A2.1). The comparable figures for Nombe for the period covering the last 5000 years are presented in Table 4.5 in grams/litre. The range for non wet-sieved units is 600-3700 g/m^3 and the figure for wet-sieved units is 6200 g/m^3. Although there is considerable overlap, the Nombe figures range higher than those from Kamapuk. The mean figure for all Stratum A units (detailed in Table 4.5) at Nombe is 1400 g/m^3 whereas that for all units at Kamapuk is 1005 g/m^3.

Bulmer's data are even more difficult to use in any comparisons. Her central highlands research was essentially a survey to identify potential sites and showed the wealth of sites for the first time. Excavations at the rockshelters of Kiowa and Yuku were completed by the end of 1960. Although large amounts of fauna, stone and other artefactual material were found no attempt was made to quantify total amounts of material recovered. While Bulmer provides a note to her readers that "the variation in area sampled should be kept in mind when considering the numbers of implements recovered from different levels" (Bulmer 1966/76:91), no further data are given on the actual volumes of deposit removed. I have therefore had to use the incidence of types of material within her rather vaguely defined categories for comparison.

Table 5.4 **Numbers of artefacts recorded from Kiowa rockshelter, Simbu Province, Papua New Guinea**

				Artefacts by frequency					Fauna
Level		Lab No	^{14}C Dates Range	Stone	Waste flakes	Shell	Pottery	Bone	MNI
1									23
2				152	226	2	3	1	726
3	top	1371	4 700 – 4 980	42	59	0	0	0	423
4				66	77	0	0	4	518
5				43	92	1	0	1	493
6	top	1370	5 940 – 6 260	38	64	0	0	0	408
7				80	139	1	0	2	339
8				96	325	0	0	1	476
9		1367	9 100 – 9 500	34	98	0	0	1	88
10A	top	1368	9 720 – 10 120	11	21	0	0	0	176
10B				21	41	0	0	0	327
11				6	0	0	0	0	290
12A	top	1366	10 210 – 10 490	19	69	0	0	0	221
12B ?									
12C									119

Notes: W.flakes: waste flakes

The faunal material was not all retained for analysis and only the cranial fragments of the already biased sample are represented here.

In the 1966/76 version of her M.A. thesis Bulmer gives much younger figures for four of the Kiowa radiocarbon results but since, in her 1979 unpublished paper she quotes the 1964 figures I have quoted those here.

Source: Adapted from Bulmer (1966/76: Table 2; 1979)

Table 5.5 **Numbers of artefacts recorded from Yuku Cave,Western Highlands Province, Papua New Guinea.**

Level	Lab No	^{14}C date range	Artefacts by frequency					Fauna
			Stone	W flakes	Shell	Wood	Bone	MNI
1			3	22	1	0	0	49
2			17	51	4	3	1	133
3A-B	GX3111B	4 350 – 4 790	64	264	1	0	1	523
C-D			56	164	0	0	0	129
4A			31	128	0	0	0	452
B			18	70	0	0	3	
C			4	5	0	0	1	
D-E	GX3113B ANU358	9 400 – 10 000 9 630 – 9 930	10	3	0	0	0	
5A			6	0	0	0	1	
B-C	GX3112B	11 760 – 12 440	7	5	0	1	0	
D-E			3	17	0	0	0	
6			1	0	0	0	0	46
7			23	17	0	0	0	69

Note:

In Bulmer (1966/76), seven layers (1-7) are identified. But in Bulmer (1979:Table 7) there are eight stratigraphic layers (A-H) and the relationship between these sets of information is not discussed. It is therefore possible that I have misinterpreted her data

Source: Adapted from Bulmer (1966/76: Table 7; 1979)

Bulmer's data may indicate that the period of major use for Kiowa rockshelter was in the Holocene period with two peaks after about 2500 bp and between about 6000-9000 bp. It may also indicate that at Yuku there was an increase in intensity of occupation may after 9400 bp with a peak about the middle of the fifth millennium. However, the figures may merely indicate changes in the quantities of deposit removed or functional or spatial variations in time or within the site. There is insufficient evidence presented to be certain that trends in site use are being shown.

Bulmer excavated another site in the Madang Province from 1972 to 1973. It is an open site called Wanlek situated on a grass ridge running across the Kaironk Valley near Simbai. The greatest density for stone artefacts, waste flakes and fragments of oven stones comes from Layers 3-5 and seems to indicate a separate period of settlement from the first Pleistocene occupation which contained postholes, charcoal and a few scattered stone flakes. The dates are as shown in Table 5.6.

Table 5.6 **Pleistocene radiocarbon dates from Wanlek, Madang Province**

Lab No	Date range bp	Excavation layer
GX 3328	11 570 – 12 420	Layer 9
GX 3329	13 700 – 14 500	Layer 13
GX 3331	14 650 – 15 500	Fill of posthole in Layer 9

Source: Bulmer (1976:Table 8.1)

Little can be said of this material except that it indicates human settlement at the site at the end of the Pleistocene period. The evidence for the erection of structures during the Pleistocene is interesting. Since substantial posts were recovered, this does suggest structures designed to last a considerable period of time.

The last set of data comes from sites in the Eastern Highlands and published by Watson and Cole (1977). Since the excavator, David Cole, was unable through ill health to analyse the material he had collected, the material was analysed by Virginia Watson, who was not present during the survey or excavation. The sites are open air sites and much of the material was only from surface collections. Eight sites were excavated (over 300 square metres) but most had little depth of stratigraphy and only two sites (NFB and NFX) have more than one radiocarbon date. Many of these sites could have been used over considerable periods of time but their material had to be treated as if it was from one time period. Watson designated a number of broad phases to cover the 76 sites surveyed; firstly the Mamu Phase (from before 18,000 bp to c.3000 bp) followed by the Tentika Phase (from about 3000 bp to the present). Since the time span is so wide this assemblage is not very useful for comparison with the Nombe data.

It is more useful to examine the assemblages from NFB and NFX, the only two sites in the group from which several ^{14}C samples were submitted (NFB has five ^{14}C dates and NFX has four, see Table 5.7).

Table 5.7 Radiocarbon dates from NFB and NFX open sites in the Eastern Highlands Province, Papua New Guinea

Site	Level	^{14}C Range bp	Lab.No	Site	^{14}C Range bp	Lab.No
NFB	C II	105 – 265	I 7286	NFX	11 370 – 11 650	UW 262
	C ?	1 975 – 2 145	I 7285		12 340 – 12 900	I 7284
	C III	2 975 – 3 165	UW 261		12 940 – 13 480	I 7284-C
	C III	3 400 – 3 660	UW 260		17 300 – 18 800	RL 370
	C III	3 790 – 4 130	RL 407			

Source: Watson and Cole 1977

These results seem to indicate clearly that each site was used over several thousand years, presumably involving several separate occupations which are not archaeologically distinguishable. For the purposes of comparison here, NFB can be compared with material from Strata A at Nombe and NFX can be compared with material from Strata C.

At NFB the following cultural material was recorded: stone artefacts (including 16 axe/adzes), pottery, house remains, pig enclosure, hearth, charcoal, earth oven, firecracker rocks, obsidian, ochres, mica, quartz crystals, stone bowl, stone club head, pig teeth, vegetable material and post-contact materials such as glass and metal. Everything on that list was present in Stratum A at Nombe except pottery, house remains, pig enclosures, mica and the stone club head (these are not present at Nombe in any time period). The structural remains at NFX were dated to 17,300-18,800 bp and corroborate the evidence at Wanlek. Ash and charcoal indicate the presence of hearths and there were a considerable number of stone artefacts.

5.2 CONCLUSIONS

These general results show broad similarities and are convergent with trends identified at Nombe. Despite the disappointing nature of other published material it is very important to note that no significant results from these other sites conflict with the Nombe analysis.

Little comparable material is available for the earlier periods at Nombe when human activity was sporadic. Such activity probably consisted of brief visits to the site, except for the evidence from Kosipe, Central Province, where stone artefacts were associated with the period 23,000-26,500 bp (White *et al.* 1970: 167) and thought to be remnants from seasonal visits to the mountains to harvest *Pandanus*. The Kosipe artefacts are similar to one from Nombe found in Stratum D1. Artefacts of this type have a pronounced "waist" or tang almost certainly for hafting. These "waisted artefacts" are discussed in Chapter 9.

By the end of the Pleistocene period human activity was evident on a number of archaeological sites throughout the highlands and the increase in human presence and activity from Nombe is widely echoed. Several of these sites show a peak in activity during the first half of the last 10,000 years with a marked decline during the last 4000-5000 years.

There is good environmental evidence showing the decrease of primary forest within the highlands in the Holocene, presumably due to garden clearance (Haberle *et al* 1991, Hope 1976, 1983a and 1983b, Powell 1982) and the increase in clearance and gardening could have been accompanied by changes in human settlement distribution and patterning. The last 5000 years of human activity at Nombe certainly show some changes, particularly a decrease in the quantities of artefactual material and burnt bone found at the site. These changes are not examined in detail in these thesis for lack of time.

Nombe alone has a sequence of fairly continuous artefactual and faunal evidence going back at least 24,500 years. This produces a unique set of evidence for documenting the arrival of people at a highlands site when the climate was very different to that experienced there today and the continued use of Nombe throughout the glacial maximum and into recent environmental conditions.

Analysis of the faunal data can highlight ways in which the surrounding faunal resources were targeted, as hunting by humans became a more dominant activity at the site in the late Pleistocene and early Holocene. The analysis of the faunal data could provide clues to the way in which human populations adapted not only to natural environmental change but with time and experience were extending their own activities and influence over the region. These aspects of Nombe are examined in Chapters 7 and 8.

A summary of the main periods of human activity at Nombe is presented in Table 5.8. These major periods are used as the basis for the faunal analysis in Chapters 7 and 8.

Table 5.8 Summary of main periods of human activity at Nombe

Stratum	Date range kyr	Main sediments	Human activity
A	0 – c. 4.5	Ash, top soil	Occasional hunting, resting place
B	c. 4.5 – 10	Brown loam, ash	Base camp
C	c. 10 – 14.5	Flowstone, tephra-like sediments	Occasional hunting ? site of special significance
D1/5	c. 14.5 – 25	Redbrown clay	Occasional hunting
D2/3/4	c. 25 – ?	Various clays	? Pre-human stratum. Very slight possibility of human activity

Chapter 6

Taphonomy at Nombe

6.1 INTRODUCTION

This chapter examines the taphonomic aspects (selective processes of accumulation and subsequent attrition) of the Nombe sediments and their contents. These processes are basic and fundamental to the development of site sediments and data interpretation yet they are overlooked in much archaeological work. Many researchers have contributed to the growing awareness amongst archaeologists of the need to address the fundamental processes of site formation and the origin and transformation of objects within those sediments. I have been influenced in particular by Schiffer (1976), Binford (1981), Brain (1981), Behrensmeyer and Hill (1980), Gifford (1981) and Shipman (1981a). The importance and value of taphonomy in Australia has been confirmed by the first conference on taphonomy held at the University of New England in 1987 (Solomon, Davidson and Watson 1990; Mountain 1990).

As a first step it is necessary to examine the extent to which agents have contributed, altered or removed materials to or from the site prior to excavation. The source and origin of material evidence must be established before it is possible to isolate and analyse the individual materials present, in particular the faunal data.

Several agents, both biological and physical, have added materials to the sediments that themselves are the result of geomorphological processes. It is incumbent on the archaeologist to discuss the origin and subsequent history of material that could have been deposited at the site by human agencies. It is necessary to establish whether artefactual material has been removed at any time from the position where it was discarded by its maker or last user, whether charcoal was the product of vegetation burnt by natural events or by deliberate human firing and whether bone was the end result of natural animal death in situ, or brought to the site during non-human or human predation. David (1984:66) writes that "we must be able to identify what is truly the results of cultural phenomena from what we can call 'background noise' or the results of non-human depositional and transformational activities".

The procedure chosen to review the processes of accumulation and attrition is as follows:

- ☐ identification of the agents of deposition present at Nombe (Section 6.2)

- identification of the agents of attrition present at Nombe (Section 6.3)
- review of the primary groupings of potential archaeological evidence (artefactual stone, charcoal, shell, metal/glass, vegetable matter and animal products) in light of the activities of those agents (Section 6.4)
- particular examination of the origin and post-depositional history of bone and other faunal evidence, since this is an especially complex issue (Section 6.5)

6.2 AGENTS OF DEPOSITION IDENTIFIED AT NOMBE

There are at least three sources for the materials that were added to the sediments: manufacture or alteration by human agents, introduction by non-human animal agents and introduction by geomorphic agents.

6.2.1 Materials manufactured or altered by human agents

These include:

- **artefactual evidence**, identified at Nombe in the form of complete or broken artefacts made of metal, glass, stone, ochre, bone and shell, and waste products from their manufacture;
- evidence from **hearths and cooking pits**, including concentrations of ash/charcoal, burnt and heat-cracked stones (only present in large quantities in the top two strata at Nombe) and burnt/charred materials (burnt bone present in considerable quantities and easy to identify in all but the lowest strata);
- **bone and other resistant substances** remaining from animal bodies, eggshell and vegetable matter discarded after consumption of the edible portion (bone present at Nombe in all strata, eggshell in all but the lowest strata, vegetable matter only in top levels);
- **human skeletal material** following injury, mutilation or death, either as inadvertent discards such as teeth or deliberate burials (only present in the top two strata) or some other process; and
- **chemical residues** resulting from human excretion.

6.2.2 Materials introduced by animal agents other than human

Materials which might appear to indicate human activity could have been introduced by other animals:

- **bone and eggshell** predated from elsewhere, brought to the site and discarded after consumption of edible portion (including materials that have passed through the guts of the consumer and been excreted in pellets/scats, etc); and
- **skeletal material** following natural injury or death at site (including snail shell).

6.2.3 Materials introduced by geomorphic agents

Objects such as natural charcoal, artefacts and debris originally deposited by human or animal agents or natural processes, can be moved by slopewash movement or water action and redeposited at archaeological sites. There is no evidence from Nombe of the introduction of such materials from outside the site. However, some redeposition may have occurred within the site, especially concentrations in the old stream bed and other hollows.

6.3 AGENTS OF ATTRITION AND POST-DEPOSITIONAL CHANGE IDENTIFIED AT NOMBE

Attrition of the materials that have been added to the geomorphic sediments begins from the time of their initial deposition. Attrition and change in the archaeological materials deposited at Nombe would have been affected by the activity of a number of agents. These include humans, animals, geomorphic activity and chemical/biological decay.

6.3.1 Human activity

Human activity would have affected the development of the site in a number of ways:

- ☐ Damage by trampling on existing deposits and their archaeological contents, particularly damage to bone and shell. Materials can be reduced beyond the limit of archaeological recognition. This occurred especially during the formation of the top two strata.
- ☐ Burning and charring of materials and artefacts in fires and ovens lit by humans. This activity was most marked in the top two strata.
- ☐ The removal of materials and artefacts previously deposited on the site. The process can involve further manufacturing, processing or use, or clearance of debris and sediments for hygienic or other purposes.
- ☐ Interference with earlier deposits and their contents through other human activities connected with settlement, drainage or burial. Direct evidence for such interference is found Stratum C (Stage 4 of the sedimentary history of the site). There is no doubt that this activity has caused considerable mixing of the archaeological evidence and therefore the loss of excavated material for analytical purposes. It probably also caused direct loss of Pleistocene material thrown up to the surface and subsequently washed or eroded away.

6.3.2 Animal activity

Animal activity is also likely to have modified the site:

- ☐ damage to or removal of deposited material. Rodents have been active at Nombe, where gnawing is particularly evident on the Pleistocene bones.

Predatory animals can eat or remove debris brought in by other predators. Pigs and dogs can trample and disturb deposits, scavenge bone and other food refuse. It is probable that such activity began with the appearance of these animals during the last few thousand years.

6.3.3 Geomorphic activity

The geomorphic development of the site can modify the human evidence as a result of:

- ☐ mechanical damage to materials through pressure of deposits;
- ☐ preservation of materials by deposition of $CaCO_3$; and
- ☐ redeposition of artefactual material within the site. In the Pleistocene levels this redeposition occurred especially during the build-up of redbrown clay in Stratum D1/5 when artefactual material was probably moved down the stream banks into the stream channel by gravity slip and flooding. Later, a similar process occurred during the build-up of Stratum B deposits at the beginning of Stage 5 when artefactual material was swept into the residual channel over the top of the redbrown clay filling the older stream bed. Water action (either direct stream action or seasonal flooding) would cause the removal of the lighter elements (particularly charcoal and small bone), leaving lag deposits of the heavier, larger bone and stone artefacts. Water action was frequent during the Pleistocene period at Nombe (Stages 1, 2 and 3) and therefore a high proportion of heavier artefacts (both stone and bone) might be expected in Stratum D. In fact, although there are large and heavy artefacts and bones present in Stratum D there is also a higher proportion of small bone present than in later strata. Water action cannot therefore be held responsible for the sorting of bone. Site development in the last 10,000 years was more stable with less evidence for water action. However, there is evidence for slopewash and some seasonal flooding during the accumulation of Strata B and A (Sections 3.5.6 and 3.5.7). It seems probable that artefactual material has been both removed from and redeposited within the site by seasonal flooding. The artefacts that have remained for excavation and analysis do not appear to have been subjected to continuous weathering or erosion. Many have been well preserved by the covering of clay sediment that was introduced to the site by such water and flood action.

6.3.4 Chemical/biological decay

- ☐ Biological decay is naturally present in any organic materials through the breakdown of biological substances after death. This has particularly affected the faunal evidence.

6.4 THE NOMBE EVIDENCE AND THE ROLE OF DEPOSITIONAL AGENTS

All excavated materials were examined for evidence that might indicate which agent/agents had been responsible for their deposition and/or subsequent alteration. There is no evidence that any of the materials found at Nombe had been introduced by geomorphic action.

6.4.1 Stone artefacts

Stone artefacts are often not thought to be as strongly affected by taphonomic processes as organic substances. In practice, they can be physically changed by weathering and erosion as well as being moved from the place of final discard. The effects of trampling and heat can transform artefacts and the study of such changes contributes to theories of human activity on sites (Hiscock 1990). There is little evidence on the stone artefacts recovered from any Nombe strata of continuous erosion or weathering such as might be expected from extensive water action or continuous rolling in slopewash deposition. The stone artefacts generally appear to be in good condition with fresh, sharp edges that indicate they were covered by sediment soon after they were dropped by the last user or maker. Artefacts are often coated with calcium carbonate but are fresh in appearance once this has been removed. Redeposition of artefacts has probably occurred, especially into the bed of the Pleistocene stream and the channel in the subsequent clay filling of that bed, causing a large build-up of artefactual materials in certain parts of the site and consequent thinning of artefactual evidence in others. Few areas of original human activity can now be identified below Stratum B.

6.4.2 Charcoal

Charcoal is extremely rare on the site except in the top few centimetres of Stratum A. The few samples collected are normally associated with recognisable hearths and with other clear evidence of human activity. Timber used for fires has generally been reduced to ash and powder by human activity but some small yet easily identifiable pieces have been incorporated into the sedimented materials of the Consolidated Block by a covering of calcium carbonate. However, it is difficult to allocate such finds to a particular stratum with certainty. The only charcoal identified from Pleistocene levels is from one or two discrete areas at the base of the redbrown clay where it is associated with burnt bone and fire-affected stone. There is no evidence that any of the Nombe charcoal was brought to the site by other than human agencies. It is probable that some of the charcoal originating on the site was later removed by periodic flooding or reduced by trampling to minute proportions, making it impossible to collect archaeologically. Gillieson identified carbon in the sediment samples throughout the sediment sequence and small quantities of burnt soil peds (Gillieson and Mountain 1983: Figure 5) although only in very small percentages in the lowest strata.

6.4.3 Shell

Three classes of shell were recovered from the site:

- ☐ **bird eggshell** is mainly present in the upper strata of the site where it appears in association with other evidence of human activity, badly crushed and fragmented. This is an indication of human predation as it is unlikely that other animal predators would carry eggs back to their lair.
- ☐ occasional fragments of **freshwater** or **marine shell** only occur in recent strata associated with human settlement as a result of food debris or trading activity.
- ☐ **snail shell**, often whole, undamaged and extremely well preserved, is present in greatest quantity in the Pleistocene clay strata where it is interpreted as a naturally occurring live element of the site unassociated with human activity. Snails are known to inhabit damp rocky caves and the large collections of snail shell in Pleistocene clay probably represent a group of snails overwhelmed by flood clay while æstivating. Most of the snail shell recovered from the Pleistocene strata was well preserved whereas all shell in the upper two strata was crushed and broken.

6.4.4 Modern materials

Modern materials, such as glass and metal, occur in Stratum A and show no evidence that they were deposited at any other times than in the recent present. There is one fragment of glass in Stratum B(B) which is presumed to have penetrated from a higher level.

6.4.5 Vegetable matter

This occurs only in Strata A and B and appears to be the result of human consumption or at least, collection of plants such as *Pandanus*. There are carbonised seeds preserved by a cover of calcium carbonate in the Consolidated Block of D79 (not included in this analysis). It is unlikely that Pleistocene plant material would have survived unless preserved in this way.

6.4.6 Bone and other organic substances from animals (teeth, carapace, claw)

It is bone and other organic substances which cause the main taphonomic problems, in particular the difficulties of identification as the product of human or other animal agents. The remainder of this chapter examines the most significant taphonomic factors in the further analysis of bone.

6.5 TAPHONOMIC PROBLEMS OF THE BONE ASSEMBLAGE AT NOMBE

6.5.1 Introduction

Bone occurs throughout the site and has been recovered in considerable quantities from Stratum D2 upwards (Table 6.1). The taphonomic problems of this set of data are very complex and must be addressed before the faunal evidence can be analysed.

In a site as complex as Nombe, where considerable changes have occurred over long periods of time, it is obvious that the deposition and attrition factors are more or less continuous and often contemporaneous. The archaeologist has to group the sediments and the archaeological evidence contained within them, into convenient divisions representing blocks of time in a bid to piece together the total processes of change at one site. The Nombe data for this purpose has been divided into five major strata (A, B, C, D1/5 and D2/3/4, see Chapter 4). In Chapter 5, in which the evidence for human activity was examined, Stratum B was divided into three further subdivisions so that the differences in human activity during the early Holocene could be compared. For an overall examination of the changes in faunal data it is not necessary to subdivide the data from Stratum B. Each division contains a body of faunal evidence which is analysed to interpret the overall situation within that division. This very artificial method of describing continuous change is one way of translating what is only a small fraction of the original total evidence into an interpretation of what might have actually happened in prehistory.

I follow the terminology of Klein and Cruz-Uribe (1984:3): all bone material that was left at the site over time is the **deposited assemblage**. At Nombe there would have been one deposited assemblage for each time period chosen, i.e. five in all. These five deposited assemblages have each been translated through time into a **fossil assemblage** that was available to the original excavator. Both White and I have removed a major amount of that fossil assemblage for analysis and publication. What each researcher removed from the site is their **sample assemblage**. From this point I add two further categories to those of Klein and Cruz-Uribe. Their sample assemblage is technically a **site sample assemblage**. The researcher then selects from this assemblage the material to be analysed: this is the **research sample assemblage** and may vary according the to topic being researched. This current analysis of Nombe is therefore based on a "research sample assemblage" which has to represent the five main time divisions, or strata, covering more than 30,000 years. For simplicity, the term 'sample assemblage' will be used in this study to refer to the 'research sample assemblage'.

Two of the three agents of deposition (human and other animal) (Section 6.2) were responsible for depositing faunal evidence at Nombe. All four identified agents of attrition (Section 6.3) subsequently affected that faunal evidence.

Section 6.5.2 examines the relationship between the faunal materials recovered through excavation (the site sample assemblage) and the total faunal material present in the site at the time of excavation (the fossil assemblage).

There are clear indications of a major distinction in the physical appearance of the faunal data from the top two Holocene strata (A and B) and that from the three Pleistocene strata (C, D1/5 and D2/3/4) and this question is examined in Section 6.5.3. Then follows a careful consideration of factors involved in the physical variation of bone at Nombe (Section 6.5.4) so that differences between the available sample assemblage and the originally deposited assemblage can be explored. Only then is it possible to discuss the original deposition of bone at the site, whether by animal or human predation or through natural death *in situ* (Section 6.6).

6.5.2 The relationship between the sample assemblage and the fossil assemblage at Nombe

The sample assemblage of faunal materials used in the present analysis is only a proportion of the fossil assemblage or total faunal materials available at the site at the time of excavation. Three factors which have reduced this proportion are examined.

Excavated material excluded from this analysis

The site was previously excavated by White in 1964, when large amounts of faunal material were removed (total amount not documented; see White (1972)). This material was not used in the present analysis.

The constraints of time and labour made it obvious that the total amount of faunal data from the author's excavations at Nombe between 1971 and 1980 was too large to be analysed for the thesis. Therefore there was a deliberate decision to exclude certain excavated areas from the present analysis, leaving a sample of all the areas excavated (Section 4.2.1).

The effects of excavation and laboratory procedures on the sample assemblage

Methods of bone collection in the field altered as the project developed (Section 2.4).

1971: Material from the upper two strata (A and B) was sieved through 6.5 mm wire sieves. Since the sediments in the lower strata (C and D) contained far more clay than those above, hand sorting had to be used to supplement dry sieving. An unknown proportion of the smaller fraction of archaeological material was lost through the mesh of the sieve or unrecovered by hand sorting.

1974-5: The same methods were employed as in 1971.

1979-80: The introduction of wet-sieving techniques produced much larger quantities of bone material (especially the smaller fraction) from all types of sediment. The increase in quantity of bone recovered by the wet-sieving technique is discussed in Section 4.3.

All bone recovered from the site was transported from the highlands to Port Moresby and then to the Australian National University, Canberra. Although care was taken to protect the bone as far as possible, some breakage inevitably occurred in transport and laboratory handling, especially among the large quantities of brittle, highly burnt and fragmented bone from Strata A and B.

Stratigraphic disturbance within the site

It became obvious during 1981-3, from the inconsistent results of the radiocarbon dating, that stratigraphic disturbance leading to inversion had occurred on the site during prehistoric time, particularly in the late Pleistocene deposits of Stratum C (Section 3.5.4). All archaeological units were then reviewed for the presence of any evidence of stratigraphic impurity. The mixing involved units at the base of Stratum B, through Stratum C and into the top of Stratum D. This disturbance incorporated the materials that had apparently been dug out from Stratum D towards the end of the Pleistocene and then subsequently thrown onto the existing surface. Programs of sediment analysis and further dating made it possible to identify units which contained earlier materials.

There are also two surface units of Stratum A that have been designated as mixed due to possible inclusion of materials from previous excavation dumps. This process resulted in the removal of 50 archaeological units (and all materials found within the 5.3 kg of sediment from those units) from the corpus under analysis (Section 4.2.2). Such mixed units were designated as 'mixed' in the computerised database. Table 6.1 shows the total quantities of bone recovered from the areas chosen for analysis at Nombe, as well as the final quantities of bone involved in the present analysis which remained after elimination of all mixed units.

Table 6.1 **Bone from squares used for analysis at Nombe grouped by stratum and sieving technique**

	Total units excavated			Non mixed units only		
Stratum	**Bone (grams)**	**Volume (litres)**	**No of units**	**Bone (grams)**	**Volume (litres)**	**No of units**
Wet-sieved units:						
Stratum A	736	119	18	736	119	18
Stratum B	7 376	188	32	7 215	182	31
Stratum C	1 624	156	32	307	43	10
Stratum D1/5	3 119	355	66	2 760	298	55
Stratum D2	274	74	13	274	74	13
Stratum D3	18	16	3	18	16	3
Totals:	13 147	907	164	11 310	732	130
Non wet-sieved units:						
Stratum A	6 946	5 343	45	6 736	5 273	43
Stratum B	24 967	5 961	77	22 250	5 610	69
Stratum C	702	1 090	12	302	700	7
Stratum D1	5 037	2 522	43	4 893	2 460	42
Stratum D2	2 252	325	8	252	325	8
Stratum D3/4	104	261	7	104	261	7
Totals:	38 319	15 561	193	34 847	14 688	177
Totals all units:	**51 465**	**16 469**	**357**	**46 157**	**15 420**	**307**

Note: Totals may not agree through rounding

This shows that although nearly 51.5 kg of bone were recovered from the areas of the site selected for analysis and washed, sorted and weighed, only just over 46.1 kg were considered sufficiently stratigraphically pure and unmixed to justify further analytical procedures.

The sample assemblage is estimated roughly to be 50-60% of the total fossil assemblage available at the site taking all these factors into consideration.

6.5.3 Physical properties of the sample assemblage

It was obvious from the first year of excavation that the bone material could be divided broadly into two groups.

- ☐ **Group 1**. The material from the upper strata (Stratum A and B dating from the Holocene period) was heavily affected by heat (presumably through contact with fire, embers and ashes) and included a high percentage of discoloured material (ranging from black and grey through dark brown to a mottling of brown and cream). The material was brittle and broke easily during excavation, transportation and laboratory handling. There appeared to be relatively few whole bones present (with the exception of an unusual set of bones from Stratum A in square C3), the range of fragment size seemed less than in Group 2 and there were many small, brittle and burnt fragments which could not be identified. The bone felt light in comparison to that from Group 2.
- ☐ **Group 2**. In contrast, the bone recovered from all varieties of Strata D (all Pleistocene in date) was remarkably pale, often a startling white, and appeared

to have been less affected by heat. It was much tougher and did not break as easily. The size range appeared to be greater, from very tiny whole bones to well-preserved large bones, and breakage seemed far less, with many complete and therefore more easily identifiable bones. The proportion of pieces that could not be identified due to fragmentation and burning seemed far lower. The individual pieces often felt heavy in comparison to similar sized pieces from the upper strata.

There is only a small quantity of bone from Stratum C and it does not easily fall into either group. It appears to contains elements of both groups.

One of the most suitable measurements to test this impression of significant physical differences between Groups 1 and 2 bone at Nombe would have been the size range of individual fragments and an assessment of completeness of individual specimens. However, when the initial decisions as to which methods of analysis were to be employed were made in 1980 (Section 7.2.2.2), it was decided not to take measurements on individual items of bone. Time did not permit detailed analyses of such a large quantity of bone nor were such measurements necessary for the aims of the faunal analysis (Section 7.1.1). The variables that were chosen (taxon, body part, weight and percentage of burning) would provide sufficient information. Therefore, quantification of the apparent differences between Group 1 and Group 2 bone had to be carried out using information as available. Table 6.2 shows the variation in physical characteristics through the proportion of burning (which certainly accounts for differences in colour and brittleness) and the proportions of unidentifiable bone present (which reflect both the brittleness and the levels of breakage present throughout the site).

Table 6.2 Physical variations between bone from Strata A/B and Strata D

	Group 1 Strata A and B				Group 2 All Strata D			
	Wet-sieved		Non wet-sieved		Wet-sieved		Non wet-sieved	
	%	kg	%	kg	%	kg	%	kg
Burnt bone	84	7.9	73	28.9	14	3.0	13	5.5
Unidentified bone	53	3.7	33	18.9	31	2.0	15	1.0

***Note*:** Percentages are by weight.

These figures certainly show a marked difference in both the percentage of burning and of unidentified bone for Groups 1 and 2. The factors accounting for these variations are discussed in Section 6.5.4.

In order to estimate the change in size of individual bone fragments between Groups 1 and 2, the fragments in a representative square (M71) which included both groups were counted and weighed and the mean weight calculated. This is not wholly satisfactory since a mean does not show the range of bone size. Further, completeness is not estimated by this method. The results are set out in Table 6.3.

Table 6.3 Variation in the weight of bone fragments from one square (M71)

	Units	Group 1 Strata A/B	Group 2 All Strata D
Mean weight of bone fragments	grams	0.7	1.9
Mean weight of identified bone fragments	grams	1.4	3.4
Mean weight of unidentifiable bone fragments	grams	0.3	0.4
% of unidentifiable bone (by no. of fragments)	%	66	53
% of unidentifiable bone (by weight)	%	36	12

The figures from M71 show that there is an increase in the mean weight of bone fragments, especially in the weight of identified fragments which increased by more than 100%. Although the unidentified fragments did not increase significantly in size they were certainly not present in such large amounts in Group 2 as in Group 1.

6.5.4 Factors involved in the physical variation in the Nombe bone

The interpretation of these differences involves a discussion of the factors involved in the processes of bone deposition, preservation and attrition (Sections 6.2 and 6.3).

Effects of chemical and biological change on bone through time

This is a vast and very complex topic. The nature of the bone itself (composition, completeness, shape and size) has an important part in the decay or preservation process (Shipman 1981a:21-41). For example, pieces with a high proportion of compact bone generally survive better than pieces with a high proportion of cancellous bone.

The composition of bone will change inevitably after death. Many of these changes will be diagenetic (caused by changes in the sedimentary matrix enclosing the bone), such as the addition of fluorine from ground water and compaction due to sediment pressure. Other changes are the result of biological decay, such as the decline in collagen. It is often difficult to distinguish between these changes and together they cause fossilisation and petrification, increasing the chances for the preservation of the bone. The chemical composition of bone and its change over time is attracting a great deal of research and the knowledge is advancing rapidly. A program of chemical testing was carried out by the Research School of Chemistry, Australian National University on a series of bone samples from Nombe. This was carried out initially to assist in the program of conventional ^{14}C dating. The elements monitored were hydrogen, carbon, nitrogen and fluorine. It was hoped that the results might show a general trend in decline of hydrogen, carbon and nitrogen with decreasing levels of human activity at the site and perhaps an increase in fluorine with age. At the same time it was realised that local site conditions, as well as variations in species within the samples and the effects of burning on the bone, might well interfere with such trends and cause variations that would mask them. Table 6.4 shows the results.

Table 6.4 Chemical tests in bone samples from Nombe

Stratum	H%	C%	N%	F%
A	0.43 – 1.12	2.32 – 6.71	0.00 – 1.13	0.01 – 0.21
Mean:	0.81	5.37	0.51	0.09
B	0.29 – 0.99	3.49 – 5.96	0.00 – 0.92	0.01 – 0.10
Mean:	0.73	4.75	0.37	0.05
D	0.31 – 0.78	2.02 – 6.09	0.00 – 0.17	0.03 – 0.23
Mean:	0.56	3.55	0.05	0.09
X	0.36 – 0.66	2.10 – 4.91	0.00 – 0.38	0.05 – 0.33
Mean:	0.54	3.27	0.07	0.13

Note: X refers to the bone chosen from those units where stratigraphic mixing had occurred. The bone analysed was of extinct fauna which is likely to have been displaced from its original sediment matrix (Stratum D) and which should therefore show chemical results similar to those bone samples taken directly from Stratum D.

Table 6.4 shows that there are considerable differences between the bone from the Pleistocene strata and that from the Holocene strata in terms of their hydrogen, carbon, nitrogen and fluorine content. There were insufficient samples available from Stratum C for testing. Nitrogen is known to decrease with chemical decay over time and eventually the collagen disappears altogether. This is evident from many bone samples in the Pleistocene clays, which renders them unsuitable for radiocarbon dating. Hydrogen and carbon show a decrease with aging of the bone, but it is unclear whether this is due to a natural decrease over time or to additional elements that have been added within the top strata from the increasing effects of human settlement. Fluorine can be added to bone from ground water over time. However, there is no clear trend for fluorine from the Nombe results and this may be due to the unsuitability of samples from a limestone cave, from a mixture in species of the samples provided or from the unavoidable effects of burning on samples from the Holocene strata. However a general trend of increase from Stratum B downwards is indicated. These results certainly help to explain the differences noted in the bone from the Holocene and Pleistocene strata.

Effects of heat on bone

Bone is affected in a number of ways when subjected to heat, flames and smoke. Discolouration and an increased tendency to brittleness and breakage are changes that are particularly obvious to the archaeologist. Factors affecting the colour change include temperature, the presence of oxygen, the quantity and properties of the fuel used, the size and density of the fragment, the amount of flesh still attached to the bone and the length of time the process continued. Classification of 'burnt' bone is difficult without resort to experimental data. Discolouration on bone can also be caused by chemical change from elements in ground water. Although there is no doubt that most of the bone classified as 'burnt' in the higher levels has been in a fire, it is far less easy to be sure that the smaller proportions of 'burnt' bone from the lower levels are the result of human action. This point is repeated in Section 7.2.2.1. Further literature on this topic includes Aplin (1981), Shipman, Foster and Schoeninger (1984), Spenneman and Colley (1988) and David (1990).

Section 7.2.2.1 includes a description of the methods used in classification of the Nombe discoloured bone. This can be compared with the classification employed by Aplin, where he discusses the attritional history of the bone from Kamapuk shelter (Aplin 1981:38). He divides that bone into three categories: calcined, burnt and unburnt (Table 6.5). The Kamapuk bone all falls within the last 5000 years, the time period covered by Stratum A at Nombe.

Table 6.5 Burnt and calcined bone at Kamapuk Cave, Western Highlands, Papua New Guinea

Time units	Burnt bone (%)	Calcined bone only (%)
I	32	4
I/II, II & II/III	33	5
III	33	4

***Notes*:** Burnt bone includes both categories
Source: Calculated from Aplin (1981: Table A2.1)

David (1990) classifies bone into unburnt, carbonised and calcined using colour variations, and attempts to show that short-lived natural bushfires cause less damage than do longer periods of exposure to heat in hotter, more intense fire.

Calcined bone occurs rarely at Nombe and where it does it is almost totally in the surface layers. David's classification might lead one to suspect that only the Stratum A bone was the product of human cooking fires and that the Stratum B bone was the product of natural firing. However, it is more reasonable to believe that heavily burnt (calcined and brittle) bone at Nombe was quickly reduced by human activity and became too small and powdery to be recovered or was removed by water action. Heat causes bone to become brittle and break more easily and there were considerable quantities of broken, 'burnt' fragments that were unidentifiable in the top two strata, suggesting that this bone had been subjected to the effects of many fires and that subsequent trampling had broken much of the burnt and charred material.

Table 6.6 Burnt and unidentifiable bone from Nombe

	Wet -sieved units			Non wet-sieved units		
	Burnt bone		Unidentified bone	Burnt bone		Unidentified bone
Stratum	Mean	Range	Mean	Mean	Range	Mean
Stratum A	62	10 – 98	37	67	16 – 95	47
Stratum B	63	0 – 100	23	79	6 – 100	53
Stratum C	35	0 – 96	33	41	2 – 95	25
Stratum D1/5	14	0 – 55	17	10	0 – 60	32
Stratum D2	3	0 – 93	12	14	0 – 14	23
Stratum D3/4	3	0 – 5	23	0	0 – 0	83

Note: Range is the range of percentages of burnt bone in all units of each stratum.

It must be remembered that the quantity of sediment (and therefore of bone) available in Strata C, D2 and especially in D3/4 was limited (see Tables 4.10 and 4.12).

Table 6.6 shows that the percentage of burnt and unidentifiable bone is higher in the top strata and that the percentage of burnt bone declines very steeply below those strata. In the surface units of the site the bone is very variable in appearance and in some units the proportion of unburnt bone is high, especially in places that are well protected. In more exposed areas the percentage of unburnt bone drops to low levels. It is likely that any unburnt bone retaining edible parts were removed quickly by scavenging dogs (present only late in the sequence). Human activity produces a high level of burnt and brittle bone that resists the process of chemical change but is more likely to splinter into small unidentifiable fragments with subsequent trampling. As the level of human activity declines and the likelihood of water action increases, so the percentage of burnt and unidentifiable fragments declines and the number of identifiable bones increases. The high percentage of unidentifiable bone in the three wet-sieved units from Stratum D3/4 is probably misleading due to the small size of the sample and the presence of heavy, immovable, cemented calcium carbonate and clay inside a large piece of unidentifiable bone, so increasing its weight. Another small sample is present in the Stratum D2 bone from the non wet-sieved units. A total of 526 gm was recovered and there was dark staining on a few fragments which, although of a very different nature from the usual dark brown staining found at higher levels, was finally classified as 'burnt' since there was no way to test for mineral staining. The weight of these fragments was sufficient to give a figure of 14% 'burnt' bone from that unit overall.

Effects of sediment matrix on preservation

Bone quickly covered by sediments containing a high proportion of clay (and thus protected from atmospheric decay) can be well preserved for thousands of years, whereas bone covered by fine ash and loam is more vulnerable to fast decay by chemical and biological agents.

Table 6.7 shows the variation in the bone material of similar age and deposited under similar circumstances but recovered from different sediment matrices. This table suggests that the nature of the sediment matrix may play a significant part in the preservation (and therefore recovery) of faunal data. But the only way that this can be tested is by practical experiments.

Table 6.7 **Variations in physical state of bone from Nombe Strata B by sediment groups**

	Non wet-sieved units		Wet-sieved units	
Sediment type	Burnt bone %	Unidentified bone %	Burnt bone %	Unidentified bone %
1	84	31	92	53
2	44	44	41	54

Notes: Sediment type 1 includes brown loams with many bones: Strata B4 and B9.
Sediment type 2 includes redbrown clays: Strata B3, B6, B8 and a black loamy clay Stratum B7.

Effects of mechanical reduction of bone

Various agents are responsible for the breakage, crushing and fragmentation of bone at a site. These include human activities such as cooking, mastication and discard, trampling on any current surface or disturbance into levels below the current ground surface, chewing and crunching by carnivores and rodents, scavenging by pigs and other animals, physical movement by water and damage from falling stone or weight of sediment. The degree and nature of any chemical change in the bone may increase this damage or protect the bone against further reduction.

Table 6.8 **Variation of burning and brittleness of bone in the top strata of Nombe (Strata A and B)**

	Non wet-sieved units		Wet-sieved units	
Stratum	Burnt bone %	Unidentified bone %	Burnt bone %	Unidentified bone %
A	57	32	69	47
B (Top)	71	27	88	50
B (Centre)	86	12	93	57
B (Bottom)	78	25	41	54

Table 6.8 shows that the proportions of burnt bone increase from Stratum A into the first two levels of Stratum B, then decline slightly. This probably suggests that most unburnt bone was removed from the surface fairly soon after deposition, leaving high levels of burnt bone in levels where human activity is high. The levels of unidentified bone are higher in the wet-sieved units than for the non wet-sieved units showing that a higher proportion of the smaller unidentifiable broken fragments were being recovered by the wet-sieving technique.

6.6 IDENTIFICATION OF PREDATOR ACTIVITY AND BONE ACCUMULATION

Most of the bone at Nombe originated as prey of either human hunters or other animal predators. It is necessary to examine the bone from the five sample assemblages to decide which predators (other than humans) were active at each period of time. Klein and Cruz-Uribe (1984:6) state that 'the principal criteria for inferring the bone collector are sedimentary and geomorphic context, the objects associated with bones, and the surficial characters of the bones themselves'. The sedimentary/geomorphic factors are addressed in Chapter 3 and the association with other objects and signs of human activity is addressed in Chapter 4. Surficial features include teeth marks, damage from artefact use and fracture patterns. To identify the species of predator involved I would add analysis of species range, the body size of species present and the proportions of particular body parts.

J. Hope (1973:6), in her analysis of bone from Clogg's Cave, suggests some features that may indicate carnivore predation:

- ☐ the presence of bones from the carnivore involved.
- ☐ the presence of animal faeces or coprolites, and
- ☐ indications of damage on bones by teeth marks or particular fracture patterns associated with predation by certain species.

There were no faeces or coprolites recorded in the Nombe deposits but the two other factors can be discussed further.

6.6.1 Predators identified at Nombe

It is extremely likely that animal agents other than human were active on the site and contributed bone, both through their own death and, to a greater extent, through their predation strategies. The following species have been positively identified at Nombe:

- dog (*Canis* sp.),
- thylacine (*Thylacinus cynocephalus*),
- dasyurids (*Dasyurus albopunctatus*), and
- a number of birds of prey including owls (*Tyto alba*, *Tyto tenebricosa* and a species of *Ninox*) and the raptor *Harpyopsis novaeguinae.*

Table 6.9 shows the strata in which the remains of these predators were found.

Table 6.9 Predators at Nombe identified from faunal evidence

	Stratum							
Predators	**A**	**B Top**	**B Centre**	**B Bottom**	**C**	**D1/5**	**D2**	**D3/4**
Homo sapiens sapiens	P	P	P	-	-	-	-	-
Canis sp.	P	-	-	-	-	-	-	-
Thylacinus cynocephalus	P	-	P	P	P	P	P	-
Dasyurus albopunctatus	P	P	P	P	-	P	P	-
Harpyopsis novaeguinae	-	P	P	P	-	-	-	-
Tyto alba	P	-	-	-	-	P	-	-
Tyto tenebricosa	-	-	-	P	-	-	-	-
Ninox sp.	P	-	-	-	-	-	-	-

P = Present

No remains of any predator were recovered from the lowest Stratum (D3 and D4), in which only small quantities of bone were excavated, but both the thylacine and the dasyurid were present in Stratum D2 which has no positive signs of human activity. There is a discussion in Chapter 4 of the evidence for human presence and activity at the site which concludes that evidence for human predation was clearly dominant only in the top two strata although people were obviously active at the site from Stratum D1/5 onwards and the presence of humans at the site in the basal levels cannot be totally discounted.

Canis sp. only occurs in Stratum A and was probably present as a hunting companion and camp scavenger (Section 8.2).

Thylacinus cynocephalus remains were found in most strata dating from 33,000 years bp upwards and was obviously a major predator at the site, perhaps living in the cave for shorter or longer periods. It was the largest indigenous predator that was coexistent with human occupation in New Guinea although the New Guinea examples seem to have been smaller than the Australian examples (Section 8.2). The maximum number of fragments recorded from this species occur in Pleistocene levels - Stratum D2 has 10 specimens (46.9 g) and Stratum D1/5 has 22 (110.7 g). Translated into percentages, 50% of the thylacine remains (by weight) or 52% (NISP) occur in Stratum D1/5 and a further 21% (by weight) or 24% (NISP) in the Stratum D2. I believe there is little doubt that the species used the site as a den and that thylacines were at least sporadic site occupiers throughout the late Pleistocene period. These Pleistocene specimens are likely to have resulted from natural death *in situ* or predation by other thylacine at times when the site was used as a den. I have not found any direct reference indicating whether the thylacine will consume its own species, but the wolf certainly does (Mech 1969:180). It is also possible that humans successfully hunted the animal at times during the Pleistocene.

The thylacine bones from Strata A and B display a high proportion of burning (common to all bone from these strata). The bone from the top two strata (A and B) together represent less than one quarter of the total recorded number of specimens or total weight. These animals may have been victims of human predation.

The introduction of the dog probably caused competition for prey between the two species and this, together with predation by *Homo sapiens*, may have been responsible for the disappearance of the thylacine from most regions of New Guinea and Australia (Section 8.2). Both thylacine and dog were present at some time during the last 5000 years at Nombe.

Dasyurus albopunctatus is a smaller predator (the largest only reach about 700 g) than the thylacine. Recorded remains (Section 8.2) from the upper strata are probably the results of human predation since the high proportion of burnt bone and artefacts throughout those levels indicate a high level of human activity, leaving little possibility that other predators apart from raptorial birds were able to use the site. Bone from Strata A and B represents half of the recorded dasyurid bone by weight and two-thirds by number of fragments. The bone from Stratum D1/5 and D2 could represent either the prey of humans or of thylacines or the natural death of animals while using Nombe as a lair.

Smaller dasyurids have not been included in Table 6.9 since none is identified to species level and they are more likely to have lived in the forest surrounding the site rather than in the cave. Their post-cranial remains probably represent human, raptor or owl predation in the Holocene levels and prey of either humans or one of the larger predators living on the site during the Pleistocene. Unspecified small dasyurid cranial remains were recorded from Strata A, B, D1/5 and D2/3/4.

Raptor and owl remains are distributed throughout the upper and lower strata (missing only from the small volumes of Strata D2 and C sediment) and presumed either to be from human predation or to have come from natural death in cliff roosts above the site, regardless of human presence at Nombe (see Section 8.2).

Highland **snakes**, mainly elapids and boids, are likely to have been natural occupants of the site at times and are certainly predators of other small mammals. It is unlikely, however, that they contribute bone through their own predation strategies as their gastric juices and venom work over several days to dissolve their prey thoroughly (Young 1981:284), so that no identifiable bones remain (Section 8.2).

The remains of recent predators such as the feral domestic cat (introduced after European settlement) do not occur and these animals are unlikely to have contributed significantly to the archaeological deposits at Nombe.

6.6.2 Identification of predator species through bone characteristics

Attempts to gain a clear indication of which bone has been contributed by which predator are complex and difficult. Within Australasia several attempts have been made using faunal data from archaeological sites to disentangle the remains of human predation from those of various carnivores (Hope, J. *et al* 1978; Bowdler 1984; Flood 1980; Baynes, Merrilees and Porter 1975). Australian researchers are also now working on the identification of features in bone deposits caused by particular local species (David 1984; Geering 1990; Solomon and David 1990). In other areas of the world there is now a large body of interesting work on the interpretation of bones from large species (Haynes 1981, 1983, 1990; Foley 1983; Frison 1987; Binford 1987) and from small species (Andrews 1983; Avery 1982; Dodson and Wexlar 1979; Korth 1979; Hoffman 1988) and the identification of bone from animals hunted by humans from many deposits (Binford 1981; Brain 1981; Gamble 1983; Payne 1983).

The present analysis of the Nombe data has had to be limited to very straightforward techniques that could be accomplished given the time constraints and overall aims of the work involved.

Fracture patterns as indications of species activity

Shipman (1981a:104-108) discusses some of the problems involved in the study of breakage patterns on bone. This work is contentious and has been heavily criticised, as has Shipman's interpretation of humanly scavenged bone based on possible marks made by artefacts (Shipman 1983; Gifford-Gonzales 1989). All of this work, at early hominid sites in Africa, was carried out with large animal species. The average body size of the Nombe fauna is small (between about 0.30 and 3.0 kg), although there are a few larger species, especially the thylacine, macropodidae and large flightless birds present throughout. The average small bones therefore occurring in the deposits are very easily broken and do not retain clearly identifiable breakage patterns, especially from the upper strata where the effects of burning are paramount. The study of breakage patterns might be worthwhile on the larger well-preserved fragments of bone (especially perhaps the echidna bone) in the Pleistocene levels, where it is extremely likely that the thylacine, in particular, was an active agent for bone collection.

Shipman (1981a:111) states that carnivores generally prefer particular skeletal elements, including vertebral spines and gonial angles of mandibles, ribs (often cracked) and scapulae, ilia and the ends of long bones (all frequently chewed). Teeth marks are present on some bones but although rodent gnawing is evident throughout the stratigraphy, marks which are specific to either dog, thylacine or dasyurid and which can be identified easily by the naked eye have not been isolated. Artefact marks have also not been identified on the Nombe bone. However, because of the length of time involved with more basic sorting, weighing and identification, there was no time for a program of examination for specific damage to any bone. Such evidence might result from the use of a high-powered or scanning electron microscope in work similar to that of Shipman (1981b) and Shipman and Rose (1983). Microscopic studies might also identify bones that had been exposed to digestive juices, as in Geering's work on bone from owl pellets of *Tyto novaehollandiae castanops* (Geering 1990). It is difficult to identify such marks on heavily burnt and fragmented bone but would be possible on the bone from the Pleistocene levels. However, no studies of thylacine or *Dasyurus albopunctatus* bone collecting or damage marks have been carried out which could serve as a basis for examination or interpretation of the Nombe bone.

Predation habits of thylacine

We need to examine what is known of the predation habits of the animal to see if any features can be isolated and recognised in the bone.

The thylacine clearly had dens or lairs to which it took prey (see Section 8.2). Bone would accumulate from uneaten parts of the prey, provided it was covered before being scavenged by other smaller predators, and also from the consumed bones passed out in a scat (Mellett 1974) and subsequently buried by sediment. It is not known in detail which parts of any species were more often left unconsumed, but Mech (1969), working on the wolf, says that smaller prey are often consumed entirely, whereas the skull, mandible, vertebrae and long bones of larger prey (eg adult moose) are left. Other smaller bones could be crunched, swallowed and excreted from the body in a scat. It is not known whether the thylacine chewed or gnawed bone, as for example Haynes (1981) has found on bone at wolf dens, but no obvious marks have been identified at Nombe that suggest thylacine gnawing.

If no particular features of bone collection can be isolated, perhaps differences in the overall patterning of body parts from one species over time might suggest different predation strategies. It was decided to compare the proportions of major body parts between material from a late Pleistocene stratum (where the bone could be the result either of thylacine or human predation) and that from an early Holocene stratum (presumed to be the result of human predation). Three species with well-preserved large bones were chosen, a large macropod (*Dendrolagus* spp.), cassowary and

Zaglossus, all too large to have been predated normally by *Dasyurus albopunctatus*. Table 6.10 shows the results.

Table 6.10 Body parts of *Zaglossus*, Large macropod (*Dendrolagus* spp.) and cassowary from Strata B and D1/5

	Stratum B		Stratum D1/5	
Body part	NISP	%	NISP	%
ZAGLOSSUS BRUIJNII				
Cranial	16	17	23	7
Axial	27	29	166	50
Forelimb	36	39	84	26
Hindlimb	12	13	45	14
Extremity	2	2	10	3
Totals	93	100	328	100
Weight	250 g		1250 g	
LARGE MACROPOD (*DENDROLAGUS* SPP.)				
Cranial	70	19	49	20
Axial	125	33	96	39
Forelimb	51	13	23	9
Hindlimb	36	10	11	4
Extremity	96	25	70	29
Totals	378	100	249	100
Weight	960 g		1100 g	
CASSOWARY				
Cranial	8	3	0	0
Axial	127	47	34	85
Forelimb	25	9	1	3
Hindlimb	60	22	1	3
Extremity	53	19	4	10
Totals	273	100	40	100
Weight	1194 g		110 g	

Totals may not agree because of rounding.

There is sufficient similarity in these results (especially in the case of the large macropod) to suggest that the same predator (human) was working during both periods, on the reasonable assumption that the behavioural patterns of discard over the time period concerned were not significantly different. However, there are significant differences, especially in the higher proportions of axial fragments in the Pleistocene cassowary and *Zaglossus* bone, possibly pointing to different predators. The cassowary data are not as satisfactory since there is very little cassowary bone in the Pleistocene. This suggests different predation strategies, possibly involving the discard by Pleistocene thylacine of bones such as ribs and vertebrae with less edible flesh but a higher total destruction of bone in more fleshy body parts. A thylacine would certainly have been capable of eating all *Zaglossus* bone. Human consumers of the same animal would probably discard most *Zaglossus* bone after eating the meat. Unfortunately the only animals with really heavy bone (diprotodontid and *Protemnodon* species) which could retain butchery marks occur in very low numbers and only in the Pleistocene strata.

It has not proved possible with the techniques and time available to distinguish bone from thylacine predation from that produced by human hunters in the Pleistocene levels, but it is most likely that both were active.

Predation by birds of prey

Four species were identified from the Nombe deposits*: Harpyopsis novaehollandiae, Tyto alba, Tyto tenebricosa, and Ninox sp.* All four predate smaller prey and regurgitate bone in their pellets but each species has a different level of stomach acidity which results in highly variable proportions of regurgitation from the original amount ingested (Dodson and Wexlar 1979). The authors state that owls may be very selective in their choice of food species, often relying heavily on one particular local species, but they did find that barn owls (including *Tyto alba*) take 95% of their prey in the mouse-size range, which would fall in the 'very small animal' range used in the Nombe analysis. Dodson and Wexlar (1979:282) also state that 'due to their strong tendency to digest bone the diurnal predators, (including eagles), would seem to have a poor potential for contribution to the fossil record'. Hoffman (1988: Tables 1 and 3) shows clearly that the large diurnal birds of prey, in this case hawks, absorb a far higher proportion of consumed prey than owls and the bone regurgitated by hawks was often damaged and fragile.

Menzies has identified the bones from pellets found in four roosts of *Tyto tenebricosa* collected by Bulmer at about 2400 m in the Kalam area of the Bismarck-Schrader Ranges (Majnep and Bulmer 1977:119). The numbers of bones and the species involved are clearly shown in Table 6.11. The following analysis makes it clear that most of the prey were of the 'very small animal' body size but that significant catches were taken of 'small' species and an occasional 'medium' species was captured. (The body size classification used here is discussed in Section 7.5.2.) The ecological niches of such prey extended from primary undisturbed forest to gardens and disturbed areas and from arboreal to terrestrial habitats. *Rattus exulans* is the commonest rodent found around human settlements today and *R. ruber* (see note below Table 6.11) likes gardens and garden fallow.

Table 6.11 Bone from owl pellets (Schrader ranges, 2400 m)

Size category	Species	Minimum numbers	Proportion (%)
1-5kg	*Mallomys rothschildi*	1	
	Sub-total	**1**	**<1**
300g -1kg	*Pseudocheirus forbesi*	17	
	Microperoryctes longicauda	9	
	Parahydromys asper	1	
	Macruromys major	1	
	Sub-total	**28**	**23**
<300g	*Petaurus breviceps*	9	
	Cercartetus caudatus	4	
	Pseudocheirus mayeri	1	
	Antechinus melanurus	4	
	Pogonomys sylvestris/mollipilosus	32	
	Pogonomelomys sevia/mayeri	11	
	Melomys rufescens	3	
	Melomys platyops	1	
	Melomys lutillus	1	
	Rattus ruber/exulans [a]	21	
	Rattus niobe	2	
	Nyctimene ? cyclotis	3	
	Synconycteris crassa (now *australis)*	2	
	Sub-total	**94**	**76**
	Total	**123**	**100**

Note: a: The problems of the classification *Rattus ruber* have been discussed by Calaby and Taylor 1980. I think it likely that the specimens referred to by Bulmer would now be classified as *Rattus steini* or *Rattus verecundus* (Taylor, Calaby and van Deusen 1982).
Source: Majnep and Bulmer (1977:119)

Menzies also identified bones from four grassland roosts of either *Tyto alba* or *Tyto capensis* between 1600 m and 1800 m in the Kalam area (Table 6.12)

Table 6.12 Bones from owl pellets 1,600-1,800 m in the Kalam area.

Size category	Species	Minimum numbers	Proportion (%)
300g-1kg	*Microperoryctes longicauda*	1	
	Sub-total	**1**	**1**
<300g	*Cercartetus caudatus*	1	
	Pogonomys species	1	
	Pogonomelomys ? mayeri	1	
	Rattus exulans/ruber[a]	114	
	Sub-total	**117**	**99**
	Total	**118**	**100**

***Note* a**: See note on *Rattus ruber* in Table 6.11.
Source: Majnep and Bulmer 1977:120. From four grassland roosts of either *Tyto alba* or *Tyto capensis*

While *Cercartetus*, *Pogonomys* and *Pogonomelomys* are at least partly arboreal, the small bandicoot *Microperorycte*s and the *Rattus* species are terrestrial. This suggests that owls will hunt over a wide variety of ecological niches. However, the very high number of bones from *Rattus* spp. certainly confirms that barn owls often tend to concentrate on particular species, Tables 6.11 and 6.12 clearly indicate the overwhelming abundance in the 'very small animal' body-size range. In recent times, the prey has obviously included large quantities of the rats that live close to, or in, human settlements. Korth (1979) has also examined bone from owl pellets showing that the animals present tend to be predominantly nocturnal or crepuscular mammals (generally rodents) and some birds. He also examined hawk pellets and found that these contained partially digested and heavily etched bone.

As far as Nombe is concerned, these research results have a few obvious implications: first it seems clear that *Harpyopsis novaeguineae* is unlikely to have contributed much bone to the deposits, secondly, major contributors may well have been *Tyto alba* (the barn owl) and *Tyto tenebricosa* (the Sooty owl); and finally, that the proportions of the 'very small animals' category must be examined in an effort to isolate owl bone within the deposits (Section 6.6.3.4).

One feature of bone noted in Dodson and Wexlar (1979) is that bone from barn owls is relatively undamaged. In square C3, directly under the cliff wall, there is a collection of well-preserved, unburnt bone in the top level. This might have been the result of owl pellets falling from the cliff above into the deposits. In order to test the idea, a comparison between that bone and bone of similar age and similar site position, but showing a more normal index of burning and breakage, was undertaken. Table 6.13 provides the details of this comparison. An explanation of the size range is given in Section 7.5.2.

Table 6.13 Comparison of bone from Stratum A in square C3 with bone from Strata A in square B71

		C3		B71	
Species adult body weight		mass g	%	mass g	%
Large:	over 5 kg	253.0	26	78.9	21
Medium:	5 - 1 kg	685.6	70	269.2	71
Small:	300 g - 1 kg	35.8	4	27.9	7
Very small:	less than 300 g	0.2	<1	1.3	<1
Totals:		**974.5**	**100**	**377.3**	**99**

The ratio between the four groupings is very similar in both cases. The high proportion of bone from large animals, does not suggest a significant contribution from birds of prey for either assemblage. An analysis by minimum numbers or numbers of individual specimens would raise the proportions of the smaller animals but would be likely to show marked variation between the two data sets. Since the bones from B71 are heavily burnt and subsequently broken and associated with human artefacts it is assumed that they represent largely the results of human predation. If this is true then it is unlikely that the assemblage from C3 represents a total group of prey from a raptor or owl on the cliff above the site although there may be a small proportion of pellet material present in both.

Abundance of 'very small species' bone at Nombe

Smaller predators such as the dasyurids and owls will accumulate high percentages of bones derived from small mammals, amphibians and reptiles, whereas larger predators will concentrate more on larger prey and are less likely to accumulate large proportions of small bone. Therefore it is of interest to look at the proportions of small bone through the site. Table 6.14 shows the percentages by weight, numbers of identified specimens (NISP) and minimum numbers of animals (MNI) for the small species for each major stratum as a proportion of the entire accumulation in each stratum.

Table 6.14 Proportion of 'very small species' in the entire faunal evidence

	MNI[a]		NISP[b]		Mass	
Stratum	Number	%	Number	%	g	%
A	17	4	88	2	19	<1
B	48	3	255	2	61	<1
C	16	30	81	15	8	2
D1/5	140	38	769	21	65	1
D2/3/4	30	40	171	29	26	3
Totals:	235		1364		179	

Notes:

'Very small species' includes bone from the following species: small ringtail possums (including Petaurus breviceps and Pseudocheirus mayeri), small dasyurids, small murids (including Pogonomelomys sevia and Melomys rubex), small bats (including Rousettus sp.), small and tiny birds (including small passerinae, small columbidae, small galleriformae and psittacidae), small reptiles (skinks and lizards), frogs.

[a] MNI: minimum number of individuals

[b] NISP: count of all identified bone fragments

Table 6.14 clearly shows that the proportions of the 'very small species' are significantly higher in the Pleistocene levels (if judged by the number of individuals or number of specimens present) than in the later Holocene strata where it is of little importance in the overall abundance of bone by all three methods of documentation. An important consideration in interpreting these results is the employment of wet-sieving techniques (the only method that will effectively recover very small bones). This matter is discussed in Section 4.3 and Table 4.2 shows that there was a higher number of wet-sieved units in Strata C and D1/5 than in the strata below or above so it may be assumed therefore that these strata would show a higher percentage of smaller bone. In order to see whether the higher percentages of small bone in the

Pleistocene strata are simply the result of increased wet-sieving, an analysis was run on a site sequence of entirely wet-sieved units. The results are shown in Table 6.15.

Table 6.15 Proportion of 'very small species' to total bone (Wet-sieved Strip)

	MNI		NISP		Mass	
Stratum	Number	%	Number	%	g	%
A	39	25	66	11	9.4	2
B	68	18	151	3	21.9	<1
C	19	25	66	4	5.5	3
D1/5	142	70	530	75	35.8	8
D2	37	52	134	66	18.2	9
Totals:	305		947		90.8	

Table 6.15 clearly shows the remarkable rise in the abundance of very small animals in the lower strata of the site and their comparative rarity in the later, more decisively human strata. Wet-sieving alone does not account for these changes, although the figures in the table are considerably higher throughout the site than in Table 6.14 as would be expected from a totally wet-sieved sample. Table 6.15 does seem to show that the rise in 'very small Species' is most significant between Strata C and D1/5.

The presence of large amounts of 'very small species' can be interpreted in three very different ways:

- ☐ it may represent human predation on a wide range of extremely small species, which are difficult to hunt and provide very small amounts of flesh;
- ☐ these are bones deposited by small to medium sized carnivores, such as owls or dasyurids; or
- ☐ it is the result of differential sorting of bone by water activity.

To examine the last theory first: Korth (1979) examines the hypothesis that hydraulic sorting may be a major factor contributing to the selective preservation of microvertebrate bone. Nombe was a site that experienced frequent water activity during the formation of the Pleistocene strata but it is not likely that carcasses could have originated from site other than Nombe itself as the water had to travel through the karst system to emerge at Nombe. Carcasses could have been tumbled in water on the site or swept away during flooding. A more specific examination of the bone would be required to record the exact condition of the microvertebrate bone from different time periods to test the idea carefully but it would not, in my opinion, account for the considerable rise in microvertebrate remains in the Pleistocene strata.

The first interpretation is even more doubtful, requiring as it does increased human predation of these tiny species. It is most unlikely that people at Nombe in the late Pleistocene would need to hunt such small and uneconomic species in any numbers when there is good evidence from the rest of the faunal data that larger, more meaty species, often completely terrestrial and therefore easier for humans to trap, were available in the surrounding forest. Increased abundance of 'very small species' at Nombe seems to be a good indicator of either the lack of human activity or at least the sporadic nature of human visits, allowing the natural predators of the area to establish themselves and therefore the prey of medium and small sized carnivores is present at these times.

Work done by Aplin (1981) on the fauna from Christensen's excavations at Kamapuk suggests that the percentage of small animals there was low, comparable to the situation at Nombe during the accumulation of Stratum A and probably under similar conditions of active human presence. The figure given by Aplin (1981: Table 4.1) range from 0.4 to 3.5% using the number of identified specimens and from 0.1 to 0.7% using bone mass for all five test areas. David's figures (1984:36) for rodents at Walkunder Arch, Queensland, in a relict rainforest region also point clearly to a decrease in the numbers of small mammals during periods of human occupation and *vice versa*. Such data can provide a useful confirmation of declining or increasing human activity at archaeological sites though local circumstances must always be taken into consideration since in some sites a rise in small mammal remains may well indicate an increase in the human predation of such species.

6.7. CONCLUSIONS

The taphonomic factors affecting bone at Nombe cannot be unravelled from one another without further analysis. Nevertheless, individual factors can be seen to have affected the bone at different periods of time. Bone in the top two strata (A and B) has been heavily affected by human activities, such as the lighting of fires, cooking of food and constant movement on the site. Bone affected by heat has been preserved from chemical change but subjected to mechanical reduction and is not well protected by the light, ashy sediments. The unburnt fraction is likely to have been scavenged or subjected to chemical decay. The input of bone predated by other carnivores is unlikely to be significant.

Bone discarded at the site during the formation of the earlier strata (C and D) often had the protection of anaerobic clay sediments but has been the subject of chemical change causing the loss of collagen (nitrogen) and carbon. The action of periodic flood water has probably removed some smaller and lighter elements from these Pleistocene assemblages. However, the proportion of very small bone is considerably higher in these strata than in the later Holocene strata, probably due to the activities of owls and dasyurids at times of human absence. The thylacine was also present and probably used the site as a den or lair, contributing large and medium bone to the deposits. There is no easy method of differentiating between bone predated by human hunters and that contributed by the thylacine. However, it is also clear from other indications of human activity (Chapter 4) that humans were present sporadically throughout the late Pleistocene and must have been responsible for at least some of the faunal remains in Stratum D1/5 and probably a greater proportion of the small quantities in Stratum C.

Physical differences were already present between Pleistocene and Holocene bone as a result of the changing processes of geomorphic development and the physical processes of change and decay in bone material. The increased activities of human hunters and consumers from the beginning of the Holocene period exacerbated these differences. Physical examination of the bones did not allow identification of which predator might be responsible for the presence of particular bones. However, the analysis of species variation in the next chapter does provide further information about the presence and behaviour of non-human hunters.

Chapter 7

Faunal Analysis

7.1. INTRODUCTION

Chapter 6 presented the taphonomic problems of the site data and a discussion of the bone material. Major differences were identified in the physical appearance of the bone from the upper strata (Group 1) and that from the lower strata (Group 2). These differences were related to two sets of processes:

- ☐ the effects of human activity at the site, in particular in causing bone discarded after flesh consumption to be burnt and become brittle (thus increasing the quantity of unidentified bone); and
- ☐ the natural processes of change which moved and redeposited bone within the site, subjected it to erosional factors and changed the chemical composition of the bone structure.

Most of the Nombe bone was introduced to the site by predator activity (both human and animal). The material was examined in an attempt to identify which bones had been predated by each or any of the various predators present.

This chapter documents the aims of the faunal analysis, followed by a description of the field, laboratory and analytical techniques used to fulfil those aims. The classification of taxa is discussed, as is the computerisation of the resultant data.

Large quantities of animal bone were found at Nombe by White (1972). White does not give weights for the faunal material from any of his sites but bases his evaluation on a minimum number of animals estimated from the best preserved cranial fragments; in the case of Niobe (Nombe) that figure was 925 (1972:129). His approximate estimate of the volume of deposit removed at Nombe in 1964 (taking into account the large amount of natural rock present) was 3.5 m^3 for each of his two broad divisions (1972:129). On the assumption that all of White's deposits would be classified as Strata A and B and since they were dry-sieved by techniques similar to those used in 1971 and 1974-5, I estimate that the total weight of bone in White's excavation was approximately 12.5 kg. This is based on bone from 7 m^3 excavated from Strata A and B in two squares adjacent to White's excavations (A2 and H71).

Table 7.1 Estimated quantities of bone recovered from excavations at Nombe

	White[a]	Mountain	Total
Total bone recovered	c.12.5 kg	c.51.5 kg	c.64.0 kg
Volume of deposit removed	c.7.0 m^3	c.16.5 m^3	c.23.5 m^3

Note [a]: Estimate by Mountain (explanation in text above).

White analysed only the best preserved cranial material and his analysis was limited to basic family groups. However, it gave an indication of the richness and remarkably good state of preservation of the faunal material from the site. The subsequent excavations showed that extremely well-preserved Pleistocene fauna was also present in deposits with human artefacts. The recovery of extinct species previously unrecorded within Papua New Guinea (Flannery, Mountain and Aplin 1983) increased the importance of the fauna and determined that the faunal analysis would be the major focus of the research.

7.1.1 Aims of the faunal analysis

1. To identify all taxa present (from both cranial and postcranial material) in order to provide a large and complete body of bone for analysis and to avoid the problems of interpretation which arise where a small (probably biased) sample is used. Grayson (1981) discusses the hazards of interpretations from small and biased samples.
2. To analyse variation in species abundance throughout the site to provide evidence for:
   - ☐ the contribution of predators (including humans) to the accumulation of bone especially in the Pleistocene strata; and
   - ☐ the reconstruction of the changing environment throughout the late Pleistocene into the Holocene period
3. To examine the process and implications of extinction of some species in the Pleistocene fauna at Nombe and in particular the relation between the megafauna and human exploitation.
4. To provide evidence of the methods and range of human hunting in the past in the Nombe locality.
5. To set up a database that could be used and expanded by other researchers (both for archaeological or zoological purposes).

It was not intended, at this stage of analysis, to undertake detailed studies of species development, gender, or damage to individual bones.

7.2 TECHNIQUES EMPLOYED IN THE FIELD AND LABORATORY

7.2.1 Field recovery techniques

The dry-sieving in loams and ashes, hand sorting from the heavier sediments and clays, and wet-sieving in 1979/80 has already been described (Section 2.4). Bone recovered between 1971 and 1975 was not treated or washed in the field. Bone from the wet-sieving undertaken in 1979/80 was wet when removed from the sieving process and sun-dried prior to packing.

7.2.2 Laboratory techniques

The bone from each archaeological unit of sediment (whether from a 1979/80 wet-sieved bucket or an earlier larger dry-sieved/hand-sorted unit of sediment) was treated together. All material was kept together and eventually entered into the computer database as a unit.

Treatment after unpacking was as follows:

☐ bones were washed (generally only in water); some bones were treated with dilute acid to remove $CaCO_3$; dental picks were used to remove $CaCO_3$; bone was then rinsed and oven-dried. An electronic vibrating bath with detergent was used occasionally;

☐ the total quantity of dry bone was weighed;

☐ the burnt pieces were sorted and weighed;

☐ unidentifiable bone was weighed.

7.2.3 Classification of 'burnt' bone

A satisfactory definition of 'burnt' is not easy without resort to practical experimental data (Section 6.5.4.2). Bone discolouration may be caused by chemical staining from minerals in the ground-water or surrounding sediment matrix. Where the bone was coloured black, dark brown or grey it was taken to be 'burnt'. Where it was clearly mottled with brown patches over more than half the surface, or showed clear differentiation between coloured and uncoloured portions, it was also recorded as the result of contact with heat and classified as 'burnt'. This process was not totally satisfactory, as was clearly shown by discrepancies in figures recorded by different research assistants. All assemblages were finally checked by myself in order to make sure that the criteria of 'burning' were at least consistent in this analysis. In cases where the percentage of burning is very low, it cannot be assumed that the discolouration has been caused by heat alone, but as the percentage of 'burning' rises and becomes more consistent, it is very probable that the major cause of discolouration was contact with hot ashes or burning wood and charcoal.

7.2.4 The level of identification of taxon

In 1983-4, when the identification was undertaken, the comparative collections were often patchy or inadequate for the Nombe faunal suite. Dr. Jeanette Hope had built up a good basic but small collection of material from the highlands of Papua New Guinea and this was invaluable together with the collections of the C.S.I.R.O. Wildlife Division. My own experience of this suite was limited and the time needed to identify 50 kg was limited. Nevertheless, identification of all body parts was attempted. Assistance with particular species identification was received from the following people:

Dr L. Dawson	Thylacine
Dr T. Flannery	Macropodidae
Dr G. G. George	Phalangeridae and Pseudocheridae
Dr J. Menzies	Phalangeridae, Pseudocheiridae and some bats
Dr J. Van Tets & Mrs D. Spencer	Bird material
Dr C. Pardoe	Human material
Dr K. Aplin & Dr J. Hope	Assisted with several identifications.

The analysis aimed to demonstrate the changing occurrence of species throughout the site. It was therefore not necessary to treat each identifiable bone fragment as one analytical component with its own description under several variables. Although this is common in faunal analysis, it would have required a database of over 25,000 records each with about 15 variables or 375,000 discrete items of information. Further, for reasons outlined below, this was unnecessary for the type of broad analysis covering more than 30,000 years.

Material was classified by Class, Order, Family or Species according to the level of identification. Faunal data was analysed as a series of assemblages each from a discrete archaeological unit (Section 4.2.2). Only those archaeological units designated as undisturbed were used for the analysis.

The identification level of taxon was necessarily conservative. Fragments were often recorded only as from a Family or Family size (for explanation of this category of the classification system see Section 7.3.2.) rather than attempting to identify their Genus or Species. Species identification depended very largely, although not entirely, on dental features, and such identifications were usually confirmed by one of the experts listed above. Unique species, such as *Zaglossus bruijni* or *Casuarius bennetti* were easily recognisable in post-cranial as well as cranial pieces. However, most of the post-cranial material was only identified to the Family size level. This process was aided by the assumption that if only one species had been identified from cranial data in one Family size level then the post-cranial bone was likely to belong to that species. For example there was only one medium sized macropod present in the cranial material, *Thyogale brunii*, therefore in analysis all post-cranial bone classified as medium sized macropod, MACS, were assumed to be from *Thyogale brunii*. This assumption may be incorrect, especially given the proliferation of new species under identification at present, however, the classification provides a useful overall identification of faunal data from Nombe. All identified specimens were assigned to a category of body part and the total weight of all cranial and post-cranial specimens was recorded for each classification chosen.

The following example (from a fictional archaeological unit) illustrates the the use of the classification of the faunal material (see Table 7.2 for details of the classification). The unit contains:

- ☐ one fragment of a left femur of an unspecified Diprotodontid; Family - DIPR
- ☐ two right mandibles and one left mandible of *Thylogale brunii*; Species - THYG.BR
- ☐ two left humeri and a right ulna of a small sized unspecified macropod; Family size - MACS
- ☐ four left mandibles of *Phalanger carmelitae*; Species - PHAL.CA
- ☐ some *Phalanger* species post-cranial; Family size - POSL
- ☐ two left pelvic fragments of a small unspecified murid; Family size - MURS
- ☐ three large Pteropodidae teeth; Family size - PTEL
- ☐ one tibiotarsus of an unspecified megapode; Genus - MEGA.SP.
- ☐ three snake vertebrae; Family - SERP
- ☐ two long bones from a frog; Order - ANUR

Data on each of these ten categories would be entered as a separate line of information with the variables being the designation of the unit, information about the taxon, the weight of cranial and post-cranial bone present and the total number of each body part present. Examples of the computer data from the faunal database are set out in Appendix A, Computing and Analysis.

7.3 CLASSIFICATION OF FAUNAL DATA

7.3.1 Problems of Linnaean classifications in archaeology.

An understanding of the complexities of zoological classification may be seen as peripheral to the analysis of faunal remains from an archaeological site. However, classification is an attempt to make sense of the relationships which exist in the environment, and human activity has been a major (and increasingly dominant) force in the process of change within those relationships. Prehistory attempts to understand some of the relationships between early human society and the numerous environments to which parts of that society adapted and also, by its own behaviour, altered. In order to reconstruct these past environments information is required about individual elements within the environment and the relationship between what existed in the past (as an unknown) and what exists now (and can be studied).

Classification is a human attempt to explore those linkages through time, as mythology is another human attempt to explain relationships within time and space. Dwyer's plea for a minimal use of vernacular English names for Papua New Guinean species until local language classifications have been thoroughly researched (Dwyer 1983c) is a worthwhile attempt to relate folk taxonomy and Linnaean classification. The partnership between Bulmer and Majnep, (Majnep and Bulmer 1977, 1990a-f) is a positive and productive attempt to 'cross reference' two classification systems for the benefit of both communities. Prehistory attempts to reconstruct what is already long dead and over. Understanding classification systems can be a tool in this process.

A revolution is taking place in the classification of the components of life through the array of new techniques being applied to evolutionary biology. Before commencing the faunal analysis I spent considerable time investigating the changing basis on which different researchers since the mid-eighteenth century have devised various classification schemes. The classical Linnaean division into recognisable classes of fish, amphibians, reptiles, birds and mammals appears basic and adequate for the task until one adds information from extinct species. In addition, genetic research shows that there are often very significant similarities between two visually different species. I began to appreciate the problems of devising classificatory schemes to accommodate the extraordinary whether in the present or in prehistory. Hand and Archer (1987) discuss the current revolution and the difficulties of the traditional system and how the concepts of 'reptiles', 'fish' and 'amphibians' do not represent natural biological entities since 'birds' and 'mammals' both arose from the earlier groups of 'reptiles'. Both should be classified as subordinate to the level of 'reptiles'.

There has always been considerable discussion about the details of classification on extant as well as extinct species (Archer and Clayton 1984; Groves 1989). Linnaeas, for example, classified the American opossum with pigs, hedgehogs and shrews because all possessed sharp teeth; the independence of the marsupial group was not recognised until early in the nineteenth century.

There are many subdivisions of the structure that can and have been used for various classificatory schemes of the marsupials. Simpson, in 1945, disregarded the rank levels between Superfamily and Order to gain flexibility in the marsupial superfamily ranking. This was largely replaced by Ride's scheme (1964), which established a multi Order system. This was re-analysed by Kirsch in the 1960s and 1970s using the immunological reactions of serum proteins to provide new evidence of marsupial relationships (Kirsch 1977). This work showed a close relationship between the bandicoots and dasyurids so that both became new Suborders under the Order

Polyprotonda. Further revisions were made during the 1970s and 1980s again replacing the Orders with new groupings.

There are obvious pitfalls for the faunal analyst who does not intimately follow such current classificatory changes. It is crucial for the archaeologist using faunal analysis to keep sufficiently abreast of developments in faunal classification so that he/she can select the most appropriate and up-to-date authorities in their respective fields. When in doubt I followed Flannery (1990) for the mammals, since he has produced the most up-to-date and comprehensive treatise on all New Guinean mammals. The bird classification follows Beehler (1978).

There are major problems in the process of matching the actual faunal data to the purely descriptive information provided for many species, since new species are often described from incomplete specimens and also frequently rely on surface features of the animals body, such as colour, rather than variation in bone shape and size. However, for most of the specimens identified from the Nombe data, there are sufficient dental details for species recognition and assistance from many of the experts who were responsible for the current changes in mammal taxonomy assisted in the task. This is not to deny that there has been some disagreement over some of the initial identifications: for example Section 8.2 documents problems in the identification of large Pteropodids. As with all forms of archaeological identification, there may well be disagreement in the future over particular identification but the flexibility of the database allows for change in taxonomic category. The detailed identification of the bird bone was carried out by Mrs. D. Spencer, under the supervision of Dr. J. Van Tets. The reptile and frog classification is more basic since it is impossible to identify the remains at anything below a family level. For the purposes of computation, analysis and discussion Class, Order, Family, Genus and Species provided a working framework for the current study.

7.3.2 Faunal size categories and Linnaean classifications

A central part of this study is the determination of predation strategies by humans and animals. The hierarchy of predation depends (among other factors) on animal size. It was therefore essential to develop a grouping of animals by size within related families in addition to the normal Linnaean classification. This sub-classification was termed 'Size of Family' (code SFAM) and is included in Table 7.2. This solved the additional problem of post-cranial bones which could only be identified to a broad Family size level and enabled them to be included in the analysis.

For example, in the Pseudocheiridae family, there was cranial material enabling the identification of two large species *Pseudocheirops cupreus* and *Pseudocheirops corinnae*; one medium species *Pseudocheirus forbesi* and one small species *Pseudocheirus mayeri*. In addition, two other families of possums, the Petauridae and the Acrobatidae, had small species present: *Petaurus breviceps* and *Distoechurus pennatus*. There was also post-cranial bone unidentifiable beyond family level but which could be grouped into large, medium and small possums. To provide comparability of data across cranial and post-cranial bone and to create divisions of the Pseudocheiridae, the Petauridae and the Acrobatidae families relevant to predation, species were divided into large, medium and small species. These are specific *size categories* but are still linked into the Linnaean classification system.

Pseudocheirops cupreus is also given a size classification of large possum with a computer code of POSL (see Table 7.2). This size category also applies to *Pseudocheirops corinnae* and to all the post-cranial material from the large possums, which presumably comes from either of those two species. Thus when analysing predation, we can refer to 'large possums' (POSL), and investigate the evidence for predation of this specific family size group.

This system of size categories has the very significant advantage of providing a far larger sample of bone for predation analysis than would be possible with a purely Linnaean classification. In this way an analytically robust series of data subsets is created which has far greater functional (and therefore archaeological) importance.

In subsequent analysis, these size categories are used frequently, often in combination with normal family or species classification.

(Later in this chapter a further classification of the entire faunal suite by body-size is used. This is based purely on adult animal body weight and should not be confused with these family size categories.)

Table 7.2 lists the taxa present on the site together with their Linnaean classifications and family size categories. Computer codes used for faunal classification are included, as are the family size classifications (between the two vertical lines). These codes are used in tables later in this chapter to identify both species and size categories.

Computer codes						Full description
Class	Order	Family	Family Size[a]	Genus	Species	Class, Order, Family, Family Size, Genus, Species, (Body size category) (Common names for major categories)
MAMM	PRIM	HOMO	--	HOMO.SP	HOMO.SA	MAMMALIA, PRIMATA, HOMINIDAE (Humans), *HOMO* SPECIES, *HOMO SAPIENS*
MAMM	ARTI	SUID	--	SUS.SPE		ARTIODACTYLA, SUIDAE (Pigs), *SUS* SPECIES
MAMM	CARN	CANI	--	CANI.SP		CARNIVORA, CANIDAE (Dogs), *CANIS* SPECIES
MAMM	MONO	TACH	--	ZAGL.SP	ZAGL.BR	MONOTREMATA, TACHYGLOSSIDAE (Echidnas), *ZAGLOSSUS* SPECIES, *ZAGLOSSUS BRUIJNI*
MAMM	DASY	THYL	--	THYL.SP	THYL.CY	DASYUROMORPHIA, THYLACINIDAE (Thylacines), *THYLACINUS CYNOCEPHALUS*
MAMM	DASY	DASY	DASL			DASYURIDAE, Large Dasyurids
MAMM	DASY	DASY	DASL	DASY.SP	DASY.AL	*DASYURUS* SPECIES, *DASYURUS ALBOPUNCTATUS*
MAMM	DASY	DASY	DASS			Small Dasyurids
MAMM	PERA	PERO	PERL			PERAMELEMORPHIA, PERORYCTIDAE, Large Bandicoots
MAMM	PERA	PERO	PERL	ECHY.SP	ECHY.KA	*ECHYMIPERA* SPECIES, *ECHYMIPERA KALUBU*
MAMM	PERA	PERO	PERL	ECHY.SP	ECHY.RU	*ECHYMIPERA RUFESCENS*
MAMM	PERA	PERO	PERL	PERO.SP	PERO.RA	*PERORYCTES* SPECIES, *PERORYCTES RAFFRAYANA*
MAMM	PERA	PERO	PERS			Small Bandicoots
MAMM	PERA	PERO	PERS	MICR.SP	MICR.LO	*MICROPERORYCTES* SPECIES, *MICROPERORYCTES LONGICAUDA*
MAMM	DIPR	DIPR				DIPROTODONTIA, DIPROTODONTIDAE (Diprotodons)
MAMM	DIPR	MACR	MACL	PROT.SP		MACROPODIDAE, Large macropods, *PROTEMNODON* SPECIES
MAMM	DIPR	MACR	MACL	PROT.SP	PROT.NO	*PROTEMNODON NOMBE*
MAMM	DIPR	MACR	MACL	PROT.SP	PROT.TU	*PROTEMNODON TUMBUNA*
MAMM	DIPR	MACR	MACL			Large macropods
MAMM	DIPR	MACR	MACL	DEND.SP		*DENDROLAGUS* SPECIES (tree kangaroos)
MAMM	DIPR	MACR	MACL	DEND.SP	DEND.NO	*DENDROLAGUS NOIBANO*
MAMM	DIPR	MACR	MACL	DEND.SP	DEND.DO	*DENDROLAGUS DORIANUS*
MAMM	DIPR	MACR	MACL	DEND.SP	DEND.GO	*DENDROLAGUS GOODFELLOWI*
MAMM	DIPR	MACR	MACM			Medium macropods
MAMM	DIPR	MACR	MACM	THYL.SP	THYL.BR	*THYLOGALE* SPECIES, *THYLOGALE BRUNII*
MAMM	DIPR	MACR	MACS			Small macropods
MAMM	DIPR	MACR	MACS	DORC.SP	DORC.VA	*DORCOPSULUS* SPECIES, *DORCOPSULUS VANHEURNI*

Note: a: For an explanation of family size see Section 7.3.2

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Table 7.2 Taxa classification for Nombe data

Computer codes						Full description
Class	Order	Family	Family Size[a]	Genus	Species	Class, Order, Family, Family Size, Genus, Species, (Body size category) (Common names for major categories)
MAMM	DIPR	PHAL	--	PHAL.SP		PHALANGERIDAE, *PHALANGER* SPECIES (Cuscuses)
MAMM	DIPR	PHAL	--	PHAL.SP	STRI.GY	*STRIGOCUSCUS GYMNOTIS*
MAMM	DIPR	PHAL	--	PHAL.SP	PHAL.CA	*PHALANGER CARMELITAE*
MAMM	DIPR	PHAL	--	PHAL.SP	PHAL.SE	*PHALANGER SERICEUS*
MAMM	DIPR	PSEU	POSL			PSEUDOCHEIRIDAE, Large Possums
MAMM	DIPR	PSEU	POSL	PSEP.SP	PSEP.CU	*PSEUDOCHEIROPS* SPECIES, *PSEUDOCHEIROPS CUPREUS*
MAMM	DIPR	PSEU	POSL	PSEP.SP	PSEP.CO	*PSEUDOCHEIROPS CORINNAE*
MAMM	DIPR	PSEU	POSM			Medium possums
MAMM	DIPR	PETA	POSM	DACT.SP	DACT.PA	PETAURIDAE, *DACTYLOPSILA* SPECIES, *DACTYLOPSILA PALPATOR*
MAMM	DIPR	PSEU	POSM	PSEU.SP	PSEU.FO	*PSEUDOCHEIRUS* SPECIES, *PSEUDOCHEIRUS FORBESI*
MAMM	DIPR	PSEU	POSS			Small possums
MAMM	DIPR	PETA	POSS	PETA.SP	PETA.BR	*PETAURUS* SPECIES, *PETAURUS BREVICEPS*
MAMM	DIPR	PSEU	POSS	PSEU.SP	PSEU.MA	*PSEUDOCHEIRUS* SPECIES, *PSEUDOCHEIRUS MAYERI*
MAMM	DIPR	ACRO	POSS	DIST.SP	DIST.PE	ACROBATIDAE, *DISTOECHURUS* SPECIES, *DISTOECHURUS PENNATUS*
MAMM	RODE	MURI	MURL			RODENTIA, MURIDAE Large murids
MAMM	RODE	MURI	MURL	HYOM.SP	HYOM.GO	*HYOMYS* SPECIES, *HYOMYS GOLIATH*
MAMM	RODE	MURI	MURL	MALL.SP	MALL.RO	*MALLOMYS* SPECIES, *MALLOMYS ROTHSCHILDI*
MAMM	RODE	MURI	MURM			Medium murids
MAMM	RODE	MURI	MURM	ANIS.SP	ANIS.IM	*ANISOMYS* SPECIES, *ANISOMYS IMITATOR*
MAMM	RODE	MURI	MURM	HYDR.SP		*HYDROMYS* SPECIES
MAMM	RODE	MURI	MURM	PARA.SP	PARA.AS	*PARAHYDROMYS* SPECIES, *PARAHYDROMYS ASPER*
MAMM	RODE	MURI	MURM	UROM.SP	UROM.AN	*UROMYS* SPECIES, *UROMYS ANAK*
MAMM	RODE	MURI	MURM	UROM.SP	UROM.CA	*UROMYS CAUDIMACULATUS*
MAMM	RODE	MURI	MURM	XENU.SP		*XENUROMYS* SPECIES
MAMM	RODE	MURI	MURS			Small murids
MAMM	RODE	MURI	MURS	MELO.SP	MELO.RU	*MELOMYS* SPECIES, *MELOMYS RUBEX*
MAMM	RODE	MURI	MURS	POGO.SP	POGO.SE	*POGONOMYS* SPECIES, *POGONOMYS SEVIA*
MAMM	CHIR	PTER	PTEL			CHIROPTERA, PTEROPODIDAE, Large fruit-eating bats
MAMM	CHIR	PTER	PTEL	-	DOBS.MO	*DOBSONIA* SPECIES, *DOBSONIA MOLUCCENSIS*
MAMM	CHIR	PTER	PTEL	PTER.SP		Large pteropodids
MAMM	CHIR	PTER	PTES	ROUS.SP		Small fruit-eating bats, *ROUSETTUS* SPECIES

Note: a: For an explanation of family size see Section 7.3.2

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Table 7.2 (continued) **Taxa classification for Nombe data**

Computer codes						Full description
Class	Order	Family	Family Size[a]	Genus	Species	Class, Order, Family, Family Size, Genus, Species, (Body size category) (Common names for major categories)
AVES	CASU	CASU	AVEL	CASU.SP	CASU.BE	Birds, CASUARIFIIFORMES, CASUARIIDAE (Cassowaries), Large birds, *CASUARIUS* SPECIES, *CASUARIUS BENNETTI*
AVES	--	--	AVEM			Medium birds
AVES	COLU	COLU	AVEM	LCOL.SP		COLUMBIFORMES, COLUMBIDAE, Medium Birds, Large pigeons & doves
AVES	COLU	COLU	AVEM	MCOL.SP		Medium pigeons & doves
AVES	COLU	COLU	AVES	SCOL.SP		Small pigeons & doves
AVES	FALC	ACCI	AVEL	HARP.SP	HARP.NO	FALCONIFORMES, ACCIPITRIDAE (Hawks & eagles), *HARPYOPSIS* SPECIES, *HARPYOPSIS NOVAEGUINAE*
AVES	GALL	MEGA	AVEM	MEGA.SP		GALLIFORMES, MEGAPODIIDAE (Megapodes), *MEGAPODIUS* SPECIES
AVES	GALL	MEGA	AVEM	MEGA.SP	AEPY.AR	*AEPYPODIUS ARFAKIANUS*
AVES	GALL	MEGA	AVEM	MEGA.SP	MEGA.FR	*MEGAPODIUS FREYCINET*
AVES	-	-	AVES			Small birds
AVES	GRUI	RALL	AVES	GALL.SP		GRUIFORMES, RALLIDAE (Rails), *GALLINULA* SPECIES
AVES	GRUI	RALL	AVES	GALL.SP	GALL.TE	*GALLINULA TENEBROS*
AVES	PASS	PASS	AVES	LPAS.SP		PASSERIFORMES (Perching birds), PASSERIDAE, Large perching birds
AVES	PASS	PASS	AVES	MPAS.SP		Medium perching birds
AVES	PASS	PASS	AVES	SPAS.SP		Small perching birds
AVES	PSIT	PSIT	AVES			PSITTACIFORMES, PSITTACIDAE (Parrots)
AVES	STRI	STRI	AVEM	NINO.SP		STRIGIFORMES, STRIGIDAE (Typical owls), *NINOX* SPECIES
AVES	STRI	TYTO	AVEM	TYTO.SP	TYTO.AL	TYTONIDAE (Barn Owls), *TYTO* SPECIES, *TYTO ALBA*
AVES	STRI	TYTO	AVEM	TYTO.SP	TYTO.TE	*TYTO TENEBRICOSA*
REPT						REPTILIA
REPT	TEST	CHEL				TESTUDINES, CHELIDAE(Turtles)
REPT	SQUA	LACE				SQUAMATA, LACERTILIA(Lizards)
REPT	SQUA	SCIN				SCINCIDA (Skinks)
REPT	SQUA	SERP				SERPENTIA (Snakes)
AMPH	ANUR					AMPHIBIA, ANURA (frogs)

Note: a: For an explanation of family size see Section 7.3.2

Table 7.2 (continued) **Taxa classification for Nombe data**

7.3.3 Computation of faunal data

The extremely large body of data (25,000 identifiable bones from 45 species and other less specific categories) required computerisation at a time when relatively few archaeologists used computers. The requirements for the system design were:

- ☐ all identifiable faunal material could be classified (by occurrence) into 44 body parts (or more, if later required);
- ☐ all data must be linked back to the unit from which they were excavated;
- ☐ all units must be allocable to a stratigraphic feature of the site and through it to the chronology;
- ☐ for the faunal data, there must be a coding system with unique codes for any existing and possible future taxonomic classifications and sufficient flexibility to enable ongoing classification changes as new taxonomic reviews change the terminology, (which in the event, proved very necessary);
- ☐ data must be kept in a form so that they can easily be used for analysis and can provide almost any type of information subset for later analysis.

The database gives immediate information on the body parts and taxa present at any area or strata of the site. It also provides the ability to cluster information from any species or required grouping of taxa.

Body parts were identified according to a modified version of the list provided by Gifford and Crader (1977). This list however includes all classes of bone necessary for the general identification of minimum numbers and analysis of particular areas of the body. It will be possible to produce more detailed analyses of separate groups of data at later stages of research. Apppendix 2 sets in more detail the computing aspects of the analysis. Table 7.3 lists body parts and computer codes.

Table 7.3 List of body parts and codes.

Cranial parts	Code	Postcranial parts	Code
Cranium	CRA	Vertebrae	VERT
Braincase (fragments)	BC	Atlas	ATL
Premaxilla right	PXL	Axis	AXI
Premaxilla left	PXR	Rib	RIB
Premaxilla right+teeth	PXTL	Scapulae	SCP
Premaxilla left+teeth	PXTR	Clavicle	CLV
Maxilla right	MXL	Coracoid	COR
Maxilla left	MXR	Pelvis	PEL
Maxilla right+teeth	MXTL	Long bone[a]	LBN
Maxilla left+teeth	MXTR	Humerus left	HML
Mandible right	MNL	Humerus right	HMR
Mandible left	MNR	Radius left	RDL
Mandible right+teeth	MNTL	Radius right	RDR
Mandible left+teeth	MNTR	Ulna left	ULL
Teeth	TTH	Ulna right	ULR
		Femur left	FML
		Femur right	FMR
		Tibia left	TBL
		Tibia right	TBR
		Fibula left	FBL
		Fibula right	FBR
		Tibiotarsus left	TBTL
		Tibiotarsus right	TBTR
		Tibiometatarsus left	TMTL
		Tibiometatarsus right	TMTR
		Podial	PD
		Phalanges	PHA
		Claw	CLW
		Carapace	CRP

***Notes*:** Codes adapted from Gifford and Crader (1977)

[a]: Fragment of long bone which cannot be identified further.

7.4 PRESENTATION OF WET-SIEVED AND NON WET-SIEVED RESULTS

Before discussing suitable measures of bone abundance, the decision to deal with bone from the dry- and wet-sieving techniques as a single body of evidence must be examined.

Faunal evidence produced through wet-sieving techniques will naturally produce a higher ratio of smaller unidentifiable fragments as well as small individual pieces (such as teeth or frog's bones) which will only rarely be recovered by coarser dry-sieved techniques.

Table 7.4 Quantity and percentage of sediment processed by different sieving techniques by stratigraphical levels of Nombe

Stratum	Non wet-sieved sediment Volume (litres)	Wet-sieved sediment Volume (litres)	Proportion of strata volume wet-sieved
A	5 273	119	2%
B	5 610	182	3%
C	700	43	6%
D1/5	2 460	298	11%
D2/3/4	646	90	12%

Table 7.4 presents the percentage (by volume) of sediment processed for the five chosen stratigraphical levels. The volume of sediment wet-sieved in each stratum is less than 10% except for Strata D1/5 and D2 sediments where the percentage is marginally higher than 10%. This slightly increases the quantity of small bones and fragments recovered in those levels relative to the volume of sediment. I ran a series of checks using only the wet-sieved material from all strata to ensure that the overall trends are not only caused by this effect (see, for example, Tables 6.14 and 6.15).

7.5 RELATIVE ABUNDANCE OF SPECIES

Mammal bone is represented in very large quantities in the record with bones from bird and even more so, bones from reptiles and amphibians hardly figuring at all (Table 7.5).

Table 7.5 Abundance of faunal classes over entire site

MAMMALS:	
Cranial bone	9 271 g
Post cranial bone	18 163 g
Total of mammal bone	27 434 g
Total number of identified fragments (NISP)	23 232
Number of faunal categories present	58
Number of species present	36
BIRDS:	
Amount of cranial bone	7 g
Amount of post cranial bone	1 575 g
Total amount of bone	1 582 g
Total number of identified fragments (NISP)	526
Number of faunal categories present	16
Number of species present	7
REPTILES	
Amount of cranial bone	5 g
Amount of post cranial bone	152 g
Total amount of bone	157 g
Total number of identified fragments (NISP)	169
Number of faunal categories present	4
Number of species present	Unknown
AMPHIBIANS:	
Amount of cranial bone	0 g
Amount of post cranial bone	19 g
Total amount of bone	19 g
Total number of identified fragments (NISP)	468
Number of faunal categories present	1
Number of species present	Unknown

Although there is a large amount of faunal data in the Nombe sample it can be seen from Tables 7.2 and 7.4 that many problems that commonly confront the faunal analyst are present. The range of species varies from large bulky animals with thick solid bones, such as the extinct macropods and tree kangaroos, to the fragile bone of tiny birds, murids and frogs. Some pieces (largely cranial) can be identified to species level, whereas others can only be identified as belonging to a family or to an even broader category such as order or class.

In many cases, very few specimens were found, leaving the problem of how to present an accurate estimation of species abundance. In order to overcome at least the basic problems of such small samples (as discussed at length in Grayson 1981) the information has been amalgamated into the five broad stratigraphic divisions. This provides satisfactory samples for Strata A, B and D1/5 but still leaves very small samples of bone in Strata C and D2/3/4.

7.5.1 Measures employed to represent relative abundance and diversity of species

The topic of measuring assemblage diversity is very complex and there is a considerable amount of literature available, such as Grayson (1973, 1984), Uerpmann (1973), Ziegler (1973), Casteel (1977), Lie (1980), Bobrowsky (1982), Klein and Cruz-Uribe (1984), Hesse and Wapnish (1985) and many others. Much of the literature is concerned with the analysis of large assemblages which frequently contain either large predators or large domesticated species. It is not easy to identify techniques that are applicable to an assemblage that is very diverse in animal size, low in individual numbers and contains some extremely small samples.

There are three main methods of measuring abundance: by minimum numbers of animals present, by bone weight and by the number of unidentified specimens. There are also many variations on these three basic methods each with its own advantages and problems. Since time was limited and the analysis had to be reasonably straight forward, the three main methods were explored. There follows a brief discussion of each method and its applicability to the chosen Nombe sample.

1. Analysis by *minimum numbers (MNI)* alone will distort the evidence in the case of a single or small numbers of bone present from an individual species, which will count as one separate animal for each unit. This is particularly evident in the Nombe case, since even with the amalgamation of all available archaeological units, there is often very little distance between the units in use. This would seem to be unsuitable for the Nombe sample.

2. Presenting the faunal data as *bone weight* distorts the evidence in another direction towards the species with dense, heavy bone and is obviously biased towards the units containing a lot of large species rather than those This is clearly a major problem with a sample that containing a wide range of body sizes as in the Nombe sample.

3. Analysis using *numbers of identified specimens (NISP)*, can be biased where the expected number of bones from one species are greater than those expected from another. In the case of extinct species such information is lacking and even with newly described species of small mammals it is rare to be able to find the total number of bones in the animal. Expressing abundance by this method also has problems with varied levels of fragmentation. The Nombe data does have such variation as fragmentation must increase during periods of heavy human activity and may decrease when human activity is less frequent although some animal predators shred the bones of their prey to a greater extent than others. Judging by the levels of human indicators at Nombe (see Chapter 4), it is likely that the NISP method will also distort the proportions of bone during the Holocene levels, although perhaps less than the first two methods.

Grayson warns of the dangers of inappropriate methods (Grayson 1984) and there are clearly problems in presenting the Nombe data by ANY of these methods, given the difficulties of sample size, distance between units, and the variation in collection methods. Klein and Cruz-Uribe (1984: 29) advocate using both the NISP and MNI methods together in order to provide more information than is possible by either method alone. I finally chose to follow their example but to add bone weight also and to use a combination of all three methods as the most honest means of expressing abundance on a broad front across the sample. This enables the reader to compare the results expressed as percentages of the totals available in each stratum, see Tables 7.7 to 7.10. In later analysis where there was simply insufficient time to produce this range of results, the NISP method is used, which probably gives a less biased result overall than either of the other methods.

Taxa are amalgamated as far as possible: for example, the cranial data from all individual species of phalangers can be amalgamated with the post-cranial data of unspecified phalangers to create the largest possible samples where species variations do not matter. This obviously cannot be done where the analysis is concerned with differences between species and many taxa cannot be amalgamated and present very low numbers: this is true for the diprotodontids, the eagle or skinks.

7.5.2 Animal body-size classification

To overcome some of the huge variations in the body size of species, four size categories were created (Table 7.6), based on adult body weight of each species concerned. This can only be approximate and there is overlap between these categories and some room to argue different specifications. Nevertheless, these size categories represent species groups that would be targets for the different predators apparently active in the site. Apart from a little bone resulting from natural animal death, most of the bone must have been brought to the site by predators.

Table 7.6 Classification of species present in the Nombe data by body size

Taxa and family size abbreviation [a]	
Large body weight (over 5 kg adult body weight)	
Homo sapiens	101
Thylacinus cynocephalus	106
Canis species	107
Diprotodontidae	102
Protemnodon species	103
Dendrolagus species	104
Large macropods (MACL)	104
Zaglossus bruijni	105
Sus species	108
Casuarius bennetti	109
Medium body weight (c. 1 - 5 kg adult body weight)	
Harpyosis novaeguineae	206
Medium macropods (MACM)	201
Small macropods (MACS)	202
Phalangeridae (PHAL.SP)	203
Pseudocheiridae (POSL)	204
Large murids (MURL)	205
Snakes	207
Small body weight (c.300 g - 1 kg adult body weight)	
Dasyurus albopunctatus (DASL)	303
Owls (STRI)	308
Medium possums (POSM)	301
Large bandicoots (PERL)	302
Medium murids (MURM)	305
Large fruit bats (PTEL)	306
Medium birds (AVEM)	309
Turtle	310
Very small body weight (less than 300g adult body weight)	
Small dasyurids (DASS)	402
Small bandicoots (PERS)	404
Small possums (POSS)	401
Small murids (MURS)	403
Small fruit bats (PTES)	407
Small birds (AVES)	405
Lizards	406
Skinks	409
Frogs	408

Note: [a] For explanation of family size abbreviations see Table 7.2

The **Large** body-size animals (over 5 kg adult body weight) are generally the heavy-bodied terrestrial species and the partly arboreal tree kangaroos, all of which provided large quantities of flesh to a predator. The **Medium** body-size animals (1-5 kg adult body weight) are more often arboreal in habit (although this category also includes the smaller terrestrial macropods), all still providing a good meal to a thylacine or human hunter. The **Small** body-size animals (300 g-1 kg adult body weight) can be very diverse in habit and include the prey of the smaller carnivores such as the dasyurids and the birds of prey (owls), as well as being possible prey for the larger hunters. Bone, from the category of **Very Small** body-size animals (under 300 g adult body weight), probably results largely from predation of the dasyurids and birds of prey and are unlikely to be a major component for either the thylacine or humans.

7.5.3 Abundance of species throughout the site

Tables 7.7 to 7.10 clearly demonstrate the variation in species abundance throughout the site. Each body-size category is presented by minimum numbers, number of identified specimens and weight of bone. It is obvious that, in most cases, the NISP figure is between the figures for MNI and weight. Data for Reptilia, Lacertilia and Scincida are not included since there are very few individuals in the last two categories (12 throughout the site) and the Reptilia cannot be assigned to any size category. Summary graphs of NISP proportions follow as Figures 7.1 to 7.4.

Codes are used in the following tables and graphs so that each group can be accurately related back to Table 7.2 and so that long descriptions or misleading vernacular descriptions, are avoided.

Table 7.7 Relative abundance of Large animals (over c. 5kg adult body weight) by stratum

	Minimum numbers of individuals		Number of identified specimens		Weight of bone	
Faunal category	Number	%	Number	%	grams	%
STRATUM A						
HOMO.SA	1	8	14	4	68	9
CANI.SP	1	8	2	<1	3	<1
THYL.CY	1	8	1	<1	18	3
DEND.SP	4	33	258	73	448	62
ZAGL.BR	1	9	6	2	24	3
CASU.BE	3	25	57	16	136	19
SUS SP	1	8	15	4	21	3
Totals	12	100	353	100	718	100
STRATUM B						
HOMO.SA	1	2	12	2	124	5
THYL.CY	1	2	8	1	12	<1
DEND.SP	15	37	378	49	959	37
ZAGL.BR	11	27	93	12	250	10
CASU.BE	11	27	273	36	1 194	46
SUS SP	2	5	5	<1	35	1
Totals	41	100	769	100	2 574	100
STRATUM C						
THYL.CY	1	20	1	4	32	35
DEND.SP	2	40	14	58	34	37
ZAGL.BR	1	20	6	25	13	14
CASU.BE	1	20	3	13	14	15
Totals	5	100	24	100	93	100
STRATUM D1/5						
THYL.CY	1	3	22	3	111	4
DIPR.SP	1	3	7	1	479	16
PROT.SP	4	11	71	11	575	19
DEND.SP	7	19	174	27	524	17
ZAGL.BR	22	59	329	51	1250	41
CASU.BE	1	3	40	6	110	4
SUS SP	1	3	1	<1	1	<1
Totals	37	100	644	100	3 050	100
STRATUM D2/3/4						
THYL.CY	2	22	10	11	47	9
DIPR.SP	1	11	5	5	42	8
PROT.SP	2	22	36	39	269	50
DEND.SP	1	11	16	17	50	9
ZAGL.BR	2	22	24	26	133	24
CASU.BE	1	11	1	1	2	<1
Totals	9	100	92	100	543	100

Note: Totals may not agree because of rounding

Table 7.8 Relative abundance of Medium animals (c. 1 - 5 kg adult body weight) by stratum

	Minimum numbers of individuals		Number of identified specimens		Weight of bone	
Faunal category	Number	%	Number	%	grams	%
STRATUM A						
MACM + MACS	71	28	758	28	1 157	33
PHAL.SP	124	50	1 298	49	1 771	50
POSL	40	16	366	14	361	10
MURL	14	6	210	8	221	6
SERP	1	<1	29	1	29	<1
Totals	250	100	2 661	100	3 539	100
STRATUM B						
HARP.NO	1	<1	3	<1	10	<1
MACM + MACS	150	15	1 282	13	2 040	16
PHAL.SP	652	64	6 657	65	8 437	67
POSL	143	14	1 473	14	1 283	10
MURL	76	7	766	8	892	7
SERP	1	<1	1	<1	1	<1
Totals	1 023	100	10 182	100	12 663	100
STRATUM C						
MACM + MACS	4	20	35	14	28	12
PHAL.SP	10	50	192	75	173	75
POSL	4	20	18	7	16	7
MURL	1	5	10	4	12	5
SERP	1	5	1	<1	1	<1
Totals	20	100	256	100	230	100
STRATUM D1/5						
MACM + MACS	12	8	189	10	290	11
PHAL.SP	77	53	1 392	72	1 910	72
POSL	38	26	201	10	265	10
MURL	17	12	167	9	201	8
SERP	1	<1	1	<1	2	<1
Totals	145	100	1 950	100	2 668	100
STRATUM D2/3/4						
MACM + MACS	2	14	30	14	37	20
PHAL.SP	6	43	143	65	98	53
POSL	4	29	31	14	29	16
MURL	2	14	17	8	20	11
Totals	14	100	221	100	184	100

***Note*:** Totals may not agree because of rounding

Table 7.9 Relative abundance of Small animals (c.300 g - 1kg adult body weight) by stratum

	Minimum numbers of individuals		Number of identified specimens		Weight of bone	
Faunal category	Number	%	Number	%	grams	%
STRATUM A						
DASL	1	<1	3	<1	1	<1
OWL	2	2	2	<1	2	<1
POSM	19	14	92	13	42	13
PER	17	12	46	6	29	9
MURM	50	36	103	14	67	21
PTEL	46	33	445	62	160	50
MEGA.SP	3	2	12	1	10	3
AVEM	1	<1	13	2	9	3
Totals	139	100	716	100	320	100
STRATUM B						
DASL	5	<1	11	<1	5	<1
OWL	1	<1	1	<1	2	<1
POSM	30	6	123	3	100	5
PER	52	10	220	5	114	6
MURM	54	10	337	8	239	12
PTEL	379	71	3 751	84	1507	74
MEGA.SP	9	2	12	<1	56	3
AVEM	2	<1	7	<1	5	<1
CHEL	1	<1	1	<1	2	<1
Totals	533	100	4 463	100	2030	100
STRATUM C						
POSM	2	15	8	5	6	11
PER	2	15	6	3	3	6
MURM	2	15	10	6	13	25
PTEL	5	38	148	85	29	55
MEGA. SP	1	8	1	<1	1	2
AVEM	1	8	1	<1	1	2
Totals	13	100	174	100	53	100
STRATUM D1/5						
DASL	2	4	5	2	3	2
OWL	1	2	1	<1	1	<1
POSM	9	19	59	20	26	18
PER	16	33	70	23	32	22
MURM	9	19	72	24	46	31
PTEL	7	15	79	26	26	18
MEGA.SP	3	6	10	3	13	9
AVEM	1	2	3	1	1	<1
Totals	48	100	299	100	148	100
STRATUM D2/3/4						
DASL	1	5	3	3	3	6
POSM	6	29	29	29	12	24
PER	7	33	27	27	8	16
MURM	5	24	23	23	21	41
PTEL	2	10	19	19	7	14
Totals	21	100	101	100	51	100

Note: Totals may not agree because of rounding

Table 7.10 Relative abundance of Very Small animals (less than c.300 g adult body weight) by stratum

	Minimum numbers of individuals		Number of identified specimens		Weight of bone	
Faunal category	Number	%	Number	%	grams	%
STRATUM A						
DASS	1	6	1	1	1	5
PETS	1	6	1	1	1	5
MURS	8	47	60	68	11	57
ROUS.SP	2	12	10	11	2	11
AVES	1	6	4	5	2	11
REPT	3	17	6	7	1	5
ANUR[a]	1	6	6	7	1	5
Totals	17	100	88	100	19	100
STRATUM B						
DASS	1	2	1	1	1	2
PETS	12	25	29	11	12	20
MURS	16	33	159	62	32	52
ROUS.SP	6	13	20	8	4	7
AVES	5	10	16	6	7	11
REPT	3	6	11	4	4	7
ANUR[a]	5	10	19	7	1	2
Totals	48	100	255	100	61	100
STRATUM C						
PETS	1	6	4	5	1	13
MURS	4	25	42	52	6	75
AVES	1	6	1	1	<1	<1
REPT	2	12	2	3	<1	<1
ANUR[a]	8	50	32	40	1	13
Totals	16	100	81	100	8	100
STRATUM D1/5						
DASS	1	<1	1	<1	<1	2
PETS	5	4	31	4	10	15
MURS	38	27	376	49	36	55
ROUS.SP	1	<1	2	<1	<1	2
AVES	5	4	7	1	3	5
REPT	4	3	7	1	1	2
ANUR[a]	86	61	345	45	13	20
Totals	140	100	769	100	65	100
STRATUM D2/3/4						
DASS	1	3	1	<1	1	4
PETS	2	7	12	7	6	23
MURS	8	27	88	51	12	46
AVES	3	10	5	3	4	15
ANUR[a]	16	53	65	38	3	12
Totals	30	100	171	100	26	100

***Note*:** Totals may not agree because of rounding

[a] Since the only bones recorded for frogs were undifferentiated long bones, minimum numbers have been estimated by dividing the number of long bones by 4.

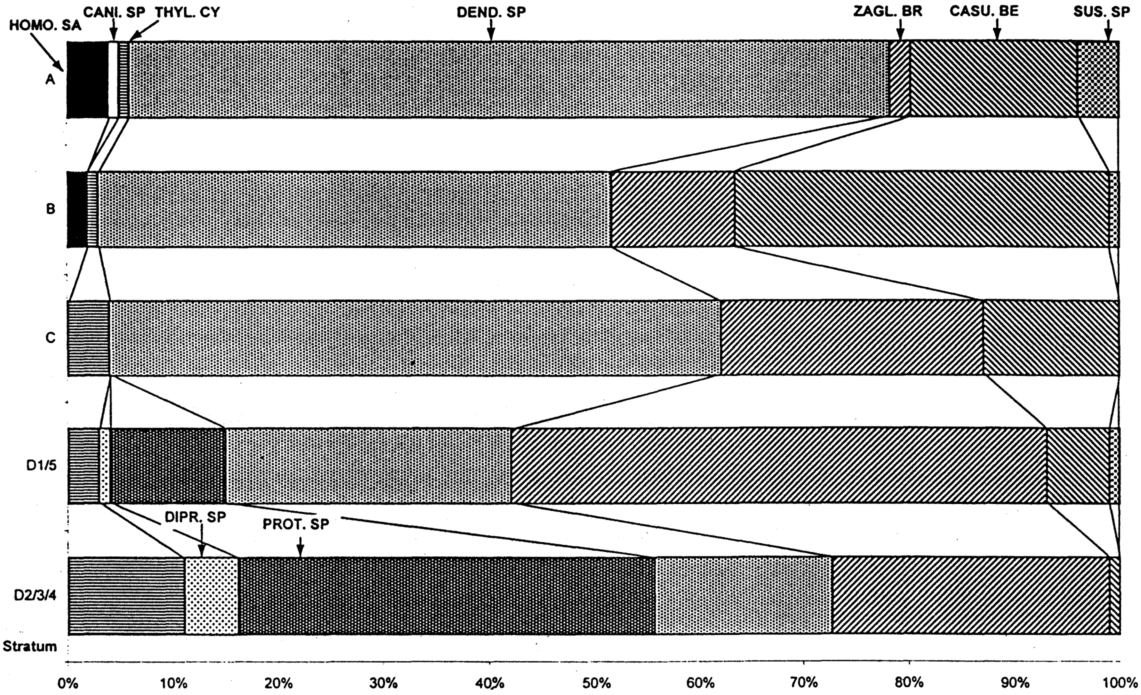

Figure 7.1 Relative abundance of Large animals by NISP (over c 5 kg adult body weight) by stratum

Source: Table 7.7

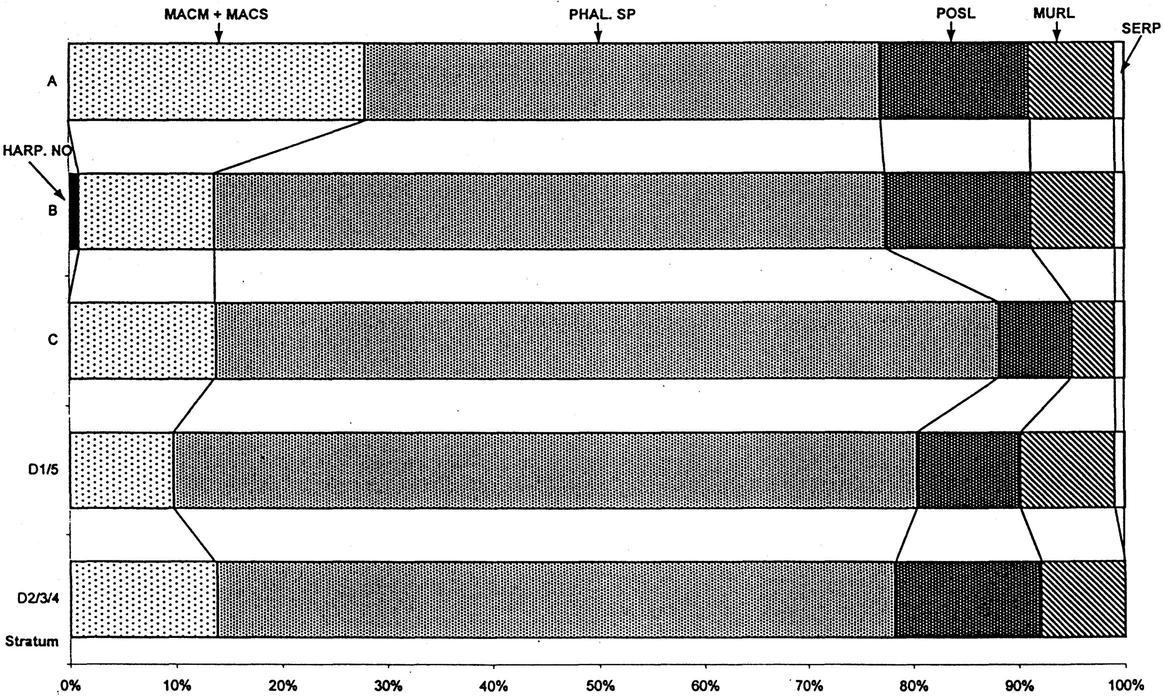

Figure 7.2 Relative abundance of Medium animals by NISP (c .1 - 5 kg adult body weight) by stratum

Source: Table 7.8

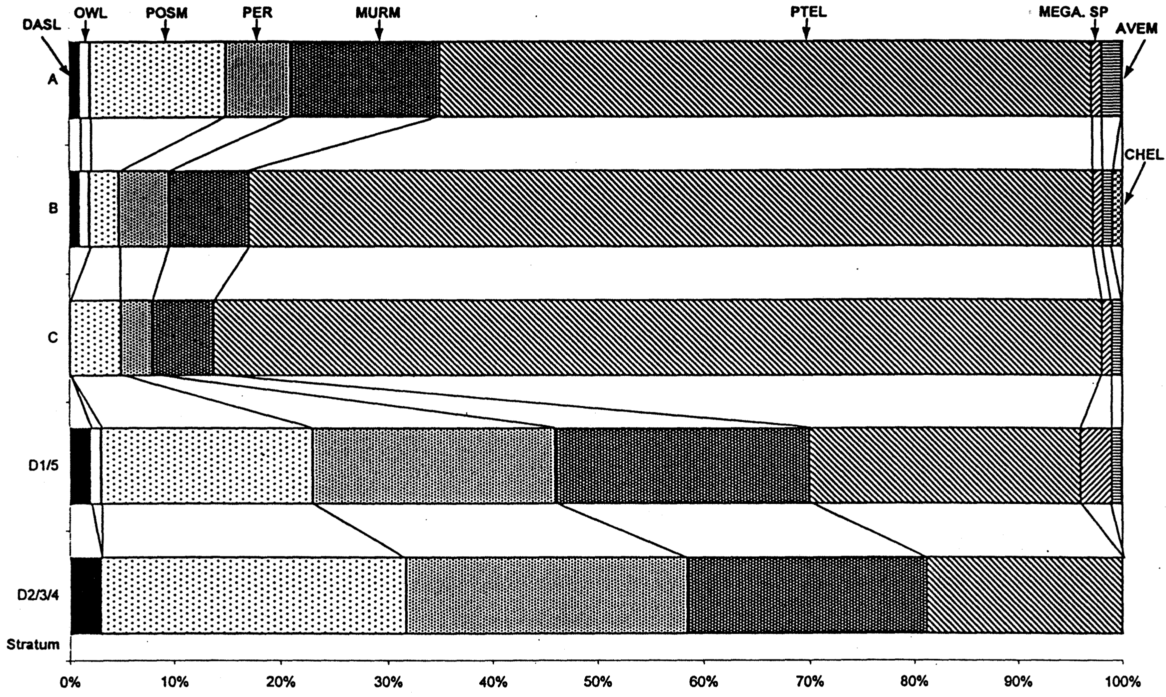

Figure 7.3 Relative abundance of Small animals by NISP (c.300 g - 1 kg adult body weight) by stratum
Source: Table 7.9

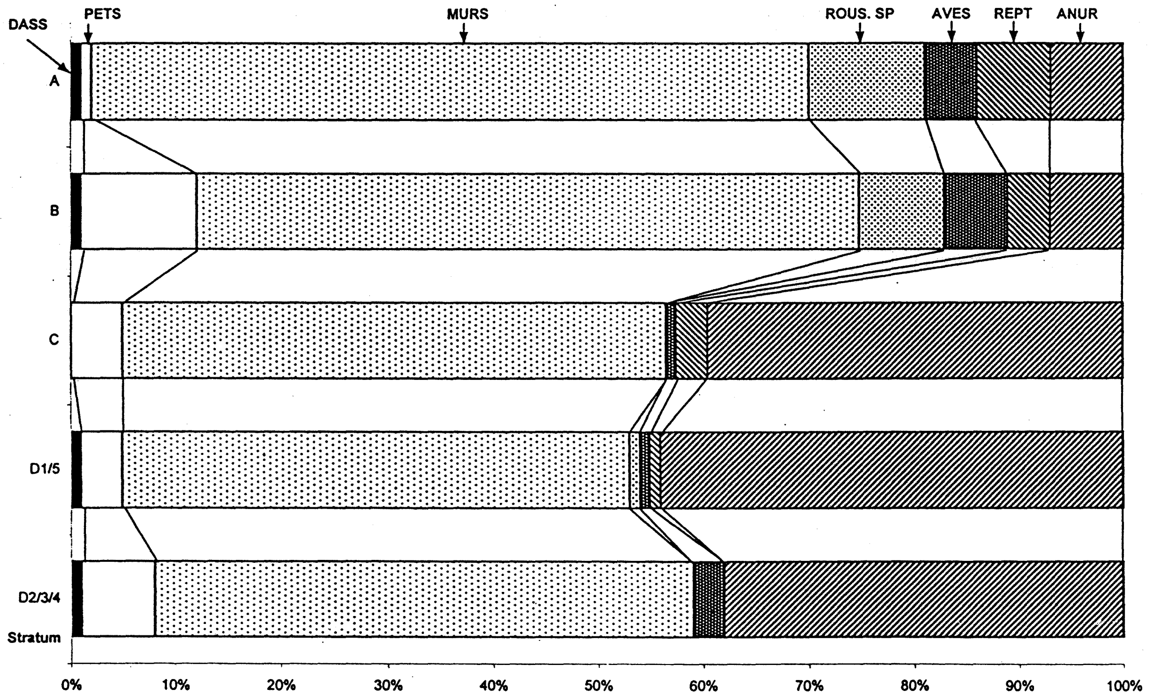

Figure 7.4 Relative abundance of Very Small animals by NISP (less than c.300 g adult body weight) by stratum
Source: Table 7.10

7.5.4 Conclusions

The **Large animals** in Table 7.7 show some significant trends. The steady decrease in the proportion of thylacine, in particular, is very marked. This trend can be taken to show that humans were also in competition with the thylacines, both as predators and for space and habitat, as human occupation increases at the beginning of the Holocene.

The general increase in the proportion of cassowary bone shows that humans are fairly efficient at trapping these large, shy, flightless birds. Cassowary occurrence peaks in Stratum B where the bird is second only to *Dendrolagus* in abundance. The thylacine was less likely to risk a dangerous fight with the bird's powerful legs and deadly claws and only one cassowary bone was recorded from both Stratum D1/5 and Stratum D2/3/4.

The trend in *Zaglossus* bone is intriguing. It represents about a quarter of all 'Large' animal bone in the basal levels. Thylacines could have had considerable success killing these animals once they had located them. By Stratum D1/5 *Zaglossus* has risen to half the 'Large' bone present. This could have been the result of either thylacine or human predation. *Zaglossus* has been recorded in the alpine zones at over 4100 m and may well have been a fairly common inhabitant of the cold regions of alpine grassland and upper forests during the late Pleistocene, which must have been within easy reach of the site. Their proportion as part of the 'Large' bone decreases again to about 25% in Stratum C, down to about 12% in Stratum B and in the last stratum down to 2% as human settlement and activity increases. The species is unknown in the locality today and is becoming increasingly rare within hunting ranges from settlements in other areas (Morren 1986:140).

The extinct species of diprotodontid and *Protemnodon* represent nearly half the 'Large' bone in the basal levels, I believe from written reports (see entry in Section 8.2) that thylacines were capable of predating these beasts. But there is no direct evidence as to the predator responsible for the bone from those species. By Stratum C these species had disappeared and the highest proportion of 'Large' animal bone in Stratum C is the tree kangaroo which, although certainly vulnerable to thylacine attacks while on the ground, is more vulnerable to human hunting. It is clear that, as the large species of *Protemnodon* and diprotodontidae ceased to be available for hunting, the remaining *Dendrolagus* species were increasingly targeted. (The extinct *Dendrolagus noibano* and the two extant species are not differentiated in the tables, but the differences are examined in Chapter 8 where the topic of extinction is discussed in further detail.) By the time Stratum A was accumulating, *Dendrolagus* was by far the most common 'Large' species present.

A brief comment on the pig remains. There are recorded finds of this species in the Holocene strata, which is to be expected, but there is one tooth which was recovered from the Pleistocene redbrown clay of Stratum D1. There is no doubt in my mind about its archaeological context (redbrown clay was removed from the interstices of the pulp area) but I always had doubts about the age of the specimen, since no other pig remains were recovered from any other Pleistocene stratum.

Trends within Table 7.8, showing the abundance of 'Medium sized' species are less pronounced, presumably because this category represents the major predation target for both human hunters and the thylacine throughout the entire occupation of the site. Medium and small macropods are high in the basal levels, where there is a surprisingly high proportion of arboreal phalangers and possums, indicating that a range of predators were probably active including the agile dasyurid, certainly capable of tree climbing and catching these small nocturnal tree dwellers. The ground cuscus *Strigocuscus gymnotis* is not represented in the lowest strata. The proportions of medium and small macropods rise quite sharply in the last 5000 years and this may be due to a decline in 'Large' animals and possibly an increase in grasslands allowing more medium macropods to breed in the locality. A decline in forest may also account for lower proportions of *Phalanger* species in the same time period.

The outstanding trend in the pattern of the 'Small' animals in Table 7.9 is the dramatic rise in the proportion of the fruit bats, which is as pronounced in Stratum C as it is in Stratum B. This trend is discussed in more detail in Chapter 8 as evidence of a major change in human hunting strategies.

In all levels of Stratum D there is fairly equal occurrence of the medium possums, the bandicoots, the medium murids and the fruit bats. This might indicate the presence of small predators such as birds of prey and the *Dasyurus albopunctatus*. As the proportions of fruit bats rise, that of bandicoots, medium possums and murids decline. This suggests an increasing specialisation in human hunting of bats within the locality in the late Pleistocene, as many larger species become rare or inaccessible (discussed in more detail in Chapter 8).

Examination of the proportions of the 'Very small' animals suggests the dominance of non-human predators (this point is argued in more detail in Section 6.6.2.4). Small murids represent the highest proportions throughout the sequence, but frogs are also very important in the three lowest strata (D and C). I suggest that these 'Very small' species are either prey of small dasyurids or of birds of prey roosting on the cliffs above, or were natural inhabitants of the site at times when it was a damp environment with an active water-course running through it probably interspersed with fallen rocks and other suitable dry places for small rodents.

Table 7.11 summarises the faunal data by animal size and strata.

Table 7.11 Summary of faunal data by animal body size and strata

	Minimum numbers of individuals		Number of identified specimens		Weight of bone	
Faunal category	Number	%	Number	%	grams	%
STRATUM A						
Large species	11	3	351	9	715	16
Medium species	250	60	2 661	70	3 539	77
Small species	139	33	716	19	320	7
Tiny species	17	4	88	2	17	<1
Totals	417	100	3 816	100	4 591	100
Quantity of sediment:	*5 391 litres*					
Burnt bone:	*59%*					
Unidentifiable bone:	*38%*					
STRATUM B						
Large species	42	3	771	5	2 577	15
Medium species	1 023	62	10 182	65	12 663	73
Small species	533	32	4 463	28	2 030	12
Tiny species	48	3	255	2	60	<1
Totals	1 646	100	15 671	100	17 330	100
Quantity of sediment:	*5 792 litres*					
Burnt bone:	*80%*					
Unidentifiable bone:	*41%*					
STRATUM C						
Large species	5	9	24	4	93	24
Medium species	20	37	256	48	230	60
Small species	13	24	174	33	53	14
Tiny species	16	30	81	15	8	2
Totals	54	100	535	100	384	100
Quantity of sediment:	*743 litres*					
Burnt bone:	*46%*					
Unidentifiable bone:	*40%*					
STRATUM D1/5						
Large species	36	10	643	18	3 049	51
Medium species	145	39	1 950	53	2 668	45
Small species	48	13	299	8	148	3
Tiny species	140	38	769	21	65	1
Totals	369	100	3 661	100	5 930	100
Quantity of sediment:	*2 758 litres*					
Burnt bone:	*14%*					
Unidentifiable bone:	*22%*					
STRATUM D2/3/4						
Large species	9	12	92	16	543	67
Medium species	14	19	221	38	184	23
Small species	21	29	101	18	53	7
Tiny species	29	40	171	29	25	3
Totals	73	100	585	101	805	100
Quantity of sediment:	*736 litres*					
Burnt bone:	*5%*					
Unidentifiable bone:	*17%*					

Note: Totals may not agree because of rounding

The dominance of the 'Medium' sized species in Table 7.11 is no surprise. This is the most available group of species within the mid and upper montane forest and moss forest, comprising the smaller macropods and all larger phalangers, possums and murids. Both humans and thylacines were apparently very successful in hunting these species since the proportions of this group show a considerable rise in the Holocene strata dominated by human hunting.

The proportions of the 'Small' species show some variation over time, largely reflecting changes in the presence of the large fruit bat, although it declines in Stratum D1/5, where the proportion of Large species is highest. The balance between the bone from the four size categories is fairly even in the basal levels, perhaps indicating that several different sized predators were contributing fairly equally to the accumulation of bone. All other strata show an uneven balance with at least one animal group dropping below 10%. This uneven occurrence of animal groups could well indicate human activity at the site as human hunting choices would be expected to produce a bias towards favoured species. Human presence would further alter the balance by deterring other predators from the site.

What is particularly revealing is the dramatic reduction over time, especially during the late Pleistocene, in the proportions of both 'Very Small' and 'Large' species. As human hunting begins to dominate bone accumulation, the 'Very Small' species decline and almost disappear from the record in the Holocene period. It has already been suggested (Chapter 6) that a high proportion of these 'Very Small' species may be a useful indicator of either the reduction in human presence, with possibly lengthy periods of time between human visits to the site through much of the Pleistocene strata. The reduction in proportion of bone from the 'Large' species is not quite so pronounced but also shows a rapid decline towards the end of the Pleistocene. There is little doubt that as the four largest species disappear from the record, and presumably become extinct, human effort was switched to other available prey. *Zaglossus* and *Dendrolagus* and the cassowary continue to contribute and account for 'Large' bone in the upper levels, while not replacing the quantities of meat and other necessities that had been available from extinct species earlier in time.

Human bone itself begins to contribute in small quantities in Strata A and B as the occasional human hunting of the Pleistocene was replaced by more intensive occupation of the site and humans begin their domination of the environment. Humans are not only in competition with other predators for food but also compete for space and habitat as human occupation increases at the beginning of the Holocene.

Table 7.12 Density of bone by body size and strata

Body-size category	Stratum A g/litre	Stratum B g/litre	Stratum C g/litre	Stratum D1/5 g/litre	Stratum D2/3/4 g/litre
Large	0.07	0.13	0.03	0.23	0.13
Medium	0.49	1.76	0.34	0.71	0.30
Small	0.13	0.77	0.23	0.11	0.14
Very small	0.02	0.04	0.11	0.28	0.23

Table 7.12 presents the density of bone in grams per litre for each body size in each stratum. This indicates that, as expected, the density levels for the 'Medium' and 'Small' body size species is greatest in Strata A and B where hunting of these easily available animals is high. The highest density levels for the 'Large' species is in Stratum D1/5, which also has the highest density levels for the 'Very Small' animals. These figures give a more accurate comparison for the abundance of bone in each stratum than comparison between proportions of species but confirm that the overall trends are similar.

Chapter 8

Environmental Evidence from the Faunal Data

8.1 INTRODUCTION

The faunal analysis provides information relevant to several specific aspects of the research such as predation strategies, environmental conditions and the extinction of certain species. At the primary level it provides proportions of taxa present at five periods of time in the development of the site. At a higher level of interpretation this corpus of faunal data must not be seen as fully representative of the animals living at any time in the locality. The bone represents only the prey brought into the shelter by various predators, together with the bone of any animal that died naturally while at the site. Predators do not consistently sample the entire range of available species within any particular distance of a site and the bone in no way represents everything living within the locality at any time period. This is particularly true of human predators, whose activities are governed as much by social and cultural factors as by environmental factors. At the same time, humans visit and hunt in environments outside those available in the immediate vicinity. Nombe is situated in a mountainous terrain where it was always possible to obtain species from an altitudinal range between about 1400 m (the valley of the River Mai) to over 2800 m within an hour or two's walk from the site. Higher altitudes are available further to the west of the limestone escarpment of Mount Elimbari within perhaps half a day to a day's walk.

Nevertheless each species carries information relating to environmental and habitat conditions and analysis of this information can point to particular strategies used by predators working from the site, as well as contribute to theories of change in the climatic and vegetative regimes dominant around the site. There is therefore a need to examine the environmental and ecological factors suggested by the species suite present in each stratum at Nombe in order to reconstruct human activity over time. For this purpose I document relevant information in this chapter about all species and taxa present in the sample assemblage.

The Nombe bone was largely the result of the predation strategies of a number of human and non-human hunters, using the cave as a base or lair or the overhanging cliffs as a roost. Each hunter uses different territory, hunts at varying times of the twenty-four hour cycle, has individual limitations as to the size and vulnerability of its targeted prey and adapts through different mechanisms to change. There is now a considerable amount of information about each extant species of predator and potential prey: their recorded distribution, their environmental and altitudinal preferences, their behaviour within their local habitat, their feeding and often their breeding patterns. Twenty years ago there was little information on New Guinea, and what had been written was scattered through many sources. Today we have the first comprehensive publication on the mammals of New Guinea (Flannery 1990), and excellent publications on birds and frogs (Menzies 1976). These are only a few of the many publications arising from ongoing research into many areas of natural history.

Of particular importance have been the cooperative studies of Bulmer, the expatriate anthropologist, and Majnep, the Kalam scholar resident in the Kaironk region of the Bismarck-Schrader Range (Majnep and Bulmer 1977, 1990a-f). Bulmer refers to the 'three layers of life within the mid-montane forest' which is the natural environment for the Nombe rockshelter under Holocene climates. His layers consist of:

☐ the upper leafy zones of trees, often including thick clumps of epiphytic shrubs and ferns, where there are many hiding and nesting places for the medium and smaller sized arboreal mammals and birds;
☐ the ground layer used by the heavier, larger species and flightless birds; and
☐ the understorey of roots and cavities in the undergrowth where many murids, reptiles and burrowing mammal species such as the *Zaglossus* and bandicoots find shelter and food.

These three layers of forest activity are important niches for different species.

In so far as these 'three layers of life' are home for different species, documenting them will provide useful clues to the patterns of environmental change over time, as well as suggesting strategies in human hunting. We know that the occupation of Nombe, on the one hand, spans the transition from Pleistocene to Holocene climates and, on the other, covers the period of the appearance of horticulture in the early Holocene. Human activities, especially forest clearance and the increasing populations that may be assumed to have been supported by the new economy, had marked effects on forest extent and composition (see for example Golson and Gardner 1990).

The question arises as to whether present-day knowledge of behaviour of a particular species necessarily means that we can assume similar habits in the prehistoric past. Some species today are found in a number of habitats and appear to have the capacity to adapt competently to new environmental circumstances. This does not seem to be true for many of the species found in the primary forest or regions well away from human settlements. It is therefore reasonable to suggest, from present knowledge, that some species have an inherent ability to adapt, whereas others do not, and to use this information to reconstruct past behaviour and change.

8.2. ENVIRONMENTAL AND ECOLOGICAL INFORMATION ON ALL TAXA PRESENT IN THE SAMPLE BONE ASSEMBLAGE

8.2.1. Discussion

This section identifies those features of each of the 88 taxa or species from Nombe which provide evidence on the origin of the bone, the contemporary environment and vegetation zones and the predation or hunting strategies employed. Summarised at the beginning of each entry is coded information on four specific aspects of behaviour:

- the **diet**, with three symbols:

O	omnivorous
C	carnivorous (including insectivorous)
H	herbivorous

- the **niche** in which each group normally operates, with four symbols:

A	arboreal
T	terrestrial
U	underground
V	volant

- the **broad habitat** in which the animal occurs, with four symbols:

R	primary mid-montane rain forest
M	higher altitude moss forest
A	very high alpine grass and shrub-land
G	disturbed zones of secondary regrowth and gardens

- the **altitudinal range** from which each taxon has been recorded

If an animal belongs to more than one category, then more than one symbol occurs, the first symbol representing the primary category.

The body weights used throughout the faunal analysis and which appear in several chapters of this thesis are derived from the data under each taxon set out below.

Some taxa consist of cranial bone identified to species level as well as post-cranial bone that often can only be identified to family level. If several taxa are present in any family group the first information is about the more general level of identified material (the post-cranial), followed by information about particular species (cranial). The classification of faunal data follows that in Table 7.2. Section 7.3 discussed the basis of this classification. Each taxon category was allocated a number for use in computation; these are set out in Tables 7.2 and 7.6 and in more detail in section 8.2.2.

In constructing this data I have used many sources. Flannery's work (1990) formed a basis, supplemented especially by Ziegler (1982), Hope, J. (1976), Hide, Pernetta and

Senabe (1984), Majnep and Bulmer (1977, 1990), Dwyer (1980, 1982b, 1983a, 1985a, 1990), Flannery and Seri (1990) and Hyndman and Menzies (1980).

Many recent publications have advanced the state of the taxonomy. Of these, the most important for this study are Aplin and Archer (1987), Archer (1982a), Flannery, Archer and Maynes (1987), George (1987), Groves (1982, 1987), Groves and Flannery (1990), Menzies and Pernetta (1986). I have had to extensively revise my classification of the Nombe faunal data, originally identified during the early 1980s, in light of all this ongoing research. Ongoing revisions required a system of classification and analysis which was sufficiently flexible to accommodate these changes. The system used is set out in detail in Appendix 2.

8.2.2. Introduced Species

Homo sapiens 101

Diet: O

Niche: T/A/U

Habitat: All

Altitude: Found throughout.

Since there are scattered pieces of human bone in the top stratum they have been included in the bone analysis. These fragments include teeth, finger joints, small cranial fragments and a few pieces of long bone. Many are burnt. They presumably have come from normal processes like tooth evulsion, accidents, finger joint removal (common in the recent past, especially by women as a sign of mourning), perhaps the disturbance of earlier burials and possibly the charred remains of human enemies, dispatched and consumed. Undisturbed burials are not included in the analysis. Local caves were sometimes used as burial places in the past.

Occurrence at Nombe: Human bone and teeth fragments occur in Strata A and B only.

Sus species 108

Introduced domesticated species now also feral.

Diet: O

Niche: T

Habitat: R/G

Altitude range of feral pig: 0-3000 m.

The species, as a feral animal, is common from sea level to about 1500 m although G. Hope has recorded it from the high altitudes on Mount Albert Edward (Hope and Hope 1976). Feral pig is now more common away from intensely occupied areas.

Groves (1981) discussed the taxonomy of pigs in New Guinea where it is clear that the wild and domestic populations often are allowed to interbreed. He rejects the claims for a separate species (*Sus papuensis*) and concludes that New Guinean pigs represent a hybridisation between *Sus scrofa vittatus* and *Sus celebensis*, a process that may have occurred in the Moluccas (Groves 1981:66).

Occurrence at Nombe: Pig bone and teeth occur in Strata A and B. One tooth was recovered from Stratum D1. Fifteen fragments occur in all.

(The antiquity of the pig in New Guinea is discussed in section 9.3.4).

Canis familiaris 107

Introduced domesticated predator now also feral.

Diet: C

Niche: T/U

Habitat: G/R/M/A

Altitude range: Feral populations have been recorded from sea level to alpine grasslands.

Gollan (1984) discusses the introduction and distribution of the dingo to Australia. Bellwood (1985:227) discusses the dating of the dog in Indonesia. There is no evidence of any canid specimen within New Guinea from the Pleistocene or indeed from the early period of the Holocene. The earliest date for dog in New Guinea is from the coast (Bulmer, S. 1975:23-4).

The dated specimens in Australia are little older than 3000 years or younger and Gollan concludes that it is unlikely that the dingo was introduced into Australia until about 4000 years ago.

Bellwood mentions (1985:227) that in Timor the first date for dog is not until the last thousand years.

Little work has been carried out on the canids of New Guinea, although there is an extensive folklore about the wild canid populations which are probably restricted to high altitude grassland regions such as the Star Mountains. Dogs are common in villages today and, in many communities where hunting is still a serious activity, they are an important adjunct to human effort (Dwyer 1990, Majnep and Bulmer 1990 a-f).

Occurrence at Nombe: Only two canid teeth were recovered, from Stratum A.

Rattus *species*

No species of *Rattus* were identified from the deposits at Nombe although Dwyer found several *Rattus* species on Mount Elimbari, both exotic and endemic(Dwyer 1978).

8.2.3. Endemic and Indigenous Species

MAMMALS (Mammalia)

Monotremata, Tachyglossidae

Zaglossus bruijni: **105**

Diet: O

Niche: T/U

Habitat: R/M/A

Altitudinal range: Found from 0-4000 m. Now rare except in high zones well away from occupied areas.

These large echidnas, which can weigh nearly 10 kg as fully adult specimens, have been recorded from sea level up to sites well within the alpine zones. They are obviously very adaptable animals, shy and terrestrial. *Zaglossus* are presumed to be mainly insectivores, especially eating worms, ants and termites. They are obviously easier to catch with the aid of dogs to sniff them and flush them out of their hiding places, often in the understorey or in holes they have dug in the ground (Hide, Pernetta and Senabe 1984:313), where humans can kill them easily. Thylacines would be equally as capable of hunting them as dogs.

Dwyer (1990) describes the Etolo people as particularly liking the meat of the species but reporting the animal to be rare and only present at altitudes in their region well over 1000 m. In the Simbu region these animals are now extremely rare and appear to be retreating to the zones well away from human habitation. There are concerns that the species is already under threat of extinction through over hunting often with dogs (George 1979:96).

Occurrence at Nombe: Found in all strata but far more frequent in Stratum B and D1/5. The short, robust physique of this animal means that many of the post-cranial bones are sturdy and resist decay, so that most of the surviving material is post-cranial but very easily recognised and identified.

Dasyuromorphia, Thylacinidae

Thylacinus cynocephalus: **106**

Diet: C

Niche: T/U

Habitat: G/R/M/A

Altitude range: Likely to have been found 0-4000 m. Now extinct in New Guinea.

The thylacine represents the largest indigenous predator known to have existed within the period of human occupation of New Guinea. There is some variation in body size of the specimens present at Nombe (L. Dawson pers. comm. 1982). All are significantly smaller than many Australian examples but still fall within the general range of the species as known. The weight of adult animals has been estimated to fall within a range of 15-35 kg (Smith 1982:244).

Thylacines were capable of successfully attacking large macropods, as shown in an article in the *Sydney Gazette and NSW Advertiser* (21st April 1805), which refers to the 5 lb of kangaroo meat remaining in the stomach of a thylacine killed by dogs at Dalrymple (the weight of the entire macropod was 45 lb). There is a report of a thylacine successfully defending itself against an attack by a bull-terrier and tearing the dog's skull apart with one bite (Mackay reported in Le Souef and Burrell 1926). There are reports of Australian species eating echidnas (Troughton 1967), and Wart (1919) as reported in Smith (1982) relates a bushman's discovery of a thylacine den half-full of bones including a half-grown calf, which must have been dragged to the site by the thylacine.

The species is said to have been adapted for running (Smith 1982:247). Many writers speak of their ability to follow prey for hours without tiring. This behaviour would not appear to be suitable in the forests of highland New Guinea, but judging by the variation within their environmental distribution, the species must have been very adaptable. Smith (1982:250) writes that "The animal's limb proportions would be better adapted to stalking under dense cover followed by a sudden burst of speed" which would enable them to hunt successfully in forest (the habitat of the large extinct species of diprotodon and *Protemnodon*), as well as the more open alpine grasslands. Keast (1982:681) states that "the diet of the thylacine was apparently small macropodids, echidnas, rats, birds and lizards. All items that would be better stalked than pursued".

It had physical features well suited to the hunting of large prey, such as the ability to rear up on its hind legs balanced on its tail. The molars are adapted to slicing and crushing and the jaws could be opened extremely wide, reportedly to 120°, as wide as some snakes (Beresford and Bailey 1981). It is unlikely such a species would find difficulty in killing large (perhaps 200-300 kg) and presumably rather slow animals such as the diprotodontid and even, on occasions, tackling formidable opponents such as cassowaries and *Zaglossus*.

As Smith (1982:250) says in summary, "Probably as one of Australia's (and Papua New Guinea's) largest predators, it was flexible in both behaviour and habitat, but thick forest may have been the preferred habitat".

Keast (1982) has compared the anatomy of the thylacine to that of the wolf and also to some smaller members of the dasyuroid assemblage. He concludes that Moeller (1968) was correct when he stated that the thylacine was an "overgrown dasyurid".

Keast states that "although it is clear that the thylacine was adequate for its role as pursuit carnivore .... it is different from the Wolf in virtually all structural features relating to the pursuit carnivore role" (1982: 675,681). This information does not assist in providing any living species as a model for detailed comparison of hunting behaviour or diet.

Occurrence at Nombe: Fragments of six individuals recovered. The highest number of identified fragments were found in the Stratum D1/5, although they could all come from one animal, followed by fragments in Strata D2/3/4, in which there are two animals present, and single animals occurring in Strata A, B and C.

Dasyuromorphia, Dasyuridae

Dasyurus albopunctatus: 303

Diet: C
Niche: T/U/A
Habitat: R/M/A
Altitude range: Recorded from sea level to c. 4000 m.

This is one of the largest and fiercest carnivores surviving in New Guinea. Majnep relates that it will frequently badly injure hunting dogs (Majnep and Bulmer 1990f;15) and can attack and kill young pigs by attacking the throat. Nevertheless the animal, even at its largest, only weighs about 700 g and is unlikely to have been capable of a successful attack on the larger animals such as *Protemnodon* or diprotodontids. It certainly could not have dragged carcases of animals much larger than itself far from the point of death, although it has the ability to bite off extremities. It is an omnivorous opportunistic feeder and includes insects and other invertebrates, frogs, fish, rodents and small ringtail possums and gliders as well as grasses and fruits in its seasonal diet in various forested environments.

Agile and mainly terrestrial, it is capable of considerable climbing and leaping (similar to the abilities of a cat, which unfortunately may be responsible for declining numbers of dasyurids in regions where the cat is now feral). It can be found widely distributed from sea level to alpine grasslands and is more common in forests over 1000 m.

Occurrence at Nombe: Rare, one individual in Stratum A, five in Stratum B, two in Stratum D1/5 and one in Stratum D2/3/4.

The smaller dasyuridae (*Neophascogale, Myoictis, Murexia, Phascolosorex* and *Antechinus* and other species) are thought to feed mainly on arthropods (mainly insects) with some vegetable component (Fox 1982:102), but some will also prey on small mammals and birds (probably up to and perhaps larger than 500 g body weight).

These species vary from about 20 to 450 g in adult body weight, many are at least partly arboreal and diurnal but adapted to a number of varied ecological niches, from primary forest to gardens and disturbed zones to alpine grasslands They are known to be eaten by raptors and other birds of prey.

Occurrence at Nombe: There are rare occurrences of small dasyurids that are incomplete and cannot be identified to species level. There is evidence for only one animal each from Strata A, B, D1/5 and D2/3/4.

Peramelemorphia, Peroryctidae (Bandicoots):

All Peroryctidae are found in rainforest and are terrestrial creatures which probably eat insects, worms, fruits and snails. At present several species seem to coexist in the same area. Groves and Flannery (1990) have recently discussed their taxonomy and initiated some changes in nomenclature. George and Maynes (1990) have discussed the New Guinea bandicoots. Four species (three large and one small) are found at Nombe.

Large bandicoots: **402**

Echymipera kalubu: **302**

Diet: O
Niche: T/U
Habitat: G/R
Altitude range: This species has been recorded from sea level to 2000 m but is more common between 1000 and 1200 m.

This species seems to be the largest bandicoot present at Nombe (adults weighing up to 1.5 kg). It is fond of various fruits and can be hunted successfully at night near *Pandanus, Ficus* and *Zingziber* when fruiting.

Occurence at Nombe only three specimens, two from Stratum A and one from Stratum D1/5.

Echymipera rufescens: **302**

Diet: O
Niche: T/U
Habitat: R/G
Altitude range: Has been recorded from sea level to 1400 m, although more common below 1200 m.

This species is reported in some areas to be easier to catch with the aid of dogs (Hide, Pernetta and Senabe 1984). It seems to be sympatric with *E. kalubu.*

Occurrence at Nombe: This species is also very rare at the site. There are only two examples of *Echymipera rufescens* (Stratum B).

Peroryctes raffrayana: **302**

Diet: O

Niche: T/U

Habitat: G/R/M/A

Altitude range: Has been recorded from c. 600 to 4000 m.

This species also likes fruit but will eat insects also. Majnep records that it is found in *Nothofagus* forest as well as *Casuarina* stands and open grasslands (Majnep and Bulmer 1990e).

Occurrence at Nombe: More frequent at Nombe than the other two large bandicoots. Ten animals occur in Stratum B and six in the top level Stratum A. Single occurrences are found in the Strata D2/3/4, D1/5 and C.

Small bandicoots: **404**

Occurrence at Nombe: Post-cranial material, which because there is only one species present in the small bandicoot family size category (PERS) must belong to this species, shows a similar pattern of greatest abundance (thirteen individuals) in Stratum B, six occurrences in Strata D1/5, four in Stratum D2/3/4 and a single occurrence each in Strata A and C.

Microperoryctes longicauda: **404**

Diet: O

Niche: T/U

Habitat: R/M/A

Altitude range: Recorded from c.1000 to c.4000 m but more common at higher altitudes.

Flannery caught this species at the forest edge at 3000 m and it was present in the material collected in the Cartensz alpine grasslands site of Mapala (Hope, J. 1976:212). Majnep and Bulmer (1990e) found it to be fairly common in bush-fallow and forest in the Kaironk and Majnep describes the methods used by the women to hunt this species in the *Nothofagus* forest.

Occurrence at Nombe: This species is the most common bandicoot at the site. Forty nine animals are represented in all, twenty nine of which are in Stratum B, ten in Stratum D1/5, nine in Stratum A and a single occurrence in Stratum D2/3/4.

Diprotodontia, Diprotodontidae

Diprotodontids: **102**

Diet: H
Niche: T
Habitat: R/M
Now extinct.

At least two species of diprotodontid have been described from the highlands of New Guinea (Flannery and Plane 1986, Hardjasasmita 1985). Flannery and Plane describe *Hulitherium thomasetti* as an animal of up to 200-300 kg, a herbivore living in the highest zones of forest, browsing amongst the trees. It was smaller than its Australian relatives, described as bear-like in form with highly mobile limbs not unlike the giant panda.

Occurrence at Nombe: There are twelve fragments of diprotodontid post-cranial bone, with one animal present from each of the lowest two strata, Stratum D2/3/4 and Stratum D1/5 (Flannery, Mountain and Aplin 1983). Flannery is of the opinion (Flannery 1990:28) that two of these specimens come from a small species similar to *Hulitherium thomasetti* (perhaps the size of a small pig) but there is insufficient evidence as no cranial material was recovered. There is no reason to suggest behavioural or habitat differences between *Hulitherium thomasettii* and the Nombe species, both probably browsing in the upper montane forests and out into the more open shrub lands beyond.

Diprotodontia, Macropodidae

Protemnodon *species:* **103**

Diet: H
Niche: T
Habitat: R/M
Now extinct.

Examples of these large extinct macropods were first recorded from New Guinea in the Pliocene deposits at Otibanda, near Wau, where two species occur (*Protemnodon otibandus* and *P. buloloensis*) probably living in lowland rainforest (Anderson 1937; Plane 1967a, 1967b).

Occurrence at Nombe: Pleistocene *Protemnodon* occur in the two lowest strata only. Two new species have been described from Stratum D2/3/4 and Stratum D1/5 (Flannery, Mountain and Aplin 1983).

Protemnodon tumbuna: **103**

Diet: H

Niche: T

Habitat: R/M

Now extinct.

P. tumbuna has only been found at Nombe so far (Flannery, Mountain and Aplin 1983). It is described by Flannery (1990:28) as "undoubtedly a browser of the montane forest, certainly terrestrial in habit and judging from its dentition, its diet may well have comprised fallen fruit, leaves and substage plant species". It compares in size with the modern grey kangaroo, over 18 kg adult body weight. He suggests that it was similar to the Australian *Protemnodon* and "probably possessed a long neck, very short feet and short hind limbs, suggesting that it may have been slow moving and have reached into bushes to feed" (Archer, Flannery and Grigg 1985:32). This diet would have allowed it to occupy both the high moss forest and forest edge zones into the shrub lands at the beginning of the alpine vegetation zone.

Occurrence at Nombe: Three individuals are represented, two in Stratum D2/3/4 and one from Stratum D1/5.

Protemnodon nombe: **103**

Diet: H

Niche: T

Habitat: R/M/A?

Now extinct.

P. nombe is smaller in size; in fact Flannery claims that it is the smallest known species of *Protemnodon* (Flannery, Mountain and Aplin 1983:91). The dentition leads to the conclusion that it is also a forest browser probably sharing the same range of environments as *P. tumbuna*.

Occurrence at Nombe: Two individuals are represented in the lowest two strata.

Dendrolagus *species:* **104**

These are the largest endemic mammals in the highlands of New Guinea and rather improbably they are tree kangaroos, which can climb into high branches of rainforest trees. They descend to the ground to browse on leaves and fruit, so would be vulnerable to attack by thylacine. It is possible that the extinct species *D. noibano* was replaced by the similar but slightly smaller *D. dorianus* species during the Pleistocene.

Occurrence at Nombe: There is extensive post-cranial material from two family size categories (Large macropod (MACL) and *Dendrolagus* species (DEND.SP)), both of which must represent bone from the *Dendrolagus* species as the body sizes of the macropods are very distinct. The post-cranial bone shows a similar pattern to that of the cranial, being highest in the early Holocene Stratum B, with reduced amounts in Stratum A, single occurrences in Strata C and D2/3/4 and slightly increased numbers in Stratum D1/5.

Dendrolagus noibano: **104**

Diet: H
Niche: A/T
Habitat: R/M
Now extinct.

This species, the largest of the New Guinea tree kangaroos, is known only from remains at Nombe (Flannery, Mountain and Aplin 1983). It is thought to have been slightly larger than *Dendrolagus dorianus* so probably grew to 20 kg in adult body weight (the teeth have been estimated as 13% larger than those of the average *D. dorianus*). Little is known about its habits, but size alone would not have prevented it from being at least partly arboreal; even the extinct Australian *Bohra paulae* (Flannery and Szalay 1982), at up to 60 kg body weight, had similar post-cranial adaptations to modern tree-kangaroos that would have enabled it to climb trees.

Occurrence at Nombe: Present only in the lowest two strata, with two individuals in Stratum D1/5 and one in Stratum D2/3/4.

Dendrolagus dorianus **104**

Diet: H
Niche: A/T
Habitat: R/M
Altitude range: Recorded from c.600 to 4000 m.

This species grows to 18 kg in adult body weight. In the highlands it is an upper montane forest species now found particularly in the moss forest, perhaps due to the pressure of hunting in the more heavily populated areas and its particular vulnerability to hunting with dogs (George 1979). Although a clumsy climber it can make great leaps of up to 18 m from the tree tops to the ground when necessary (Archer, Flannery and Grigg 1985:40). It is a formidable fighter and is known to have crushed the snout of an attacking dog with one paw.

Occurrence at Nombe: The species does not occur in the Stratum D2/3/4, but there are three individuals in the higher Pleistocene Stratum D1/5, single individuals in Strata C and A and ten in Stratum B.

Dendrolagus goodfellowi: **104**

Diet: H

Niche: A/T

Habitat: R/M

Altitude range: Recorded from c.1200 to nearly 3000 m but more common at the lower part of the range.

This is the smallest of the *Dendrolagus* species, growing to about 8.5 kg, generally living in rugged regions of mid-montane *Nothofagus* and *Castanopsis* forests. George (1979) suggests that traditional hunting may have reduced the populations that lived previously in the more accessible, less rugged slopes. Majnep says that the *Dendrolagus goodfellowi* is hunted by stalking and shooting.

Occurrence at Nombe: None from Stratum D2/3/4, two individuals in the major Pleistocene stratum D1/5 and in Stratum A, four in Stratum B and a single animal in Stratum C.

Thylogale brunii: **201**

Diet: H

Niche: T

Habitat: G/R/M/A

Altitude range: Recorded from sea level to over 4000 m but more common at higher altitudes, especially in the more open alpine grasslands.

This adaptable wallaby is found in different habitats, in the upper alpine grasslands, in disturbed and more open patches of forest, such as abandoned gardens and old landslip zones, and in the extensive lowland grasslands. J. Hope reported bones of the species at 3964 m in the Carstenz Mountains (Hope 1976). Majnep says that this species lives in open grassland country at lower altitudes than *Dorcopsulus vanheurni*, which is a forest dweller (Majnep and Bulmer 1990a:56-7).

Occurrence at Nombe: One individual occurs in the lowest Stratum D 2/3/4, five in the other Pleistocene Stratum D1/5, a single individual in Stratum C and much higher numbers in Strata B (64) and A (35). This pattern is also followed by the post-cranial material (MACM).

Dorcopsulus vanheurni: **202**

Diet: H

Niche: T

Habitat: R/M

Altitude range: Recorded from 800 to c.3100 m but more common between 1100 and 2500 m.

This is the smallest macropod found at Nombe. Groves (1982) concludes that this species is part of *Dorcopsulus macleayi* but Flannery discusses the two species as having separate features, although both are present in the Central Highlands of Papua New Guinea. I have insufficient evidence to be able to distinguish these species in the faunal remains and therefore have retained my original classification of the early 1980s, later personally confirmed by Flannery, who has viewed all the Nombe macropodid material.

This fast and agile little animal only grows to about 1.5-2 kg in adult body weight and lives on leaves and fallen fruit in the mid- and upper montane forests. Majnep (Majnep and Bulmer 1990a) speaks of it resting under trees for many hours, just sitting on its haunches motionless. It is effectively hunted by dogs tracking and following it until it slows and can be shot. The increase in human population among the Kalam has caused more wallabies to be hunted with dogs which will chase and kill them independently, as presumably would have thylacines. Majnep speaks of a recent sharp decline in the numbers of these little forest wallabies in the Kalam area. He also writes (Majnep and Bulmer 1990a:41) about the many pit-traps used by his ancestors to catch these animals on their recognised tracks. The people near Nombe have told him that "there were plenty of disused wallaby pits in the bush" (Majnep and Bulmer 1990a:49). *Dorcopsulus* meat was especially popular for use in the Kalam initiation ceremonies for young men, being smoke-dried for the festival.

Occurrence at Nombe: This is the most common species of macropod from the deposits at Nombe, especially in the Holocene Strata A (36 individuals) and B (86 individuals). In the Pleistocene strata it is rare, three in Strata C and D1/5, and only one in Stratum D2/3/4.

Diprotodontidia, Phalangeridae

Phalangers: 203

A great deal of work has been carried out recently on *Phalanger* taxonomy resulting in new species names and groupings (Menzies and Pernetta 1986; Groves 1987; George 1987; Flannery, Archer and Maynes 1987). The three species represented at Nombe are all reasonably large-sized animals well worth hunting in the forests.

Occurrence at Nombe: There is a large amount of post-cranial material of *Phalanger* but it was not possible to differentiate between the bones of the three species known to be present from the cranial data. Bones are extremely common in Stratum B (449 individuals), common in both Stratum A (95) and Stratum D1/5 (61) but rare in Strata D2/3/4 and C (six each).

Strigocuscus gymnotis: **203**

Diet: H

Niche: T/U

Habitat: R/M

Altitude range: Recorded from sea level to about 2700 m.

This is a largely terrestrial species, usually larger than the other two species, growing to nearly 5 kg in adult body weight, so it can be larger than the scrawny dogs that the hunters often use to sniff it out of understorey lairs. It adapts to altitudes from sea level to about 2700 m, although the examples living at higher altitudes are smaller than specimens found lower down. It climbs and feeds in branches at night but is often found resting during the day in burrows in tree roots, in holes near streams or in rock niches and caves, which makes it especially vulnerable to dogs. It is known to eat meat as well as fruit such as *Pandanus, Elaeocarpus, Ficus* and green leaves such as *Rungia* and ferns. It also has a taste for sweet potato. There is 'strong magic' in some places such as Simbai (Majnep and Bulmer 1990d:27) connected with its capture and disposition.

Occurrence at Nombe: Common in Stratum B (29) and well represented in Stratum A (nine) but rare elsewhere on the site (two in Stratum D1/5, one in Stratum C).

Phalanger carmelitae: **203**

Diet: H

Niche: A/T

Habitat: R/M

Altitude range: Recorded from c.1400 to over 3500 m.

The smallest phalanger found at Nombe lives largely in the trees of the mid-montane forests. Adults grow to over 1 kg in body weight. It rests during the day in clumps of epiphytes in the branches. *Pandanus* fronds are a dietary favourite along with other leaves and maybe occasional insects or meat. Majnep (Majnep and Bulmer 1990d) reports that this species lives at lower altitudes than *P. sericeus* but has similar habits, being arboreal but feeding frequently on the ground and sometimes found in undergrowth cavities feeding on soft dry wood-pulp.

Occurrence at Nombe: It is the most common of the Nombe phalangers although it does not occur in Stratum D2/3/4. Twenty-one individuals were recovered from Stratum D1/5, two in Stratum C and 183 in Stratum B. The top strata has 28 individuals.

Phalanger sericeus: 203

Diet: H

Niche: A/T

Habitat: M

Altitude range: Recorded from c.1500 to c.4000 m but more common at higher altitudes.

This phalanger grows up to 2-2.5 kg adult body weight and often lives in primary forest at higher altitudes than *Phalanger carmelitae*, being adapted to the cooler climate with its thick fur. Flannery posits that its teeth may show specialised adaptation to a folivorous diet (Flannery 1990:129). Majnep (Majnep and Bulmer 1990c:23) reports that it eats a variety of ferns and leaves, some terrestrial and growing in abandoned gardens and clearings, as well as *Casuarina* fruit, but that it normally sleeps in dry hollows or forks of branches high up in trees in the *Nothofagus* forest.

Occurrence at Nombe: This is the only one of the three Nombe phalangerids to be more common in the Pleistocene than in the Holocene levels. There are 20 individuals in Stratum D1/5, one in Stratum D2/3/4, three in Stratum C, 13 in Stratum B and only four in the top Stratum A.

Diprotodontidia: Pseudocheiridae, Acrobatidae and Petauridae

Possums:

The Nombe possums technically belong to three families; the Pseudocheiridae, the Acrobatidae and the Burramyidae. Their variation in body size is of more importance when trying to allocate species to different predators, therefore I have constructed three family size groups to cover similar sized species.

- The **large possums** (POSL) consist of *Pseudocheirops cupreus* and *P. corinnae* (Pseudocheiridae)
- The **medium possums** (POSM) include *Pseudocheirus forbesi* (*Pseudocheiridae*) and *Dactalonyx palpator* (Petauridae)
- The **small possums** (PETS) include *Pseudocheirus mayeri* (Pseudocheiridae), *Petaurus breviceps* (Petauridae) and *Distoechurus pennatus* (Acrobatidae).

Large possums: 204

Occurrence at Nombe: A large group of post-cranial bones, especially in the Holocene stratum A (41 individuals) and B (143 individuals), with lower numbers in the Pleistocene levels, two in Stratum C, eleven in Stratum D1/5 and four in the lowest stratum D2/3/4.

Pseudocheirops cupreus: 204

Diet: H

Niche: A/T/U

Habitat: M/A

Altitude range: Recorded from c.1700 to c.4000 m, more common above 2500 m.

This arboreal possum can grow to 2-2.5 kg and lives on leaves and shoots such as epiphytic orchids. It is nocturnal and can come down and rest in tree roots or hollow trunks and the complex of undersurface spaces that Majnep and Bulmer term the 'undercroft' (Majnep and Bulmer 1990b).

Occurrence at Nombe: This possum was present in fairly large numbers during the entire period of sediment accumulation, with a single individual in the lowest Stratum D2/3/4, 36 in Stratum D1/5, three in Stratum C, 69 in Stratum B and 29 in Stratum A.

Pseudocheirops corinnae: 204

Diet: H

Niche: A/T

Habitat: R/M

Altitude range: Recorded from c.1200 to c.2500 m.

This species, which can grow to about 1 kg in adult body weight, is nocturnal and has the habit of sitting still on a branch without cover during the day and once seen can be easily shot. In places it appears to live at slightly lower altitudes than *P. cupreus*. It eats *Ficus* fruit and leaves and bamboo shoots as well as other leaves. It is said by Yuro hunters (of South Simbu Province) to be more arboreal than *P. cupreus* and therefore more difficult to capture (Hide, Pernetta and Senabe 1984:344), although this conflicts with information from other areas.

Occurrence at Nombe: This possum is not as common as *P. cupreus* but is present through all the sediments. The highest numbers are present in Stratum B (69), followed by Stratum D1/5 (36) and Stratum A (29) with three in Stratum C and one in the lowest Stratum D2/3/4.

Medium possums: 301

The post-cranial bone from the two species present is not nearly as abundant as that of the larger possums and phalangers. It is most abundant in the top levels with ten individuals present in Stratum A, nine in Stratum B, only one in Stratum C, six in Stratum D1/5 and two in Stratum D2/3/4.

Pseudocheirus forbesi: **301**

Diet: H

Niche: A/T

Habitat: M

Altitude range: Recorded from c.500 to c.2800 m.

This species weighs between 500 g and 1 kg as an adult. Majnep reports that it eats fruit (*Ficus* and *Casuarina)* and insects (Majnep and Bulmer 1990c:51) as well as soft, wood pulp. It inhabits especially the *Castanopsis* forest below the *Nothofagus* zone, building dreys in tree ferns and vines.

Occurrence at Nombe: It occurs throughout the Nombe sediments with 20 individuals in Stratum B, 16 in Stratum A, a single animal in Stratum C, eight in Stratum D1/5 and six in Stratum D2/3/4.

Dactylopsila palpator: **301**

Diet: C

Niche: T/A

Habitat: R/M

Altitude range: Recorded from c.1200 to c.2800 m but more common at high altitudes in the moss forest.

This is a small mainly terrestrial species that is common from 1500 m up to 2800 m in primary forest. It eats insects and inhabits the subterranean cavities under the ground surface of the forest. It has an extremely long digit with which it probably tears open burrows to extract the larvae in tree trunks. It nests in the undergrowth and fallen trees and old tree ferns. Among the Kalam, along with other species with mottled fur, this species is thought to bring sickness to garden plants, so it is not eaten by people currently working in gardens (Majnep and Bulmer 1990c:73).

Occurrence at Nombe: Rare occurrences only, with ten individuals in Stratum B, three in Stratum A and only a single individual in Strata C and D1/5.

Small possums: **401**

The post-cranial and unidentifiable cranial material of small possums is not common at Nombe. There are several species of small possum including *Cercartetus caudatus* that might be expected to be present but were not identified.

Occurrence at Nombe: Only two individuals in Stratum D2/3/4 rising to five in Stratum D1/5, a single individual in Strata C and A and seven in Stratum B.

Pseudocheirus mayeri: **401**

Diet: H

Niche: A/T

Habitat: M/A

Altitude range: Recorded from c.1500 to c.3600 m but more common at higher altitudes in the moss forest.

This small possum can grow to adult size of about 200 g. It constructs dreys of moss and lichen not far off the ground and spends the day there.

Occurrence at Nombe: Only four individuals, two in Stratum B and single individuals from Strata D1/5 and D2/3/4.

Petaurus breviceps: **401**

Diet: O

Niche: V/A/T

Habitat: G/R/M

Altitude range: Recorded from sea level to c.3000 m.

This little gliding possum grows to an adult weight of about 100 g. It is nocturnal and eats fruit (*Pandanus* and *Casuarina*), spiders and beetle larvae. It makes nests in dead tree-ferns, trunks or the undergrowth cavities, or in clumps of epiphytic orchids on branches.

Occurrence at Nombe: Only five individuals, two in Stratum B and single individuals in Strata C, D1/5 and D2/3/4.

Distoechurus pennatus: **401**

Diet: O

Niche: A/T

Habitat: R

Altitude range: Recorded from sea level to 1900 m.

Another very small possum growing to less than 50 g in adult body weight. It makes nests in leafy vegetation. It is reported to eat small tree fruit and insects and is an active arboreal climber.

Occurrence at Nombe: Only two individuals, single specimens in Stratum B and D1/5.

Rodentia: Muridae

Large murids: **205**

There are two species which are especially large, *Mallomys* sp., which can grow to an adult weight of 1.8 kg, and *Hyomys goliath*, which grows to about 1 kg. I have included both in my Medium size category (between 1 and 5 kg), since it would be difficult to distinguish the post-cranial bones of these two species. There is considerably more of the larger species amongst the cranial remains, so that it is probable that most of the post-cranial also belongs to *Mallomys* sp.

There has been a revision of *Mallomys* since the original identification of the specimens (Flannery, Aplin, Groves and Adams 1989) but I do not have sufficient knowledge of the new species *M. aroaensis*, which is obviously sympatric with *M. rothschildi*, to revise my identification and have left them classified as *M. rothschildi*.

Occurrence at Nombe: Although there are only single occurrences in Strata D 2/3/4 and C, there are 16 individuals in Stratum D1/5 and 66 in Stratum B, with 23 in the top Strata A.

Mallomys rothschildi: 205

Diet:	H
Niche:	A/T
Habitat:	R/M/A

Altitude range: Recorded from c.1500 to c.2500 m.

This desirable and still abundant nocturnal species, can grow to 1.8 kg in body weight, eats largely shoots and greens, being especially partial to bamboo. It is arboreal and often rests in hollows or clumps of epiphytes up to 10 m above the ground, where it can move from tree to tree easily. It also moves along the forest surface and can be found in the understorey or even in rock lairs. It is an important *kapul'* for garden magic amongst the Kalam (Majnep and Bulmer 1990b).

Occurrence at Nombe: Present throughout, although there are only single occurrences in Stratum D2/3/4 and two in Stratum C. It is more common in the rest of the site, 16 being recovered from Stratum D1/5, 72 in Stratum B and 11 in Stratum A.

Hyomys goliath: 205

Diet:	H
Niche:	A/T/U
Habitat:	G/R/M

Altitude range: Recorded from c.1500 to c.2800 m.

Smaller than *Mallomys*, this is nevertheless an impressive rodent, that can grow to about 1 kg. It is found living in the understorey of trees or in rocks, in disturbed areas especially around gardens, eating *Pandanus* nuts and shoots of bamboo, sword grass and palms. Majnep records that it will invade gardens and dig up and eat sweet potato (Majnep and Bulmer 1990b:61); since it is terrestrial, dogs can be used to hunt it out; it can also be trapped. Majnep says that it occurs in disturbed areas of the forest "where the sun gets in" (Majnep and Bulmer 1990b:76) and will feed on the shoots of epiphytic ginger plants.

Occurrence at Nombe: Rare, only nine individuals are found, four each in strata A and B and a single individual from Stratum D1/5.

Medium murids: **305**

This category covers post-cranial and unidentified cranial material from a wide range of murids having an adult body weight between about 300 g and about 1 kg. Six species have been identified from cranial data: *Uromys anak*, *U. caudimaculatus*, *Anisomys asper*, *Parahydromys asper*, *Hydromys* sp. and *Xenuromys* sp.

Occurrence at Nombe: The highest abundance of medium murid bones comes in the top level with 39 individuals. Stratum B has 25, Stratum C two, Stratum D1/5 nine and the lowest Stratum D2/3/4 has five.

Uromys anak: **305**

Diet:	H
Niche:	T/U/A
Habitat:	R/M

Altitude range: Recorded from 850 to c.2800 m.

The males of this species are considerably larger than the females and can grow up to 1 kg or more. It is sympatric with *U. caudimaculatus* in the mid-montane altitudes but is more common in the lower oak forest than *Nothofagus* forest. It can inhabit the ground and subterranean cavities and a group can be flushed out by dogs. Majnep, however, writes that this species will explore the upper branches of *Pandanus* trees, bite off the fruit heads and often drop the uneaten part to the ground below the branches. He also says that groups will nest in clumps of epiphytes or the dead foliage at the crown of *Pandanus* trees. He records an unusual trapping method in which a temporary fence is constructed around an entire tree in which a nest is located (Majnep and Bulmer 1990b:67). He writes that local *Pandanus* trees are protected by platform-like barriers around their trunks to prevent these rodents from damaging the growing nuts.

Occurrence at Nombe: There are 16 individuals recorded: 12 in Stratum B and single individuals from Strata A, C, D1/5 and D2/3/4.

Uromys caudimaculatus: **305**

Diet:	H
Niche:	T/U/A
Habitat:	G/R/M

Altitude range: Recorded from sea level to c.2000 m, often at lower altitudes than *U. anak*.

Majnep (Majnep and Bulmer 1990b) says that this species lives in open country often near streams, feeding on small fruit, nuts, seeds, as well as insects and small amphibians. It can nest in the trees, in the crowns of *Pandanus* or clumps of epiphytic moss and fern found on large *Casuarina* as well as in ground and underground nests. It can grow up to 600-700 g as an adult.

Occurrence at Nombe: Some 21 individuals were found, seven in Stratum A, 11 in Stratum B, a single specimen in Stratum C and two in Stratum D2/3/4.

Anisomys imitator: **305**

Diet: H
Niche: T/U
Habitat: R/M Recorded from sea level to c.3500 m.

This species can reach an adult weight of over 500 g. Flannery (1990:194) suggests that its powerful incisors and weakly developed molars may indicate a diet of hard-shelled soft food such as *Pandanus, Elaeocarpus* and *Ficus* fruits and nuts. It makes a nest in the base of tree ferns, under logs or in sword grass clumps.

Occurrence at Nombe: 13 individuals, nine from Stratum B and two each from Strata A and D1/5.

Parahydromys asper: **305**

Diet: C
Niche: T/U
Habitat: R/M
Altitude range: Recorded from 700 to c.2200 m.

This waterside rodent, weighing up to about 600 g, eats insects, worms and the horsetail fern near streams, but according to Majnep (Majnep and Bulmer 1990b) does not swim.

Occurrence at Nombe: Only five examples are recorded, all in the Holocene levels: two from Stratum A and three from Stratum B.

Hydromys sp.: **305**

The single example may be *Hydromys chrysogaster*, but is too incomplete to be sure. This species could well occur near Nombe as it has been reported from sea level to nearly 2000 m. It is a nocturnal water rat of medium size (up to 500 g). It also is found in forests, eating fruits and probably small vertebrates and Dwyer has recorded it at 1900 m on Mt. Elimbari. Majnep records it as eating tadpoles and small insects in the water but says that it has a strong smell and is not hunted or eaten often by humans (Majnep and Bulmer 1990f:21).

Occurrence at Nombe: A single specimen is from Stratum B.

Xenuromys species: 305

There is only one species (*Xenuromys barbatus*) recorded as existing at present in Papua New Guinea but K. Aplin, who identified this bone, recorded it as damaged and not sufficiently intact to be certain of its identification.

Occurrence at Nombe: The single specimen is from Stratum B.

Small murids: 403

There is a considerable quantity of unidentifiable cranial material from small murids, as well as much post-cranial bone. Only two species have been identified: *Melomys rubex* and *Pogonomelomys sevia.*

Occurrence at Nombe: The highest number come from Stratum D1/5 (38), with 14 in Stratum B, eight in Stratum A, eight in Stratum D 2/3/4 and four in Stratum C.

Melomys rubex: 403

Diet:	H
Niche:	A/T/U
Habitat:	M

Altitude range: Recorded from 900 to c.3000 m.

This tiny species (adults under about 50 g) can climb well into the tops of the upper montane forest trees.

Occurrence at Nombe: A single example from Stratum B.

Pogonomelomys sevia: 403

Diet:	H
Niche:	A/T/U
Habitat:	M

Altitude range: Recorded from c.1400 to 3100 m.

This species is most commonly found living in the foliage of moss forest trees or in alpine grasslands where it can often nest in *Pandanus* trees.

Occurrence at Nombe: Only two individuals are recorded, one each in Strata B and D 1/5.

Chiroptera: Pteropodidae

Large pteropodids: 306

There is a large amount of both cranial and post-cranial material from large fruit bats found in the Nombe deposits. There are at least two species present including *Dobsonia moluccensis*. I could not decide in the early 1980s which other species was present (or indeed whether more than one other species was present) and labelled the cranial material other than *Dobsonia moluccensis* simply 'Large pteropodid species'.

Much later, during 1988, Dr. J. Menzies came to work on the *Phalanger* material in the collections and had a brief look at the large bats. He identified the presence of the large fruit bat *Aproteles bulmerae*, which he had identified from S. Bulmer's materials from the site of Kiowa (Menzies 1977), only about 4 km from Nombe, and which Hyndman subsequently found as the living species in a cave in the Hindenburg Wall at 2300 m in the northern area of Western Province (Hyndman and Menzies 1980). At Kiowa it appears that a population of *Aproteles bulmerae* was replaced by other species during the early years of the Holocene, whereas at Nombe there seem to be examples of *Aproteles bulmerae* present at all levels. The entire collection of large fruit bat crania must be carefully re-examined to extract the exact numbers involved.

Occurrence at Nombe: There are 182 individuals in the post-cranial material throughout the deposits, but it is clear that there are negligible numbers in the Pleistocene levels. Stratum A contains 24 individuals and there are 150 in Stratum B, whereas there are only four in Stratum C, two in Stratum D1/5 and two in Stratum D2/3/4.

From the cranial data there are 64 individuals in all, 14 from Stratum A, 48 from Stratum B, with single examples from Strata C and D1/5.

Aproteles bulmerae **306**

Diet: H
Niche: V/A/T
Habitat: R?
Altitude range: unknown but recorded at c.2300 m (extant) and 1530 m (extinct) at Kiowa by c.9000 bp (Menzies 1977).

Occurrence at Nombe: Present but cannot be quantified without further research.

Dobsonia moluccensis: **306**

Diet: H
Niche: V/A/T
Habitat: R/M
Altitude range: Found from sea level to about 2700 m.

This large fruit-eating bat weighs up to c 550 g as an adult. It often roosts in cave interiors in large colonies or singly in overhangs. Dwyer (1975) researched colonies on the back of Mt. Elimbari close to Nombe. *Dobsonia* eats garden fruit such as bananas and pawpaws, and wild fruit such as *Ficus*, *Castanopsis* and *Eurya tigang* and the semi-cultivated *Pangium edule* among other foods. Since it is occasionally caught in ground deadfall traps it presumably can forage terrestrially. It is very manoeuvrable in flight so that perhaps it can operate at least partly in forest conditions.

Occurrence at Nombe: Very large numbers occur especially in Stratum B, where 336 individuals are recorded. Only 28 are recorded from Stratum A, five from Stratum C and four from Stratum D1/5.

Small fruit bats: 407

Diet: H

Niche: V/A/T

Habitat: R

Altitude range: Found from sea level to about 1850 m.

These are *Rousettus* species, up to about 100 g in adult weight, mainly represented by cranial material with a small quantity of post-cranial. It roosts in caves and eats fruit.

Occurrence at Nombe: There are only nine examples in all, two from the Stratum A, six from Stratum B, one in Stratum D1/5.

BIRDS

Cassowaries

***Casuarius bennettii:* 109**

Diet: H

Niche: T

Habitat: R/M

Altitude range: Found from sea level to the tree line.

Growing up to about 1 m in height with adults weighing 26 kg, this is the smallest of the cassowaries of New Guinea but is still a formidable terrestrial animal. They are extremely shy birds, seldom seen, but can be tracked by droppings and spoor, especially in the fruiting season of certain trees such as *Elaeocarpus*, *Syzygium*, *Endiandra* and *Pandanus*, which are favourite foods. They are known to eat insects too. The species is still found in the highlands, where it is frequently hunted. Majnep discusses the hunting of the cassowary (Majnep and Bulmer 1977:150) by spring trap, chasing juveniles with dogs or occasionally driving it out of the forest and trapping it in grasslands. The nests are on the forest floor with eggs amongst the roots just covered with leaves, and the eggs are collected and eaten by humans. Eggshell is common in Strata A and B at Nombe.

Occurrence at Nombe: Sixteen individuals, three in the top Stratum A, 11 in stratum B and single individuals from Strata C, D1/5 and D 2/3/4.

Birds of prey/raptors:

Both owls and eagles could have nested on the cliff face above the site and it is possible that the shelter itself was sufficiently high in the Pleistocene for owls to roost in the roof.

Harpyopsis novaeguineae: **206**

Diet: C
Niche: V/A/T
Habitat: R/M
Altitude range: Sea level to 2800 m.

This is the largest diurnal raptorial bird in New Guinea (up to 85 cm in height) and a very effective hunter of medium-sized arboreal animals such as *Mallomys rothschildi* or *Pseudocheirops cupreus*, as Majnep and Bulmer relate (1977:139). These authors state that this bird will take wallabies, young dogs and pigs and young children as well as a variety of smaller birds, snakes, lizards and carrion. Large untidy nests are built at the tops of tall trees or on crags. The plumage is highly valued in many areas of the highlands.

Occurrence at Nombe: Only one individual is present from Stratum B.

Owls: 308

The Sooty owl (*Tyto tenebricosa*) is normally larger than the barn owl (*Tyto alba*), but they both eat a range of small mammals.

Tyto tenebricosa: **308**

Diet: C
Niche: V/A/T
Habitat: R/M/A
Altitude range: Recorded from sea level to 3500 m.

This owl is a large (36 cm in height) and most ferocious bird, feeding on animals including the largest rodents (*Mallomys rothschildi*). The nests are in hollow trees or holes in rocks, although it can roost in holes in the ground or in stream banks.

Occurrence at Nombe: Only one individual was present in Stratum B.

Tyto alba: **308**

Diet: C
Niche: V/A/T
Habitat: G/R/M
Altitude range: Found up to about 2000 m.

This smaller owl (32 cm height) hunts in garden and bush fallow areas, nesting in rock-clefts and hollow trees.

Occurrence at Nombe: Remains of two individuals from Stratum A and Stratum D1/5.

Ninox *sp.*: **308**

Diet: C

Niche: V/A/T

Habitat: G/R/M

Altitude range: Found from sea level to c.3000 m.

There is actually only one Ninox species reported from the area, so it is likely that this bone belongs to *Ninox theomacha*. This bird is 27 cm in height and inhabits wooded areas.

Occurrence at Nombe: One individual from Stratum A.

Megapodes: **307**

Both recorded species cover their eggs with rotting vegetation covered by sediment to form mounds. They eat mainly insects. Egg shell has been recorded from both Holocene strata at the site.

Occurrence at Nombe: Post-cranial bones occur in Strata A and B, with one individual in each stratum.

Aepypodius arfakianus: **307**

Diet: H

Niche: T

Habitat: R/M

Altitude range: Found from 1000 m to 2000 m.

This is the largest species (height 44 cm), common at about 1500 m.

Occurrence at Nombe: It is recorded from all but Stratum D2/3/4. In Stratum A there were two individuals, eight in Stratum B, one in Stratum C and two in Stratum D1/5.

Megapodius freycinet: **307**

Diet: H

Niche: T

Habitat: R

Altitude range: Found up to an altitude of about 1500 m.

This is smaller than *Aepypodius afakianus* (33 cm in height) but seems to be sympatric with that species.

Occurrence at Nombe: Only three, a single individual each from Strata A, B and D1/5.

Other medium sized birds: 309

Occurrence at Nombe: A few post-cranial bones were identified as belonging to medium-sized birds (assigned weights between 300 g and 1 kg). In all, only four individuals were present, one from each stratum except Stratum D2/3/4.

Large and medium-sized pigeons/doves: 309

Occurrence at Nombe: One individual of a large Columbidae was recovered from Stratum B and some bones of a medium-sized Columbidae also.

Small birds: 405

Gallinula tenebrosa: 405

Diet:	H
Niche:	T
Habitat:	G/R

Altitude range: Found fairly widely up to altitudes of about 1400 m.

This moorhen (height 28 cm) lives on the edge of water.

Occurrence at Nombe: One example of this species from Stratum B.

The other small birds are not identified to species level so no information can be given as to habitat or altitude. Post-cranial bone includes single individuals in Strata A, B, D1/5 and D2/3/4. Other identifications include two individuals of *Gallinula* species (Strata B and D1/5), a small Columbidae in Stratum D2/3/4, a Psittaciforme in Stratum B, a group of Passeriformes (large in Strata B and D1/5, medium in Strata B, D1/5 and D2/3/4 and small in Strata B, C and D1/5).

REPTILES

Serpentia: Snakes 207

The most abundant bones in this class are snake vertebrae. These are likely, at least in the Holocene strata, to indicate human predation as presumably snakes were eaten by human hunters in the past as they are nowadays. The vertebrae have not been measured, which would have given some idea of the size and species range, but it is likely they belong to tree pythons (Boidae)

Occurrence at Nombe: One hundred and forty-one vertebrae were recorded. They are found in all strata except the basal levels, but they may in fact constitute only one individual in each of the top four Strata A, B, C and D1/5 (although from the size range this is unlikely).

Scincida: 409

Six small **skinks** are present with single specimens in Strata A and C and four in Stratum D1/5. These are likely to be either natural inhabitants of the cave or the prey of smaller predators. Skinks may be eaten today by humans, usually being consumed near the place of capture, which could, of course, be inside the cave.

Lacertilia: 406

Small lizards are present in the top strata only, two in Stratum B and one in Stratum A. They can eat flesh and plants and can survive in most ecological niches up to about 3000 m. Again these are likely to be the prey of smaller predators.

Chelidae: 310

A single **freshwater turtle** appears in Stratum B. Dornstreich records that turtle is among the foods eaten by the Gadio in Enga Province, but this is at altitudes below 1500 m (Dornsteich 1973:419).

Other reptile bones are rare and not well identified and indicate only a single individual from the top three Strata A, B and C.

ANURA: FROGS 408

Diet: C
Niche: A/T/U
Habitat: G/R/M/A
Altitude range: Reported from sea level to alpine grassland swamps.

There are over 200 species in New Guinea (Menzies 1976), usually found in damp areas. They vary in size from under 25 mm in length to over 150 mm. Frogs are collected and eaten regularly by present-day highlanders, especially women and children during gardening activities. However, as with small reptiles, the carcases are usually cooked and eaten near the place of capture rather than taken back to the village. The frog bones from Nombe have not been measured and therefore cannot be grouped into species or even size classes. They were identified from long bones only. In order to allow minimum number analysis, these totals have been divided by four. The bones are very small and were only recovered in the wet-sieved units.

Occurrence at Nombe: Large quantities appear in Stratum D1/5 (345 bones), with far fewer in all other strata. Some 65 bones were recorded from Stratum D2/3/4, 32 in Stratum C, 19 in Stratum B and only six in Stratum A.

Table 8.1 summarises the environmental and ecological data on the taxa present in the Nombe deposits.

Table 8.1 Environmental and ecological information on Nombe species and their stratigraphical occurrence

	Diet	Niche	Habitat	Stratum D2/3/4	D1/5	C	B	A
Large species - over 5kg adult body weight								
Homo sapiens	O	TAU	All				●	●
Thylacinus cynocephalus	C	TU	GRMA	●	●	●	●	●
Canis species	C	TU	GRMA					●
Diprotodontid family	H	T	RM	●	●			
Protemnodon tumbuna	H	T	RM	●	●			
Protemnodon nombe	H	T	RM	●				
Dendrolagus noibano	H	AT	RM	●	●			
Dendrolagus dorianus	H	AT	RMA		●	●	●	●
Dendrolagus goodfellowi	H	AT	RM		●	●	●	●
Zaglossus bruijni goodfellowi	O	TU	RMA	●	●	●	●	●
Casuarius bennetti	H	T	RM	●	●	●	●	●
Sus species	O	T	GR		●		●	●
Medium species - Between 1 - 5kg adult body weight								
Harpyopsis novaeguinae	C	VAT	RM				●	
Thylogale brunii	H	T	GRMA	●	●	●	●	●
Dorcopsulus vanheurni	H	T	RM	●	●	●	●	●
Phalanger sericeus	H	A	MA	●	●	●	●	●
Phalanger carmelitae	H	A	RM		●	●	●	●
Strigocuscus gymnotis	H	T	RM		●	●	●	●
Pseudocheirops cupreus	H	A	MA	●	●	●	●	●
Pseudocheirops corinnae	H	A	RM	●	●	●	●	●
Mallomys rothschildi	H	AT	RMA	●	●	●	●	●
Hyomys goliath	H	TU	GRMA		●		●	●
Snake	C	ATU	GR		●	●	●	●
Small species - Between 300g - 1kg adult body weight								
Pseudocheirus forbesi	H	AT	MA	●	●	●	●	●
Dactylopsila palpator	C	TUA	RM		●	●	●	●
Dasyurus albopunctatus	C	TAU	RMA	●	●		●	●
Peroryctes raffrayana	O	TU	GRMA	●	●	●	●	●
Echymipera kalubu	O	TU	GR		●			●
Echymipera rufescens	O	TU	GR				●	
Microperoryctes longicauda	O	TU	RMA	●	●		●	●
Anisomys imitator	H	TU	RM		●		●	●
Uromys anak	H	TUA	RM	●	●	●	●	●
Uromys caudimaculatus	H	TU	GRM	●		●	●	●
Parahydromys asper	C	TU	RM				●	●
Xenuromys species		TU					●	
Hydromys species	O	TU	RM				●	
Pteropodid species	H	VAT		●	●	●	●	●
Dobsonia moluccensis	H	VAT	RM		●	●	●	●
Megapodius freycinet	H	T	R		●		●	●
Aepypodius arfakianus	H	T	RM		●	●	●	●
Tyto alba	C	VAT	G		●			●
Tyto tenebricosa	C	VAT	RMA				●	
Ninox species	C	VAT	RM					●
Medium bird species		VAT			●	●	●	●
Large Columbidae species		VAT					●	
Medium Columbidae species		VAT					●	
Fresh water turtle	CH		R				●	
Very small species - Under 300g adult body weight								
Pseudocheirus mayeri	H	AT	MA	●	●		●	
Petaurus breviceps	O	VAT	GRM	●	●	●	●	
Distoechurus pennatus	O	AT	R		●		●	
Small dasyurid species	C	TA	GRMA	●	●		●	●
Small murid species	H	ATU		●	●	●	●	●
Pogonomelomys sevia	H	ATU	M		●		●	
Melomys rubex	H	ATU	M				●	
Rousettus species	H	VAT	R		●		●	●
Small bird species				●	●		●	●
Small Columbidae family				●				
Psittacidae family							●	
Gallinula species					●		●	
Gallinula tenebros	O	T	GR				●	
Large passerine species					●		●	
Medium passerine species				●	●		●	
Small passerine species					●	●	●	
Snakes	CH	TU	All		●	●	●	●
Skinks	CH	TU	All		●	●		●
Lizards	CH	TU	All				●	●
Frogs	C	ATU	All	●	●	●	●	●
			TOTALS	**28**	**48**	**29**	**58**	**43**

***Abbreviations*:**	Diet:	**O** Omnivorous	**C** Carnivorous	**H** Herbivorous	
	Niche:	**V** Volant	**A** Arboreal	**T** Terrestrial	**U** Underground
	Habitat:	**R** Primary montane rainforest	**G** Gardens & secondary regrowth	**M** Moss forest	**A** Alpine grasslands

8.3 ENVIRONMENTAL IMPLICATIONS OF FAUNAL ANALYSIS FROM PLEISTOCENE AND EARLY HOLOCENE STRATA

The aim of this section is to use the available current ecology of highland fauna to suggest which environments were being exploited and targeted by human hunters while using the site of Nombe. There was always a range of environments available as a predation catchment to human hunters from the cave, which is situated on a steep slope, from neighbouring valleys at about 1500m, to limestone peaks over 2200m within two hours climb of the site (Figure 2.2 and Plate 1) .The current ecological information has to be set against the knowledge of environmental change that has been extensively documented by such authorities as Walker, Hope and Haberle, for example in Walker and Hope (1982), Hope and Hope (1976) and Haberle, Hope and De Fretes (1991).

It is not possible to interpret the faunal data from Nombe on the assumption that the mere presence of the majority of species is indicative of particular environmental conditions. The situation is far more complex. There is an overall tendency for different but closely related species within the highlands today to occupy slightly different environmental niches (often taking the form of altitudinal variations), but these are extremely difficult to document with accuracy and local conditions may well produce different patterning for the same species. Authorities tend to provide the broadest possible altitudinal range with the result that there is usually a generous overlap for similar species. Also it has to be remembered that species could have changed their habits over time and it is not possible to be certain that the conditions in which species thrive today are identical to those occupied by their ancestors thousands of years ago. However, using caution, some interesting inferences can be put forward using present-day behavioural knowledge.

The focus of the more detailed faunal analysis in this chapter is restricted to the Pleistocene strata and the early Holocene Stratum B. This covers the time period from about 33,000 bp to about 5000 bp, during which it is known that New Guinea experienced the effects of worldwide climatic changes associated with the Late Glacial maximum and subsequent warming towards the relatively stable climate of the Holocene period. Human activity begins at the site about 25,000-24,000 bp and continues through to modern times, but sustained site activity is not established until the early Holocene. Therefore, the information contained in these strata can both provide indications of the natural environmental background and major changes to climate and vegetation (which affected all animals living in the locality), and also suggest ways in which human groups affected by those changes used particular strategies to adapt and survive in different environmental circumstances.

The analysis examines three sets of data from related species which show ecological and behavioural differences between them.

8.3.1 Possums and cuscus

The first set of data to be examined in some detail concerns the families generally known as possums and cuscuses, including Phalangeridae (cuscus), Pseudocheiridae (possums), Acrobatidae (possums) and Petauridae (possums). The ten species present in the Nombe faunal records, range from large phalangers to tiny petaurids. They comprise animals that can inhabit mid-montane rainforest, moss forest or alpine grasslands, and animals which are both terrestrial and arboreal, that can occupy all of Bulmer's 'forest layers'.

The following analysis on the data from four strata (D2/3/4, D1/5, C and B) compares a clearly humanly predated early Holocene sample (Stratum B), the basal stratum (Stratum D2/3/4) and the Late Pleistocene Strata D1/5 and C both dated within the period of environmental change.

Table 8.2 **Abundance of cuscus and possum species from Pleistocene and early Holocene strata**

Species	MNI		NISP		Weight	
	No	%	No	%	grams	%
STRATUM B						
PHAL.SE	13	3	34	3	83	4
PHAL.CA	183	49	554	50	1137	61
STRI.GY	29	8	67	6	133	7
PSEP.CU	69	18	234	21	307	17
PSEP.CO	57	15	158	14	158	9
PSEU.FO	20	5	42	4	27	1
DACT.PA	1	<1	18	2	15	<1
PSEU.MA	2	<1	5	<1	2	<1
PETA.BR	2	<1	3	<1	1	<1
DIST.PE	1	<1	1	<1	1	<1
Totals	377	100	1116	100	1864	100
STRATUM C						
PHAL.SE	3	23	4	15	9	21
PHAL.CA	2	15	7	26	17	40
STRI.GY	1	8	2	7	5	12
PSEP.CU	3	23	8	30	9	21
PSEP.CO	1	8	2	7	2	5
PSEU.FO	1	8	2	7	1	2
DACT.PA	1	8	1	4	<1	<1
PSEU.MA	-	-	-	-	-	-
PETA.BR	1	8	2	7	<1	<1
DIST.PE	-	-	-	-	-	-
Totals:	13	100	27	100	43	100
STRATUM D1/5						
PHAL.SE	18	20	79	29	173	33
PHAL.CA	21	24	53	19	143	28
STRI.GY	2	2	5	2	11	2
PSEP.CU	36	40	108	40	175	34
PSEP.CO	2	2	4	1	3	<1
PSEU.FO	8	9	19	7	11	2
DACT.PA	1	1	1	<1	1	<1
PSEU.MA	1	1	2	<1	1	<1
PETA.BR	1	1	1	<1	<1	<1
DIST.PE	1	1	1	<1	<1	<1
Totals:	89	100	273	100	517	100
STRATUM D2/3/4						
PHAL.SE	2	17	4	15	9	30
PHAL.CA	-	-	-	-	-	-
STRI.GY	-	-	-	-	-	-
PSEP.CU	1	8	5	19	7	23
PSEP.CO	1	8	3	11	2	7
PSEU.FO	6	50	12	46	10	33
DACT.PA	-		-		-	
PSEU.MA	1	8	1	4	<1	
PETA.BR	1	8	1	4	2	7
DIST.PE	-		-		-	
Totals	12	100	26	100	30	100

Note: Totals may not agree because of rounding

Quantities of data are so variable and the number of very small samples so frequent that it is only possible to assess the broadest trends in Table 8.2. Nevertheless, the data can still be very revealing.

In the lowest stratum (D2/3/4) by far the highest proportion (about half) of these animals is *Pseudocheirus forbesi*, together with significant amounts of material from *Pseudocheirops cupreus* and *Phalanger sericeus*. All these species can be found in the higher, colder altitudes of moss forest or even alpine grasslands. *Phalanger sericeus* in particular now inhabits the higher reaches of the forest right up to the edge of the tree-line, well above the normal habitats of other phalangers. The large possum *Pseudocheirops cupreus* also prefers higher altitudes, and *Pseudocheirus forbesi* also occurs nearly up to 3000 m and can be found in the moss forest, although it also inhabits lower altitudes. The high percentage of this small tree-dwelling possum is surprising but the presence of *Dasyurus albopunctatus* provides a possible predator which may account for the remains in these levels. It has to be remembered that the quantities of bone in the lowest level are extremely small and there was only a minimum number of six individuals present. In the much higher quantities of bone from Stratum D1/5, *Pseudocheirops cupreus* has the highest frequencies followed by *Phalanger sericeus*, so there is still a dominance of the species adapted to the colder altitudes. But here there is very little *Pseudocheirus forbesi* and much greater occurrence of *Phalanger carmelitae*. This arboreal cuscus now lives in the mid-montane rainforest, and is frequently hunted by highland communities today (Dwyer 1990). Stratum C shows fairly high proportions of both *Pseudocheirops cupreus* and *Phalanger carmelitae*, with diminishing proportions of the high-altitude *Phalanger sericeus*. In the species from Stratum B, (presumed to be predominantly the result of human predation), *Phalanger carmelitae* has become the dominant species, representing half of the animals present. The only other species of importance are *Pseudocheirops cupreus* and *Pseudocheirops corinnae*, the latter found today at lower altitudes than *P. cupreus*. *Phalanger sericeus* has practically disappeared. Both *Pseudocheirops corinnae* and *P. cupreus* are commonly hunted today.

It is clear that the high-altitude species dominate the early strata at Nombe suggesting a colder climate with vegetation of a type now more common at altitudes above about 2600 m. The range of cuscus and possum available for predation by the thylacine and the smaller dasyurids, and later by human predators, comprised those species that today are adapted to life in the upper zones of the forest. By the end of the Pleistocene species which are more common now in the mid-montane rainforests had become more dominant, suggesting that the tree line had risen and that the local Nombe environment had changed, with the higher-altitude species replaced by mid-montane species.

8.3.2 Macropodids

Another family of animals that is broad enough and sufficiently well-represented to provide data through which to examine changes in local environmental conditions is that of the Macropodidae. Table 8.3 summarises this analysis. The quantities here can be greater than for cuscuses and possums as there is a clear size distinction which enables post-cranial data from the species established to be added to the cranial information. The individual species of *Dendrolagus* and *Protemnodon* have not been shown as the general trends are more apparent without splitting the data into smaller subsets.

Table 8.3 Abundance of macropods at Nombe
in Pleistocene and early Holocene strata

Species	MNI		NISP		Weight	
	No	%	No	%	grams	%
STRATUM B						
PROT.SP.	-	-	-	-	-	-
DEND.SP.	16	10	378	23	346	15
THYL.SP.	64	38	712	43	130	55
DORC.VA	86	52	570	34	739	31
Totals:	166	100	1660	100	2386	101
STRATUM C						
PROT.SP.	-	-	-	-	-	-
DEND.SP.	2	33	15	30	34	55
THYL.SP.	1	17	3	6	8	13
DORC.VA.	3	50	32	64	20	32
Totals:	6	100	50	100	62	100
STRATUM D1/5						
PROT.SP.	4	18	58	14	575	40
DEND.SP.	6	27	174	41	525	37
THYL.SP.	8	36	94	22	230	16
DORC.VA.	4	18	96	23	102	7
Totals:	22	99	422	100	1431	100
STRATUM D2/3/4						
PROT.SP.	2	33	27	37	268	76
DEND.SP.	1	17	16	22	50	14
THYL.SP.	2	33	29	40	36	10
DORC.VA.	1	17	1	1	<1	<1
Totals:	6	100	73	100	355	100

Note: Totals may not agree because of rounding.

The basal Strata D2/3/4 has two equally weighted groups of macropods, *Protemnodon* and *Thylogale brunii*. *Protemnodon* is thought to have lived in the upper reaches and edges of the Pleistocene forest into the alpine shrub lands and *Thylogale* is known to inhabit open grasslands including the subalpine grasslands adjacent to the tree-line of moss forest.

The extremely low proportions of *Dorcopsulus vanheurni* in the stratum indicate that there was little thick forest near the site since the species today inhabits primary mid-montane forest. However, forest may not have been far away but, with plenty of larger prey close at hand, the predators responsible for the bones in this stratum may have been able to provide ample supplies for their needs without moving far from the cave.

The later Pleistocene Stratum D1/5, in which the first incontestable evidence of human activity appears, shows a substantial rise in *Dorcopsulus* and *Dendrolagus* and a fall in *Protemnodon* and *Thylogale*, although all four groups were clearly available to predators from the site at that time.

The tree kangaroos include the extinct *Dendrolagus noibano*, found only at Nombe, so that external information about its altitudinal range is unavailable. The extant species, especially *Dendrolagus dorianus*, occur in the high forests or well within the mid-montane forest. *Dendrolagus dorianus* was found amongst the faunal remains at the Mapala shelter in Irian Jaya, at an altitude of 3996 m not far from the tree-line (Hope, J. 1976). Hope interprets their presence as an indication of human hunting in the forests below the site but perhaps these animals also forage in the shrubby forest edges.

The rise in the proportions of *Dorcopsulus* suggests that this forest species was available within hunting range from Nombe, presumably at lower altitudes

The figures for Stratum C are unsatisfactory as there is so little macropod bone present (only 62 g), but, for what they are worth, they show high proportions of the forest wallaby, *Dorcopsulus vanheurni*, followed by large proportions of *Dendrolagus* (both *D. dorianus* and *D. goodfellowi*). By the early Holocene (Stratum B) it appears that both *Thylogale* and *Dorcopsulus* were being hunted in large numbers, with considerable proportions of *Dendrolagus* (both *D. dorianus* and *D. goodfellowi*) also present. The return of the highly adaptable *Thylogale* suggests that it could be found breeding at that time, not on the high altitude alpine grasslands but in the disturbed regions of the forest, perhaps even on emerging anthropogenic grasslands of lower altitudes. J. Hope (1977) says that *Thylogale* appears to adapt quickly to new disturbance and is thus advantaged by initial forest clearance.

8.3.3 Large and Medium murids (MURL and MURM)

The third group of species chosen for examination in detail to show environmental change is that of Large and Medium sized murids (as defined within Section 7.5.2). However, the amount of material from Strata D2/3/4 and C is so thin that they are of no use in general predictions of change and no proportions are shown. The results from Stratum D1/5 and Stratum B show little in the way of change in predation patterns over time.

Table 8.4 Abundance of Large and Medium Sized Murids (MURL and MURM) in Pleistocene and early Holocene strata

Species	MNI		NISP		Weight	
	No	%	No	%	grams	%
STRATUM B						
MALL.RO	72	64	297	70	342	75
HYOM.GO	4	4	21	5	20	4
ANIS.IM	9	8	28	7	20	4
UROM.CA	11	10	34	8	29	6
UROM.AN	12	11	39	9	44	10
PARA.AS	3	3	4	<1	1	<1
HYDR.SP	1	<1	1	<1	1	<1
Totals:	112	100	424	99	457	99
STRATUM C						
MALL.RO	1		4		1	
HYOM.GO	--		--		--	
ANIS.IM	--		---		--	
UROM.CA	1		1		<1	
UROM.AN	1		1		9	
PARA.AS	--		--		--	
HYDR.Sp	--		--		--	
Totals:	3		6		10	
STRATUM D1/5						
MALL.RO	168	88	56	77	80	88
HYOM.GO	1	<1	7	10	2	2
ANIS.IM	21	11	8	11	5	5
UROM.CA	-	-	--		--	
UROM.AN	1	<1	2	3	4	4
PARA.AS	-	-	--		--	
HYDR.SP	-	-	--		--	
Totals:	191	99	73	101	91	99
STRATUM D2/3/4						
MALL.RO	2		4		6	
HYOM.GO	--		--		--	
ANIS.IM	--		--		--	
UROM.CA	2		2		3	
UROM.AN	1		1		2	
PARA.AS	--		--		--	
HYDR.SP	--		--		--	
	5		7		11	

Notes: Totals may not agree because of rounding; percentages are not meaningful for strata with small numbers.

These figures do little except to suggest the dominance of one species throughout the site history: that of *Mallomys rothschildi,* the largest murid present at the site, growing to a size similar to many large cuscuses. It is now found largely in primary undisturbed upper and mid-montane forests and is described as truly arboreal with well-adapted scansorial feet. However, the bones of this species were recovered from the high-altitude, sub-alpine shrub land shelter of Mapala (Hope, J. 1976:212) and its presence (fresh faeces and bones) was noted by G. Hope up to 4500 m in the Cartensz Mountains. Perhaps like many murids this creature is capable of adaptation to different environments and its occurrence in Stratum D2/3/4 and Stratum D1/5 indicates that it was present in the colder conditions, perhaps living at the forest edge and in the upper forest zones that may have existed around and above the site at the time.

A more likely interpretation is that there are several species of *Mallomys* present in the Nombe data and that at different times, under differing environmental conditions, there was a change in the species predated. Flannery *et al.* (1989) describe two new species *Mallomys* spp., both of which are restricted to the sub-alpine zones. *Mallomys* sp. were certainly commonly hunted from the site during the early Holocene at Nombe as they are today.

8.4 CONCLUSION

There are trends within other individual species which can confirm the broad environmental changes suggested by the faunal analysis. Some have already been commented on in Chapter 7. The high profile of the *Zaglossus* in the early strata (see table 7.7) suggests that the climate was colder then and as the temperature increased so the animal became less common. The cassowary is not found in high altitudes and is generally a forest species. The increase in numbers in Strata B (see Table 7.7), as the temperatures increase, also support the concept of increased forest growth round the site during the Late Pleistocene and Early Holocene, although the trend probably also indicates an increase in predation as humans learn to track and trap the animal.

A broad overall interpretation of the environmental implications of the faunal data would suggest that it was colder at Nombe around 30,000 bp than at present and that species that today can be found in the upper moss forest and open alpine grasslands, including *Zaglossus bruijni, Thylogale brunii, Phalanger sericeus, Pseudocheirops cupreus, Pseudocheirus forbesi, Pseudocheirus mayeri, Peroryctes raffrayana, Mallomys rothschildi, Dasyurus albopunctatus* and *Microperoryctes longicauda,* were locally available for predation.

During the period from about 24,000 bp to about 16,000 bp, during the glacial maximum, there must have been many changes in the local vegetation and its dependent faunal populations. Many predators were probably using the site, both small and large, including human hunters. The suite of animals present in Stratum D1/5 suggests a variety of available environments. These obviously included open alpine shrub/grasslands, now even closer just above a lowered tree-line, as is evident by the continuing high proportions of *Zaglossus bruijni, Pseudocheirops cupreus, Phalanger sericeus* and *Thylogale brunii,* together with the presence of occasional species known to tolerate colder altitudes today, such as *Aepypodius arfakianus* and

Pogonomelomys sevia. However, there were also high proportions of animals more suited to forest conditions, such as *Dorcopsulus vanheurni*, *Dendrolagus goodfellowi* and *Phalanger carmelitae*, as well as the presence of species such as *Megapodius freycinet*, *Distoechurus pennatus*, *Tyto alba* and *Rousettus* bats, which suggest that predators were also able to exploit the resources of primary mid-montane forest within easy reach of the cave. Since the period of Stratum D1/5 covers the glacial maximum with temperatures lower than those for the period of Stratum D2/3/4, the better representation of forest species in the former must surely reflect the appearance of human hunters with their greater mobility.

The faunal trends from Stratum C for the last 6000 years of the Pleistocene would appear to register the presence of locally thicker forest as the tree line presumably rose with the ameliorating climate. Four species (*Protemnodon nombe*, *P. tumbuna*, *Dendrolagus noibano* and the diprotodontid) had become extinct by about 16,000 bp.

By about 10,000 bp further changes were occurring. The large meaty animals of the forest edge were reduced to *Zaglossus*, the cassowary and extant *Dendrolagus*, probably, as now, all shy species difficult to locate. Human hunters were having to target the smaller prey, such as the wide range of cuscus and possum of the mid- and upper montane forests as well as large and medium-sized murids, terrestrial bandicoots and fruit bats. Alpine grassland was now out of range for either human or animal predators based at Nombe. The site was situated by then in mid-montane forest with, as now (Dwyer 1978), some thinner moss forest vegetation surviving on restricted areas over 2550 m at the top of Mount Elimbari and further to the west.

The faunal evidence from Stratum B indicates that similar animals to those in Stratum C are present but that the quantities had increased greatly, certainly due to increased human predation, the topic of the following chapter. The continuing decrease in the high altitude *Phalanger sericeus* and concomitant rise in numbers of *P. carmelitae*, the forest cuscus, confirms that mid-montane forest was now dominant and well established near the site. The greatly increased numbers of *Thylogale brunii* indicates the increasing occurrence of disturbance, likely to be the first major forest clearance in the region (J. Hope 1977). The forest wallaby, *Dorcopsulus vanheurni*, decreases at the same time.

Excellent information has thus been extracted through analysis of the faunal data to reconstruct changing environmental conditions within the vicinity of Nombe during the late Pleistocene and early Holocene periods during which time human hunters began to visit the site and exploit the available species, gradually adapting to the different suite of species that replaced those of the earlier periods. The next chapter follows those adaptations through an examination of human hunting strategies.

Chapter 9

Extinctions and Hunting at Nombe in the Late Pleistocene and Early Holocene

9.1 INTRODUCTION

> Very widely (in Papua New Guinea) the story that we hear is that, before pigs and various crops were introduced, people gained their livelihood by hunting. At those times women also hunted and gathered wild plants in the forest. And when ceremonies were held, they killed and cooked kapuls, like pigs are now killed and cooked, and divided and distributed and exchanged the meat, as gifts of pork are now distributed and exchanged. This is certainly the tradition in my area, and in my travels in other regions I have from time to time been told similar stories of how the ancestors used to hunt in the local mountain forests. Majnep in (Majnep and Bulmer 1990a:33)
>
> By the time we were born it was like today, when the population here has become numerous and has reduced the number of kapuls (forest animals) so that there are only a few about and it is really hard to catch them. Majnep in (Majnep and Bulmer 1990a:29)

The first impact of people at the site of Nombe can be documented through the recovery of artefacts in the late Pleistocene deposits of Stratum D1/5, dated broadly to between 25,500-24,400 and 14,800-14,500 bp. The bones from several large animal species are found both here and in the previous stratum but do not re-occur in the subsequent deposit. Is there a relationship between these two sets of data? It has already been established that, without further scrutiny of the bone, isolation of specific specimens that show the effects of human or animal predation is impossible. However, more indirect analytical means are available. Analysis of the faunal data has suggested that there were major changes in the climatic conditions at the site (Chapter 8) during the Late Pleistocene. Can faunal analysis also suggest changes in predation strategies over the same time period?

In Chapters 7 and 8 variation in the relative abundance of species throughout the site was discussed in the context of the environmental implications. In this chapter there is an examination of two linked topics: the extinction of a few species of large animals before the end of the late Pleistocene period and the human predation strategies employed during the Pleistocene and early Holocene periods. I have chosen to concentrate on these earlier time periods here in accordance with the overall aims and design of the thesis (Chapter 1).

9.2 EXTINCTION OF SPECIES AT NOMBE

9.2.1 Four large Pleistocene species

In the lowest levels of the site, remains of four, relatively large, herbivorous animals have been identified as members of species that are now extinct. I prefer not to use the term 'mega-fauna' as it conjures up an image of beasts too heavy to be removed from their place of death. The extinct species at Nombe are in some cases not very much larger than extant species and are certainly not in a 'mega' category. All specimens were well within the capacity of human hunters to lash to a stout pole and carry back to a hunting or base camp.

The four herbivorous species are diprotodontids (for which only post-cranial bone was recovered), *Protemnodon nombe*, *Protemnodon tumbuna* and *Dendrolagus noibano*. The discovery of these three new species has been published by Flannery, Aplin and myself (1983), Flannery providing the descriptions of the holotypes and other bones. The thylacine was also present and will be discussed later.

These four taxa all occur in Stratum D2/3/4 where there is very little evidence for human presence and where they could have been the victims of thylacine attack, dragged back to a lair sometime before c.25,000 bp. There is no other predator (apart from humans) capable of killing and dragging the carcasses back to a cave. These four taxa also all occur in Stratum D1/5 in which human activity is well documented. The total number of bones recovered is not great, although some are large and have considerable mass.

9.2.2 Comparable data for large Pleistocene species

Evidence for comparable large extinct species has been recovered from four or five sites in New Guinea. There are a few Pliocene species which have some parallel in the Nombe Pleistocene specimens. All Pleistocene species are believed (from the find spots in which their remains have been recorded) to have lived in the late Pleistocene in the highlands of New Guinea at altitudes of about 1500 m or more, but evidence is still fairly sparse.

The Pliocene finds are from the Arawe Otibanda Formations in the Morobe Province (Plane 1967a, 1967b), known as the Awe fauna. These finds are from a lowland rainforest environment and not from highland altitudes. They include three species of diprotodontids: *Nototherium watutense*, a browsing species about the size of a cow (Anderson 1937), *Kolopsis rotundus*, also a browser which was smaller in size (Plane 1967b) and *Kolopsoides cultridens*, of uncertain diet and about the size of a goat (Plane 1967b). There were also three large extinct macropodids: *Protemnodon otibandus*, a browser of the lowland forests, *"Protemnodon" buloloensis*, smaller than *P. otibandus*, and *Watutia novaeguineae* (Flannery *et al.* 1989). Bones from a dasyurid, a murid and a *Thylacinus* were also recovered (Hoch 1987).

In Irian Jaya, diprotodontid remains (*Zygomaturus nimborensis*) have been recovered (Hardjasasmita 1985; Flannery 1990), but no dating or environmental data are given for the find.

Several finds have been made of species assigned to the Pleistocene period. The most extensive remains were recovered at Pureni Swamp in the Southern Highlands published by Flannery and Plane (1986): bones of a diprotodontid, *Hulitherium thomasettii*, were found with a cassowary, a murid and the skull of a forest cuscus (*Phalanger carmelitae*). *Hulitherium thomasettii* is thought to have weighed between 75 and 200 kg and to have been a browsing species of the upper montane forest. It has no immediate close relatives and its morphology marks it as different from other zygomaturine diprotodontids from New Guinea or Australia. It appears to have possessed great limb mobility, possibly allowing it to browse standing on its hind legs like a bear or panda (Flannery and Plane 1986:74). Powell (1972) has described the environmental conditions of what is now the Pureni Swamp in the Western Highlands, at about 38,000 bp when the diprotodontid *Hulitherium thomasettii* inhabited the area at an altitude of c.1500 m. The bones came from a "semi-organic fossil layer containing bones and plant remains crudely bedded in a grey-black sandy silt matrix" (Flannery and Plane 1986:67). A radiocarbon date of 38,600 ± 2500 bp (ANU 231) was obtained from wood in the deposit.

> Locally, conditions changed from open water with marginal conifers to grass-swamp surrounded by conifers and to bog forest on the site itself. Regionally, conditions ameliorated from rather cool with mixed forest dominant and subalpine nearby, to mild with beech forest dominating the slopes and mixed forest and subalpine grassland further away, and to relatively warm with oak forest and oak-beech forest dominant. In all cases, however, the extrapolated environment was colder than that experienced at the present time in this area.
> Powell (1972:338)

Flannery and Plane point out that the altitudinal range of about 1500-2000 m in other parts of the world is occupied by large herbivores such as the giant panda (China), mountain gorilla (Africa) and spectacled bear (South America). *Hulitherium thomasettii* may be a marsupial that is ecologically equivalent to these species. The post-cranial diprotodontid bones from Nombe are interpreted as coming from a slightly smaller animal that, however, shows considerable similarities with the post-cranial of *H. thomasettii*. Flannery (1990) reports that *Zygomaturus nimborensis* is even smaller but shows considerable differences from the *Hulitherium*. G. Hope (pers. comm.) has found other diprotodontids in the highlands of Irian Jaya and C. Ballard (pers. comm.) now has another probable *Protemnodon* in the Tari Basin, Southern Highlands of Papua New Guinea.

A large macropodid tooth (*Protemnodon* or *Sthenurus*) was recovered from the clays at Kafiavana by White's excavations. It was associated with a small phalangerid mandible and rodent bone in levels below those of the lowest human artefacts. Plane

(1972) discounted the possibility of a carnivore's den as "We know of no carnivore large enough to have preyed on a macropod which was probably as large as the living red kangaroo" (Plane 1972:168), but since there are reports (Section 8.2) of thylacine dragging a calf or large macropod back to lairs, I believe that thylacines could tackle the small extinct highland fauna also. This would mean that *Thylacinus cynocephalus* could have been the major predator of *Protemnodon* in the basal levels at Nombe, and that Kafiavana could also have been a thylacine lair. The age of that macropodid specimen is unknown although it has to be older than the lowest radiocarbon date from the site (ANU-41b (acid-insoluble fraction) ≥10,730±370 bp). A more exact date for this specimen might be very revealing.

The two *Protemnodon* species from Nombe are small in comparison with Australian Pleistocene *Protemnodon*. *Protemnodon tumbuna* was larger, reaching perhaps 50-60 kg while *P. nombe* only reached 20-40 kg adult weight. The low-crowned teeth of both new species indicate that these animals were adapted to a different diet than other macropods, such as the grazing, grass-eating *Thylogale* species, and are presumed to have been leaf-browsing inhabitants of the higher montane forests.

The extinct *Dendrolagus noibano* is slightly larger than *Dendrolagus dorianus*, the largest of the extant tree kangaroos of New Guinea, and is the smallest of the extinct Pleistocene species from Nombe. It must also have been an inhabitant of the upper montane forest, living in the trees. It could only have been preyed upon by the thylacine or humans when it descended to the ground at night where perhaps it was rather slow and cumbersome, although still a ferocious adversary for a thylacine or for human hunters. Dwyer (1990:92) describes the reactions of *Dendrolagus dorianus* on being cornered: "this large tree kangaroo became enraged; it was all teeth and claws. It was safer if two people combined their efforts, and a brave dog was helpful".

9.2.3 Date of extinction of four Pleistocene species at Nombe

Prior to the production of three radiocarbon dates indicating the presence of Stratum D snails alongside much younger bone, I had maintained the view that the elements of extinct fauna recovered from Strata C and B were *in situ*. Examination of the extinct fauna in Stratum B revealed that this bone was frequently heavily burnt, whereas similar bone in the lower levels was normally unburnt. This means either that the bones of extinct animals in Stratum B indeed belong to animals that were living during the early Holocene period and were hunted, cooked and consumed at that time or that, as suggested by the conflicting radiocarbon dates, they were merely components of the earlier clays dug up by people during the late Pleistocene and dumped over Stratum C deposits. Here they became mixed with material in the top levels of Stratum C and/or base levels of the subsequent Stratum B occupation and were charred and burnt in the early Stratum B fires. This matter will only be finally resolved by a direct date on the actual bone concerned, which would be difficult since the nitrogen levels in the bone tested is negligible. The evidence of the radiocarbon dates, however, has drawn me to the conclusion that these pieces were in fact original components of the Stratum D1/5 clays which were then displaced during the digging of Trench A1/2.

If this reconstruction is correct, the four extinct species are original elements of the *in situ* deposits of Stratum D2/3/4 and Stratum D1/5 only and therefore at Nombe cannot be dated later than about 14,800-14,500 bp. These species may have survived in isolated areas of the highlands long after this date but of this we have no evidence. Menzies (1987), however, makes the intriguing suggestion, that a stone carving of an animal with a long snout from the Ambun Valley, Enga Province, now in the Australian National Gallery, Canberra, was not a stylised echidna as has been suggested (Anon 1965) but the folk memory of the diprotodontid.

If the extinction of these four species did not occur until about the time of the glacial maximum, it suggests that rapid extinction did not occur in New Guinea and that indeed there was a long period during which humans co-existed with now extinct species in the highland environment. This would not confirm Martin's blitzkrieg "rapid overkill theory" (Martin 1967,1984). In the mountainous terrain it would be unlikely that mass extinction of large species could occur with any speed, unless the animals moved together as a large herd, for which we have no evidence. Individual small populations must have been able to retreat to undisturbed regions. The density levels for human populations were presumably very low during the late Pleistocene and, even with the developing sophistication of predation skills, it seems unlikely that humans were responsible for the initial demise of these animals.

9.2.4 Presence and extinction of the thylacine

Thylacinus cynocephalus remains have been recorded from every stratum at Nombe (Section 8.2). It was clearly a most successful and adaptable predator throughout most of the prehistory of New Guinea and Australia, in varied habitats from sea level to high mountain altitudes. There seems little doubt that competition from the introduced dog led to a decline from which the species never recovered.

> Its extinction on the mainland, as well as in New Guinea, can probably be blamed on the Australian Dingo (Archer 1974) and New Guinea wild dog, both of which are adapted to open country. It is possible that the thylacine might have survived in dense forest if they (dingo and wild dogs) were its only competitors, but the additional presence of man was probably critical. To this must be added the decline in natural prey....If hunting pressure were not directly responsible, it at least put such a strain on the species that it was unable to cope with other pressures. Smith (1982:250)

In Australia, thylacine remains have been dated from throughout the Pleistocene and early Holocene becoming rare from about 3000 BP onwards by which time the dog had arrived (White with O'Connell 1982:104). Archer (1974) gives a date of 0±80 years BP for the most recent dated thylacine remains on the Australian mainland recovered from north west Western Australia. Smith (1982) also agrees with Archer (Archer 1974) that the ecological replacement by the dingo and predation by human hunters were largely responsible for the extinction of the species. The only place where thylacines survived into living memory was in Tasmania which was without dogs until the arrival of Europeans.

Dawson has examined the remains from Nombe (20 cranial fragments and 22 post-cranial) and, although they belong to small specimens of the species, of a similar size to the remains from Kiowa cave (only 4 km south of Nombe), there is no basis for suggesting that a subdivision of the species is justified (Dawson 1982). There are only six individuals represented over more than 30,000 years; but, for perhaps 20,000 years of that period the species must have used the site on a regular basis, in the intervals between sporadic human occupation up until perhaps the end of the Pleistocene. The thylacine bone from the Holocene levels is heavily burnt and probably constitutes the remains of animals captured by human hunters. During the last few thousand years, the animals must increasingly have been in direct competition for food with members of the *Canis* species, introduced to New Guinea probably about 4000 years ago. It is not possible to give a more precise date for the demise of the thylacine from the Nombe data without direct dating of the bone. The thylacine bone from Kiowa was recorded from Level 9, dated to between about 6000-9000 bp (Bulmer 1979, 1966/76; Van Deusen 1963), though there is no information as to whether it was in a context of human predation with a high percentage of burnt bone and artefacts or a situation that might be interpreted as another thylacine lair surrounded by the debris of its own prey.

9.3 PREDATION STRATEGIES DURING THE LATE PLEISTOCENE AND EARLY HOLOCENE PERIODS AT NOMBE

9.3.1 Research into hunting strategies in highland New Guinea

The Nombe faunal data provides a unique opportunity to hypothesise about the development of human predation strategies during the Late Pleistocene and Holocene periods. Hunting is still an important activity of many highland and highland fringe communities today and a considerable amount of research has been carried out in a number of regions. The documentation of techniques and the calculation of the energetics involved in these operations can supply further comparative material for the interpretation of the Nombe data. It must not be forgotten however, that all New Guinea societies have evolved to their present forms over many thousands of years and modern ethnographic parallels do not supply exact comparative data for the behaviour of human beings in the highlands more than 10,000 years ago. Similarly, documentation of techniques used and species hunted in specific altitudes cannot be broadly applied to other altitudinal situations where the environmental conditions are different.

In Chapter 8 an analysis of the suite of species present in the lowest Pleistocene strata (D2/3/4 and D1/5) shows that many of the species present are found today in the upper zones of forest and in the more open shrubs and grasses of the alpine zone. This is in line with other environmental evidence (Bowler *et al.* 1976).

Hope and Hope (1976) state that the period from about 33,000 to between c.14,800 and 14,500 years ago was considerably colder than the present climate (although there were certainly climatic variations during that time), so vegetation and faunal zones were shifted downhill. Quite clearly the suite of animals available 25,000 years ago (including the large extinct browsing species) demanded different predation strategies to those used today in catching a range of medium to small mid-montane rainforest species.

There is now a considerable body of ethnographic literature to draw on. Dwyer's flow of reports (1974, 1975, 1978, 1980, 1981a, 1982a, 1983a, 1983b, 1984, 1985a, 1985c, 1989, 1990) which stem from his time spent with the Bobole community at altitudes between about 1100 and 1500 m in the Southern Highlands and the Rofaifo people of Mount Elimbari are of especial interest here on account of his careful and precise documentation of the techniques used to obtain the catch and the energetics involved. Bulmer worked for many productive years with the Kalam people in Simbai region of the Schrader Ranges, hunting at ranges between 1500 and 2700 m (Bulmer, R. 1967, 1968, 1976; Bulmer and Menzies 1972/73; Bulmer and Tyler 1968; Majnep and Bulmer 1977). His work on the Kalam classification of the environment and his exploration of their conceptualisation and understanding of biological species through analysis of local traditions and language is being continued by Majnep assisted by Pawley (Majnep and Bulmer 1990a-f). Hide *et al.* (1984) have described hunting in South Simbu, Hyndman has documented the hunting of the Wopkaimin in the Star Mountains (Hyndman 1982, 1984, 1990) and Gorecki and Pernetta (1989) have dealt with aspects of hunting while travelling amongst the people along the lower Jimi and Yuat rivers. Many other anthropologists, such as Kelly (1977, 1988), Healey (1980), Morren (1986, 1989), Clarke (1971) and Dornstreich (1973), have also researched the human/animal relationship within highland and highland fringe societies, and the activities and beliefs associated with the capture and consumption of wild flesh.

A starting point for assessing the interesting field research done over the past twenty or so years into the strategies of hunting in New Guinea is R. Bulmer's overview paper (1968). He points out that hunting was not undertaken for purely economic or dietary gain but that "the reports of numerous observers suggest that enthusiasm for hunting is frequently greater than its material contribution to the satisfaction of human needs would appear to warrant" (Bulmer 1968:305). I believe that this is not only true today, when there are usually alternative sources of dietary sustenance, but was likely to have been true in prehistory also, even at times when people depended on the results of hunting to satisfy their subsistence requirements to a much higher extent. The sheer pleasure of hunting must be remembered (Dwyer 1974; Majnep and Bulmer 1990a), as there is a danger in interpreting faunal data only in terms of economic gain or energetic profit.

The antiquity of large-scale, socially organised hunting no longer appears as ancient as was thought several years ago (see for example, the discussion by Binford, Klein and others in Nitecki and Nitecki 1987) and various researchers have suggested that scavenging may have been more effective than hunting among very early human groups (Shipman 1983, Shipman and Rose 1983). In fact, it is suggested by several scholars that it was not until the Upper Palaeolithic stage in Europe that well-organised social hunting can be identified from archaeological deposits (Straus 1987). Trinkaus (1987) puts forward cogent reasons for believing that it was not physically possible for early hominids to enter into fully fledged cooperative hunting which he argues therefore did not appear until modern *Homo sapiens* had evolved. Neanderthal people, it is argued, carried out only "endurance - and strength-oriented and largely opportunistic foraging patterns" (Trinkaus 1987:125) which enabled them to survive extreme climatic rigours but did not allow the manufacture of the more sophisticated range of artefacts found in the Upper Palaeolithic of Europe made by the less muscular *Homo sapiens sapiens.* Trinkaus claims that the faunal records of the Mousterian sites support the hypothesis that foraging was opportunistic, poorly organised and energetically inefficient because of the high proportion of small/medium-sized or weak animals procured, a lack of large and dangerous prey, and a considerable proportion of material scavenged from other predators. It is "primarily for later Upper Palaeolithic populations that we have unquestionable archaeological evidence of systematic, planned exploitation of larger mammals on a regular basis" (Trinkaus 1987: 131).

There can be little doubt that the first humans to arrive in New Guinea some time before 40,000 bp were *Homo sapiens sapiens* but what evidence do we have for their capacity to hunt? Apart from the Nombe faunal data, there is very little, although the sites of Yuku and Batari (which may extend into the late Pleistocene) and Kiowa and Kafiavana (which cover the last few thousand years at the end of the Pleistocene), do have faunal evidence; but their analyses are neither of a kind or at a stage to supply comparative data for Nombe.

Hunting strategies, as Bulmer points out, depend on many factors, including the very important question of what animals were available in the local environment, what technologies were in current production, what else was available to eat on a seasonal basis (especially plant foods) and what the importance of hunting was to the local community. Some of these factors are impossible to evaluate in the prehistoric archaeological context and others can only be partially answered in a very unsatisfactory way. However, a number of suggestions can be made as to the predation strategies used at Nombe from about 25,000 to 5000 years ago.

The evidence used comes almost exclusively from the faunal remains themselves. Many of the techniques prominent in the ethnographic record of hunting - snaring, trapping, netting and shooting with bows and arrows of wood - are not incorporated into the archaeological record. It must be remembered that traps are made from plant fibres, wood and other organic materials and it would be unusual for them to survive in prehistoric contexts of any antiquity, except in highly anaerobic conditions as can exist in swamps or bogs. (Preserved organic fish traps and nets in the Mesolithic cultures of northern Europe have been found in just these conditions (Mellars 1978).) Similarly, the stone tools which may have been used in the manufacture of hunting artefacts, show little evidence of such use.

So far, the analyses of stone artefacts from the highlands of New Guinea (White 1967, 1972; Watson and Cole 1977; Mangi 1984), although scrupulous, have not established clear stages of technological development. Indeed, such research has established the proposition that many stone tools changed very little over extremely long periods of time. Examination of the mental images held by the modern makers and users of stone tools has been a far more revealing line of enquiry (White and Thomas 1972, White, Modjeska and Hipuya 1977). It appears that shape and finish were of little importance and that the main purpose was to produce an edge of required sharpness or strength for the function in hand. There is thus little possibility of identifying the origins or development of complex hunting techniques through the recovered artefacts. Fortunately, however, there are clues to be found in the analysis of the faunal data.

9.3.2 Modern hunting strategies

R. Bulmer (1968) lists hunting strategies as follows:

Stalking - following a free-moving prey.

Ambush - where the hunter waits for the prey at a place it is expected to visit.

Luring - towards a hidden hunter by imitating an animal noise or using artificial tracks or perches.

Besetting - using intimate knowledge of a prey's whereabouts (for example, asleep in a lair or tree or cave) to surprise the prey when off guard.

Chase - where the prey has become aware of the hunter and, often already wounded, tries to escape.

Drives - causing the prey to move into a trap by use of noise, fire or other signals that will frighten it.

Trapping - by knowledge of a prey's behaviour causing it to go through a narrow opening in which there is a trap or a disguised pit which will imprison the animal until collected and killed by the hunter.

The basic techniques of stalking, ambush, luring, besetting and chase depend on the hunter's knowledge of a particular species' behaviour and haunts and on an intimate knowledge of their environment. Such hunting techniques are far from simple. In the words of Majnep:

> You shouldn't think that hunting is easy; far from it, hunters have to climb tree after tree after tree, until their elbow joints have no strength left in them, and have to go on walking and searching and climbing until at last they find a tree with a kapul lair in it and they manage to make a kill. (Majnep and Bulmer 1990a:29)

Once located and caught, the animal is killed with a spear, a bow and arrow, or merely a club or axe. The means of producing these from organic materials are conditioned in the tool-kit of edge-ground axes (perhaps better described as hatchets) (see Plate 6), sharp-edged flakes and steep-edged scrapers that formed part of the equipment of people in the earliest stages at Nombe. The presence of large species in Stratum D1/5 has been interpreted in Chapter 7 (Table 7.10) as the result of both thylacine and human predation. The most successful human predation strategies in those circumstances may have been small groups of hunters working in cooperation to locate the prey and then either to ambush or lure the animals for dispatch. The hunters perhaps would be operating diurnally; the thylacine nocturnally.

Trapping and the more complex forms of ambush involving nets or nooses require technological skill and constant maintenance to allow high yields and continued captures. They probably generally produce higher protein yields with lower energy input than stalking, luring or chasing medium or small individual animals, though the capture of one large animal is probably the most efficient form of hunting. Dwyer (1983a) has compared energy returns from hunting in three modern communities: the Rofaifo hunters of Mount Elimbari, Simbu, the Etolo hunters of Bobole, Southern Highlands and the Gadio Enga of the Western Highlands. The Gadio Enga inhabit an area of low population density and hunt feral pigs; the Etolo, in an area of extremely low population density, use both complex trapping and hunting at separate seasons of the year to provide about half of their dietary protein; and the Rofaifo practice occasional hunting in what is now a degraded area of upper montane forest in a region with a generally high population density. There are obviously many complex factors involved in this comparison, but it is clear that the pig hunters produce both the highest number of grams of protein per hour of hunting and the highest quantity of protein per person per day. The intensive trapping and frequent hunting of medium and small species by the Etolo yields one-third less protein per head per day while Rofaifo hunting is far more unprofitable and provides a negligible amount of protein per head per day. The comparisons highlight the value of large species in hunting and the rise in energy requirements when only medium and small species are available, although both trapping and hunting techniques are employed. One Gadio Enga hunter needs to spend only 8.5 hours a day to produce 10 g of protein per person in a community of 100 people, the Etolo would employ three men on a full day's hunting to produce 10 g and every Rofaifo man would be hunting all and every day to produce the same amount (Dwyer 1983a:164). Present-day faunal availability is often the direct result of human alteration of the environment, while the introduction by people of exotic species such as pig and dog had long-term implications for hunting.

Strategies such as complex trapping are employed to a greater extent when other activities occupy a lot of time, such as planting, weeding and garden maintenance. Dwyer (1990) discusses the complex time-sharing that is practised by the Etolo people in dividing their year into a series of food-producing activities such as sago production, making new gardens, harvesting the pandanus crop and obtaining protein from game species and pigs. All present-day hunting in the highlands of New Guinea is combined with the production of plant foods through agriculture and this is the main factor that has influenced the predation strategies from the Pleistocene into the mid-Holocene period.

9.3.3 Prehistoric hunting strategies

Kelly (1988), as an anthropologist, has made some very useful comments about the ways in which archaeologists could analyse their data to provide information on the evolution of predation strategies in the prehistoric record of the highlands of New Guinea.

Kelly's propositions are based on Dwyer's studies of the Etolo of the southern highlands fringe, who, while they hunt at somewhat lower altitudes (1100-1500 m), hunt a suite of game which largely overlaps that cited for the highlands (Kelly 1988:160). Dwyer (1982a:531-3) reports a group of animals caught predominantly in deadfall traps: these are *Peroryctes raffrayana* (78% of total capture of this species), *Dorcopsulus vanheurni* (77%), *Anisomys imitator* (88%) and *Uromys anak* (75%).

Another group is taken largely by hunting and includes *Pseudocheirops cupreus* (97%), *Phalanger vestitus* (now *P. sericeus*) (97%) and *Dendrolagus dorianus* (100%). Deadfall traps take predominantly terrestrial species captured while they are foraging. Hunting takes arboreal species, while they are resting during the day, and can be materially assisted by the use of dogs. Dwyer (1983:159) reports that *Pseudocheirops cupreus* makes up half the catch of hunters using dogs and only 10% of those hunting without, while the hunting of *Phalanger vestitus* is unaffected by the use of dogs, but requires tree climbing or tree felling. Other animals were preferentially taken in tree traps. Kelly (1988:161) concludes that the data

> suggest that the distribution of game found at highlands sites may contain clues to the methods by which they were taken, and that changes in distribution over time may indicate changes in these methods.

He concentrates on two aspects: the role of the axe as an essential implement in hunting and trapping, and the role of the dog.

> The appearance of ground ax-adzes at Highlands rock shelters at levels dated to 10,000 BP suggests the hypothesis that intensive trapping was practiced at this date and that rock shelter sites may have been associated with this endeavour. This hypothesis might be tested by consideration of the distribution of faunal remains found at the lowest levels dating to this period. The presence of significant numbers of those animals infrequently taken by hunting would provide support for this hypothesis. The presence of animals typically taken by hunting would also be expected......(Kelly 1988:162)

> If hunting and trapping were the principal means of obtaining animal protein, the dog would be likely to be rapidly incorporated into this existing economic orientation. Hunting success would be expected to increase, particularly in relation to certain species. The introduction of the dog should thus be reflected in changes in the distribution of faunal remains. For example, Dwyer's data suggest that major gains in the rate of capture of the coppery ringtailed possum would be expected while the proportion of the cuscus *P. vestitus* would remain unchanged. Changes in the distribution of faunal remains may thus provide the best index of the earliest appearance of dog in New Guinea currently available. (Kelly 1988:162-3)

The antiquity of the edge-ground axes and waisted blades

The chronology of the ground axe-adze (Bulmer, S 1977) is not firmly established in New Guinea. While White (1972:95) claims it to be present throughout the sequence at Kafiavana which goes back before 10,000 years ago (1972:91), dates from other sites are younger (White with O'Connell 1982:67) However, there is an edge-ground specimen (Plate 14) from the bottom of Stratum D1/5 at Nombe (dating 14,500-14,800 to 24,400 to 25,500). This can be compared with the edge-ground 'hatchets' (Dickson 1981) of Australia, the earliest of which have a similar antiquity (White with O'Connell 1982:59). Ethnographic evidence shows these one-handed tools to have been used for a variety of functions including notching of tree trunks and opening of tree limbs in the hunting of arboreal animals and cutting down trees to gain materials for clubs and spears (Dickson 1976:34).

In addition, at the same level as the edge-ground tool, there is an example of the distinctive artefact known as the waisted blade or axe (Plate 15), which is present in late Pleistocene contexts at a range of New Guinea sites, from Kosipe at 1980 m (White, Crook and Buxton 1970), through Yuku at 1280 m (S. Bulmer 1975:30-1) to the Huon Terraces at sea-level and extending back to beyond 40,000 years bp (Groube *et al.* 1986). These large, heavy, blunt-edged hafted tools must have been useful in forest conditions in operations such as thinning, trimming and ringbarking. Bulmer (1977) speculates about their use in arboreal hunting and collecting and Groube

(1989:296, 298) describes them as tools of "primary forest clearance" used to encourage the growth and production of food plants in rainforest habitats (see also Mountain 1991b).

The introduction of the dog

The introduction of the dog (Section 8.2) into New Guinea cannot be dated precisely. There is no archaeological evidence to suggest that there were any canids present before the middle of the Holocene period at the earliest. There is bone of young dog in the Mapala rockshelter deposits in the Carstensz Mountains of Irian Jaya (Hope, J. 1976:212) but not in the early levels which are dated to about 5000 bp, so the specimen must be later than that date. Dog at Nombe is only found in Stratum A which accumulated during the last 5000 years and White only found dog remains in the very top level at Aibura cave. I cannot find any mention of dog from Yuku or Kiowa at all. The earliest reliable date for dog in New Guinea is from the coast, in ceramic contexts, about 2500 years ago (Bulmer, S 1975:50). Evidence from Australia would suggest that the dingo was introduced no earlier than 4000 years ago (Gollan 1984).

Arboreal and terrestrial species in archaeological faunal deposits

There are, however, difficulties with Kelly's suggestion that the introduction of the dog as an assistant in hunting should reveal itself through the recovered proportions of certain species in archaeological deposits. Rarely does the analysis of archaeological remains lead to such a clear and unambiguous result. The processes of original deposition and subsequent taphonomy are very complex, as earlier chapters in this thesis have shown. Also, unless there is a very finely tuned chronology for faunal data, it is going to be extremely difficult to identify how different hunting strategies contributed to any particular faunal assemblage. The same considerations affect his hypothesis about deadfall trapping in the faunal record. There are always difficulties in the use of ethnographic information to interpret the prehistoric record, particularly when, as in the Etolo case, there is an altitudinal difference to be taken into consideration. as well as natural and anthropogenic environmental changes over the tens of thousands of years of human occupation.

Nevertheless, it is worth pursuing his basic hypothesis that different species may suggest different strategies of predation. The straightforward pursuit of animals by stalking, luring, ambush and chase often involves daytime capture of nocturnal and often arboreal species asleep in burrows, nests and tree branches. Trapping and complex ambushing usually targets the terrestrial species that are known to move along certain tracks (often at night). I therefore decided to look at the differences between the different strata at Nombe in the occurrence of terrestrial and arboreal species in the Medium and Small body-size categories, without feeling the need to be bound by the Etolo data presented by Kelly from Dwyer (Kelly 1987). There was a basic problem in the production of a large enough sample for analysis. *Dendrolagus* was added to increase the number of arboreal species, though it could be argued that by introducing this large species into the sample the basis of the analysis is invalidated. Table 9.1 shows the results. This analysis has been conducted using the values for the number of identified specimens as these consistently fall between those for minimum numbers and weight and therefore represent the occurrence of species most accurately.

Table 9.1 Analysis of terrestrial and arboreal species (mainly Small and Medium body size) in the five main Nombe strata

Stratum	D 2/3/4		D 1/5		C		B		A	
Species	NISP	%	NISP	%	NISP	%	NISP	%	NISP	%
Aboreal animals										
DEND.NO	1	3	6	1	-	-	-	-	-	-
DEND.DO	-	-	19	5	1	2	37	2	2	<1
DEND.GO	-	-	6	1	12	20	21	1	7	1
PHAL.SE	4	11	79	19	4	7	34	2	7	1
PHAL.CA	-	-	53	13	7	12	554	26	83	13
PSEP.CU	5	13	108	26	8	13	234	11	102	16
PSEP.CO	3	8	4	1	1	2	158	7	32	5
MALL.RO	4	11	56	14	4	7	297	14	53	8
PSEU.FO	12	31	19	5	2	3	42	2	32	5
Terrestrial animals										
THYO.BR	2	5	13	3	1	2	245	11	131	20
DORC.VA	1	3	8	2	14	24	263	12	114	17
STRI.GY	-	-	5	1	2	3	67	3	23	3
HYOM.GO	-	-	7	2	-	-	21	1	19	3
PERO.RA	1	3	1	<1	1	2	21	1	10	2
ECHY.KA	-	-	1	<1	-	-	-	-	3	<1
ECHY.RU	-	-	-	-	-	-	4	<1	-	-
MICR.LO	2	5	18	4	-	-	50	2	15	2
ANIS.IM	-	-	8	2	-	-	28	1	10	2
UROM.CA	2	5	-	-	1	2	34	2	12	2
UROM.AN	1	3	2	<1	1	2	39	2	1	4
PARA.AS	-	-	-	-	-	-	4	<1	2	<1
Totals:	**38**	**100**	**413**	**100**	**59**	**100**	**2153**	**100**	**658**	**100**
Arboreal %		77		84		66		65		49
Terrestrial %		24		15		35		35		51

Note: Totals may not agree because of rounding

In Stratum D2/3/4, three-quarters of the Medium and Small body-sized animals represented in Table 9.1 are conventionally classified as arboreal. This might lead to the conclusion that only human hunters could be responsible for such a pattern of predation but it has already been argued in earlier chapters (Sections 4.6.5 and 6.5.4.2) that the absence of strong indicators of human presence, such as a high level of burnt bone, the presence of charcoal or undoubtedly human artefacts well sealed in the sediments of these levels, suggests that humans were not present during the formation of these clays. The presence of bones from arboreal animals alone cannot be taken as a strong indicator of human hunting. Arboreal species, which usually spend their sleeping hours tucked into a fork in the tree-tops or in a hole in the epiphytic growth on a branch, can and do come to the ground during feeding and activity periods. Certainly if the thylacine is presumed to be the major predator during this period, it is surprising to find such a high percentage of arboreal species present, though, it must be remembered that we are dealing with only a proportion of the entire prey and that most of the large terrestrial animals have not been included in the analysis. The results suggest that other smaller predators, in particular *Dasyurus albopunctatus* which is a very aggressive predator (Section 8.2), may have been active in hunting the smaller arboreal species (such as *Pseudocheirus forbesi*). Thylacines, believed to be nocturnal hunters, were targeting the larger prey as well as catching occasional medium-sized phalangers and possums on the ground at night. Scavenging of carcasses is also likely to have been carried out by animal predators. There is a slight probability that humans were indeed active in the area at the time and were responsible for hunting the arboreal species although other indicators do not bear this theory out.

Stratum D1/5 shows an even higher proportion of arboreal prey. This may be the result of continued nocturnal hunting by dasyurids and thylacines, amplified by the introduction of sporadic but successful human predation of arboreal animals during the day. Two species indicating a colder climate are, as already noted in Chapter 7, present in higher proportions than earlier: *Phalanger sericeus* and *Mallomys* spp. (see Section 8.2) but there are increases in the forest species of *Pseudocheirops cupreus* and the first appearance of *Phalanger carmelitae*, indicating perhaps that the human hunters were hunting over a wide altitudinal range and targeting the forest at lower levels as well as the open subalpine grasslands above the site.

There is an obvious increase in terrestrial species at the expense of arboreal species in Stratum C, whose beginning is dated quite firmly to about 14,800-14,500 bp. I do not believe that an interpretation wholly in terms of an introduction or increase in deadfall traps, such as Kelly might propose, would be appropriate. The main changes indeed concern

- ☐ an increase of one species classed as arboreal, *Dendrolagus goodfellowi*, and one classed as terrestrial, *Dorcupsulus vanheurni*, both of them animals of mid-montane forest, whose upward extension would be a major part of the environmental change brought about by the ameliorating climate after the glacial maximum;
- ☐ a decrease of species from the upper montane moss forest and sub-alpine grasslands/shrublands (namely, *Dendrolagus noibano*, *Phalanger sericeus*, *Mallomys* spp. (perhaps one of the new sub-alpine species), *Pseudocheirus forbesi* and *Microperoryctes longicauda*) due to the protraction of these environments; and
- ☐ a decrease in one arboreal species, *Pseudocheirops cupreus*.

The technology to cope with these changes was probably already available from Pleistocene experience in lower altitudes. It is interesting that of the species with increased proportional representation in Stratum C, one is cited on the basis of Dwyer's Etolo evidence as predominantly taken in deadfall traps (*Dorcopsulus vanheurni*), and *Dendrolagus goodfellowi* is rarely taken and only then in tree traps (Kelly 1988:161). The forest species that decline are mostly hunted by the Etolo.

Stratum B represents a stabilisation of the pattern developed in Stratum C, with an environment of mid-montane rainforest fully developed under a climatic regime similar to that of today. There is a big change in the proportion of *Thylogale brunii* which, as a species of the forest edge and disturbed growth, should have been advantaged by human clearances for agriculture. This is an interesting situation possibly providing indirect evidence for local clearance, early in the Holocene, of the limestone areas on which forest was probably thinner than on the heavier neighbouring soils. The other steep rise in Stratum B is in the proportions of the forest cuscus *Phalanger carmelitae* and also a rise in the *Mallomys* spp. (probably here *M. rothschildi* and not necessarily the high altitude species, Section 8.2). whereas the forest wallaby (*Dorcopsulus vanheurni*) declines in proportions.

Another rise in terrestrial species occurs in Stratum A, where there is almost a balance between terrestrial and arboreal species. *Thylogale brunii* again increases in proportion as clearance proceeds. We should note at the same time, however, that there is little increase in bandicoots or rodents. Forest species continue to be well represented. An explanation for the higher proportion of terrestrial animals overall in Stratum A is best found in terms of the changing ecology of the area under human agricultural impact, accompanied by pigs and perhaps even dogs rather than purely in terms of new hunting strategies, although these could be partly responsible for the change.

9.3.4 Human hunting strategies from Nombe

In the earliest stratum at the site, natural predators, such as thylacines and dasyurids, used Nombe as a lair and bones from their prey have been recovered from these strata. People began to use the site, probably as a temporary hunting camp, from about 25,000-24,000 bp. Four large Pleistocene species, now extinct, not only coexisted with people in the highlands at that time, but their remains are found at Nombe. I find it hard to believe that human hunters did not take advantage of the presence of large fleshy and, at least in the case of diprotodontids, probably slow-moving animals. Diprotodontids would surely have been easier to catch than wild pig, *Protemnodon* perhaps more difficult, moving fairly fast through the undergrowth but large and unable to climb or disappear into the understorey. Pit traps would be an obvious technique to use for either of these terrestrial species, and successful hunting of the *Dendrolagus* required the ability to locate it in trees and trap or spear it. The advantages of capturing such large prey are obvious, with their capacity to provide an abundant supply of protein and fat requirements for a small group, as well as good quantities of bone, gut, sinew and skin. Pre-agricultural highlanders in New Guinea had a wide range of game flesh and plant foods available as dietary resources, but at least in recent times there has been a shortage of fats and oils. Small and medium forest animals are lean and sparse with little fat on the flesh. The plant foods are largely leafy greens, shoots and fruits, which do not supply oils. Two species that today supply essential oil or fat, are the rich oily nuts, especially of the *Pandanus* species, and the pig with its thick coating of fat under the skin. The large extinct fauna that lived in the cold upper montane forests of the late Pleistocene were probably also reasonably provided with fat to survive in high altitudes. This commodity, among other desirable products of the carcass, would have made the capture of a diprotodontid, *Protemnodon* or large *Dendrolagus* one of the prime aims of a hunting party to Nombe.

It is clear that without further careful examination of the individual bones it is not possible to isolate the prey of the first human hunters from that of the thylacines. Both predators probably targeted a similar range of terrestrial species - extinct fauna, *Zaglossus bruijni* and the cassowary. They were both capable of capturing a wide range of smaller game, although probably hunting at different hours of the day. During periods when the cave was empty of both of those large predators, smaller carnivores moved in and increased the quantities of small prey. Frogs may well have lived independently in the wet areas of the cave when all other predators were absent.

By the beginning of Stratum C, about 14,800-14,500 bp, changes are apparent in the faunal patterns. The quantity of undisturbed sediment from the end of the Pleistocene is very small and the amount of bone recovered from that sediment low, so that only very broad trends can be indicated from the results of this analysis. There is no sign that the extinct fauna survived into this stratum and the number of *Zaglossus* bones is drastically reduced, although the proportion of Medium-sized species remains very similar to that in Stratum D1/5. The increase in the representation of terrestrial mid-montane species indicates the spread of forest around the site as the tree-line rose.

I believe there is one unequivocal indication of human predation at the time: a dramatic rise in the proportion of bat bone, which dominates the Small body-size category (Table 7.9). This trend is continued in Stratum B and is still high even in Stratum A providing a clue to one of the strategies used by late Pleistocene hunters to replace the large Pleistocene species which were dying out through an inability to adapt to changing climatic conditions and perhaps because of over-hunting by humans and even by thylacines. Large fruit bats, whether *Aproteles bulmerae* or *Dobsonia moluccensis*, roosting and nesting in the many limestone caves and sink-holes (or dolines) of the locality were not worth targeting while there was an abundance of large prey that was relatively easy to capture. But once these large prey began to decline, prey-switching was necessary.

Fruit bats had been present in the Nombe fauna throughout the sequence but it is possible that they were only present in small numbers in the surrounding environment during the period of Stratum D2/3/4 and D1/5 since they need fruit trees from which to feed and in the colder moss forests these are rare. Their numbers may have increased as the mid-montane forest became more abundant closer to the limestone belt in which their roosting caves were situated. This may have provided a rich resource which could have been used as an alternative to the declining, and increasingly hard to locate, Pleistocene species. Bat-hunting technology still in use in the area is technologically simple and could well have been in use in the late Pleistocene to provide a substantial quantity of meat at one kill.

Dwyer documents the fact that Rofaifo hunters built structures of branches and twigs at the mouth of a cave and that men caught the bats as they tried to escape (Dwyer 1975). During our 1974 Nombe excavations (during June), the excavation team was able to watch the progress and eventual outcome of a combined community bat-hunt. This occurred at the sink-hole of Wirrawena on the dip slope above Nombe. Preparation in the form of tree felling must have been taking place over many weeks prior to the event. Several local communities banded together for the first time in thirty years to entrap all the flying fox (*Dobsonia moluccensis*) inside (Mountain 1979). It took many hours to prepare the site and gather the necessary logs and vines. Women supplied constant food and small children watched from the safety of peripheral fires as their male relatives wove an intricate net of branches and trunks out further and further over the opening. This process took four days. At night, when the bats normally foraged for food, the noise of singing and shouting around the hole prevented them from venturing out of a diminishing space to freedom. After three nights the net was practically complete; grass had been strewn over the entire lid and it was quiet for the first time since the operations had begun. All adult men (over the age of about twelve) were sitting on a portion of the flexible lid with a stout stick in hand. As the hungry bats rose to escape for food, they lifted the grass and the nearest man grabbed the bat and clubbed it to death and threw the carcass to waiting relatives. I do not know the exact numbers captured that night but it was certainly well over a hundred. Salisbury (1965) mentions a figure of 1600 animals taken during a bat hunt conducted during his field work in the 1950s. The technology employed involves the use of efficient cutting tools for trees and lianes and the traditional (and breathtaking) skills and sheer courage of the men in building the net over a sink-hole that, in the Wirrawena case, was over ten metres deep and twenty-five in diameter.

Bats do show signs of seasonal breeding, unlike many of the other small forest species (Dwyer 1982a, 1975). Dwyer gives the breeding season of the *Dobsonia* *moluccensis* (1975) as September to November. Hamilton-Smith says that most bats have an unusually low reproduction rate and that as many as half the number of bats born never reach sexual maturity (Hamilton-Smith 1978). The females nurse their offspring for five to six months after the birth and the colony remains at the one site during this period, so bat hunts could have been held over several months once a colony had established residence. Dwyer (1974) noted bat hunts in April, June, September and November, providing about 1 kg of protein in 5.1 hours of effort. This species is abundant at altitudes of up to 2700 m. They may occur in vast numbers: Dwyer (1975) counted over 1000 animals flying across a narrow pass at the top of Mount Elimbari and estimated that because of his restricted view there may have been up to three times that number returning to roosts in inaccessible caves on the face of the Elimbari scarp.

Prey-switching from individual specimens of large species to large numbers of much smaller animals would be good reason to continue visiting Nombe. The excavations at the nearby site of Kiowa (Bulmer, S 1966/76) at 1530 m also recovered large quantities of bat bone in the terminal Pleistocene levels. The numbers indicate that there the hunters were targeting a larger species, *Aproteles bulmerae*, in the early years of occupation at the end of the Pleistocene. Bulmer says that "it appears that it (*Aproteles bulmerae*) may have been the reason for the original occupation of Kiowa as it comprised nearly 70% of the animals taken" (Bulmer, S 1979:11). Remains of this species ceased to appear in the archaeological deposits after about 10,000 bp and were replaced by *Dobsonia moluccensis*. Hamilton-Smith (1978:85) comments that "disturbance to or destruction of that site (a roosting cave) particularly during the maternity season, can readily lead to a massive decrease in, or even extinction of, a population". Bat bone retains its importance at that site and never drops below 41% of the cranial sample analysed (Bulmer, S 1979). This evidence suggests that both Nombe and Kiowa were shelters from which late Pleistocene human hunters raided roosting bat colonies in adjacent caves. This would supply large amounts of meat, and other resources such as skins and bone.

The animals found in Stratum B at Nombe indicate that the local environment had attained its present suite of mid-montane species. Both the number of individual species present (58) and the quantity of bone increased dramatically. These indications along with other evidence for increased human activity (Chapter 4) suggest that the site had become a base camp for fairly continuous hunting. A wide range of Medium and Small forest species was present with a number of birds (especially megapodes and their eggs), a turtle, many rodents and the only bone of the large eagle *Harpyopsis novaeguineae*. The proportion of Large prey is about the same as in Stratum C and much lower than during the earlier strata, consisting mainly of *Dendrolagus dorianus*, *D. goodfellowi* and cassowary with a reduced amount of *Zaglossus bruijni*. The cuscus and possums are dominated by *Phalanger carmelitae* and *Pseudocheirops cupreus* followed by *Pseudocheirops corinnae,* all of which rank highly in most forest hunting expeditions in the highlands today (Majnep and Bulmer 1990b, 1990c; Dwyer 1990).

There have been claims by Bulmer that the pig was present before the end of the Pleistocene at both Kiowa and Yuku (Bulmer 1975:16). White has claimed that there are pig bones from about 6000 bp at Kafiavana (White 1972). At Nombe there is one tooth that was recovered from the Pleistocene clay but since there is no more pig bone until the middle of Stratum B in the Holocene I do not find it reliable evidence for Pleistocene pig and would say that the earliest dates for pig bone at Nombe cannot be earlier than 6000 to 7000 bp and there are very few specimens even at that date. Most of the pig bone is from Stratum A. The arrival of pig in the highlands introduces a powerful element for change since, as a domestic animal, it either has to be hand-reared and fed until it is bonded to the person who reared it in order to retain a relationship with that community or, as a feral animal, it can compete for forage with other wild animals and in foraging disturb and alter the vegetation patterns in which it lives. It represents a major source of protein whether domesticated or wild and has clearly altered the predation patterns for many highland communities during the Holocene period. In many ways the pig has replaced the niche left open by the extinction of the large herbivorous macropods but at lower altitudes. The question of whether or not there were Pleistocene pigs or even early Holocene pigs in New Guinea cannot be answered here. Some recent results from accelerator dating suggest that this was not the case but the results require much further examination before acceptance. I will merely say that it is far from conclusive at present that pig was present in the highlands before the end of the Pleistocene period. It is more likely that it was not an element of most communities until about the mid-Holocene.

The trends of human predation at the early Holocene site of Nombe are broadly echoed in the Kiowa data. Bat dominates here according to S. Bulmer (1979) as mentioned earlier, followed by cuscus, macropods, rats and ringtailed possums with some bandicoot. Other species groups are present at various times in the sequence. The material from Yuku (Bulmer 1979) shows a domination of cuscus followed by macropodid and rats. This site is situated at a much lower altitude (1280 m) than Nombe and Kiowa and provides larger proportions of reptiles, the lower altitude *Phalanger orientalis* (not represented at Nombe at all although there is some evidence at Kiowa) and pig.

White's (1972) early Holocene faunal data from three highland sites (excluding Aibura, which only has a record beginning in the Late Holocene) shows a similar range of species deriving from a forested environment. The data from Kafiavana (White 1972) and Nombe (Tables 7.7-7.10) show the dominance of macropodids and phalangers and rodents, whereas Batari (White 1972) has slightly higher proportions of *Pseudocheirops* in addition to other species.

There is no doubt that human beings during the 5000 years of the Holocene were the dominant species of predator, whose activities were beginning to change the distribution of species, both plant and animal. In the final chapter I shall examine these changes throughout the highland region more generally, to see how the detailed evidence from the site of Nombe conforms with trends emerging from other sources of evidence and how the changes that are abundantly clear in the last period of the Holocene can be seen to have their roots in the very beginnings of human occupation of the highlands of New Guinea.

Chapter 10

Human Impact on the New Guinea Highlands in the Pleistocene

10.1 INTRODUCTION

In Chapter 1 three issues were identified as major foci for this research:

1. the nature of the relationship between the first human occupants and the environment they found in the high valleys on the eastern side of the Elimbari limestone escarpment,
2. the relationship between humans and extinct animals in the highlands during the late Pleistocene and the process and chronology of extinction; and
3. the identification of markers indicating the change in subsistence activities from pure hunting and gathering to the introduction of agriculture.

The analysis of material from Nombe rockshelter has furthered our understanding of all three of these issues despite the initial problems that arose from the lack of an integrated strategy during earlier excavations.

The analysis of the excavation data, together with the geomorphological analysis by David Gillieson and extensive radiocarbon dating by the ANU Radiocarbon Laboratory, enabled a comprehensive model of the depositional history of the site to be presented (Chapter 3). An analysis of the changing levels of human activity at the site (Chapter 4) showed that people had undoubtedly been active at the site during the Pleistocene, from about 25,000 bp and that there was intense activity on the site from about 10,000 bp onwards. A comparison with archaeological data from other highlands sites (Chapter 5) was undertaken although the lack of consistent and comprehensive data from each site resulted in this analysis being less than satisfactory.

An examination of the taphonomic aspects of the site (Chapter 6) established major differences between bone from the Pleistocene and Holocene and led to consideration of the problems of a bone assemblage that may contain the results of activity by several small and two major predators (humans and thylacines).

At the beginning of the research it was anticipated that faunal analysis would provide the substantive data for addressing the three main issues of the thesis. These data are the basis for the arguments put forward in Chapters 7, 8 and 9, which involve the identification of a large body of faunal material linked to current knowledge on the ecology and habits of each species identified in the Nombe deposits. Such faunal data are unique in the archaeological record of the New Guinea highlands. Only three other researchers have analysed faunal collections (White 1972; Bulmer, S 1979; Aplin 1981). Of these only Aplin provides a thorough analysis, based on all data present. However, the Kamapuk site which he studies, dates to the last 4500 years which has not been a period of central concern in this study. White, working in the late 1960s when knowledge of New Guinea fauna was limited, particularly from the osteological point of view, used only very general information on broad family categories using cranial material and Bulmer used a sample of cranial material in her analysis of the Kiowa data.

This leaves the Nombe site as having the only comprehensive Pleistocene faunal data in highland New Guinea, there being no faunal material at all from other sites, NFX, Wanlek and Kosipe. However, the material from the terminal Pleistocene site of Kiowa allows a useful general comparison with the material from Stratum C and B at Nombe. There is a possibility that at Batari, the lowest levels might belong to the late Pleistocene and also a high probability that the lowest Yuku data are late Pleistocene but there is no well-dated Pleistocene faunal material.

10.2 ISSUE 1: THE HUMAN-ENVIRONMENT INTERACTION IN THE HIGHLANDS DURING THE PLEISTOCENE

The only model at present for the Pleistocene occupation in the highlands of New Guinea comes from Hope and Hope (1976) who argue that people would have been attracted to the extensive forest-grassland ecotone and shrub-rich grasslands beyond, created by the lowering of the tree-line in the colder Pleistocene. This mid-1970s model grew from the pioneering environmental research in the highlands of Papua New Guinea carried out by G. Hope (1976), Walker (1970), Flenley (1972) and Löffler (1972) amongst others. Hope and Hope used the evidence from palaeontological research, glacial research and sea level change to construct a framework of the changes in vegetational zones that occurred in New Guinea from the later Pleistocene to the present. As the climate became colder in the later Pleistocene, the altitude of the forest edge on the higher slopes of the inland montane regions decreased, opening a zone of stunted, shrubby, fern-rich, vegetation growth phasing into alpine heaths and grasslands above. This created a new resource zone which provided relatively open communication throughout the higher altitudes of the mountainous spine of mainland New Guinea.

Hope and Hope (1976) suggest this zone was important for early human activity, especially hunting, communication and perhaps plant collection and demonstrated that the equivalent forest margins are used today for similar purposes (although these are now isolated areas at higher altitudes). They suggested that the larger, now extinct

Pleistocene fauna could have been living within this zone, although at that time Hope and Hope were writing, there were no conclusive finds of extinct fauna from sites above 1500 m asl: "We suggest that the lower subalpine grasslands and the forest edge within the altitude range 1800 to 2500 m may have been an important zone for the Pleistocene population of montane New Guinea" (1976:46).

They tested this hypothesis against the archaeological evidence available at that time. While the evidence from the site of Kosipe supported their model, the evidence from other sites was fragmentary but did not disprove the model.

Certainly the modern representatives of those habitats, much reduced under Holocene climates, are favoured areas for hunting and travel. The lowered tree-line allowed access to such regions in principle for all the sites of Pleistocene activity: Kosipe (1940 m) must at times have been almost at the edge of the forest, while Nombe (1750 m), Wanlek (1680 m) and NFX (1550 m) could not have been very far below. Nombe, however, is the only site with the faunal data with which to test this model.

The shelter was not only situated close to the tree-line during the late Pleistocene but the first human occupation occurs around 24,000-25,000 bp when, with temperatures beginning to fall towards the glacial maximum at around 18,000 bp, the forest was reaching its lowest altitude of about 2200 m. At that time there would have been access from the site to the small area of shrub-rich grasslands and forest margins which would have existed along the top of the Elimbari ridge directly above and adjacent to Nombe. To the east of Nombe there is much larger block of higher land rising to well over 2200 m with several peaks at between 2500 - 2600 m. This area, between Nombe and modern Watabung on the Highlands Highway, is less than two hours walk today and within easy reach of Nombe. These zones were therefore well within the range for Pleistocene hunters using Nombe as a shelter or temporary base for hunting.

The faunal evidence from Nombe shows that humans and animal predators were successful in hunting a wide range of animals now found in higher altitude areas and recorded from the sub-alpine shrub-grasslands including *Zaglossus bruijni, Thylogale brunii, Microperoryctes longicauda, Phalanger sericcus* and *Mallomys* spp. The Pleistocene fauna at Nombe also includes the four large now extinct species (diprotondid, *Protemnodon nombe, P. tumbuna* and *Dendrolagus noibano)* which were presumably living near the forest margins and within walking distance of Nombe. Since there has not yet been analysis of the identifiable marks on the bone, we cannot be certain which predator (human or thylacine) was responsible for the predation of these species. Nevertheless, a reasonably clear indication of human activity in Stratum D1/5 is the considerable increase of the density of Large and Medium bones in the sediment compared with the density of similar bone in the basal Stratum D2/3/4.

The evidence from Nombe substantiates the Hope and Hope model for Pleistocene use of the forest edge. The fauna from Stratum D 1/5 includes species which are now found in the cold, alpine grasslands which were certainly present in the site up to and including the period of glacial maximum. More recent environmental research (Haberle, Hope and De Fretes (1991) and Haberle (research in progress)) further strengthens the thesis of human activity in the upper forest and above in the later Pleistocene.

There is some evidence from elsewhere that substantial structures may have been built in forested areas where there were no suitable rockshelters or caves. At NFX there is a scatter of late Pleistocene dates (Watson and Cole 1977: 130, Table 16), a hearth was dated to 12,680 ± 280 bp and charcoal, said to be from post remains belonging to one of a number of (not necessarily contemporaneous) structures dated to 18,050 ± 750 bp (Watson and Cole 1977: 194). At Wanlek S. Bulmer (1977:65) briefly reports a number of structures, including a small pole house and some very large post holes, dating to between 15,000 and 12,000 bp. There are also some unpublished late Pleistocene dates from other parts of the highlands (C. Ballard and J. Mangi, pers. comm.)

The best site for evidence of late Pleistocene activity, besides Nombe, is Kosipe (White, Crook and Buxton 1970), the high-altitude open site from which a series of stone artefacts, including waisted artefacts, were obtained together with dates from about 26,500 bp. The site would have been very close to the tree line, with straightforward access to the extensive sub-alpine grasslands of the ridges above. Pollen has been extracted at Kosipe (Hope, G. 1982) both from the archaeological site and from the neighbouring swamp 50 m below in the valley, where the commencement of a large increase of carbonised particles at 30,000 bp is a strong indication that this is the start of settlement with burning of the reed swamp (Hope 1982:217). The pollen spectra from both sites produce no certain pollen from the nut-bearing *Pandanus,* whose seasonal exploitation was the explanation proffered by White (White et *al.* 1970: 168-69) for the existence of the site. However, hunting at the forest edge and into the open shrub-grasslands would have been an equally feasible motive for its occupation, and bone would not have survived there. Hope's evidence suggests a comparison between the burning activities in evidence at Kosipe and the modern practice of burning high altitude zones for hunting, for example on Mount Albert Edward (3990 m) (Hope, G. 1980a, 1982:217).

Similar small-scale clearance by burning has been documented by palynological work in both the Western Province at Telefomin and in Irian Jaya. Hope (Hope, G. 1983a) records that at Telefomin there were increased amounts of carbon particles, suggesting early human interference, at an altitude of about 1500 m. This site would always have been well within the forest limits but at the period of the glacial maximum was not very far from the extensive alpine grassland of the neighbouring mountain chains. Of three clearance phases recorded in the palynological record, the first, between 18,000 and 15,500 bp, is of relevance here. This clearance seems to have resulted from and been maintained by the firing of the wet swamp forest accompanied by an increase in grass pollen and some increase in that of *Castanopsis,* though *Nothofagus* maintains very high values (Hope 1983a:30).

The second palynological site for which there is an indication of early burning is in the Baliem valley at 1600 m (Haberle, Hope and De Fretes 1991), again well-sited for high altitude access. An exposed section at Supulah Quarry shows that the local vegetation was dominated by *Nothofagus* forest about 28-25,000 years ago but the presence of well-preserved pieces of charcoal indicate at least two fires had occurred on the site causing subsequent slope erosion. "Given the wet environment of a beech forest, the occurrence of natural fires would be very unlikely ... the fire is most readily explained by human burning activities" Haberle, Hope and De Fretes (1991).

Is there nevertheless a possibility that the burnings documented by Hope and Haberle were natural events and not small-scale human clearances? In moist rainforest, particularly at high altitudes where mist and cloud are persistent and vegetation constantly damp, fires are a rare event. Can we say for certain that such conditions existed in the past? Walker and Chen (1987:82) agree with other researchers that the climate in the highlands during the late Pleistocene was more arid than today, but there is palynological data to show that the species growing in the moss forest today were present in the high altitudes 30,000 years ago and it is unlikely that the undergrowth would have been sufficiently dry to burn easily at any time. Experiments in the areas of the eastern Amazon forest showed that "sustained combustion was not possible in the primary forest even after prolonged rainless periods (more than 30 days)" (Uhf and Hauffman 1990:437, 446), although the forest burned far more readily once disturbed by human activity and the forest edge was more vulnerable to fire.

If human beings were indeed firing small areas of the highlands landscape some 30,000 years ago, what was their objective? Hope, in a discussion about the open vegetation communities of the highlands, writes that he suspects that "even pre-agricultural societies widened natural clearings with fire and perhaps by felling without clear economic incentive" (Hope 1980b: 161). This may be true, but even if the clearance were carried out without strong motivation, the results would have been beneficial to those who had cleared the area. Clearance provides areas of young growth which rapidly attracts grazing animals, such as the macropods, in particular the *Thylogale* species. Small clearings may have provided a more comfortable living area in the forest for temporary settlement in the absence of rockshelters or caves. The clearing increases light and thereby increases the production of some subcanopy species of plants. "Natural clearings created by tree falls are the starting point of regeneration cycles: pioneer species appear rapidly, seedlings and saplings previously stunted by shade growing again and new seeds are deposited by birds and animals" (Bourliere 1983:83). Bailey *et al.* (1989), using a range of African and other data, suggest that early human hunter-gatherers may have utilised the edge of the tropical rainforest rather than the interior forest where high canopy trees inhibit production of many plants suitable for human consumption. Although the New Guinea rainforest data were not included in their discussion, I believe their conclusions hold equally for similar environments in New Guinea.

It is likely that 'persistent cloudiness and mist' (Hope ,G 1983b:40) was typical of the altitudes between 1500 and 2100 m during the late Pleistocene and the pollen diagrams for Kosipe, Telefomin and Supulah, lying within those altitudes, show evidence of Nothofagus forest. Golson (in press) argues that in these conditions the high-altitude nut *Pandanus* would have been the only plant resources of consequence; for example, *Pandanus brosimos* and perhaps the tough-shelled and now little known *P. antarensis* which is found in abundance in the lower levels of Manim rockshelter at the very beginning of the Holocene. He goes on to suggest that the existence of high-altitude firing could be associated with *Pandanus* exploitation and promotion. If fire was being used for plant and animal management in the high-altitude *Nothofagus* forests, as suggested here, it is reasonable to presume that the same practice was part of subsistence strategies in the more resource-rich forests of middle and lower altitudes. As Headland (1987) discusses for lowland rain forest, carbohydrate foods such as tubers and even fruit and nut species tend to thrive at the forest edge and in more open areas of disturbed forest rather than in the interior of high-canopied rainforest. Wild yams *(Dioscorea* spp.) and the now rare New Guinea *Pueraria lobata* tuber in particular are found in similar situations in New Guinea. The creation of small zones of clearance in the forest would encourage these plants and allow humans to benefit from the clearance in future visits (Mountain l991b).

In a stimulating article, Groube (1989) discusses a theory of forest exploitation and management that developed from the recovery of a series of very large but blunt and waisted stone artefacts on the coastal terraces of the Huon Peninsula, where some were sealed by tephra dated to more than 40,000 bp. He suggests that such artefacts, which presumably were hafted, may have been used for ring-barking large rainforest trees and for a range of functions in the general clearance of undergrowth around plants of especial value to the early communities. Groube's thesis helps explain the large altitudinal spread of waisted axes, where the factor common to the sites where they occur is the existence of forest.

Waisted artefacts have been recorded from Kosipe (White *et al.* 1970), Kiowa and Yuku (Bulmer 1982), Kuk (Golson pers. comm.) and Nombe where one complete artefact and one tang were found, both in Stratum D1/5. A well-used edge-ground axe was also recovered from Stratum D 1/5 at Nombe. The striations can be clearly seen on the edge in Plate 6. None of the waisted artefacts from the highlands match the massive weight of the Huon examples, but they still could have been used in forest plant management and to ring-bark trees too large to fell. The use of ring-barking would imply that people were managing their environment with positive foresight and not merely using opportunistic strategies for day-to-day survival.

Such sophisticated strategies are surely consistent with people who were capable of making sea-crossings more than 200 km out of sight of land to arrive at Manus Island during the late Pleistocene (Ambrose, Frederickson and Spriggs pers. comm.). The range of sea-crossings now documented within northern Sahulland suggests that the Pleistocene hunter-gathers of the region were competent and consistent coastal voyagers. They could equally well have learnt to manage and manipulate food resources of the tropical rainforest in their new environments.

In the extreme environments of highland New Guinea with which we are concerned, the evidence suggests that high-altitude hunting and gathering would have procured rich oily nuts from the *Pandanus* and fat from the large forest-edge animals. There would also have been valuable supplies of other desirable materials, such as large bone, gut and pelts.

10.3 ISSUE 2: EXTINCTIONS

The presence of four large herbivorous species in the Nombe D strata provides the only Pleistocene site in New Guinea where there is an association between humans and these extinct fauna. Although it has not been possible so far to isolate the bone definitely predated by humans, the analysis of the faunal material has provided some ideas about that relationship. It is clear that there was a long period of coexistence between the extinct species and humans, from about 25,000-24,000 bp, when people first occupied Nombe to about 15,000-14,000 bp when the extinct fauna has vanished from the Nombe record. This was certainly not the rapid overkill suggested by Martin (1967).

The evidence from Nombe suggests that kills of large animals were rare: only a handful of individuals from four species in a deposit that spans 10,000 years. It would certainly be interesting to examine this bone in further detail for any signs of human predation. The species presumably found it difficult to adapt to the environmental changes of the late Pleistocene and hunting by humans and thylacines may have exterminated the last of them.

10.4 ISSUE 3: EARLY HOLOCENE ADAPTATIONS AND THE TRANSITION TO HORTICULTURE

Hope (1983b) describes the changed environmental conditions at the end of the Pleistocene and into the early Holocene period as involving the freeing of the montane valleys and slopes above 1500 m from persistent cloud cover which allowed the mixed oak forest to spread to higher altitudes in warmer conditions.

The food resources of these forests are known to be considerable and varied. There are many food plants, including the products of tree species such as *Castanopsis, Eleocarpus, Sterculia* and *Pandanus,* as well as edible greens, leaves, fungi and wild tubers (Powell 1976). There is also a wide variety of small and medium mammals that are hunted still by many communities (Dwyer 1990; Majnep and Bulmer 1990). The abundance of small mammals in tropical rainforest is high, both in species diversity and probably in the number of individuals present (Fleming 1975:297). The species diversity for these mammals is higher in tropical forests than in the tropical grasslands. "Relative abundance is inequitably distributed among species: one to three species are usually dominant" (Fleming 1975:298).

Terminal Pleistocene predation at Nombe in Stratum C clearly concentrates on bats, probably through targeting roosting colonies at neighbouring caves, and this is also the picture in the first occupation from Kiowa, only 4 km away. Occupation begins at Kafiavana at this period where, although the faunal data are very general (White 1972:92) it is clear that bats, macropods, *Phalanger* and *Zaglossus* were being predated. At other sites, other local species would have been targeted, such as local wallabies at Yuku. At Manim, local *Pandanus* was also exploited at this time (Christensen 1975).

Predation levels at Nombe rose dramatically in the early Holocene in Stratum B. The bone density (Table 7.12) of the Medium and Small species in Stratum B is more than double that of Stratum D1/5, although the density of the Large species is well below that for the earlier levels. All the evidence clearly shows that the early Holocene was the peak period of human activity at the site.

The claim for agriculture in the early Holocene (Golson and Hughes 1980) was made from evidence from the site of Kuk in the Western Highlands, to the west of the Elimbari massif. Since 1980 there has been increasing debate on the interpretation of the early Holocene evidence at Kuk and agriculture may be no earlier than 6000 bp (Golson 1989). Feil (1987) has suggested that agriculture is relatively recent in the Eastern Highlands of Papua New Guinea in comparison to the Western Highlands, through a bold and imaginative attempt to use the prehistoric record from the highlands to construct a model to explain the present social and cultural differences between the two areas. Ballard (1989) found this model selective and rather simplistic, although he applauded Feil's overall intentions. Golson and Gardner (1990) argue that the Eastern Highlands did not have an entirely different agricultural history from regions further west. The Nombe data clearly shows sporadic human visits during the Pleistocene in the Eastern Highlands and intense human activity and permanent occupation in the early Holocene. While this does not imply cultivation, there is strong evidence of increased human environmental modification.

There are a number of strong indications (section 10.2) that humans were modifying the environments in the upper regions of New Guinea forests during the late Pleistocene as a prelude to the introduction of more full scale forest clearance later in the Holocene (Mountain 1991b).

The pollen evidence shows that forest clearance (Powell 1982) was well under way by 5000 bp with increased quantities of secondary growth at the expense of primary forest species in several records from the Western Highlands and Simbu Provinces. Haberle, Hope and De Fretes (1991) show that in the Baliem Valley forest clearance dates back to before 7000 bp.

The suite of species found in Stratum B (10,000-4,500 bp) at Nombe includes many of the present day inhabitants of the mid-montane forest such as high numbers of *Phalanger carmelitae, Pseudocheirops cupreus* and P. *corinnae.* The site by this time, would have been surrounded by montane forest without any access to alpine and shrub-rich grasslands. Two species of Medium body-weight macropods occur in Stratum B, the forest wallaby, *Dorcopsulus vanheurni,* and the very adaptable *Thylogale brunii.* Since the forest wallaby lives on leaves and fallen fruit in the mid and upper montane forest it is not unexpected to find these bones in this Stratum. However, *Thylogale brunii is* well adapted to open grasslands and disturbed and open patches of forests (for example today it occurs in abandoned gardens and old landslip zones). The presence of almost as many *Thylogale* as *Dorcopsulus* in Stratum B appears to indicate that there may have been considerable areas of disturbance within the local forest environment and could be an indication that limited forest clearance was occurring in the Elimbari area during the early Holocene period. Pig is definitely present from the middle of the Stratum B deposits. Perhaps all this is an indication of shifting agriculture on limestone hill slopes combined with still high levels of hunting and collecting from the rich resources in the forests, which would not be heavily impacted. The subsistence economy thus suggested, a mix of shifting agriculture, forage-based pig domestication and forest exploitation, would be like that typical of some highland fringe communities today (Golson and Gardner 1990:406-7). The economy resembled that of the Etolo, whom Kelly (1987) describes as being at low population densities on a very adequate and varied diet. We can envisage small communities of this type replicated throughout the highlands in the early Holocene, different aspects of whose activities are archaeologically expressed in the higher numbers of rockshelters occupied from the end of the Pleistocene and the subsequent appearance of horticulture at the site of Kuk (Golson and Hughes 1980).

10.5 THE FUTURE

The research on the Pleistocene material from Nombe has successfully provided evidence of the relationship between early occupants and their environment. The faunal analysis, in particular, has proved a very sensitive indicator of human adaptation to environmental change in a way that was not possible from surviving cultural material.

There is still much that can be learnt from the Nombe data. Further analysis of the data from Stratum B and Stratum A would contribute further to the developing understanding of the intimate two-way relationship between humans and their highland environment. The relation between humans, pigs, dogs and forest species changed rapidly in the last 5000 years and the data could be compared to the faunal analysis by Aplin at Kamapuk (Aplin 1981).

Further analysis of the Stratum D1/5 could elucidate the problem, still unsolved at present, of which bone represents the prey of thylacines and which results from human hunting. Attention to more detailed analysis of bone from particular species, such as *Zaglossus bruijni* could provide interesting data on the age and size range of the animals.

Analysis of the stone artefacts could now be profitable in light of what has been achieved through the bone. A study of snail shell could also help to reveal environmental change. More refined techniques like these would add important detail to the evidence and conclusions presented in previous chapters.

Human groups proved able to incorporate the cold higher altitudes of the late Pleistocene New Guinea into their subsistence systems. With the climatic change at the end of the Pleistocene they were able to make the highlands an area of denser and more permanent settlement. Humans emerged the winners in their 30,000 year relationship with the highland environment. Whether they survive a further 30,000 years depends on how these people manage the relationship between themselves and their present and future environment.

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Appendix 1

Radiocarbon age determinations of Nombe samples.

Radiocarbon Dating Research Laboratory, Australian National University

ANU Lab No	Age	d^{14}C $^{0}/_{00}$	δ^{13}C $^{0}/_{00}$	D^{14}C $^{0}/_{00}$
2562	6 360± 210	-531± 12.0	-7.9± 0.4	-547± 11.6
2563	16 500± 280	-868.4± 4.4	-12.9± 0.4	-871.6± 4.3
2564	26 000± 1 050	-959.6± 4.7	-8.6± 0.4	-960.9± 4.5
2565	29 600± 500	-974.1± 1.5	-11.1± 0.4	-974.8± 1.4
2566	32 100± 950	-981.1± 2.1	-11.6± 2.0	-981.6± 2.0
2568	30 600± 550	-977.4± 1.4	-12.3± 0.4	-978± 1.3
2569	11 400± 190	-758.3± 5.5	-24± 2.0	-758.8± 5.6
2570	3 420± 310	-345.2± 24.1	-24± 2.0	-346.5± 24.2
2571	98.6± 0.8	-11.8± 6.3	-24± 2.0	-13.8± 7.5
2573	103.4± 1.3	36.1± 12.0	-24± 2.0	34± 12.6
2574	490± 70	-57.5± 6.3	-24± 2.0	-59.4± 7.3
2575	1 990± 90	-217.5± 7.3	-24± 2.0	-219.1± 8.0
2576	10 250± 250	-711± 3.6	-8.9± 0.4	-720.3± 3.5
2578	27 000± 550	-963.6± 2.3	-3.1± 0.4	-965.2± 2.2
2579	10 250± 100	-710.9± 3.5	-8± 0.4	-720.7± 3.4
2580	16 700± 180	-868.3± 2.8	0.1± 0.4	-874.9± 2.7
2581	13 900± 130	-812.9± 3.0	1.3± 2.8	-822.7± 2.8
3073	100.4± 0.9	5.7± 8.0	-24± 2.0	3.7± 9.0
3074	5 810± 180	-500.9± 11.1	-11.1± 0.4	-514.8± 10.8
3074B	5 030± 110	-463.4± 7.1	-23.2± 0.4	-465.3± 7.1
3075	6 410± 60	-546.7± 3.4	-21.8± 0.4	-549.6± 3.4
3075B	5 900± 110	-506.5± 6.5	-11.1± 0.4	-520.2± 6.3
3076A	5 870± 110	-504.9± 6.7	-11.4± 0.4	-518.4± 6.5
3329	10 7.9± 0.5	119± 5.1	-7.1± 0.4	78.9± 5
3681	11 650± 160	-758.9± 4.7	-11.3± 0.4	-765.5± 4.6
3682	27 600± 900	-9 666.7± 3.5	-11.2± 0.4	-967.6± 3.4
3683	6 210± 730	-537.3± 40.5	-24± 0.4	-538.2± 40.4
3683	13 150± 500	-800.1± 12.1	-10.3± 0.4	-806± 11.7
3684	3 220± 280	-315.2± 23.5	-14.2± 0.4	-330± 23.0
3684	5 340± 120	-484.2± 7.2	-23.4± 0.4	-485.8± 7.2
3685	510± 150	-63.9± 16.9	-26.2± 0.4	-61.6± 16.9
3685	900± 80	-96.7± 8.2	-20.1± 0.4	-105.5± 8.1
3686	9 000± 200	-666.5± 8.3	-14± 0.4	-673.8± 8.1
3686	9 560± 280	-698.5± 10.4	-23.8± 0.4	-699.2± 10.4
3687	8 070± 350	-622.4± 15.9	-9.9± 0.4	-633.8± 15.4
3687	8 320± 840	-644.1± 35.2	-23.5± 2.0	-645.1± 35.1
3688	5 880± 210	-509.3± 12.8	-14.8± 0.4	-519.3± 12.5
3688	6 740± 120	-566.3± 6.2	-23.4± 0.4	-567.7± 6.2
3689	5 090± 220	-467.8± 14.1	-23.5± 0.4	-469.4± 14.0
3689	3 250± 220	-315.9± 18.0	-12.5± 0.4	-333± 17.5

Appendix 2

Computing and Analysis

by Barry Shaw

Notes

1. This appendix should be read in conjunction with Chapter 7, Faunal Analysis.
2. Several tables are repeated in this appendix from the body of the thesis to provide a more complete discussion of the computing and data methods used. The text in the Chapters in which these tables appear usually give more background information than is given here

Introduction

Dr Barry Shaw was computing adviser and designer of the database systems and programs as assistant to Mary-Jane Mountain. He was also on site during the entire excavation in 1979-80 and therefore had a very detailed understanding of the site, the data and its problems. Any necessary computer programs and procedures were written by Barry Shaw, data entry and analysis was done by Mary-Jane Mountain.

Computers, Archaeology and the Nombe data

The excavations at Nombe were undertaken at a time when techniques for the management and analysis of large amounts of data were only just being developed. For the 1971 and 1974/75 excavations, data recording focused on data identification and labelling systems to facilitate manual analysis since computerisation was unlikely. However, by the 1979-80 fieldwork season archaeologists had begun using computers to manage and analyse their data. There was therefore an expectation that a PhD student would use a computer as a tool to facilitate simple and efficient management and to generate more effective analysis of the Nombe data which would in turn increase the data's power to support the hypotheses of the thesis.

However, it did not prove to be simple. Archaeological and faunal computer data management and analysis techniques at that time proved so rudimentary for such a large body of data (in spite of the claims of their authors) that the development of a suitable computerised data management and analysis system for the Nombe data took several years.

Existing methodology in Archaeological Computing

The focus of computing for Australian archaeological and faunal analysis has been on the analysis of moderate amounts data on a small number of artefacts or faunal material. Very few sites have produced a similar volume of faunal material as Nombe and there was therefore little Australian experience on which to build for the computerisation of the Nombe material. Archaeologists generally used SPSS (Statistical Package for the Social Sciences) for their analysis, which at that time focused on data analysis rather than management while zoologists wrote or commissioned specific programs for each faunal analysis.

As a result, the Australian experience proved generally irrelevant to the computerisation of the Nombe data in two ways. First, there was very little experience in the management of such large volumes of archaeological/faunal data; and second, there was little or no use of the archaeological unit as the primary focus of analysis.

The normal Australian analytical focus was on each artefact or bone and their attributes. However for Nombe, with 24,395 faunal items originating from 357 excavation units, (each with 30 archaeological attributes) the focus had to be on the occurrence of fauna within each unit rather than the analysis of the faunal items themselves. Thus it is the excavation unit rather than the faunal item or archaeological artefact that had to be central to the analysis.

As a result, it was necessary to develop for Nombe two computational systems:

1. an excavation unit-based data entry, management and editing system capable of efficiently managing such a large amount of faunal and archaeological material; and
2. computational procedures and programs to analyse faunal and archaeological data within excavation units rather than analyse the faunal and archaeological items themselves.

With hindsight, it may have been fruitful to investigate the methods used for data management in excavations in other countries which produced large amounts of faunal or archaeological material.

These problems did not become evident until many existing programs and techniques had been evaluated.

In the early 1980s several archaeologists who had developed computer programs for management and analysis of data sensed the increasing importance of computer analysis for archaeology, and expanded these limited programs in the expectation that they could be used for a very broad range of archaeological data. Several of these programs were evaluated and, in spite of the sincere belief of their authors that they were suitable, none came remotely close to a capacity to manage or analyse the Nombe data. Considerable time was unnecessarily consumed in these evaluations.

The most common problem was that programs had been developed originally to meed the needs of a specific site or set of data. As a result, they made implicit assumptions about the data which were often not even evident to their authors. Further problems included:

- Most programs were limited to 32 or 64 variables;
- None were sufficiently robust and error-free to be reliable;
- The types of analysis available within each program were very limited.
- All programs were extremely slow to run and would have severely limited the amount of analysis.

Another difficulty was the very large Nombe dataset. There were 357 excavated units and about 100 identified faunal types, each with about 50 attributes. The final database comprises one faunal table of 3635 faunal items each with 50 faunal attributes related to 357 excavation units, each with 30 archaeological attributes. A "faunal item" is the occurrence of one species in a particular unit; this may include several body parts of that species within that archaeological unit. The total number of identified body parts within these "faunal items" was 24,395: a very large and complex archaeological-faunal database by any standards.

The data entry and management of such a large body of data was a problem in itself. Slow response times of the DEC-10 computer of the ANU Research School of Pacific Studies meant that direct entry or editing of such a large amount of data was impossible. In addidition, many of the Nombe species were being reclassified and many bones were being re-identified as the faunal assemblage was examined by various faunal experts. This continual updating and data management was almost impossible on the DEC-10 computer.

Further, the hierarchical database available at that time on the DEC10 computer could not accommodate the number of variables nor the amount of missing cells in the Linnean classifications.

Discussions with archaeologists with experience in computing (such as Ian Johnson, author of MINARC, an archaeological database and analysis program) and fauna specialists revealed a number of different possible techniques and several were very helpful and not only supplied details of their approaches but also supplied computer program code for possible modification: we thank them for their assistance. Further discussions with zoologists working on faunal analysis showed that their focus on hierarchical analysis based on ever-decreasing data subsets: class, order, family, genus and species was most appropriate but they too had not had experience with such large datasets.

During this period of searching for computer solutions, a microcomputer was purchased and the data entered on a dedicated data entry and management program, PFS. This proved fast and flexible but required data to be later merged into a larger dataset since it was limited to 64 variables.

Changes in excavation unit size through wet sieving.

In 1979 wet sieving was used through a very fine mesh. These archaeological units were much smaller and the amount of recorded material from each unit much greater. This required backward linkages to earlier non-wet sieved units to provide comparable analytical units. This further complicated the computerisation and analysis, requiring separate, but linked, databases for wet sieved and non-wet sieved units. With the availability of improved database programs the wet sieved and non-wet sieved datasets were merged.

Data identification, entry and analysis

Data for each bone was entered onto an A4 analysis sheet which also included links to the archaeological data, then entered into a microcomputer using a dedicated data entry and editing program (PFS). Programs for preliminary analysis were written in NPL, a database management language which had no relational capabilities and therefore made analysis slow and cumbersome. Data often had to be processed overnight and analysis had to use data subsets because programs could not handle the large number of fields in the merged data. dBase II then became available, with good relational capabilities, and was used to interrogate and manage the data. Even so, the large Nombe database had to be split into several subsets.

Improvements in microcomputer speed and memory, and in dBase as a program, enabled considerable improvements in data analysis. Specific program modules were then written for major searches and data interrogation, creating cross-tabulated summary data, calculating minimum numbers and other tasks. Mary-Jane Mountain was proficient at data searches and analysis using the dBase language.

As the analysis progressed, more powerful microcomputers and programs became available. The data is now on an IBM compatible Pentium Pro computer using FoxPro 2.6 for analysis and management. Analysis requiring overnight processing in 1983 can now be done in a few seconds.

DIFFERENCES BETWEEN THE ARCHAEOLOGICAL AND FAUNAL DATABASES

The hierarchical nature of the faunal data

Since zoological (faunal) classifications are based on a hierarchical Linnean tree, this led us to investigate the use of a hierarchical database, as commonly used by zoologists. The hierarchical database programs available at that time this would have been satisfactory provided only zoological data was included. But much of the data on the fauna, necessary for the taphonomic analysis, and the archaeological data, did not fit this structure.

For example, many bird bones could be only be identified as far as Class aves, yet body size was taphonomically important, and such bones were classified into medium and small birds, which enabled taphonomic analysis of hunting or predation strategies and patterns. In addition, it was important to be able to associate the archaeological data (including the stratigraphical data) with the occurrence of a particular species.

Taphonomic classification and database coding system

The mixed faunal and taphonomic requirements of the data were resolved by including a classification of *family* size (coded as SFAM, see following table), to enable the division of animals on the basis on adult body size and family grouping. This created an operational variable for each bone linked the same sized members of different families for use in taphonomic analysis of hunting/predation strategies.

The database enables analysis at any level from species through to class as well as providing a variable by which flexible grouping of similar sized animals could be grouped. The codes used are set out in Table A1.

A further problem was that the faunal taxonomy was changing as new faunal research results became available. Early in the research the difficulty of remaining up to date with changing taxonomy became a major, and time consuming, problem. There was even a danger that keeping the database up to date could consume all available research time given the 25,000 identified bones in the data. It was therefore necessary to design the database so that global changes to the taxonomic data on each bone could be made on an ongoing basis. Further, many bones identified only to one level by Mary-Jane Mountain, were later identified in more detail through advice from another researcher. In addition, many classifications were split into different Linnean groupings.

The classification in Table A3 was used to classify each identifiable body part of an animal. A numeric code for each classification was used to enable global changes in the common event of changed taxonomic classifications but is not included here.

Most faunal analysis by archaeologists includes a great deal of additional data on each bone such as breakage, extent of burning, fracture patterns, size etc. However, with 25,000 identified bones from 44 possible body parts originating in 357 excavation units and covering over 80 taxonomic classifications, the work involved would be far beyond this thesis. The faunal data was therefore simplified to the number of occurrences of each body part of each taxonomic classification in each unit. The resultant faunal database comprises 55 fields x 2636 records. To ease analysis, an additional six fields were duplicated from the archaeological database. (In any further work on the database, one of these sets of duplicated fields should be removed and the faunal and archaeological databases linked through the amalgamation number.)

Coding systems

The detailed codes used are set out in the tables in the following pages. Only a summary is given here.

Each excavation unit was given a unique number, (amalgamation number) to identify and link the faunal and archaeological databases.

The hierarchical taxa classification coding system is based on a set of alpha codes to provide easier visual identification of the codes than would be possible with numeric codes. An example from one species:

Class	MAMM	Mammalia
Order	DIPR	Diprotodontia
Family	MACR	Macropodidae
Genus	PROT.SP	Protemnodon
Species	PROT.NO	Protemnodon nombe

In excavation unit 516 two bones of this species were found: a left mandible with teeth (code MNTL) and one loose tooth (TTH).

Summary of procedures

Each excavation unit produced several items of faunal material: bones, snail shell, eggshell, carapaces etc. These were identified and coded according to:

1. taxonomic classification (Table A1);
2. body size/weight of the animal (Table A2); and
3. body part (Table A3).

THE BASIC FEATURES OF THE NOMBE DATABASE

The following pages give examples of the database components and the linkages between them.

Table A.1 Taxa classification for Nombe: *The Taxonomic Database*

Computer codes						Full description
Class	**Order**	**Family**	**Family Size^a**	**Genus**	**Species**	**Class, Order, Family, Family Size, Genus, Species, (Body size category)** **(Common names for major categories)**
MAMM	PRIM	HOMO	--	HOMO.SP	HOMO.SA	MAMMALIA, PRIMATA, HOMINIDAE (Humans), *HOMO* SPECIES, *HOMO SAPIENS*
MAMM	ARTI	SUID	--	SUS.SPE		ARTIODACTYLA, SUIDAE (Pigs), *SUS* SPECIES
MAMM	CARN	CANI	--	CANI.SP		CARNIVORA, CANIDAE (Dogs), *CANIS* SPECIES
MAMM	MONO	TACH	--	ZAGL.SP	ZAGL.BR	MONOTREMATA, TACHYGLOSSIDAE (Echidnas), *ZAGLOSSUS* SPECIES, *ZAGLOSSUS BRUIJNI*
MAMM	DASY	THYL	--	THYL.SP	THYL.CY	DASYUROMORPHIA, THYLACINIDAE (Thylacines), *THYLACINUS CYNOCEPHALUS*
MAMM	DASY	DASY	DASL			DASYURIDAE, Large Dasyurids
MAMM	DASY	DASY	DASL	DASY.SP	DASY.AL	*DASYURUS* SPECIES, *DASYURUS ALBOPUNCTATUS*
MAMM	DASY	DASY	DASS			Small Dasyurids
MAMM	PERA	PERO	PERL			PERAMELEMORPHIA, PERORYCTIDAE, Large Bandicoots
MAMM	PERA	PERO	PERL	ECHY.SP	ECHY.KA	*ECHYMIPERA* SPECIES, *ECHYMIPERA KALUBU*
MAMM	PERA	PERO	PERL	ECHY.SP	ECHY.RU	*ECHYMIPERA RUFESCENS*
MAMM	PERA	PERO	PERL	PERO.SP	PERO.RA	*PERORYCTES* SPECIES, *PERORYCTES RAFFRAYANA*
MAMM	PERA	PERO	PERS			Small Bandicoots
MAMM	PERA	PERO	PERS	MICR.SP	MICR.LO	*MICROPERORYCTES* SPECIES, *MICROPERORYCTES LONGICAUDA*
MAMM	DIPR	DIPR				DIPROTODONTIA, DIPROTODONTIDAE (Diprotodons)
MAMM	DIPR	MACR	MACL	PROT.SP		MACROPODIDAE, Large macropods, *PROTEMNODON* SPECIES
MAMM	DIPR	MACR	MACL	PROT.SP	PROT.NO	*PROTEMNODON NOMBE*
MAMM	DIPR	MACR	MACL	PROT.SP	PROT.TU	*PROTEMNODON TUMBUNA*
MAMM	DIPR	MACR	MACL			Large macropods
MAMM	DIPR	MACR	MACL	DEND.SP		*DENDROLAGUS* SPECIES (tree kangaroos)
MAMM	DIPR	MACR	MACL	DEND.SP	DEND.NO	*DENDROLAGUS NOIBANO*
MAMM	DIPR	MACR	MACL	DEND.SP	DEND.DO	*DENDROLAGUS DORIANUS*
MAMM	DIPR	MACR	MACL	DEND.SP	DEND.GO	*DENDROLAGUS GOODFELLOWI*
MAMM	DIPR	MACR	MACM			Medium macropods
MAMM	DIPR	MACR	MACM	THYL.SP	THYL.BR	*THYLOGALE* SPECIES, *THYLOGALE BRUNII*
MAMM	DIPR	MACR	MACS			Small macropods
MAMM	DIPR	MACR	MACS	DORC.SP	DORC.VA	*DORCOPSULUS* SPECIES, *DORCOPSULUS VANHEURNI*

Note: a: For an explanation of family size see Section 7.3.2

table continues next page...

Table A.1 Taxa classification for Nombe: *The Taxonomic Database* (continued)

Computer codes						Full description
Class	Order	Family	Family Size[a]	Genus	Species	Class, Order, Family, Family Size, Genus, Species, (Body size category) (Common names for major categories)
MAMM	DIPR	PHAL	--	PHAL.SP		PHALANGERIDAE, *PHALANGER* SPECIES (Cuscuses)
MAMM	DIPR	PHAL	--	PHAL.SP	STRI.GY	*STRIGOCUSCUS GYMNOTIS*
MAMM	DIPR	PHAL	--	PHAL.SP	PHAL.CA	*PHALANGER CARMELITAE*
MAMM	DIPR	PHAL	--	PHAL.SP	PHAL.SE	*PHALANGER SERICEUS*
MAMM	DIPR	PSEU	POSL			PSEUDOCHEIRIDAE, Large Possums
MAMM	DIPR	PSEU	POSL	PSEP.SP	PSEP.CU	*PSEUDOCHEIROPS* SPECIES, *PSEUDOCHEIROPS CUPREUS*
MAMM	DIPR	PSEU	POSL	PSEP.SP	PSEP.CO	*PSEUDOCHEIROPS CORINNAE*
MAMM	DIPR	PSEU	POSM			Medium possums
MAMM	DIPR	PETA	POSM	DACT.SP	DACT.PA	PETAURIDAE, *DACTYLOPSILA* SPECIES, *DACTYLOPSILA PALPATOR*
MAMM	DIPR	PSEU	POSM	PSEU.SP	PSEU.FO	*PSEUDOCHEIRUS* SPECIES, *PSEUDOCHEIRUS FORBESI*
MAMM	DIPR	PSEU	POSS			Small possums
MAMM	DIPR	PETA	POSS	PETA.SP	PETA.BR	*PETAURUS* SPECIES, *PETAURUS BREVICEPS*
MAMM	DIPR	PSEU	POSS	PSEU.SP	PSEU.MA	*PSEUDOCHEIRUS* SPECIES, *PSEUDOCHEIRUS MAYERI*
MAMM	DIPR	ACRO	POSS	DIST.SP	DIST.PE	ACROBATIDAE, *DISTOECHURUS* SPECIES, *DISTOECHURUS PENNATUS*
MAMM	RODE	MURI	MURL			RODENTIA, MURIDAE Large murids
MAMM	RODE	MURI	MURL	HYOM.SP	HYOM.GO	*HYOMYS* SPECIES, *HYOMYS GOLIATH*
MAMM	RODE	MURI	MURL	MALL.SP	MALL.RO	*MALLOMYS* SPECIES, *MALLOMYS ROTHSCHILDI*
MAMM	RODE	MURI	MURM			Medium murids
MAMM	RODE	MURI	MURM	ANIS.SP	ANIS.IM	*ANISOMYS* SPECIES, *ANISOMYS IMITATOR*
MAMM	RODE	MURI	MURM	HYDR.SP		*HYDROMYS* SPECIES
MAMM	RODE	MURI	MURM	PARA.SP	PARA.AS	*PARAHYDROMYS* SPECIES, *PARAHYDROMYS ASPER*
MAMM	RODE	MURI	MURM	UROM.SP	UROM.AN	*UROMYS* SPECIES, *UROMYS ANAK*
MAMM	RODE	MURI	MURM	UROM.SP	UROM.CA	*UROMYS CAUDIMACULATUS*
MAMM	RODE	MURI	MURM	XENU.SP		*XENUROMYS* SPECIES
MAMM	RODE	MURI	MURS			Small murids
MAMM	RODE	MURI	MURS	MELO.SP	MELO.RU	*MELOMYS* SPECIES, *MELOMYS RUBEX*
MAMM	RODE	MURI	MURS	POGO.SP	POGO.SE	*POGONOMYS* SPECIES, *POGONOMYS SEVIA*
MAMM	CHIR	PTER	PTEL			CHIROPTERA, PTEROPODIDAE, Large fruit-eating bats
MAMM	CHIR	PTER	PTEL	-	DOBS.MO	*DOBSONIA* SPECIES, *DOBSONIA MOLUCCENSIS*
MAMM	CHIR	PTER	PTEL	PTER.SP		Large pteropodids
MAMM	CHIR	PTER	PTES	ROUS.SP		Small fruit-eating bats, *ROUSETTUS* SPECIES

Note: a: For an explanation of family size see Section 7.3.2

table continues next page...

Table A.1 Taxa classification for Nombe: The Taxonomic Database *(continued)*

Computer codes						Full description
Class	**Order**	**Family**	**Family Size**[a]	**Genus**	**Species**	**Class, Order, Family, Family Size, Genus, Species, (Body size category) (Common names for major categories)**
AVES	CASU	CASU	AVEL	CASU.SP	CASU.BE	Birds, CASUARIFIIFORMES, CASUARIIDAE (Cassowaries), Large birds, *CASUARIUS* SPECIES, *CASUARIUS BENNETTI*
AVES	--	--	AVEM			Medium birds
AVES	COLU	COLU	AVEM	LCOL.SP		COLUMBIFORMES, COLUMBIDAE, Medium Birds, Large pigeons & doves
AVES	COLU	COLU	AVEM	MCOL.SP		Medium pigeons & doves
AVES	COLU	COLU	AVES	SCOL.SP		Small pigeons & doves
AVES	FALC	ACCI	AVEL	HARP.SP	HARP.NO	FALCONIFORMES, ACCIPITRIDAE (Hawks & eagles), *HARPYOPSIS* SPECIES, *HARPYOPSIS NOVAEGUINAE*
AVES	GALL	MEGA	AVEM	MEGA.SP		GALLIFORMES, MEGAPODIIDAE (Megapodes), *MEGAPODIUS* SPECIES
AVES	GALL	MEGA	AVEM	MEGA.SP	AEPY.AR	*AEPYPODIUS ARFAKIANUS*
AVES	GALL	MEGA	AVEM	MEGA.SP	MEGA.FR	*MEGAPODIUS FREYCINET*
AVES	-	-	AVES			Small birds
AVES	GRUI	RALL	AVES	GALL.SP		GRUIFORMES, RALLIDAE (Rails), *GALLINULA* SPECIES
AVES	GRUI	RALL	AVES	GALL.SP	GALL.TE	*GALLINULA TENEBROS*
AVES	PASS	PASS	AVES	LPAS.SP		PASSERIFORMES (Perching birds), PASSERIDAE, Large perching birds
AVES	PASS	PASS	AVES	MPAS.SP		Medium perching birds
AVES	PASS	PASS	AVES	SPAS.SP		Small perching birds
AVES	PSIT	PSIT	AVES			PSITTACIFORMES, PSITTACIDAE (Parrots)
AVES	STRI	STRI	AVEM	NINO.SP		STRIGIFORMES, STRIGIDAE (Typical owls), *NINOX* SPECIES
AVES	STRI	TYTO	AVEM	TYTO.SP	TYTO.AL	TYTONIDAE (Barn Owls), *TYTO* SPECIES, *TYTO ALBA*
AVES	STRI	TYTO	AVEM	TYTO.SP	TYTO.TE	*TYTO TENEBRICOSA*
REPT						REPTILIA
REPT	TEST	CHEL				TESTUDINES, CHELIDAE(Turtles)
REPT	SQUA	LACE				SQUAMATA, LACERTILIA(Lizards)
REPT	SQUA	SCIN				SCINCIDA (Skinks)
REPT	SQUA	SERP				SERPENTIA (Snakes)
AMPH	ANUR					AMPHIBIA, ANURA (frogs)

Note: a: For an explanation of family size see Section 7.3.2

Each species or group was classified according to adult body weight to provide data on hunting and predation strategies. The following table sets out the codes for each family. The first digit of each code is a body weight category, the second and third digits are species group identifiers within each body weight category.

Table A.2 Classification of species present in the Nombe data by body size

Taxa and family size abbreviation [a]	
Large body weight (over 5 kg adult body weight)	
Homo sapiens	101
Thylacinus cynocephalus	106
Canis species	107
Diprotodontidae	102
Protemnodon species	103
Dendrolagus species	104
Large macropods (MACL)	104
Zaglossus bruijni	105
Sus species	108
Casuarius bennetti	109
Medium body weight (c. 1 - 5 kg adult body weight)	
Harpyosis novaeguineae	206
Medium macropods (MACM)	201
Small macropods (MACS)	202
Phalangeridae (PHAL.SP)	203
Pseudocheiridae (POSL)	204
Large murids (MURL)	205
Snakes	207
Small body weight (c.300 g - 1 kg adult body weight)	
Dasyurus albopunctatus (DASL)	303
Owls (STRI)	308
Medium possums (POSM)	301
Large bandicoots (PERL)	302
Medium murids (MURM)	305
Large fruit bats (PTEL)	306
Medium birds (AVEM)	309
Turtle	310
Very small body weight (less than 300g adult body weight)	
Small dasyurids (DASS)	402
Small bandicoots (PERS)	404
Small possums (POSS)	401
Small murids (MURS)	403
Small fruit bats (PTES)	407
Small birds (AVES)	405
Lizards	406
Skinks	409
Frogs	408

Note: [a] For explanation of family size abbreviations see Table 7.2

Each bone was classified according to body part code and its occurrence entered according to its amalgamation number.

Table A.3 List of body parts and codes.

Cranial parts	Code	Postcranial parts	Code
Cranium	CRA	Vertebrae	VERT
Braincase (fragments)	BC	Atlas	ATL
Premaxilla right	PXL	Axis	AXI
Premaxilla left	PXR	Rib	RIB
Premaxilla right+teeth	PXTL	Scapulae	SCP
Premaxilla left+teeth	PXTR	Clavicle	CLV
Maxilla right	MXL	Coracoid	COR
Maxilla left	MXR	Pelvis	PEL
Maxilla right+teeth	MXTL	Long bone[a]	LBN
Maxilla left+teeth	MXTR	Humerus left	HML
Mandible right	MNL	Humerus right	HMR
Mandible left	MNR	Radius left	RDL
Mandible right+teeth	MNTL	Radius right	RDR
Mandible left+teeth	MNTR	Ulna left	ULL
Teeth	TTH	Ulna right	ULR
		Femur left	FML
		Femur right	FMR
		Tibia left	TBL
		Tibia right	TBR
		Fibula left	FBL
		Fibula right	FBR
		Tibiotarsus left	TBTL
		Tibiotarsus right	TBTR
		Tibiometatarsus left	TMTL
		Tibiometatarsus right	TMTR
		Podial	PD
		Phalanges	PHA
		Claw	CLW
		Carapace	CRP

***Notes*:** Codes adapted from Gifford and Crader (1977)

[a]: Fragment of long bone which cannot be identified further.

Source: Table 7.3

Additional data for each taxa:

CRBO	Weight of cranial bone of each taxa present in the unit.
PCBO	Weight of post-cranial bone of each taxa present in the unit.
MIN	Minimum numbers of each taxa present in the unit.

An example of the first 55 records of the faunal database is given in the following table.

Table A.4 Example of Faunal Database: *the first 55 records of the database.*

AM	SREC	ST	P	CHR	AREA	W	CL	ORD	FAM	SFAM	GEN	SPEC	SIZ	CRBO	PCBO	CRA	BC	PXL	PXR	PXTL	PXTR	MXL	MXR	MXTL	MXTR	MNL	MNR	MNTL	MNTR	TTH	VERT	ATL	AXI	RIB	SCP	CLV	COR	PEL	LBN	HML	HMR	RDL	RDR	ULL	ULR	FML	FMR	TBL	TBR	FBL	FBR	TBTL	TBTR	TMTL	TMTR	PD	PHA	CLW	CRP	MIN
1	1	A1	T	1	AB71	O	MAMM	DIPR	MACR	MACM			201		23.5																1				1			3		2								1									5			2
1	2	A1	T	1	AB71	O	MAMM	DIPR	MACR	MACM	THYG.SP	THYG.BR	201	8.6										1	1			3	1	4																														3
1	3	A1	T	1	AB71	O	MAMM	DIPR	MACR	MACS			202		4.1																									1																	6			1
1	4	A1	T	1	AB71	O	MAMM	DIPR	MACR	MACS	DORC.SP	DORC.VA	202	1.4														1	1																															1
1	5	A1	T	1	AB71	O	MAMM	DIPR	PHAL	-	PHAL.SP		203	2.4	13.0								1	1					1		1								1		2	1		1	2	1				3											3
1	6	A1	T	1	AB71	O	MAMM	DIPR	PHAL	-	PHAL.SP	PHAL.CA	203	6.5														1	1	1																													1
1	7	A1	T	1	AB71	O	MAMM	DIPR	PSEU	POSM			301		1.8																									1	1		1	1	1															1
1	8	A1	T	1	AB71	O	MAMM	DIPR	PSEU	POSM	PSEU.SP	PSEU.FO	301	0.7														2																															2
1	9	A1	T	1	AB71	O	MAMM	PERA	PERO	PERS	MICR.SP	MICR.LO	302	0.4															1																														1
1	10	A1	T	1	AB71	O	MAMM	RODE	MURI	MURL			205	0.4																1																													1
1	11	A1	T	1	AB71	O	MAMM	RODE	MURI	MURM			305		0.4																																	1												1
1	12	A1	T	1	AB71	O	MAMM	RODE	MURI	MURM	ANIS.SP	ANIS.IM	305	0.5								1								1																													1
1	13	A1	T	1	AB71	O	MAMM	CHIR	PTER	PTEL	-	DOBS.MO	306	0.8									1			1																																	1
1	14	A1	T	1	AB71	O	MAMM	ARTI	SUID	-	SUS.SPE		108	8.7																3																													1
1	15	A1	T	1	AB71	O	REPT	SQUA	SERP				206		5.8																5																												1
1	16	A1	T	1	AB71	O	AVES	CASU	CASU	AVEL	CASU.SP	CASU.BE	109		10.2																						1																				1		1
2	1	A1	T	1	AB71	O	MAMM	DIPR	MACR	MACM			201		12.5																3							1																			6			1
2	2	A1	T	1	AB71	O	MAMM	DIPR	MACR	MACM	THYG.SP	THYG.BR	201	3.9												1	2			1																													2
2	3	A1	T	1	AB71	O	MAMM	DIPR	MACR	MACS			202		3.4																																										7			1
2	4	A1	T	1	AB71	O	MAMM	DIPR	PHAL	-	PHAL.SP		203	11.3	21.2										1	2	2		2	2								2		4	2			1	1	2	1	1	1											4
2	5	A1	T	1	AB71	O	MAMM	DIPR	PHAL	-	PHAL.SP	PHAL.CA	203	2.3														1																																1
2	6	A1	T	1	AB71	O	MAMM	DIPR	PSEU	POSM			301		3.0																							1		1	1			1	1				2											2
2	7	A1	T	1	AB71	O	MAMM	DIPR	PSEU	POSL	PSEP.SP	PSEP.CO	204	2.1											1			1	1	2																														1
2	8	A1	T	1	AB71	O	MAMM	RODE	MURI	MURM			305	0.4	0.2															3								1																						1
2	9	A1	T	1	AB71	O	MAMM	ARTI	SUID	-	SUS.SPE		108	1.1																1																													1
2	10	A1	T	1	AB71	O	REPT	SQUA	SERP				206		3.5																3																												1
3	1	A1	B	1	AB71	O	MAMM	DIPR	MACR	MACM			201		11.5																1							1					1														8			1
3	2	A1	B	1	AB71	O	MAMM	DIPR	MACR	MACM	THYG.SP	THYG.BR	201	2.1								1				1																																	1
3	3	A1	B	1	AB71	O	MAMM	DIPR	MACR	MACS			202		1.7																																									4			1
3	4	A1	B	1	AB71	O	MAMM	DIPR	MACR	MACS	DORC.SP	DORC.VA	202	0.7											1																																		1
3	5	A1	B	1	AB71	O	MAMM	DIPR	PHAL	-	PHAL.SP		203	5.5	21.6								1			2	1			2	2										4	1		2	2	2	2	1													4
3	6	A1	B	1	AB71	O	MAMM	DIPR	PSEU	POSM			301		3.0																									1	1			2	1			1	1		2										2
3	7	A1	T	1	AB71	O	MAMM	DIPR	PSEU	POSM	PSEU.SP	PSEU.FO	301	1.8														1	1																														1
3	8	A1	B	1	AB71	O	MAMM	DIPR	PETA	POSM	DACT.SP	DACT.PA	301	0.7															1	1																													1
3	9	A1	B	1	AB71	O	MAMM	RODE	MURI	MURL			205	1.6												1			2																														1
3	10	A1	B	1	AB71	O	AVES	CASU	CASU	AVEL	CASU.SP	CASU.BE	109		1.6																																										1		1
4	1	A1	B	1	AB71	O	MAMM	DIPR	MACR	MACM			201		4.9																									1																	3			1
4	2	A1	B	1	AB71	O	MAMM	DIPR	MACR	MACS			202		1.7																																									5			1
4	3	A1	B	1	AB71	O	MAMM	DIPR	MACR	MACS	DORC.SP	DORC.VA	202	1.5														1	1																														1
4	4	A1	B	1	AB71	O	MAMM	DIPR	PHAL	-	PHAL.SP		203	6.6	12.6											2	2											1		2	2			2	1	1		1	1		1									2
4	5	A1	B	1	AB71	O	MAMM	DIPR	PSEU	POSM			301		2.1																									4	3																			4
4	6	A1	B	1	AB71	O	MAMM	DIPR	PSEU	POSL	PSEP.SP	PSEP.CO	204	0.8														1																															1
4	7	A1	B	1	AB71	O	MAMM	DIPR	PSEU	POSM	PSEU.SP	PSEU.FO	301	2.3												2	1																															2
4	8	A1	B	1	AB71	O	MAMM	DIPR	PETA	POSM	DACT.SP	DACT.PA	301	0.7												1																																1
4	9	A1	B	1	AB71	O	MAMM	RODE	MURI	MURL			205		0.6																																	1												1
4	10	A1	B	1	AB71	O	MAMM	RODE	MURI	MURL	MALL.SP	MALL.RO	205	1.5										1	1																																		1
4	11	A1	B	1	AB71	O	MAMM	RODE	MURI	MURM			305	2.1											2																																		2
4	12	A1	B	1	AB71	O	MAMM	CHIR	PTER	PTEL			306		0.2																																									1			1
10	1	A1	T	1	AB71	O	MAMM	DIPR	MACR	MACL	DEND.SP		104		35.1																6											1					1										2	8			1
10	2	A1	T	1	AB71	O	MAMM	DIPR	MACR	MACM			201		22.7																5							2			1					1			1	1							3	3	1		1
10	3	A1	T	1	AB71	O	MAMM	DIPR	MACR	MACM	THYG.SP	THYG.BR	201	15.1								5				1	1			2																														5
10	4	A1	T	1	AB71	O	MAMM	DIPR	PHAL	-	PHAL.SP		203	15.4	73.2							2	2			3	2			6	2			7				4		5	4	3	2	6	2	4	5	1	1	4										6
10	5	A1	T	1	AB71	O	MAMM	DIPR	PHAL	-	PHAL.SP	PHAL.CA	203	3.0									1						1																															1
10	6	A1	T	1	AB71	O	MAMM	CHIR	PTER	PTEL			306		7.5																									3	3	1		1			2														3
10	7	A1	T	1	AB71	O	MAMM	DIPR	PSEU	POSL	PSEP.SP	PSEP.CU	204	15.5								1	2					3	3	3																														3

THE ARCHAEOLOGICAL DATABASE

The information extracted for each excavated unit and included in the computer database is set out in the following table. There are 357 units in the archaeological database.

Table A.5: Structure of Archaeological Database

Field No & Name	Description	Units
1 AMNO	Amalgamation number	
2 STCOD	Stratum code	
3 SQ	Square	
4 SBSQ	Sub square	
5 MIX	Mixed or unmixed unit	
6 ST	Stratum	
7 SPBU	Spit or bucket number	No
8 BAG	Bag number	No
9 POS	Position within the stratum	
10 DATE	Date of excavation	
11 AREA	Area name (several squares amalgamated together)	
12 TEP	Whether unit contained tephra or not	
13 VOL	Volume of sediment in unit	Litres
14 BONE	Quantity of bone in the sediment	gm
15 BNTPC	Proportion of Postcranial bone that was classified as "burnt"	
16 FRAGS	Number of fragments of bone present	No
17 ARTST	Quantity of artefactual stone present	gm
18 OCHRE	Quantity of ochre present	gm
19 OBSID	Quantity of obsidian present	gm
20 SNAIL	Quantity of snail shell present	gm
21 EGG	Quantity of bird egg shell present	gm
22 SHELL	Quantity of other shell present	gm
23 CHAR	Quantity of charcoal present	gm
24 VEG	Quantity of vegetable matter present	gm
25 GLASS	Quantity of glass present	gm
26 OTHER	Quantity of any other materials present	gm
27 WT	weight of total sediment present	Kg
28 STWT	weight of non-artefactual stone	Kg
29 NOBUC	Number of buckets processed for the unit	No
30 BNTBN	Total weight of burnt bone present	gm
30 WS	Wet-seived or not wet seived	WS=1, NWS=0

Relationship between Archaeological and Faunal Database

The Archaeological and Faunal Databases are linked through the amalgamation number of each to produce a dataset on each unit.

The relationships between the different types of data and the databases are represented in Figure A.1.

Figure A.1 Summary of Nombe Data Management System